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Contents

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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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Introduction

The Internet of Things requires and triggers the development of standards and protocols in order to allow heterogeneous devices to communicate and to leverage common software applications. Several standardization initiatives currently co-exist, in individual SDOs or partnerships (e.g. ETSI SmartM2M, ITU-T, ISO, IEC, ISO/IEC JTC 1, oneM2M, W3C®, IEEE™, OASIS®, IETF®, etc.) and also in conjunction with a number of industrial initiatives (e.g. All Seen Alliance, Industrial Internet Consortium (IIC), Open Connectivity Foundation (OCF), Platform Industrie 4.0, Thread group, etc.).

It is therefore necessary to understand the global dynamics of IoT standardization in order to leverage on existing standardization activities, if relevant, vis-à-vis existing initiatives and to ensure a thorough understanding of market needs and requirements.

The essential objective of the present document is to analyse the status of the current IoT standardisation; to assess the degree of industry and vertical market fragmentation; and to point towards actions that can increase the effectiveness of IoT standardisation, to improve interoperability, and to allow for the building of IoT ecosystems.

A specific objective of the present document is to develop a set of recommendations that are aimed at supporting material for the Large Scale Pilots (LSPs) the set of EU funded projects that address the large-scale deployment of IoT in certain "vertical" domains, such as Smart Cities or Smart Mobility. Those recommendations are a supporting material for the LSPs that take into account the needs of the vertical domains that they are targeting. These include the Standards landscape for IoT (who does what, what are the next milestones) and identification of potential interworking frameworks (e.g. oneM2M).

1 Scope

The scope of the present document is to provide an overview of the IoT standards landscape: requirements, architecture, protocols, tests, etc. to provide the roadmaps of the IoT standards, when they are available.

The essential objectives are:

- To analyse the status of current IoT standardisation.
- To assess the degree of industry and vertical market fragmentation.
- To point towards actions that can increase the effectiveness of IoT standardisation, to improve interoperability, and to allow for the building of IoT ecosystems.

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] AIOTI WG03: "IoT LSP Standard Framework Concepts", Release 2.0, October 2015".

[i.2] ETSI TR 103 376: "SmartM2M IoT LSP Use Cases and Standards gaps".

[i.3] ANSI/ISA 95: "Enterprise-Control System Integration".

[i.4] Recommendation ITU-T Y.2238: "Overview of Smart Farming based on networks".

[i.5] European Commission White Paper: "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system".

[i.6] TOGAF model for Enterprise Architecture.

[i.7] AIOTI WG09: "Report on Smart Mobility".

[i.8] AIOTI WG03: "Reports on IoT Standards.

[i.9] AIOTI WG06: "Report on Smart Farming and Food Safety Internet of Things Applications".

[i.10] ITU-T Technology Watch Report: "ICT as an Enabler for Smart Water Management".

3 Definitions and abbreviations

3.1 Definitions

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

H2020 ICT-30: grouping IoT research and innovation projects and coordination & supporting actions (CSA)

NOTE: The STF will liaise with this group of research projects via the IERC and the selected H2020 ICT-30 IoT CSA selected proposal.

H2020 SCC3: Smart Cities CSA is in H2020 "Secure, clean and efficient energy", Call - Smart Citites and Communities (SCC) with SCC 3 - 2015 on "Development of system standards for smart cities and communities solutions".

NOTE: The STF will liaise with these projects via the selected H2020 SCC3 CSA.

IoT European Research Cluster (IERC): cluster on the Internet of Things research (and innovation) projects)

NOTE: The IERC is now totally integrated in WG1 as part of AIOTI.

oneM2M: Partnership Project (EPP) on M2M launched by a number of SSOs including ETSI

Functional Safety: standards defining safety as freedom from unacceptable risk

NOTE: The most effective way to eliminate risks is to design them away. The purpose of safety is to protect people from harm. Functional safety achieves this via systems that lower the probability of undesired events, thereby minimizing mishaps.

3.2 Abbreviations

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

2G	Second generation of wireless mobile telecommunications technology
3G	Third generation of wireless mobile telecommunications technology
3GPP	Third Generation Partnership Project
4G	Fourth generation of wireless mobile telecommunications technology
6LoWPAN	IPv6 over Low power Wireless Personal Area Networks
ACE	Authorization for Constrained Environments
ACEA	European Automobile Manufacturers Association
ACS	Auto Configuration Servers
ADASIS	Advanced Driver Assistance System Interface Specifications
ADSL	Asymmetric Digital Subscriber Line
AIDC	Automatic Identification and Data Capture
AIOTI	Alliance for IoT Innovation

NOTE: In particular AIOTI WG3 on IoT Standardization.

AIOTI WG03	Alliance for IoT Innovation Working Group 3
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
APT	Asian Pacific Telecommunity
ARIB	Association of Radio Industries and Businesses
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATIS	Alliance for Telecommunications Industry Solutions
AV	Audio-Video
AVB	Audio Video Bridging
B2B	Business to Business
B2C	Business to Customer
BACS	Building Automation and Control Systems
BBF	BroadBand Forum

BLE	Bluetooth Low Energy
BR/EDR	basic rate/enhanced data rate
BSS	Base Station Subsystem
C2C-CC	Car 2 Car Communication Consortium
C-ACC	Cooperative Adaptive Cruise Control
CALM	Communications Access for Land Mobiles
CAN	Controller Area Network
CCC	Car Connectivity Consortium
CCSA	China Communications Standards Association
CDD	Common Data Dictionary
CDMA	Code division multiple access
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CI	Common Interface
CIM	Common Information Model
CIP	Common Industrial Protocol
CLEPA	European Association of Automotive Suppliers
CMS	Central Management System
CoAP	Constrained Application Protocol
COSEM	Companion Specification for Energy Metering
CPE	Customer-Premises Equipment
CSA	Coordination and Support Actions
CSCG	Cyber Security Co-ordination Group

NOTE: Which will provide input regarding security standardization for Europe.

CT	Core Network & Terminals
CTA	Cordless Terminal Adapter
CWMP	CPE WAN Management Protocol
D2D	Device-to-Device
DDS	Data Distribution Service
DECT	Digital Enhanced Cordless Telecommunications
DICOM®	Digital Imaging and Communications in Medicine
DIN	German Institute for Standardization
DM	Device Management
DNP	Distributed Network Protocol
DSL	Digital Subscriber Line
DSRC	Dedicated short-range communications
DTLS	Datagram Transport Layer Security
EASA®	European Aviation Safety Agency
EDGE	Enhanced Data rates for GSM Evolution
EIP-SCC	European Innovation Partnership on Smart Cities and Communities
EN	European Norm
EPB	Energy Performance of Buildings
EPBD	Energy Performance of Buildings Directive
ERM	Electromagnetic compatibility and Radio spectrum Matters
ETSI	European Telecommunication Standards Institute
EU	European Union
EUC	Equipment Under Control
FAA	Federal Aviation Administration
FEC	Forward Error Correction
FG	Focus Group
FHIR®	Fast Healthcare Interoperability Resources
FI-PPP	Future Internet Public-Private Partnership
FOTS	Field Operational Tests
FP	Fixed Part
FSK	Frequency-shift keying
GAA	Generic Authentication Architecture
GBLS	GNSS-Based Location System
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GS	Group Specification
GSM	Global System for Mobile Communications

HAN FUN	Home Area Network Functional protocol
HAN	Home Automation Network or Home Area Network
HART®	Highway Addressable Remote Transducer protocol
HCD	Hardcopy Device
HDLC	High-Level Data Link Control
HG	Home Gateway
HGI	Home Gateway Initiative
HIMSS	Healthcare Information and Management Systems Society
HL7®	Health Level Seven International
HLA	High Level Architecture
HLAP	High Level Application Protocol
HMI	Human Machine Interface
HRN	Health Records Network
HSPA	High Speed Packet Access
HTTP	HyperText Transfer Protocol
HyP	Hybrid Part
I2V	Infrastructure-to-Vehicle
IACS	Industrial Automation and Control Systems
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IERC	IoT European Research Cluster
IETF	Internet Engineering Task Force
IHE	Integrating the Healthcare Enterprise
IIC	Industrial Internet Consortium
IIRA	Industrial Internet Reference Architecture
IMT	International Mobile Telecommunications
IoT	Internet of Things
IoT LSP	Internet of Things Large Scale Pilots

NOTE: Part of the H2020 Work Program 2016-2017.

IP	Internet Protocol
IPSO	Internet Protocol for Smart Object
IPv6	Internet Protocol version 6
ISA	International Society of Automation
ISCI	ISA Security Compliance Institute
ISCI	ISA Security Compliance Institute
ISG	Industry Specification Group
ISM	Industrial, Scientific and Medical
ISMS	Information Security Management System
ISO	International Organization for Standardization
ITS	Intelligent Transportation System
ITS-S	ITS Station
ITU-R	International Telecommunication Union - Radio Sector
ITU-T	International Telecommunication Union - Telecommunication Sector
JSON-RPC	Remote Procedure Call protocol encoded in JavaScript Object Notation
KA	Knowledge Areas
LAN	Local Area Network
LLN	Low power and Lossy Network
LON	Local Operator Network
LPWAN	Low Power Wide Area Network
LR-WPAN	Low-Rate Wireless Personal Area Network
LSP	Large Scale Pilot
LTE	Long Term Evolution
LTN	Low Throughput Network
M2M	Machine-to-Machine
MAC	Media Access Control
MAN	Metropolitan Area Network
MBMS	Multimedia Broadcast/Multicast Service
MFD	Multifunction Device
MQTT	MQ Telemetry Transport

MTC	Machine Type Communications
NFC	Near Field Communication
NWK	Network
OAA	Open Automotive Alliance
OAG	Open Applications Group
OAGIS	Open Applications Group Integration Specification
OASIS	Advancing Open Standards for the Information Society
OBU	On-Board Units
OCF	Open Connectivity Foundation
OGC	Open Geospatial Consortium
OIC	Open Interconnect Consortium
OLE	Object Linking and Embedding
OLN	Outdoor Lighting Network
OMA	Open Mobile Alliance
OMG	Object Management Group
OPC	OLE for Process Control
OS	Operating System
OUI	Organizationally Unique Identifier
PAN	Personal Area Network
PAS	Publicly Available Specification
PCHA®	Personal Connected Health Alliance
PDA	Personal Digital Assistant
PHD	Personal Health Device
PHY	Physical layer
PII	Personally Identifiable Information
PKI	Public Key Infrastructure
PLC	Power Line Communications
PP	Portable Part
PSA	Protocol Standards Association
PSID	Provider Service Identifier
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RAN	Radio Access Networks
REST	Representational State Transfer
RFID	Radio-frequency identification
RSU	Road Side Units
RTPS	Real-Time Publish-Subscribe
SA	Services & Systems Aspects
SAE	Society of Automotive Engineers
SAML	Profile of Security Assertion Markup Language
SAREF	Smart Appliance Reference ontology
SC	Smart Cities
SCIM	System for Cross-domain Identity Management
SCN	Satellite Communications and Navigation
SDO	Standards Developing Organisation
SE	Smart Environment
SEG-CG	Smart Energy Grid Co-ordination Group
SERCOS®	Serial Real-time Communications System
SF	Smart Farming
SIB	Standards Information Base
SL	Smart Living
SN	Sensor Network
SNRA	Sensor Network Reference Architecture
SOAP	Simple Object Access Protocol
SRD	Short Range Devices
SSC	Smart Sustainable Cities
SSCC-CG	Smart and Sustainable Cities and Communities Coordination Group
SSO	Standards Setting Organisation
SW	Smart Wearables
TCP	Transmission Control Protocol
TEDS	Transducer Electronic Data Sheets
TETRA	Terrestrial trunked Radio

TIM	Transducer Interface Module
TISA	Traffic and Traveller Information
TLS	Transport Layer Security
TM	Traffic Management
TOGAF®	The Open Group Architecture Framework
TR	Technical Report
TS	Technical Specification
TSDSI	Telecommunications Standards Development Society India
TSG	Technical Specification Group
TTA	Telecommunications Technology Association
TTC	Telecommunications Technology Committee
UA	Unified Architecture
UDP	User Datagram Protocol
UI	User Interface
ULE	Ultra Low Energy
UMTS	Universal Mobile Telecommunications System
UPnP	Universal Plug and Play
USP	Universal Service Platform
UWB	Ultra Wide Band
V2X	Vehicle-to-Everything
VGP	Vehicle Gateway Platform
VMS	Video Management System
VoIP	Voice over Internet Protocol
W3C	Worldwide Web Consortium
WAN	Wide Area Network
WAVE	Wireless Access in Vehicular Environments
WBAN	Wireless Body Area Network
WG	Working Group
WITS	Water Industry Telemetry Standards
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Networks
WPAN	Wireless Personal Area Network
WRC	World Radio Communication Conference
WRS	Wireless Relay Station
WSN	Wireless sensor networks
WSP	Wireless Short-Packet
XACML	eXtensible Access Control Markup Language
xDSL	x Digital Subscriber Line
XKMS	XML Key Management Specification
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol
XSD	XML Schema Language
XSF	XMPP Standards Foundation
XSPA	Cross-Enterprise Security and Privacy Authorization

4 Overview of the IoT Standards Landscape

4.0 Introduction

The starting point for the present document is the AIOTI report on "IoT LSP Standard Framework Concepts" [i.1] which gave several ways of visualising the landscape in order to simplify and facilitate the usage of the information in various IoT application domains. The AIOTI landscape diagram in figure 1 shows the logo of SDO identified for all the LSP in two dimensions (AIOTI WG3), the horizontal axis represents the market type and the vertical axis represents the technology that these initiatives cover and focus on.

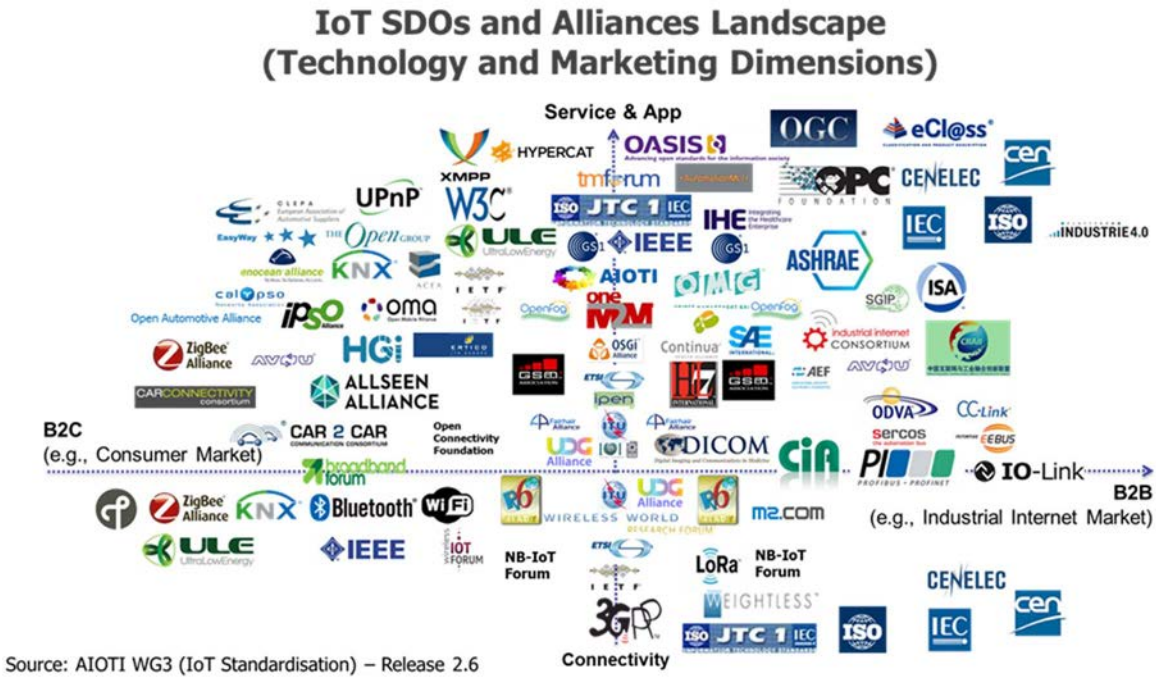

Figure 1: IoT SDOs and Alliances Landscape (Technology and Marketing Dimension)

The present document expands on the AIOTI work by looking at details of the relevant standards within the suggested AIOTI SDOs and more. The present document also expands on the on the standards by reviewing the scope of each of the standards.

The benefit of analysing the standards landscape is to promote and suggest existing technology reusability that can be used by the LSPs. Another derived benefit is to identify any challenges derived from discovered gaps. This last aspect is aligned with the objective of another TR in this study, ETSI TR 103 376 [i.2].

Some of the standards apply to specific verticals and this is addressed in AIOTI WG3 also see figure 2. Some of these standards apply across verticals and it is not the focus of the present document to repeat the information but to make the comparison clear and highlight its relevance to the particular vertical if applicable.

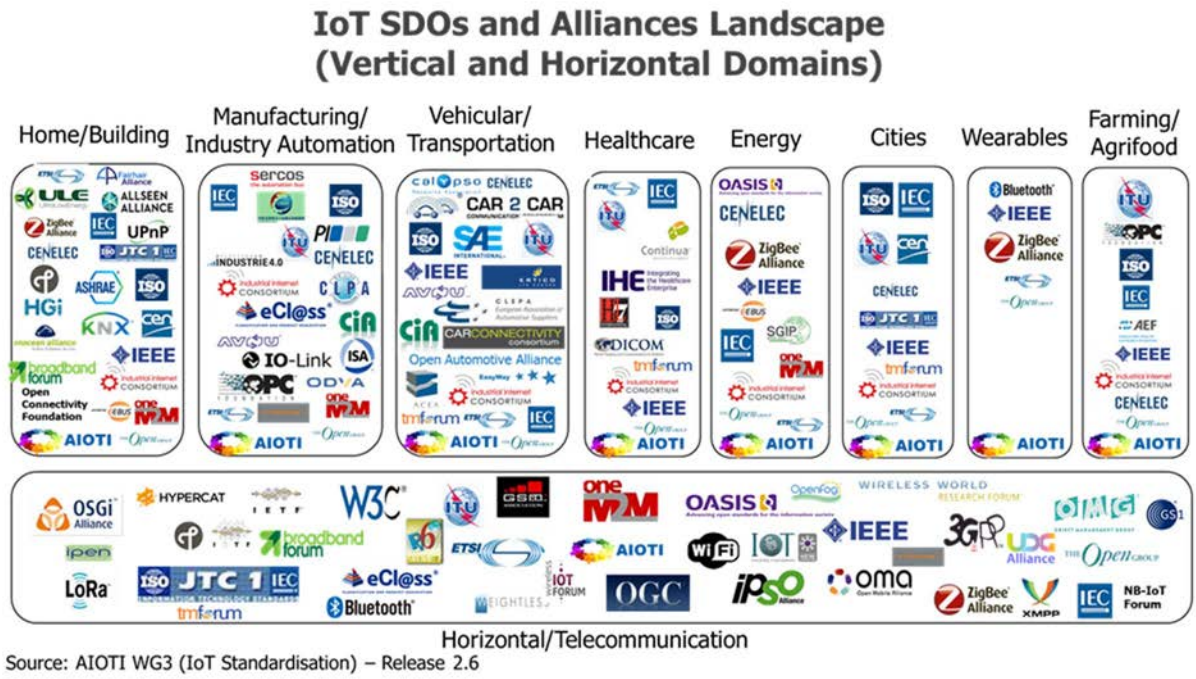

Figure 2: IoT SDOs and Alliances Landscape (Vertical and Horizontal Domain)

4.1 Vertical domains covered

As a support for the IoT Large Scale Pilot, the vertical domains that are addressed in the present document are those where such LSP will be defined and, for some, selected and undertaken. These domains are the following:

- **Smart Cities:** The modern cities need to evolve and become structured, interconnected ecosystems where all components (energy, mobility, buildings, water management, lighting, waste management, environment, etc.) are working together in support of humans. By using the IoT technology, the cities are expected to achieve this transition while maintaining security and privacy, reducing negative environmental impact and doing it in a reliable, future proof and scalable manner.

- **Smart Living environments for ageing well (e.g. smart house):** It is expected that the IoT will support the continuously growing population of elderly people in living longer, staying active, non-dependent and out of institutional care settings, together with reducing the costs for care systems and providing a better quality of life. This should be achieved in particular with IoT for smart home and home automation supporting technologies. Following the LSPs technology distribution, this vertical domain includes the Healthcare as well as the Smart home, e.g. Home/Buildings vertical domains shown in figure 2.

- **Smart Farming and food security:** The application of IoT technologies to the overall farming value chain will improve its optimisation and, as a consequence, food safety in general. Technologies such as data gathering, processing and analytics as well as orchestrated automation technologies supported by IoT are expected to achieve this.

- **Smart Wearables:** The integration of intelligent systems to bring new functionalities into clothes, fabrics, patches, aids, watches and other body-mounted devices will provide new opportunities and applications. Basic technologies such as nano-electronics, organic electronics, sensing, actuating, localization, communication, etc. will be offered to the end-user, with an associated range of problems such as acceptability, ease of use, privacy, security or dependability.

- **Smart Mobility (smart transport/smart vehicles/connected cars):** The Internet of Things applied to the mobility domain may create the potential for major innovations across a wide variety of market sectors, with mobility applications such as self-driving and connected vehicles, multi-modal transport systems and "intelligent" transportation infrastructure from roads or sea ports to parking garages.

- **Smart Environment (smart water management):** IoT will be a key building block to solutions for vertical applications such as environmental monitoring and control that will use sensors to assist in environmental protection by monitoring air, water quality/quantity monitoring along water infrastructure (including water resource management), atmospheric or soil conditions and noise pollution.

- **Smart Manufacturing:** In support of the European manufacturing industry, all forms of competitive industries will have to massively incorporate more intelligence that will rely in particular on IoT through advanced connected objects providing sensing, measurement, control, power/energy/raw materials management and communication, both wired and wireless.

5 A Proposed Enterprise View of the IoT Framework

5.0 Introduction

One of the objective of the present document is to analyse the IoT standards landscape. However before going into the details of the standards landscape, it is important to take a view of the IoT framework and try to put a structure into the framework from which we can see how the standards landscape play an important part in the overall LSP.

There are many elements that make up an IoT LSP, its more than just the technology, there are other relevant aspects to be taken into consideration which include the stakeholder views, regulatory aspects (e.g. city) making up an enterprise view. The study to analyse the various elements has already started within the AIOTI group. This includes; the LSP landscape; the IoT architecture and standards landscape. The study in the present document is not to duplicate the AIOTI work but rather to build on what's already started and provide a comprehensive view that can be used by the LSPs.

The AIOTI study points out that the complexity with IoT comes from the fact that IoT intends to support a number of different applications covering a wide array of disciplines that are not all part of the ICT domain. To this AIOTI have defined an IoT framework and all the elements that make up the framework and how they can support the LSP.

Taking an overview of all these elements can be overwhelming without structural view. Hence, it is proposed in this section to include an enterprise view of such IoT framework covered by AIOTI and as such see how the elements fit together for a LSP." The proposal here is to view the IoT framework as an enterprise architecture comprising of the many parts that make an IoT framework. This view can be represented in the diagram below and this is in line with the TOGAF® model for Enterprise Architecture [i.6].

Figure 3 presents the enterprise view of the minimal set of components IoT framework should contain:

- An Architecture Reference Model which will consist of an IoT architecture integrating all components that make up an IoT system.

- An IoT domain containing the view of what make up an IoT.

- A Standards Information Database to hold any relevant standards that can be used. The main focus of the present document.

- A Reference Library which will hold any re-useable information that can be used across the pilots.

- A Governance Repository which will house any policies, regulations that may apply to any LSP.

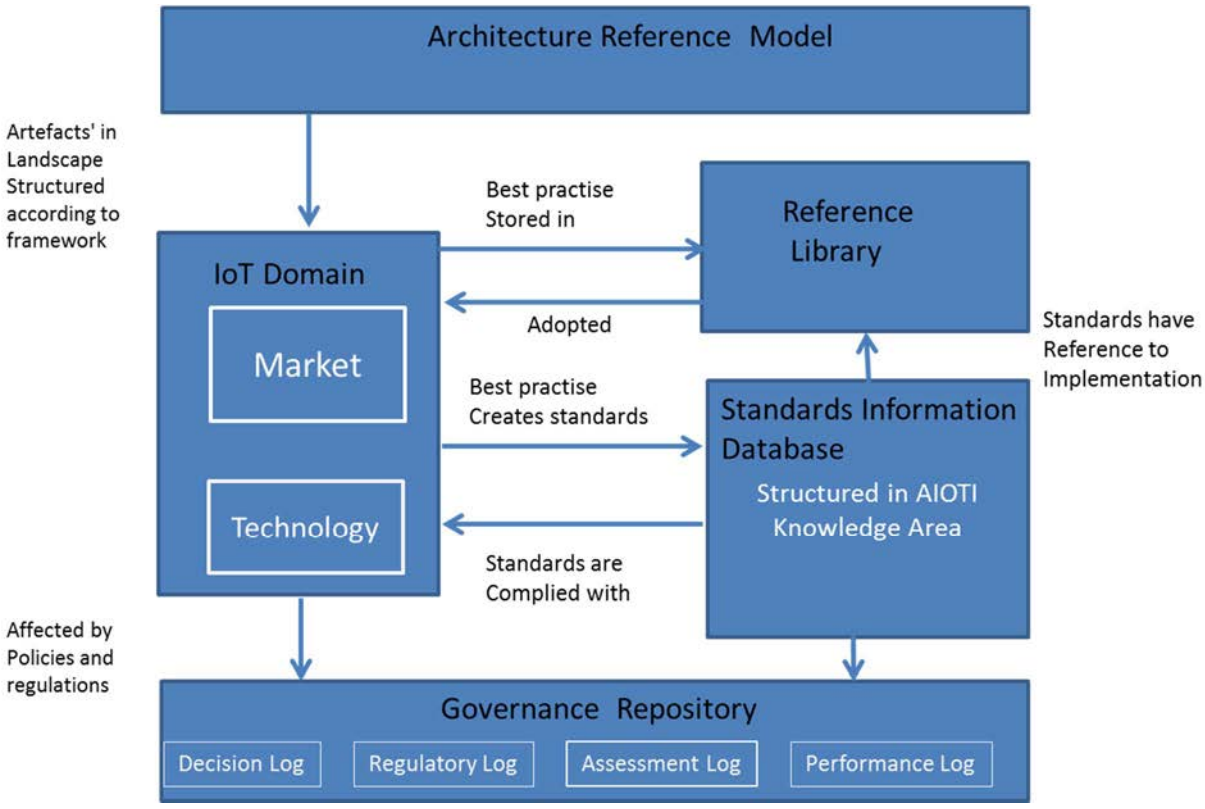

Figure 3: IoT Framework Enterprise view

5.1 IoT Domains for Standards Landscape

A Landscape is a representation of assets deployed within the operating enterprise at a particular point in time. The landscape is likely to exist at multiple levels of abstraction to suite different architecture objectives (TOGAF [i.6]).

AIOTI defines two domains as landscape, Market and Technology (AIOTI [i.1]), a horizontal domain represents the market type and vertical domains represent the technology/solution/knowledge area that these initiatives cover and focus on. The market domain represents the customer (i.e. Business to Customer: B2C) market, as well as the industrial internet (i.e. Business to Business: B2B) market. The technology domain covers areas of technology that are related to services and applications as well as technology areas that are related to connectivity (AIOTI WG3 [i.8]). AIOTI in addition to the two domains that are mentioned also provides information about:

1) the Projection of the initiatives on Vertical and Horizontal Domains; and

2) the Mapping of the Initiatives into Knowledge Areas.

5.2 Standards Information Database

5.2.0 Introduction

Standards are published documents that establish specifications and procedures designed to ensure the reliability of the materials, products, methods, and/or services people use every day. The standards information database represents where all relevant standards to an application should be stored; the Standards Information Base (SIB) captures the standards with which new architectures have to comply, which may include industry standards. AIOTI has come up with a set of standards that are relevant to the Large Scale Pilots. In order to better represent the standards landscape across the various technology areas, AIOTI has come up with the concept of "knowledge area". It is suggested that this area of the repository will house (i.e. store the list of standards identified in the present document) the standards within IoT with the relevant SDO/Alliance. Some of the standards are common across the Large Scale Pilots and some are specific. The details of possible standards will be covered in detail within the next sections. The governance (includes location, owner and maintenance) of the SIB is for further study.

5.2.1 Overview of the Knowledge Areas

The Knowledge Areas (KA) used in the present document are the ones defined by the AIOTI WG03. However, considering that the definition in the AIOTI report on "IoT Landscaping" [i.1] are sometimes ambiguous, they are detailed below with more precision, in particular regarding the nature of the standards that can be found in each of the KAs. These definitions are used for the classification of Standards in the subsequent clauses.

Communication and Connectivity

This KA covers mainly specification of communication protocols at all layers, e.g. PHY, MAC, NWK, Transport, Service, and Application layers. It includes the management associated with the Knowledge Area.

Examples of the type of standards that can apply to this KA are:

- Connectivity at physical and link layer
- Network layer
- Service level and application enablers
- Application level API, data models and ontologies
- Management of the protocols

Integration/Interoperability

This KA covers mainly specification of common IoT features required to provide integration (assembly of sub-systems) and interoperability (interoperation of heterogeneous sub-systems).

Examples of the type of standards that can apply to this KA are:

- Profiles
- Testing Specification

Applications

This KA covers the support of the applications lifecycle. This includes development tools, application models, deployment, monitoring and management of the applications.

NOTE: The application level protocols, APIs, data models, ontologies, etc. are part of the "Communication and Connectivity" and/or "Integration/Interoperability" KA.

Examples of the type of standards that can apply to this KA are:

- Flexible remote management
- Support methods for installing, starting, updating applications

Infrastructure

This KA covers the design, deployment, and management of computational platforms and infrastructures (e.g. network elements, servers, etc.) that support IoT-based usage scenarios.

Examples of the type of standards that can apply to this KA are:

- Virtualization
- Mobile-Edge Computing
- Network Management
- Network Dimensioning, Network Planning
- Functional Safety

IoT Architecture

It covers the specification of complete IoT systems, with a focus on architecture descriptions.

Examples of the type of standards that can apply to this KA are:

- Reference Architecture

Devices and sensor technology

This KA covers mainly device and sensor lifecycle management.

NOTE: The communication protocols between devices and other elements are covered in the "Communication/Connectivity" KA.

Examples of the type of standards that can apply to this KA are:

- Device Monitoring
- Sensor/actuators virtualization
- Configuration management

Security and Privacy

This KA covers all security and privacy topics.

Examples of the type of standards that can apply to this KA are:

- Communications security and integrity
- Access Control
- Authorization, Authentication, Identity Management
- PII (Personally Identifiable Information) Management

5.3 Reference Library

A reference library which will hold any re-useable information that can be used across the pilots, also include reusable standards, practices, guidelines and other forms of reference material that can be leveraged in order to accelerate the creation of any new architectures for pilots.

5.4 Governance Repository

When considering a vertical industry, for example Smart City, there are regulatory aspects specific to each city that will shape the deployment of Smart City such as governmental law on parking for example. In some cases, these may be quality performance objectives specific to a manufacturing plant. This information will influence the decision of the technology and it is suggested that they be located in the Governance Repository.

5.5 Architecture Reference Model

An Architecture Model for IoT will consist of an IoT architecture integrating all components that make up an IoT system, an architecture models in where platforms interact with each other and with other system components. This architecture model could be one of the models discussed later on in the present document however what this is suggesting is that any architectural model will be located in this repository at this level.

5.6 Summary

These clauses have presented an enterprise view of how an IoT landscape framework can look like using an enterprise model structure as a guide. The reason for presenting this enterprise view is first to show how complex all the elements needed for an IoT LSP are and to also present a view that helps to put the entire element in context for the reader and users that are considering using the information in the present document for LSP operation.

Having presented an enterprise view, the present document now focuses on reviewing the Standards Landscape database. This database is the key element to all content that make up the framework described. This importance is derived from the importance of how standard supports the interoperability of all the components that make up the framework for IoT pilot.

The approach herein to the next sections is to take each proposed LSP and consider the standards available across the market today and to analyse if these standards are sufficient as they are for the pilots and what advantages each one presents.

6 Common Standards Across Vertical Domains

6.0 Introduction

A number of the Standards identified in the IoT Landscape are used in several of the Vertical Domains analysed. As soon as one such standard is used in at least 3 of the Vertical Domains, it is considered in the present as a "Common Standard" and listed in the current clause.

In this clause and the following ones, the first column refers to the SDO short name as it is defined in Annex A, together with the SDO full name and a description of its scope and mission.

In the tables below, the 7 rightmost columns correspond to the different Vertical Domains:

- SC: Smart Cities
- SL: Smart Living
- SF: Smart Farming
- SW: Smart Wearables
- SMo: Smart Mobility
- SE: Smart Environment
- SMa: Smart Manufacturing

The meaning of an "X" in a cell is that the Standards described in the row apply to the Vertical in the column.

6.1 Communication and Connectivity

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
3GPP multi-purpose	ETSI TS 123 002 (network architecture) ETSI TS 123 401 (Packet Radio Service) ETSI TS 136 300 (Radio Access Overall description)	The 3GPP standards cover Radio, Core Network, and Service Architecture for cellular mobile networks. The different versions are named: GSM, GPRS (2G), EDGE, UMTS (3G), HSPA, LTE (or 4G), LTE-Advanced. The specifications cover all aspects of a radio telecommunication system. LTE is significantly more spectrally-efficient than 2G or 3G, hence transporting data over a 4G network can be done at a much lower cost per bit. The LTE-ADVANCED standard version is still evolving. New networks are being rolled out, and leading-edge features are being added to 4G to satisfy the market need for ever-increasing data rates. http://www.3gpp.org/specifications/specifications.	X	X	X	X	X	X	
3GPP for MTC (Machine Type Communications)	LTE- (LTE for MTC) , EC-GSM, NB-IoT	LTE-(LTE for MTC): New categories of communications, complying with IoT requirements, are being launched in the 3GPP standards and they belong to LTE-ADVANCED and LTE-ADVANCED PRO (4.5G). They are evolving standards. EC-GSM (or EC-GPRS) provides an extended coverage capability, as a global connectivity solution for cellular IoT that leverage existing module ecosystem and allows for deep indoor coverage. It may also include eDRX, for extended battery life of the device (up to 15 years). NB-IoT is a new narrowband radio technology which will provide improved indoor coverage, support of massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption and optimized network architecture. NB-IoT standards are under progress.	X	X	X	X	X	X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
Bluetooth	Bluetooth BR/EDR (basic rate/enhanced data rate) Bluetooth Low Energy (BLE)	Bluetooth is a global wireless communication standard that connects devices. Communication between Bluetooth devices happens over short-range, ad hoc networks known as piconets. The network ranges from two to eight connected devices. When a network is established, one device takes the role of the master while all the other devices act as slaves. Piconets are established dynamically and automatically as Bluetooth devices enter and leave radio proximity. There are different versions of the core specification of Bluetooth. The most common are Bluetooth BR/EDR (basic rate/enhanced data rate) and Bluetooth with low energy functionality. http://www.bluetooth.com/what-is-bluetooth-technology/bluetooth-technology-basics.	X	X	X	X	X	X	
DASH7 Alliance	DASH7 (ISO 18000-7)	An open-source RFID-standard for wireless sensor networking using ISM frequency bands. It allows multi-kilometre ranges with a maximum bitrate of 200 kbit/s. especially designed for energy efficiency firstly targeting wireless sensor networks. DASH7 can be very suitable for various applications such as building automation, access control and smart energy. It can also power location-based services allowing a fine-grained localization at the scale of a city relying on the principle of "checking-in" at different "venues" (building entries, specific points along the street, etc.). Moreover, and thanks to RFID tags, Smart City logistics services can be implemented.	X	X				X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
EnOcean Alliance®	ISO/IEC 14543-3-10: Wireless Short-Packet (WSP)	The EnOcean Alliance provides an interoperable wireless standard, ratified by the IEC, to develop an energy harvesting technology used for self-powered wireless monitoring and control systems for sustainable buildings, building automation, transportation, logistics. Through micro energy converters (mechanical motion, indoor light, temperature difference, electromagnetic), EnOcean enables wireless communication between battery-less wireless devices and controllers, gateways. EnOcean devices can be integrated at different points of a Smart City (building, bus stops, etc.) allowing the wireless transmission of commands triggering specific services where a usual switch/button cannot be envisioned. https://www.enocean-alliance.org/en/enocean_standard/.	X	X				X	
ETSI	Terrestrial trunked Radio (TETRA); ETSI EN 300 392	TETRA is a set of standards that describe a common mobile radio communications infrastructure throughout Europe. It is targeted primarily at the mobile radio needs of public safety groups (police, fire departments, etc.), utility companies and other companies that provide voice and data communications services at the scale of a metropolitan area (i.e. city) TETRA relies on digital trunking and TETRA products come with built-in encryption to ensure privacy and confidentiality. TETRA introduces various advantages when compared to other mobile technologies (e.g. GSM) such as long range communications, efficient mobility support, and direct communications in the absence of a network, one-to-many communications, etc. However, TETRA has the disadvantage of providing a slower data transfer rate.	X		X		X		

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
ETSI DECT	ETSI TS 102 939-1 (DECT ULE phase 1) ETSI TS 102 939-2 (DECT ULE phase 2) Digital Enhanced Cordless Telecommunications (DECT); Ultra Low Energy (ULE); Machine to Machine Communications; Part 1: Home Automation Network (phase 1 and 2) ETSI EN 300 175 (DECT; Common Interface (CI) multi-part specification)	The ULE specification is the result of a cooperation between the ULE Alliance and ETSI. DECT Ultra Low Energy (ULE) is a technology based on the established DECT standard and intended for Machine-to-Machine communications such as Home and Industrial automation. The main characteristics of the technology are ultra-low power consumption and wider coverage DECT ULE provides bi-directional radio communication with medium range, data protection, and Ultra Low Power consumption between different types of Portable Devices and Radio Fixed Parts. The technology is suitable for sensors, alarms, Machine-to-Machine (M2M) applications, utility meters and industrial automation. The set of features defined in the "Home Automation Network (HAN), phase 1" is primarily targeted to provide a global M2M solution within domestic scenarios. http://www.etsi.org.	X	X				X	X
IEEE 802 LAN/MAN	IEEE 802.11 (WLAN) IEEE 802.15.4 (LR-WPAN)	The IEEE 802 LAN/MAN Standards Committee develops and maintains a set of wireless technology access standards for personal (802.15), local (802.11) and metropolitan (802.16) area networks. These standards cover wireless networks ranging from a few centimetres (WPAN) to thousands meters (WMAN). They specify the media access control (MAC) and physical layer for the implementation of wireless networks. IEEE 802.11 standard and its amendments cover Wireless local area networks, with a typical range up to 100m, using generally unlicensed spectrum. IEEE 802.15 focuses on Wireless Personal Area Network (WPAN). IEEE 802.15.4 standard and its amendments cover Low-Rate Wireless Personal Area Networks (LR-WPANs). http://standards.ieee.org/about/get/.	X	X	X	X	X	X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
IEEE PLC	IEEE 1901.2 (Low-Frequency Narrowband Power Line Communications for Smart Grid Applications) Amendment IEEE 1901.2a (2015)	The PLC standards cover communications and networking over power lines, heterogeneous networking involving power line communication in various networking scenarios and standards relevant to equipment for PLC. IEEE 1901.2 specifies communications for low frequency (less than 500 kHz) narrowband power line devices via alternating current and direct current electric power lines. This standard supports indoor and outdoor communications over low voltage line (line between transformer and meter, less than 1 000 V), through transformer low-voltage to medium-voltage (1 000 V up to 72 kV) and through transformer medium-voltage to low-voltage power lines in both urban and in long distance (multi-kilometre) rural communications. https://standards.ieee.org/develop/wg/LF_NB_PLC_WG.html.	X	X				X	
IETF 6lo	Definition of Managed Objects for 6LoWPANs (IETF RFC 7388) 6LoWPAN-GHC (IETF RFC 7400) Transmission of IPv6 Packets over Recommendation ITU-T G.9959 Networks (IETF RFC 7428) Ipv6 over BLUETOOTH® Low Energy (IETF RFC 7668)	The IETF WG 6lo targets IPv6 over low power area networks, i.e. over networks of resource-constrained nodes in terms of memory, processing resources and bandwidth. It introduces mechanisms for packets fragmentation/assembling, headers encapsulation, compression, routing in mesh topologies, network self-configuration/management, and interworking with full IPv6 networks. https://datatracker.ietf.org/wg/6lo/documents.	X	X	X	X	X	X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
IETF CoRE	The Constrained Application Protocol (CoAP) (IETF RFC 7252) Group Communication for CoAP (IETF RFC 7390) Observing Resources in CoAP (IETF RFC 7641)	The IETF WG CoRE provides a framework for resource-oriented applications intended to run on constrained IP networks. CoAP is designed in such a way to ease the mapping of the heavy HTTP protocol into a more lightweight protocol running over UDP (instead of TCP) for a simplified integration of constrained devices with the web. Nodes on the constrained network, called devices are responsible for one or more resources that may represent sensors, actuators, and combinations of values or other information. Devices send messages to change and query resources on other devices. They can send notifications about changed resource values to devices that have subscribed to receive notification about changes. A device can also publish or be queried about its resources. Compared to HTTP protocol, CoAP offers a low communication overhead and require less processing resources. Although it is transported over UDP packets, CoAP includes a simple but efficient congestion and packets recovery mechanisms. http://datatracker.ietf.org/wg/core/documents.	X	X	X	X		X	
IETF ROLL	IETF RFC 6550, RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks; IETF RFC 6551, Routing Metrics Used for Path Calculation in Low-Power and Lossy Networks; IETF RFC 6552, Objective Function Zero for the RPL	These standards address routing issues for Low power and Lossy Networks (LLN). LLNs are made up of many embedded devices with limited power, memory, and processing resources. They are interconnected by a variety of links, such as IEEE 802.15.4, Bluetooth, Low Power WiFi, wired or other low power PLC (Powerline Communication) links. IETF RFC 6550 defines an adapted routing protocol, RPL. https://datatracker.ietf.org/wg/roll/documents/.	X	X	X	X		X	
IETF XMPP	IETF RFC 6120 (Extensible Messaging and Presence Protocol (XMPP): Core) and IETF RFC 6121 (Extensible Messaging and Presence Protocol (XMPP): Instant Messaging and Presence) XMPP-IoT extensions in progress	The XMPP Standards Foundation (XSF) is an independent, non-profit SDO whose primary mission is to define open protocols for presence, instant messaging, and real-time communication and collaboration on top of the IETF's Extensible Messaging and Presence Protocol (XMPP). The XSF community has initiated a new interoperable extension series to enable sensors and actuators to communicate in the IoT world. http://www.xmpp-iot.org https://datatracker.ietf.org/wg/xmpp/documents/.		X	X	X	X		

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
LoRa Alliance	LoRaWAN	LoRaWAN is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things in regional, national or global network. LoRaWAN target key requirements of internet of things such as secure bi-directional communication, mobility and localization services. This standard provides seamless interoperability among smart Things. It allows long range communication at low bit rate using ISM frequency bands. https://www.lora-alliance.org/.	X		X	X		X	
OASIS MQTT	Message Queuing Telemetry Transport (MQTT)	MQTT is an extremely lightweight and reliable (over TCP) connectivity protocol designed for M2M communications and the IoT. It is a client/server publish/subscribe messaging transport protocol designed to support messaging transport from remote locations/devices involving small code footprints (e.g. 8-bit, 256 KB ram controllers), low power, low bandwidth, high-cost connections, high latency, variable availability, and negotiated delivery guarantees. MQTT protocol offers mechanisms for resource discovery, bi-directional communication, QoS level specification, and scalability. http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/os/mqtt-v3.1.1-os.html.	X	X	X	X	X	X	
OMG	DDS v1.4 - Data Distribution Service (DDS™); DDSI-RTPS v2.2 - The Real-time Publish-Subscribe Wire Protocol DDS™ Interoperability Wire Protocol (DDSI-RTPS™)	The Data Distribution Service is a middleware protocol and API standard for distributed application communication and integration. http://portals.omg.org/dds/omg-dds-standard/.	X	X	X		X	X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
ZigBee®	ZigBee® PRO ZigBee® RF4CE	ZigBee® technology uses the globally available, license-free 2,4 GHz frequency band. It enables wireless applications using a standardized set of high level communication protocols sitting atop low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks. ZigBee® PRO: wireless mesh, low-power networking capable of supporting more than 64 000 devices on a single network. ZigBee® RF4CE: two-way device-to-device control applications for low-power and low-latency control ZigBee® IP: open standard for an Ipv6-based wireless mesh networking solution with seamless Internet connections to control low-power, low-cost devices. http://www.zigbee.org/zigbee-for-developers/network-specifications/.	X	X	X	X	X	X	
ETSI ERM TG28	ETSI GS LTN 001 (ISG LTN), "Low Throughput Networks (LTN); Use Cases for Low Throughput Networks" Under update with: DTR/ERM-TG28-505 (ETSI TR 103 249), "ERM; Low Throughput Network (LTN); Use cases and System Requirements" ETSI GS LTN 002 (ISG LTN), "Low Throughput Networks (LTN); Functional Architecture" Under update with: DTS/ERM-TG28-504 (ETSI TS 103 358), "ERM; Low Throughput Networks (LTN); Architecture" ETSI GS LTN 003 (ISG LTN), "Low Throughput Networks (LTN); Protocols and Interfaces" Under update with: DTS/ERM-TG28-503 (ETSI TS 103 35), "ERM; Low Throughput Networks (LTN); Protocols for interfaces A, B and C"	In ETSI, the ERM/TG28 committee is responsible for the standardization of low power IoT networks, named Low Throughput Networks (LTN). The key requirements of LTN systems are: low power and low complexity modems in devices, high link budgets, high network capacity. There are three LTN work items in ERM/TG28, intended to produce 3 documents as updates to former ISG LTN reports and specifications, more specifically to take into account the recent evolution towards short messages.	X	X	X			X	X
Z-Wave®	Z-Wave® standard ratified as Recommendation ITU G.9959	The Z-Wave® protocol is a wireless, RF-based communications technology. The standard defines a protocol designed for short range, two-way mesh topology automation networks. It addresses specifically the control, monitoring and status reading applications in residential and light commercial environments.		X	X	X		X	

6.2 Integration/Interoperability

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
AllSeen Alliance	AllJoyn® framework Program Management Document Interoperability Test Procedures	AllJoyn® framework is an open-source project that enables interoperability among connected devices and software applications based on a D-bus message bus. Developed services include device and app discovery, secure communications, etc. Promoted by the Linux Foundation®, the AllJoyn® open-source framework aims at making AllJoyn-empowered devices to communicate with each other easily. The technology is based on a Client/Server model also seen as producer/consumer model. Moreover, the AllJoyn® Certified program includes conformance testing and provides interoperability testing to help OEMs ensure that products work well together.	X	X		X		X	
EnOcean Alliance	EEPs (EnOcean Equipment Profiles) Generic Profiles	Both EnOcean Equipment Profiles and Generic Profiles describe the data communication of products utilizing the EnOcean Radio Protocol and enables manufacturers to develop interoperable products. The Generic Profiles enable devices to have self-described dynamic communication. https://www.enocean-alliance.org/en/enocean_standard.	X	X				X	
IEEE PLC	IEEE 1905.1, Standard for a Convergent Digital Home Network for Heterogeneous Technologies Amendment IEEE 1905.1a (Support of New MAC/PHYs and Enhancements)	IEEE 1905.1 defines an abstraction layer for multiple home networking technologies that provides a common interface to widely deployed home networking technologies: IEEE 1901 over power lines, IEEE 802.11 for wireless, Ethernet over twisted pair cable, and MoCA 1.1 over coax. In IEEE 1905.1a, additional network technologies are supported by an extensible mechanism using an IEEE OUI and an XML-formatted document. https://standards.ieee.org/develop/wg/CDHN.html.	X	X				X	
IPSO Alliance	IPSO SmartObject Starter Pack IPSO SmartObject Expansion Pack	The availability of Internet Protocol (IP) on constrained devices with memory sizes of 16 kilobytes or less, including IPV6 and 6LowPAN, has made possible a new kind of interoperability for connected devices and Smart Objects. IPSO Smart Object Guidelines provide a common design pattern, an object model that can effectively use the IETF CoAP protocol to provide high level interoperability between Smart Object devices and connected software applications on other devices and services. http://www.ipso-alliance.org/so-starter-pack/.	X	X		X	X	X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
IPv6 Forum	Ipv6 Ready Logo Phase-2: (Test Specifications and Test Tools	The Ipv6 Forum "Ipv6 Ready Logo" Program is a conformance and interoperability testing program intended to demonstrate that Ipv6 is available and ready to be used. The Ipv6 Ready Logo Committee defines the test specifications for Ipv6 conformance and interoperability testing, to provide access to self-test tools and to deliver the Ipv6 Ready Logo. https://www.ipv6ready.org/?page=phase-2-tech-info.	X	X		X	X	X	
OCF	IoTivity framework OCF set of specifications V1.0.0 (OCF core architecture, interfaces, protocols and services, Remote access, resource type, security, smarthome device)	The Open Connectivity Foundation has been founded with the goal of defining the connectivity requirements and ensuring interoperability of the devices that make up the IoT. The OCF efforts include specification, certification and branding in order to efficiently achieve the goal of interoperability of devices, networks, and applications. The OCF set of specifications defines a common communication framework based on industry standard technologies to wirelessly connect and intelligently manage the flow of information among devices, regardless of form factor, operating system or service provider. Moreover, OCF is also providing an implementation (IoTivity project) of the specified software stack allowing both application developers and device manufacturers to deliver interoperable products across various platforms. Finally, OCF is also seeking interoperability at the data level by providing an online tool (oneIoTa Data Model Tool) that encourage the design on interoperable device data models for the IoT.	X	X		X		X	
OMA Open Mobile Alliance	Network API (or NetAPI) RESTful Network API Template OMA Service Exposure Framework (in progress)	The Network APIs expose underlying network services and capabilities to applications (messaging, location, payment, device capability discovery, etc.). http://technical.openmobilealliance.org/Technical/technical-information/specifications-for-public-comment	X	X		X			

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
oneM2M	ETSI TS 118 101 Functional Architecture ETSI TS 118 104 Service Layer Core Protocol Specification Test and conformance specifications for interoperability (Rel 2): ETSI TS 118 112 oneM2M Base Ontology ETSI TS 118 113 Interoperability Testing, ETSI TS 118 114 LWM2M Interworking; ETSI TS 118 115 Testing Framework, ETSI TS 118 118 Test Suite Structure & Test Purposes ETSI TS 118 121: oneM2M and AllJoyn® Interworking ETSI TS 118 123:Home Appliances Information Model and Mapping ETSI TS 118 124: oneM2M and OIC Interworking	An M2M services platform built upon devices, gateways, and servers. It allows end-to-end communication between data source and applications. oneM2M is network centric. It allows interoperability between devices and application through the use of uniform interfaces and APIs. oneM2M reaches to achieve interoperability through different standardisation efforts. The different working groups produce specifications for a reference architecture (ARC WG), a messaging protocol (PRO WG), a data Management, Abstraction and Semantics (MAS WG), but also interoperability testing (TST WG). oneM2M ARC WG develops and specifies an architecture for an M2M system. oneM2M PRO WG develops and specifies APIs, protocols and message formats used across oneM2M interfaces, including mapping to commonly used M2M protocols (HTTP, CoAP, MQTT). oneM2M MAS deals with the technical aspects related to management of M2M entities and/or functions. It also deals with support for application specific abstraction and semantics. oneM2M TST WG identifies and defines test requirements for the oneM2M system and the services related to it. It also develops and maintains a set of specifications for conformance and interoperability testing. http://www.onem2m.org/technical/latest-drafts.	X	X	X	X	X	X	
ETSI SmartM2M	SAREF ETSI TS 103 264 (Smart Appliance Common Ontology and oneM2M mapping)	SAREF is the Smart Appliance Reference ontology that has been standardized by ETSI SmartM2M as ETSI TS 103 264 (Smart Appliance Common Ontology and oneM2M mapping). SAREF is a shared model of consensus that facilitates the matching of existing assets (standards/protocols/datamodels/etc.) in the smart appliances domain. SAREF provides building blocks that allow separation and recombination of different parts of the ontology depending on specific needs.	X	X		X		X	
WiFi Alliance	Certification: Wi-Fi Test Suite	The Wi-Fi Test Suite is a software platform to support certification program development and device certification. http://www.wi-fi.org/certification/wi-fi-test-suite.	X	X		X	X		

6.3 Application

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
BBF	TR-069/CPE WAN Management	A bidirectional device management protocol that connects end-user devices to auto-configuration servers. It is intended for devices such as set-top boxes, VoIP phones, modems, routers, gateways, etc. The standard TR-069 is primarily a device management protocol. However, the rich routines specified in the standard go beyond device management to include application management by supporting methods for installing, starting, stopping/restarting applications running on remote managed devices.	X	X				X	
OMA	OMA-DM OMA-LWM2M	A joint specification between the Device Management (DM) and the Data Synchronisation (DS) working groups at the OMA. OMA-DM is designed for mobile device management (mobile, tablets, PDAs). It offers services such as device configuration, software update, and fault management. OMA-LWM2M is the counterpart of OMA-DM for M2M and IoT devices. It targets mainly constrained devices using light and compact protocol and efficient data model. In addition to device management, the OMA standards for device management include routines for, application management by supporting methods for installing, starting, stopping/restarting applications running on remote managed devices. Moreover, OMA standards can be used to retrieve data and thus they can be used as messaging protocols.	X	X		X		X	
OSGi	Part of OSGi Core Release 6 Specification	The OSGi technology also provides flexible remote management and interoperability for applications and services over a broad variety of devices and a variety of defined communication and messaging protocols, including UPnP, TR069, OMA DM, HTTP/REST, JSON-RPC. https://www.osgi.org/developer/downloads/release-6/release-6-download/.	X	X		X	X	X	

6.4 Infrastructure

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
3GPP	GSM, GPRS, EDGE, UMTS, HSPA, LTE, LTE-Advanced and LTE-ADVANCED PRO (4.5G)	Thanks to wide coverage, mobility support, and good data transfer, a cellular radio network is a proper communication infrastructure for the IoT. However, due to the shared radio resources, the great number of connected things, the communications characteristics (periodic, small data messages, etc.), rather than connecting all things, a cellular radio network is more likely to connect some devices (gateways, user devices, etc.) depending on the application scenario.	X	X	X	X	X	X	
BBF	BBS-BUS WT-069 Issue 2, CPE WAN Management Protocol - Universal Service Platform (USP) (In development).	BBF is developing an evolution of TR-069 (see clause 7.6) to propose an Universal Service Platform (USP) covering existing use cases, machine-to-machine/IoT use cases, and the virtualization of broadband user services, prioritized by their potential business value.	X	X	X	X		X	X
ETSI TETRA	Terrestrial trunked Radio (TETRA); ETSI EN 300 392	TETRA provides a digital mobile radio system for professional use that allows bi-directional communications. Due to its limitations in connecting a large number of devices across one city, a TETRA network may be considered as a secondary infrastructure targeting specific services (Transportation, Police, Fire departments, etc.)	X		X			X	
IEEE	802.11s (Public WiFi)	The 802.11 standards specify a configuration where Wi-Fi devices connect through a mesh topology allowing the deployment of a Wi-Fi infrastructure. Public Wi-Fi networks can be a key technology for some Smart City applications. Indeed, a Wi-Fi-grade wireless network may enable various IoT applications through the provision of high data rate and low latency communication network; and can be very convenient for connecting mobile gateways.	X	X	X	X	X	X	
ITU-T	Recommendation ITU G.992.x (xDSL)	xDSL is a digital subscriber line (DSL) and data communications technology that enables faster data transmission over copper telephone lines. It is the most important internet communication infrastructure for internet access in a metropolitan area or across a city. The ADSL technology offers a reliable and efficient communication mean enabling some QoS demanding application in the field of IoT such as voice and video communications.	X	X	X			X	X
ITU-T	Recommendation ITU G.651, ITU G.652	Optical access networks are supported by Fiber infrastructures. The fiber technology, when available, offers very high speed internet connection for end-users; and permits the implementation of very delay-sensitive applications but also QoS-based applications.	X	X	X		X	X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
LoRa Alliance	LoRaWAN	LoRaWAN is a telecommunication network technology that allows long-range communication at low bit rate using ISM frequency bands. It can be used as a primary communication infrastructure to connect battery-powered and resource-constrained devices. Regarding its data transfer performance, the LoRa technology may be advised for IoT applications that do not require frequent data exchanges.	X		X	X		X	
oneM2M	ETSI TS 118 101 Functional Architecture ETSI TS 118 102 Requirements	These standards define the oneM2M architecture and support the deployment of IoT infrastructures, using service platforms that provide multi-domain support and interoperability with a middleware offering e.g. identification and naming of devices and applications.	X	X	X	X		X	X
OSGi	OSGi Core Release 6 Specification OSGi Compendium Release 6 Specification (services)	These specifications enable dynamic and modular end-to-end connectivity and facilitate the componentization of software and applications	X	X	X	X	X	X	X
IEC	IEC 61508	IEC 61508 is an international standard published by the International Electrotechnical Commission of rules applied in industry. It is titled Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES). IEC 61508 is intended to be a basic functional safety standard applicable to all kinds of industry. It defines functional safety as: "part of the overall safety relating to the EUC (Equipment Under Control) and the EUC control system which depends on the correct functioning of the E/E/PE safety-related systems, other technology safety-related systems and external risk reduction facilities". The standard covers the complete safety life cycle, and may need interpretation to develop sector specific standards.	X	X	X	X	X	X	X

6.5 IoT Architecture

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
AIOTI	IoT high level architecture	AIOTI WG3 has developed a High Level Architecture (HLA) for IoT that should be applicable to AIOTI Large Scale Pilots. The HLA takes into account existing SDOs and alliances architecture specifications. AIOTI WG3 recommends that the HLA be the basis for further discussion with the Large Scale Pilot (LSP) WGs in order to promote architectural convergence among the WGs.	X	X	X	X	X	X	X
IEEE	P2413 (Standard for an Architectural Framework for the Internet of Things (IoT))	The P2413 WG was initiated through the guidance of the IEEE-SA's Industry Strategic IoT Team with a focus to integrate market needs with the developing IoT technology landscape. The standard described here defines an architectural framework for the Internet of Things (IoT), including descriptions of various IoT domains, definitions of IoT domain abstractions, and identification of commonalities between different IoT domains. The framework provides a reference model that defines relationships among various IoT verticals (e.g. transportation, healthcare, etc.) and common architecture elements. It also provides a blueprint for data abstraction and the quality "quadruple" trust that includes protection, security, privacy, and safety." It follows ISO/IEC/IEEE 42010 architecture styleOrganized along architectural viewpoints Defines architecture reference models that address all of the concerns framed by its governing viewpoint Adheres to a service-oriented architecture approach Note that it allows various application protocols incl. REST and is not limited to web service Puts the Thing in centre of value creation https://standards.ieee.org/develop/project/2413.html.	X	X	X	X			

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
Industrial Internet Consortium (IIC)	Industrial Internet Reference Architecture (IIRA) tech-arch.tr.001	The Architecture Task Group of IIC has created a framework for expressing the reference architecture(s) of the Industrial Internet. The Industrial Internet Reference Architecture (IIRA) is a standard-based open architecture for IISs. To maximize its value, the IIRA has broad industry applicability to drive interoperability, to map applicable technologies, and to guide technology and standard development. The description and representation of the architecture are generic and at a high level of abstraction to support the requisite broad industry applicability. The Industrial Internet Reference Architecture is fully described by the analysis on the set of specific concerns in viewpoints. The architecture view point presented here is described from the view point of stakeholders that make up an internet, this include: Business, usage, functional and implementation view. http://www.iiconsortium.org/IIRA-1-7-ajs.pdf.	X	X	X	X		X	
ISO/IEC JTC1	Information technology - Internet of Things Reference Architecture (IoT RA) (under development)	The IoT RA will specify IoT Conceptual Model, conceptual reference model, and reference architecture from different architectural views, common entities, and interfaces between IoT domains. http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=65695.	X	X	X	X	X	X	
ITU-T	Recommendation ITU-T Y.2060 "Overview of the Internet of Things"	ITU-T has developed an IoT Reference Model which provides a high level capability view of an IoT infrastructure. Reference model proposed in this architecture it is a 4 layer generic model that can apply to an IoT architecture model. The proposed layers include: application layer; service support and application support layer; network layer; device layer. Supporting layers include management and security. The concept of gateway capabilities are mentioned that allows different systems to communicate but this Gateway types are not mentioned. This work also covers types of business model that can be supported using IoT reference model. https://www.itu.int/rec/T-REC-Y.2060-201206-I. These standards are still being developed at the time of writing the present document.	X	X	X	X		X	

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
ITU-T	Recommendation ITU-T Y.2068	Functional framework and capabilities of the Internet of things. Describes the functional framework of the Internet of things (IoT) in three different views, the IoT basic capabilities, and additional capabilities for the integration of cloud computing and big data technologies with the IoT. This recommendation is used in conjunction with Y.2060, It provides a different view of the proposed architecture model. It presents the definition of capabilities that make up functional view of the architecture model. This recommendation has some elements that can apply to all of the knowledge areas proposed here. https://www.itu.int/rec/T-REC-Y.2068/en.	X	X	X	X		X	
oneM2M	ETSI TS 118 101 Functional_Architecture	Describes the end-to-end oneM2M functional architecture, including the description of the functional entities and associated reference points. oneM2M functional architecture focuses on the Service Layer aspects and takes Underlying Network-independent view of the end-to-end services.	X	X	X	X	X	X	X
Future Internet Public-Private Partnership (FI-PPP)	Fiware	FIWARE or FI-WARE is a middleware platform, driven by the European Union, for the development and global deployment of applications for Future Internet. The API specification of FIWARE is open and royalty-free that facilitate creation and delivery of Future Internet applications and services in a variety of areas, including smart cities, sustainable transport, logistics, renewable energy, and environmental sustainability https://www.fiware.org/.	X	X	X	X	X	X	X

6.6 Devices and Sensor Technology

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
3GPP	GSM, GPRS, EDGE, UMTS, HSPA,	The 3GPP standards cover Radio, Core Network, and Service Architecture for cellular mobile networks. 3GPP mobile device standards is evolving with releases that are aimed at supporting IoT application.	X	X	X	X	X	X	X
3GPP MTC (Machine Type Protocol)	LTE	LTE-: LTE M2M communications. Associated with it are new categories being launched in the 3GPP standards known as LTE Advance and Advance Pro (4.5G) and the devices provide access.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
3GPP Narrow band IoT	LTE Advance LTE-Advanced Pro (4.5G)	NB-IOT, a new narrowband radio technology to address the requirements of the Internet of Things (IoT). The new technology will provide improved indoor coverage, support of massive number of low throughput devices, low delay sensitivity, ultra-low device cost, low device power consumption and optimized network architecture. LTE-Advance LTE-Advanced Pro (4.5G) standard is still growing and evolving. New networks are still being rolled out, and leading-edge features are being added to 4G to satisfy the market need for ever-increasing data rates and device technology are also evolving. Standards not available yet.	X	X	X	X		X	X
BBF	TR-069	TR-069 (Technical Report 069) is a technical specification that defines an application layer protocol for remote management of end-user devices. It was published by the Broadband Forum and entitled CPE WAN Management Protocol (CWMP). As a bidirectional SOAP/HTTP-based protocol, it provides the communication between customer-premises equipment (CPE) and Auto Configuration Servers (ACS). It includes both a safe auto configuration and the control of other CPE management functions within an integrated framework. The protocol addresses the growing number of different Internet access devices such as modems, routers, gateways, as well as end-user devices which connect to the Internet, such as set-top boxes, and VoIP-phones. The TR-069 standard was developed for automatic configuration and management of these devices by Auto Configuration Servers (ACS). Amendments are as follows: TR-181 (Device Data Model. TR-142 (Framework for TR-069 enabled PON Devices). TR-135 (Data Model for a TR-069 Enabled STB). TR-106 DSLHomeTM Data Mode.l Template for TR-069-Enabled Devices DSL Forum. Includes protocols for managing different devices. Although not so much a device but application that support devices this standards qualifies to be in this section because it is a device management application. https://www.broadband-forum.org/cwmp.php.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
ETSI DECT	ETSI EN 301 406	Digital Enhanced Cordless Telecommunications (DECT); Harmonized EN for Digital Enhanced Cordless Telecommunications (DECT) covering the essential requirements under article 3.2 of the R&TTE Directive; Generic radio. The specification applies to terminal equipment for the Digital Enhanced Cordless Telecommunications (DECT) common interface. DECT terminal equipment consists of the following elements: a) Fixed Part (FP); b) Portable Part (PP); c) Cordless Terminal Adapter (CTA); d) Wireless Relay Station (WRS) (FP and PP combined); e) Hybrid Part (HyP) (a PP with capability to act as a FP to provide PP to PP communication). Radio band 1,88 -1,9 GHz.	X	X	X	X		X	X
ETSI ERM	ETSI EN 301 908 Part 1 and 2	Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks; Part 1: Harmonized EN for IMT-2000, introduction and common requirements, covering essential requirements of article 3.2 of the R&TTE Directive. IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 2: CDMA Direct Spread (UTRA FDD) User Equipment (UE). The specification applies to the following radio equipment type: User Equipment for IMT-2000 CDMA Direct Spread (UTRA FDD). https://www.etsi.org/deliver/etsi_en/301900_301999/30190801/03.02.01_60/en_30190801v030201p.pdf.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
ETSI DECT-ULE	ETSI TS 102 939-1/2	Digital Enhanced Cordless Telecommunications (DECT); Ultra Low Energy (ULE); Machine to Machine Communications; Part 1: Home Automation Network (phase 1 and 2). The set of features defined in the "Home Automation Network (HAN), phase 1" is primarily targeted to provide a global M2M solution within domestic scenarios. It specifies the first set of functionalities of the ETSI radio technology named DECT Ultra Low Energy (ULE). DECT ULE provides bi-directional radio communication with medium range, data protection, and Ultra Low Power consumption between different types of Portable Devices and Radio Fixed Parts. DECT ULE is based on the proven and established DECT standard. ULE has all the traditional strengths of DECT (interference free, license free, security, authentication, long range, ready internet etc.). https://www.etsi.org/deliver/etsi_ts/102900_102999/10293902/01.01.01_60/ts_10293902v010101p.pdf. The application layer protocol HAN FUN (Home Area Network Functional protocol) covers the following functions: Protocol Definition, Device Definition, Device Management http://www.ulealliance.org/downloads.aspx?c=w.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
IEEE - ISO/IEC JTC 1/SC 31/WG 6	ISO/IEC/IEEE 21450:2010 (adoption of IEEE 1451.0™-2007) - Information technology - Smart Transducer Interface for Sensors and Actuators - Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats ISO/IEC/IEEE 21451-1:2010 (adoption of IEEE 1451.1™-1999) - ISO/IEC/IEEE 21451-2:2010 (adoption of IEEE 1451.2™-1997) - ISO/IEC/IEEE 21451-7:2011 - Information technology	ISO/IEC/IEEE 21450:2010 provides a common basis for members of the ISO/IEC/IEEE 21451 series of International Standards to be interoperable. It defines the functions that are to be performed by a transducer interface module (TIM) and the common characteristics for all devices that implement the TIM. It specifies the formats for Transducer Electronic Data Sheets (TEDS). It defines a set of commands to facilitate the setup and control of the TIM as well as reading and writing the data used by the system. Application programming interfaces (APIs) are defined to facilitate communications with the TIM and with applications. It defines the functions that are to be performed by a transducer interface module (TIM) and the common characteristics for all devices that implement the TIM. ISO/IEC/IEEE 21450 defines the functions that are to be performed by a transducer interface module (TIM) and the common characteristics for all devices that implement the TIM. Application programming interfaces (APIs) are defined to facilitate communications with the TIM and with applications. ISO/IEC/IEEE 21451 family of standards for "Smart Transducer Interface for Sensors and Actuators" http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=45020&development=on.	X	X	X				X
ISO/IEC	ISO/IEC 29182	The ISO/IEC 29182 series can be used by sensor network designers, software developers, and service providers to meet customer requirements including any applicable interoperability requirements. The ISO/IEC 29182 series are comprised of seven parts: • Part 1: General overview and requirements • Part 2: Vocabulary and terminology • Part 3: Reference architecture views • Part 4: Entity models • Part 5: Interface definitions • Part 7: Interoperability guidelines The purpose of the ISO/IEC 29182 series is to provide guidance to facilitate the design and development of sensor networks. Improve interoperability of sensor networks, and make sensor networks plug-and-play, so that it becomes fairly easy to add/remove sensor nodes to/from an existing sensor network. http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45261.	X	X	X	X	X	X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
IETF CoRE	IETF RFC 7641 (Observing Resources in the Constrained Application Protocol (CoAP))	The state of a resource on a CoAP server can change over time. This document specifies a simple protocol extension for CoAP that enables CoAP clients to "observe" resources, i.e. to retrieve a representation of a resource and keep this representation updated by the server over a period of time. The protocol follows a best-effort approach for sending new representations to clients and provides eventual consistency between the state observed by each client and the actual resource state at the server. http://datatracker.ietf.org/wg/core/documents/.	X	X	X	X	X	X	X
M2.COM	M2.COM is a brand new platform form factor for sensors. It adopts the standardized, frequently used M.2 form factor and is defined as an evolutionary module that combines general wireless connectivity with additional built-in computing ability powered by Micro-controller Unit (MCU).	A standard module form factor for sensors and sensor nodes benefits all those in this eco-system, including sensor makers, module makers, and sensor integrators. You no longer need to put everything into one sensor but can develop M2.COM and your sensor carrier board separately. Now the sensor maker can choose different M2.COM modules to transmit data by different methods, and the module maker can develop another M2.COM module that supports many sensors. This efficiently reduces the learning curve and helps you concentrate on your own area of expertise.	X		X			X	
OGC	SensorML	SensorML is an approved Open Geospatial Consortium standard. SensorML provides standard models and an XML encoding for describing sensors and measurement processes. SensorML can be used to describe a wide range of sensors. Sensor Model Language (SensorML) provides standard models and an XML encoding for describing any process, including the process of measurement by sensors and instructions for deriving higher-level information from observations. Processes described in SensorML are discoverable and executable. All processes define their inputs, outputs, parameters, and method, as well as provide relevant metadata. SensorML models detectors and sensors as processes that convert real phenomena to data. The main objective is to enable interoperability, first at the syntactic level and later at the semantic level (by using ontologies and semantic mediation), so that sensors and processes can be better understood by machines, utilized automatically in complex workflows, and easily shared between intelligent sensor web nodes. http://www.opengeospatial.org/standards/sensorml.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
OMA	OMA-DM	OMA Device Management is a device management protocol specified by the Open Mobile Alliance (OMA) Device Management (DM) Working Group and the Data Synchronization (DS) Working Group. OMA DM specification is designed for management of mobile devices such as mobile phones, PDAs, and tablet computers. Device management is intended to support the following uses: Provisioning - Configuration of the device (including first time use), enabling and disabling features. Device Configuration - Allow changes to settings and parameters of the device. Software Upgrades - Provide for new software and/or bug fixes to be loaded on the device, including applications and system software. Fault Management - Report errors from the device, query about status of device. Includes protocols for managing different devices. Although not so much a device but application that support devices this standards qualifies to be in this section because it is a device management application.	X	X	X	X		X	X
oneM2M	ETSI TS 118 106 (Management enablement (BBF)	Specifies the usage of the BBF TR-069 protocol and the corresponding message flows including normal cases as well as error cases to fulfil the oneM2M management requirements. Includes protocols for managing different devices. Although not so much a device but application that support devices this standards qualifies to be in this section because it is a device management application.	X	X	X	X	X	X	X
OCF (was UPnP Forum)	UPnP Device Management	UPnP Device Management provides a common solution through defining standard management actions and data models, which can be implemented in devices running different execution environments. UPnP DM also allows defining new data models for specific device usage. The implementation of UPnP Device Management v1 includes Basic Management Service and Configuration Management Service as defined by UPnP Forum. Includes protocols for managing different devices. Although not so much a device but application that support devices this standards qualifies to be in this section because it is a device management application. http://upnp.org/specs/dm/dm1/.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
ZigBee® Alliance	ZigBee® PRO, ZigBee® RF4CE	ZigBee® specifications also provide remote control of the devices. See ZigBee® Alliance in clause 7.1 http://www.zigbee.org/zigbee-for-developers/network-specifications.	X	X	X	X		X	X

6.7 Security and Privacy

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
3GPP	ETSI TS 133 220 Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture Describes the security features and a mechanism to bootstrap authentication and key agreement for application security from the 3GPP AKA mechanism. ETSI TS 133 102 (Technical Specification Group Services and System Aspects; 3G Security; Security architecture (Release 9)) ETSI TS 121 133 (Technical Specification Group (TSG) SA; 3G Security; Security Threats and Requirements") ETSI TS 133 120 (Technical Specification Group (TSG) SA; 3G Security; Security Principles and Objectives".)	3GPP can provide the "bootstrapping of application security" to authenticate the subscriber by defining a generic bootstrapping function based on AKA protocol. 3GPP has a series standards om security that address authentication, bootstrapping: Threats and Requirements" (ETSI TS 121 133) and implement the security objectives and principles described in ETSI TS 133 120. A security mechanism is an element that is used to realise a security feature. All security features and security mechanisms taken together form the security architecture http://www.3gpp.org/ftp/tsg_sa/wg3_security/_specs	X	X	X	X	X	X	X
ETSI DECT	ETSI EN 300 175-7	Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 7: Security features. The document specifies the security architecture, the types of cryptographic algorithms required, the way in which they are to be used, and the requirements for integrating the security features provided by the architecture into the DECT CI. It also describes how the features can be managed and how they relate to certain DECT fixed systems and local network configurations.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
Hypercat	Hypercat 3 specification	Hypercat is an open, lightweight JSON-based hypermedia catalogue format for exposing collections of uniform resource identifiers (URLs) for exposing information about IoT assets over the web. Hypercat allows a server to provide a set of resources to a client, each with a set of semantic annotations. Implementers are free to choose or invent any set of annotations to suit their needs. A set of best practices and tools is currently being developed. Using HTTPS, REST and JSON, each Hypercat catalogue may expose any number of URIs, each with any number of resource description framework-like (RDF-like) triple statements about it. http://www.hypercat.io/standard.html	X	X	X	X	X	X	X
IEEE		IEEE Cyber Security for the Smart Grid. This report details the cyber security vulnerabilities that exist in the Smart Grid value chain, the efforts undertaken by certain countries to mitigate these vulnerabilities, and the measures that need to be implemented going forward. Four such instances of cyber security breaches are highlighted in this report.	X		X			X	
IEEE	IEEE 2600-2008	IEEE Standard for Information Technology: Hardcopy Device and System Security. This standard defines security requirements (all aspects of security including but not limited to authentication, authorization, privacy, integrity, device management, physical security and information security) for manufacturers, users, and others on the selection, installation, configuration and usage of hardcopy devices (HCDs) and systems; including printers, copiers, and multifunction devices (MFDs). This standard identifies security exposures for these HCDs and systems, and instructs manufacturers and software developers on appropriate security capabilities to include in their devices and systems, and instructs users on appropriate ways to use these security capabilities.	-	X	X	X		X	X
IETF	IETF RFC 5246	Transport Security The primary goal of the TLS protocol is to provide privacy and data integrity between two communicating applications. The protocol is composed of two layers: the TLS Record Protocol and the TLS Handshake Protocol. At the lowest level, layered on top of some reliable transport protocol (e.g. TCP [TCP]), is the TLS Record Protocol Version 1.2 of the Transport Layer Security (TLS) protocol. The TLS protocol provides communications security over the Internet. The protocol allows client/server applications to communicate in a way that is designed to prevent eavesdropping, tampering, or message forgery. https://tools.ietf.org/html/rfc5246.							

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
IETF	Oauth	Oauth is an open standard for authorization, providing methods to access server resources on behalf of a resource owner. IETF RFC 6749 the Oauth 2.0 authorization framework. The Oauth 2.0 authorization framework enables third-party applications to obtain limited access to HTTP services, either on behalf of resource owners by orchestrating approval interaction between the resource owner and the HTTP service, or by allowing third-party applications to obtain access on their own behalf.	X	X	X	X		X	X
IETF	Authentication and Authorization for Constrained Environments (ACE)	Certain IoT deployment scenarios require a flexible and dynamic authorization solution that does not rely on static configuration of access control lists. The IETF ACE working group defines how to use OAuth 2.0 as an authorization framework with Internet of Things (IoT) deployments, thus bringing a well-known and widely used security solution to IoT devices. Where possible vanilla OAuth 2.0 is used, but where the limitations of IoT devices require it, profiles and extensions are provided. The charter of the group can be found at: https://datatracker.ietf.org/wg/ace/charter/. The technical specification can be found at: https://tools.ietf.org/html/draft-ietf-ace-oauth-authz-01. Use cases are documented in https://datatracker.ietf.org/doc/rfc7744/. DTLS profile could also be relevant http://tools.ietf.org/html/draft-ietf-dice-profile-17.	X		X	X		X	X
ISO/IEC	ISO/IEC 27000-series	Information security standards The series provides best practice recommendations on information security management, risks and controls within the context of an overall information security management system (ISMS), similar in design to management systems for quality assurance (the ISO 9000 series).	X	X	X	X		X	X
OASIS	Security Services (SAML) TC eXtensible Access Control Markup Language (XACML) TC	Cross-Enterprise Security and Privacy Authorization (XSPA) Profile of Security Assertion Markup Language (SAML) for Healthcare v1.0. Cross-Enterprise Security and Privacy Authorization (XSPA) Profile of XACML v2.0 for Healthcare v1.0. Cross-Enterprise Security and Privacy Authorization (XSPA) Profile of WS-Trust for Healthcare v1.0. This series of documents describes a framework that provides access control interoperability useful in the healthcare environment. Interoperability is achieved using WS-Trust secure token request/response elements to carry common semantics and vocabularies in exchanges specified below.	X	X	X	X		X	X
oneM2M	ETSI TS 118 103	TS security solution for M2M system. Security solutions applicable within the M2M system.	X	X	X	X		X	X

SDO	Standards	Description/Analysis	SC	SL	SF	SW	SMo	SE	SMa
W3C		XML Key Management Specification (XKMS 2.0) Bindings. This is a two part standard. Part 1 of this specification covers the XKMS protocols and services. Part 2 of the W3C Recommendation for the XML Key Management Specification (XKMS Version 2.0) covers different protocol bindings with security characteristics for the XML Key Management Specification the XKMS Activity Statement.	X	X	X	X	X	X	X
ISO/IEC	ISO/IEC 29100:2011 provides a privacy framework	This International Standard provides a high-level framework for the protection of personally identifiable information (PII) within information and communication technology (ICT) systems. It is general in nature and places organizational, technical, and procedural aspects in an overall privacy framework. It: • specifies a common privacy terminology; • defines the actors and their roles in processing personally identifiable information (PII); • describes privacy safeguarding considerations; and • provides references to known privacy principles for information technology. ISO/IEC 29100:2011 is applicable to natural persons and organizations involved in specifying, procuring, architecting, designing, developing, testing, maintaining, administering, and operating information and communication technology systems or services where privacy controls are required for the processing of PII.	X		X	X		X	X

6.8 Conclusion

A large number of ICT standards may apply to several IoT vertical domains. This set of generic solutions has the potential to provide a common ground to the developers of IoT solutions, irrespective of the specific domain in which they may be applied.

However, this potential will only materialize if the development of IoT standards in vertical domains is making effective use of those standards rather than reinventing similar but not complaint ones, thus increasing the fragmentation of the IoT standards landscape.

With regards to Security and Privacy, IoT platforms have to ensure data privacy, integrity and transmission accordingly to the information sensibility.

7 Smart Cities Standards Landscape

7.0 Introduction

Smart Cities content is made up of many services e.g. smart transportation, Smart Home, smart waste management to mention just a few. These clauses will not focus on individual services that make up Smart Cities, rather their focus is on the standards that are available that enable the framework to function as a Smart City.

7.1 Communication and Connectivity

There are no specific communication and connectivity requirements for Smart City all are covered in generic clause.

7.2 Integration/Interoperability

There are no specific Integration/Interoperability requirements for Smart City all are covered in generic clause.

7.3 Application

SDO	Standards	Description	Analysis
TALQ™	Outdoor Lighting Network (OLN) Central Management System	The TALQ specification specifies an application language and protocol for operation and management of Outdoor Lighting Networks (OLN). This has been identified and confirmed by customers and key players in the lighting industry as one of the needs to be addressed to increase the market of OLN solutions The OLN is a communication network of outdoor devices such as Light Points controllers, Gateways, Segment Controllers, Sensors, for purpose of saving energy and maintenance optimization. Central Management System as an application server providing web or PC based user interface able to manage the lighting infrastructure (e.g. assets, schedules, manual overrides, alarm triggers), and monitor the operating conditions (e.g. burning hours, voltages, failures) and performance reports (maintenance, energy consumption).	The TALQ Consortium aims to establish a globally accepted standard for management software interfaces to control and monitor heterogeneous outdoor lighting networks. This way interoperability between Central Management Systems (CMS) and Outdoor Lighting Networks (OLN) from different vendors will be enabled such that a single CMS can control different OLNs in different parts of a city or region. TALQ accelerates the introduction of networked outdoor lighting.

7.4 Infrastructure

There are no specific infrastructure requirements for Smart City all are covered in generic clause.

7.5 IoT Architecture

SDO	Standards	Description	Analysis
ITU-T	ITU-T Focus Group on Smart Sustainable Cities FGSSC-Setting the framework for an ICT architecture of a smart sustainable city (05/2015).	These Technical Specifications describe the ICT architecture development framework of Smart Sustainable Cities and concludes on corresponding architecture views and guides. It presents a multi-tier SSC ICT architecture from communications view, emphasizing on a physical perspective.	Very useful view because it presents the architecture from physical elements perspectives hence an implementer of Smart City not familiar with technology will have an idea where the elements are located from architecture perspectives.

7.6 Devices and Sensor Technology

There are no specific device and sensor requirements for Smart City all generic requirements apply.

7.7 Security and Privacy

There are no specific security requirements for Smart City all generic security requirements apply.

7.8 Summary of Smart Cities Standards Landscape

These clauses have presented a snap shot of the degree of standards available for Smart City.

From the list of standards above, there appears to be enough standards available that will support putting together a Smart City today with a lot of interworking solutions needed. Most of the standards identified in Smart Cities apply to generic standards work being done by different bodies today to get harmonisation however the main differentiator in Smart City will be the service. The conclusion then is that the ingredients for a Smart City are here today but there is still work in order to ensure a seamless interoperability and the gaps are the degree of seamlessness presented by the different architectures. To fill this gap we should address the seamlessness or plug and play in these architectures which will be addressed in another report (ETSI TR 103 376 [i.2]).

8 Smart Living Standards Landscape

8.0 Introduction

These clauses cover smarting living and ageing well aspects looking at standards that contribute to IoT to support continuous growth of population of elderly people in living longer, staying active, independent and out of institutional care settings, while at the same time reducing the costs for care systems and providing a better quality of life for vulnerable categories of citizens. Following the LSPs technology distribution, this vertical domain includes in addition the Smart home, e.g. Home/Buildings vertical domains shown in figure 2, which are closely linked with smart living. AIOTI WG5 has focused on two main issues - Elderly Care and Smart Home/Home Automation supporting technologies - that can be bridged by IoT. This is a follow on from AIOTI work considering specific standards available today to help achieve Smart Living.

8.1 Communication and Connectivity

SDO	Standards	Description	Analysis
DICOM	DICOM multi-part standard (PS3.1 to PS 3.20, among which are PS3.7: Message Exchange PS3.8: Network Communication Support for Message Exchange PS3.12: Formats and Physical Media.	The DICOM Standard facilitates interoperability of medical imaging equipment.	This standard specifies: • For network communications, a set of protocols to be followed by devices claiming conformance to the Standard. • The syntax and semantics of Commands and associated information that can be exchanged using these protocols. • For media communication, a set of media storage services to be followed by devices claiming conformance to the Standard, as well as a File Format and a medical directory structure to facilitate access to the images and related information stored on interchange media. • Information that have to be supplied with an implementation for which conformance to the Standard is claimed. http://dicom.nema.org/standard.html.

SDO	Standards	Description	Analysis
ITU-T	FG M2M TR: D2.1: M2M service layer: requirements and architectural framework FG M2M TR: D3.1: M2M service layer: APIs and protocols overview Recommendation ITU-T Y.2065 Service and capability requirements for e-health monitoring services Recommendation ITU-T Y.2075: Capability framework for e-health monitoring services	The ITU-T's standardization activity in the e-health domain has until now produced specifications from service, interoperability, data and security perspectives.	FG M2M identified a minimum set of common requirements of vertical markets, focusing on the health-care market (FG ended in 12-2013) and APIs and protocols supporting e-health applications and services. D2.1 identifies requirements of the M2M service layer and provides an architectural framework of the M2M service layer and its relationship with the IoT reference model. D3.1 provides an overview of APIs and protocols for the M2M service layer and the related API and protocol requirements. Y.2065 and Y.2075 provide requirements for e-health monitoring services. The annexes contain description of use cases and components deployment. https://www.itu.int/en/ITU-T/techwatch/Pages/ehealth-standards.aspx.
KNX®	KNX standard approved as ISO/IEC 14543-3, CENELEC EN 50090, , EN 50491, CEN EN 13321-1 and Chinese Standard GB/T 20965	KNX is a standard for Home and Building Control.	The KNX Bus is a manufacturer and application domains independent system. Via the KNX medium to which all bus devices are connected (twisted pair, radio frequency, power line or IP/Ethernet), they are able to exchange information. Bus devices can either be sensors or actuators needed for the control of building management equipment such as: lighting, blinds/shutters, security systems, energy management, heating, ventilation and air-conditioning systems, signalling and monitoring systems, interfaces to service and building control systems, remote control, metering, audio/video control, white goods, etc. All these functions are controlled, monitored and signalled via a uniform system. http://www.knx.org/knx-en/downloads/index.php.

SDO	Standards	Description	Analysis
LON	ISO/IEC 14908: Information technology -- Control network protocol ISO/IEC 14908-1: Part 1: Protocol stack ISO/IEC 14908-2: Part 2: Twisted pair communication ISO/IEC 14908-3: Part 3: Power line channel specification ISO/IEC 14908-4: Part 4: IP communication These standards have been ratified by regions as ANSI/CTA-709 (US), EN 14908 (EU), GB/Z 20177 (China)	LON is a standard for Home and Building Automation and Control	LON stands for Local Operation Network. LONTalk® is a communication protocol for networked control systems in commercial Building Automation, Controls and Building Management. The protocol provides peer-to-peer communication for networked control and is suitable for implementing both peer-to-peer and master-slave control strategies. The standard describes services in layers 2 to 7. In the layer 2 (data link layer) specification, it also describes the MAC sub-layer interface to the physical layer. The physical layer provides a choice of transmission media. The interface described in this specification supports multiple transmission media at the physical layer. In the layer 7 specification, it includes a description of the types of messages used by applications to exchange application and network management data. A LonWorks® network is a network of intelligent devices (such as sensors, actuators, and controllers) that communicate with each other using the LonTalk over one or more communications channels to exchange information. http://www.lonmark.org/technical_resources/standards.
Thread	Thread stack standard	The Thread stack is an open standard for reliable, cost-effective, low-power, wireless D2D (device-to-device) communication.	The stack is designed specifically for Connected Home applications where IP-based networking is desired and a variety of application layers can be used on the stack. The Thread standard defines a Unified Convergence Layer Built on open standards and Ipv6 technology with 6LoWPAN as its foundation and running on standard 802.15.4 radios.

SDO	Standards	Description	Analysis
ETSI	ETSI TS 103 326 "Smart Body Area Network (SmartBAN); Enhanced Ultra-Low Power Physical Layer" ETSI TS 103 325 "Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN" ETSI TS 103 378 "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model"	ETSI TC SmartBAN 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.).	TC SmartBAN's scope includes in particular low power and low energy physical and MAC layers, network layer, security, interference mitigation and coexistence mechanisms, priority management, QoS and lawful intercept, data heterogeneity management, semantic interoperability support for standardisation in the area of Body Network Area technologies. This technology is also applicable to WSN clusters. ETSI TS 103 326 and ETSI TS 103 325 address all the aforementioned issues related to physical and MAC layers. ETSI TS 103 378 main objective is to specify, formalize and standardize Smart BAN (and WSN cluster) unified data/entities representation formats (e.g. measurements, control/monitoring data, sensors, actuators, relays and sink/hub), semantic open data model and corresponding ontology (service level and semantic interoperability included).

8.2 Integration/Interoperability

SDO	Standards	Description	Analysis
ASHRAE	ISO 16484-5: BACnet - A Data Communication Protocol for Building Automation and Control Networks ISO 16484-6: Method of Test for Conformance to BACnet	BACnet™ is a data communication protocol for building automation and control.	BACnet provides a standard way of representing the functions of any device, as long as it has these functions, as collections of related information called "objects," each of which has a set of "properties" that further describe it. One of the object's most important properties is its identifier. As devices have common appearances on the network in terms of their objects and properties, messages can manipulate this information in a standard way. It makes possible the interconnection of different vendors' equipment that uses the BACnet protocol http://www.bacnet.org/Overview/index.html.

SDO	Standards	Description	Analysis
CEN/ TC247	EN ISO 16484-3 Building automation and control systems (BACS) - Part 3: Functions EN 15232 Energy performance of buildings	EN ISO 16484-3 covers requirements and definitions regarding BACS and application software, generic function types for plant/project specific applications and engineering functions for building controls and operations. EN 15232 is part of a series of standards aiming at international harmonization of the methodology for the assessment of the energy performance of buildings, called "EPB set of standards".	EN ISO 16484-3 provides communication functions for the integration of other dedicated special system processes. The functional requirements are subdivided as follows: - System management and application software - Engineering process and tool software - BACS application processing programs and plant/application specific function types (e.g. demand/response, optimum-start-stop etc.) The functions are subdivided into the following types: - input and output functions; - processing functions; - management functions and required communications; - operator functions. As part of the "EPB set of standards", EN 15232 complies with the requirements for the set of basic EPB documents prEN ISO 52000-1:2015, CEN/TS 16628 and CEN/TS 16629 developed under EU Mandate M/480, and supports essential requirements of EU Directive 2010/31/EC on the energy performance of buildings (EPBD).
Continua	Design Guidelines	The Personal Connected Health Alliance (PCHA) is a membership association formed by Continua, mHealth Summit and HIMSS to transform healthcare through personalized, interoperable connected health solutions.	Continua's Design Guidelines contain references to the standards and specifications that Continua selected for ensuring interoperability of devices. It also contains additional Design Guidelines for interoperability that further clarify these standards and specifications by reducing options in the underlying standard or specification or by adding a feature missing in the underlying standard or specification. http://www.continuaalliance.org/products/design-guidelines.
HGI	HGI-RD001-R2.01: Home Gateway Technical Requirements: Residential Profile HGI-RD027-R3 Home Gateway QoS Module requirements	HGI publishes requirements for the hardware and software elements for broadband services in the digital home. HGI's scope includes home gateways, home networks, and the Smart Home.	The scope of HGI covers requirements and test plans for devices and service support in the digital home, within two main themes: connectivity and service enabling, with specific reference to Smart Home scenarios..

SDO	Standards	Description	Analysis
HL7	HL7 Version 3 Clinical Document Architecture (CDA) Fast Healthcare Interoperability Resources (FHIR)	HL7 standards support clinical practice and the management, delivery, and evaluation of health services.	The HL7 Version 3 CDA® is a document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of exchange between healthcare providers and patients. The FHIR (Fast Healthcare Interoperability Resources) Specification is a standard for exchanging healthcare information electronically. http://www.hl7.org/implement/standards/index.cfm?ref=nav.
IHE	Integration Profiles Technical Frameworks	IHE has created a set of information resources and tools for vendors and users of healthcare information systems to help them integrate systems and share information more effectively.	Technical Frameworks: Detailed reference documents that guide systems developers and integrators in implementing standards. Integration Profiles: Understand the standards-based integration capabilities defined in the IHE Technical Frameworks, in plain language http://www.ihe.net/Profiles.
ITU-T	Recommendations H.820-H.849 : Interoperability compliance testing of personal health systems (HRN, PAN, LAN and WAN) Recommendations ITU-T H.860 and H.869 Multimedia e-health data exchange services	See ITU-T in clause 7.1.	Question 28/16 (Multimedia framework for e-health applications) is undergoing a work on standardization of Multimedia Systems to support e-health applications: the result is a set of recommendations for e-health multimedia services and applications. https://www.itu.int/ITU-T/studygroups/com16/sg16-q28.html.
ZigBee®	ZigBee®e Health Care	See The ZigBee® Alliance in clause 7.1.	ZigBee® Health Care offers a global standard for interoperable products enabling secure and reliable monitoring and management of non-critical, low-acuity healthcare services targeted at chronic disease, aging independence and general health, wellness and fitness. http://www.zigbee.org/zigbee-for-developers/applicationstandards/zigbee-health-care.
ETSI	ETSI TR 103 327 "Smart Body Area Networks (SmartBAN); Service and application standardized enablers and interfaces, APIs and infrastructure for interoperability management".	ETSI TC SmartBAN 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.).	ETSI TC SmartBAN solutions in particular concern the description and the specification of a standardized infrastructure for Smart BAN and WSN cluster entities, interactions/interworking and data access, irrespective of whatever lower layers and radio technologies are used underneath. On the service and application side, standardized APIs for secure interaction and access to SmartBAN data/entities (data management mechanisms, semantic discovery of devices/data).

8.3 Application

SDO	Standards	Description	Analysis
DICOM	PS3.19: DICOM PS3.19 2015c - Application Hosting	This part of the DICOM Standard defines an interface between two software applications.	One application, the Hosting System, provides the second application with data, such as a set of images and related data. The second application, the Hosted Application, analyses that data, potentially returning the results of that analysis, for example in the form of another set of images and/or structured reports, to the first application. Hosted Application programs written to that standardized interface can 'plug-into' Hosting Systems. http://dicom.nema.org/standard.html.

8.4 Infrastructure

SDO	Standards	Description	Analysis
HGI	Home Gateway/Service Gateway platform	The work on enabling Services has moved beyond triple-play to encompass a delivery framework for Smart Home services.	This architecture includes support for a standard, general-purpose software execution environment in the HG (for third party applications), API definitions, device abstraction, and interfacing with Cloud based platforms.

8.5 IoT Architecture

SDO	Standards	Description	Analysis
ISO/IEEE PHD	ISO/IEEE 11073™ family of standards for Point-of-care medical device communication	The ISO/IEEE Personal Health Device (PHD) WG operates under the IEEE Engineering in Medicine and Biology Society (EMB). Its standards are harmonized with ISO and considered as international standards.	The IEEE 11073™ family of standards for medical-device communication is designed to help healthcare product vendors and integrators create interoperable devices and systems for disease management, health and fitness and independent living that can help save lives and improve quality of life for people worldwide. It is intended to enable interoperable communication for traditional medical devices, as well as personal health devices, and bring in other benefits, such as reducing clinical decision-making or reducing gaps and errors across the spectrum of healthcare delivery. http://standards.ieee.org/develop/wg/PHD.html.

8.6 Devices and Sensor Technology

There is no specific device and sensor standard for Smart Living. Most of the generic device and sensor standards in clause 6.6 apply.

8.7 Security and Privacy

There is no specific security standard for Smart Living. Most of the generic security standards in clause 6.7 apply.

8.8 Summary of Smart Living Landscape

These clauses have presented the degree of industry and vertical fragmentation for Smart Living based on some of the standards identified above. The list indicates a snap shot of the standards that are available to support Smart Living. Many SDOs are focused in this area and actively working on creating standards that are able to support Smart Living but their coverage is fragmented.

9 Smart Farming Standards Landscape

9.0 Introduction

The Internet of Things (IoT) is transforming the agriculture industry and enabling farmers to contend with various challenges they face such as water shortages, limited availability of lands, difficult to manage costs, to mention a few. New innovative IoT applications are addressing these issues and increasing the quality, sustainability and cost effectiveness of agricultural production. Today's large and local farms can, for example, leverage IoT to remotely monitor sensors that can detect soil moisture, crop growth and livestock feed levels, remotely manage and control their smart connected harvesters and irrigation equipment, and utilize artificial intelligence based analytics to quickly analyse operational data combined with 3rd party information, such as weather services, to provide new insights and improve decision making.

Smart Farming is about the application of data gathering (edge intelligence), data processing, data analysis and automation technologies on the overall value chain. Smart Farming is strongly related, but not limited, to the concepts of Precision Agriculture and Precision Livestock Farming. Farming modalities may include the production of vegetables, cattle (including dairy production) and others. Food safety/health/traceability refers to the awareness, prevention and risk-based measures of foodborne illnesses, from food production to consumption (AIOTI WG6 [i.9]). The following sections cover the standards that can apply to an IoT framework today when it comes to putting together a system for Smart Farming.

9.1 Communication and Connectivity

There are no specific communications and connectivity requirements for Smart Farming, all generic requirements apply.

9.2 Integration/Interoperability

There are no specific integration/interoperability requirements for Smart Farming, all generic requirements apply.

9.3 Application

SDO	Standards	Description	Analysis
Open source farming	OpenAG is building collaborative tools and platforms to develop an open-source ecosystem of food technologies that enables and promotes transparency, networked experimentation, education, and local production. By making the science behind modern agriculture more accessible, it is hoped to break down the barrier of entry and put the power of food production back in the hands of the people.	An open alliance group not necessary standards but creates frame work for Smart Farming.	http://mitcityfarm.media.mit.edu/about/.
IETF/ETSI	Cloud computing standards which include SCIM (System for Cross-domain Identity Management) IETF RFC 7643, IETF RFC 7644, IETF RFC 7642.	Includes standards that enable cloud standards coordination.	https://cloudstandards.cesnet.cz/en/etsi.

9.4 Infrastructure

SDO	Standards	Description	Analysis
ITU-T	Recommendation ITU-T Y.2238 Series Y: Global information infrastructure, Internet Protocol aspects and next-generation networks. Next Generation Networks - Service aspects: Service capabilities and service architecture Overview of Smart Farming based on networks	Recommendation ITU-T Y.2238 considers the actualized convergence service for agriculture, namely Smart Farming, as a solution to cope with various problems caused by severe conditions or the gap of viewpoints between people engaged in farming and IT engineers. In particular, this Recommendation defines service capabilities for Smart Farming, provides a reference model for Smart Farming, and identifies network capabilities required to produce an infrastructure which supports Smart Farming.	https://www.itu.int/rec/T-REC-Y.2238/en. Standards still being developed.

9.5 IoT Architecture

There is no specific architecture requirements for Smart Farming, all generic requirements in clause 6.5 apply here.

9.6 Devices and Sensor Technology

SDO	Standards	Description	Analysis
NASA/ A Drone Industry Standards Body	DRONES: DO-178C, Software Considerations in Airborne Systems and Equipment Certification	The primary document by which the certification authorities such as FAA, EASA and Transport Canada approve all commercial software-based aerospace systems.	There are so many articles on the benefit drones will play in Smart Farming to bring about more efficiency in farming hence it is useful to mention the availability of standards for Drones. https://en.wikipedia.org/wiki/DO-178C http://dronesafetycouncil.com/.

9.7 Security and Privacy

There are no specific securities requirements for Smart Farming, all generic requirements in clause 6.7 apply here.

9.8 Summary of Smart Farming Standards Landscape

Most of the standards described above are standards that are applicable across other vertical domains. There are few specific standards for Smart Farming such as the Recommendation ITU-T Y.2238 [i.4]. There seems to be more proprietary solutions for Smart Farming than standards solutions which could be because this area is not as advanced in standards area compared to the other verticals.

10 Smart Wearables Standards Landscape

10.0 Introduction

Wearable vertical is related to all connected devices that are temporary or permanently wore by an end-user. Smart Wearables can exist as independent objects such as smartwatch, heart monitor, etc. or embedded within textiles achieving what we call smart clothes such as an activity monitor baby onesie, or a micro-radar-equipped jean to act as a user interface to smartphone.

Wearable connected devices may exist either independently or connected to a mobile gateway which is usually a smartphone or a tablet. Indeed, some devices if connected with WLAN or WAN network access technologies can operate independently and communicate directly to remote services, while other devices connect through WPAN to a smartphone or a tablet in order to reach the targeted services running on this gateway or on remote servers.

Wearable my also refer to body area networks since different wearable objects may be connected through the same network (e.g. WPAN). For example, an end user may wear different sensors connected through Bluetooth® to his/her smartphone.

10.1 Communication and Connectivity

This area is covered by the following common standards.

SDO	Standards	Description	Analysis
ANT+	ANT/ANT+ Protocol	ANT/ANT+ is a protocol and a silicon solution for ultra-low power practical wireless networking applications.	ANT+ facilate interoperability betweeen ANT+ Allicance member devices and the collection, automatic transfer and tracking of sensor data. Its finds applications in sport, wellness manadement and home health monitoring. ANT+ defines device profiles that specify data formats, channels parameters and network keys.

SDO	Standards	Description	Analysis
ETSI	ETSI TS 103 325 "SmartBAN Low Complexity MAC" ETSI TS 103 326 "SmartBAN Enhanced Ultra-Low Power PHY" ETSI TS 103 378 "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model"	ETSI SmartBAN TC develops standards for body area networks (BAN). BAN technology is the use of small, low power wireless devices wich can be carried or embedded inside or on the body.	ETSI TS 103 325 specifies low complexity MAC for SmartBAN. It applies to short range, wirekless communication between wearable sensors devices and the hub coordinator. The document specifies a MAC protocol designed in order to ease the spectrum sharing with other devices (channel structure, MAC frame formats, MAC functions). ETSI TS 103 326 specifies the ultra-low power physical layer for transmetting on the medium in SmartBAN (packet formats, modulation, FEC). ETSI TS 103 378 objectives are to specify, formalize and standardize Smart BAN unified data/entities representation formats, semantic open data model and corresponding modular ontology (service level and semantic interoperability included).
IEEE	IEEE 802.15.6 (WBAN)	IEEE 802.15.6 is an international standard for wireless body area networks (WBAN). It is aimed for low power, short range and reliable wireless communications. It uses existing ISM bands as well as frequency bands approved by national medical and/or regulatory authorities.	This standard includes support for quality of service, extremely low power and data rates up to 10 Mbps. The standard considers effects on portable antennas and thus proposes techniques to minimize the specific absorption rate.
IEEE	RuBee 1902.1	RuBee is a wireless data communications protocol operating the low frequency radio wave range of 30 - 900 kHz. It is very resistant to interferences but offers very low data rate and for a very short range.	It is considered as an alternative for IEEE 802.15.4 (ZigBee® & 6lowpan) for certain applications such as in high security facilities.

10.2 Integration/Interoperability

This area is covered by the following common standards.

SDO	Standards	Description	Analysis
ETSI	ETSI TR 103 327 "Smart Body Area Networks (SmartBAN); Service and application standardized enablers and interfaces, APIs and infrastructure for interoperability management" ETSI TS 103 378 "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model"	ETSI TC SmartBAN 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.)	TC SmartBAN's scope includes in particular infrastructure mechanisms, open semantic data model and associated modular ontology providing solutions for interoperability management in Smart BANs. It covers the networking and communication level up to the service and application level. The expected solutions mainly concern the description and the specification of a standardized infrastructure for Smart BAN entities, interactions/interworking and data access, irrespective of whatever lower layers and radio technologies are used. On the service and application side, standardized APIs for secure interaction and access to SmartBAN data/entities (data management mechanisms, semantic discovery of devices/data).

10.3 IoT Architecture

This area is covered by the following common standards:

SDO	Standards	Description	Analysis
ISO/IEEE PHD	ISO/IEEE 11073™ family of standards for Point-of-care medical device communication	Covered under 8.5	Covered under 8.5

10.4 Security and Privacy

There are no specific security requirements here all generic security requirements in clause 6.7 apply.

10.5 Summary of Smart Wearables Standards Landscape

These clauses haves presented the degree of industry and vertical fragmentation for Smart Wearables based on some of the standards identified above. The list indicates a snap shot of the standards that are available to support Smart Wearables. Many SDOs are focused in this area and actively working on creating standards that are able to support Smart Wearables but are fragmented.

11 Smart Mobility Standards Landscape

11.0 Introduction

In its "white paper on transport" [i.5] published in March 2011, the European Commission defined ten goals for a competitive and resource-efficient transport system.

Part of the goals involved increasing the efficiency of transport and of infrastructure usage by benefiting from the information systems. Indeed, the transport vertical domain is experiencing a major evolution due to its encounter with the digital technologies. Initiatives like the cooperative Intelligent Transport Systems, the electronic tolling, the eCall which raises an alert automatically in case of accident or the Smart Tachograph will enhance the traveller's experience and safety on the roads. The Smart Mobility report from AIOTI WG09 [i.7] describes these new technologies and their requirements.

The next clauses cover the Smart Mobility aspects of the IoT standardization. They identify the main SDOs and alliances which consider application of IoT and device communications in the mobility domain.

11.1 Communication and Connectivity

SDO	Standards	Description	Analysis
3GPP V2X	TR 36.885 (RAN Study on LTE-based V2X Services)	The Radio Access Network (RAN) Group is working on TR 36.885, to evaluate performance of LTE for V2X communication and identify changes to LTE physical layer, RAN protocols, and interfaces to support V2X communications (started early 2016).	ftp://ftp.3gpp.org/Specs/archive/36_series.
CiA	ISO 11898 series	CAN is a multi-master serial bus system with multi-drop capabilities. The CAN messages are broadcasted on the bus. Originally developed for use as an in-vehicle network in passenger cars (CAN bus), CAN is now used in many other industries.	The original (or Classical CAN) data link layer protocol has been standardized in the ISO 11898 series. More recently, it has been improved as the CAN FD (Flexible Data Rate) protocol, defined in the same document (ISO 11898-1). The standards also describe several physical layer options. Most common is the high-speed transmission as standardized in ISO 11898-2. The other physical layer standard used in the automotive industry is ISO 11898-3, a so-called fault-tolerant, low-power transmission.

SDO	Standards	Description	Analysis
CEN/ISO	EN ISO 17575 Electronic fee collection - Application interface definition for autonomous systems EN ISO 12855 Electronic fee collection - Information exchange between service provision and toll charging ISO/TS 18750 Intelligent transport systems - Cooperative systems - Definition of a global concept for Local Dynamic Maps ISO 29281 Intelligent transport systems - Communications access for land mobiles (CALM) - Non-IP networking CEN/TS 16157 Intelligent transport systems - DATEX II data exchange specifications for traffic management and information	CEN TC 278 is responsible for standardization in the field of telematics for traffic and road transport. Through joint working groups, TC 278 is working closely with the ISO TC 204 committee, responsible for developing standards in the same field of action. CEN standards are also often ISO standards.	A large set of standards is being produced, dealing specifically with issues relating to the identification of applications and services, C-ITS, embedded HMI, traffic management, tolling or eCall. http://standards.cen.eu/dyn/www/f?p=204:7:0:::FSP_ORG_ID:6259&cs=1EA16FFFE1883E02CD366E9E7EADFA6F7. http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=54706&published=on&wikipedi=true.
ETSI ERM	ETSI EN 302 571 (Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band) ETSI EN 300-674-2 (Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s/250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band; [-1] Road Side Units (RSU)/[-2] On-Board Units (OBU) ETSI EN 302 858/ETSI ETSI EN 303 396/ETSI EN 301 091 (vehicular radars) ETSI EN 302 065/ETSI EN 303 883 (SRD Devices using UWB)	TG37 provides and manages ETSI deliverables for radio-related ITS matters. TG SRR covers the field of automotive and surveillance radar applications. TGUWB (Ultra Wide Band) covers Short Range Devices (SRD) using broadband air interfaces and systems using Ultra Wide Band (UWB) technologies for communications purposes, sensor applications and networks.	These European norms (EN) contain the Harmonised Standards covering the essential requirements of article 3.2 of the Directive 2014/53/EU (also called RE-D, Radio Equipment Directive) http://www.etsi.org.
ETSI ITS	ETSI TR 101 607 (Cooperative ITS (C-ITS); Release 1) ETSI EN 302 663 (Access layer specification for ITS operating in the 5 GHz frequency band) ETSI EN 302 636 Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking	ETSI TR 101 607 lists standards, specifications and other deliverables which have been developed to form a consistent set of standards as the basis for the Release 1 of ITS, including standards for interoperability developed in accordance with the work plan of the Mandate M/453.	ETSI EN 302 663 defines the parameters and frequencies to be applied in Europe when using IEEE 802.11-2012/802.11p. The access technology defined is called ITS-G5. ETSI EN 302 636 is a series of European norms that specify the GeoNetworking protocols for dissemination of messages over geographical areas. http://www.etsi.org.
IEEE 802 LAN/MAN	IEEE 802.11-2012 (WLAN, amendment 802.11p, integrated in 2012)	See IEEE 802 LAN/MAN in clause 7.1.	This amendment (well-known as 802.11p amendment), integrated in the main standard in 2012, contains an adaptation for V2V communications, i.e. communication outside the context of a BSS.

SDO	Standards	Description	Analysis
IEEE P1609	IEEE 1609.3: WAVE - Networking Services IEEE 1609.4: WAVE - Multi-channel Operation IEEE 1609.11: WAVE - Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)	See IEEE standards association in IEEE 802 LAN/MAN in clause 7.1.	IEEE P1609 is a suite of "standards for Wireless Access in Vehicular Environments (WAVE)". They define architecture and a complementary, standardised set of services and interfaces that collectively enable secure vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications. https://standards.ieee.org/develop/wg/1609_WG.html.
IETF ITS	charter document for IETF95	The IETF ITS group is expected to meet for its first official meeting at IETF95 in April 2016.	According to its draft charter, the goal of this group is to standardize IP protocols for establishing direct and secure connectivity between nearby moving networks. As many protocols are being developed at link layer level, the objective is to establish IP paths across them in an interoperable manner. The envisioned scenarios are C-ACC (Cooperative Adaptive Cruise Control) and platooning (or vehicle streams).
ITU-R	Agenda Item (AI 1.12)	During the WRC15 the APT (Asian Pacific Telecommunity) has proposed a new Agenda Item (AI1.12) for the upcoming WRC-19 to investigate the potential of a harmonization of the ITS spectrum world-wide.	.
SAE	J2735_201601: DSRC (Dedicated Short Range Communications) Message Set Dictionary™		J2735 specifies a message set, and its data frames and data elements, specifically for use by applications intended to utilize the 5,9 GHz DSRC/WAVE (cf. IEEE P1609) communications systems.

11.2 Integration/Interoperability

SDO	Standards	Description	Analysis
3GPP V2X	TR 22.885 (Study on LTE Support for Vehicle to Everything (V2X) Services); TS 22.185 (Service requirements for V2X services; Stage 1); TR 22.891 (3GPP; Technical Specification Group Services and System Aspects; Feasibility Study on New Services and Markets Technology Enablers; Stage 1) for Smarter.	3GPP has recently started working on C-ITS for LTE-Advanced and 5G (known as Smarter).	These documents identify the main use cases where LTE could be used for V2X scenarios and the corresponding requirements. ftp://ftp.3gpp.org/Specs/archive/22_series.
ACEA	Scientific Advisory Group reports.	The Scientific Advisory Group reports are published regularly.	They cover topics such as Driving Innovation, eCall, Electric Vehicles, Infrastructure, Intelligent Transport Systems, Urban Logistics, Urban Transport Policy, Weights and Dimensions. http://www.acea.be/publications

SDO	Standards	Description	Analysis
AVNU Alliance®	Profile for automotive use and certification tests from the automotive Certification Test Subgroup (CDS). Related standards: IEEE 802.1 Audio Video Bridging (AVB); IEEE 1722 AVB Transport Protocol (AVBTP); IEEE 1733 Layer 3 Transport Protocol for Time-Sensitive Applications in Local Area Networks.	The AVNU Alliance is an industry forum dedicated to the advancement of professional-quality audio video transport by promoting the adoption of the IEEE 802.1 Audio Video Bridging (AVB), and the related IEEE 1722 and IEEE 1733, standards over various networking link-layers.	The AVNU Alliance enables deterministic networking via certification of compliance and interoperability for devices using open IEEE standards. The AVNU certification program ensures interoperability of networked devices in a broad range of applications including professional AV, automotive, industrial control and consumer. A fully networked car according to AVNU alliance allows access to all sensors and cross-domain communication. http://avnu.org/automotive/
C2C-CC	C2C Profile.	The C2C-CC plays an important role in the development of European standards for C-ITS and helps validate the systems by getting involved in FOTS and interoperability testing.	The C2C-CC European profile specifies the standards profile that have to be used by C-ITS vehicles to enable interoperability. It contains a system specification complemented by a selection of standards and parameters. It allows to test the aspects that are going to be used by day 1 applications.
CCC	MirrorLink® includes a certification process for - Devices communication protocol implementation, interoperability with complementary MirrorLink-enabled device or system. - Applications: Testing program to validate the API usage, industry guidelines for user interfaces.	CCC member companies have created MirrorLink, a standard technology for drivers to connect their smartphones to their vehicles.	CCC publishes specifications for exchange of data between car and smartphones and for applications certification. http://www.mirrorlink.com/
CEN/ISO	EN 16454 Intelligent transport systems - Esafety - Ecall end to end conformance testing CEN ISO/TS 14907 Electronic fee collection - Test procedures for user and fixed equipment EN 15509 Electronic fee collection - Interoperability application profile for DSRC.		A large set of standards is being produced. These standards focus on testing and interoperability. http://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:6259&cs=1EA16FFFE1883E02CD366E9E7EADFA6F7. http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=54706&published=on&wikipedi=true.
CLEPA	CLEPA position on Road Safety Automated Driving CLEPA Position Paper Open Telematics Platform.	CLEPA represents the automotive supply industry in Europe.	CLEPA publishes regularly position papers on topics related to its members activities. http://clepa.eu/what-we-do/publications/.

SDO	Standards	Description	Analysis
ERTICO	Platforms coordination: • navigation/digital maps linked to Advanced Driver Assistance Systems (ADASIS) • eMobility ICT Interoperability Innovation (eMI3) • Traffic and Traveller Information (TISA) • Traffic Management 2.0 (TM 2.0) • Transport Network ITS Spatial Data (TN-ITS)		ERTICO Platforms are focused on deployment of different services. http://ertico.com/projects-categories/platforms/.
ETSI ITS	ETSI EG 202 798 - Intelligent Transport Systems (ITS); Testing; Framework for conformance and interoperability testing".		ETSI EG 202 798 provides an ITS testing framework for conformance testing and an ITS testing framework for interoperability testing. This testing framework provides guidance for development of conformance and interoperability test strategies, test systems and the resulting test specifications for ITS.
ITU-R	Recommendation ITU-R M.1890: "ITS - Guidelines & Objectives" Recommendation ITU-R M.2228: "Advanced ITS Radiocommunications" Recommendation ITU-R M.2084: "Radio interface standards of vehicle-to-vehicle and vehicle-to infrastructure communications for intelligent transport systems applications".		Recommendation ITU-R M 1890 provide general guidelines for ITS communications. Recommendation ITU-R M.2228 is a technical describing ITS systems ans applications Recommendation ITU-R M.2084 issued by Question ITU-R 205-5/5 identifies specific radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communications for Intelligent Transport System applications.
SAE	J2945: DSRC Minimum Performance Requirements (work in progress)		SAE J2945 specifies the minimum communication performance requirements of the DSRC Message sets, the associated data frames and data elements defined in SAE J2735 DSRC Message Set Dictionary. The document consists of multiple sections. Each section describes a specific message set's requirements. For example, J2945-1 represents Basic Safety Message communication minimum performance requirements.

11.3 Application

SDO	Standards	Description	Analysis
CCC	MirrorLink.		The MirrorLink specifications contain features for Device and App discovery, control and easy configuration by the user, Remote UI in the vehicles (smartphone screen replication, UPnP®, audio control). http://www.mirrorlink.com/.
CEN/ISO	ISO 24102 Intelligent transport systems; Communications access for land mobiles (CALM); ITS station management ISO 24101 Intelligent transport systems - Communications access for land mobiles (CALM) - Application management		These standards specify the management of ITS-Stations and their applications.
IEEE P1609	IEEE 1609.12: WAVE - PSID Identifier Allocations		IEEE 1609.12 defines the values allocated for WAVE application identifiers.

11.4 Infrastructure

SDO	Standards	Description	Analysis
CEN/ISO	EN 16072 Intelligent transport systems - Esafety - Pan-European eCall operating requirements EN 16062 Intelligent transport systems - Esafety - eCall high level application requirements (HLAP) using GSM/UMTS circuit switched networks.	See CEN/ISO in clause 10.1.	These standards specify the infrastructure for the eCall functionality.
ETSI TC ITS	ETSI EN 302 636 .	Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network architecture.	This standard specifies the network architecture for communication-based Intelligent Transport Systems (ITS). The network architecture is focused on, but not limited to, vehicular communication. The architecture enables a wide range of ITS applications for road safety, traffic efficiency as well as for infotainment and business.
ITU-T	.	See ITU-T in clause 7.1.	A VGP (Vehicle Gateway Platform) is being standardized by Question 27/16 in terms of telecommunications. It identifies global Vehicle Gateway standards needed to allow plug-and-play of consumer devices working in vehicles and support ubiquitous connectivity in heterogeneous environments for global, seamless services/applications using Intelligent Transportation Systems.

SDO	Standards	Description	Analysis
CEN/ISO	EN 16072 Intelligent transport systems - Esafety - Pan-European eCall operating requirements EN 16062 Intelligent transport systems - Esafety - eCall high level application requirements (HLAP) using GSM/UMTS circuit switched networks.	See CEN/ISO in clause 10.1.	These standards specify the infrastructure for the eCall functionality.
OAA	New features for Android to allow developers to add car modes to their apps.	The OAA (Open Automotive Alliance) is a global alliance of technology and auto industry manufacturers whose objective is to bringing the Android platform to cars.	With OAA enhancements, developers are able to take advantage of template based frameworks which provide app customization for the developer while also providing app familiarization for the driver to reduce distraction. http://www.openautoalliance.net
ISO	ISO 26262 Road vehicles - Functional safety	International standard for functional safety of electrical and/or electronic systems in production automobiles.	The standard ISO 26262 is an adaptation of the Functional Safety standard IEC 61508 for Automotive Electric/Electronic Systems. ISO 26262 defines functional safety for automotive equipment applicable throughout the lifecycle of all automotive electronic and electrical safety-related systems. ISO 26262 is a risk-based safety standard, where the risk of hazardous operational situations is qualitatively assessed and safety measures are defined to avoid or control systematic failures and to detect or control random hardware failures, or mitigate their effects. It is intended to be applied to electrical and/or electronic systems installed in "series production passenger cars" with a maximum gross weight of 3 500 kg. It aims to address possible hazards caused by the malfunctioning behaviour of electronic and electrical systems.

11.5 IoT Architecture

SDO	Standards	Description	Analysis
3GPP V2X	TR 23.785 (Study on architecture enhancements for LTE support of V2X services) ETSI TS 123 246 (Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description).	See 3GPP in clause 6.1 and clause 7.1.	The objective of TR 23.785 (under progress) is to study the required enhancements to existing 3GPP architecture and functionalities to support V2X. ETSI TS 123 246 specifies the 3GPP architecture for broadcasting. This is one of the main technologies to be used for Infrastructure-to-Vehicle (I2V) communications. ftp://ftp.3gpp.org/Specs/archive/23_series.
CEN/ISO	ISO 21217 Intelligent transport systems - Communications access for land mobiles (CALM) - Architecture	See CEN/ISO in clause 10.1.	This standard specifies the architecture of the ITS Station. It has been harmonized with ETSI EN 302 665.
ETSI ITS	ETSI EN 302 665	See ETSI ITS in clause 10.1.	ETSI EN 302 665 specifies the architecture of ITS stations in C-ITS supporting a variety of existing and new access technologies and ITS applications. This architecture considers a diverse set of terminals to accommodate the ITS-S: handheld devices, cars, trucks, public vehicles such as buses, but also the traffic lights, VMS or monitoring centers traffic. Mobile ITS-S are housed in mobile devices, typically smartphones or navigators, or in vehicles. The ITS-S infrastructure is divided between roadside ITS-S and central ITS-S, e.g. at traffic management locations. www.etsi.org.
IEEE P1609	IEEE 1609.0: WAVE - Architecture	See IEEE P1609 in clause 10.1.	IEEE 1609.0 defines the architecture of the WAVE protocol stack and its integration with other protocols from IEEE LAN/MAN and SAE.
oneM2M	ETSI TR 118 526 (Vehicular Domain Enablement)	See oneM2M in clause 6.2 and clause 7.2.	This Technical Report examines how the current oneM2M System can be used in the Vehicular Domain and includes a study of advanced features which the future oneM2M release(s) could support for this vertical domain.

11.6 Devices and Sensor Technology

SDO	Standards	Description	Analysis
ETSI TC SES	ETSI TS 103 246 - Satellite Earth Stations and Systems (SES) - GNSS based location systems.	ETSI TS 103 246 describes the functional requirements applicable to location systems, based on a synthesis of types of applications relying on location-related data. It provides a generic architecture for GNSS-based location systems (GBLS) that combine GNSS and other navigation technologies with telecommunication networks for delivery of location-based services. It covers the Performance Features for the data provided by the GBLS as well as location data exchange protocols and laboratory tests based on constellation simulators for assessing performances of GBLS.	Positioning is an important topic for smart mobility. www.etsi.org.
IEC	IEC 62196: Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles	The objective of IEC TC 23 (Electrical accessories) SC 23H (Plugs, Socket-outlets and Couplers for industrial and similar applications, and for Electric Vehicles) is to prepare standards for connection products intended for the connection of electric vehicles to the supply network and/or to dedicated supply equipment.	This family of standards specifies the plugs and sockets for the charging of electrical vehicles.

11.7 Security and Privacy

SDO	Standards	Description	Analysis
3GPP V2X	TR 33.885	Study on Security Aspect for LTE support of V2X Services.	3GPP SA3 has identified three key issues to resolve and some resulting requirements for the security in 3GPP support of V2X: V2X communication security, Authorization for LTE-V2X radio resources, V2X Entities secure environment ftp://ftp.3gpp.org/Specs/archive/33_series.
CEN/ISO	ISO/TR 12859 ISO/TS 19299	ISO/TR 12859 Intelligent transport systems - System architecture - Privacy aspects in ITS standards and systems ISO/TS 19299 Electronic fee collection - Security framework.	These standards tackle the security and privacy issues.
ETSI ITS	ETSI TS 102 940	ETSI TS 102 940 specifies a security architecture for C-ITS communications.	It identifies the functional entities required to support security in an ITS environment and the relationships that exist between the entities themselves and the elements of the ITS reference architecture defined in ETSI EN 302 665. It also identifies the roles and locations of a range of security services for the protection of transmitted information and the management of essential security parameters. These include identifier and certificate management, PKI processes and interfaces as well as basic policies and guidelines for trust establishment.
IEEE P1609	IEEE 1609.2-2013: WAVE - Security Services for Applications and Management Message.	IEEE Standard for Wireless Access in Vehicular Environments Security Services for Applications and Management Messages.	This standard defines secure message formats and processing for use by Wireless Access in Vehicular Environments (WAVE) devices, including methods to secure WAVE management messages and methods to secure application messages. It also describes administrative functions necessary to support the core security functions.

11.8 Summary of Smart Mobility Standards Landscape

This clause has presented the main initiatives in the Smart Mobility domain. This domain has adopted separate technologies according to the region of the world where the technology will be deployed: Europe, North America and International. However, international harmonization is an active topic, and even though different, the duplicate standards present a high level of similarities, at least from architecture and data definition point of views. In the Smart Mobility domain as well, the work has focused on communication technologies, integration and interoperability and system architecture. At the contrary of other domains, the systems considered are considering mainly devices which communicate at a peer to peer level, so the standardization of the infrastructure is less developed. The major part of the devices is installed at manufacturing, so the device management is less a challenge that in other domains such as Smart Cities or Smart Homes.

12 Smart Environment Standards Landscape

12.0 Introduction

There are two folds to Smart Environment on one hand it can be described in its relation to nature such as Smart Water or Smart Energy on the other hand it also relates to physical space which has its relevance to computing and therefore connected devices within that space. The global dictionary describes this aspect of Smart Environment as interaction of different devices and computing systems (http://www.igi-global.com/dictionary/smart-environment/27178).

These clauses of the present document will consider both aspects of Smart Environment as interaction of connected devices IoT and this is an enabler for Smart Water or Smart Energy. The standards for connected devices already apply to most of the work covered in Smart City, Smart Living and Smart Wearables hence most of the standards identified in those sections also apply here.

The rest of these clauses will focus on the Smart Energy aspect particularly Smart Water/Energy.

The AIOTI WG 10 in presenting its study on Smart Environment specifically mentioned Smart Water. Water is used to produce energy; energy is needed to provide water. Both water and energy are needed to grow food crops; crops can in turn be used to provide energy through biofuels. Similarly, desalination and treating waste water requires tremendous amount of energy which in turn implies using a lot of water in the process for the power that is needed. Both water and energy use can have adverse impact on the ecosystems. Climate change will affect the availability and use of both energy and water. Supplies of water and energy are thus interdependent ITU-T has carried out a study on this topic and looked at the effect of ICT on Water and Energy as well as the effect of climate change on both, (ITU-T Smart Water Report [i.10]).

NOTE: Most of the standards relating to energy is already covered in SEG-CG (Smart Energy Grid-Coordination Group).

12.1 Communication and Connectivity

12.1.1 Smart Space

The standards in this area can be found in the common clause 6.1. additional standards are found below.

SDO	Standards	Description	Analysis
ITU-T	G.hnem (Home NetworkingAspects for Energy management)	The standard defines low complexity home networking devices for home automation, home control, electrical vehicles, and SmartGrid applications.	G.hnem is an enabler for SmartGrid applications. It includes: Utility-based demand response programs via broadband internet communications or AMI systems, remote troubleshooting, support for real-time demand response, and flexible control of appliances.
CEN	EN 13757 (M-Bus)	EN 13757 is a standard for the data transmission between smart meters and data concentrators.	The specification specifies how the data from the meters is to be transmitted from the meter to the authority's back office system in a secure manner.

SDO	Standards	Description	Analysis
ISO/IEC JTC1	SWG7 Sensor Networks IEC 29182, IEC 62591,	IEC 29182: Sensor network, architecture, application interfaces. IEC 62591 (WirelessHART): wireless sensor networking technology based on the Highway Addressable Remote Transducer protocol (HART).	ISO 29182 defines the reference architecture of a sensor network (SN). Through its different parts, it provides general overview of an SN, a reference architecture, entity models, interface definitions, applications profiles and interoperability guidelines. art. 5 (ISO/IEC 29182-5) provides the interface definitions between the SN entities. WirelessHART is a multi-vendor, interoperable wireless standard. It uses a time synchronized, self-organizing, and self-healing mesh architecture. It supports operation in the 2,4 GHz ISM Band.

12.1.2 Smart Water/Energy

There are no specific communication and connectivity requirements for Smart Water/Energy all are covered in generic clause.

12.2 Integration/Interoperability

12.2.1 Smart Space

This area is covered by the following common standards.

SDO	Standards	Description	Analysis
ITU-T SG16	F.744	Ubiquitous sensor network middleware, applications, identification	F.774 provides Service description and requirements for ubiquitous sensor network middleware.
ISO/IEC	ISO/IEC 29182-7	Sensor Network Reference Architecture (SNRA) - Part 7: Interoperability guidelines	The ISO/IEC 29182-7 standard provides an overview and guidelines for interoperability for heterogeneous sensor networks.

12.3 Application

12.3.1 Smart Space

This area is covered by the following common standards.

SDO	Standards	Description	Analysis
ISO/IEC	ISO/IEC 30128	Generic Sensor Network Application Interface	This International Standard covers: description of generic sensor network applications' operational requirements, description of sensor network capabilities, and mandatory and optional interfaces between the applications.

12.3.2 Smart Water/Energy

There are no specific requirements identified here all are covered in generic clause.

12.4 IoT Architecture

12.4.1 Smart Water/Energy

SDO	Standards	Description	Analysis
Zigbee®	ZigBee® Smart Energy version 1.1. The latest version for product development, adds several important features including dynamic pricing enhancements, tunnelling of other protocols, prepayment features, over-the-air updates.	All ZigBee® Smart Energy products are ZigBee® Certified to perform regardless of manufacturer, allowing utilities and consumers to purchase with confidence. Every product needed to implement a robust ZigBee® Smart Energy home area network (HAN) is available. These products make it easy for utilities and governments to deploy smart grid solutions that are secure, easy to install and consumer-friendly.	http://www.zigbee.org/zigbee-for-developers/applicationstandards/zigbeesmartenergy/.
IEC	IEC 62056-1-0:2014 Smart metering standardisation framework. IEC 62056-3-1:2013 Use of local area networks on twisted pair with carrier signalling. IEC 62056-5-3:2013 DLMS/COSEM application layer. IEC 62056-6-1:2013 Object Identification System (OBIS) IEC 62056-6-2:2013 COSEM interface classes. IEC 62056-7-6:2013 The 3-layer, connection-oriented HDLC based communication profile. IEC 62056-8-3:2013 Communication profile for PLC S-FSK neighbourhood networks. IEC 62056-9-7:2013 Communication profile for TCP-UDP/IP networks.	IEC 62056 is a set of standards for Electricity metering data exchange. The IEC 62056 standards are the International Standard versions of the DLMS/COSEM specification for Smart Meters.	https://en.wikipedia.org/wiki/IEC_62056.
CEN/CLC/ ETSI	CEN/CLC/ETSI/TR 50572: Functional reference architecture for communications in smart metering systems	TR 50572 concerns the following communications deliverable within M/441: A European standard comprising a software and hardware open architecture for utility meters that supports secure bidirectional communication upstream and downstream through standardized interfaces and data exchange formats and allows advanced information and management and control systems for consumers and service suppliers.	ftp://ftp.cen.eu/cen/Sectors/List/Measurement/Smartmeters/CENCLCETSI_TR50572.pdf.

SDO	Standards	Description	Analysis
OGC (Open Geospatial Consotium)	WaterML 2.0 is a standard information model for the representation of water observations data, with the intent of allowing the exchange of such data sets across information systems. Through the use of existing OGC standards.	It aims at being an interoperable exchange format that may be re-used to address a range of exchange requirements.	http://www.opengeospatial.org/standards/waterml.
ISO 50001	Energy Management System: ISO 50001:2011 provides a framework of requirements for organizations to: Develop a policy for more efficient use of energy. Fix targets and objectives to meet the policy. Use data to better understand and make decisions about energy use. Measure the results. Review how well the policy works, and Continually improve energy management.	This International Standard specifies requirements applicable to energy use and consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance. It applies to all variables affecting energy performance that can be monitored and influenced by the organization. This International Standard does not prescribe specific performance criteria with respect to energy.	http://www.iso.org/iso/home/standards/management-standards/iso50001.htm.

12.5 Devices and Sensor Technology

12.5.1 Smart Water/Energy

SDO	Standards	Description	Analysis
PSA	Protocol Standards Association WITS-DNP3 Protocol. Water Industry Telemetry Standards (WITS) - Distributed Network Protocol (DNP) WITS provide the following solution: Reduces configuration errors due to machine readable outstation capabilities files - only allows configuration of features and parameters that are actually supported by the outstation Version control of outstation configuration and application programs Connection management; Callback testing, fallback paths for different media, e.g. Serial, Ethernet, GPRS, PSTN/GSM, etc.	The WITS protocol is an extension of the generic DNP3 protocol. It describes methods and structures that build on DNP3 to provide interoperability between different vendors equipment, with all the benefits that brings to the Water Industry.	http://www.witsprotocol.org/

12.6 Security and Privacy

There are no specific security and privacy requirements for Smart Energy requirement identified on the energy aspects relate to Smart Grid studies (Editor's note: include reference to smart Grid standards).

12.7 Summary of Smart Environment Standards Landscape

These clauses have presented the degree of industry and vertical fragmentation for Smart Environment based on some of that standards identified above.

For the Smart Water/Smart Energy aspects, the list indicates a snap shot of the standards that are available. Many SDOs are focused in this area and actively working on creating standards. Many of these standards are from the Smart Grid or the WSN standardisation communities resulting in a high fragmented standards landscape.

13 Smart Manufacturing Standards Landscape

13.0 Introduction

Smart Manufacturing is an evolution of the current manufacturing systems that intends to make a massive usage of some emerging information and communication technologies such as Big Data, Cloud Computing or Cybersecurity, in order to improve their effectiveness and their agility. The application of the Internet of Things to industrial processes will happen at all levels of the "manufacturing pyramid" (as defined in ISA-95 [i.3]), from the device level up to the enterprise level. The optimization of the data flows between manufacturing (sub-) systems is going to be a key success factor with a particular importance of the "Integration/Interoperability" and "Infrastructure" Knowledge Areas (KA - as defined by the AIOTI). In support of this new approach, a number of existing standards and Reference Architectures are already available.

The next clauses cover the Smart Manufacturing aspects of the IoT standardization and identify the main SDOs and alliances that consider the application of IoT and device communications in the manufacturing domain.

13.1 Communication and Connectivity

SDO	Standards	Description	Analysis
Automation ML E.V.	AutomationML	The goal of AutomationML is to standardize data exchange in the engineering process of production systems.	The AutomationML initiative is an open consortium dedicated to the promotion and development of AutomationML. All parts of AutomationML are going to be standardized internationally within IEC 62714.
CiA	ISO 11898 series	The aim of the CiA (CAN) in Automation) international group is to provide a platform for future developments of the CAN (Controller Area Network) protocol and to promote the image of CAN.	CAN is a multi-master serial bus system with multi-drop capabilities. Originally developed for use as an in-vehicle network in passenger cars (CAN bus), CAN is now used in many other industries. The original (or Classical CAN) data link layer protocol has been standardized in the ISO 11898 series. More recently, it has been improved as the CAN FD (Flexible Data Rate) protocol, defined in ISO 11898-1. CAN is a basis on which other higher-level protocols, such as ODVA's DeviceNet™, are defined.

SDO	Standards	Description	Analysis
IEC	IEC 61131 IO-Link (IEC 61131-9)	EC 61131 is an IEC standard for programmable controllers.	IEC 61131-9, also known as "IO-Link", is a fieldbus independent and manufacturer independent communication standard and can be integrated into any existing fieldbus via a corresponding interface.
IEC	IEC 61158	IEC 61158 is the standard for Fieldbus, a family of industrial computer network protocols used for real-time distributed control.	Fieldbus is a way to connect instruments in a manufacturing plant. It works on a network structure which allows a variety of network topologies.
IEC	IEC 61360	IEC 61360 - Common Data Dictionary (CDD) is a common repository of concepts for all domains based on the methodology and the information model of IEC 61360 series.	It provides an unambiguous identification of classes and properties, a commonly approved terminology, a hierarchy of concepts.
IEC	IEC PAS 62030	IEC PAS 62030 is a Publicly Available Specification for Modbus, a standard providing serial communication protocol for industrial devices.	Modbus comes with as a real-time industrial Ethernet suite, including the RTPS (Real-Time Publish-Subscribe) protocol.
IEC	IEC 62541	IEC 62541 is a standard for OPC Unified Architecture.	OPC UA is developed by the OPC Foundation (see below).
IEC	IEC 62656-1	IEC 62656-1 specifies the logical structure for a set of spreadsheets, used as "data parcels", to define, transfer and register product ontologies.	This standards addresses an improvement of the management of the IEC Common Information Model (CIM).
ISA	ANSI/ISA-95	ISA-95 is an international standard from the International Society of Automation (ISA) for developing an automated interface between enterprise and control systems.	This standard has been developed for global manufacturers. It was developed to be applied in all industries, and in all sorts of processes, like batch processes, continuous and repetitive processes. There are 5 parts of the ISA-95 standard.
ISO/IEC	ISO/IEC 14443	It is an international standard that defines identification cards, contactless integrated circuit cards and proximity cards used for identification, and the associated transmission protocols.	Implementations of the standard include Near Field Communication (NFC).
ISO/IEC	ISO/IEC 15459	It is a series of standards that address Automatic Identification and Data Capture (AIDC) techniques.	ISO/IEC 15459-1:2014 specifies a unique string of characters for the identification of individual transport units.
ISO/IEC	ISO/IEC FDIS 29161	It is an information technology standards for the Unique identification for the Internet of Things.	It is under development.
ISO/IEC	ISO/IEC 62264	Same as ANSI/ISA-95.	
MESA	B2MML®	B2MML is an XML implementation of the ANSI/ISA-95, Enterprise-Control System Integration, family of standards (ISA-95), known internationally as IEC/ISO 62264.	B2MML consists of a set of XML schemas written using the World Wide Web Consortium's XML Schema language (XSD) that implement the data models in the ISA-95 standard.

SDO	Standards	Description	Analysis
OAGi	OAGIS OAG Integration Specification	OAGIS defines a common content model and common messages for communication between business applications. This includes application-to-application (A2A) and business-to-business (B2B) integration.	The OAGIS standard covers data exchange requirements for business systems and applications, including manufacturing and operations management systems.
ODVA	DeviceNet	DeviceNet™ is a digital, multi-drop network that connects and serves as a communication network between industrial controllers and I/O devices, providing users with a network to distribute and manage simple devices throughout the architecture.	DeviceNet utilizes CAN (Controller Area Network) for its data link layer.
	EtherNet/IP	EtherNet/IP™ provides users with the network tools to deploy standard Ethernet technology (IEEE 802.3 combined with the TCP/IP Suite) for industrial automation applications while enabling Internet and enterprise connectivity.	EtherNet/IP offers various topology options. Through its reliance on standard Internet and Ethernet standards, EtherNet/IP is an industrial Ethernet network that is ready for the Industrial Internet of Things.
	CIP	The Common Industrial Protocol CIP) is a comprehensive suite of messages and services for industrial automation applications. CIP allows users to integrate these applications with enterprise-level Ethernet networks and the Internet.	CIP addresses a large variety of industrial automation applications: control, safety, energy, synchronization & motion, information and network management.
OPC Foundation	OPC UA	The OPC Unified Architecture (UA) is a platform independent service-oriented architecture that integrates all the functionality of the initial OPC (OLE for Process Control) specifications into one vendor neutral framework.	On top of expanding the OPC Classic capabilities, OPC UA addresses platform independence (hardware and OS), security and extensibility (in particular regarding information modelling).
SERCOS	SERCOS III	Sercos III is the third generation of the Sercos interface, a globally standardized open digital interface for the communication between industrial controls, motion devices, input/output devices (I/O), and Standard Ethernet nodes.	Sercos III merges the hard real-time aspects of the Sercos interface with Ethernet. All of the functionality required to configure a Sercos III interface is contained in a stack that is available in both "hard" and "soft" versions.

13.2 Integration/Interoperability

SDO	Standards	Description	Analysis
AVNU Alliance		The AVnu Alliance enables deterministic networking via certification of compliance and interoperability for devices using open IEEE standards.	The AVnu certification program ensures interoperability of networked devices in a broad range of applications including industrial control.
SERCOS International	SERCOS	sercos International e.V. supports a Conformance Laboratory at the University of Stuttgart.	Products successfully passing conformance testing may display a label, and are integrated in an index of certified devices.

13.3 Application

SDO	Standards	Description	Analysis
IEC	IEC 61131-3	IEC 61131-3 is the third part of the IEC 61131 standard for programmable logic controllers.	Part 3 of IEC 61131 deals with programming languages and defines two graphical and two textual PLC programming language standards.

13.4 Infrastructure

SDO	Standards	Description	Analysis
IEC	IEC 62061 Safety of machinery: Functional safety of electrical, electronic and programmable electronic control systems.	IEC 62061 is the machinery specific implementation of IEC/EN 61508. It provides requirements that are applicable to the system level design of all types of machinery safety-related electrical control systems and also for the design of non-complex subsystems or devices.	The standard is concerned with functional safety requirements intended to reduce the risk of injury or damage to the health of persons in the immediate vicinity of the machine and those directly involved in the use of the machine.

13.5 IoT Architecture

A number of "generic" - non "vertical specific" - IoT architectures are gathered in clause 6.4, most of them applying to Smart Manufacturing. On top of this, some IoT Architectures specific to Smart Manufacturing are listed in the table below.

SDO	Standards	Description	Analysis
DIN	DIN 91345 RAMI 4.0	RAMI4.0 (Reference Architecture Model for Industrie 4.0) consists of a three-dimensional system that describes all crucial aspects of Industrie 4.0.	RAMI4.0 is allowing complex interrelations to be broken down into smaller and simpler clusters. The three dimensions of the model are: layers (from asset to business); hierarchy levels (from Product to Connected World) and Life-cycle and Value Stream (IEC 62890).
IEC	IEC 62832	IEC 62832 is a Reference model for the representation of production facilities, also know as Digital Factory.	It provides description models for the inclusion of factory assets in the Digital Factory Repository that will support exchange of information with tools such as Modelling, Monitoring, Planning, etc.

13.6 Security and Privacy

Most of the security and privacy standards that apply to Smart Manufacturing are also applicable to other vertical domains and can be found in clause 6.7 addressing the "generic" standards for Security and Privacy.

However, the issues of security and privacy are considered as key within the Smart Manufacturing community and some new initiatives may provide specific results in the near future.

SDO	Standards	Description	Analysis
IEC	IEC 62443	IEC-62443 (formerly ANSI/ISA-99) is the set of standards; technical reports and other information that defines procedures for implementing electronically secure Industrial Automation and Control Systems (IACS).	IEC 62433 is organized in 4 groups: General (concepts, models, terminology); Policy and Procedures, under review to better align with ISO 27000; System Integrator addressing suitable technologies and security assurance levels; Component Provider addressing requirements for IACS secure IACS components. The ISA Security Compliance Institute (ISCI) operates the first conformity assessment scheme for IEC 62443 IACS cybersecurity standards.

13.7 Summary of Smart Manufacturing Standards Landscape

The Smart Manufacturing landscape is very broad, reflecting the complexity of the evolution of the current base of Manufacturing Systems to take into account the latest developments in Information Technologies and IoT in particular. The role of standards in this new "industrial revolution" is generally recognized as central and a key to the success.

Manufacturing is relying on a very broad and diverse set of standards, spanning hierarchical levels (from the field to the business layer), enabling the communication of information between various applications domains across the life-cycle. It also reflects the geographical diversity between Europe, North America, and Asia situations.

Smart Manufacturing will start with a widespread utilization of existing mainstream standards, including their adaptation to address specific requirements (e.g. those linked to the requirement of Manufacturing Control that demand adaptation of mainstream standards like specific versions of Ethernet that address latency constraints). But the introduction of new ICT technologies will require a large effort from the standardization community that has started and will continue in the coming decade.

In particular, IoT requires taking into account a new range of devices. Though sensors and actuators are not new in this picture, the extension of the range of devices and the need for easier integration and smother interoperability requires an adaptation of the existing standards. Similarly, taking into account new deployment models such a Cloud Computing in a context of IoT based applications will require that existing standards be updated as well.

14 Conclusions and Recommendations

14.1 Applying the IoT Enterprise Framework

A proposed Enterprise view of the IoT Framework defined in clause 5 can be used by a Large Scale Pilot (LSP) to conceptualise their pilot study. In this clause it was suggested that the Standards Information Database (SIB) will house the standards landscape which is the focus of the present document.

The proposal of how this framework would be useful will be for example to think of an LSP provider that has a vision of the IoT domain it wants to operate in. This LSP will choose its Architecture based on the standards that are available in the SIB (i.e. information in the present document). The choice of the SIB to use will be influenced by the governance aspects such as regulation of the area of operation for example. The choice will also need to make reference to any existing model available, which will be in reference library.

The Structure of the SIB into the Knowledge areas will hopefully make this easier for the LSPs.

14.2 Proposed Recommendations

The following remarks and recommendations can be made:

1) There are many connectivity and interoperability standards and specifications that are not IoT-specific. What is missing is the choice across verticals for ***one solution*** that allows for interoperability.

2) The recommendation to the LSPs is to adopt same solutions across the verticals, at least as much as possible adopt interoperable solutions amongst the different LSPs.

3) Encourage the large SDOs/SSOs to strengthen collaboration and cooperation, and to accelerate the provisioning of necessary IoT standards and specifications that will strengthen the adoption of IoT as a major ICT platform, thus supporting the EC's objective to make the IoT available and secure. Collaboration should aim to develop new solutions rather than recreate silos or duplicate solutions. Encourage the development of education and dissemination material of IoT standards and specifications (from a strictly objective standpoint, in particular across all concerned SDOs).

4) Regularly organize "progress report" events to advertise the progress made with IoT standards, specifications and Open Source towards the IoT Service Customers (e.g. SMEs and industries) thus supporting the EC's objective to make the IoT available and secure. The IoT Large Scale Pilots (LSPs) and Coordination and Support Actions (CSA) can be a very supportive environment for this.

Annex A:
List of SDOs involved in IoT Standardization

A.1 SDOs, SSOs and IoT Standardization

This clause is recalling the notion of SDO and SSO:

- SDO: Standards Developing Organisation
- SSO: Standards Setting Organisation

In the present document, the notion of SDO includes both SDOs and SSOs.

A.2 List of SDOs

The table below will provide a summary of the SDO's and SSO involved in IoT Standardization. The list below contains a largely overlapping set of organisation between AIOTI and STF505.

Acronym	Name	Mission
3GPP	Third Generation Partnership Project	The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. The 3GPP standards are organized into four Technical Specification Groups (TSG): Radio Access Networks (RAN), Services & Systems Aspects (SA), Core Network & Terminals (CT).
ACEA	European Automobile Manufacturers Association	The European Automobile Manufacturers' Association (ACEA) represents the 15 Europe-based car, van, truck and bus manufacturers. It defines and advocates the common interests, policies and positions of the European automobile industry.
AIOTI	Alliance for IoT Innovation	The Alliance for Internet of Things Innovation (AIOTI) was initiated by the European Commission in order to develop and support the dialogue and interaction among the Internet of Things (IoT) various players in Europe. The overall goal of the AIOTI is the creation of a dynamic European IoT ecosystem to unleash the potentials of the IoT.
AllSeen Alliance		The AllSeen Alliance is a cross-industry consortium dedicated to enabling the interoperability of devices, services and apps that comprise the Internet of Things.
ANT+	ANT+ Alliance	The ANT+ Alliance is an open special interest group of companies who have adopted the ANT+ promise of _interoperability.
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	ASHRAE is a global society advancing human well-being through sustainable technology for the built environment. Its objective is to advance the arts and sciences of heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world.
AVNU	AVNU Alliance	The AVNU Alliance is a community creating an interoperable ecosystem servicing the precise timing and low latency requirements of diverse applications using open standards through certification.
BBF	Broadband Forum	The Broadband Forum is an organization driving broadband wireline solutions and empowering converged packet networks worldwide to meet the needs of vendors, service providers and their customers. The objective of BBS-BUS is to provide the broadband industry with technical specifications, implementation guides, reference implementations, test plans, and marketing white papers for the deployment, management, and consumption of services by the broadband end user.
Bluetooth	Bluetooth SIG	The Bluetooth Special Interest Group (SIG) are the curators, caretakers and innovators of *Bluetooth*® technology.

Acronym	Name	Mission
C2C-CC	Car 2 Car Communnication Consortium	The CAR 2 CAR Communication Consortium (C2C-CC) is a nonprofit, industry driven organisation dedicated to the objective of further increasing road traffic safety and efficiency by means of cooperative Intelligent Transport Systems (C-ITS) with Vehicle-to-Vehicle Communication (V2V) supported by Vehicle-to-Infrastructure Communication (V2I).
CCC	Car Connectivity Consortium	The CCC (Car Connectivity Consortium) is a non-profit organization of automakers, smartphone vendors and aftermarket car electronics providers whose objective is to provide a simple way to connect any device to any car.
CEN	Comité Européen de Normalisation	CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 33 European countries.
CiA	CAN in Automation	The aim of the CiA international group is to provide a platform for future developments of the CAN (Controller Area Network) protocol and to promote the image of CAN.
CLEPA	European Association of Automotive Suppliers	CLEPA represents the automotive supply industry in Europe.
Continua	Continua Health Alliance	The Personal Connected Health Alliance (PCHA) is a membership association formed by Continua, mHealth Summit and HIMSS to transform healthcare through personalized, interoperable connected health solutions.
DASH7™	DASH7 Alliance	The DASH7 Alliance (D7A) is a group of companies and universities managing the evolution of the Dash7 Alliance protocol.
DICOM®	Digital imaging and communications in medicine	DICOM - Digital Imaging and Communications in Medicine - is *the* international standard for medical images and related information (ISO 12052). It defines the formats for medical images that can be exchanged with the data and quality necessary for clinical use.
DIN	German Institute for Standardization	DIN is a privately organized non-profit provider of standardization services with nearly 100 years' experience. More than 32 000 external experts from industry, research, consumer protection and the public sector come together at DIN to develop market-oriented standards and specifications that promote global trade and innovations, assure efficiency and quality, and help protect the environment and society as a whole.
EnOcean	EnOcean Alliance	The EnOcean Alliance develops and promotes self-powered wireless monitoring and control systems for sustainable buildings by formalizing the interoperable wireless standard.
ERTICO	ERTICO	ERTICO - ITS Europe is a partnership of around 100 companies and institutions involved in the production of Intelligent Transport Systems (ITS). Together, ERTICO Partners conduct a range of activities to develop and deploy ITS.
ETSI	European Telecommunication Standards Institute	ETSI, the European Telecommunications Standards Institute, produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and Internet technologies.
ETSI DECT	Digital Enhanced Cordless Telecommunications	ETSI TC DECT has the overall responsibility over DECT (Digital Enhanced Cordless Telephone) and ULE (Ultra Low Energy) technologies.
ETSI ERM	ElectroMagnetic Compatibility and Radio Spectrum Matters	ETSI TC ERM is responsible to co-ordinate on ETSI positions on an adequate level of electromagnetic compatibility and an effective and efficient use of radio spectrum.
ETSI ITS	Intelligent Transport Systems	ETSI TC ITS is responsible for the development and maintenance of standards, specifications and other reports on the implementation of V2V communications and interactions in C-ITS (Cooperative ITS). Its scope extends from wireless access (excluding issues specific to the radio frequency) to generic services and corresponding applications. Security and the implementation of the tests are also discussed.
ETSI SES	Satellite Earth Stations and Systems	TC SES focuses on Satellite Earth Stations and Systems and includes the Satellite Communications and Navigation (SCN).
ETSI SmartBAN	Smart Body Area Network	The goal of the Technical Committee SmartBAN is to define a standard for low power devices and networks to be used in short range links supporting, e.g. healthcare, wellness and sport relating applications operating around a human body.
ETSI TETRA	Terrestrial Trunked RAdio	TETRA is a digital trunked mobile radio standard developed to meet the needs of traditional Professional Mobile Radio (PMR) user organisations such as Public Safety, Transportation, Utilities, etc.

Acronym	Name	Mission
(FI-PPP).	Future Internet Public-Private Partnership Programme	The Future Internet Public-Private Partnership (FI-PPP) is a European programme for Internet innovation. It is aimed at accelerating the development and adoption of Future Internet technologies in Europe, advancing the European market for smart infrastructures and increasing the effectiveness of business processes through the Internet. The technological core of the FI-PPP is called FIWARE and is built to facilitate access to services, cloud hosting, Internet of Things connection, data and context management or security.
HGI	Home Gateway Initiative	HGI publishes requirements for the hardware and software elements for broadband services in the digital home. HGI's scope includes home gateways, home networks, and the Smart Home.
HL7	Health Level 7 International	Health Level Seven International (HL7) is a not-for-profit, ANSI-accredited standards developing organization dedicated to providing a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services
IEC	International Electrotechnical Commission	The International Electrotechnical Commission (IEC) is the world's leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies.
IEEE	Institute of Electrical and Electronics Engineers	The IEEE Standards Association, a standards-setting body within IEEE, develops standards through a process that brings together a broad stakeholder community. IEEE standards set specifications and best practices based on current scientific and technological knowledge. These standards span wired and wireless connectivity, encryption, data security, etc.
IETF	Internet Engineering Task Force	The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.
IETF CoRE	Constrained RESTful Environments WG.	The IETF WG CoRE provides a framework for resource-oriented applications intended to run on constrained IP networks.
IETF ROLL	Routing Over Low power and Lossy networks	The IETF ROLL WG is focused on routing issues for Low power and Lossy Networks (LLN).
IETF XMPP	eXtensible Messaging and Presence Protocol	The XMPP Standards Foundation (XSF) is an independent, non-profit SDO whose primary mission is to define open protocols for presence, instant messaging, and real-time communication and collaboration on top of the IETF's Extensible Messaging and Presence Protocol (XMPP).
IHE	Integrating the Healthcare Enterprise	IHE is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information.
IIC	Industrial Internet Consortium	The Industrial Internet Consortium is an international consortium that is setting the architectural framework and direction for the Industrial Internet. The consortium's mission is to coordinate vast ecosystem initiatives to connect and integrate objects with people, processes and data using common architectures, interoperability and open standards. Industrial Internet systems cover energy, healthcare, manufacturing, public sector, transportation and related industrial systems.
IPSO	Internet Protocol for Smart Object Alliance	The IPSO Alliance is an association of organizations and individuals that promote the value of using the Internet Protocol for the networking of Smart Objects.
IPv6	IPv6 Forum	The IPv6 Forum is a worldwide consortium with the mission to advocate IPv6 by improving technology, market, and deployment user and industry awareness of Ipv6.
ISO	International Organization for Standardization	ISO is an independent, non-governmental international organization with a membership of 161 national standards bodies.
ISO/IEC JTC1	ISO/IEC JTC1	ISO and IEC have a joint technical committee called JTC 1. Its WG10 focuses on the Internet of Things. JTC1 published an IoT report in 2014.
ITU-R	ITU Radio communications Sector	The ITU Radio communications Sector (ITU-R) is one of the three sectors of the International Telecommunication Union (ITU) and is responsible for radio communication. In the past years ITU-R has handled the mobility topic in SG5 (Terrestrial Services) WP 5A (Land Mobile Services).
ITU-T	ITU Telecommunication Sector	ITU-T develops international standards which act as defining elements in the global infrastructure of information and communication technologies (ICTs).
KNX	KNX Association	KNX Association is a group of leading companies active in many fields of home and building control. As common goal, these companies promote the development of building installation systems in general and KNX as the world's only open STANDARD for home and building control.

Acronym	Name	Mission
LON	LONMARK International®	LONMARK International membership is open to any manufacturer, distributor, engineer, system integrator, or end-user committed to the development, specification, and use of open, interoperable products utilizing ISO/IEC 14908-1 and related standards. LONMARK's mission is to enable the easy integration of multi-vendor systems based on these standards.
LoRa	LoRa Alliance®	The LoRa Alliance is an open, non-profit association of members collaborating together and sharing experience to drive the success of the LoRa protocol, LoRaWAN.
M2.COM	M2.COM	M2.COM is a brand new platform form factor for sensors.
OAA	Open Automotive Alliance	The Open Automotive Alliance (OAA) is a global alliance of technology and auto industry manufacturers whose objective is to bringing the Android platform to cars.
OASIS®	Advancing Open Standards for the Information Society	OASIS is a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society.
OASIS MQTT	Message Queuing Telemetry Transport	The OASIS MQTT TC provides a standard for the MQTT Protocol compatible with MQTT V3.1, together with requirements for enhancements, usage examples, best practices, and guidance for use of MQTT topics with commonly available registry and discovery mechanisms.
OCF	Open Connectivity Foundation	The OCF is creating a specification and sponsoring an open-source project in order to make all of the connected things (devices, phones, computers) communicate easily. OCF is the former OIC (Open Interconnect Consortium).
OGC	Open Geospatial Consortium	The OGC (Open Geospatial Consortium) is an international not for profit organization committed to making quality open standards for the global geospatial community.
OMA™	Open Mobile Alliance	OMA is an international standards setting body that develops enablers and network-agnostic protocols to enable operators and developers to create interoperable applications on mobile networks.
OMG	Object Management Group	The Object Management Group® (OMG®) is an international technology standards consortium. OMG Task Forces develop enterprise integration standards for a wide range of technologies and industries.
oneM2M	oneM2M	The purpose and goal of oneM2M is to develop technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide.
OSGi™	OSGi Alliance	The OSGi Alliance is a worldwide consortium providing open specifications for the development of applications.
PSA	Protocol Standards Association	The Protocol Standards Association (PSA) was established for the maintenance and management of the WITS-DNP3 protocol. The PSA has ownership of the Standard and also the responsibility to ensure it continues to meet the requirements of the water industry.
SAE	Society of Automotive Engineers	The Society of Automotive Engineers supports three technical sectors, Aerospace, Automotive and Commercial Vehicles. The DSRC TC at SAE is responsible for developing and maintaining SAE Message Set Standards, Recommended Practices, and Information Reports for use with short-to-medium-range wireless communication protocols specifically designed for road vehicle use.
TALQ	TALQ Consortium	The TALQ Consortium aims to establish a globally accepted standard for management software interfaces to control and monitor heterogeneous outdoor lighting networks.
Thread	Thread Group	Thread Group was launched with one goal in mind: to create the very best way to solve reliability, security, power and compatibility issues for connecting products around the home.
W3C	World Wide Web Consortium	The W3C mission is to develop protocols and guidelines that ensure the long-term growth of the Web. The Web of Things Interest Group aims to define global standards to enable discovery and interoperability of services, extending the Web from a Web of pages to a Web of Things. It focuses on a platform of platforms with an abstraction layer relying upon metadata standards (http://www.w3.org/WoT).

Acronym	Name	Mission
WiFi Alliance	WiFi Alliance	Wi-Fi Alliance® is a worldwide industry association whose objective is to drive new technologies and applications and certify Wi-Fi products using wireless networking technology (mainly based on IEEE 802.11).
ZigBee®	ZigBee® Alliance	ZigBee® is a set of wireless standards that devices use to connect to one another.
Z-Wave®	Z-Wave® Alliance	The Z-Wave® Alliance is comprised of industry leaders throughout the globe that are dedicated to the development and extension of Z-Wave®.

Annex B:
Change History

Date	Version	Information about changes
December 2015	0.1	First publication of the TS after approval by TC SmartM2M
March 2016	0.0.6	Version for TC SmartM2M review
March 2016	0.0.6b	Results from TC SmartM2M review incorporated, submitted to AIOTI WG3
April 2016	0.0.6d	Review version for TC SmartM2M
April 2016	0.0.6e	Update following feedback from SmartM2M telephone review
May 2016	0.0.6f	Include update on Smart Environment and Smart Manufacturing
May 2016	0.0.7	Clean up of update and submission to SmartM2M
June 2016	0.0.7c	Clean up of TR following update from SmartM2M meeting and update from Team
July 2016	0.0.8	Version following review phase
August 2016	0.0.9	Clean version for submission to SmartM2M #39
September 2016	0.0.9	Editorial checks done by Technical Officer before EditHelp processing

History

Document history		
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