COSMOS

Cultivate resilient smart Objects for Sustainable city applicatiOnS

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SEVENTH FRAMEWORK PROGRAMME

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1 Introduction

1.1 About this deliverable

An important goal for a project is to create acceptance among end-users and stakeholders. In order to achieve this, it is important to identify and perform standardization activities to increase the relevance and impact of the project outcome.

As a result, COSMOS plans to contribute to the most important European and International standardization organizations such as: World Wide Web Consortium (W3C) [W3C1], European Telecommunications Standards Institute (ETSI) [ETSI1], International Organization for Standardization (ISO) [ISO1], International Telecommunication Union (ITU) [ITU1], The Internet Engineering Task Force (IETF) [IETF1]. Experience from other projects as well as the trends in the field will be considered along with existing or currently proposed standards.

This document presents the activities taken in this direction and lists the foreseen steps considered in order to increase acceptance and relevance of the COSMOS project outcomes.

This is the third iteration on the project deliverables dedicated to standardization. We have followed an incremental approach and used D8.2.2 [COSMOS-D8.2.2] as the basis for this version of the deliverable. Some of the content in D8.2.2 is present in this version as well but updates were made whenever necessary.

1.2 Document structure

This deliverable has been written so that it can be consulted as a stand-alone document therefore, as mentioned above, parts of it are also found in D8.2.2 or in other relevant deliverables. References to the extended content are also marked accordingly.

The document is structured as follows. Chapter 2 begins with a short reiteration through the key Concepts aimed by the project and continues with a brief description of the current achievements and foreseen outcomes after year 2 of the project.

This is followed by a stakeholder analysis in Chapter 3 where relevant academic, industrial and standardization organizations are presented. Since we have not identified any changes in the stakeholder structure, the corresponding section is identical with its equivalent from D8.2.2. An update of the relevant standardization bodies and their activities is done in section 3.3 whenever applicable.

Chapter 4 is dedicated to standardization activities and presents the standards that were observed and considered during the design and development phase of the project along with the associated events, meetings and other activities. The update on the contribution to open-source projects and other relevant organizations as well as the adherence to standards (component wise) is also presented in this chapter.

A summary is provided in Chapter 5.

This is a public deliverable, therefore it is meant to be read as a stand-alone document without prior knowledge about the project goals and proposed solution or about relevant standardization bodies and standards. As a result, some content from the projects Description of Work document is reiterated along with a brief description of the relevant standardization bodies and standards.

2 COSMOS concepts and expected outcomes

2.1 Key concepts of COSMOS

COSMOS aims at developing an IoT framework where:

- Things are able to learn based on others experiences.
- Situational knowledge acquisition and analysis mechanisms make things aware of conditions and events affecting their behavior.
- Adaptive selection approaches facilitate to manage the uncertainty and volatility introduced due to real-world dynamics.
- Decentralized management mechanisms in IoT based systems allowing applications to exploit increasing amount of interconnected things.
- Socially-enriched coordination will consider the role and participation scheme of things in and across networks.
- Management decisions and runtime adaptability will be based on things security, trust, administrative, location, relationships, information, and contextual properties.
- End-to-end security and privacy, with hardware-coded security approaches for security and privacy on storage

2.2 Achievements and foreseen outcomes

COSMOS in Y3 has provided more abstracted implementations to support on the one hand augmented sequences of operations, such as the Smart Events flows and the Social autonomic apps, including tools and mechanisms to harvest and analyse data that lead to extended knowledge acquisition and awareness. Additionally the reliability and volatility of the various devices is addressed by developing methods to dynamically monitor Thing attributes, so as to promote mechanisms for failure and complex event detection.

COSMOS will also provide mechanisms for privacy and consent management, following the release of data that is incorporating user requirements, as well as fuzzification of data values for better masking of critical attributes such as location features. Software implemented methods will ensure the filtering of sensitive data. This will be achieved by the use of software Privelets and the Consent management FC, integrated into COSMOS. In addition, safeguarding data privacy will be accomplished, by both hardware and software approaches to security in both communication of Things as well as storage of data.

The COSMOS approach to handling large volumes of data, generated by the real time applications, is to develop new mechanisms for data analysis, interplay of computation and storage, which lead to the approaches of computation, either close to the source, or close to the storage. Social behaviour of Things is monitored and rated, while Trust is evaluated and linked to the solutions offered by the Things in their counterparts of the social network. Finally, mechanisms will be provided, which allow Things to react in an autonomous and predictive way. All such autonomous functionalities will be a joint effort of the Situation Awareness (SAw) and Planner FCs, which along with their reliance in common standards of communication like the newly introduced MQTT, can communicate and create chains of Complex Event Detection as well as individual self-handling.

3 Stakeholder analysis

We have identified the following categories of stakeholders relevant for both the design and development stage of the project as well as for the exploitation. Stakeholders are relevant for drawing the requirements of the COSMOS platform or acting as a reference points. They are also important since the proper positioning of the project increases the chances of a better exploitation of the results.

3.1 Research and academia stakeholders

The *Global Standards Initiative on Internet of Things* (IoT-GSI) [ITU2] promotes a unified approach in ITU-T for development of technical standards (Recommendations) enabling the Internet of Things on a global scale. ITU-T Recommendations developed under the IoT-GSI by the various ITU-T Questions - in collaboration with other standards developing organizations (SDOs) – will enable worldwide service providers to offer the wide range of services expected by this technology. IoT-GSI also aims to act as an umbrella for IoT standards development worldwide.

The *World Wide Web Consortium* (W3C) [W3C1] has initiated the *Semantic Sensor Networks Incubator Group* (SSN-XG) [SSN-XG1] to develop the *Semantic Sensor Network* (SSN) ontology which can model sensor devices, systems, processes, and observations. The Incubator Group has now transitioned into the Semantic Sensor Networks Community Group.

The OGC's *Sensor Web Enablement* (SWE) standards enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useable via the Web. SWE standards are developed and maintained by OGC members who participate to the OGC Technical Committee's Sensor Web Enablement Working Group.

IEEE P2413 [P2413], would form a framework for interoperability among connected devices and related applications in home automation, industrial systems, telematics and all other sectors that are expected to use IoT in the coming years. While leaving room for differences across those industries, the standard would allow for sharing of data across IoT systems. The P2413 Working Group, doesn't want to replace existing IoT groups. Rather it aims to create a standard architecture so IoT systems for all industries can work together. So far the most advanced contributions to the P2413 group are heavily inspired from the IoT Architectural Reference Model as released by the IoT-A project in late 2013 and then maintained by the IoT Forum; In particular Siemens is pushing their "customised" version of the ARM to this group.

3.2 Industrial stakeholders

The following sections describe the relation of COSMOS with different industrial stakeholders.

3.2.1. Service providers

Service providers are always interested in solutions, both hardware and software, which support innovative services and whose time to market is reduced. COSMOS will integrate components which will favor not only quick application development and deployment but also that of monitoring and adaptation capabilities, critical for providing high quality reliable services.

3.2.2. Device manufacturers

One of the challenges, which device manufacturers face when developing devices meant to be integrated by solution integrators, is in providing ready-to-use hardware platforms with minimum development effort. The trend is to adhere to well-known standards or to support emergent ones, in order to provide an additional selling point in comparison to their competitors. COSMOS will ease application development and hardware integration by proving facile means of exposing and using data from sensors and actuators.

Also, through the hardware coded security features COSMOS should appeal device manufactures which are interested in incorporating security features into their devices.

3.2.3. Mobile network operators

Virtual Entities (VE) are exposed using both fixed and mobile internet connections, often in harsh environments from both the traffic and accessibility perspective. Access to VE data, managing the VE network and its load on large scale deployments is only possible when the support between the network operators and COSMOS platform providers is mutual.

Network operators could also exploit the potential of developing new services for their subscribers by using COSMOS VE data exchange mechanisms. Data can be exchanged either through the message bus communication channels or through the semantically annotated REST interfaces.

3.2.4. Solution Integrators

Solution integrators are among the stakeholders who are interested in both hardware as well as software aspects of a solution. From the hardware perspective, one of the things which is often considered is how software is deployed on the devices. Hardware needs to be easily deployed and configured, with minimum development effort. The same applies nowadays to software; integrators prefer off-the-shelf software packages which only require little integration effort and less development. COSMOS intended to facilitate such integration since VEs, once deployed, should be easily used in a variety of scenarios with a minimum effort.

On the other hand, COSMOS should be aware of the requirements facing solution integrators since they are those in close relation with software developers, customers or service providers.

3.2.5. Software developers

Software developers are involved in writing the code exposing the VEs as well as integrating them into applications or other software components. It is therefore crucial that interface specifications, design patterns, and other reusable components provided by COSMOS are well described, easy to understand and to implement and, finally, that additional development effort is reduced as much as possible.

Direct feedback from software developers is needed in order to align COSMOS development with the developers' expectations.

3.3 Standardization bodies

This section describes the standardization bodies whose activities are relevant to COSMOS. It includes the descriptions and the missions of these organizations as they state them as well as the possible impact to the work performed in COSMOS or to the existing and new standards.

3.3.1. The World Wide Web Consortium

W3C is an international community that develops standards, protocols and guidelines to support the long-term growth of the Web. W3C has built several working groups to write technical reports which are used to promote the development of standards based on community consensus. These groups facilitate the exchange of innovative ideas and concepts.

COSMOS will follow the work of Semantic Web Interest Group which includes W3C Members and non-Members targeting the development of innovative Semantic Web applications based on W3C's Semantic Web technologies (RDF, OWL, SPARQL, etc.).

W3C also includes a group, Semantic Sensor Networks Incubator group (SSN-XG), the goal of which is to develop a sensor description ontology and to provide guidelines for semantic mark-up in Semantic Sensor Networks. A result of the group's work is SSN-XG, a sensor ontology that describes sensors from a device, platform and operational perspective.

W3C has shown also direct interest in the IoT field through their Web of Things at W3C Interest Group [WoT] which shows many similarities with the concepts proposed by COSMOS.

3.3.2. Internet Engineering Task Force

The Internet Engineering Task Force (IETF) is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual.

The process of creating an Internet Standard is straightforward: a specification undergoes a period of development and several iterations of review by the Internet community and revision based upon experience, is adopted as a Standard by the appropriate body and eventually published. In practice, the process is more complicated, due to (1) the difficulty of creating specifications of high technical quality; (2) the need to take into consideration the interests of all of the affected parties; (3) the importance of establishing widespread community consensus; and (4) the difficulty of evaluating the utility of a particular specification for the Internet community.

The goals of the Internet Standards Process are:

- technical excellence;
- prior implementation and testing;
- clear, concise, and easily understood documentation;
- openness and fairness; and
- timeliness.

The IETF Constrained RESTful environments (CoRE) Working Group has done the major standardization work for the REST protocol. In order to make it suitable to IoT and M2M applications, various new functionalities have been added. The core of the protocol is specified in RFC 7252 [RFC7252], important extensions are in various stages of the standardization process

Constrained Application Protocol (CoAP) is a software protocol intended to be used in very simple electronic devices that allows them to communicate interactively over the Internet. It is particularly targeting small low power sensors, switches, valves and similar components that need to be controlled or supervised remotely, through standard Internet networks. CoAP is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity. Multicast, low overhead, and simplicity are extremely important forIoT and M2M devices, which tend to be deeply embedded and have much less memory and power supply than traditional internet devices have. Therefore, efficiency is very important. CoAP can run on most devices that support UDP or a UDP analogue.

IETF CoRE - Framework for resource-oriented applications intended to run on constrained IP networks

The following IETF working groups has been identified as relevant for COSMOS:

- **roll:** Routing Over Low power and Lossy networks;
- **dice:** DTLS in Constrained Environments (DTLS stands for Datagram Transport Layer Security);
- **core:** Constrained RESTful Environments;
- **6lo:** IPv6 over Networks of Resource-constrained Nodes;
- **ace:** Authentication and Authorization for Constrained Environments;
- **homenet:** Home Networking;
- **6man:** IPv6 Maintenance (6man);
- **dnssd:** Extensions for Scalable DNS Service Discovery.

3.3.3. ITU Telecommunication Standardization Sector

The ITU Telecommunication Standardization Sector (ITU-T) is one of the three sectors (divisions or units) of the International Telecommunication Union (ITU); it coordinates standards for telecommunications.

The following relevant groups have been identified:

- Internet of Things Global Standards Initiative (IoT-GSI);
- Joint Coordination Activity on Internet of Things (JCA-IoT);
    - networks aspects of identification of things, and ubiquitous sensor network (USN);
    - maintains list of approved IoT international standards and work in progress;
- ITU-T Study Group 17 - security of applications and services for the Internet of Things (IoT);
- ITU-T Focus Group on Smart Sustainable Cities (FG-SSC);
- Open platform for smart city stakeholders, non-governmental organizations, ICT organizations and consortia to exchange knowledge in the interests of identifying the

standardized frameworks needed to support the integration of ICT services in smart cities.

The evolution of the work in the different Focus groups whose activities are related to the ones developed in COSMOS is presented in different documents released by each group. After the analysis of their content and considering that technical inputs are following IoT-A reference architecture, it is important to highlight the contributions done by these two documents generated by the Smart Sustainable Cities Focus Group.

The first document is “Smart sustainable cities: An analysis of definitions” [ITU-T1] released in October 2014. The report was created with “the aim of establishing a concrete definition for smart sustainable cities which can be used worldwide”. The text includes the key words that have to be considered while evaluating Smart City deployments and also the different criteria and attributes of the key aspects evaluated. The second document whose content directly applies over COSMOS progress is “An overview of smart sustainable cities and the role of information and communication technologies” [ITU-T2]. It contains the main definition of what ITU understand by Smart and Sustainable City, the text describes the role of ICT technologies in the process of building such cities and how they should react versus the different operational conditions that can suffer a city.

3.3.4. OPC Foundation

OPC [OPC1] is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries. It is platform independent and ensures the seamless flow of information among devices from multiple vendors. The OPC Foundation is responsible for the development and maintenance of this standard.

OPC technologies were created to allow information to be easily and securely exchanged between diverse platforms from multiple vendors and to allow seamless integration of those platforms without costly, time-consuming software development.

Initially, the OPC standard was restricted to the Windows operating system. As such, the acronym OPC was borne from OLE (Object Linking and Embedding) for Process Control. These specifications, which are now known as OPC Classic, have enjoyed widespread adoption across multiple industries, including manufacturing, building automation, oil and gas, renewable energy and utilities, among others.

Along with the introduction of service-oriented architectures in manufacturing systems came new challenges in security and data modelling. The OPC foundation developed the OPC UA specifications in order to address these needs; they did, at the same time, provide a feature-rich technology open-platform architecture that was future-proof, scalable and extensible.

These new OPC specifications provide a lot of similarities with the concepts and applications from the IoT field therefore COSMOS will explore the possibility to bridge these two domains (industrial and IoT oriented) in order to increase their interoperability.

A number of recent reports and articles such as [OPCUA1], [OPCUA2 or] [MicrosoftIoT] are dedicated to this topic and present the similarities and the cross-usage potential between these two domains.

Since OPC-UA follows the Service Oriented Architecture paradigm, COSMOS VEs can use data exposed through OPC-UA endpoints if these are properly annotated in the VE registry.

3.3.5. European Telecommunications Standards Institute

The European Telecommunications Standards Institute (ETSI), produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.

ETSI is a not-for-profit organisation which bridges manufacturers, network operators, national administrations, service providers, research bodies, user groups and consultancies. It has more than 750 ETSI member organizations drawn from 63 countries world-wide.

The organization has standardised the Global System for Mobile communications (GSM) cell phone system and is currently working on European telecommunication standards such as HiperLAN or TETRA.

One of ETSI's Technical Committees is TC M2M which is focused on machine-to-machine communication with limited or no human intervention. The topics of the TC include the middleware layer with various application service and specific business-processing engines for any devices capable of replying to requests for data.

COSMOS will explore the concepts and ideas proposed by TC M2M in the context of VE interactions since VEs are expected to enjoy lot of autonomy.

4 Standardization activities

4.1 Standards to observe and consider

The following sections list a number of standards which are going to be observed and considered in the development of Cosmos, besides those already mentioned. These descriptions are mainly excerpts from the publicly available descriptions and contain the key aspects which are relevant for COSMOS. The standards are highly relevant for COSMOS development and this list will be revised if needed during the project.

4.1.1. Industrie 4.0

In less than a decade we have witnessed an explosive increase in the volume of data being produced and consumed worldwide. If, in 2005 the amount of data across the globe was estimated to 130 exabytes, in 2012 this values has increased to 462 exabytes and the forecast for 2020 is of 14,996 exabytes.

As a result of the widespread digitalization covering all aspects of human activities, the industry field has also been affected by the rapid development of the data driven technologies.

The emergence and evolution of cyber-physical systems, IoT and cloud computing, lead to what is now dubbed as the fourth industrial revolution.

Although not a standard, Industrie 4.0 [Industrie4.0] is the answer to these rapid developments. As an initiative of the German government which targets the computarization of manufacturing processes, it promotes a set of recommendations and design principles for new or updated industrial developments. The goal is to achieve an increase in productivity and reduced time to marked values by flexible production means. This would be obtained by providing factories with self* capabilities (self-optimization, self-configuration, self-diagnosis, etc.) extended interoperability, information transparency and enrichment as well as advanced technical support for the employees.

These capabilities are also found in different forms in various components developed by COSMOS. Not only some derivates of the components have been directly used by industrial partners into Industrie 4.0 scenarios, but they also have the potential to provide bridges between the industrial field (production) and consumer scenarios (after sales monitoring, feedback and support).

As part of the Industrie 4.0 initiative, Siemens CT has used a tailored version of the semantic registry core into one of its internal projects. At the time this document was edited, work was ongoing for the exploration of semantic bridges between Industrie 4.0 applications and consumer IoT applications such as those proposed by COSMOS.

4.1.2. IEEE P2413 – Standard for an Architectural Framework for the IOT

The architectural framework defined in this standard will promote cross-domain interaction, aid system interoperability and functional compatibility, and further fuel the growth of the IoT market. The adoption of a unified approach to the development of IoT systems will reduce industry fragmentation and create a critical mass of multi-stakeholder activities around the world.

This standard 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.

As said earlier, current discussion are driven by the work achieved by the FP7 IoT-A project. Indeed COSMOS is already following the Architectural Reference Model [ARM] and related methodology.

The P2413 working group has met two times during 2015 in order to collect and analyse inputs from other groups that have worked on reference models (ITU-T, ISO/IEC, IoT-A, etc.) and to establish liaisons with the other relevant organizations: IIC, oneM2M, ISG/LTN, ETSI TG28, ISO/IEC JTC 1/WG 10, and IEEE 802.24

Besides following the IoT-A reference model, which is one of the models considered by the P2413 working group, COSMOS has also considered extending its semantic model based on the P2413 recommendations for Universal Thing Description. At the time this document was created P2413 din not publicly provided yet a reference model for things description.

4.1.3. ISO 37120 – Sustainable development of communities

This standard defines and establishes methodologies for a set of indicators to steer and measure the performance of city services and quality of life [ISO37120]. It follows the principles set out and can be used in conjunction with the under development standard ISO 37101 - Sustainable development in communities - Management systems - General principles and requirements, when published, and other strategic frameworks.

ISO 37120:2014 is applicable to any city, municipality or local government that undertakes to measure its performance in a comparable and verifiable manner, irrespective of size and location.

Since the standard is focused on establishing such methodologies there is no direct architectural impact on COSMOS.

Nevertheless, most of the IoT use cases and applications are targeting the urban environment and many involve collecting raw data from the city which could be translated, after an appropriate processing stage, into key performance indicator for the city.

The architecture of COSMOS is meant to be generic and to support a multitude of scenarios. Its ability to facilitate data collection and processing along with the semantic description support recommend it for developing monitoring solutions which could adhere to the ISO 37120 standard.

COSMOS will explore the use of the standard with regards to its transportation section, as part of the Madrid use case scenario.

4.1.4. ISO 27001 – Information technology— Security techniques — Information security management systems — Requirements

An Information Security Management System (ISMS) is a systematic approach to managing sensitive information in order for it to remain secure and known only to authorized parties. It includes people, processes abut also IT systems by applying a risk management process. The main components of ISO27001 family are:

- ISO/IEC 27001 [ISO27001] is the best-known standard in the family providing requirements for an ISMS.
- ISO/IEC 27001:2013 specifies the requirements for establishing, implementing, maintaining and continually improving an information security management system within the context of an organization. It also includes requirements for the assessment and treatment of information security risks tailored to the needs of the organization.

The ISO27001 standard has undergone major refactoring with an updated version being released in late 2013/early 2014, after 2 years of work. Along the typical changes and content updates, the standard has received a new setup. The old format has been replaced by a plan-do-check-act approach which also integrates rick management. The new format has been synthesized in the so called Annex SL. This new format comes to embrace commonalities between already existing and partially overlapping discipline standards. It removes redundant information for companies wishing to embrace more than one standard within the same family. Still ISO27001 retains its "controls and objectives" approach in order to facilitate companies the adherence to the standard. The new format comes as mandatory as of January 2016. The new ISO/IEC 27001:2013 is intended to be applicable by organizations, regardless of type, size or nature. Also, the new format of the ISO27001 standard set a new trend for all ISO releases - starting with 2015 all standards will adhere to the new format in order to ease their implementation.

4.1.5. ISO/IEC 20922 - Information technology -- Message Queuing Telemetry Transport

MQTT was developed within OASIS consortium, a non-profit organisation that drives the development, convergence and adoption of open standards for the global information society. MQTT 3.1.1 has now become an ISO / IEC standard [ISO-MQTT2016].

MQTT has become one of the most popular IoT protocols due to it is light weight, openness and simplicity. The protocol runs on TCP/IP and its key functionalities are:

- Publish/subscribe messaging scheme enabling one to many distribution of information.
- Messaging transport agnostic of the data included in the messages.
- Different QoS to set data messages priority and requirements. These modes are *at least once*, *at most once* and *exactly once.*

The main features of the protocol are further described below in section 4.2.3 since OASIS was in charge of its development.

4.1.6. ISO/IEC 19086 - Information technology - Cloud computing - Service level agreement (SLA) framework and technology

Service Level Agreements have been acknowledged as a means to achieve increased and guaranteed Quality of Service regarding offered resources related to Telecom or Cloud services. Standardization of the description of these agreements is currently active in ISO 19086 series of draft standards, that mainly relate to Cloud based services, however a large majority of them are also used in conjunction with IoT related applications and platforms and will be even more included in the case of Edge computing in cooperative paradigms. Metrics in the case of Cloud computing have been more or less obvious, including mainly availability in various forms. However in the case of IoT, the diversity of the field (as well as the fact that in many cases the offering of the data is performed via Cloud services), requirements may be different or more demanding in terms of expressivity.

4.1.7. 3GPP Machine Type Communications

The 3rd Generation Partnership Project (3GPP) [3GPP] unites six telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, 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 project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security, quality of service - and thus provides complete system specifications. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks.

3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level.

The Four Technical Specification Groups (TSG) in 3GPP are:

- Radio Access Networks (RAN);
- Service & Systems Aspects (SA);
- Core Network & Terminals (CT);
- GSM EDGE Radio Access Networks (GERAN).

The Working Groups, within the TSGs, meet regularly and come together for their quarterly TSG Plenary meeting, where their work is presented for information, discussion and approval.

4.1.8. IEEE Smart Cities Group

IEEE has created a specific working group on Smart cities [IEEE-SC] since world population is constantly growing and cities are expected to group most of citizens. A smart city aims at bringing together technology government and society to enable a sustainable end efficient use of resources.

The domains that are considered of interest for this working group are:

- Smart Buildings
- Smart Living
- Smart Transportation
- Smart Energy
- Smart Communications
- Smart Networks
- A Self-Aware Digital Hub
- Environmental Awareness (i.e. changing weather conditions; human defined changes)

This WG periodically releases technical documents that cover novel research and reference results from different smart city initiatives.

COSMOS is closely following the work of this WG, the activities of this young group are related with other IEEE groups like IEEE IoT [IEEE-IoT] where proposals for IoT scenarios are being now proposed. COSMOS has presented a proposal for including Smart Transportation one developed in Madrid because it is covering some of the hot topics already identified by both WGs.

4.1.9. IEEE-SA IoT Ecosystem Study

The main objective of this group is to recognize stakeholders in key regions of the world to create an IoT Ecosystem Study. The study comprises three principal areas: Market, Technology, and Standards, along with an examination of the role of academia and research and the importance of user acceptance.

The next big event that this WG is preparing is the Internet of Things World Forum. COSMOS has submitted a joint paper among several partners, although final result has not been already provided. The audience of the conference covers several groups of relevant stakeholders in the IoT scenario.

COSMOS has contributed to the work developed in this WG exploiting the synergy between the previous IEEE Smart Cities WG and this. The proposal submitted focused on the improvement of Smart Transportation system in cities based on the technology that is being developed under the framework of COSMOS project.

4.2 Other relevant organizations

4.2.1. IoT Forum

COSMOS is complying as much as possible with the IoT Architectural Reference Model and associated methodology as far as COSMOS Architecture is concerned (as handled in WP2/Task 2.3). The IoT ARM is the main result of the FP7 EU project IoT-A. The ARM has already been adopted (or is being adopted) by many FP7 and SmartCity projects.

In the context of WP2 we will provide feedback to the Working Group “Architecture and interoperability” of the IoT Forum [IoTForum1] which has pledged sustaining and evolving the IoT ARM after the completion of the IoT-A project (late November 2013). This feedback will relate to the usability and possible improvements.

WG 2 of the Forum will compile a document that gives some return of experience of applying the ARM to concrete project (COSMOS being one of those projects).

4.2.2. European Computer Manufacturers Association

The European Computer Manufacturers Association (ECMA) [ECMA] is an industry association founded in 1961. It is driven by industry to meet the needs of industry, generating a healthy competitive landscape based on differentiation of products and services, rather than technology models, generating confidence among vendors and users of new technology. ECMA facilitates the timely creation of a wide range of global ICT and Consumer Electronics standards, e.g. for programming languages, ECMAScript, Business Communications, Near Field Communications, High Rate Wireless Communications, Electromagnetic Compatibility (EMC) etc.

COSMOS uses the JSON format for data transfers among components as well as among VEs. This format is an ECMA standard, namely ECMA-404. We are closely monitoring this standard as well as a potential release of a standardized JSON schema format.

4.2.3. Organization for the Advancement of Structured Information Standards

The Organization for the advancement of Structured Information Standards (OASIS) [OASIS] is a not-for-profit consortium that drives the development, convergence and adoption of open standards for the global information society. OASIS promotes industry consensus and produces worldwide standards for security, Internet of Things, cloud computing, energy, content technologies, emergency management and other areas. OASIS open standards offer the potential to lower cost, stimulate innovation, grow global markets, and protect the right of free choice of technology. The consortium has more than 5,000 participants representing over 600 organizations and individual members in more than 65 countries.

The Message Queuing Telemetry Transport (MQTT) [MQTT1] protocol is an open and lightweight publish/subscribe protocol designed specifically for M2M and mobile applications. It is useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium [MQTT2].

MQTT supports many features including:

- The publish/subscribe message pattern to provide one-to-many message distribution and decoupling of applications;
- A messaging transport that is agnostic to the content of the payload;
- The use of TCP/IP to provide basic network connectivity;
- Three qualities of service for message delivery:
    - "At most once", where messages are delivered according to the best efforts of the underlying TCP/IP network. Message loss or duplication can occur. This level could be used, for example, with ambient sensor data where it does not matter if an individual reading is lost as the next one will be published soon after;
    - "At least once", where messages are assured to arrive but duplicates may occur;
    - "Exactly once", where message are assured to arrive exactly once. This level could be used, for example, with billing systems where duplicate or lost messages could lead to incorrect charges being applied;
    - A small transport overhead (the fixed-length header is just 2 bytes), and protocol exchanges minimised to reduce network traffic;
    - A mechanism to notify interested parties to an abnormal disconnection of a client using the Last Will and Testament feature.

OASIS Technical Committees under the category of IoT/M2M are developing MQTT standard as presented above. COSMOS is using this messaging protocol which fulfils part of the requirements that have been identified by the project. Although message bus will evolve to the usage of other technologies, OASIS progress will be considered for assuring the interoperability of COSMOS solutions with MQTT.

During the third year of the project the work developed by OASIS in the development of MQTT standard has been accepted and adopted by ISO/IEC. MQTT version 3.1.1 became ISO/IEC 20922:2016 standard.

4.2.4. EPC global

EPCglobal is a joint venture between GS1 (formerly known as EAN International) and GS1 US (formerly the Uniform Code Council, Inc.). It is an organization set-up to achieve worldwide adoption and standardization of Electronic Product Code (EPC) technology.

As stated by EPCglobal [EPC1]: "EPCglobal is leading the development of industry-driven standards for the *Electronic Product Code* (EPC) to support the use of Radio Frequency Identification (RFID)" so the main focus of the group currently is to create both a worldwide standard for RFID and the use of the Internet to share data via the EPCglobal Network.

EPCglobal's board of governors includes representatives from EPCglobal, GS1, Auto-ID Labs, Cisco Systems, DHL/Exel Supply Chain, Haier Group Company, Johnson & Johnson, Kimberly-Clark Corporation, LG Electronics, Lockheed Martin Corporation, METRO AG, Novartis Pharma AG, Office of the Secretary of Defense, Procter & Gamble, Sony Corporation, The Dow Chemical Company and Wal-Mart Stores, Inc.

Although the scope of the EPCglobal is narrower than the current IoT field (aiming only on RFID-based mechanisms), it might be worth monitoring EPCglobal and considering possible leverage of the standards outside the RFID domain.

4.2.5. IEEE Standards Association

The IEEE Standards Association (IEEE-SA) [IEEE-SA] is an organization within IEEE that develops global standards in a broad range of industries, including: power and energy, biomedical and health-care, information technology, telecommunication, transportation, nanotechnology, information assurance and many more.

IEEE-SA is a community rather than a governmental organization which is conducted by bodies which clearly do standardising work.

COSMOS follows the activities of several WGs as it has been already presented in the previous sections. The monitoring of standardization activities of IEEE includes deep technical groups like IEEE P2413, and also other WGs with a wider view of the technology or targeting specific applications.

4.2.6. European Research Cluster on the Internet of Things

The aim of European Research Cluster on the Internet of Things (IERC) [IERC] is to address the large potential for IoT-based capabilities in Europe and to coordinate the convergence of ongoing activities. It has created a number of activity chains in order to favour close cooperation between the projects addressing IoT topics and to form an arena for exchange of ideas and open dialog on important research challenges. The activity chains are defined as work streams that group together partners or specific participants from partners around well-defined technical activities that will result into at least one output or delivery that will be used in addressing the IERC objectives. Following activity chain are defined within IERC:

- **AC1** - Architecture approaches and open platforms
- **AC2** - Naming and addressing schemes. Means of search and discovery
- **AC3** - IoT innovation and pilots
- **AC4** - Service openness and interoperability issues/semantic interoperability
- **AC5** - Governance, Privacy and Security issues

- **AC6** - Standardisation and pre-regulatory research
- **AC7** - Cognitive Technologies for IoT
- **AC8** - Societal Impact and Responsibility in the Context of IoT Applications

Atos as project coordinator has provided inputs to the deliverable D1.2 of IERC AC3 cluster "Inventory of IERC tangible outcomes and showcasing plan – Summer 2015". This document contains the information of how the different technical components we are developing in the project fit in the framework of the innovative pilots Madrid, Camden and Taipei which are covered by the project. Since the document inputs were submitted by end of April, there is some information such TRL that will be refined in future versions.

4.2.7. Alliance for Internet of Things Innovation

The Alliance for Internet of Things Innovation (AIOTI) initiated by the European Commission and various relevant IoT players (industrial, research, academia and SMEs) in order to develop and support the dialogue and interaction among all the parties involved. AIOTI defines its main goal as *"the establishment of the AIOTI is the creation of a dynamic European IoT ecosystem to unleash the potentials of the IoT"*.

AIOTI has been divided in different working groups addressing some transversal issues in the IoT domain and others whose main focus is the boost of specific vertical domains. Figure 1 shows the AIOTI structure.

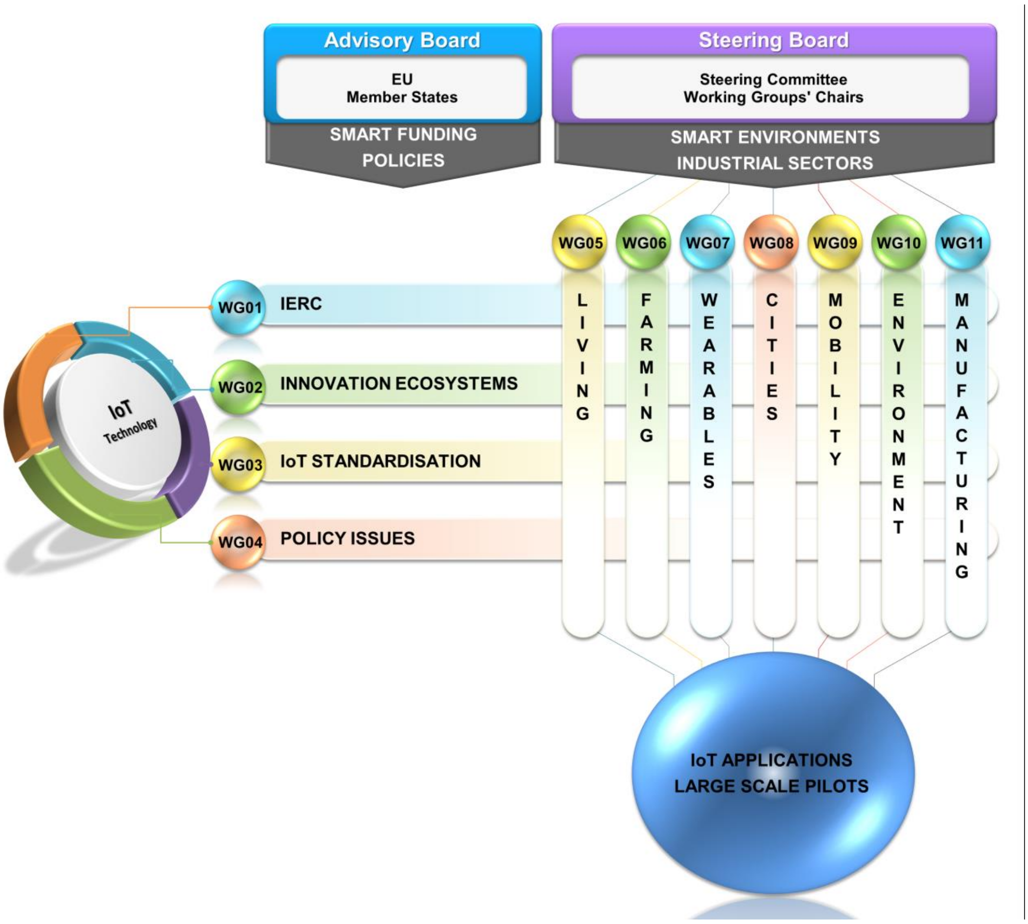


Figure 1 AIOTI structure [AIOTI]

AIOTI is expected to gather the different requirements identified in IoT and also groups already running such as IERC. The AIOTI will assist the European Commission in the preparation of future IoT research as well as innovation and standardisation policies.

COSMOS is following and participating in two main WG; WG2 – Innovation Ecosystems, and WG8 – Smart Cities. The documents that are currently under development establishes the key aspects that needs to be covered by Large Scale Pilots, WG2 focus on IoT domains, not specific vertical, and WG8 are elaborating recommendations with a clear focus on Smart Cities. One of the conclusions that can be derived from them is that and interoperability represents a must for AIOTI, COSMOS approach aligns with this view and the developments are conceived as use-case agnostic and from a generic point of view. During the third period of the project, COSMOS will actively contribute to this two WGs since COSMOS feedback can be very valuable for the identification of problems and opportunities in current IoT and Smart Cities deployments, and the other way around, the project can benefit from the collaboration of other members of AIOTI to increase the project impact.

4.3 COSMOS Adherence to Standards

Year 2 of the project has been focused on extending the COSMOS components and starting their integration which would allow developing the first project demonstrators. As in the first year of the project, adherence to known standards has been considered.

4.3.1. VE Registry

Virtual Entities are the key elements of COSMOS and are meant to facilitate the access to IoT Resources for solution developers. COSMOS has adopted the semantic technologies for supporting VE description.

The VE Repository as well as its VE Semantic Annotation tool are relying on the RDF and OWL standards as introduced by W3C.

Semantic description has been extended to other entities as well such as a more general Domain Specific Ontology (DSO) for Smart Homes that has information on things like House Insulation as well as information on the type of sensors being provided.

In the context of the DSO for Camden we identify attributes that can be described in Boolean fashion as well as those that can be summed up in a more enumerated way. Figure 2 displays the design of the DSO.

Those identifiers of Boolean fashion as mentioned previously are the mainly the signifiers of individual sensor existence, as well as the existence of types of insulation, heat meters and heating controls. Use of the Ontology can be made for any Smart Home scenario for future consideration with appropriate modifications in the form of enhancements. An example would be the Use Case of Taiwan, where there is need for Smart Home semantic description with a specific focus to electrical devices and energy consumption.

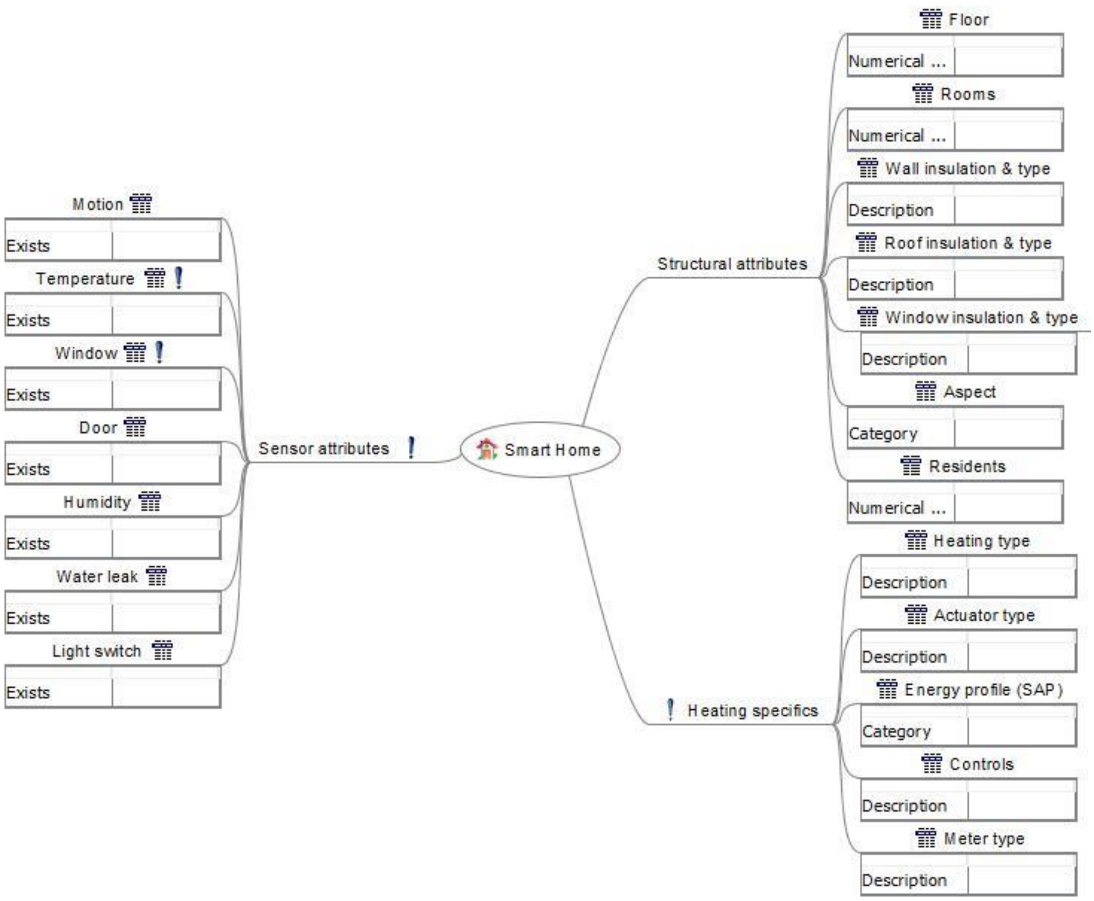


Figure 2: Smart Home Domain Specific Ontology Map

4.3.2. Hardware Cryptographic Accelerators

During the course of the project different hardware modules have been developed. These modules serve as the so-called root-of-trust for the COSMOS platform and are integrated in a FPGA platform device (the device of choice is Xilinx Zynq). The main components developed are:

- A cryptographic accelerator implementing the AES standard,
- a key agreement mechanism (i.e. Diffie-Hellman), elliptic curve based key exchange module and,
- a true random number generator exploiting the inherent minute differences that apprear during manufacturing of semiconductor devices.

The hardware cryptographic accelerator module is responsible for high-speed encryption and decryption of data payloads e.g. images taken by the bus surveillance cameras. The hardware cryptographic accelerator implements the functionality as per FIPS-197 [FIPS197]. As the standard specified fixed length key and data block sizes are specified, in this case both having a length of 128bits. Both development and verification (targeted verification with pre-generated stimuli) tasks adhered to the FIPS-197 standard in order to ensure full compliance. In order to test the hardware cryptographic module two sets of test vectors were used. The first test vector set was taken from FIPS-197 while the second set was generated using Crypto++ [Crypto] – an open source but certified crypto-library. The compliance to the standard is assured by usage of the FIPS-197 provided test vectors which help to identify any deviations. The standard not only provides the golden references but also guidelines on how to exhaustively perform testing and verification activities.

The Diffie-Hellman key exchange module, like the cryptographic accelerator, is a stand-alone hardware module which implements a key agreement protocol. The key agreement protocol is implemented according to NIST SP800-65A [NIST-SP800] standard using the elliptic curve parameters recommended by NIST [NIST]. The standard provides inputs with respect to the needed mathematical apparatus but also guidelines on how to perform performance oriented implementations. As the standard is software oriented we have adapted the inputs to hardware focused activities. An addition to the standard is the NIST provided annex which exemplifies the computational steps neded to implement the key agreement mechanism.

The true random number generator implements a function to generate a random stream of bits based on a naturally occurring physical phenomenon, in our case the noise of a simple silicon transistor. There are no standards in place for the generation of true random numbers but there are metrics used to verify the quality of the generated numbers. For verifying the output of the true random number generator we have used the NIST SP 800-22 [NIST-SP800-22] recommendations as well as their software suite. The NIST provided test suite evalues large quantities of data and provides metrics with respect to the quality of the generator. The test suite shall be used as a “minimum necessary” condition to be met by the random number generator.

The hardware modules are connected to the main system bus which is available in the platform FPGA device. The system bus of choice is AXI (Advanced eXtensible Interface) – a complex and high performance protocol. As the developed modules do not need such a highly complex interface, the APB (Advanced Peripheral Bus) protocol was selected as an interface. Thus a bridge between the two bus systems had to be developed. In order to provide full compliance with both interfaces, the AMBA protocol specification [AMBA] was used. AMBA (Advanced Microcontroller Bus Architecture), developed by ARM Holdings, is the de-facto standard in terms of hardware, inter-module, communication protocols. The standard presents both the protocol as well as basic information regarding possible hardware implementations of the proposed bus systems.

For requirements we have used FIPS-140-1 [FIPS140] which specifies security requirements which must be met by production-grade hardware and software components. These requirements have been considered during the development of the COSMOS security primitives in order to facilitate integration and further development activities.

4.3.3. Social Monitoring and Planner Components

The Social Monitoring component is responsible for monitoring social connections between VEs and to that end, uses a triple store with the semantic description of the numerous social relations between them. The Planner component makes use of semantic descriptions too for the technique of CBR and as such, both previously mentioned components adhere to the RDF and OWL standards of W3C.

After researching the possibility of using an already well-established Ontology in the components of Social Monitoring and Planner, it has been found that, most probably, none of the existing Ontologies offer what the components demand. Especially for the Social

Monitoring, the FOAF ontology was investigated, but could not offer solutions for social relations between VEs, as it is geared towards connections between individuals in social networks.

In fact, the decision to use semantic descriptors for these components has been strongly encouraged by the fact the key concepts of the platform, namely the VEs, are also semantically described using the same standards of representation.

In the case of the Planner, communicative connections established with the Message Bus are made using AMQP 1.0 which is a communication protocol standard (ISO/IEC 19464:2014) through the use of RabbitMQ as the technology implementing the Message Bus. However for year 2 NTUA has changed the approach into the more uniform MQTT Protocol which has been chosen as an OASIS standard as of revision 3.1.1. MQTT is a binary protocol emphasising lightweight publish / subscribe messaging, targeted towards clients in constrained devices. It should be noted that it has well defined messaging semantics for publish / subscribe.

The technology implementing MQTT is the Java library of Eclipse Paho and specific MQTT messaging nodes in Node-RED.

4.3.4. Experience Sharing Component

The Experience Sharing component implements communication and knowledge sharing between VEs. To this end, a RESTful implementation of this component's communication is used.

The project team is considering using JSON (open standard format ECMA-404) as the basic format for data exchange in all VE2VE and VE2Platform communications. While current implementations vary, future work is oriented to that end. During year 1 the FCs using JSON format are data of the Privelets component and Planner data received through the Message Bus. In the course of year 2 the Experience Sharing FC has also adopted the approach of JSON object communication.

Further work includes the investigation of a possible use of the JSON schema standard draft v4 (IETF), which while not yet a clear standard, is being actively monitored by NTUA, as a means to ensure data format compliance in communications. Initial implementation is being investigated for the Data Mapper.

Additionally during year 2 NTUA has investigated the use of the Apache Avro data serialization through JSON schemas, as is demanded by the Cloud Storage FC for the structure indication of the persistent storage of data. Sustained testing has been made in the case of the Camden Data Bridging component, into implementing as needed both JSON Schema v4 and Avro Schemas. Both schema types have been considered due to the multi target nature of data forwarding through the bridge towards Functional Components such as the SAw and the Planner as well as the Cloud Storage.

The Bridging itself as is defined in Node-RED is making use of Function nodes implementing JavaScript code. The coding inside these nodes follows the JavaScript Lint suggestion of coding style which although not a clear standard are maintaining a uniform style of coding, without fostering questionable coding practices.

4.3.5. CEP engine

The µCEP Engine provides native support to MQTT protocol. This messaging protocol has been selected due to its light and reliable nature. The final version accepted by under ISO/IEC 20922 on MQTT and related protocols are being followed by stream analysis developers, especially those ones under the categorization of IoT/M2M. Providing a native support of MQTT in a real-time CEP Engine is a key feature because it "provides a lightweight publish/subscribe reliable messaging transport protocol suitable for communication in M2M/IoT contexts where a small code footprint is required and/or network bandwidth is at a premium".

Not only µCEP instances are planned to be deployed in centralized environments, but also in distributed ones. In such sense, the overall scope of the deployment ranges from simpler to complex devices, forming part of heterogeneous networks of sensors and embedded devices, where COSMOS offers a single, efficient solution for data analytics close to the source.

4.4 Contribution to Open-Source projects

4.4.1. OpenStack Swift

In April 2012, IBM joined the OpenStack open source foundation as a founding and platinum member. The IBM Haifa Research team was the first to make major IBM contributions to OpenStack by contributing a volume driver for the IBM Storwize and SVC storage systems to OpenStack's Nova and Cinder. These drivers enable clients with IBM storage products to fully participate in OpenStack deployments, and serve as a platform for future functions being developed by IBM Research. Since then the team has been very active in the OpenStack community, continuously contributing to the community, serving as core members, and participating and presenting at the OpenStack Summits.

Particularly relevant to COSMOS are two of our presentations at the OpenStack Summit in Paris in November 2014. The first presentation, "Docker Meets Swift: A Broadcaster's Experience", presents the storlet mechanism which the IBM Haifa Research team developed for OpenStack Swift, and demonstrates how storlets can be used for media workflows and other scenarios. The storlets capability is being exploited by the COSMOS project.

The second presentation, "The Perfect Match: Apache Spark Meets Swift", focuses on the integration between Spark and OpenStack Swift, demonstrating the advanced models for executing Spark jobs directly on Swift objects. This capability will be exploited by the COSMOS project. This work also involves our open source contributions to the Apache Spark framework which enable OpenStack Swift to be a supported Apache Spark data store.

In April 2015, the IBM work on storlets was released to open source [StorletBlog, StorletGit]. This work was partially funded by the COSMOS research project.

4.4.2. Apache Spark

In June 2015, IBM announced a major commitment to Apache®Spark™, calling it potentially the most important new open source project in a decade that is being defined by data [IBM2015].

In October 2015, IBM presented "How Spark enables the Internet of Things : Efficient integration of multiple Spark components for Smart City use cases" at the Apache Spark Summit Europe [AS2015]. This presentation covers work done as part of the COSMOS project by IBM, the University of Surrey and ATOS.

4.4.3. Pinterest Secor

IBM is also in the process of contributing extensions to the open source Pinterest Secor project [Secor]. These extensions were developed in the COSMOS project in order to implement the Data Mapper, and include support of OpenStack Swift as an additional Secor target (other than Amazon S3).

4.5 Partner contribution to standardization activities

The following sections describe the partner contribution with regards to standardization activities, either from the observation or contribution perspective.

4.5.1. NTUA

In the context of Draft Standard ISO-19086-2, ICCS (focusing on the IoT domain) collaborates with the SLALOM project (focusing in Cloud SLA specifications and participating in ISO 19086 draft committee as a liaison) in order to provide input for SLAs that could be offered specifically for the IoT domain and scope and whether they can be described with the current modelling approach of the standard. COSMOS has offered the IoT viewpoint and concrete examples from the services offered within the COSMOS environment, resulting in the initial set of proposed metrics that are included in the following table:

IoT Domain Services	**Aspects per category**			
Sensing Services	Quality of Data Value	Sensitivity	Battery Life	Minimum Sample Interval
Data Delivery	Availability	Latency	Throughput	#users
Event Processing	Event reaction time	Computed Events per second	Size of Complex rule	
Intelligence /Prediction	% of error	Prediction Horizon	Response Time	
Encryption	Key bit size	Encryption Delay	Data block size	Encryption Algorithm Selection
Privacy	Field selection from data schema		Parametric Blurring of Values	

Table 1 - COSMOS proposed metrics (initial set)

Achieving the existence of standardized and machine understandable SLA descriptions could result in machine-based ranking and selection of IoT services and data, increase QoS and boost uptake of the respective IoT applications, or even extend to more time/quality critical ones (e.g. in the healthcare domain).

COSMOS survey results

The results from the COSMOS survey regarding IoT related SLA metrics has a number of useful conclusions. Initially the scope of the survey was deemed successful, since the need for having SLAs at the IoT level was considered as at least important by 75% of respondents. Sensing and data delivery services (as was expected due to the IoT context) were considered the more relevant for SLAs.

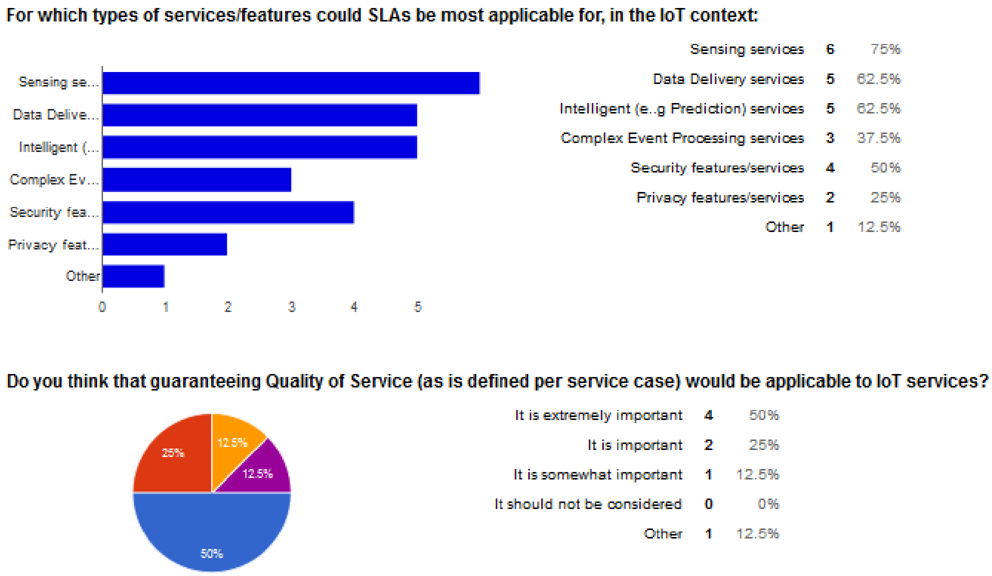
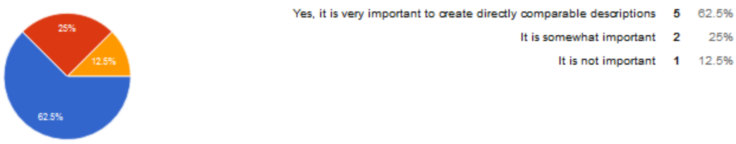


Figure 3 – COSMOS survey results I

Standardization of descriptions was also indicated as a must by 75% of the respondents

Do you consider that creating standardized, machine understandable descriptions would be beneficial for comparison of these services?



If you are supporting a related SLA at the moment, would you be interested to transform/evaluate your current SLA in the form proposed by SLALOM/ISO?

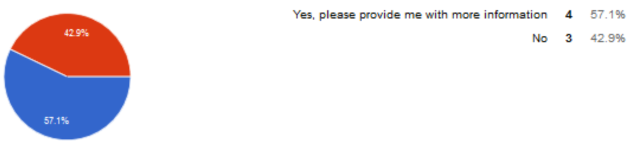


Figure 4 – COSMOS survey results II

Key needed attributes have also been identified per category, such as sensor capabilities, data availability and latency, while other more exotic features (such as prediction horizon for estimation services) were also acknowledged.

For some of these features (e.g. the ability to decide which fields would be forwarded), since they are static or handled through e.g. privacy&consent forms, no specific SLA description should be created. For other cases, such as availability, similar examples from Cloud services exist, so they will not be the main focus of our approach.

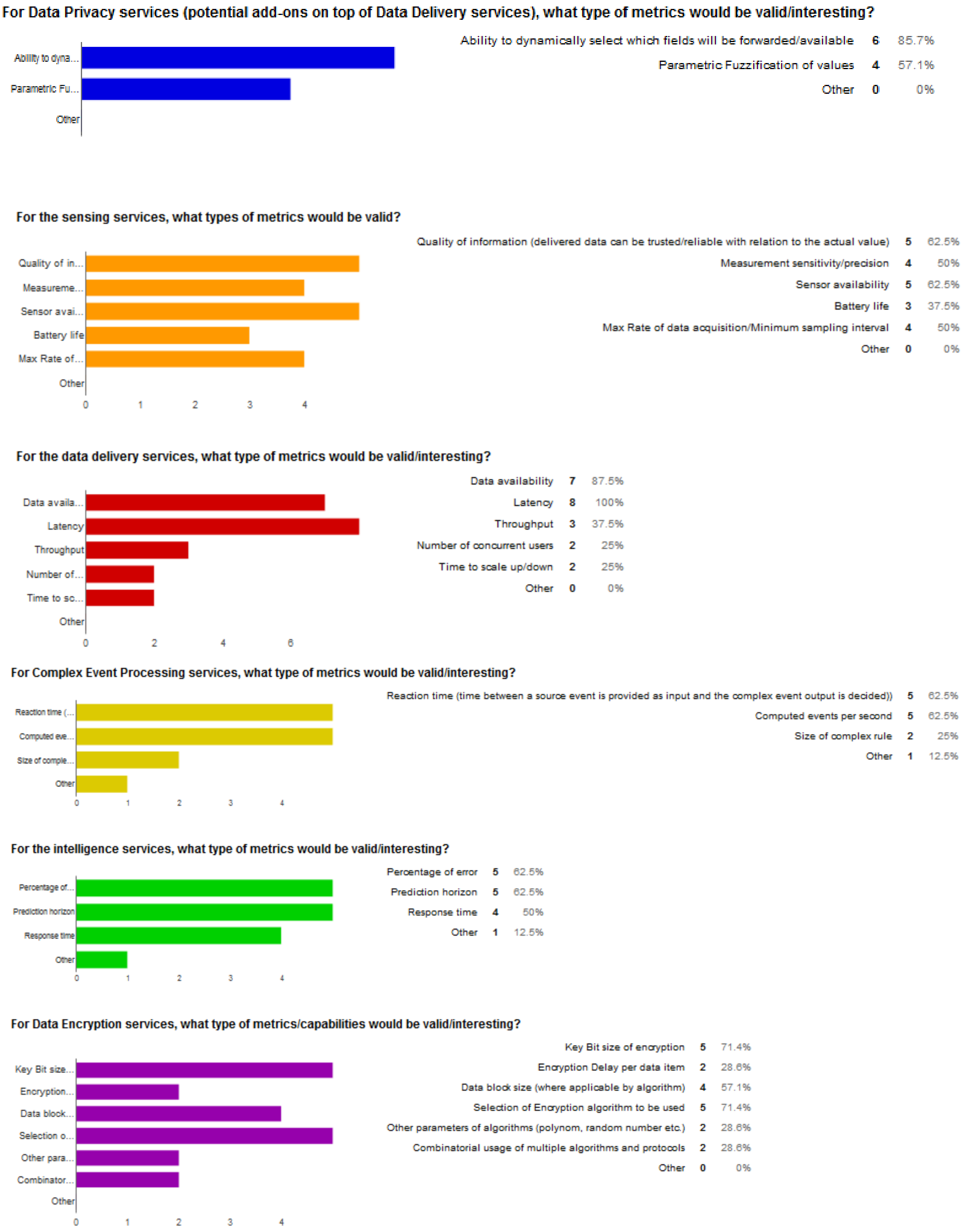


Figure 5 – COSMOS survey results III

Based on the results, the proposed metrics and categories (in green) appear in the following table:

IoT Domain Services	Aspects per category			
Sensing Services	Quality of Data Value	Sensitivity	Battery Life	Minimum Sample Interval
Data Delivery	Availability	Latency	Throughput	#users
Event Processing	Event reaction time	Computed Events per second	Size of Complex rule	
Intelligence /Prediction	% of error	Prediction Horizon	Response Time	
Encryption	Key bit size	Encryption Delay	Data block size	Encryption Algorithm Selection
Privacy	Field selection from data schema		Parametric Blurring of Values	

Table 2 – COSMOS proposed matrics (final set)

Example SLA candidates based on survey

In order to select 1-2 indicative examples from the IoT domain, the results from the survey were analyzed. Furthermore the goal was to select more exotic features and not ones typically found in all Cloud services such as availability.

For the type of services, sensing, data availability and prediction services were the most prominent ones. From these the features that were mostly interesting were:

<u>Sensing services</u>

- **Quality of information**: this is a feature that is a combination of the sensor base capabilities and the data transfer quality, which primarily depends on the transmission medium and can be enhanced with error identification and correction techniques. While in typical service uses QoI is considered as a must-have (no one dares think of a corrupt disk as an option in Cloud computing, it should not happen in any case), in the sensor domain variations are considered reasonable due to the inherent measurement process. Thus it is a metric that was selected for description. This metric can also include other aspects (submetrics) such as e.g. maximum missing values in a data flow (e.g. % of overall values).
- Sensor availability: not of specific concern in terms of description since it is a common metric in current Cloud SLAs (not in terms of sensors but in terms of e.g. VM availability, however the definition would be quite similar)

<u>Data Delivery</u>

- **Latency**: is a measure of time delay that describes how long it takes for a packet of data to move from one designated point to another in a given system. This was indicated as specifically important by users and it is understandable since many applications depend on low latency for effective operation. Thus it is one of the selected metrics. However, there is the matter of how it can be defined as measurable and able to be validated, given that the starting time/triggering is within the data provider's control. So one alternative could be to link this metric with the minimum sampling interval metric of the Sensing category. But even in this case this indirect way of measuring it applies only to e.g. periodic data and not event-driven data.

- Data availability: not of specific concern in terms of description since it is a common metric in current Cloud SLAs. One interesting aspect of this is potentially the missing values in a data flow, which however can be included in the QoI metric.

Prediction Services

- Prediction error: this should be defined in terms of common model metrics (e.g. Mean Absolute Error)
- **Prediction horizon**: this is in terms of multi-step ahead prediction in e.g. time series models. This is also heavily tied with the error. It is anticipated that the larger the horizon gets (for the same model) the larger the error will be. Thus any description of this metric should also include how the error increases when the horizon increases.

Conclusions- Example SLA descriptions based on 19086-2 draft

As mentioned previously, the goal of this effort was focused on the following points:

- Investigate whether IoT metrics can be considered as parts of SLAs
- Investigate what form these metrics should have
- Benchmark the ongoing draft standard ISO 19086-2 to check whether it is expressive enough to include them, thus resulting in changes to its description model (if it is not)
- Conclude whether a new standard should be pursued for the expressed purpose (description of IoT related SLA metrics) or an existing one (even draft) can be used without duplication of effort by the community

In order to address these, we targeted the metric of data loss guarantees, since this may be more typical of untrustworthy sensory environments, a common case in the IoT domain. The resulting description of the sensor provider, giving 90% guarantees on the acquired values by a subscriber in a range of minimum 12 values per hour, was used. This specific example very much resembles the data acquisition process COSMOS performs in the Madrid traffic Use case, when obtaining data from the measurement points of the city infrastructures. We managed to create the description, based on an instantiation of the 19086-2 draft standard that appears in the following images:

```
},
    "parameters": [
        {
            "name": "monitoring cycle",
            "referenceId": "MC_001",
            "unit": "hour",
            "parameter": "12",
            "note": "promise to deliver 12 values per hour from each data item"
        }
    ],
    "underlyingMetrics": [
        {
            "name": "Total number of samples gathered",
            "referenceId": "COUNT_001",
            "unit": "",
            "scale": "interval",
            "expression": {
                "expression": "COUNT_001= COUNT(SAMPLE_001)+COUNT(SAMPLE_002)",
                "expressionLanguage": "ISO80000"
            },
            "samples": [
                {
                    "name": "Traffic throughput sensor Data",
                    "referenceId": "SAMPLE_001",
                    "scale": "interval",
                    "value": "Car Throughput",
                    "unit": "vehicles/hour"
                },
                {
                    "name": "Traffic Speed sensor Data",
                    "referenceId": "SAMPLE_002",
                    "scale": "interval",
                    "value": "Speed",
                    "unit": "km/hour"
                }
            ]
        }
    ]
}
```


Figure 6 – Description sample


```
"name": "Sensor Service guarantee for estimated quantity of data ",
"referenceId": "QOD_001",
"scale": "NOMINAL",
"expression": {
    "expression": "PRV_001 > PARAM_002",
    "expressionLanguage": "ISO80000"
},
"parameters": [
    {
        "name": "Unreceived values percentage limit",
        "referenceId": "PARAM_002",
        "unit": "%",
        "parameter": "10"
    },
    {
        "name": "Calculation cycle",
        "referenceId": "CC_001",
        "unit": "day",
        "scale": "INTERVAL",
        "parameter": "1"
    }
],
"underlyingMetrics": [
    {
        "name": "Percentage of received values",
        "referenceId": "PRV_001",
        "unit": "%",
        "scale": "RATIO",
        "expression": {
            "expression": "PRV_001= COUNT_001/24*MC_001*LENGTH(SAMPLES)",
            "expressionLanguage": "ISO80000",
            "note": "More generic parametric expression based on size of samples
        },
        "parameters": [
            {
```


Figure 7 – Description sample

The rationale behind the SLA metrics offered in the IoT domain have also been used in the context of the COSMOS marketplace (www.eventflows.com), as a field to be populated by events developers to describe QoS features of their produced data. The results of this effort were also communicated to the ISO committee for the drafting of the standard in which ICCS participates (ISO-IECJTC1-SC38) Furthermore, the provided examples have been sent as input to the main editor of 19086-2 to be included in a technical annex of the standard, as examples of the model application.

4.5.2. Siemens

Siemens is one of the contributors to the IEEE P2413 Working Group confirming again its strong involvement and support for the development of the IoT domain.

All standardization efforts in Siemens are coordinated by a central headquarters team. As a result there can be no direct contribution of Siemens CT to any working group.

Nevertheless Siemens CT is in close contact with headquarters standardization team, with regular meetings being held to align our efforts and identify inputs in both directions: for the standardization as well as for the research and development activities as we will later present with regards to the semantic support in COSMOS.

Since IEEE P2413 just started during COSMOS first year of execution, Siemens team involved in Cosmos contacted internal contact and peer technical groups who contribute. First year activity was dedicated to identify where and how content currently based on IOT-A might be enlarged with Cosmos specific aspects.

ISO 37120 is a standard under close observation by Siemens since it is linked to activities in both the IoT as well as the infrastructure and city domain.

ISO 27001 as well is a standard under observation as any commercial solution must ensure the data security for the service providers and end customers. Security is therefore something to be considered from the lowest level of device specification and development to the highly integrated solutions which involve the interaction between devices and multiple software components and platforms.

Siemens has been strongly involved into the design of the COSMOS semantic model and related components. Existing and widely accepted ontology reuse was encouraged. Also, the results of other European projects have been applied such as those from IoT-A or IoT.est. The semantic model of COSMOS was therefore designed so that, for instance, the definition of the physical entities whose properties are exposed by VEs, is not part of the model. Instead the user can make reference to any other ontology which properly describes the physical entity.

Siemens has proposed the semantic description of the message bus topics and, since this approach presents a strong reuse potential even outside the project boundaries, it will support the dissemination of these results as well as any possible inclusion into a standard, either for message buses or as a stand-alone ontology.

Currently, the semantic model proposed by COSMOS provides “hooks” for the description of the things, the physical entities which are related to the IoT services and to the VEs. This is because, at this moment, there is no standard agreed for the description of things. We are in close contact with the standards team for both the P2413 recommendations for Universal Thing Description (UTD) as well as for the Web of Things interest group at W3C regarding the Things Description Language. Siemens is contributing to both groups.

4.5.3. ATOS

Having the role of a big industrial partner, ATOS is adopting and integrating a bunch of technologies in COSMOS based on their state of standardization, what provides implementation choice, flexibility, speed, agility and skills. Moreover, for those shelf-made developments, in this case the constrained-driven Complex Event Processing (CEP) engine, ATOS is following closely different standardization bodies in order to build a tool that is aligned with recognized standards.

Concerning the different technologies chosen for building up the Message Bus component, the underlying protocol for the publication/subscription of messages is the ISO/IEC 19464:2014, which is commonly known as Advanced Message Queuing Protocol (AMQP) protocol v1.0. This standard is while adopted by the community to connect hundreds of critical systems in Telecommunications, Defence, Manufacturing, Internet and Cloud Computing. In fact, relevant companies such as NASA, VMware or AT&T use it in their systems. When it comes to the CEP engine under development, AMQP is being used as the communication interface for the collection of data feeds and the publication of complex events.

In regard to event processing, ATOS has been closely following the Event Meta-model and Profile (EMP) RFP, which is a pending proposal to the Object Management Group (OMG), an international, open membership, not-for-profit technology standards consortium founded in 1989. The purpose of this RFP is well aligned with the current development state of the CEP, which treats Events as observations of state rather than actions of processes. In this direction, developing a common terminology for modelling events will help supporting interoperability among CEP engines, enable richer event classification, and facilitate identification of event patterns and anomalous conditions.

ATOS has promoted Madrid Smart Transportation for being selected by IEEE IoT Scenarios group.

The project has focused the contribution on how the system developed by the COSMOS can facilitate usage of public transportation system to those citizens with special needs.

The documentation provided focuses on two main aspects:

- Improvement of citizens' life through the adoption of IoT technologies. This section covers the main benefits for the final users, and how IoT enables a significant advance in the fulfilment of their daily needs.
- Technical contribution. This second part highlights which elements and concepts belonging IoT paradigm have been exploited in the scenario presented. The main contribution on the technical aspects are focused on:
    - Metadata search
    - Situational Awareness

ATOS has also contributed to the deliverable D1.2 of IERC AC3 cluster "Inventory of IERC tangible outcomes and showcasing plan – Summer 2015". The document contains the information of how the different technical components we are developing in the project fit in the framework of the innovative pilots.

4.5.4. IBM

The role of IBM in the project concerns infrastructure such as cloud storage, therefore standardization activity concerns technologies applicable to the IoT domain although the context is more general. IBM Research – Haifa has been actively contributing to open source software communities such as OpenStack Swift and Apache Spark. At this stage of the project, these contributions have not yet involved specific standardization activities, and we currently do not foresee standardization activities related to cloud storage infrastructure for IoT workloads. On the other hand, in the data management, analytics and cloud storage infrastructure domains, we adopt open interfaces such as the OpenStack Swift REST APIs, and the Apache Spark analytics framework.

4.5.5. UNIS

UNIS undertake an active role in the IoT Forum, being part of the board (secretary position) and also chairing the WG on architecture and Interoperability which is also in charge of maintaining and evolving the Architectural Reference Model. For that reason UNIS has been very active (even leading D2.3.2) in applying strictly the ARM methodology to COSMOS architecture. In addition UNIS had the opportunity to present the ARM to the IEEE P2413 group in the course of April 2015 (the slide set was prepared by Francois Carrez (UNIS) and eventually presented by Joachim Walewski from Siemens).

5 Summary of Actions

Wide acceptance among stakeholders is an important goal for every research and development project. This document describes the efforts taken by the project consortium in this direction and lists foreseen step (see the table below) in order to increase the relevance of the project outcomes.

Body	Action	Leading partner
IEEE	Contribution to the development of the P2413 – Standard for an Architectural Framework for the IOT standard. Focus on the Universal Thing Description (UTD) with regards to the semantic model of COSMOS; Formal presentation of the IoT ARM to P2413	SIEMENS, UNIS
ISO	Close observation of the ISO 37120 – Sustainable development of communities standard and of ISO 27001 - Information technology— Security techniques — Information security management systems — Requirements. Identification of relevant aspects for the Cosmos research and development activities as well as possible contributions to the standards.	SIEMENS
W3C	Close observation and contribution to W3C WoT interest group and the Thing Description Language activity which is also relevant for the semantic model of COSMOS	SIEMENS
IEEE	Contribution to IEEE IoT Scenarios Group. Proposal submitted focused on the Smart Transportation use case considered in the project and presented in the previous section.	ATOS
IERC	Contribution to D1.2 - Inventory of IERC tangible outcomes and showcasing plan – Summer 2015	ATOS

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