H2020 Work Programme 2016-2017
H202-IoT-02-2016
Duration: 36 months

CROSS FERTILISATION THROUGH ALIGNMENT, SYNCHRONISATION AND EXCHANGES FOR IoT

H2020 – CREATE-IoT Project

Deliverable 06.04

IoT pre-normative activities

Revision : **1.00**
Due date : **30-06-2017 (m06)**
Actual submission date : **21-07-2017**
Lead partner : **ERCIM**

Dissemination level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Summary					
No and name	**D06.04 IoT pre-normative activities.**				
Status	Released	**Due**	m06	**Date**	30-06-2017
Author(s)	D. Raggett (ERCIM), O. Vermesan (SINTEF), R. Bahr (SINTEF), E. Darmois (ETSI), A. Kung (TL), L. Manteau (GTO)				
Editor	Dave Raggett (ERCIM)				
DoW	Report on IoT pre-normative activities. The work has been carried out within task T06.02 (Pre-normative and standardisation activities), and is the first out of three deliverables from this task. The task focuses on providing recommendations on reference implementations and contributes to pre-normative activities, to standardization, both horizontally and vertically in various domains. The recommendations on the reference implementation of promising IoT standards serving the interoperability and openness objectives will come from the coordinated consolidation of results obtained through standard implementation and pre- normative activities at the platform and/or pilot levels.				
Comments					

Document history

Rev.	Date	Author	Description
0.00	27-02-2017	SINTEF	Template/Initial version.
0.01	21-04-2017	SINTEF	Overall information, description of work, and contribution of partners.
0.02	27-04-2017	SINTEF	The document reference structure.
0.03	15-06-2017	ERCIM	Purpose and target group, Relations to other activities in the project, Background, IoT European LSPs, Introduction, IoT LSPs overview, and some comments and restructuring.
0.04	29-06-2017	ERCIM	Inputs (and some updates) on all main sections.
0.05	10-07-2017	SINTEF	Clean-up version.
0.06	17-07-2017	SINTEF	Updates and modifications.
0.07	19-07-2017	SINTEF	Refinements and changes.
0.08	20-07-2017	ETSI	Review.
0.09	21-07-2017	SINTEF	Review comments considered.
1.00	21-07-2017	SINTEF	Final version released.

Table of contents

List of figures

List of tables

1. EXECUTIVE SUMMARY

1.1 Publishable summary

The Internet of Things (IoT) seeks to enable services based upon sensors and actuators that are connected to the Internet. Standards are critical to unlocking the benefits across many potential application areas, reducing the costs and risks, and providing the confidence needed for sustainable growth of the IoT ecosystem. This potential for growth is currently being held back by fragmentation due to a plethora of non-interoperable platforms, standards and technologies.

This report surveys the context for pre-normative activities for the IoT large-scale pilot projects that are part IoT European Large-Scale Pilots Programme [1]. These activities start with gathering ideas for use cases, analysing the resulting requirements, and looking at how these can be met with existing standards, and where new standards may be needed. To fill the gaps, it is appropriate to survey existing work to build upon the experience gained through previous and ongoing research and innovation activities.

This report, by principally addressing pre-normative activities, is complementary to CREATE-IoT D06.01 "Strategy and coordination plan for IoT interoperability and standard approaches" [3] whose focus is more on the strategies regarding on-going standardisation.

1.2 Non-publishable information

None, the document is classified as public.

2. INTRODUCTION

2.1 Purpose and target group

CREATE-IoT is a Coordination and Support Action for the IoT European Large-Scale Pilots Programme. The project's aim is to stimulate collaboration between IoT initiatives, foster the take up of IoT in Europe and support the development and growth of IoT ecosystems based on open technologies and platforms. This requires strategic and operational synchronisation and alignment through frequent, multi-directional exchanges between the various activities under the IoT Focus Areas. It also requires cross fertilisation of the various IoT Large Scale Pilots for technological and validation issues of common interest across the different application domains and use cases.

This report introduces the role of standards in respect to the goals of the IoT Large-Scale Pilots, with an emphasis on pre-normative activities. Standards are key to reducing the costs and risks for developing and consuming IoT solutions, and to expand opportunities for all concerned by reducing friction in the market.

To facilitate coordination in relationship to standards, the CREATE-IoT project has set up several Activity Groups with participants from across the IoT European Large-Scale Pilots Programme. Activity Group 2 focuses on "IoT Standardisation, Architecture and Interoperability". The first face to face meeting for Activity Group 2 took place on Wednesday, 7th June 2017, as part of the IoT Week 2017 in Geneva. As a first example of cross-LSP coordination, CREATE-IoT has developed an online survey to collect input from the Large Scale IoT Pilots whose results are summarised in section 5.

2.2 Contributions of partners

ERCIM: Task leader and deliverable responsible. Contribute to pre-normative activities and to standardisation through maintenance of W3C standardisation groups in using Web technologies to develop IoT applications (WoT) with an initial focus on horizontal solutions for issues such as semantic interoperability, security, discovery and scaling. Guide pilots on ongoing IoT standardisation efforts in general. Moreover, W3C guide pilots on progress and use of WoT standards, contribution of pilot technology to WoT standardisation. W3C also support new W3C standardisation groups as needed by pilots.

SINTEF: Contribute to the pre-normative IoT standardisation activities through its participation in the AITOTI working group WG03 and by the interaction with the stakeholders in the IoT LSPs. SINTEF helped with the structure of the report and as a reviewer of its content.

ETSI: Contribute to this task based on the work done in 1) IoT-EPI Coordination and Support Action; and 2) the ETSI Specialist Task Force on "IoT Standards Landscape and Gap Analysis in support of the IoT LSPs whose results of this activity will be available in time for the start of the CSA. ETSI helped with the extension of the survey of the LSPs towards pre-normative activities and provided a section on ETSI in respect to the links to standards development organisations.

TL: Contribute to the coordination of the pre-normative interoperability activities in LSP1, considering the recommendations of the C2 actions of EIP-AHA. TRIALOG contributed a section on the ITU in respect to the links to standards development organisations.

GTO: By its presence in several SDOs as diverse as AIOTI, W3C, GP (Global Platform), oneM2M and 3GPP, GTO contribute to pre-normative activities relevant to IoT domains, contribute to alignment between above organizations, and propose a set of recommendations for LSP and commercial deployments in terms of openness, security and interoperability.

NUIG: Participate in the related activities to pre-normative and standardisation activities, particularly to align LSPs and the IoT-EPI projects with the AIOTI WGs and the IERC Activity Clusters. Particularly on semantics, privacy and security and federation.

MI: Support the standardization effort towards international SDOs, including to the ITU-T, where MI is Rapporteur on Research and Emerging Technologies for the IoT and for Smart Cities. It relays relevant initiatives to create new work items and potential recommendations at the ITU. It will also support the cooperation with the IEEE community, where MI is Vice-Chair of the IEEE Sub-Committee on IoT. It will also support interaction and cooperation with other for a, such as the IoT Forum (hosted by MI), the IPv6 Forum, etc.

AS: Support the standardization effort related to personal data protection, with a focus on ISO and IEC.

2.3 Relations to other activities in the project

This report was produced as a deliverable of Task 06.02 for Work Package 6 (IoT Interoperability and Standardisation). The relationship to the other Work Packages (WPs) in the project is illustrated in the WPs Part diagram of CREATE-IoT Technical Annex [1]. Together with WP05, WP06 gets inputs from the task activities in WP01, WP02, and WP03. There are also synergies to European Large-Scale Pilots in D01.01 and to the IoT standard analysis identification in D06.01 [3] to get the global picture of pre-normative and standardisation activities. The outputs of D06.04 will be useful for the subsequent deliveries in WP06 concerning the standardisation activities and the value chain integration framework in WP04.

To facilitate coordination across the Large Scale IoT Pilots, CREATE-IoT has launched a number of Activity Groups in cooperation with the U4IoT Coordination and Support Action. The scope of each of the Activity Groups are described and illustrated in D01.01 (IoT FA strategy and coordination plan) [18]. The activities outlined in the present document refers in particular to Activity Group 2 ("IoT standardisation, architecture and interoperability").

3. PRE-NORMATIVE IOT ACTIVITIES OVERVIEW

3.1 Background

Standards are essential to modern business, providing certainty for customers compared to the risks of proprietary solutions. Likewise, standards reduce the risks for investors and through re-use, the costs for developers themselves. In combination with the network effect, this can dramatically expand the market size for hardware, software and services. Therefore, understanding the role of standards in the creation of conditions for sustainable growth of the IoT ecosystem is essential. This potential for growth is currently hindered both by fragmentation due to a plethora of non-interoperable platforms, standards and technologies and by the lack of standard-based solutions to address some of the most pressing challenges for IoT, such as interoperability or security.

Task 06.02 is focusing on providing recommendations on reference implementations and contributes to pre-normative activities, to standardization, both horizontally and vertically in various domains. The recommendations on the reference implementation of promising IoT standards serving the interoperability and openness objectives will come from the coordinated consolidation of results obtained through standard implementation and pre- normative activities at the platform and/or pilot levels.

3.2 Mapping the IoT Ecosystem: the AIOTI approach

The AIOTI (online at https://www.aioti.eu/) was launched by the European Commission together with key IoT players in March 2015 with a view to encourage dialogue amongst the IoT stakeholders in Europe and to support plans for the IoT Large-Scale Pilots. It is now an independent organisation.

The organisation of AIOTI, as outlined in Figure 1, illustrates the challenge of covering the IoT ecosystem in a global and coherent manner. In particular, the needs of "vertical" domains (as tackled in Work Groups 05 to 13) have to be balanced with the expectations of "horizontal", cross-domain approaches (as tackled in Work Groups 01 to 04).

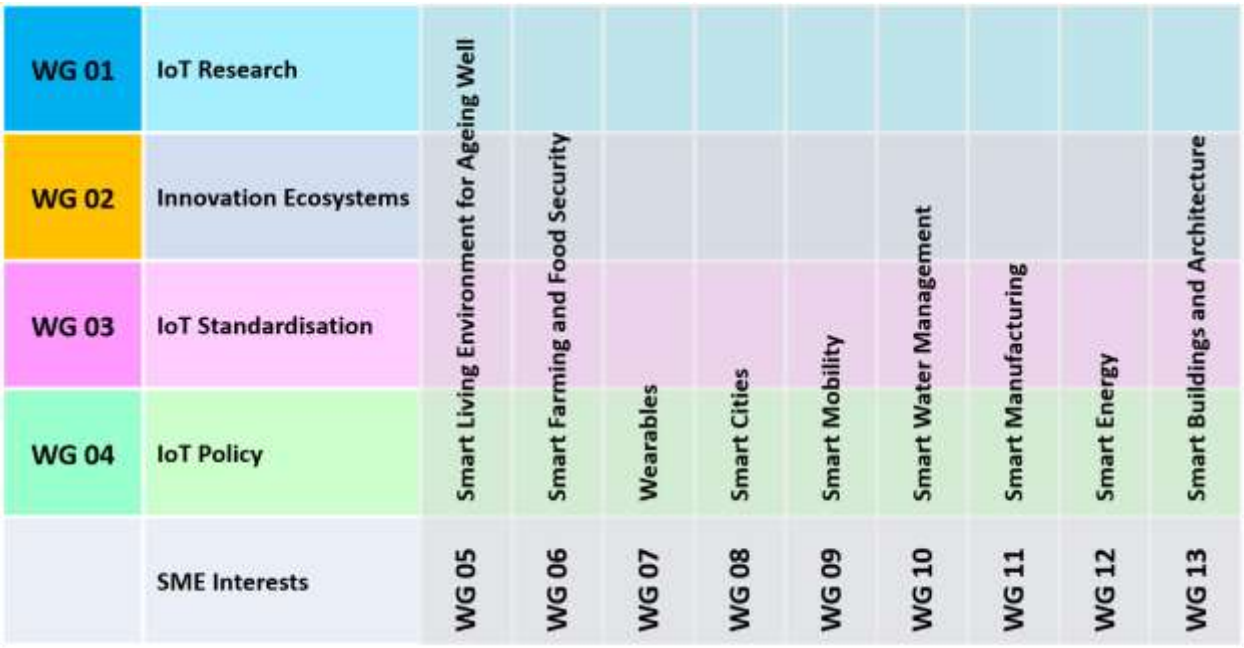

Figure 1: AIOTI "Horizontal" and "Vertical" Work Groups

The "horizontal" Work Groups are addressing several of the issues that the present report also tackles. The pre-normative activities are in scope of WG 01 (IoT Research) for the identification of progress in research that can further materialise in standardisation, WG 02 (Innovation Ecosystems) for recommendations to stimulate the development of open innovation ecosystems for IoT innovation, and WG 03 (IoT Standardisation).

Of particular relevance to the present report, AIOTI WG 03 focuses on IoT standardisation. Its mission is: to identify and, where appropriate, make recommendations to address existing IoT standards, to provide analyses of gaps in standardisation, and to develop strategies and use cases aiming for (1) consolidation of architectural frameworks, reference architectures, and architectural styles in the IoT space, (2) (semantic) interoperability and (3) personal data and personal data protection to the various categories of stakeholders in the IoT space.

The Working Groups have produced reports that have been useful for each of the planned pilot domains sought to provide advice for proposal writers. The reports cover:

- The background and motivation for each pilot
- Existing initiatives in the pilot's domain
- Technical dimensions and recommendations
- Business models and user acceptability

AIOTI WG 03 has produced several reports that may serve as input to the IoT Large-Scale Pilots, e.g. a landscape of IoT standards development organisations, a high-level architecture, and studies relating to security and privacy, as well as semantic interoperability. These will be introduced later in this report.

3.3 Basic framework used by IoT European Large-Scale Pilots Programme

The benefits of standards were outlined above. The challenge for the IoT Large-Scale Pilots is to select appropriate domain independent ("horizontal") and domain dependent ("vertical") standards, and to figure out how to address any identified gap in standards. The starting point is to identify suitable use cases, and identify promising solutions. To grow the market, the aim is to learn from what worked and what didn't and feed this into future standards to fill the gaps, and to update existing standards to be a better fit.

The default approach to standardisation is to first collect representative use cases, analyse them to obtain the requirements, identify relevant technical approaches, check for matching standards, identify gaps where new standards are needed, create proof of concept implementations, build a coalition of parties with an interest in creating the missing standards, submit the work to a new or existing standards activity. Work to mature the specifications, identify testable assertions, assess market support for the proposed standard, put in place certification for conformance to the new standard, collect errata and apply corrections, and identify gaps/improvements for the next version of the standard.

3.4 Domain independent pre-normative standardisation

Many of the requirements for standards are the same across different application domains, e.g. communication technologies, protocols, and generic frameworks for metadata. The requisite pre-normative activities involve analysing use cases to identify what kinds of domain independent requirements are applicable. Some guidance is provided in the AIOTI reports. The term "horizontal domain standards" is sometimes used as a synonym for "domain independent standards".

3.5 Domain dependent pre-normative standardisation

Some requirements necessitate domain specific standards, for example, for integration with existing systems, to fulfil domain specific regulatory requirements, and the domain specific

ontologies needed for semantic interoperability. The term vertical domain standards is sometimes used as a synonym for domain dependent standards.

3.6 IoT European Large-Scale Pilots pre-normative activities

Each of the pilots will conduct pre-normative activities around the use cases they wish to address, the requirements that these entail, the landscape of relevant horizontal and vertical standards, how this can fulfil the requirements, and what additional activities are needed where there are gaps. The following section introduces each of the pilots, the standards that they have already identified, and a discussion around the uses cases they want to work on.

4. IoT European LSPs: preliminary views

The ambition of the European Commission's Internet of Things Focus Area (IoT-FA) is to foster the take up of IoT in Europe and to enable the emergence of IoT ecosystems supported by open technologies and platforms. This is being addressed through a complementary set of activities structured around IoT large-scale pilot projects. The projects are intended to make use of the rich portfolio of technologies and tools so far developed and demonstrated in reduced and controlled environments, and extend them to real-life use case scenarios with the goal of validating advanced IoT solutions across complete value chains with actual users and proving its enormous socio-economic potential. The IoT large-scale pilots are intended to stimulate the development of IoT solutions through integration of advanced IoT technologies across the value chain, demonstration of multiple IoT applications at scale and in a usage context, and as close as possible to operational conditions. This includes integration, research and development across the value chain, and the validation of user acceptability.

4.1 Introduction

The five IoT Large-Scale Pilots (LSPs) that have been funded are as follows:

1. ACTIVAGE for Smart living environments for ageing well
2. IoT2020 for Smart Farming and Food Security
3. MONICA for Wearables for smart ecosystems
4. SynchroniCity for Reference zones in EU cities
5. AUTOPILOT for Autonomous vehicles in a connected environment

The LSPs commenced at the start of 2017 and will run for three years (four years for IoF2020). At the time the present report was written, the LSPs have only been in operation for a few months and there is only limited information available about each of them.

To facilitate coordination, the CREATE-IoT, U4IoT and the five IoT Large-Scale Pilots have set up several Activity Groups with representatives from each LSP. Of particular relevance to this report, Activity Group 2 addresses IoT standards, architectures and interoperability. The first meeting of Activity Group 2 took place on Wednesday 7th June 2017 as part of the IoT Week in Geneva. As a first initiative for cross-LSP coordination, CREATE-IoT WP6 has developed an online survey for an initial information gathering.

4.2 The landscape for the standardisation areas covered by the IoT Large-Scale Pilots

The AIOTI Working Group 03 report on IoT LSP Standard Framework presents the global dynamics and landscape of IoT Standards Development Organisations, Alliance and Open Source Software initiatives with a view to:

- Leverage on existing IoT standardization, industry promotion and implementation of standards and protocols,
- Use as input for LSP standards framework and gap analysis, and provide a guideline for the future project proposals associated with future IoT related calls financed by the EC on the positioning of these initiatives within this landscape.

The AIOTI report notes that there is a growing awareness in the market and in the standardisation arena with respect to the need of IoT standards convergence.

Ongoing efforts in this perspective (e.g., recent actions to strengthen the collaboration among relevant SDOs involved in the horizontal/telecommunication dimension) are good premises of a simplification of this standards landscape in the medium term.

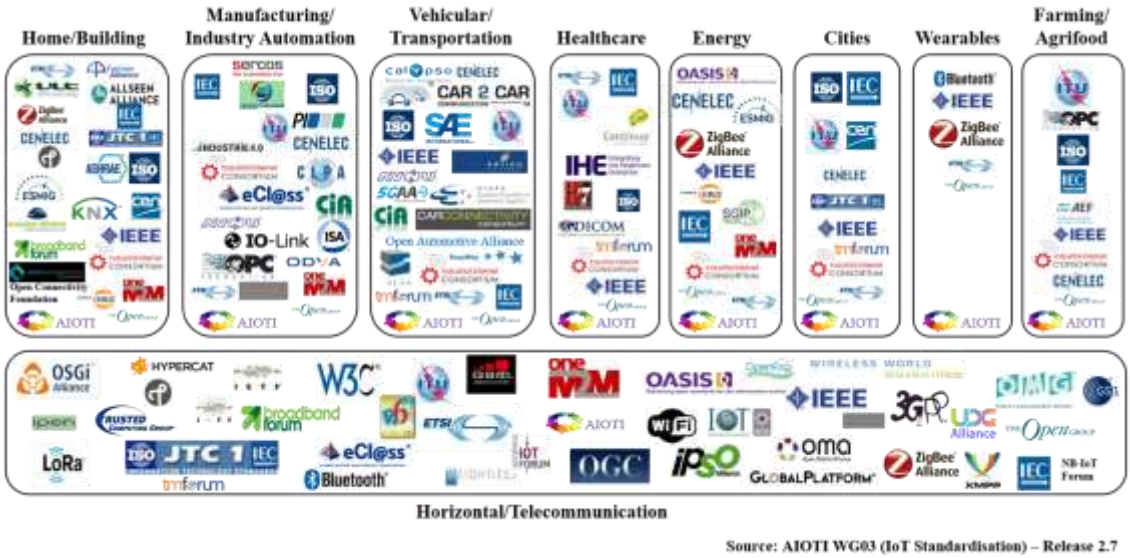

Figure 2: IoT Standard Landscape as a background for the European LSPs Programme [3][19]

4.3 Horizontal and vertical standards in support of the LSPs

The following covers the standards that have been identified as relevant to each LSP, either through the Activity Group 2 survey, or from the AIOTI studies for each pilot area.

4.3.1 ACTIVAGE: Smart living environments for aging well

Horizontal standards	AIOTI HLA, Bluetooth BLE, IETF 6LoWPAN, IETF CoAP, IoTivity, IPSO Alliance, oneM2M, W3C, OMA LwM2M
Vertical standards	IEEE 1073, ETSI BAN

4.3.2 IoF2020: Smart farming and food security

Horizontal standards	IoF 2020 is currently compiling the plans of the 19 use cases and can provide further information at a later moment in time
Vertical standards	

The "Farming and Agri-food" domain has invested quite an amount of work in activities to facilitate interoperability. Important related activities are AGROVOC, GODAN as well as e.g. ISOBUS, EPCIS, agroXML, UN/CEFACT. IoF2020 involves the FIWARE Foundation that aims at facilitating a northbound interoperability for the exchange of context related information when using the ORION context broker that connects IoT devices. IoF2020 partners are involved in related standardisation activities already for a long time. Therefore, the LSP support actions could facilitate the horizontal aspects for an IoT related semantic interoperability.

4.3.3 MONICA: Wearables for smart ecosystems

Horizontal standards	3GPP NB-IoT, AIOTI HLA, Bluetooth BLE, DASH7, ETSI SAREF, IEEE LR-WPAN, IETF 6LoWPAN, IETF CoAP, IETF Oauth, IETF ROLL, OASIS XACML, OASIS MQTT, oneM2M, OSGI Core, WiFi Alliance
Vertical standards	OGC SensorThings API UWB – IEEE 802.14a

4.3.4 SynchroniCity: Reference zones in EU cities

Horizontal standards	3GPP NB-IoT, AIOTI HLA, BBF TR069, Bluetooth BLE, IETF 6LoWPAN, LoRa, OMA NetAPI, oneM2M, OSGI Core, ZigBee
Vertical standards	Agri-AEF, Smart Cities -oneM2M, ETSI ISG CIM for Smart Cities and other cross cutting Context Information management, Industrie4.0

4.3.5 AUTOPILOT: Autonomous vehicles in a connected environment

Horizontal standards	3GPP NB-IoT, AIOTI HLA, ETSI SAREF, IEEE P2413, ISO/IEC JTC1 IoT RA, oneM2M, W3C
Vertical standards	5GAA, ADASIS, CEN TC 278, ETSI TC ITS, ETSI TC ERM, SENSORIS

Note that, at this phase of the project, only a standards of interest survey is available. Please refer to AUTOPILOT Deliverable D5-7 "Standardisation plan" for more information.

4.4 Future pre-normative research needs in the IoT applications context

This is very open ended as it is hard to predict what will be adopted by the IoT ecosystem in the future. However, current challenges suggest some topics of interest as presented below:

- How to support semantic interoperability in a more scalable way that works well across isolated or weakly coupled communities. If different communities are tackling what are broadly similar use cases, they should address many of the same requirements, but are likely to end up with different approaches. It is unrealistic to expect isolated or weakly coupled communities to agree to a common ontology. Moreover, imposing an ontology may hinder innovation by failing to address the specific needs of each community. One approach is to use bridging ontologies that relate the concepts in the community specific ontologies. One opportunity for research is the potential role of context dependent mapping rules, in which the mapping depends on both the ontologies and the specific data. This would be a step beyond today's context independent mappings, e.g. as used by Inter-IoT and other IoT-European platforms Initiative (IoT-EPI) projects (online at www.ioti-epi.eu).
- Challenges for securing systems of systems. Each IoT standards community tends to approach security slightly different from the others. However, for open markets of services, where one needs to connect services from different vendors and using different underlying standards, there is a huge challenge to establish end-to-end security and build trust across the different systems. One opportunity is to make use of an abstraction layer that decouples applications from the underlying systems. What kinds of standards are needed at the different layers in the abstraction stack and how can they be coordinated?
- Opportunities for federated systems and services. Commercial Internet solutions providers tend to rely on centralised cloud based services. However, these are at greater risk from cyberattacks compared to distributed peer to peer architectures that can be designed to resist denial of service attacks. If the European Union is to compete effectively with the extremely large US Internet companies, we need to find a way to enable the network effect for federated services on a European scale. One potential example is a ride sharing economy based upon peer to peer IoT solutions as a competitive alternative to Uber.
- Challenges for distributed open ecosystems of services. What would be expected there is a simple means to discover and compose services from different vendors and using different standards and different platforms. Smart applications will need to be able to adapt to variations in the interaction models and capabilities from one vendor to the next. The requirements for

contractual relationships between suppliers and consumers of services also need to be addressed. Further work is needed on standards for how to express Service Level Agreements, and terms and conditions, together with mechanisms for payments and automated negotiation. This points to further rationale and opportunities for abstraction layers like the Web of Things.

- Opportunities for combining different scientific disciplines, e.g. AI, Cognitive Science and Computational Linguistics. Traditional approaches to data modelling are based upon symbols and logical inference. By blending ideas from Cognitive Science, there is an opportunity to make recall and reasoning based upon the statistics of experience, and bridging the gap to how humans think.

4.5 Gaps in standards and regulations used by IoT Large-Scale Pilots

The following table lists the criticality of a set of gaps (identified in the ETSI TR 103 376 [16]) as seen from the perspective of the participants in Activity Group 2.

Note that this data is also reported in D06.01 [3], and is repeated here for convenience in the following analysis of some considerations for filling these gaps.

Table 1: Perceived criticality of standard gaps per LSP [3]

Nature of the gap	ACTIVAGE	AUTOPILOT	IoF2020	MONICA	SYNCRONICITY
Competing communications and networking technologies	Low	Medium	High	Medium	Medium
Easy standard translation mechanisms for data interoperability	Medium	Medium	Medium	Low	Medium
Standards to interpret the sensor data in an identical manner across heterogeneous platforms	Medium	High	Medium	High	High
APIs to support application portability among devices/terminals	Medium	Low	Medium	Medium	Medium
Fragmentation due to competitive platforms	High	Low	Medium	N/A	Medium
Tools to enable ease of installation, configuration, maintenance, operation of devices, technologies, and platforms	Medium	Medium	Low	High	High
Easy accessibility and usage to a large non-technical public	Medium	-	Low	High	High
Standardized methods to distribute software components to devices across a network	Medium	Low	Medium	Low	Medium
Unified model/tools for deployment and management of large-scale distributed networks of devices	Medium	-	Medium	Medium	Medium
Global reference for unique and secured naming mechanisms	Medium		Low	Low	Medium
Multiplicity of IoT HLAs, platforms and discovery mechanisms	High	Low	Medium	Medium	High
Certification mechanisms defining “classes of devices”	High	-	Low	N/A	Medium

Nature of the gap	ACTIVAGE	AUTOPILOT	IoF2020	MONICA	SYNCRONICITY
Data rights management (ownership, storage, sharing, selling, etc.)	High	Medium	High	Medium	Medium
Risk Management Framework and Methodology	Medium	Medium	Medium	Medium	High

4.6 Recommendations on reference implementations

4.6.1 UNIFY-IoT review of IoT platforms

An extensive survey of IoT platforms has been carried out by the UNIFY-IoT Project. The public report on IoT platform activities [17] provides an overview of IoT platforms followed by a systematic analysis and concise description of the platforms and their features. The purpose was to analyse the IoT platforms both commercial and open source, while mapping the IoT use cases and applications around the platforms and presenting the factors that are relevant for the adoption of the platform. The analysis offers a comprehensive looking at all aspects of platform activity, from elements like communication capabilities, to the availability and quality of documentation, the ease of use of APIs, SDK environments and the use of innovation support events such as pit stops or hackathons to engage with platform adopters and potential platform adopters.

As part of this work, UNIFY-IoT conducted a survey among the IoT-EPI projects to understand current platforms of choice within the research community. Based upon 35 responses, the following lists the chosen platform in decreasing order of popularity:

1. OpenIoT
2. FIWARE
3. IoT-ARM (IoT-A)
4. OGC SWE
5. IoTivity
6. Hyper/CAT
7. 5GVIA
8. UDG
9. OpenWSN

One observation is that more than 50% of the platforms that the IoT-EPI projects are utilizing are Open Source. This is very unlike the trend in the global market where the proportion of open source platform is below 5% and the majority dominated by commercial offerings.

UNIFY-IoT also looked at commercial IoT platforms and ranked them by relevancy analysis. In order of decreasing relevancy these platforms were as follows:

1. PTC ThingWorx (Industry)
2. Microsoft Azure (Cloud)
3. Amazon AWS (Cloud)
4. IBM Watson IoT (Cloud)
5. PTC Axeda (Telco)
6. GE (Industry)
7. Kaa (Cloud)
8. ThingsSpeak (Cloud)
9. Xively (Cloud)
10. Carriots (Telco)
11. Cisco (Telco)
12. EVRYTHNG (Cloud)

Further information and pointers to additional resources are given in an appendix to the UNIFY-IoT report [17].

One issue raised by the UNIFY-IoT is that today, the providers of IoT platforms are fragmented and in the near future, there is a need for designing overarching, integrated IoT platforms that bring the devices, networks and endpoints together in the companies' and IoT ecosystems that develop various IoT applications. In this context, the IoT platforms need to enable a complete IoT/IT/OT ecosystem converging the consumer/business/industrial applications by collecting and sharing data broadly within an organization, sectors, and IoT applications. This need to be converted into an IoT platform strategy, based on open specifications, strong interoperability principle, security and standardization.

4.6.2 A preliminary view of LSPs on platforms

In the above section, the existing tension between the utilisation of Open Source platforms by a majority of the IoT-EPI projects, and the global market hugely dominated by commercial offerings has been outlined. This is obviously a challenge for the LSPs both in terms of the possible synergies between LSPs coming from the best possible alignment in the choice of platforms, and in terms of the acceptability by the IoT ecosystem of the solutions selected, and possibly enriched, by the LSPs during the development of their use cases.

The CREATE-IoT survey of the IoT Large-Scale Pilots shows initial interest in the following platforms:

AUTOPILOT	FIWARE, oneM2M
IoF2020	FIWARE, CRYSTAL, SOFIA
MONICA	FIWARE, oneM2M, Open source LinkSmart middleware components, open source SCRAL component
SynchroniCity	FIWARE, oneM2M, Eclipse OM2M, OpenDaylight IoTDM
ACTIVAGE	FIWARE, SOFIA, IPSO Framework

This shows the popularity of open source IoT platforms like FIWARE (and to a lesser extent CRYSTAL and SOFIA), and of the oneM2M IoT standard suite.

FIWARE (https://www.fiware.org) is an open cloud-based platform with an innovation ecosystem for the creation of new applications and Internet services. There is a suite of generic enablers (tools and libraries) for a wide range of purposes. This includes support for business intelligence (analytics), context management, and open APIs using either XML or JSON for requests and responses. FIWARE provide support for multiple IoT protocols, e.g. M2M (oneM2M), MQTT (OASIS), LightweightM2M (OMA) and CoAP (IETF). FIWARE has been developed with substantial support from the European Commission via the Future Internet Public-Private Partnership (FI-PPP).

CRYSTAL (http://www.crystal-artemis.eu/) is a former ARTEMIS joint undertaking project that focused on embedded systems engineering with a focus on safety-critical embedded systems and architecture platforms. SOFIA is a former ARTEMIS FP7 project that developed a semantic interoperability platform. It was followed by the SOFIA2 project and is now available as a commercial product, see http://sofia2.com/home_en.html.

OneM2M (http://www.onem2m.org/) which is mostly popular within the ICT sector, defines a suite of standards for accessing resources with RESTful APIs over common protocols such as CoAP and MQTT.

Beyond the initial choice of platforms (or platform features) by the LSPs, the question of the rationalisation, simplification and, most importantly, of interoperability may iduce some further reflections and decisions as to the choice of their actual deployment platforms.

Some general considerations when evaluating IoT platforms are as follows:

Location	Is the platform suitable for the network edge, the fog, the cloud or some form of distributed peer to peer architecture?
Pluggable protocol support	Does the platform support an extensible range of protocols? These can be further divided into IoT communication technologies and Internet backhaul protocols.
IoT standards support	Does the platform support an extensible range if IoT standards, e.g. oneM2M, OCF, OPC-UA, and so forth
Security and trust	What security capabilities are supported and how well do they scale with the number of connected devices? Some factors include the kinds of identifiers for devices, services, people, companies, etc., support for data integrity and encryption, access control, third party attestations, and means for bootstrapping trust?
Safety	Does the platform comply with relevant safety regulations?
Resilience	Is there support for policy based control of system behaviour in the presence of faults and cyber-attacks? Does the system provide for defence in depth? Can you use machine learning to monitor behaviour and signal anomalous conditions?
Provisioning and device management	What support is there for managing large collections of devices? Does this provide automated control of software updates?
Analytics and business intelligence	Which support for value middleware capabilities?
Context management	What support is there for storing and reasoning with information describing the context?
Semantic interoperability	Is there support for declarative descriptions of devices with both interaction models and semantic models that can be used to enable service providers and service consumers to know that the meaning of the data they exchange?
Privacy	Does the platform support the new EU General Data Protection Regulation (GDPR), which is intended to intend to strengthen and unify data protection for all individuals within the European Union?
B2B	Does the platform enable business to business services? This relates to the need for service level agreements, and the potential for automated negotiation of terms and conditions, and where appropriate payment mechanisms.

5. THE STANDARDIZATION POTENTIAL OF IOT IN EUROPE

5.1 The EU harmonised standardisation and regulatory framework for IoT

5.1.1 Approach

The European Commission has published its ICT Standardisation Priorities for the Digital Single Market on 19 April 2016 [4]. The starting point is the importance of common standards across Europe for ensuring the interoperability of digital technologies as the foundation of an effective Digital Single Market. Standards ensure that technologies work smoothly and reliably, providing economies of scale, foster research and innovation along with open markets.

The report notes that the value of digital systems increasingly derives from cross-sector applications, data and technology convergence. The proliferation of IoT standards increases complexity and hinders innovation. This makes it important to map all relevant standards, and to encourage dialogue for a shared understanding across researchers, innovators and standards setters. This places a premium on being able to define and use standards that enable interoperability across a broad range of platforms and communications technologies.

The proposed approach involves identifying a list of priority building blocks for the Digital Single Market: 5G communications, cloud computing, the IoT, (big) data technologies and cybersecurity[1]. These will support application areas such as eHealth, smart energy, intelligent transport systems, connected and automated vehicles, including trains, advanced manufacturing, smart homes and sites, as well as smart farming and food security,

With respect to the IoT, the Commission plans to work with standards organisations and develop consensus under the umbrella of the AIOTI. This includes work on reference architectures, protocols and interfaces, open APIs, support for innovation activities, and the development of missing standards. In addition, there is interest in promoting an interoperable IoT numbering space with an open system for object identification and authentication. Other work will explore options and guiding principles for trust, privacy and end to end security.

The Commission will promote the uptake of IoT standards in public procurement to avoid lock-in, notably in the area of smart cities, services, transport and utilities including water and energy.

5.1.2 Roadmap

The EU Rolling Plan for ICT Standardisation [5] states (in section 1.3.2) "The Rolling Plan identities EU policy priorities where ICT standardisation and ICT standards should be considered as part of policy making. The Rolling Plan is a strategic document focussing on the support those standards, technical specifications, and standardisation in general can provide in the context of EU policy priorities, to ensure interoperability (including avoidance of technology lock-in) in the ICT domain.

The Rolling Plan looks at the standardisation landscape in relation to the EU policy priorities. It identifies possible areas for action and may go into suggesting a plan or roadmap regarding effective standardisation support."

Section 1.4 notes that "standards may be referenced in the context of EU Regulations or Directives. Harmonised European Standards may be used to demonstrate compliance with so-called essential requirements, and thus enable products to be placed on the European market. Standardisation

[1] To which might be added Artificial Intelligence and Machine Learning as increasingly important technologies for realizing the potential of data, especially given the role of the IoT for producing a huge flood of data.

requirements in respect of these issues are covered in the Annual Union Work Programme, and will be the subject of mandates."

In addition, standards can play a role in support of industrial or innovation policy, EU funded Research and Innovation projects, and in government internal policies for public procurement relating to internal information exchange, infrastructure and systems design.

The European Commission is seeking new standardisation initiatives to further support the effective take up and implementation of standards in the priority domains identified in the Rolling Plan. These could cover, for example:

- Awareness, promotion, conferences, information and education to all stakeholders including societal stakeholders, in particular for the cooperation with R&I and the SMEs involvement;
- Implementation of field operational tests, pilot projects and interoperability testing;
- Exchange of good practice between Member States and between Standardisation Organizations, including international cooperation;
- Guidelines for procurers on how to mention standards;
- Monitoring the use of standards in IT systems and in IT procurement;
- Encouraging major IT suppliers to implement selected standards in their products.

The priority areas are as follows:

- Societal Challenges: eHealth; Active and Healthy Aging; Accessibility of ICT products and services e-Skills and e-Learning; Emergency communications; and eCall
- Innovation for the digital single market; e-Procurement, Pre-and Post-award e-Invoicing; Card, Mobile and Internet Payments XBRL; and Online Dispute Resolution (ODR)
- Sustainable growth: Smart Grids and Smart Metering; Technologies and Services for a Smart and Efficient Energy Use ICT Environmental Impact; EETS (European Electronic Toll Service); Intelligent Transport Systems; Advanced Manufacturing; and Robotics
- Key enablers and security. The Internet of things is part of the list together with other ones such as: Cloud computing; Public Sector Information, Open Data and Big Data; Electronic identification and trust services including e-signatures; Network and Information Security; or ePrivacy.

The Rolling Plan sets out policy objectives, standards, legislation and policy documents, together with proposed actions.

5.2 The potential for IoT standardization in Europe

5.2.1 Identification of gaps

This section looks at gaps that were identified in the June 2017 survey of the Large-Scale Pilots, as well as others that are have been identified during pre-normative activities at W3C.

ETSI TR 103 376 [16] characterizes gaps by the type (Technology, Societal, Business), the scope, the difficulties it generates, and other appropriate descriptions.

Some of the gaps identified in this report have been submitted to the evaluation of LSPS in the CREATE-IoT WP6 survey with the results shown in Table 1.

The data indicates that the one of the most important technology gaps is in respect to standards to interpret the sensor data in an identical manner across heterogeneous platforms, in other words, semantic interoperability for sensor data.

5.2.2 Proposal for new IoT standardization work

With different organisations working independently on IoT standards, it is inevitable that they will come up with different approaches even when they are addressing similar use cases. One example

of this is for smart homes, where OCF, oneM2M, ETSI SAREF and the Japanese ECHOnet consortium all differ in the details for the capabilities they selected for home appliances. Furthermore, individual vendors seek to differentiate their products from their competitors via different product capabilities. This makes it impractical to impose a single ontology.

A more effective approach is to design ontologies for each standards suite (e.g. OCF, oneM2M, ECHOnet) and to relate them via a bridging ontology. This approach is being investigated by the W3C Web of Things Interest Group. Another idea is to work on defining best practices for modular ontologies to make it easier for vendors to describe their particular products' capabilities in a standard way.

When it comes to mapping between ontologies, the most appropriate mapping may depend on the context, i.e. the value of the data and the context in which it is situated. A way to express such context dependent mappings would be an advance in the state of the art.

The next level down of importance covers gaps concerning standards for management of services, devices, technologies and platforms; usability by non-technical experts, and data rights management (ownership, storage, sharing, selling, etc.). This points to the need for pre-normative activities that pool experience, gather use cases and best practices, and prepare the way for further standardisation.

5.2.3 Links with ongoing IoT standardization (SDOs)

The CREATE-IoT survey of the IoT Large-Scale Pilots showed that they are interested in standards emanating from the following standards organisations. More details will be found in the CREATE-IoT Deliverable D06.01 [3].

	Standards organisations involved
Horizontal standards	3GPP, AIOTI, BBF, Bluetooth, ETSI, IEEE, IETF, IoTivity, IPSO Alliance, ISO/IEC JTC1, LoRa, OASIS, OMA, oneM2M, OSGI, W3C, WiFi Alliance, ZigBee
Vertical standards	5GAA, ADASIS, Agri-AEF, CEN, ETSI, IEEE, Industrie 4.0, OGC, SENSORIS

These organisations are active in the current IoT standardisation landscape. One of the challenges of pre-normative activities (that are the focus of attention of the current report) will be to identify the most appropriate and relevant organisation(s) to use as channel to standardisation. The following section will outline some potential places where the on-going pre-normative activities can find a potentially good channel for their results.

5.3 Potential channels for pre-normative activities towards standardisation

5.3.1 European Telecommunication Standards Institute (ETSI)

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.

In addition to the current work done in Technical Committees (e.g., SmartM2M, 3GPP, ITS or DECT), several expanding or emerging ETSI activities are expected to provide important contributions to IoT:

- The SAREF specification within TC SmartM2M. The objective of SAREF (Smart Appliances REFerence ontology), launched in 2014 and standardised in 2015, is to create a shared

semantic model of consensus to enable the missing interoperability among smart appliances. SAREF is to be considered as an addition to existing communication protocols to enable the translation of information coming from existing (and future) protocols to and from all other protocols that are referenced to SAREF. SAREF has gradually grown into a modular network of standardized semantic models that continues to evolve with already standardised extensions in Energy, Environment and Buildings. Others ae on the roadmap for Smart Cities, Smart AgriFood, Smart Industry and Manufacturing, Automotive, eHealth/Ageing-well and Wearables.

- TC SmartBAN is developing standards for use in Body Area Network (BAN) in order to enable the use of small, low power wireless devices which can be carried or embedded inside or on the body. The work involves items such as: low complexity Medium Access Control (MAC) and routing requirements for SmartBANs; an ultra-low power Physical Layer for on-body communications between a hub and sensor nodes; a distributed multi-agent based IoT reference architecture; and a system description, including an overview and use cases
- The ISG CIM on Context Information Management. This Industry Specification Group (ISG) has been created in order to develop technical specifications and reports to enable multiple organisations to develop interoperable software implementations of a cross-cutting Context Information Management (CIM) Layer and bridge the gap between abstract standards and concrete implementations. The CIM Layer enables applications to update, manage, and access context information from many different sources, as well as publishing that information through interoperable data publication platforms.

5.3.2 International Organization for Standardization (ISO)

IoT standardisation activities on IoT have taken place in ISO/IEC JTC1/WG10. In 2017 all activities were transferred to a newly created subcommittee (SC41). SC41 focuses on setting up a framework, through standard projects such as ISO 20924 (Internet of Things — Definition and Vocabulary) or ISO 30141 (Internet of Things Reference Architecture (IoT RA)). A contribution from CREATE-IoT was made asking for two orientations: one on the integration of non-functional concerns (safety, security, privacy) and one on co-creation.

In parallel a study was carried out by JTC1/SC27 on security and privacy that led to the creation of two study periods, one in SC27/WG4 on security one in SC27/WG5 on privacy for about three years. During the SC27 meeting in April 2017, it was agreed to work towards a common proposal that will be discussed at the next SC27 meeting in October 2017 in Berlin. CREATE-IoT intends to be active in this new standard, considering the input from the IoT large scale projects.

ISO activities on Smart Cities - Smart cities standardisation activities are taking place in ISO/IEC JTC1/WG11 and in ISO/IEC JTC1/SC27 on privacy. WG11 deals with framework standards such as ISO 30145-1 (Smart city business framework), ISO 30145-1 (Smart city business framework), ISO 30145-3 (Smart city engineering framework) or ISO 30146 (Business indicators). SC27/WG5 is carrying a study period on privacy in smart cities. During the meeting in April 2017, it was agreed to discuss jointly with WG11 the preparation of a new work item proposal on privacy management guidelines for Smart cities. CREATE-IoT intends to be active in this new standard, taking into account the input from the IoT large scale projects.

ISO activities on Big Data - Smart cities standardisation activities are taking place in ISO/IEC JTC1/WG9 and in ISO/IEC JTC1/SC27 on privacy and security. WG9 deals with framework standards such is ISO Big Data - Definition and Vocabulary, and ISO 20547 Big data - Reference architecture. SC27/WG4 and SC27/WG5 focus on ISO 20547 Part 4 (Big data – Reference architecture – security and privacy fabric). CREATE-IoT is active on all these standards.

ISO activities on security-by-design and privacy-by design - These activities are taking place in ISO/IEC JTC1 SC27. All major standards on security of information systems come from this subcommittee, for instance ISO 27001 (ISMS requirements), ISO 27002 (ISMS Code of practice

for information security controls), or ISO 27005 (Information security risk management). All major standards on privacy also come from this subcommittee, for instance ISO 29100 (Privacy framework), ISO 29134 (Privacy impact assessment guidelines), ISO 29151 (Code of practice for PII protection), ISO 27550 (Privacy engineering), ISO 27551 (Enhancement to ISO/IEC 27001 for privacy management - Requirements). CREATE-IoT project representative is involved in 27550.

ISO activities on system and software engineering - These activities are taking place in ISO/IEC JTC1 SC7. All major standards on system and software engineering are published in this subcommittee in particular ISO 15288 (System life cycle). CREATE-IoT will monitor the on-going activities of this SC in order to see whether contributions have to be made in the area of Co-creation of IoT applications.

5.3.3 International Telecommunication Union (ITU)

ITU standardisation activities are managed in study groups (SG). There are two SG of interest, SG17 (security) and SG20 (IoT and applications, smart cities). SG17 is working closely with ISO SC27, for instance ISO 29151 is a joint SG17 – SC27 standard. During the SC27 meeting in April 2017, it was agreed to explore the possibility to start a new standard on privacy preference management. The focus proposed by ITU was on IoT and OneM2M. As a result, a study period on privacy preference management has been established. CREATE-IoT will be active in this study period.

5.3.4 Standardization of IoT platforms for Activity and Healthy Ageing

Standardization on the domain of Active and Healthy Ageing is an ongoing procedure. The European Innovation Partnership on Active and Healthy Ageing (EIP-AHA) is divided in Action Groups (AG) in order to work independently on different aspects of AHA. There are six AGs but the one of interest is AG C2 which focuses on independent living solutions. The objective of this AG is to develop interoperable independent living solutions including guidelines and business models through open standards considering two sides, application profiles and platform profiles. Through this partnership, many existing standards have been chosen to be utilized in the domain of AHA, i.e. standards for communication (Bluetooth, Wi-Fi), interoperability standards (W3C, HL7, Continua), along with standardization bodies (ISO and IEEE).

Active and Assisted Living (AAL) Programme is also expected to have an impact of the domain of AHA. This program aims to help in the improvement of the quality of life of elderly people by promoting the development of innovative products, services and systems for ageing well related to all aspects of human life. It also aims to trigger the interest and the participation of research groups but also SMEs in order to support the beginning of research, development and innovation in technologies and services for ageing well in the information society. Moreover, it aims to foster the exploitation of industrial opportunities providing an EU framework for developing common approaches and facilitating the localisation and adaptation of common solutions.

Last but not least, it is worth mentioning the W3C Web Accessibility Initiative (WAI) Guidelines include guidelines and techniques for making websites and web applications more easily accessible from disabled or elderly people. The most prominent standards are the WCAG2.0 and the UAAG.

In parallel, ITU has launched a focus group Focus Group on Data Processing and Management to support IoT and Smart Cities & Communities. The kick-off will take place in July 2017. CREATE-IoT plans to lead the work on security and privacy.

5.3.5 World Wide Web Consortium (W3C)

W3C is an international member funded community focussing on defining Web technology standards. Many of these are applicable to Web browsers, e.g. HTML, CSS, SVG, MathML, and

a suite of standards for browser APIs. Others relate to Linked Data and the Semantic Web, e.g. the Resource Description Framework (RDF), SPARQL, OWL and so forth. A third area involves the extensible markup language (XML), XML Schema, and standards for using XML for messaging (Web Services). W3C recently started work on standards relating to the IoT, starting with a Workshop in 2014, followed by launching a Web of Things Interest Group in early 2015 and a Working Group in 2017. W3C has a strong commitment to accessibility (one Web for all), internationalisation and security.

These areas are relevant to the IoT. Web browsers are available for a very broad range of devices and provide a basis for rich user interaction with distributed services. Linked Data provides a lingua franca for data and metadata in a variety of formats. XML is commonly used for data exchange, especially in the enterprise. Many of W3C's APIs make use of the JavaScript Object Notation (JSON).

W3C aims to counter the fragmentation of the IoT through a semantic interoperability framework that decouples applications from the underlying IoT standards, protocols, data formats and communication patterns, and enables discovery, composition and adaptation to variations across devices from different vendors. The goal is to reduce the costs and risks for developing IoT solutions, and create the conditions for unlocking the network effect for sustainable growth in open markets of services on a Web scale, just as we enabled through our standards for Web pages, which saw sustained exponential growth over many years.

The Web of Things is based upon W3C's work on Linked Data, and covers the interaction model exposed to applications in terms of the properties, actions and events for things, the semantic models describing the kinds of things and their relationships, and metadata relating to security, trust, privacy, service level agreements and other terms and conditions. The Web of Things, as an abstraction layer for applications, is complementary to IoT standards for lower layers in the abstraction stack, and can be used at the network edge, in the fog, in the cloud or with federated peer to peer architectures. This work is still in progress, and W3C is seeking contributions from organisations with an interest in realising the huge potential of the IoT.

6. CONCLUSIONS

6.1 Contribution to overall picture

The IoT has a huge potential, but is being hindered by non-interoperable platforms, standards and a rapidly evolving set of communications technologies. Standards enable interoperability, reduce costs and risks, and expand market opportunities through increased confidence in sustainability.

Interoperability is possible at different layers in the abstraction stack, starting with the communications technologies, e.g. wireless low power wide area networks. Above this, we find suites of IoT standards such as OCF, oneM2M and OPC-UA. These may use the same underlying protocols, but are not interoperable, creating friction in the market place, and contributing to vendor lock-in.

Higher still, we come to current work on abstraction layers for semantic interoperability. This seeks to decouple applications from the underlying IoT standards, protocols, data formats and communication patterns. This is analogous to the Internet itself as an abstraction layer that decouples network applications so that developers no longer need to know about the sequence of networks used to transport their data, nor the technologies that individual networks are using. The Internet and the Web unlocked the network effect and stimulated exponential growth of hardware, software and services with a transformative effect on lives and work.

The new challenge is to unlock the network effect for open markets of IoT based services. The IoT is still immature, and it is very timely to investigate promising approaches for enabling interoperability given that the wide range of requirements across different use cases and sectors will ensure that the IoT remains a complex mix of standards rather than coalescing into just a few. The key to progressing this, is to derive requirements from use cases from different sectors, and to look for common patterns and technologies that could form the basis for the new standards that are needed to address high level interoperability.

Promising ideas include the means to use programming language independent means to describe the interaction model for things exposed to applications as objects in the same execution space as the applications. Semantic models are also needed to enable communicating parties to agree on a shared meaning for the data they exchange. Here, the challenge is that different communities will produce different semantic models, raising barriers for services that need to span communities. This could be likened to having toll gates as each road passes through a village or town, resulting in barriers to free trade and a reduction in the overall economy.

Pre-normative activities need to explore promising directions, and just as importantly, to present these in ways that are easy to explain to other communities, thereby helping to build a shared understanding on what new standards are needed. The IoT Large-Scale Pilots are still at a very early stage, but if we are to build a common approach to interoperability, it will be important to collaborate on building this shared understanding across the Pilots.

6.2 Relation to the state-of-the-art and progress beyond it

Pre-normative activities need to examine where existing standards are inadequate, and to look at promising approaches to fill the gaps. Some potential examples include: platform independent approaches to identifying security principals, and to describing their trust relationships; work on platform and programming agnostic approaches to describing interaction models for things; or scalable solutions for semantic models and their application to smart services for adaptation to devices from different vendors and offering different capabilities.

Opportunities for progressing beyond the state-of-the-art include the potential role of context dependent mapping rules between the semantic models developed by different communities and

standards organisations. Going further out, there are opportunities for blending traditional approaches to semantic models with newer ideas from Artificial Intelligence and Cognitive Science. Deep Learning is essentially about perception, and there is a need for fresh work on cognitive reasoning for smarter approaches to cyber-physical control systems.

6.3 Impacts to other WPs and Tasks

The work on Task 06.02 is strongly coupled to WP 06 Task 06.01 which is focusing on the standards landscape and recommendations on standardisation strategies. WP 06 (Standardisation) is also coupled to WP 02 (IoT Large Scale Pilots Ecosystems Arena for Sharing Common Approaches), when it comes to open APIs or common methodologies, and to WP 05 (IoT Policy Framework - Trusted, Safe and Legal Environment for IoT), especially for standardisation requirements for security and privacy. Both WP 02 and WP 05 are therefore relevant to coordinating pre-normative activities in respect to the corresponding standards.

6.4 Other conclusions and lessons learned

The Activity Group 02 meeting held during IoT Week 2017 in Geneva proved a valuable occasion for getting to know more about the IoT Large-Scale Pilots, as well as other projects, especially the IoT-EPI projects and the work they have been doing on interoperability. At six months into the Large-Scale Pilots, there is still a lot of uncertainty about the detailed requirements on the platforms and standards. We can look forward to a much more detailed exchange of ideas as the Pilots progress further, and the challenges become clearer.

7. REFERENCES

[1] IoT European Large-Scale Pilots Programme, online at https://european-iot-pilots.eu/
[2] CREATE-IoT Description of Work Sections 1-3 and 4-5.
[3] CREATE-IoT D06.01 Strategy and coordination plan for IoT interoperability and standard approaches, June 2017.
[4] European Commission: ICT Standardisation Priorities for the Digital Single Market, April 2016.
[5] European Commission: EU Rolling Plan for ICT Standardisation, 2016.
[6] DIN/DKE German standardisation roadmap – Industry 4.0.
[7] AIOTI WG03 High Level Architecture.
[8] AIOTI WG03 Landscape for IoT SDOs and Alliances.
[9] AIOTI WG05 Living Environment for Ageing Well, 2015.
[10] AIOTI WG05 Wearables, 2015.
[11] AIOTI WG05 Farming and Food Safety, 2015.
[12] AIOTI Smart Cities, 2015.
[13] AIOTI WG05 Smart Mobility, 2015.
[14] Semantic Interoperability for the Web of Things, editor: Paul Murdock, 2016.
[15] Towards semantic interoperability between Internet of Things platforms, Ganzha et al. 2017, Systems Research Institute, Polish Academy of Sciences; Warsaw University of Technology (personal communication).
[16] STF 505 TR 103 376 "SmartM2M; IoT LSP use cases and standards gaps", 10/2016. https://docbox.etsi.org/SmartM2M/Open/AIOTI/STF505
[17] UNIFY-IoT D03.01 Report on IoT platform activities, October 2016.
[18] CREATE-IoT D01.01, IoT FA strategy and coordination plan, July 2017.
[19] O. Vermesan, J. Bacquet, et.al. Cognitive Hyperconnected Digital Transformation - Internet of Things Intelligent Evolution. ISBN 978-87-93609-11-2 (Hardback), ISBN 978-87-93609-10-2 (Ebook), River Publishers 2017.