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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

In the present document "**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 lists the requirements for an initial semantic model extending SAREF for the wearables domain. This initial SAREF extension will be based on both a limited set of use cases and available existing data models. The present document is developed in close collaboration with ETSI activities in the wearables and eHealth domains, SmartM2M/oneM2M, and Wearables related EU projects and H2020 Large Scale Pilots. Further extensions are planned in the future to cover entirely the wearables 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.

[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".

NOTE: Available at https://www.etsi.org/deliver/etsi_tr/103400_103499/103411/01.01.01_60/tr_103411v010101p.pdf.

[i.5] IEEE: "P360 - Standard for Wearable Consumer Electronic Devices - Overview and Architecture".

[i.6] IEC 62471 for LED Lighting Products.

[i.7] IEC 62209 (all parts): "Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices".

[i.8] ISO 10993 (all parts): "Biological evaluation of medical devices".

NOTE: Available at https://en.wikipedia.org/wiki/ISO_10993#List_of_the_standards_in_the_10993_series.

[i.9] UL 60601-1: "Medical Electrical Equipment, Part 1: General Requirements for Safety".

[i.10] UL 60950-1: "Information Technology Equipment - Safety - Part 1: General Requirements".

NOTE: Available at https://standardscatalog.ul.com/standards/en/standard_60950-1_2.

[i.11] IEC 60065:2014: "Audio, video and similar electronic apparatus - Safety requirements".

[i.12] IEC 62368-1:2018: "Audio/video, information and communication technology equipment - Part 1: Safety requirements".

[i.13] Natalia Díaz Rodríguez, Stefan Grönroos, Frank Wickström, Johan Lilius, Henk Eertink, Andreas Braun, Paul Dillen, James Crowley, Jan Alexandersson: "An Ontology for Wearables Data Interoperability and Ambient Assisted Living Application Development". WCSC 2016: 559-568.

[i.14] Gregorio Rubio Cifuentes, Estefanía Serral, Pedro Castillejo, José-Fernán Martínez: "A Novel Context Ontology to Facilitate Interoperation of Semantic Services in Environments with Wearable Devices". OTM Workshops 2012: 495-504.

[i.15] Claudia Villalonga, Héctor Pomares, Ignacio Rojas, Oresti Banos: "MIMU-Wear: "Ontology-based sensor selection for real-world wearable activity recognition". Neurocomputing 250". 76-100 (2017).

[i.16] Ahlem Rhayem, Mohamed Ben Ahmed Mhiri, Mayssa Ben Salah, Faïez Gargouri: "Ontology-based system for patient monitoring with connected objects". KES 2017: 683-692.

[i.17] Semantic Smart Sensor Network ontology (S3N).

NOTE: Available at http://w3id.org/s3n/.

[i.18] Jack Hodges, Mareike Kritzler, Florian Michahelles, Stefan Lueder, Erik Wilde: "Ontology alignment for wearable devices and bioinformatics in professional health care".

NOTE: Available at https://pdfs.semanticscholar.org/bdc1/285017f3b09539a0f7034e4c65ab64736c2c.pdf.

[i.19] PwC: "The Wearable Life 2.0".

NOTE: Available at https://www.pwc.nl/nl/assets/documents/pwc-the-wearable-life-2-0.pdf.

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

NOTE 1: 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:

4G	fourth generation of broadband cellular network technology
AHA	Active Healthy Ageing
AIOTI	Alliance for the Internet of Things Innovation
API	Application Program Interface
BT	Body Temperature
CBT	Core Body Temperature
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
COPD	Chronic Obstructive Pulmonary Disease
DOLCE	Descriptive Ontology for Linguistic and Cognitive Engineering
DUL	DOLCE Ultra Lite
ECG	Electrocardiogram
EN	European Standard
ETSI	European Telecommunications Standards Institute
GPS	Global Positioning System
GPU	Graphical Processing Unit
IEC	International Electrotechnical Commission
IoT	Internet of Things
IP	In Person
ISO	International Organization for Standardization
IT	Information Technology
ITE	Information Technology Equipment
IWHP	Inuheat Wearable Heating Platform
LED	Light-Emitting Diode
LifeWear	Lifestyle with Wearables
MIMU	Magnetic and Inertial Measurement Unit
NB-IoT	Narrowband-IoT
NFC	Near Field Communication
OGC	Open Geospatial Consortium
OWL	Ontology Web Language
PA	Public Address
PA system	Public Address system
RF	Radio Frequency
RGB-D	Red Green Blue-Depth
S3N	Semantic Smart Sensor Network
SAR	Specific Absorption Rate
SAREF	Smart Applications REFerence ontology
SAREF4WEAR	SAREF extension for Wearables
SCI	Spinal Cord Injured
SSN	Semantic Sensor Network
STF	Special Task Force
SWE	Sensor Web Enablement
TR	Technical Report
TRL	Technology Readiness Level
TS	Technical Specification
TSi	Think Silicon S.A.
UI	User Interface
UL	Underwriters Laboratories standard
USB	Universal Serial Bus
UWB	Ultra Wide Band
WEAR	Wearable technologists Engage with Artists for Responsible innovation

4 SAREF extension for the Wearables 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 ETSI TS 103 264 [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 Wearables. 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 (see https://portal.etsi.org/STF/STFs/STFHomePages/STF566.aspx), 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, Wearables related H2020 Large Scale Pilots and EU projects. However, other initiatives coming from Wearables industrial 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 Wearables domain. The present document sets the requirements of an initial semantic model that will result in a new SAREF ontology extension for Wearables, called SAREF4WEAR and to be published in a TS document as part of STF 566 Task 3 SAREF extensions series.

5 Characteristic of Wearables

5.0 Introduction

Wearable devices and services have some common characteristics as the ones listed below. A domain-specific ontology about Wearables has to be able to model such characteristics in order to be deployable within a real-world environment.

5.1 Wearability

Unlike other devices which are agnostic to the users or rarely interact with the users, wearable devices are carried by the users and interact with them all the time. Convenience and comfort are the top considerations. The design of wearable devices needs to be small enough for convenience and portability.

5.2 Personal data protection

Wearable devices and related services collect, transmit, and store lots of personal data. The confidentiality of data is fundamental for wearable services, while data sharing is essential for the mutual interaction of users within a community.

5.3 Limited communication ability

Due to the limitation of size, weight and power supply, wearable devices are not usually equipped with wide-bandwidth network access abilities. Most of them only support narrow-bandwidth connectivity technologies, e.g. Bluetooth®, NFC and NB-IoT.

5.4 Limited storage space

According to use cases, wearable devices have limited storage space.

5.5 Limited power supply

Due to the size and comfort requirements, wearable devices are only equipped with small battery or even use solar or biological energy, which provide limited power supply.

5.6 Intelligence

As wearable devices can be carried by different users and work in different environments, they need adequate intelligence to adjust themselves to different usages.

5.7 Communication capability

Due to the variety of wearable applications, the requirements on data transmission and service quality differs a lot. Corresponding to the requirement of the communication, different wearable centric vertical applications would probably adopt different communication technologies. For instance, wearable applications that transmit multimedia content need to transfer thousands more times of data volume than that of position and biological data. Thus, wide bandwidth communication technology, such as WiFi™, 4G would be adopted by the former, and narrow bandwidth communication technologies such as ZigBee®, Bluetooth®, NB-IoT™ would be adopted by the later.

5.8 Real-time requirement

The requirement on time delay tolerance of service is a critical requirement of wearable centric vertical applications. For fitness and positioning application, several seconds delay still can be tolerant, however in healthcare scenario the latency should be less than 250 ms for non-medical application and less than 125 ms for medical application. IoT edging storage and edging computing technologies could give great help on timely responding and decision making at the edge. However, to thoroughly satisfy different levels of the real-time requirements for particular wearable centric vertical applications, there still needs adaptation on the architecture and detail deployment of the IoT network for real-time services.

5.9 Data precision

Different applications of wearables have different requirements on precision of sensing data. The data precision of wearable devices should conform to corresponding standards related to the application areas. Health monitoring applications ask for high precision of physiological signals. Such high precision needs to be maintained during the data processing and analysis phases.

6 Related initiatives

6.0 Introduction

Within clause 6 of the present document, some of the main related initiatives in term of modelling and standardization in Wearables domain are reviewed. Existing efforts range from national or international standards to rather specific models used in certain software solutions provided by industrial world actors. Therefore, the potential stakeholders identified for SAREF4WEAR extension might be classified as: public administrations, associations related to the Internet of Things and Wearables, European projects and Large-Scale Pilots, standardization bodies and alliances related to the Internet of Things and Wearables domain, as well as industrial world and alliances initiatives of the Wearables domain. For each type of stakeholder, the initiatives that have to be taken into account for SAREF4WEAR extension are described next.

6.1 Standardization initiatives and associations

6.1.0 Introduction

Clause 6.1 of the present document lists standardization initiatives that are currently active within the Wearables domain.

6.1.1 P360 - Standard for Wearable Consumer Electronic Devices

The IEEE standard [i.5] gives overview, terminology and categorization for Wearable Consumer Electronic Devices (or Wearables in short). It further outlines an architecture for a series of standard specifications that define technical requirements and testing methods for different aspects of Wearables, from basic security and suitableness of wear, to various functional areas like health, fitness and infotainment, etc.

6.1.2 IEC 62471 (LEDs and eye/skin contact)

IEC 62471 [i.6] gives guidance for evaluating the photo-biological safety of lamps and lamp systems including luminaries. Specifically, it defines exposure limits, references measurement techniques and the classification scheme for the evaluation and control of photo-biological hazards from all electrically powered incoherent broadband sources of optical radiation, including LEDs (but excluding lasers), in the wavelength range from 200 nm through 3 000 nm. This standard was prepared as Standard CIE S 009:2002 by the International Commission on Illumination. Its application within the Wearables domain concerns the suitability of the displays of wearable devices.

6.1.3 IEC 62209 SAR (Specific Absorption Rate)

The IEC 62209 series [i.7] is intended to enable the preparation of international standards on measurement and calculation methods to assess human exposure to electric, magnetic and electromagnetic fields (0 Hz to 300 GHz). Issues addressed within this document are related to:

- characterization of electromagnetic environments with regard to human exposure;
- measurement methods, instrumentation and procedures;
- calculation methods;
- methods of assessing the rate of RF energy absorption per unit body mass for specific sources commonly called a Specific Absorption Rate (SAR) measurement;
- assessment of uncertainties;
- basic standards for other sources.

6.1.4 ISO 10993 (Biocompatibility)

The primary aim of the ISO 10993 standards [i.8] is the protection of humans from potential biological risks arising from the use of medical devices. This standard combines the review and evaluation of existing data from all sources with, where necessary, the selection and application of additional tests, thus enabling a full evaluation to be made of the biological responses to each medical device, relevant to its safety in use.

The ISO 10993 series [i.8] addresses the determination of the effects of medical devices on tissues, mostly in a general way, rather than in a specific device-type situation. Thus, for a complete biological safety evaluation, it classifies medical devices according to the nature and duration of their anticipated contact with human tissues when in use and indicates, in matrices, the biological data sets that are thought to be relevant in the consideration of each device category.

The range of biological hazards is wide and complex. The tissue interaction with a constituent material alone cannot be considered in isolation from the overall device design. Thus, in designing a device, the choice of the best material with respect to its tissue interaction might result in a less functional device, tissue interaction being only one of a number of characteristics to be considered in making that choice.

Biological testing is based upon, among other things, in vitro and ex-vivo test methods and upon animal models, so that the anticipated behaviour when a device is used in humans can be adjudged only with caution, as it cannot be unequivocally concluded that the same tissue reactions will also occur in this species. In addition, differences in the manner of response to the same material among individuals indicate that some patients can have adverse reactions, even to well-established materials.

The ISO 10993 series [i.8] describe:

- the general principles governing the biological evaluation of medical devices within a risk management process;
- the general categorization of devices based on the nature and duration of their contact with the body;
- the evaluation of existing relevant data from all sources;
- the identification of gaps in the available data set on the basis of a risk analysis;
- the identification of additional data sets necessary to analyse the biological safety of the medical device;
- the assessment of the biological safety of the medical device.

The ISO 10993 series [i.8] do not cover testing of materials and devices that do not come into direct or indirect contact with the patient's body, nor do they cover biological hazards arising from any mechanical failure.

6.1.5 UL 60601-1 (Medical devices)

Aware of the need and the urgency for a standard covering electrical equipment used in medical practice, the majority of National Committees voted in 1977 in favour of the first edition of UL 60601-1 [i.9], based on a draft that at the time represented a first approach to the problem. The extent of the scope, the complexity of the equipment concerned, and the specific nature of some of the protective measures and the corresponding tests for verifying them, required years of effort in order to prepare this first standard, which can now be said to have served as a universal reference since its publication.

The original IEC approach was to prepare separate basic safety and performance standards for medical electrical equipment. This was a natural extension of the historical approach taken at the national and international level with other electrical equipment standards (e.g. those for domestic equipment), where basic safety is regulated through mandatory standards, but other performance specifications are regulated by market pressure.

It is now recognized that this is not the situation with many items of medical electrical equipment, and responsible organizations have to depend on standards to ensure essential performance as well as basic safety. Such areas include the accuracy with which the equipment controls the delivery of energy or therapeutic substances to the patient, or processes and displays physiological data that will affect patient management.

This recognition means that separating basic safety and performance is somewhat inappropriate in addressing the hazards that result from inadequate design of medical electrical equipment.

In order to achieve consistency in international standards, address present expectations in the health care community and align with developments in UL 60601-1 [i.9] this document includes two major principles:

- the first is that the concept of "safety" has been broadened from the basic safety considerations in the first and second editions of UL 60601-1 [i.9] to include essential performance matters, (e.g. the accuracy of physiological monitoring equipment);
- the second is that, in specifying minimum safety requirements, provision is made for assessing the adequacy of the design process when this is the only practical method of assessing the safety of certain technologies such as programmable electronic systems.

This standard contains requirements concerning basic safety and essential performance that are generally applicable to medical electrical equipment. For certain types of medical electrical equipment, these requirements are either supplemented or modified by the special requirements of a collateral or particular standard. Where particular standards exist, this standard should not be used alone.

6.1.6 UL 60950-1 (ITE equipment)

UL 60950-1 [i.10] is applicable to mains-powered or battery-powered information technology equipment, including electrical business equipment and associated equipment.

This standard is also applicable to such information technology equipment:

- designed for use as telecommunication terminal equipment and telecommunication network infrastructure equipment, regardless of the source of power;
- designed and intended to be connected directly to, or used as infrastructure equipment in, a cable distribution system, regardless of the source of power;
- designed to use the AC mains supply as a communication transmission medium.

This standard is also applicable to components and subassemblies intended for incorporation in information technology equipment. It is not expected that such components and subassemblies comply with every aspect of the standard, provided that the complete information technology equipment, incorporating such components and subassemblies, does comply.

This standard specifies requirements intended to reduce risks of fire, electric shock or injury for the operator and layman who may come into contact with the equipment and, where specifically stated, for a service person.

This standard also specifies requirements intended to reduce risks from acoustic outputs at communication receivers and similar devices used for voice telecommunication, regardless of transmission medium (e.g. telecommunication network, cable distribution network, wireless network).

This standard is intended to reduce such risks with respect to installed equipment, whether it consists of a system of interconnected units or independent units, subject to installing, operating and maintaining the equipment in the manner prescribed by the manufacturer.

Equipment complying with the relevant requirements in this standard is considered suitable for use with process control equipment, automatic test equipment and similar systems requiring information processing facilities. However, this standard does not include requirements for performance or functional characteristics of equipment.

6.1.7 IEC 60065 (Audio-Video equipment)

IEC 60065 [i.11] primarily concerns apparatus intended for household and similar general use but which may also be used in places of public assembly such as schools, theatres, places of worship and the workplace. Professional apparatus intended for use as described above is also covered unless falling specifically within the scope of other standards. This standard concerns only safety aspects of the above apparatus; it does not concern other matters, such as style or performance. This standard applies to the above-mentioned apparatus, if designed to be connected to the or similar network, for example by means of an integrated modem. Some examples of apparatus within the scope of this standard are:

- receiving apparatus and amplifiers for sound and/or vision;

- independent load transducer and source transducers;
- supply apparatus intended to supply other apparatus covered by the scope of this standard;
- electronic music instruments, and electronic accessories such as rhythm generators, tone generators, music tuners and the like for use with electronic or non-electronic musical instruments;
- audio and/or video educational apparatus;
- video projectors.

6.1.8 IEC 62368-1 (Combined standard - ITE + Audio/Video)

IEC 62368-1 [i.12] aims to facilitate knowledge-sharing and to alleviate high tech manufacturers' and stakeholders' concerns with the Safety Standard for:

- Audio/Video Equipment, including professional, and musical instruments;
- Consumer Electronics;
- Information Technology Equipment;
- Office Appliances; and
- Communication Technology (Telecom) Equipment.

6.2 European Projects

MONICA - Management Of Networked IoT Wearables (see https://cordis.europa.eu/project/rcn/206397/factsheet/en). The SoundCity Project MONICA aims to provide a very large scale demonstration of multiple existing and new Internet of Things technologies for Smarter Living. The solution will be deployed in 6 major cities in Europe. MONICA demonstrates a large scale IoT ecosystem that uses innovative wearable and portable IoT sensors and actuators with closed-loop back-end services integrated into an interoperable, cloud-based platform capable of offering a multitude of simultaneous, targeted applications. All ecosystems will be demonstrated in the scope of large-scale city events, but have general applicability for dynamically deploying Smart City applications in many fixed locations such as airports, main traffic arterials, and construction sites. Moreover, it is inherent in the MONICA approach to identify the official standardization potential areas in all stages of the project. MONICA will demonstrate an IoT platform in massive scale operating conditions; capable of handling at least 10 000 simultaneous real end-users with wearable and portable sensors using existing and emerging technologies (TRL 5-6) and based upon open standards and architectures. It will design, develop and deploy a platform capable of integrating large amounts of heterogeneous, interoperable IoT enabled sensors with different data capabilities (video, audio, data), resource constraints (wearables, Smartphones, Smartwatches), bandwidth (UWB, M2M), costs (professional, consumer), and deployment (wearable, mobile, fixed, airborne) as well as actuators (lights, LED, cameras, alarms, drones, loudspeakers). It will demo end-to-end, closed loop solutions covering everything from devices and middleware with semantic annotations through a multitude of wireless communication channels to cloud based applications and back to actuation networks. Humans-in-the-Loop is demonstrated through integrating Situational Awareness and Decision Support tools for organisers, security staff and sound engineers' situation rooms.

WEAR - Wearable technologists Engage with Artists for Responsible innovation (see https://cordis.europa.eu/project/rcn/206415/factsheet/en). WEAR proposes to bring wearable technology stakeholders to work more closely with designers and artists across Europe to shift the development of the EU wearable industry, drawing on the rich European landscape of wearable technology and smart textile stakeholders, toward addressing the core issues head on within the research & development stages.

XoSoft - Soft modular biomimetic exoskeleton to assist people with mobility impairments (see https://cordis.europa.eu/project/rcn/200108/factsheet/en). The XoSoft project will develop a modular soft lower-limb exoskeleton to assist people with mobility impairments. The consortium includes 5 research groups and 3 companies each with EU project experience in exoskeleton/assistive orthotics development. XoSoft, a class I medical device, assists people with low to moderate levels of reduced mobility, enabling them to remain active performing tasks of daily living, which they would otherwise either refrain from doing or could not do. It can also be used in clinics by people with disabilities such as muscle weakness or partial loss of sensory functions. Being a modular system, it comprises an ankle, knee and hip which can be use individually or combined and used unilaterally or bilaterally.

A-WEAR - A network for dynamic WEarable Applications with pRivacy constraints (see https://cordis.europa.eu/project/rcn/218402/factsheet/en). The emerging market of wearables is expected to grow exponentially in the near future, driven by the sales increase of smart clothes, watches, and eyeglasses. The future wearables are likely to be heterogeneous, operating on batteries, sun power or human motion, and endowed with smart functions. They will co-operate in a decentralized manner with each other and will be able to reach various interconnected software and applications. The main stream wearable-based architecture has been applied so far in wellbeing industries, such as eHealth or ambient assisted living, which might also reduce the costs for care and guarantee a healthy independent live in the forthcoming older society. As the digitalization and data-based economy are growing, the exploitation potential of the wearables can easily be expected to increase. Key wearables stakeholder groups in the future are also smart cities, comprising intelligent building industry and infrastructure, energy-efficient smart grid sector, public e-Services, and smart transport. Motivated by the opportunities that next-generation wearable intelligence is expected to provide, the mission of A-WEAR action is to cross-disciplinarily create new architectures, open-source software and frameworks for dynamic wearable ecosystems, with distributed localization and privacy constraints.

Smart2Go - Smart and Flexible Energy Supply Platform for Wearable Electronics (see https://cordis.europa.eu/project/rcn/219473/factsheet/en)**.** The widespread introduction of wearable devices is expected to be one of the major trends in the next one or two decades. First applications have already entered the market, like e.g. the smartwatch from Apple or various types of fitness trackers. However, the main booming period is still expected to happen in future. Health care application, internet of things as well as reshaping of the interaction between humans and electronic devices will be the main drivers for this development. Presently various obstacles still hinder the expected rapid development. Apart from legal topics, like e.g. data security, there are also technological bottlenecks. The energy supply to wearable devices is probably the most serious challenge among these technological bottlenecks. The Smart2Go project is exactly targeting this topic. The aim of the project is the creation of an autonomous energy-supply platform. Based on the results of the project it will be possible to use a wearable without caring about recharging over its entire lifetime. This aim will be achieved by the combination of a powerful battery with appropriate energy harvesting technologies. The performance of the energy supply platform will be demonstrated in two application cases.

WEARPLEX - Wearable multiplexed biomedical electrodes (see https://cordis.europa.eu/project/rcn/220257/factsheet/en). WEARPLEX is a multidisciplinary research and innovation action with the overall aim to integrate printed electronics with flexible and wearable textile-based biomedical multi-pad electrodes. It aims to answer the growing need for user-friendly electrodes for pervasive measurement of electrophysiological signals and application of electrical stimulation. It focuses on the development of the printable electronics and manufacturing processes for stretchable textile based multi-pad electrodes with integrated logic circuits that enable a significant increase in the number of electrode pads (channels) and facilitate the creation of new products in the sectors of medical electronics and life-style. The advanced printed electronics integrated in WEARPLEX electrodes will allow the individual pads to be connected in arbitrary configurations to the output leads of the electrode. Therefore, the pads will be flexibly organized into several virtual electrodes of arbitrary position, shape and size that can be connected to any standard multi-channel recording and stimulation system.

A-Patch - Autonomous Patch for Real-Time Detection of Infectious Disease (see https://cordis.europa.eu/project/rcn/220355/factsheet/en)**.** The A-Patch Research & Innovation project will research, innovate, push technology barriers, and demonstrate innovative use of Flexible and Wearable Electronics in the medical and well-being sectors, validate its prototype devices in lab and hospital environments (TRL 4-5). Industrial exploitation of the A-Patch applications will be clearly identified. The project will develop non-invasive autonomous wearable diagnostic patches for real-time remote monitoring of infection status. The A-Patch will use a novel intelligent hybrid sensor array with multiplexed detection capabilities to detect disease-specific volatile organic compounds (VOCs) from the surface of the skin, enabling rapid and highly-accurate diagnosis using a small device. Product innovations for professionals and consumers will be incorporated, and benefits demonstrated. Integration of electronic devices in connected wearable, flexible and stretchable settings, low-power interconnection, compatibility with low-cost manufacturing, efficient energy scavenging and storage, functional performance, and durability will be successfully demonstrated. To ensure reliability and enable extended usage periods, the sensor array will be self-repairing and the device will be self-powered, by advancing cutting-edge research on chemical hybrid sensors and materials.

MAXHEAT - (see https://cordis.europa.eu/project/rcn/217458/factsheet/en)**.** In 2016, Inuheat started the commercialization of the Inuheat Wearable Heating Platform (IWHP), an innovative wearable heating system with advanced features allowing an easy implementation into standard clothing manufacturing equipment. The IWHP was introduced in 8 sock lines commercialized by Seger arousing great interest among final users and clothing brands. MaxHeat is the next step in Inuheat's product pipeline. It will help outdoors enthusiasts and workers to keep warm by offering an affordable, easy to implement wearable heating system providing comfort, durability (3 years) and efficiency (8 hours battery life) while enabling full product traceability and a disruptive 2-way communication channel with the final users of the garments through a cloud network. MaxHeat has reached a TRL 7, is protected by 2 patents, and its target end users are clothing brands and final users of the heated garments. Through MaxHeat project, Inuheataims to up-scale its production and to fully develop MaxHeat cloud network.

SYMBITRON - Symbiotic man-machine interactions in wearable exoskeletons to enhance mobility for paraplegics (see https://cordis.europa.eu/project/rcn/110314/factsheet/en). SYMBITRON targets a major technological leap for symbiotic man-machine interactions. In particular, the project results will markedly improve the lives of (partially) paralyzed persons through the development of a superior wearable exoskeleton. Such systems are designed to offer Spinal Cord Injured (SCI) patients the ability to walk and overcome obstacles in their daily life. To date, wearable exoskeletons still fall short of achieving this ambitious goal, and the will to bridge the gap forms the drive behind this project. The consortium has been assembled based on the partners' key scientific and clinical competences and long-standing experience in the field of man-machine interaction, as well as their excellent infrastructure and access to a large pool of SCI patients. The central approach seems unique within the research field, owing to its patient-centred design, which results in a fully customized solution that complements the unique remaining capacities of each individual patient. SYMBITRON consortium is a priori the first to replicate physiological neuromuscular functionality in an exoskeleton, while at the same time seamlessly integrating residual human functionality (muscle characteristics, reflexes etc).

GPU-WEAR - Ultra-low power heterogeneous Graphics Processing Units for Wearable/IoT devices (see https://cordis.europa.eu/project/rcn/203335/factsheet/en). Think Silicon S.A. (TSi) has become one of the only six companies in the world that have a proven capacity to develop Graphics IP technology. This technology is essential for fulfilling the ever-increasing demand for wearable and IoT devices. Dealing with the levels of power consumption required by those devices represents a major challenge and TSi has demonstrated and patented novel multi-disciplinary approaches spanning circuits, architecture, compiler and API level optimization techniques. TSi proposal is about bringing the world's first ultra-low power optimized heterogeneous multicore embedded graphics processing unit (GPU), low-power software library and associated run-time system to TRL 9. The technical advances are to be complemented by a comprehensive innovation management strategy covering IPR protection, commercial exploitation and alliance formation. Central to supporting uptake is the release of platform and tools to the Open Developer Community, in line with best practices in the sector.

AmbuLung - Ambulatory Bio-Artificial Lung **(see** https://cordis.europa.eu/project/rcn/104053/reporting/en). The idea to initiate the Ambulung project was based on the unmet medical needs to adequately treat patients, who suffer from severe COPD, a chronic pulmonary disease, which is the 4th leading cause of death worldwide. Following this idea, AmbuLung formed a European team of clinicians, scientists, engineers and entrepreneurs from four different institutions. The objective of this European team is to create a door opening pioneer product that will trigger consecutive research and development efforts to relieve suffering from end stage lung failure. Consequently, AmbuLung goal is to create the world's first wearable bioartificial lung for long term application on COPD patients in an outpatient setting. The main objectives of this three years project were to develop a miniaturized and wearable extracorporeal lung support system, to cellularize the diffusion membrane with endothelial cells and to evaluate the developed system in pre-clinical and clinical studies.

MICRO-DRESS - Customised Wearable Functionality and Eco-Materials (see https://cordis.europa.eu/project/rcn/96356/reporting/en). Ecology and wearable functionality in garments can co-exist within a consumer-centered business scenario where wished sensors or monitoring devices, as well as the degree of eco-friendliness of outfits, will be configurable for enjoying smart, natural and healthy garments. This is the main idea of the Dress project (eco-friendliness and wearable functionality). If it may appear at first sight that this is somehow contradictory, or at least not converging, the MICRO-DRESS project's on-going work is targeted on proving that ecology and wearable functionality can co-exist. This becomes even more interesting in a user-centered business scenario, where the customer is directly involved in the design/configuration process, empowered by the freedom to configure both the technology related added value (user selectable sensors, actuators, physiology monitoring devices), as well as the degree of eco-friendliness of his/her outfits (natural and healthy garments, preserving the environment and energy resources).

EGOVISION4HEALTH - Assessing Activities of Daily Living from a Wearable RGB-D Camera for In-Home Health Care Applications (see https://cordis.europa.eu/project/rcn/106955/reporting/en). Camera miniaturization and mobile computing now makes it feasible to capture and process videos from body-worn cameras such as the Google Glass headset™. This egocentric perspective is particularly well-suited to recognizing objects being handled or observed by the wearer, as well as analyzing the gestures and tracking the activities of the wearer. The main goal of the three-year project EgoVision4Health, was to investigate new egocentric computer vision techniques to automatically provide health professionals with an assessment of their patients' ability to manipulate objects and perform daily activities. The main research objectives were:

1) to introduce the use of wearable RGB-D cameras and advance existing knowledge on object detection in first-person views; and

2) to analyze object manipulation and daily activities using detailed 3D models of the human body (hands, upper-body, full-body).

gSKIN BodyTemp - (see https://cordis.europa.eu/project/rcn/218901/factsheet/en). Wearable biosensor systems for fitness and health monitoring have become popular in the last years, however, there is no wearable technology available for accurately monitor core body temperature (CBT) to date. In consequence, gSKIN BodyTemp (gSKIN BT hereafter) project aims at providing the first thermal sensor for non-invasive, wireless and continuous CBT monitoring; also meeting size requirements to be integrated in wrist wearable devices. The invention relies on our patented heat flux technology, a cost-effective thermal sensor plus sophisticated machine learning algorithms allowing accurate (±0,2°C) and real-time CBT measurements for the first time on the wrist and under free living conditions. gSKIN BT will result on added value for high-quality wearables, improving healthcare and sport medicine by enabling ubiquitous CBT monitoring. Other valuable novelties are its reduced cost and lower energy consumption compared to the available options. Being CBT an important vital parameter involved in some of the biggest health issues (e.g. sleep disorders, Parkinson and Alzheimer diseases), gSKIN BT will be one enabler for the necessary transformation towards a patient centred preventive health care system.

BioMot - Smart Wearable Robots with Bioinspired Sensory-Motor Skills (see https://cordis.europa.eu/project/rcn/109702/factsheet/en). Wearable robots (WRs) and are person-oriented devices, usually in the form of exoskeletons. These devices are worn by human operators to enhance or support a daily function, such as walking. WRs find applications in the enhancement of intact operators or in clinical environments, e.g. rehabilitation of gait function in neurologically injured patients. Most advanced WRs for human locomotion still fail to provide the real-time adaptability and flexibility presented by humans when confronted with natural perturbations, due to voluntary control or environmental constraints. Current WRs are extra body structures inducing fixed motion patterns on its user. The main objective of the BioMot project is to improve existing wearable robotic exoskeletons exploiting dynamic sensorimotor interactions and developing cognitive capabilities that can lead to symbiotic gait behavior in the interaction of a human with a wearable robot. BioMot will use and adapt available tools to reveal how neural circuits generate behavior, and to yield new strategies for co-adaptation during use of wearable robots for walking.

WASTCArD - Wrist and arm sensing technologies for cardiac arrhythmias detection (see https://cordis.europa.eu/project/rcn/194385/factsheet/en). Abnormal heart rhythms are a major cause of cardiovascular disease and death in Europe. Sudden cardiac death accounts for 50 % of cardiac mortality in developed countries; ventricular tachycardia or ventricular fibrillation is the commonest underlying arrhythmia. In the ambulatory population, atrial fibrillation is the commonest one, and is associated with increased risk of stroke and heart failure, particularly in the aged population. If arrhythmias are detected at an early stage of heart disease, appropriate treatment can be effective, reducing disability and death. However, in the early stages of disease these may be transient, lasting only a few seconds, and thus difficult to detect. Current approaches to cardiac rhythm monitoring include:

a) non-invasive external recording devices, which are suitable for short term (< 24 h) recording;

b) implantable loop recorders, which are inserted subcutaneously beneath the chest wall and capable of monitoring heart rhythm for extended periods. But, there is considerable expense associated with the device, e.g. hospitalisation costs and risk of infection.

The proposed joint research project **WASTCArD,** through staff exchange activities, will investigate enabling technologies for non-invasive recording heart rhythm during long periods of time (> 36 h), using a wrist or arm wearable device with novel ECG sensing techniques and embedded real-time cardiac arrhythmia detection processes. The problem of extracting the far-field heart electrogram signal from noise components will be addressed using smart denoising algorithms.

Lab-on-Skin™ - A wearable medical device for improved clinical trial monitoring (see https://cordis.europa.eu/project/rcn/216831/factsheet/en). Xsensio has leveraged the most advanced innovations from the fields of nanotechnology, biochemistry, and microfluidics to develop its proprietary Lab-on-Skin™ platform. At its core, the Lab-on-Skin™ platform contains an innovative functionalized sensor chip that is capable of measuring biomarkers in sweat. With the remote, continuous, and real-time monitoring of biomarkers, ultra-low power consumption, and optimized design for mass-production, the Lab-on-Skin™ platform is highly attractive for integration into wearable devices for 24/7 monitoring of patients. In this project, Xsensio will perform a feasibility study to:

1) select a panel of biomarkers that maximize the (clinical) applications of the Lab-on-Skin™ platform;
2) obtain quantitative and qualitative market data;
3) construct roadmaps for navigating the regulatory landscape;
4) strengthen and expand its current IP position; and
5) consolidate all current and future findings into a business plan.

MONILET - Monitoring Bracelet for Health Use (see https://cordis.europa.eu/project/rcn/194665/factsheet/en). The objective of the project is to further develop and take to market the prototype of the wearable bracelet and cloud-based IT platform for 24/7 continuous medical supervision. This is the world's first wearable health monitoring platform for automated, continuous supervision of pulmonary, heart and sleep related diseases generating preventive alert. This platform exploits a patented and revolutionary wrist blood oxygen sensing technology called trans-illumination pulse oximetry. Existing systems use a fingertip monitor which is both uncomfortable to wear and has to be connected to bedside or portable machinery and is prone to disconnection and damage in an active environment e.g. on children, and during sleep.

7 Initial data models/ontologies to considered

7.0 Introduction

Within clause 7 of the present document, the main ontologies discussed in the literature that are linked to the Wearable domain are presented. Such ontologies will be considered as starting point for drafting the SAREF extension for the Wearable domain.

7.1 Active Healthy Ageing (AHA) Ontology

The objective of the AHA Ontology [i.13] is to enable the integration of existing tools, hardware, and software that assist individuals in improving and/or maintaining a healthy lifestyle. This architecture is realized by integrating several hardware/software components that generate various types of data. Some examples include heart-rate data, coaching information, in-home activity patterns, mobility patterns, and so on. Various subsystems in the AHA platform can share their data in a semantic and interoperable way, through the use of a AHA data-store and a wearable devices ontology. The ontology includes concepts such as height, weight, locations, activities, activity levels, activity energy expenditure, heart rate, or stress levels, among others. The purpose is serving application development in Ambient Intelligence scenarios ranging from activity monitoring and smart homes to active healthy ageing or lifestyle profiling.

7.2 LifeWear Ontology

The LifeWear-Mobilized Lifestyle with Wearables (LifeWear) ontology [i.14] attempts to foster Ambient Intelligence ecosystems by composing personalized services based on the user information, environmental conditions and reasoning outputs. Two of the most important benefits over traditional environments are:

1) take advantage of wearable devices to get user information in a non-intrusive way; and
2) integrate this information with other intelligent services and environmental sensors.

The proposed ontology is composed by the integration of users and services information, for semantically representing this information. Using an Enterprise Service Bus, LifeWear ontology is integrated in a semantic middleware to provide context-aware personalized and semantically annotated services, with discovery, composition and orchestration tasks.

7.3 MIMU-Wear Ontology

An enormous effort has been made during the recent years towards the recognition of human activity based on wearable sensors. Despite the wide variety of proposed systems, most existing solutions have in common to solely operate on predefined settings and constrained sensor setups. Real-world activity recognition applications and users rather demand more flexible sensor configurations dealing with potential adverse situations such as defective or missing sensors. In order to provide interoperability and reconfigurability, heterogeneous sensors used in wearable activity recognition systems should be fairly abstracted from the actual underlying network infrastructure. The MIMU-Wear ontology [i.15] comprehensively describes wearable sensor platforms consisting of mainstream magnetic and inertial measurement units (MIMUs). MIMU-Wear describes the capabilities of MIMUs such as their measurement properties and the characteristics of wearable sensor platforms including their on-body location.

7.4 SSN Ontology

The Semantic Sensor Network ontology (see https://www.w3.org/TR/vocab-ssn/), known as the SSN ontology, answers the need for a domain-independent and end-to-end model for sensing applications by merging sensor-focused (e.g. SensorML), observation-focused (e.g. Observation & Measurement) and system-focused views. It covers the sub-domains which are sensor-specific such as the sensing principles and capabilities and can be used to define how a sensor will perform in a particular context to help characterize the quality of sensed data or to better task sensors in unpredictable environments. Although the ontology leaves the observed domain unspecified, domain semantics, units of measurement, time and time series, and location and mobility ontologies can be easily attached when instantiating the ontology for any particular sensors in a domain. The alignment between the SSN ontology and the DOLCE Ultra Lite (DUL) upper ontology has helped to normalize the structure of the ontology to assist its use in conjunction with ontologies or linked data resources developed elsewhere.
While the OGC SWE standards provide description and access to data and metadata for sensors, they do not provide facilities for abstraction, categorization, and reasoning offered by semantic technologies.

Few extensions of the SSN ontology have been reported for the Wearable domain.

The HeathIoT ontology [i.16], not available online, reuses many concepts from the previous SSN to define sensors and actuators in wearables, but the main targeted domain is Smart Health.

One notable one is the Semantic Smart Sensor Network ontology [i.17], which extends SSN to account for sensors that can be reprogrammed or reconfigured depending on the context of use. The requirements used to develop this extension all stem from use cases in the Wearable domain, and more specifically for e-textile and smart fabric in the context of the Bpi France SMartSensing project.

7.5 Other Initiatives

Ontology alignment for wearable devices and bioinformatics in professional health care (see [i.18]). Web Ontology Language (OWL) based models and triple stores hold great potential for access to structured information. Not only are OWL-based ontologies extremely versatile and extendable, but triple stores are robust against changes to ontologies and data. The biomedical field illustrates this value insomuch as it employs vast amounts of information distributed across different models and repositories. This paper (i.e. Ontology alignment for wearable devices and bioinformatics in professional health care) presents a case study that sought to demonstrate the real-world value of linking disease, symptom, and anatomical models with wearable devices and physical property models and repositories. Integrating these models is both necessary and problematic: necessary to provide undifferentiated access to health care professionals, problematic because although the biomedical ontologies and repositories exist, they are not semantically aligned and their designs make alignment difficult. This case study demonstrated that manually linking multiple biomedically-related models can produce a useful tool. It also demonstrated specific issues with aligning curated ontologies, specifically the need for compatible ontology design methodologies to ease the alignment. Although this study (i.e. Ontology alignment for wearable devices and bioinformatics in professional health care) used manual ontology mapping, it is believed that systems working in tandem with subject matter experts can be developed for reducing mapping effort to verification and validity checking.

8 Use cases

8.1 Use case 1: Healthcare

8.1.0 Introduction

According to a 2016 report entitled The Wearable Life 2.0 [i.19] improvement of health is a primary motivator in the acquisition of wearables by consumers. Wearables suggested by health organizations (doctors offices, hospitals, health insurance companies) tend to be trusted by consumers. From a health practitioner perspective, wearables, as medical devices, can potentially play a significant role in the diagnosis, tracking and alleviation of medical conditions. Given such motivations of consumers and healthcare professionals, the complexity, type and range of applications of wearables is set to proliferate. Such emerging applications include, but are not limited to:

- Monitoring, capture and relay of physiological data, such as heart rate, temperature, blood pressure, neuronal activity and respiration patterns. This might be achieved, for example, by sensors embedded in clothing or affixed to the skin, which are wirelessly connected to a mobile app. Such data may be used by individuals to achieve personal fitness goals (especially when combined with features to measure distance/steps, elevation, etc.), to track ovulation, determine quality of sleep, or to assess the probability of an asthma attack. Alternatively, the data may be transmitted to a healthcare facility for analysis, e.g. to assist with diagnosis or evaluate therapeutic efficacy.

- Monitoring, capture and relay of metabolic data, for example microneedles and sensors embedded in a skin patch, connected wirelessly to a mobile app, for testing of glucose levels.

- Enhancement of musculoskeletal function, for example following an injury which has compromised mobility. This might be achieved via an exoskeletal attachment to the body (e.g. a specialized glove to aid with rehabilitation exercises) or a powered exoskeletal contraption to assist with movement of limbs.

- Analysis of gastrointestinal tract, for example using an ingestible capsule equipped with a camera, capable of wirelessly transmitting images. Sensors incorporated into a capsule/pill may also provide data (gas profiles) concerning gut microbiome activity (or help to verify that a patient has taken medicine).

- Senior assisted-living, for example a necklace with an alert button in case of a fall to wirelessly contact emergency services, or a GPS tracker in shoes to locate a missing person with dementia.

The general approach of using networked wearables to capture and relay health-related data, may also provide valuable inputs to clinical trials. Furthermore, such wearables may allow populations in remote areas to receive medical care from specialists located far away. Wearable devices, such as virtual reality headsets, may also assist with the training of medical professionals in areas such as surgery and anatomy.

8.1.1 Remote health monitoring

A service platform for vertical application would greatly magnify the usability of wearable devices. This use case supports active ageing by demonstrating how both wearable devices and a house alarm system can provide health monitoring and alert services. Such services enable patients to live independently for longer provided that reliable and secure communication networks are available to link the patient with alarm and healthcare monitoring services.

A patient who lives alone and has medical conditions which need to be regularly monitored has a wearable device to measure certain vital signs. The wearable device provides the collected information to a health information system which provides the healthcare service which can react to detected anomalies. Additionally, the patient has access to a home alarm system which has emergency pull cords and a wearable alert device, often worn as a necklace.

In such a system, the assumptions are:

- Wearable devices lack a visual user interface or has a very limited user interface.

- Wearable devices connected to cloud services via a home gateway or other IoT gateway.

- Device with UI, e.g. a laptop or a smartphone connected to cloud services.

- Devices connected to device with UI through some kind of local connectivity method, e.g. Bluetooth or USB.

The working flow is as following:

- User (or person assisting user) logs in to health care provider web site. If the user has an existing account on social networks, this could be used for the log in process.
- User starts set-up process by pressing a button at the wristband.
- User approves that the wristband is used with the remote health monitoring application.
- Wristband is actively monitoring health vital signs of user.

8.2 Use case 2: Open air public events

Open space public events like street festival may face with big issues related to sound level limits, security, crowd management, etc. Hence, the possibility of adopting networks of wearable devices would help the overall management of events with respect to the following list of main challenges to address:

- Crowd management tools (solutions for routing people to various entrances/exits).
- Live data that supports prediction of critical situations.
- Wearables for communication and real time information.
- Means to improve the communication between staff and visitors.
- Software applications to improve customer experience.
- Optimization of the sound fields.
- Use of Adaptive Sound Field Control System.
- Advanced techniques to separate music from other noise.
- Wearables on security staff.
- Wearables/app on certain categories of guests (children, disabled people).
- Video and audio recording devices (to track individuals).
- Video analytics for crowd size estimation.
- Heat maps for crowd behaviour real-time visualization.
- Active Sound Field Control loudspeakers.
- Silence Showers.
- Dissemination of segregated noise emission levels towards public authorities.
- Real-time display of noise levels or sound field data to show where the "rest areas" are (silent and less crowded areas).
- Devices/tools to speed up the process of permitting access of unregistered vehicles to the restricted area.

By addressing the challenges proposed above, the management of a plethora of scenarios will be possible.

8.3 Use case 3: Closed environment events

The key focus for the stadium-based event is maintaining and enhancing the enjoyment of the visitors by providing a 'first class' visitor experience within a safe and secure environment. The main challenge is the busy and complex sporting calendar and ensuring the appropriate service is provided for the end user. In addition, the location poses some challenges in relation to crowd safety management.

On some match days both cricket and rugby matches are in play which can cause logistical challenges. In addition, steward numbers increase to meet the additional visitors requiring stewards to be used who are unfamiliar with the stadium. Stadiums look for further enhance security in the context of the day to day management of crowds but also to increase its preventative measures in the event of extreme threats such as acts of terrorism. They wish to increase their security and communication capability by introducing state of the art methods for automated image and video analysis and situational awareness to support the control centre staff as well as the stewards who mingle with the crowds. The goal is to increase the number of detected and speed of response to events that pose a threat to security inside the stadium and its immediate surrounding e.g. identifying cars unusually stationed near entrances.

The following points list general topics or applications for which this use case is of interest for the Wearables domain:

- Some stadiums strive to become a police-free stadium. In order to achieve this, they have to prove that they can handle security on their own based on records. This would reduce costs (expensive to have police presence) which could be utilized to provide more training of stewards (upscaling of stewards):
  - stewards being able to report directly to control in a crisis;
  - need for sending key short messages quickly in case of evacuation/emergency. Currently radios and coded messages through the PA system are used;
  - provide stewards with stadium detail and updated information in real time for easier decision making and customer care;
  - voice activation/picture recognition is desired and could support the easy usage of equipment for staff members who come from various backgrounds;
  - improve speed and reach of 'lost child' description circulation to avoid lock down situation which is expensive and time consuming.
- Stadiums would like to monitor flow of people within the grounds for stadium logistics (re-route people to the most appropriate entrance or exit to avoid crowds and make crowd movement as smooth as possible) or to inform people of alternative routes, bars, etc. (also for commercial purposes).
- Real-time tracking of staff to aid with location of incidents and staff welfare.
- Cameras outside the stadium to monitor outside crowd movement.
- Integrated access control:
  - new automated turnstiles;
  - vehicle recognition, suppliers ID, car parks linked to some kind of recognition/registration;
  - scanners.
- Provide visitors with a multifunctional 'customer experience mobile application' that provides different services while at the same time engages the visitors with the stadium and in their personal safety. The mobile application could feature:
  - real-time information such as busiest travel routes, weather warnings, major incidents, etc.;
  - historic information such as Stadium Plan, team sheet, competitions, etc.;
  - customer experience driven - interactive/friends alert;
  - guide people on foot to and from the stadium from train station, buses, etc.;
  - update information on when cars can leave (following pedestrians);
  - customized to suit International matches and visitors from other countries;
  - alert feature in case of emergency;
  - panic button and location sensor;
  - car park passes and ticketing;

- cashless payments;
- commercial possibilities (sponsors, sales, competitions, marketing, etc.);
- during construction re-route around building works.

- Stadiums might like to get a license to host large concerts, but since some of them are not able to control sound, they are interested in some form of sound control.

9 Requirements

Clause 9 of the present document depicts the ontological requirements resulting from a reverse engineering process that was carried out taking as input several Wearables related initiatives from those listed in clause 5 of the present document. More precisely, these requirements have been extracted from existing data models, ontologies, datasets and standards provided by both research groups and standardization institutes, as well as from the use case descriptions.

Table 1: Requirements for the "Wearable" category

Id	Requirement
WEAR-1	A wearable device is a device that is intended to be located near, on or in an organism.
WEAR-2	A wearer is any living organism that is sensed by a wearable.
WEAR-3	The user of a wearable is any living organism, physical object or software interacting with and/or acted by a wearable.
WEAR-4	The user of a wearable may be its wearer.
WEAR-5	A wearable has some position with regards to its wearer.
WEAR-6	A near-body wearable is a device located near an organism where it does not contact the external surface of the organism directly.
WEAR-7	An on-body wearable is a device located on an organism where it contacts the external surface of the organism directly.
WEAR-8	An in-body wearable is a device located internal to an organism.
WEAR-9	Wearables can also be electronic textiles, that is, fabrics or textile-based electronic devices and components.

Table 2: Requirements for the "Wearable attribute" category

Id	Requirement
WEAR-10	A wearable may have control capabilities.
WEAR-11	A wearable may send notifications to its wearer.
WEAR-12	A wearable has an interface, which is the medium for transferring data between the wearer and the device.
WEAR-13	A wearable may have communication capabilities to interchange data with other wearables or systems.
WEAR-14	A wearable has a data transmission rate.
WEAR-15	A wearable may have storage capabilities.
WEAR-16	A wearable may have sensing capabilities, provided by one or more sensors.
WEAR-17	A wearable may sense the wearer or the wearer's environment (e.g. sound level).
WEAR-18	Relevant information about the wearer may be its location, heart rate or temperature.
WEAR-19	A wearable makes measurements with a specific precision.
WEAR-20	A wearable has an operating temperature.
WEAR-21	A wearable may have actuating capabilities, provided by one or more actuators.
WEAR-22	A wearable may identify the status of actionable entities on its environment (e.g. that a door is open or closed).
WEAR-23	A wearer may perform actions over entities in its environment using a wearable (e.g. open door, adjust sound level, etc.).
WEAR-24	The dimensions and weight of a wearable are important for convenience and portability.
WEAR-25	A wearable emits heat.
WEAR-26	A wearable is equipped with a specific power supply.
WEAR-27	A wearable has a battery life.
WEAR-28	A wearable has some biometric information.
WEAR-29	A wearable has some electrical safety information.
WEAR-30	A wearable has some emission information.
WEAR-31	A wearable satisfies some policies for collecting data, aggregating data, or associating alerts.

Table 3: Requirements for the "Location" category

Id	Requirement
WEAR-32	A wearable may know its position related to some area (e.g. in or out of some place).
WEAR-33	A wearable may know its position related to another wearable.
WEAR-34	A wearable may know the location of an area (e.g. a parking space).
WEAR-35	A wearable may be aware of the allowed capacity of a specific area.
WEAR-36	A wearable may know the location of an object (e.g. a car).
WEAR-37	A wearable may know the location of the wearer of another wearable, according to the category of such wearer (e.g. lost child, parent, staff member, etc.).
WEAR-38	A wearable may present navigation directions to its wearer.
WEAR-39	A wearable may send navigation directions to other wearables.
WEAR-40	A wearable may present navigation directions taking into account the situation of the surrounding areas.

Table 4: Requirements for the "Wearer" category

Id	Requirement
WEAR-41	A wearable may know the mean of transport of its wearer (walking, by car, etc.).
WEAR-42	A wearable may identify the range of age of the wearer (e.g. child, adult, elderly, etc.).
WEAR-43	A wearable may be aware of the parent(s)/guardian of a child.
WEAR-44	A wearable may know the range of age of the wearer of another wearable.
WEAR-45	A wearable may know the status of the wearer of another wearable (e.g. lost, found, requires assistance, etc.).

Table 5: Requirements for the "Events" category

Id	Requirement
WEAR-46	A wearable may detect different types of events (e.g. incidents, terrorist attacks, law infringements, etc.).
WEAR-47	A wearable may notify its wearer about events in its environment.
WEAR-48	A wearable may detect different types of events that take place in a specific area (e.g. traffic jam).
WEAR-49	A wearable may notify other wearables about events.
WEAR-50	A wearable may detect concentrations of people and its type (e.g. queues).
WEAR-51	A wearable may be able of quantifying concentrations of people.

10 Conclusions

The present document depicts the Wearables domain main stakeholders, as well as describes the existing initiatives and the main use cases, that should at least be considered for developing the SAREF4WEAR core extension. The present document also describes the set of ontological requirements retained to be handled in such core extension. Finally, the present document will be sent to the Wearables domain stakeholders for validation and/or dissemination purposes and might therefore be subject to a revision.

Annex A: Bibliography

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

Annex B:
Change History

Date	Version	Information about changes
20/03/2019	v0.0.1	Very early draft.
27/04/2019	v0.0.5	Early draft.
06/06/2019	v0.1.0	First stable version.
11/06/2019	v0.1.2	Use case consolidation and requirements definition fixed.
17/06/2019	v0.1.3	Consolidated stable version.
12/07/2019	v0.2.0	Conclusion clause drafted.

History

Document history		
V1.1.1	October 2019	Publication