ETSI TR 103 509 V1.1.1 (2019-10)

SmartM2M;
SAREF extension investigation;
Requirements for eHealth/Ageing-well

Reference
DTR/SmartM2M-103509

Keywords
ageing, eHealth, IoT, oneM2M, ontology, SAREF, semantic

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 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

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Foreword

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

Modal verbs terminology

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1 Scope

The present document provides requirements for an initial semantic model extending SAREF for eHealth/Ageing-well. This initial SAREF extension is based on a limited set of use cases and existing data models identified within available initiatives that are summarized in dedicated clauses of the present document. The conducted work is expected to be developed in close collaboration with in particular ETSI (in particular EP eHealth and TC SmartBAN), oneM2M, AIOTI (in particular WG 05 "Smart Living Environment for Ageing Well"), and the H2020 Large Scale Pilots (ACTIVAGE project). Other initiatives coming from eHealth/Ageing-well industrial/medical world and alliances (e.g. HL7, PCHAlliance) will also be investigated. Further extensions are envisaged in the future for entirely covering the eHealth/Ageing-well domain.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

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

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

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

[i.1] European Commission and TNO: "Smart Appliances REFerence ontology (SAREF)", April 2015.

NOTE: Available at http://ontology.tno.nl/saref, SAREF is now extended to Smart Applications REFerence ontology.

[i.2] European Commission and TNO: "D-S4 Final Report - SMART 2013-0077 - Study on Semantic Assets for Smart Appliances Interoperability", March 2015.

NOTE: Available at https://sites.google.com/site/smartappliancesproject/documents.

[i.3] ETSI TS 103 264 (V2.1.1): "SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping".

NOTE: Available at https://www.etsi.org/deliver/etsi_ts/103200_103299/103264/02.01.01_60/ts_103264v020101p.pdf.

[i.4] ETSI TR 103 411 (V1.1.1): "SmartM2M; Smart Appliances; SAREF extension investigation".

[i.5] IEEE 802.15.6 "Standard in wireless Body Area Networks (BAN) from a healthcare point of view"..

NOTE: Available at https://ieeexplore.ieee.org/document/7581523.

[i.6] ETSI TR 103 477: "eHEALTH; Standardization use cases for eHealth".

NOTE: Available at https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=46025.

[i.7] ETSI TS 103 378 (V1.1.1): "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model".

NOTE: Available at https://www.etsi.org/deliver/etsi_ts/103300_103399/103378/01.01.01_60/ts_103378v010101p.pdf.

[i.8] ETSI TS 103 327 (V1.1.1): "Smart Body Area Networks (SmartBAN); Service and application standardized enablers and interfaces, APIs and infrastructure for interoperability management".

NOTE: Available at https://www.etsi.org/deliver/etsi_ts/103300_103399/103327/01.01.01_60/ts_103327v010101p.pdf.

[i.9] SNOMED International.

NOTE: Available at http://www.snomed.org/.

[i.10] ETSI TS 118 112 (V2.0.0): "oneM2M; Base Ontology (oneM2M TS-0012 version 2.0.0 Release 2)".

NOTE: Available at https://www.etsi.org/deliver/etsi_ts/118100_118199/118112/02.00.00_60/ts_118112v020000p.pdf.

[i.11] Continua Design Guideline description.

NOTE: Available at https://www.pchalliance.org/continua-design-guidelines.

[i.12] HL7 FHIR® Specification 3 document.

NOTE 1: Available at http://hl7.org/fhir/index.html.

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.13] CareWare ITEA3 project, CareWare deliverable: D1.1. Use cases manual. 2016.

NOTE: See https://itea3.org/project/careware.html.

[i.14] Philips® HealthSuite.

NOTE: Available at https://www.usa.philips.com/healthcare/innovation/about-health-suite.

NOTE 2: Philips® HealthSuite is an example of a suitable product available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

[i.15] A. Haller, K. Janowicz, S. Cox, D. Le Phuoc, K. Taylor, M. Lefrançois, R. Atkinson, R. García-Castro, J. Lieberman, C. Stadler: "Semantic Sensor Network Ontology". W3C Recommendation, 19 October 2017.

NOTE: Available at https://www.w3.org/TR/vocab-ssn/.

[i.16] J. L. R. Moreira, L. Ferreira Pires, M. van Sinderen, L. Daniele: "SAREF4health: IoT Standard-Based Ontology-Driven Healthcare Systems". FOIS 2018: 239-252.

[i.17] L. Nachabé Ismail, M. Girod-Genet, B. El-Hassan, J. Khawaja: "Ontology based Tele-health Smart Home Care System: OntoSmart to monitor elderly". In Proceedings of CoNeCo 2016, Zurich, Switzerland, pp. 43-59, June 2016.

[i.18] INTER-IoT, INTER-IoT deliverable: "D2.4. Use cases manual", 2016.

NOTE: Available at https://files.inter-iot.eu/deliverables/accepted/D2.4%20-%20Use%20cases%20manual.zip.

[i.19] INTER-IoT, INTER-IoT deliverable: "D2.3. Use cases manual", 2016.

NOTE: Available at https://files.inter-iot.eu/deliverables/accepted/D2.3%20-%20INTER-IoT%20Requirements%20and%20Business%20Analysis.pdf.

[i.20] Abbott, T.E.F., et al., Pre-hospital National Early Warning Score (NEWS) is associated with in-hospital mortality and critical care unit admission: "A cohort study". Annals of Medicine and Surgery, 2018. 27: p. 17-21.

[i.21] ETSI TS 103 410-8: "SmartM2M; Extension to SAREF; Part 8: eHealth/Ageing-well Domain".

NOTE: Available at https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=51404.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

metadata: data about data

ontology: formal specification of a conceptualization

NOTE1: It can be viewed as the extension of metadata with the data environment view.

NOTE 2: It is used to explicitly capture the semantics of a certain reality.

semantic: meaning of data

3.2 Symbols

Void.

3.3 Abbreviations

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

AAL	Ambient Assisted Living
AHA	Active and Healthy Ageing
AIOTES	ACTIVAGE IoT Ecosystem Suite
AIOTI	Alliance for the Internet of Things Innovation
API	Application Programming Interface
ARIB	Association of Radio Industries and Businesses
ATIS	Alliance for Telecommunications Industry Solutions
AVPU	Alert, Verbal, Pain, Unresponsive
BAN	Body Area Network
BP	Blood Pressure
bpm	beats per minute
BSN	Body Sensor Network
CCSA	China Communications Standards Association
CPS	Cyber-Physical System
DAM	Daily Activity Monitoring
DICOM	Digital Imaging and COmmunications in Medicine
DUL	DOLCE+DnS UltraLite
ECG	ElectroCardioGram
EHAW	eHealth/Ageing-Well
EHPAD	Etablissement d'Hébergement pour Personnes Agées Dépendantes
EHR	Electronic Health Record
EIP	European Innovation Partnership
EMT	EMergency Trigger
EP	ETSI Project
ETSI	European Telecommunications Standards Institute
EU	European Union
EWS	Early Warning System

EXP	EXercise Promotion
FHIR	Fast Healthcare Interoperability Resources
GDPR	General Data Protection Regulation
GEN	GENeral
HL7	Health Level Seven international
HR	Heart Rate
HTTP	HyperText Transfer Protocol
ICT	Information and Communication Technology
IHE	Integrating the Healthcare Enterprise
IoT	Internet of Things
JSON	JavaScript Object Notation
LE	Low Energy
LSP	Large Scale Pilot
MAC	Medium Access Control
MDP	Mental Decline Prevention
MOH	Monitoring Outside Home
NASA	National Aeronautics and Space Administration
OGC	Open Geospatial Consortium
OHS	Office d'Hygiène Sociale
ONT	ONTological category
OWL	Ontology Web Language
PCHAlliance	Personal Connected Health Alliance
PHD	Personal Health Device
PSI	Prevention of Social Isolation
QoL	Quality of Life
QUDT	Quantities, Units, Dimensions and Types
RDF	Resource Description Framework
REST	Representational State Transfer
SAO	Stream Annotation Ontology
SAREF	Smart Appliances REFerence ontology
SAREF4EHAW	SAREF extension for eHealth/Ageing-Well
SDO	Standards Development Organization
SEMIOTICS	Smart End-to-end Massive IoT Interoperability, Connectivity and Security
ShEx	Shape Expressions
SIL	Semantic Interoperability Layer
SNOMED CT®	SNOMED Clinical Terms
SOSA	Sensing, Observation, Sampling and Actuation
SPARQL	SPARQL Protocol and RDF Query Language
SSN	Semantic Sensor Network
STF	Special Task Force
STM	Support for Transportation and Mobility
SWE	Sensor Web Enablement
TC	Technical Committee
TIA	Telecommunications Industry Association
TR	Technical Report
TS	Technical Specification
TSDSI	Telecommunications Standards Development Society India
TTA	Telecommunications Technology Association
TTC	Telecommunication Technology Committee
TV	TeleVision
UCC	Under Chronic Conditions
USA	United State of America
VoID	Vocabulary of Interlinked Datasets
W3C	World Wide Web Consortium
WG	Working Group

4 SAREF extension for eHealth/Ageing-well domain

SAREF [i.1] is a reference ontology for IoT created in close interaction with the industry during a study requested by the European Commission in 2015 [i.2] and subsequently transferred into an ETSI Technical Specification [i.3]. SAREF contains core concepts that are common to several IoT domains and, to be able to handle specific data elements for a certain domain, dedicated extensions of SAREF can be created. Each domain can have one or more extensions, depending on the complexity of the domain. As a reference ontology, SAREF serves as the means to connect the extensions in different domains. The earlier document ETSI TR 103 411 [i.4] specifies the rationale and methodology used to create, publish and maintain the SAREF extensions.

The present document specifies the requirements for an initial SAREF extension for eHealth/Ageing-well. This initial SAREF extension will be based on a limited set of use cases and existing data models identified within available initiatives that will be summarized in dedicated clauses of the present document. The work conducted in the present document has been developed in the context of the STF 566, which was established with the goal of creating SAREF extensions for the following domains: Automotive, eHealth/Ageing-well, Wearables and Water. This work is expected to be developed in close collaboration with ETSI, oneM2M, AIOTI, eHealth/Ageing-well related H2020 Large Scale Pilots and EU projects. However, other initiatives coming from eHealth/Ageing-well industrial/medical world and alliances will also be investigated.

STF 566 consists of the following two main tasks:

1) Gather requirements, collect use cases and identify existing sources (e.g. standards, data models, ontologies, etc.) from the domains of interest (Automotive, eHealth/Ageing-well, Wearables and Water) in order to determine the requirements for an initial semantic model for each of the aforementioned domains, based on at least 2 use cases and existing data models (STF 566 Task 2).

2) Specify and produce the extensions of SAREF for each of the aforementioned domain based on the requirements resulting of STF 566 Task 2 (STF 566 Task 3).

The present document focuses on STF 566 Task 2 and the extension of SAREF for eHealth/Ageing-well domain. The present document sets the requirements of an initial semantic model that will result in a new SAREF ontology extension for eHealth/Ageing-well, called SAREF4EHAW and to be published in ETSI TS 103 410-8 [i.21] as part of STF 566 Task 3 SAREF extensions series.

5 Related initiatives

5.0 Introduction

Within clause 5 of the present document, some of the main related initiatives in term of modelling and standardization in the eHealth/Ageing-well domain are reviewed. Existing efforts range from national or international standards to rather specific models used in certain software solutions provided by industrial/medical world actors. Therefore, the potential stakeholders identified for this SAREF extension might be classified as: public administrations, associations related to the Internet of Things and eHealth/Ageing-well, European projects and Large Scale Pilots, standardization bodies and alliances related to the Internet of Things and eHealth/Ageing-well domain, as well as industrial/medical world and alliances initiatives of the eHealth/Ageing-well domain. For each type of stakeholder, the initiatives that have been taken into account are described next.

5.1 Standardization bodies

5.1.1 IEEE

IEEE 802.15.6 Working Group on Body Area Network [i.5]: *"A communication standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics/personal entertainment and other."* However, only aspects related to radio technologies and Physical and MAC layers are addressed.

5.1.2 ETSI

ETSI Project (EP) eHealth should form the 'horizontal' nucleus for the co-ordination of ETSI' activities in the Health ICT domain. EP eHealth works in close co-operation with all relevant TCs, EPs and SCs within ETSI, 3GPP, and others. It has in particular the following responsibilities:

- Collect and define the Health ICT related requirements gaps from relevant stakeholders.
- Identify gaps and suggest further standardization activities to fill those gaps.
- Input the requirements, identified gaps and suggested new activities to the concerned ETSI Technical Bodies.
- Develop Health ICT related deliverables in all areas not covered by existing system specific and horizontal Technical Bodies or other SDO.
- Co-ordinate ETSI positions on Health ICT related issues and represent ETSI externally.

EP eHealth in particular is developing ETSI TR 103 477 [i.6] presenting typical eHealth domain use cases, from their analysis (actors and their roles included; from FP7/H2020 projects to current Health/eHealth industry practices), to identify gaps in standardization. This document in particular covers aspects related to network interconnectivity and semantic interoperability.

ETSI SmartBAN TC is a vertical technical committee responsible for development and maintenance of ETSI standards, specifications, reports, guides and other deliverables to support the development and implementation of Smart Body Area Network technologies (Wireless BAN, Personal BAN, Personal Networks, etc.) in health, wellness, leisure, sport and other relevant domains. It is addressing all the aspects from Physical layer up to service and application layers, as well as from the patient's vital data collection/control devices (sensors, actuators, hub/coordinator) up to the monitoring/control and decision support applications on the patients/caregivers/followers side (i.e. the global end-to-end system). Aspects related to heterogeneity/interoperability management are also addressed (including informational and semantic interoperability). ETSI SmartBAN TC has in particular standardized:

- A BAN - data, device, service/application - unified semantic and open reference model, with corresponding modular ontology [i.7].
- A BAN dedicated global and more integrated IoT Reference Architecture, with semantic interoperability management and embedded semantic-based data analytics, for generic secure interaction and access to BAN data & entities [i.8].

5.1.3 SNOMED International

SNOMED International [i.9] determines global standards for a comprehensive, multilingual clinical healthcare terminology and health terms in the world health terms (SNOMED CT®, see http://www.snomed.org/snomed-ct/get-snomed.

NOTE: SNOMED CT® is an example of a suitable terminology available and this information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this terminology, thus enabling consistent representation of clinical content in electronic health records.

5.1.4 oneM2M

Referring to https://www.etsi.org/committee/1419-onem2m and http://www.onem2m.org/about-onem2m/partners, oneM2M is the global standards initiative that covers requirements, architecture, API specifications, security solutions and interoperability for Machine-to-Machine and IoT technologies. Formed in 2012 oneM2M consists of eight of the world's preeminent standards development organizations (partners type 1): ARIB (Japan), ATIS (USA), CCSA (China), ETSI (Europe), TIA (USA), TSDSI (India), TTA (Korea), and TTC (Japan), together with (partner type 2) GlobalPlatform and over 200-member organizations. oneM2M specifications provide a framework to support applications and services such as the smart grid, connected car, home automation, public safety, and health. oneM2M actively encourage industry associations and forums with specific application requirements to participate, in order to ensure that the solutions developed support their specific needs.

oneM2M is devoted to the development of technical specifications for M2M solutions related to the service layer which can be combined with existing hardware and software solutions. The main goal of the organization is to attract and involve organizations in domains such as telematics and intelligent transportation, healthcare, utilities, industrial automation, or smart homes, among others. oneM2M prepares, approves and maintains technical specifications and reports for use cases, service layer aspects, protocols, APIs, interoperability, data collection, and many other aspects of the M2M domain. The oneM2M base ontology ETSI TS 118 112 [i.10] is the minimal ontology that enables achieving interoperability among organizations.

5.2 Alliances

5.2.1 Personal Connected Health Alliance (PCHAlliance) - Continua

PCHAlliance is a non-profit organization, mobilizing a coalition of stakeholders and aiming to make health and wellness an effortless part of daily life through personal connected health techniques. The Alliance also publishes and promotes adoption of the Continua Design Guidelines [i.11], an open implementation framework for end-to-end interoperability of personal connected health devices and systems.

5.2.2 Health Level Seven International (HL7)

Health Level Seven International (HL7) is a not-for-profit standard organization with the objective to develop and standardize a framework for exchanging healthcare information electronically: Fast Healthcare Interoperability Resources (FHIR) [i.12]. It addresses digital healthcare records and EHRs unified semantic modeling specification and standardization for their common understanding and processing (automated clinical decision support; via common set of metadata and resources definition/specification).

5.3 Associations

5.3.1 Alliance for Internet of Things Innovation (AIOTI)

AIOTI is an inclusive body of IoT industrial players - large companies, successful SMEs and dynamic start-ups - as well as well-known European research centres, universities, associations and public bodies. AIOTI was founded by the European Commission in 2015, consists of working groups (https://aioti.eu/working-groups/) covering a broad array of IoT sectors, among which one is dedicated to eHealth/Ageing-well: WG 05 "Smart Living Environment for Ageing Well". This group focuses on smart homes and smart living environments that can support vulnerable people, such as (but not limited to) elderly or disabled people. Its deliverables (available at https://aioti.eu/aioti-wg05-report-on-smart-living-environment-for-ageing-well/) include white papers, recommendation reports, as well as innovative use cases, for improving the quality of life of elderly using IoT technologies.

5.4 IoT Platforms

5.4.0 Introduction

Clause 5.4 of the present document focuses on open platforms mainly related to eHealth.

5.4.1 HL7 FHIR (Fast Healthcare Interoperability Resources)

HL7 Fast Healthcare Interoperability Resources (FHIR) [i.12] is an emerging open platform and standard that is considered as the evolution of the HL7 standards for the new generation of health data exchange. HL7 FHIR defines a collection of "resources" (data model elements) that can be mixed and adapted for particular clinical contexts through the "profiling" process. Along with W3C semantic web community, HL7 developed an RDF representation of the FHIR data model, which can be described and validated with Shape Expressions (ShEx) [i.12].

The central FHIR element is the Observation resource [i.12], which is used to support diagnosis and monitor progress, and is recommended for monitoring vital signs and device measurements. In particular, the "ECG (electrocardiogram) example using Sampled Data" [i.12] demonstrates how to serialize ECG data using the Observation resource, which offers the property valueSampledData, responsible to represent the ECG sample sequence as a series of measurements of the heart electrical activity through the SampledData element, similarly to HL7 ECG. A SampledData provides a concise way to handle the data produced by devices that sample a particular physical state at a high frequency. A typical use for this is to represent the output of an ECG device. The data type includes a series of raw decimal values, which are mostly simple integers, along with adjustments for scale and factor.

Current issue of FHIR RDF is that it presents poor quality because it is a (semi) automatic serialization of FHIR lexicon standard, and thus a straightforward serialization of the FHIR standard data model. This causes both an overload of object properties, since more than ten properties represent the "description" concept, and a lack of reuse of common terms (e.g. instead of having more than ten "description" terms, dc:description term could be reused). Although HL7 FHIR lexicon standard is widely adopted and used in industry, its semantic model is still in early stages.

5.4.2 ETSI SmartBAN global IoT Reference Architecture

ETSI SmartBAN global IoT Reference Architecture is a standardized global and more integrated IoT reference architecture, with semantic interoperability management and embedded semantic-based data analytics, for generic secure interaction and access to BAN data and entities [i.7]. This global IoT reference architecture is in particular specified on top of the SmartBAN Reference Model and is oneM2M based. It has also been clinically tested for elderly at home monitoring and control purposes in the context of the CareWare ITEA3 project (see clause 5.5.2 of the present document).

5.4.3 universAAL IoT

universAAL IoT (see https://www.universaal.info/) is an IoT solution and platform developed for smart environments and Ambient Assisted Living (AAL) applications. It is provided with dedicated data models and ontologies for handling data heterogeneity at application level.

5.4.4 Sofia2

Sofia2 is a semantics-based IoT platform that makes use of ontology-like models for providing connection management between low-level device information and applications. It is one of the platforms used in ACTIVAGE LSP (see clause 5.5.1 of the present document).

5.5 European projects and initiatives

5.5.1 ACTIVAGE LSP

ACTIVAGE LSP (see http://www.activageproject.eu) is a European Large Scale Pilot (9 deployment sites in seven European countries) on Smart Living Environments. Its main objective is to build the first European IoT ecosystem for enabling the deployment and operation of Active and Healthy Ageing (AHA) IoT based solutions and services, supporting and extending the elderly's independent living in their living environments, as well as for responding to caregivers, service providers and public authorities needs. The proposed IoT environment is built upon existing open and proprietary IoT platforms, technologies and standards that will be scaled up and interoperated through the integration new interfaces that will provide the mandatory interoperability management middleware functionality. For that purpose ACTIVAGE will mainly deliver:

- ACTIVAGE IoT Ecosystem Suite (AIOTES). AIOTES comprises both a set of techniques, tools and methodologies for interoperability management between heterogeneous IoT Platforms (at different IoT layers), and an open framework for providing semantic interoperability management for AHA purposes. It will obviously address security, privacy and trust.

- User-demand driven interoperable IoT-enabled AHA solutions that will be deployed on top of AIOTES in each of the 9 European deployment/pilot sites of ACTIVAGE LSP, provided with a common Reference Evaluation Framework and a co-design framework, for the promotion of independent living and the preservation of quality of life and autonomy.

- Semantic Interoperability Layer tools facilitating access to ACTIVAGE ontologies (i.e. ontology explorer, query translator, device semantics editor, service semantics editor, semantic Device/service auto-discovery; REST-based methods). For that purposes, SIL is also based on semantic-related standards like e.g. RDF and OWL description languages for data representation and modelling, data as well as SPARQL for data access and semantic search/query (SPARQL) and standard data serialization format like JSON for data exchange. However and even if an ACTIVAGE ontology is mentioned, it is mainly addressing devices, services and collected data semantic (see Table 1), and no dedicated eHealth, Ageing Well, AHA data model and associated ontology(ies) are provided.

Table 1: ACTIVAGE ontology concepts

Type	Description
Sensor Data	Sensory data provided by a service, i.e. real-time information provided by a sensor Smart Object measuring physical quantities.
Action	Service functionality, i.e. mostly an actuation on the physical environment through an actuator Smart Object. It can also be a request to do a virtual action (e.g. play a multimedia on a TV).
State Variable	Variable for information representing a Smart Object (sensor/actuator) state variable of the service. It is most likely to be modified by an action.

5.5.2 CareWare ITEA3 project

CareWare ITEA3 project (see https://itea3.org/project/careware.html), a three years EU project ended October 2018 and involving partners from France/Belgium/Lithuania, aims at developing and leveraging novel unobtrusive cyber physical systems for monitoring and advancing personal health and wellbeing [i.13]. CareWare draws on the results from previous researches in body area networks (BAN), wearable sensors, care technologies, electronic textiles, physiological measurements and personal health service development, and utilizes the state of the practice to produce innovative and easy to use wearable cyber-physical system (CPS) solutions. One of the two considered use cases is related to home care for the elderly and elderly remote monitoring and control. The provided technical solutions are mainly based on:

- HL7 FHIR for the Belgium consortium demonstrator.
- ETSI SmartBAN Reference Model (for semantic interoperability management, embedded semantic based data analytics and decision making support purposes) and ETSI SmartBAN global IoT Reference Architecture (for real time remote monitoring/control and alarm management purposes) for the French consortium demonstrator.

IoT applications have mainly been developed, on top of the CareWare IoT framework and in co-conception with elderly/caregivers/followers, for: elderly daily support and life quality improvement (wellbeing on patient's side), elderly remote monitoring and control, as well decision making support (on caregivers' side). CareWare technical solutions/applications have been validated and clinically tested in partnership with OHS (Office d'Hygiène Sociale) Nancy within both OHS premises *(i.e. one of its EHPAD - an housing for dependent elderly peoples - and one of its daily hospitals*) and few elderly homes.

5.5.3 MobiGuide

MobiGuide (see https://www.cvast.tuwien.ac.at/projects/mobiguide) is a European project with the objectives of developing a framework for intelligent decision-support of patients with chronic illnesses. This framework will in particular provide guidance and support of patients anytime and anywhere, as well as care management facilities to caregivers, thus reducing both patient risk and healthcare cots.

5.5.4 European Innovation Partnership on Active and Healthy Ageing (EIP on AHA)

European Innovation Partnership on Active and Healthy Ageing (EIP on AHA) is a European Commission initiative launched for enhancing research and innovation, as well as digital transformation, in the Active and Healthy Ageing (AHA) domain. Its objectives are in particular to:

- Improve the health and Quality of Life (QoL) of European elderly peoples.

- Support the long-term sustainability and efficiency of health and social care systems.
- Enhance competitiveness of EU industry through business and expansion in new markets.

This is achieved through action groups, i.e. communities of partners and stakeholders (from academia and public authorities to SMEs, large industry and SMEs, through health organizations and patients' associations) that have committed to address a specific issue of the AHA domain under an agreed upon strategic plan, and reference sites, i.e. leading regional organizations committed to investing in innovation, as well as to supporting this innovation transfer/scaling-up, for Active and Healthy ageing and across Europe. EIP on AHA has actually six active Action Groups (on - adherence to prescription falls prevention, lifespan Health Promotion, integrated care, independent living solutions, age friendly environments - issues) and 76 reference sites over Europe, which represents both an overall investment commitment of over € 4 billion for the deployment and scaling-up of digital innovation for AHA, over the 2016 to 2018 period, and a QoL improvement objective over 5 million people.

5.5.5 FIESTA-IoT Ontology

The FIESTA-IoT ontology (see http://fiesta-iot.eu/) focuses on interoperability issues and various aspects of IoT device observations, addressing management of IoT data from heterogeneous systems, environments and their entity resources. The model aims to support the federation of testbeds by interconnecting existing ontologies. By using some of the core concepts from various other ontologies such as SSN, M3-lite, WGS84, IoT-lite, Time, and DUL, the FIESTA-IoT ontology proposes its own model. The project does not intent to create new concepts in a new ontology, but instead to create an ontology in which all concepts are borrowed from existing ones. The solution focuses on the description of the basic testbeds' resources and the observations gathered from them. The FIESTA-IoT platform provides then a mechanism where interoperability between testbeds can be managed through a semantic model.

The idea behind the FIESTA-IoT ontology is to avoid overloading the IoT domain with a new ontology, but reusing as much as possible from the various existing ontologies into a single one. This would allow assuring a better interoperability with existing semantic IoT systems. For instance, IoT-lite helps internal testbeds to not recreate annotations that they already have. SSN provides the basic concepts while M3-lite provides the taxonomy that cover all the different types of resources, physical phenomena and units of measurement gathered from testbeds. Moreover, other concepts from other ontologies, like SAO, OpenIoT and VoID, and other standardizations like oneM2M, are planned to be integrated.

Even if not directly linked to eHealth vertical, FIESTA-IoT is intended to be applicable to multiple applications domains (eHealth included). Furthermore, the ontology design concepts that are retained for FIESTA-Ontology are of interest for an initial extension of SAREF for eHealth/Ageing-well (SAREF4EHAW).

5.6 Industrial/medical world initiatives

5.6.0 Introduction

Clause 5.6 of the present document focuses on open initiatives, environments and platforms.

5.6.1 Philips® HealthSuite

Philips HealthSuite digital platform [i.14] is a cloud-based platform for collection, orchestration and analysis of healthcare data. It supports data collection from smart IoT devices and wearables, as well as the management and monitoring of devices. Furthermore, a secure cloud-based infrastructure is provided for data collection and storage. Philips HealthSuite provides tools for workflows creation, as well as and rules for data flow orchestration and data acquisition. At a higher level, it offers data analytics tools and visualizations, employing machine learning algorithms for facilitating the decision making procedure. Philips HealthSuite can also interwork with third-party applications and devices through standards such as FHIR, HL7, DICOM, IHE.

6 Initial data models/ontologies to considered

6.1 WSNs/measurement world main ontologies

- OGC (Open Geospatial Consortium) Observations & Measurements (O&M), Sensor Model Language (SensorML), Semantic Sensor Web (SWE).
- W3C & OGC SOSA (Sensing, Observation, Sampling and Actuation) and SSN (Semantic Sensor Network).
- NASA QUDT (Quantities, Units, Dimensions and Types).

6.2 eHealth/Ageing-well domain main ontologies

- ISO/IEEE 11073 Personal Health Device (PHD) standards.
- ETSI SmartBAN Reference Data Model and associated modular ontologies.
- ETSI SmartM2M SAREF4EHAW.
- FHIR RDF (Resource Description Framework).
- FIESTA-IoT Ontology to support the federation of testbeds.
- Bluetooth® LE (Low Energy) profiles for medical devices proposed by Continua.
- MIMU-Wear (Magnetic and Inertial Measurement Units) ontology.
- Active and Healthy Ageing (AHA) platform wearables' device ontology.

6.3 Base Ontologies to consider for SAREF4EHAW extension

6.3.1 SAREF

SAREF ontology ([i.1], [i.4]) is based on the concept of Device. Device is made to accomplish a task by performing one or more functions in a defined space. This ontology proposes basic functions that can be combined in order to have more complex functions in a single device. A Device offers a Service which is a representation of a Function to a network that makes the function usable by other devices in the network. A Device is also characterized by a Power/Energy class that is used to optimize the energy efficiency. Finally, SAREF has been mapped with oneM2M base ontology in 2017 [i.4].

6.3.2 oneM2M

oneM2M's ontology [i.10] describes key classes, relations and properties that are necessary to enable semantic functionalities and interoperability between applications. This ontology is based on a Thing that has properties through ThingProperty. In oneM2M, a Device is a subclass of Thing that is designed to accomplish a Functionality represented in the network by a Service. To communicate over the network a Service uses an Operation.

6.3.3 SSN

SSN's ontology [i.15] describes sensors and observations, and related concepts. It does not describe domain concepts, time, locations, etc. SSN also includes a core ontology called SOSA for its elementary classes and properties. This ontology is based around a System that is represented in the physical way by a Device. An Observation is the use of a Sensing method to calculate a value of a certain Property of a FeatureOfInterest.

6.3.4 SmartBAN Reference Model

One of the objectives of SmartBAN TC is to manage BANs (Body Area Networks) interoperability at data/informational and semantic level. This is achieved via the specification, the formalization, the standardization and the use of a SmartBAN Reference Model [i.7]. This reference model does not only provide unified metadata, uniquely and unambiguously describing BAN nodes (sensors/wearables) measurements (e.g. vital data), but also a modular ontology that models extra BAN environment-related information such as, in particular: measurement and actuation processes, nodes providing the measurements or executing an actuation command, at which geolocation, for which patient (BAN contact), with which communication process, as well as the service a BAN is engaged in and that implements a service process related to a measurement or an actuation process.

A SmartBAN comprises a set of low-power embedded devices, mainly - sensors, wearables, actuators, Hub -, used to collect and monitor/control vital parameters/data of a living being (human, animal, etc.) and his environment, but not only. A SmartBAN network is organized around a Hub, which plays the role of the BAN cluster head and also serves as an intermediary Gateway node, as well as data concentrator. All these information are also modelled within the SmartBAN Reference Model and associated modular ontology.

6.3.5 SEMIOTICS project SAREF4health first try

SAREF4health ontology [i.16] is a very first try to somehow extend SAREF ontology for the health vertical, which means that it has nothing to do with ETSI SAREF4XYZ naming convention. It was introduced in the specific context of SEMIOTICS H2020 project (see https://www.semiotics-project.eu/) and thus only addresses cardiovascular accidents related emergency services. Furthermore, it is the only ontology, among all the aforementioned ones within clause 6.3 of the present document, to introduce time series concepts. This is very useful in the emergency situation detection use case, particularly real-time ECG measurements. ECG measurements are data represented as frequency-based time series that describes the property of heart electrical activity. For instance, SAREF has a problem when used for real-time ECG since it does not specify a terminology for the time series data. Consequently, SAREF4health introduces Time Series Measurements to refer to a time series of a sequence of measurements made by a ECG device during a ECG recording session (introduced as ECGRecordingSession). An ECGRecordingSession has participants, in particular the ECG Device, and the patient under ECG monitoring. Furthermore, in SAREF, the datatype property hasValue limits the value domain of a Measurement to only one numerical value. Whereas, in SAREF4health hasValues allows a Time Series Measurements to manifest multiple times as a set of numerical values, a frequency and a timestamp. To overcome the need to deal with frequency-based time series, SAREF4health also deals with performance optimization concerning time series measurements in the payload.

7 Use cases

7.1 Use case 1: elderly at home monitoring and support

In order to implement an elderly at home monitoring and support use case, the following requirements in particular, have to be set:

1) Key vital parameters of the patient have to be collected/monitored and sent remotely in real time to the caregivers and the helpers (*e.g. patient's family member*), mainly for monitoring and control purposes. This is addressed via sensors and actuators that are selected according to the patient's pathology, as well as caregivers driven. For an elderly, the following vital parameters are usually considered (ACTIVAGE - see http://www.activageproject.eu/, CareWare - see https://itea3.org/project/careware.html): heartbeat (measured through a heart rate sensor), oxygen saturation (SO2, measured through an oximeter), temperature (measured through a body temperature sensor), urinal linkage (measured through a humidity sensor), posture and fall detection (measured through accelerometer and gyroscope sensors). Few extra vital parameters like the weight and the blood pressure have also to be collected. Since no wearable devices actually exist for these extra parameters, heavier elderly-external devices (e.g. within the patient's home or caregivers premises) are used like e.g. scales and tensiometers. The technology and system that has been specifically designed for patient monitoring (local and remote) is the BSN (Body Sensor Network) or BAN (Body Area network). Already standardized at IEEE [i.5], ETSI [i.7] [i.8], and validated for eHealth/wellbeing (MobiGuide - see https://www.cvast.tuwien.ac.at/projects/mobiguide, CareWare - see https://itea3.org/project/careware.html [i.17]), a BAN is logically retained for our additional use case. Therefore, the patient/elderly is provided with a BAN for the monitoring and control of its vital signs, status and activities. This BAN mainly comprises, in respect of its patient/elderly embedded device part, all the medical/wellbeing sensors and wearables already aforementioned for elderly monitoring, a BAN coordinator or hub (*e.g. a Smartphone, a smart-watch*) with in particular data concentrator and network gateway roles. The BAN data concentrator is used for data collection and has also to be provided with embedded data analytics functionalities for local alarm management, local monitoring/control and habitant/elderly assistance purposes. The network Gateway is mainly used for data sending to the remote monitoring/control servers and applications located within caregivers or relatives premises. Please note that, for security/safety reasons, actuations on patient/elderly BAN devices have not been actually considered.

2) Patient is also interacting with the Smart Home and some of its appliances. These interactions have therefore also to be monitored and fusion with the patient's vital data, and in particular for: patient/elderly positioning inside the house (e.g. through beacons on the walls), habitant/elderly activity tracking, tracking of interactions with key appliances (e.g. with a scale for weight measurement, or for verifying if fridge or cooker was used, or if a pill organizer was opened), habitant/elderly wellbeing (e.g. maintaining a given temperature/humidity/luminosity level in accordance with habitant/elderly condition requirements). In an elderly at home monitoring and support use case, this is related to cross-domain interactions (eHealth and Smart Home) and in particular BAN interaction with home system for the aggregation of patient vital data and environment data. This aggregation is usually done at the patient dedicated data concentrator level [i.8], i.e. at the BAN hub level for our extra use case.

3) Patient, caregivers and followers have to be provided with a dedicated end-user application for real time monitoring and control support, as well as for assisted living and decision making support purposes. This application will be running within one of their devices such as Smartphones or tablets.

The elderly at home monitoring and support use case (i.e. elderly at home monitoring and support) high level end-to-end architecture is depicted in Figure 1.

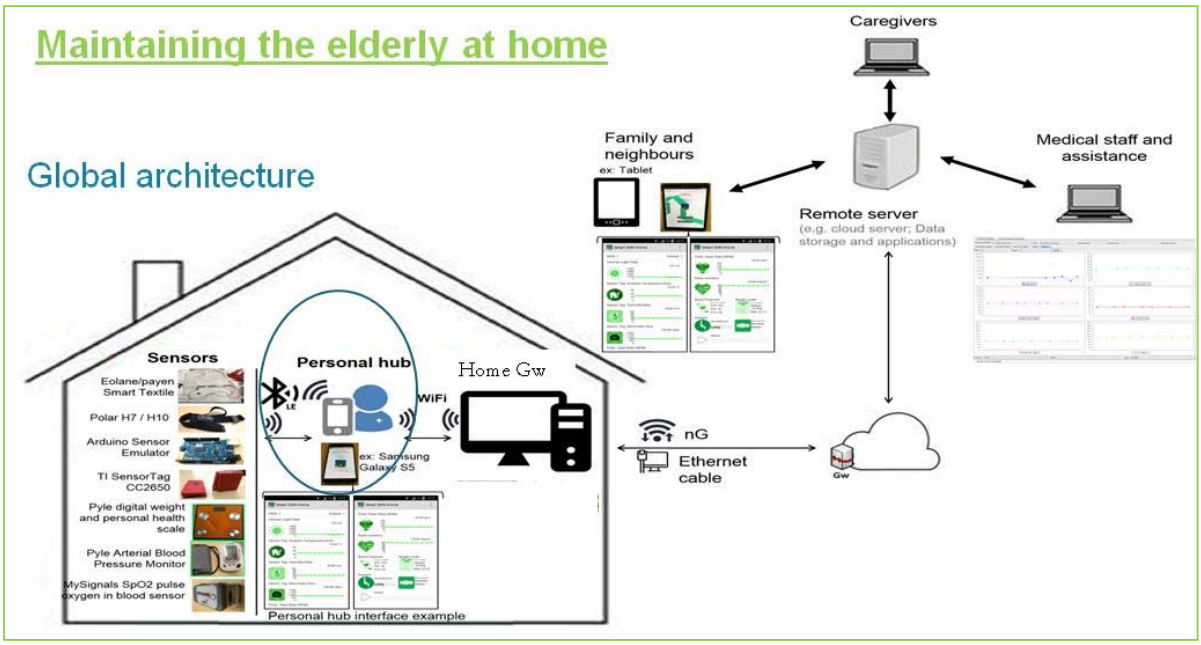

Figure 1: Elderly at home use case end-to-end-architecture

In the environment and use case depicted in Figure 1, it is mandatory to address security and privacy by design since eHealth and personal safety highly critical data and applications are addressed (even if actuations within BANs are not yet considered for quite all the existing use cases). It is also mandatory to address interoperability at multiple levels and in particular at data, device and semantic level.

7.2 Use case 2: monitoring and support of healthy lifestyles for citizens

Diets and physical activity play a crucial role for a long and healthy life. Indeed, monitoring eating habits of users will help to prevent different type of pathologies, chronic diseases and cognitive decline. However, engaging people in developing and maintaining healthier patterns of living is a challenging task. For example, redirecting a user from eating unhealthy foods requires suggesting viable alternatives. Those alternatives can be based on rational food properties or more abstract concepts such as taste. This would be done through an interface for personal devices able to collect data from the user, wearable sensors, and contextual data. Furthermore, to provide real-time feedback and notify the user with persuasive and motivational messages, adapted representation, such as text, speech, video, or graphical alerts, are also required.

Diet oriented concepts and ontologies concerning the food domain are necessary in order to specify all the relevant information such as the number of calories and nutrients consumed in a given meal. Therefore, the detailed description about each food and food properties should be established. Furthermore, an intelligent platform allowing experts to propose monitoring rules and guidelines regarding a healthy lifestyle that users should adapt for maintaining their physical and mental wellbeing would be used. External events would occur as a trigger for the system, for instance a user eating too much food or performing too low in physical activity.

Equipped with body sensor networks, wearable sensors and mobile smart devices for health monitoring, the goal is the development of an eHealth system through the integration of several IoT platforms and medical sensors. Via the monitoring of user's lifestyle in a decentralized and mobile manner, health issues caused by inappropriate diet and lack of physical activity would be prevented. These monitoring processes are meant to be decentralized from the healthcare center to the monitored subjects' homes, as well as supported in mobility situations by using on-body physical activity monitors.

The strategic importance of such complete use case is largely motivated by the fact that unhealthy, such as improper and hyper-calorie diet and insufficient physical activity, are the base of main chronic diseases.

7.3 Use case 3: Early Warning System (EWS) and Cardiovascular Accidents detection

An Early Warning System (EWS) in particular to provides risky situations detection for allowing accident avoidance. Clause 7.3 of the present document considers the following use case: provide Cardiovascular Accidents detection for truck accident risks minimization at a port area. The main objective of such use case is to decrease the risk of fatal accidents at a port area, thus improving health prevention, as well as enabling quick reaction by reducing time response. Accident risks are assessed by monitoring the truck drivers' vital signs with in particular: electrocardiogram (ECG) medical wearables, trucks position with speed and accelerometer data using the drivers' mobile phones as gateway. The detection targets health issues of drivers and the drivers' mobile phones are often used as both data concentrators and network gateways. In order to cater to all the aforementioned objectives, the EWS personalizes emergency notifications to multiple target groups with distinct information requirements.

The mandatory requirements for carrying the emergency scenario retained for clause 7.3 of the present document was already identified by the INTER-IoT consortium [i.18], [i.19]. Some of these specific requirements, also addressed by the IoT EWS of INTER-IoT [i.18], [i.19], are in particular:

- Complex medical measures.
- Definition of reference meaning for health information.

Integration of both haulier and port IoT platforms should enable real-time sensing of driver health information, in particular complex high-frequency electrocardiogram data. Those data are measure through in particular an electrocardiography device (ECG). ECG monitoring is necessary since cardiovascular emergencies are life-threatening disorders that should be recognized as soon as possible to minimize morbidity and mortality, as well as to avoid fatal accidents in the port. The carried out EWS should be able to provide both raw and processed data, e.g. ECG sequence (time series) and heart rate (HR). These raw and processed data also need to be precisely described and integrated, within a unified model, such that the port emergency control system can uniquely consume them.

The EWS considered for clause 7.3 of the present document is focusing on the cardiovascular risk detection. It is described in terms of situation types that are in particular: bradycardia, tachycardia, multiple consecutive occurrences of bradycardia within a pre-defined time interval, consecutive occurrences of tachycardia. All the aforementioned situations are mainly based on heart rate observation computed at the field gateway level (e.g. drivers' mobile phones). The considered EWS have to be able to:

- Detect arrhythmia occurrences of port truck drivers (i.e. bradycardia and tachycardia). By allowing these cardiovascular emergencies, the risk of accidents at the port area will thus be reduced.
- Trigger and send alerts according to the possible cardiovascular emergencies.

The EWS considered for clause 7.3 of the present document monitors the cardiac behavior of the driver, tracking the heart rate during the trip inside the port area. The heart rate data are provided by the ECG device located on truck drivers skin as a processed measurement from the ECG time series. Both processed heart rate and raw ECG data are made available to the EWS, which should adhere to health data privacy best practices, as well as comply to EU General Data Protection Regulation (GDPR, see https://eugdpr.org/). Thresholds used by the risk detection mechanism have been defined based on existing classifications to detect health risks, both regarding bradycardia and tachycardia (see http://www.mayoclinic.org/diseases-conditions/bradycardia/diagnosis-treatment/diagnosis/dxc-20321665 and http://www.mayoclinic.org/diseases-conditions/tachycardia/diagnosis-treatment/diagnosis/dxc-20253919), and the approach based on Early Warning Scores [i.20] should in particular be considered.

Table 2 illustrates the rules underlying each vital sign scoring function and also depicts thresholds for both arrhythmia types, i.e.: below 50 bpm for bradycardia and above 99 bpm for tachycardia.

Table 2: Classification of vital signs levels with Early Warning Scores

Score	3	2	1	0	1	2
Respiratory rate (beats/min)	> 35	31 - 35	21 - 30	9 - 20	-	-
SpO2 (%)	< 85	85 - 89	90 - 92	> 92	-	-
Temperature (C)	-	> 38,9	38 - 38,9	36 - 37,9	35 - 35,9	34 - 34,9
Systolic BP (mmHg)	-	> 199	-	100 - 199	80 - 99	70 - 79
Heart rate (bpm)	> 129	110 - 129	100 - 109	50 - 99	40 - 49	30 - 39
AVPU	-	-	-	Alert	Verbal	Pain

The heart rate score depicted in

Table 2 reflects the urgency and severity levels of the situation. For example, for heart rate of 115 bpm, the score is 2. This information allows quantifying the driver's health level since a score greater than 5 indicates that the driver requires intensive care and is in a near-death situation.

The classification of severity and urgency of the arrhythmia detected is based on similar deterministic distribution rules that are summarize in Table 3.

Table 3: Ranges of emergency severity and urgency for arrhythmias

Range	Urgency	Severity	Colour
B < A <= B x 1,1	Minor	Expected	Green
B x 1,1 < A <= B x 1,1	Moderate	Immediate	Yellow
B x 1,2 < A <= B x 1,3	Severe	Immediate	Red
B x 1,3 < A	Extreme	Immediate	Black

Variable A depicted in Table 3 represents the heart rate computed (in bpm) when the accident was detected, while variable B represents the threshold (Threshold_Bradycardia and Threshold_Tachycardia). For example, if the heart rate computed is within 10 % and 20 % above the tachycardia threshold, the EWS should issue the warning informing that the severity is moderate and the urgency is immediate.

7.4 Other relevant Use Cases

7.4.1 Daily activity monitoring

This use case is focused on the support and follow-up for caregivers in order to detect changes in patients (or assisted persons) daily activities at home allowing preventions. Various wireless sensors are deployed at the home of the assisted person. A gateway transmits the collected data to be latter interpreted in order to detect parameters such as trends and risks.

7.4.2 Integrated care for older adults under chronic conditions

This use case focuses on providing a better quality of life for people with chronic disease. It requires both daily activity monitoring and care protocols from medical entities in order to respond to emergencies and plan interventions.

7.4.3 Monitoring assisted persons outside home and controlling risky situations

This use case detects when elderly person goes outdoors and it provides assistance in order to prevent any risky situation. Through the use of wearables and the Smart City, the system detects when elderly person goes outdoors and provides information about activity to promote socialization.

7.4.4 Emergency trigger

This use case has for main purpose to report a critical situation that present risk or danger to the person. With the use of emergency buttons available for the elder person and sensors, the detected emergency is forwarded to caregivers and a local medical entity.

7.4.5 Exercise promotion for fall prevention and physical activeness

This use case monitors physical activity in order to suggest exercising through activities. Moreover, wearables and ambient sensors are used in order to monitor fall factors and prevent them.

7.4.6 Cognitive stimulation for mental decline prevention

This use case has the purpose to help and extend elders living independently through the monitoring of habits and routines at home and outside. It also detects early symptoms of pathologies with the aim to promote adapted mental and physical exercises through the interface.

7.4.7 Prevention of social isolation

This use case promotes social inclusion and mobility with the purpose to keep depression and decline away. Social activity is being monitored, linking to other peers is provided and events are proposed to elderly person through the connection to a Smart City. The interface also proposes ways to communicate and includes community activities.

7.4.8 Comfort and safety at home

This use case includes the automation of the elder home with the use of actuators such as light control, air condition, energy control, etc.

7.4.9 Support for transportation and mobility

This use case includes planned routes for elderly persons just as pedestrian assistance. With the help of the Smart City, information about transportation and mobility are gathered.

8 eHealth/Ageing-well ontological requirements

Clause 8 of the present document presents the ontological requirements resulting from a reverse engineering process that was carried out taking as input aforementioned eHealth/Ageing-well: related initiatives and stakeholders already listed in clause 5 of the present document, use cases described in clause 7 of the present document, service level assumptions presented in clauses A.1 and A.2 of the present document. The specific input resources will be drilled down below, for the main ontological (ONT category) that will be taken into account for an initial extension of SAREF for eHealth/Ageing-well (SAREF4EHAW). These requirements are listed in Table 4.

Table 4: Ontological requirements for SAREF4EHAW extension

ID	Requirement
EHAW-0	eHealth/Ageing-well system is composed of one or several devices, including actuators, sensors, and wearables.
EHAW-1	eHealth/Ageing-well system is used by actors, that are the patient(s), the caregiver(s), the helpers(s).
EHAW-2	Patients and assisted persons have profiles, including their age category (young, old), and/or pathology, and/or impairment (hearing, visual, handling, deaf), the caregiver(s) and the helper(s) that is (are) following him.
EHAW-3	Patients and assisted persons have to be uniquely identifiable.
EHAW-4	eHealth-dedicated sensors and wearables devices are used for monitoring vital parameters, or measurements, of a patient.

ID	Requirement
EHAW-5	Measurements of vital data of patient are recorded according to a measurement process. By taking the example of an elderly, the measurements that are often recorded and have thus to be modelled are: heartbeat, oxygen saturation, body temperature, urinal leakage, posture and fall. Other vital data often recorded and that have to be somehow modelled are for example: blood pressure, ECG, arrhythmias, etc.
EHAW-6	eHealth/Ageing-well actuators can be used to act upon a patient's properties or environment variables.
EHAW-7	Functional devices (non-purely eHealth/ageing-well devices) can be used for modelling/detecting daily/nightly activities or behaviours of patients, like for example gyroscopes/accelerometers can detect posture/fall, or beacons can detect indoor positioning, as well as environment interaction tracking (e.g. door opening; home, city).
EHAW-8	A BAN (Body Area Network) has to be used for collecting/aggregating patient or person parameters.
EHAW-9	A given eHealth device (sensor, wearable, actuator) and a BAN, are usually used for monitoring and control of a given patient or person.
EHAW-10	Patient (or assisted person) has behaviours that should be modelled. Reasoning and/or semantic queries and analytics have to be handled on this data/information for in particular critical situation detection and alert/alarm triggering.
EHAW-11	Patients or assisted persons have postures that have to be in particular modelled in terms of kind (e.g. falling, lying on a bed, sitting on a chair, standing under the shower, etc.) and duration.
EHAW-12	Patient (or assisted person) has daily and nightly activities that should be modelled (e.g. doing the same way or path, leaving a room, getting up or not getting back after a certain amount of time, time and patterns of sleep, etc.). Reasoning and/or semantic queries and analytics have to be handled on this data/information for in particular critical situation detection and alert/alarm triggering.
EHAW-13	Patient (or assisted person) environment, as well as patient environment interactions, should modelled. The following environment information can in particular be modelled: presence and/or motion, door opening, temperature, humidity, luminosity and pressure, smoke presence, temperature, gas, wind, CO2, windows open, Smart Appliances interactions (e.g. fridge), air quality. This also means that cross domain related interaction and semantic interoperability have to be handled.
EHAW-14	For outdoor and mobility scenarios, patients and assisted persons location (i.e. geolocation) have to be modelled.
EHAW-15	A given eHealth device (sensor, wearable, actuator) has to be uniquely identifiable.
EHAW-16	eHealth devices (sensors, wearables and actuators) can be located in the patient body, on the patient body, or around the patient body (i.e. surrounding/near environment).
EHAW-17	If the sensor/wearables is located on the body and for some eHealth/Ageing-well use cases, its body position should be monitored and modelled.
EHAW-18	eHealth devices (sensors, wearables and actuators) have properties, such as operating modes (e.g. for data sending), latency, sensitivity, velocity, etc. Those properties have to be taken into consideration.
EHAW-19	eHealth devices (sensors, wearables and actuators) are mainly constraint/embedded devices, with in particular low power and low energy constraints. They therefore have processing and battery resources and capabilities, like e.g. processor load or battery levels.
EHAW-20	An eHealth device (sensor, wearable and actuator) has an interface. This interface is mainly used for communication purposes and data/command transfer.
EHAW-21	An eHealth device (sensor, wearable and actuator) may be provided with a geolocation component and therefore may provide its geolocation that should be modelled.
EHAW-22	Sensors or wearables may have control capabilities.
EHAW-23	An eHealth device (sensor, wearable and actuator) has constraints, like for examples: validity (e.g. min or max value, etc.), operating conditions (e.g. temperatures, humidity levels, etc.), legal, security, etc.
EHAW-24	The choice of wearables has to be determined based on the patient preferences in terms of comfort and suitability.
EHAW-25	Measurements can be handled and analysed as single instant measure. They are in particular characterized by a unit of measure and a value.
EHAW-26	In some eHealth/Ageing Well use cases, measurements sessions are conducted (e.g. ECG measurement session) and samples, or measurement occurrences (consecutive or not), or aggregated values like e.g. time series or vectors have also to be recorded and modelled.
EHAW-27	Factors/data related to falls, gait, speed, etc. should be modelled for fall detection purposes.
EHAW-28	Patient, or assisted person, has daily and nocturnal activities, some of these activities are critical (risky situations) and can trigger alarms. This also means that reasoning and/or semantic queries and analytics have to be handled on this activities data/information.
EHAW-29	Co-conception with patients/caregivers design also holds for data modelling.
EHAW-30	Privacy, data anonymization and protection issues have to be taken into account during the ontology design.
EHAW-31	Ontology has to be designed using the modularity principle (i.e. decomposable in less-complex sub-ontologies that can be processed separately) for handling both embedded devices and embedded semantic analytic, which also means that the trade-off between data model richness and complexity has to be taken into account during ontology design phase.

ID	Requirement
EHAW-32	The ontology has to be rich enough to enable semantics analytics, in particular for - local alarms/alerts triggering and management, patient/person guidance and daily life support, caregiver alerting and decision making support - and at any level (device, edge, fog).
EHAW-33	Cross domain and full semantic interoperability have to be handled. This in particular means that a WoT strategy and service level extensions and modelling could be envisioned.
EHAW-34	A database of pathological diseases (e.g. SNOMED International) has to be linked in order to allow better semantic analytics such as detecting early symptoms of cognitive impairment and pathologies (e.g. physical inactivity, lack of personal hygiene, erratic paths, loss of memory).
EHAW-35	A link has to be made between patient's (or assisted person's) instant and/or continuous monitoring data/information and its Electronic Health Record (EHR), at least for those suffering for chronical pathologies.

The main information requirements of this ontology regard the ECG and the IoT domains, described as competency questions (Table 5). The scope of these questions was narrowed with the information requirements of the use case validation of INTER-IoT consortium, i.e. use case 3 already described in clause 7.3 of the present document.

Table 5: Ontological requirements for SAREF4EHAW extension (ECG)

ID	Requirement
EHAW-36	What is an ECG device and how it is composed (mereology)?
EHAW-37	What are the elements participating in an ECG recording session?
EHAW-38	What is an ECG lead, what are the types of ECG leads, what type of property an ECG lead measures and what type of measurement an ECG lead can measure?
EHAW-39	What is an ECG sample sequence?
EHAW-40	What is a time series of measurements?
EHAW-41	What is the frequency (rate) measurement of an ECG sample sequence?
EHAW-42	How to represent tri-axial acceleration data from accelerometers of an ECG device?
EHAW-43	How to integrate measurements from multiple sensors (e.g. ECG leads, accelerometer and battery monitor) of an ECG device for near real-time (frequency-based) monitoring?

9 Conclusions

The present document depicts the eHealth/Ageing well domain main stakeholders, as well as describes the existing initiatives and the main use cases, that have at least to be considered for developing SAREF4EHAW core extension. The present document also describes the 43 final ontological requirements retained to be handled in such core extension. Moreover, 59 additional service level assumptions of the eHealth/Ageing-well domain (use cases included) are presented (see Annex A of the present document), although aimed to be taken into account in future SAREF4EHAW additional extensions, for ensuring that the initial SAREF4EHAW core extension will be supporting them. The present document will be sent to eHealth/Ageing Well domain stakeholders for validation and/or dissemination purposes and might therefore be subject to a revision.

Annex A: eHealth/Ageing-well domain service level assumptions

A.1 eHealth/Ageing-well domain general service level assumptions

Clause A.1 of the present document summarizes the general service level assumptions of the eHealth/Ageing-well domain. These assumptions are resulting from a reverse engineering process that was carried out taking as input aforementioned eHealth/Ageing-well (EHAW) related initiatives and stakeholders already listed in clause 5 of the present document. The specific input resources will be drilled down below, for the general assumptions (EHAW-GEN category) that will be taken into account for an initial extension of SAREF for eHealth/Ageing-well. These assumptions are listed in Table A.1. All other service level assumptions, in particular those that are use case specific, will be listed in clause A.2 of the present document.

Table A.1: eHealth/Ageing well general service level assumptions

ID	Assumption
EHAW-GEN1	Users have profiles, including their age category (young, old), and/or pathology, and/or impairment (hearing, visual, handling, and deaf), and interact with accessible devices (big displays, big buttons, voice feedback, etc.).
EHAW-GEN2	A system may be classified according to its compliance with a given profile category, including age category, pathology, or impairment.
EHAW-GEN3	The eHealth/Ageing-well system has to be designed in co-conception with both patients and caregivers to insure the adequacy and discretion of the solution. This holds for the ontology specification.
EHAW-GEN4	The services, service components, or applications, that are implemented in a Device may change, according to the user profile or the user decisions.
EHAW-GEN5	As a device may have a battery which has a level, it may implement notification function to alert when the level of the battery is critical, and the user needs to charge the battery.
EHAW-GEN6	The IoT sensors should not require any user intervention, except (if necessary) the replacement of the power packs. The same concept should hold to ontology update/maintenance, in particular within patient' device.
EHAW-GEN7	Persons may have issues or troubles that needs to be questionable.
EHAW-GEN8	A BAN has to be used for collecting and aggregating diverse patient's parameters.
EHAW-GEN9	Data gathered and trends, as well as data/trends changes, etc., should be both monitored and made accessible to eHealth system actors.
EHAW-GEN10	Person eHealth information has to be provided to Social Services and primary healthcare for better intervention.
EHAW-GEN11	A patient should have a pathology/comfort profile, and the solution has to provide home appliances interactions for adapting the home environment to that profile (e.g. keep a room temperature steady around 25° for an elderly). This is done via dedicated actuators (e.g. for controlling heating, roller shutter, light, oven, outlets, blinds, fan, or regulating water). This also means cross-domain handling.
EHAW-GEN12	Information generated by/from the patient should be differentiable form the one generated by another collocated person.
EHAW-GEN13	Actors (patients, assisted persons, caregivers and helpers) privacy, data anonymization and protection issues have to be taken into account.
EHAW-GEN14	Effectiveness and efficiency are mandatory for care tasks performing (e.g. monitoring), which means very low latency and loss rate, real time handling, reliability low complexity and modular design.
EHAW-GEN15	Decision making tools have to be provided for both patient and caregiver/helper support. This in particular implies embedded and distributed data analytics capabilities (device/edge/fog computing).
EHAW-GEN16	Daily life related data/information has to be monitored for providing assisted living enablers and daily life improvement of patients.
EHAW-GEN17	Patients under chronic conditions have to be handled.
EHAW-GEN18	Data and parameters causing changes, trends or risks in assisted person (e.g. elders) have to be detected and monitored.
EHAW-GEN19	Outside home monitoring and assistance have to be provided for preventing any risk.
EHAW-GEN20	Cross-domain interaction and information gathering (e.g. form city, car) is mandatory for allowing mobility assistance, which in particular means interoperability handling (semantic interoperability included).

ID	Assumption
EHAW-GEN21	Critical situations have to be detected and corresponding information has to be forwarded to relevant entities such as a medical centre or the caregiver.
EHAW-GEN22	Physical and mental activities have to be promoted and measured/monitored.
EHAW-GEN23	Cognitive stimulation has to be provided for mental decline prevention. Corresponding useful data/information has to be measured and monitored for detecting early symptoms of pathologies.
EHAW-GEN24	Social inclusion and mobility have to be promoted and monitored.
EHAW-GEN25	Support for transportation and mobility has to be provided.
EHAW-GEN26	Daily life improvement of assisted persons and patients, as well as caregiver process and decision making improvement have to be supported.
EHAW-GEN27	MISs (Medical Information Systems), medical devices, medical data, semantic - interoperability has to be handled.

A.2 eHealth/Ageing-well domain additional service level assumptions

This clause summarizes the set of identified service level assumptions for specific sub-domains and associated use cases that might appear in eHealth/Ageing-well vertical and that are summarized in clause 7 of the present document. The specific input resources will be drilled down below, for each of the additional categories that could be taken into account for an extension of SAREF for eHealth/Ageing-well (EHAW). The considered categories for clause A.2 of the present document are related to eHealth/Ageing well use cases and are the following: EHAW-DAM (i.e. Daily Activity Monitoring), EHAW-UCC (i.e. Under Chronic Conditions), EHAW-MOH (i.e. Monitoring Outside Home), EHAW-EMT (i.e. Emergency Trigger), EHAW-EXP (i.e. Exercise Promotion), EHAW-MDP (i.e. Mental Decline Prevention), EHAW-PSI (i.e. Prevention of Social Isolation) and EHAW-STM (i.e. Support for Transportation and Mobility). The identified additional service level assumptions are listed in Table A.2. It should be reminded that not all these additional assumptions would be considered for the SAREF4EHAW minimal extension and base ontology. However, they are fully listed in this clause for further specializations of SAREF4EHAW ontology and are included in order to ensure that SAREF4EHAW minimal extension supports them.

Table A.2: eHealth/Ageing well additional service level assumptions

ID	Assumption
EHAW-DAM1	Medication taken has to be monitored.
EHAW-DAM2	Medical appointments information should be available.
EHAW-DAM3	The system should connect with App of medical appointments when it detects Unusual behaviours (e.g. inactivity, sleep, etc.) for triggering a medical appointment update via the dedicated service.
EHAW-DAM4	Daily monitoring and control of vital signs (blood pressure, arrhythmias, glucose, etc.) have to be provided. This is in particular achieved through sensor and wearable devices.
EHAW-DAM5	Information of Eating enough amounts of healthy food has to be provided.
EHAW-DAM6	Information of elderly normal eating times should be provided to generate an alarm for assisting and alerting the elderly.
EHAW-DAM7	Information on water level drank should be monitored, as well as information on minimum water level to drink should be made available, for generating an alert (e.g. 'drink more') to the assisted person.
EHAW-DAM8	Interactions with appliances such as fridge are monitored for eating habits control.
EHAW-DAM9	The following environment variables have in particular to be monitors via appropriate devices: presence, motion in a room, door opening, temperature, humidity, luminosity and pressure, smoke, temperature, gas, wind, CO2, motion in a room, windows open, air quality; Smart Appliances interactions.
EHAW-DAM10	Temperature in the home has to be periodically monitored for an automated adjustment of wellbeing/comfort parameters according to assisted person profile and pathology. This is in particular addressed via actuators acting on fan, air conditioner, blinds, heating, etc.).
EHAW-DAM11	Assisted person actions or inactions (e.g. person not wake up, person cannot stand up, fridge opened, heater not turned off, window/door not closed) have to be monitored for alert sending and risk evaluation purposes.
EHAW-DAM12	Smoke has to be monitored monitor for critical situation detection and management (e.g. turn off oven and critical outlets; open blinds, trigger an alarm).
EHAW-DAM13	Nocturnal activity of assisted persons has to be monitored, and in particular: time of sleep, sleep patterns (influence of polimedication), if the person gets up or leaves the room or does not go back after a certain amount of time. This in particular implies continuous or periodic measurements and time series monitoring.

ID	Assumption
EHAW-DAM14	Posture and activities of the assisted people have to be detected, monitored or estimated, in particular in terms of kind (e.g. lying in bed, sitting on a chair, using the shower, etc.) and duration and estimate the time spent in bed or chair.
EHAW-DAM15	Elderly person fall has to be detected (real time), and alert has to be sent (real time) at least to caregiver(s) and, if appropriate, to helpers.
EHAW-DAM16	Data/parameters related to person habits and behaviors have to be monitored for providing mandatory guidance and trends detection.
EHAW-DAM17	Alerts/alarms inform of changes in parameters of routine.
EHAW-DAM18	Information on activities that assisted elderly people like or are keen on should be provided.
EHAW-DAM19	Information and alerts on the elderly coming back home/entering home should be provided.
EHAW-DAM20	The solution will allow the generation of videoconferences between the end user and their caregiver.
EHAW-UCC1	Information on temperature changes for diabetic people has to be monitored, and an alert has to be generated.
EHAW-MOH1	Information on the assisted elderly leaving the apartment (duration included), turning off some electrical devices, as well as on open windows (duration included), have to be provided.
EHAW-MOH2	Information on when the assisted elderly does not arrive home at a foreseen time has to be monitored.
EHAW-MOH3	Information on when an elderly person goes outdoors, as well as his/her physical activity (steps, distance walked, etc.), has to be provided.
EHAW-MOH4	Control of assisted elderly person within a security perimeter or route outdoors has to be provided, which in particular means that both elderly security perimeter data and elderly geolocation have to be monitored.
EHAW-MOH5	Location data of assisted elderly person outdoors has to be monitored and caregivers have to be informed.
EHAW-MOH6	Elderly person assistance for streets/roads crossing in time should be provided.
EHAW-MOH7	Information on if the elderly person has got on a vehicle (speed control) should be provided.
EHAW-MOH8	Information on when elderly is outdoors or falls has to be provided, and the corresponding alerts have to be trigger and at least sent to the caregiver(s) and eventually also to the helper(s).
EHAW-EMT1	Risky and emergency situations have to be detected and somehow provided, e.g. a fall during the nightly walk to rest room, and assisted person has to be alerted, as well as either named contact or statutory service (e.g. through voice alert).
EHAW-EMT2	Device to build up typical activity for a person then set parameters for emergency trigger.
EHAW-EMT3	Risky or unhealthy habits (e.g forget to eat, has not gone out for some time) should be provided, and corresponding alerts should be triggered.
EHAW-EMT4	Information on period of inactivity (unusual lack of movement) has to be monitored, corresponding alarm has to be triggered, as well as a notification has to be sent to caregivers or emergence services.
EHAW-EXP1	System suggests to the elderly to do physical activity or other activities.
EHAW-EXP2	Factors related to falls, gait, speed, etc. should be monitored for fall detection purposes.
EHAW-EXP3	Balance training sessions monitoring should be provided.
EHAW-EXP4	Monitor amount leaving house, etc. ongoing, set alerts if it looks like activity reduced, which is in particular related to daily activity monitoring.
EHAW-MDP1	Daily habits/routines information should be available and corresponding reminders to the elderly should be triggered.
EHAW-MDP2	Suggestions triggering for elderly people on activities to do indoors for maintaining memory, habits, self-responsibility (e.g. take care of plants, etc.) have to be handled.
EHAW-MDP3	Information useful to early detect symptoms of cognitive impairment: physical inactivity, lack of personal hygiene, erratic paths, loss of memory (elderly person forgets to eat, etc.) should be generated/provided. This information should be monitored.
EHAW-MDP4	Outdoor activity that contributes to detect cognitive impairment and pathologies should be monitored, for example: repetitive visits to bank or nutrition habits based on diversity of places where the elderly person goes (not shopping at greengrocery or grocer's, too many visits to cake shop or ice cream shop, for instance, etc.).
EHAW-PSI1	Information on users social activities (going out, chatting with friends, (outdoor activities, communication with other users (e.g. through phone line), etc. should be provided.
EHAW-PSI2	The services should provide ways of maintaining contact with relatives and friends, preferably with video and audio.
EHAW-PSI3	The support system should allows messages between carers and includes options for notes from doctors, services, carers, etc.
EHAW-PSI4	Produce location-based suggestions of events/activities to do outdoors around the city the user is interested in for promoting social inclusion, which in particular means: user tracking, geolocation and activity monitoring.
EHAW-PSI5	Repetitive behaviours have to be monitored (e.g. doing the same way or path) and corresponding alerts triggered.
EHAW-PSI6	Games and community activities information should be made available (e.g. on a portal) to encourage peer support.

ID	Assumption
EHAW-CSH1	Needs and preferences in terms of look, feel and suitability in particular guide the choice of wearables.
EHAW-CSH2	Air condition measurements for e.g. turning on or of fans accordingly.
EHAW-CSH3	Turn off water if water is detected on the floor. Water presence measurement.
EHAW-CSH4	React on smoke detection. Smoke detection measurement.
EHAW-CSH6	Light up the room and the bathroom when resident get up at night, which means night activity monitoring.
EHAW-CSH7	Emergency triggers to be activated relating to Location, home hazards, burglary monitoring for emergency triggering purposes.
EHAW-STM1	Information on public transport, municipal resources, local activities, etc. made available for being visualied at the elderly person's Smartphone or the tablet.
EHAW-STM2	Accurate pedestrian detection should be monitored.
EHAW-STM3	Traffic, light and parking information should be available.
EHAW-STM4	Assisted elderly people receives information on accessible routes and public transport adapted to elderly, as well as elderly adapted and safe routes, that has to be made available to assisted elderly people.
EHAW-STM6	Information on if the assisted elderly has got on a bus and the route followed has to be provided.
EHAW-STM7	All information related to car (position, speed, direction, etc.) should be available.

History

Document history		
V1.1.1	October 2019	Publication