Internet of Things Architecture

IoT-A

Project Deliverable D6.2 – Updated Requirements List

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PU	Public	
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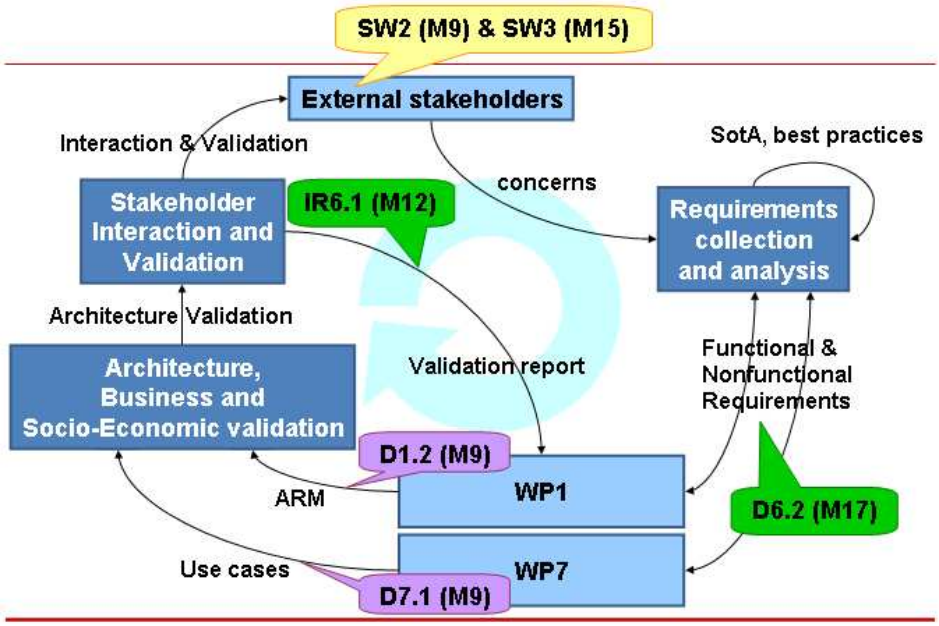
Executive summary

Requirements and external feedback are an essential input to the work on the IoT-A architectural reference model (ARM). This document provides an updated list of the initial collection of external requirements and provides a first collection of requirements from projects experts and state of the art. Further the deliverable reports the results of the interaction with stakeholders undertaken since the initial stakeholder workshop. These results are structured into feedback to IoT-A ARM and the work on requirements and additional new requirements derived during stakeholder workshops 2 and 3.

WP6 focuses on facilitating the development of the IoT-A architectural reference model by collecting functional as well as non-functional requirements from a very diverse set of actors and on validation and feedback of the achieved results.

WP6 and the IoT-A project in general follow an iterative and incremental process for achieving their objectives. The methodology used during the process is largely inspired by best practices such as IEEE Standard 1471 – Recommended Practice for Architectural Description (2000) [IEEE_1471 200], Software Systems Architecture, Second Edition [Rozanski 2005] and Mastering the Requirements Process, Second Edition [Robertson 2010].

The following figure depicts this iterative process concerning requirement collection and architecture validation. Requirements are identified and processed based on stakeholders concerns out of stakeholder workshops (SW), state of the art and best practices, in interaction with technical work packages of the project (in particular WP1 for the architectural reference model – ARM – and WP7 for the concrete architectures prototyped in the use cases). Results of this phase are the different D6.1-D6.3 deliverables which present the requirement lists and serve as a basis to validate the ARM produced in WP1. This deliverable (D6.2) results from the completion of a first cycle in the process. The other activity in WP6 is dedicated to the validation of the architecture through the ARM (based on D1.2) and concrete implementations (based on D7.1), both against the requirements and the stakeholders. This activity outputs validation reports (IR6.1 for this cycle).



Objectives

The objective of D6.2 is to provide an update on the requirements for IoT-A. This update reflects the current (as of January 2012) state of discussion regarding requirements and serves as basis and reference for further work in IoT-A.

The deliverable also presents the results of the interaction with stakeholders from 2 workshops. These results provide feedback to the IoT-A ARM and also some new requirements.

This deliverable covers mainly two objectives:

O6.1: *Provide **a set of requirements** based on both project internal requirements as well as externally collected requirements from the stakeholder group*.

O6.3: ***Interaction with** a group of **external stakeholders** including knowledge and information transfer*.

Progress of the work

This deliverable covers the stakeholder interaction done in WP6 after the first stakeholder workshop. Two stakeholder workshops (SW) have been organized – SW2 in June 2011 in Barcelona and SW3 in November 2011 in Berlin. The results represent the feedback to the IoT-A ARM; as well, new requirements collected in the two events are presented in this deliverable.

An important result and progress is the update of the initial requirement list. A significant amount of effort has been dedicated to discuss the external requirements within the project. The result is a comprehensive list of requirements formulated in terms understandable to architecture experts. Further the list was structured according the views and perspectives used in the ARM [Walewski_D1.2 2011].

The first official listing of internal requirements is presented to start a traceable discussion and processing towards a unified list of IoT architectural requirements.

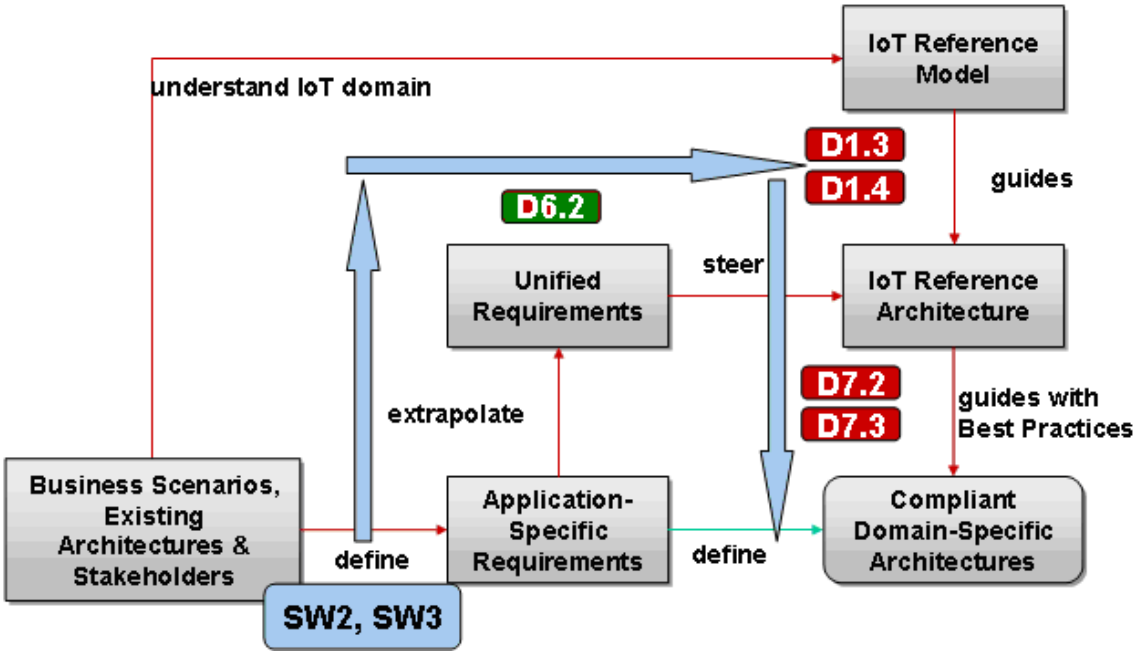
Results beyond State-of-the-Art

A broad practical approach to collect IoT architectural requirements was not reported yet.

Role and positioning of deliverable in overall project

The results of the deliverable were derived with strong interaction and discussion with WP1, while collecting input from stakeholders and the technical WPs.

This deliverable will be used by WP1 and WP7 for their future deliverables.


IoT Reference Model
understand IoT domain
D1.3
D1.4
guides
D6.2
Unified Requirements
steer
IoT Reference Architecture
D7.2
D7.3
guides with Best Practices
extrapolate
Business Scenarios, Existing Architectures & Stakeholders
define
Application-Specific Requirements
define
Compliant Domain-Specific Architectures
SW2, SW3

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1. Introduction

Business scenarios and stakeholder input are important drivers of the architecture work in IoT-A. WP6 collects business scenarios from a broad group of stakeholders, to derive a holistic view of IoT architectures and related requirements. These requirements from stakeholders as well as requirements from IoT-A experts and the technological state of the art (SotA) are listed in WP6 deliverables and are considered during the work on the IoT-A ARM.

This deliverable D6.2 presents the second iteration of the requirements list and the results of the interactions with stakeholders. Two stakeholder workshops (SW) have been organized – SW2 in June 2011 in Barcelona and SW3 in November 2011 in Berlin. The results represent the feedback to the IoT-A ARM; as well, new requirements collected in the two events are presented in this deliverable.

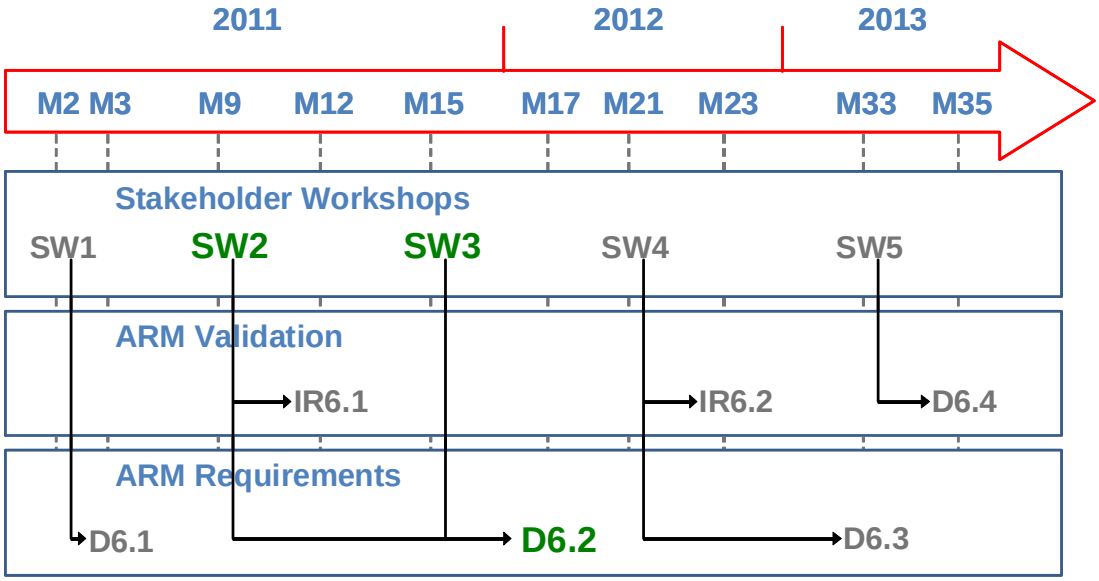

Figure 1: D6.2 in the WP6 timeline perspective

An important result and progress is the update of the initial requirement list. A significant amount of effort has been dedicated to discuss the external requirements within the project. The result is a comprehensive list of requirements formulated in terms understandable to architecture experts. Further the list was structured according the views and perspectives used in the ARM [Walewski_D1.2 2011].

The first official listing of internal requirements is presented to start a traceable discussion and processing towards a unified list of IoT architectural requirements.

1.1 Document structure

The deliverable D6.2 is structured as follows. Chapter 2 presents the final result from the first stakeholder workshop. After a presentation of the methodology applied for the work with requirements, the unified list of requirements stemming from SW1 is given. The list is structured according to the views and perspectives of the IoT-A ARM.

Chapter 3 and Chapter 4 are dedicated to the evaluation of stakeholder workshop SW2 and SW3. Chapter 3 discusses feedback to requirements from the first stakeholder workshop SW1 as well as new requirements derived from stakeholder statements. Chapter 4 discusses the feedback to the IoT-A ARM received from stakeholders.

Chapter 5 lists the requirements collected from IoT-A internal sources, i.e. the technical WPs and the SotA.

The last chapter is concluded by an outlook on the further processing of requirements for validation purposes.

1.2 Technical delta

The initial list of external requirements from the stakeholders was generalized and adapted to the language of the reference architecture. This was achieved in extensive collaboration between WP1 and WP6, taking into account feedback from external and internal sources. The resulting requirements are named as “unified requirements”. The resulting list of requirements gained in applicability and traceability regarding the IoT-A ARM.

Besides listing the revised unified requirements, the deliverable documents new results from stakeholder workshops 2 and 3. The deliverable lists officially the first collection of internal requirements from the SotA and experts in the technical work packages for further discussion and refinement.

Figure 2 shows the evolution from the initial requirements collection in D6.1, over the current update in D6.2, to the final list of requirements that will be presented at the end of the project in deliverable D6.3.

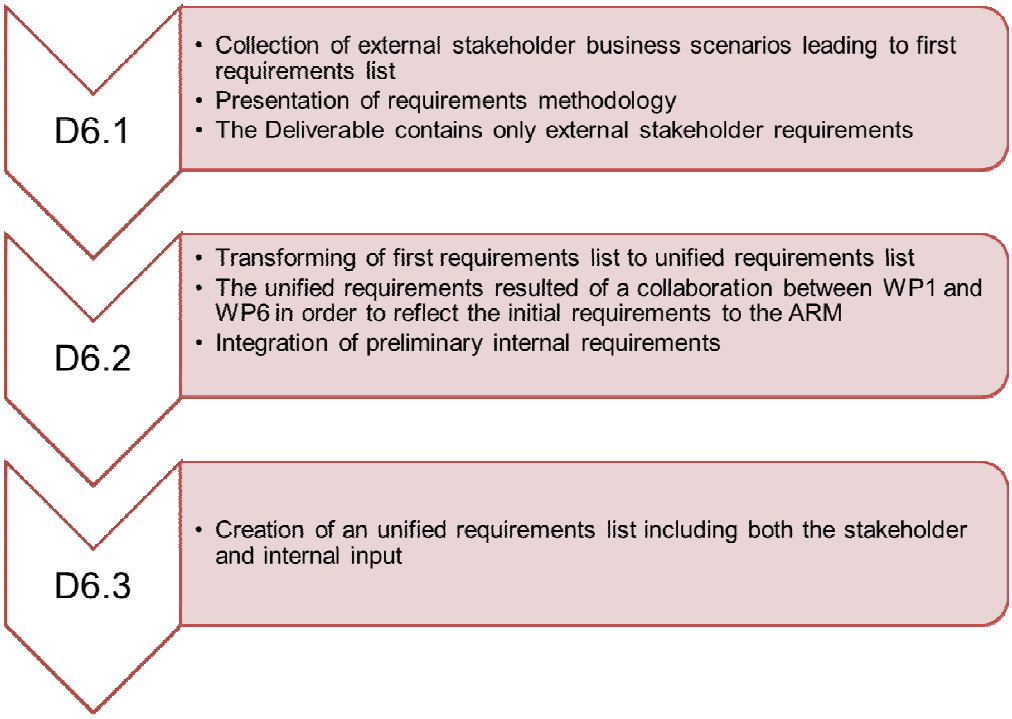

Figure 2: Evolution of requirements in three iterations

2. Refinement and unification of the stakeholder requirements

This chapter describes the first iteration of stakeholder requirements processing. After a description of the methodology we present the future structure of requirements. Finally the result of applying the methodology to the initial stakeholder requirements is presented. This list is the nucleus of the so called unified requirements list, which will be extended by new inputs from stakeholders and internal requirements by the end of the project. We also present a classification of requirements according to the views and perspectives of the IoT-A ARM.

2.1 Covered steps in the methodology

The process began with collecting requirements from the 7 stakeholders during the first stakeholder workshop (SW1) in Paris, October 2010. The members of the stakeholder group were representative of a wide range of business domains with an interest on Internet of Things: Logistics, Health Care, Technology Integration, Retail, Automotive, Service Integrators, Telecom Operators, Law, Standardization and Veterinary Medicine.

Figure 3 illustrates how the stakeholder requirements influenced the development of the ARM, specifically the views and perspectives and the definition of a vision. Besides it also served as input for the demonstrators designed by WP7.

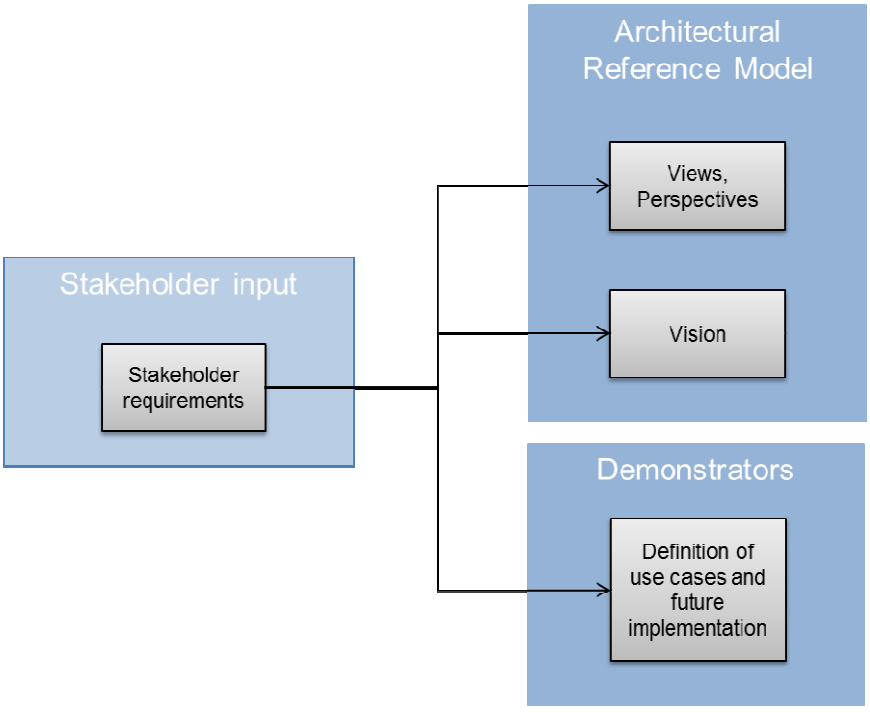

Figure 3: The process by which stakeholder requirements were developed into inputs for developing the architecture reference model

Due to the heterogeneity between the stakeholder origins, the first material in form of use cases outlined the specific interests in many contexts. This was a particular assistant step to cover many different aspects of the IoT and to receive the business needs from the diverse domains. Schematically, the whole process related to SW1 is shown in Figure 4 and further explained in the following.

The process in which the unified requirements were created and refined, started by the collection of the stakeholder business use cases, then requirements were derived, which in turn served as inputs for developing the views, perspectives and the functional decomposition.

The requirements were then reviewed individually by WP1 and WP6, each providing input relevant to their respective work packages. This resulted in a unification process in which the initial set of requirements has been transformed into the unified requirements list. The process included merging, discarding and splitting of requirements to conclude in a meaningful, comprehensive and thus substantial first update of the requirements list, so that the project objectives could be followed intelligibly. This step provided input for WP1, which used this list to develop the views and functional decomposition in [Walewski_IR1.3 2011] (see Figure 4). In a further step this resulting set of requirements was then used to refine the views and functional decomposition as found in the document [Walewski_D1.2 2011].

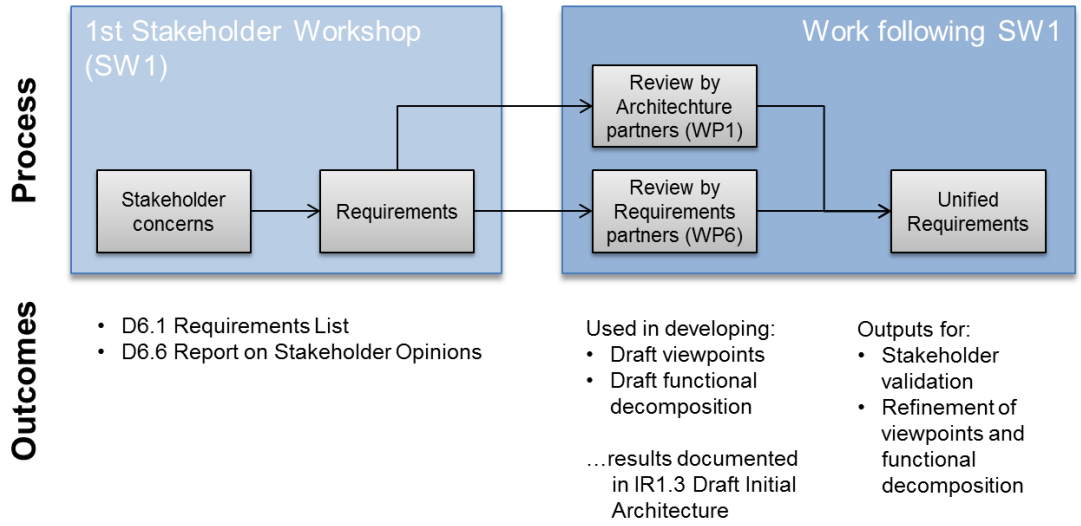

Figure 4: Overall process by which requirements were developed, so that they could serve as inputs for the requirements to the Architectural Reference Model

Additionally to project external input, a first set of internal requirements was presented in D1.2 [Walewski_D1.2 2011] which has its origin in project internal demands and constituted the Domain model as well as the Reference Architecture. This list of internal requirements is presented in Chapter 5.

2.2 Requirement fields

As part of the requirements methodology, the IoT-A project partners discussed and agreed on a list of fields for characterizing each requirement. Some of the fields are captured when creating the requirement; other fields are inserted to structure and validate the requirements. Some fields are for internal reference and traceability and not intended for publication. Since all fields are part of the methodology, we list all fields in the following table.

Field	Description
ID	Each requirement is uniquely identified by a three-digit number: UNI.*klm*.
Requirement Type	1. Functional Requirements (FR) 2. Non-Functional Requirements (NFR) 3. Design Constraints (DC) It is easier to write an appropriate fit criterion when the type of requirement is established. When one groups all of the known requirements of one type, it becomes readily apparent if some of them are missing or duplicated.
Description	The description is the intent of the requirement. It is a statement about what the system has to fulfil according to the *rationale*.
Rationale	The rationale is the reason behind the requirement's existence. It explains why the requirement is important and how it contributes to the system's purpose.
Owner / Source / Req. Name	The owner (originator) is the person or organisation who raised the requirement in the first instance, or the person to whom it can be attributed. You should attach the originator's name to the requirements so we have a referral point if questions about the requirement arise or if the requirement is rejected. The person who raises the requirement must have the knowledge and authority appropriate for the type of requirement.
Fit Criterion	A quantification or measurement to assess to which extent the original requirement is supported by the system. The scale should be at least binary (fulfilled and not fulfilled).
Priority	The priority of a requirement is the decision on the importance of the requirement's implementation. The priority depends highly on the specific domain of the application.
Dependencies	Indicate if the requirement depends on another one. Relations between two or more requirements should be noted and separated by comma(s).
Conflicts	Conflicts between requirements imply that there exists contradiction upon system implementation, or one requirement makes the implementation of another requirement less feasible. Values: default "(none)" or requirement number(s), separated by comma(s).
View	One or several views to which the requirement is related.
Functionality Group	One or several functionality groups in the functional decomposition to which the requirement is related.
Functional Component	One or several components in the functional decomposition to which the requirement is related. These functional components are part of the groups listed in the functionality-group field.
Domain Model	One or several domain-model entities to which the requirement is related.
Perspective	One or several perspectives to which a requirement is related.
Originating Business Scenario	Business scenario on which the requirement is based. Default value: "(none specific)"
System Use Case	ID of the System Use Case (c.f. as defined in D1.2 & ff. - Appendix) that needs the requirement under consideration. To be provided for validation purposes after writing the ARM documents.
Demonstration Business Scenario	Name or ID of the scene from the story line defined by WP7 that meets the requirement. Default value: "(none specific)". To be provided for validation purposes at the time the demonstrations are ready.

2.3 Unified requirements list

The following sections present the list of unified requirements. The requirements were either associated to a view or to a perspective of the IoT-A reference model. An overview of all existing views and perspectives of the IoT-A reference architecture is shown in Figure 5. For a detailed description of views and perspectives we refer to Chapter 3 of IoT-A D1.2.

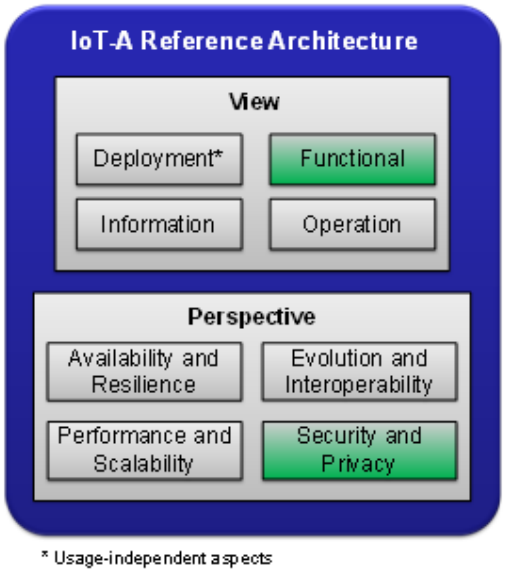

Figure 5: The IoT-A Reference Architecture views and perspectives, cf. D1.2 Chapter 3

While all requirements are associated either to a view or a perspective, some requirements are associated to multiple views resp. perspectives. Seen from the IoT-A reference architecture, there exist requirements for all views resp. perspectives. A table showing the associations of requirements to views and perspectives is given in the following Section 2.4.

To keep the table more compact and readable, we use abbreviations for the requirements type. The requirements are classified as functional requirements (FR), non-functional requirements (NFR) and design constraints (DC).

The unified requirements are formulated with reference to an IoT system that is created with guidance provided in the ARM. Notice that the term “the system” is used according to IEEE 1471, which defines a “system” as “A collection of components organized to accomplish a specific function or set of functions" [IEEE_1471 2000]. In other words, the extent and composition of a system depends on its intended use. In one application scenario a system can thus be a collection of RFIDs and a tag reader that provides the RFID IDs via a web service. In another application scenario, a system can be large and complex. An example for the latter category are road-traffic management systems. Also notice, that composite services provided by the IoT do not always map on one single IoT system. An example for this is a hypothetical extension of Google maps, in which the route calculation between two points A and B not only takes into consideration traffic announcements, but also road conditions based on footage provide by surveillance cameras and predicted traffic volumes based on local event schedules (football games). Such a service would thus poll information from widely different IoT systems (traffic report system, intelligent road-surveillance system, geospatial enriched event data, …).

So when reading the requirements please keep in mind that, depending on the use case, some requirements may not needed by specific implementations of the architecture. The dependency of system requirements on application scenarios is currently under investigation by the architecture work package of IoT-A.

ID	Description	Rationale	Originating Business Scenario	Req. Type
UNI.001	The system shall provide a means to allow people to use Internet of Things services anonymously	Citizens want to protect their private data	Smart city	NFR
UNI.002	Human users have control how their data is exposed to other users	Citizens want to protect their private data	Smart city	NFR
UNI.004	The system shall enable the semantic description of physical entities	I would like a way to create and exchange semantics between objects in order to design new applications	Smart city	NFR
UNI.003	The system shall enable the provision and exchange of semantics between services in order to support the design of new applications	I would like a way to create and exchange semantics between objects in order to design new applications	Smart city	NFR
UNI.005	The system shall support event-based, periodic, and/or autonomous communication between devices	The remote monitoring device gathers patient measurements, data and or events. Data may be communicated each time the device gathers the data, accumulated measurements may be communicated periodically (e.g., hourly, daily), or data may be delivered upon request or upon certain events	e-Health	FR
UNI.008	The system shall be able to run applications and services in and interoperable manner	The problem is to provide a framework, a set of scenarios where these applications could be developed in harmony, in an interoperable way and in a way that responses to the real needs of organization and people	(none specific)	NFR
UNI.010	The system shall enable autonomous goal-driven (task-driven) collaboration between devices or services	Smart objects should collaborate in order to realize a common goal (such as traffic lights in order to reduce traffic or pollution).	Smart city	NFR
UNI.012	The system shall be able to handle interference between IoT devices (avoidance and detection)	In order to achieve a reliable eHealth service the system must be interference-free	e-Health	NFR

ID	Description	Rationale	Originating Business Scenario	Req. Type
UNI.014	The system shall support devices to activate themselves into a collaboration	The remote monitoring device is prepared for use and communication by the action of the patient or clinician. This may involve physically attaching or placing the device, registering the device, setting up the communications channels to M2M application entities, setting up the communications capabilities of the device and providing for secure communications.	e-Mobility	FR
UNI.015	Devices shall have the possibility to be remotely controlled and configured	The remote monitoring device may be configured by via the M2M network by the M2M application entities. The configuration capability could span simple parametric changes, such as, reporting rates, event or alarm trigger levels, and dosing levels to downloading and securely restarting new operating software	e-Health	FR
UNI.016	The system shall support physical entity location tracking (geo spatial and/or logical location)	High value assets need to be tracked in order to avoid theft and also to know where they are currently located	e-Mobility	FR
UNI.018	The system shall support data processing (filtering, aggregation/fusion, ...) on different IoT-system levels (for instance device level)	The remote monitoring device gathers patient measurements, data and or events. Data may be communicated each time the device gathers the data, accumulated measurements may be communicated periodically (e.g., hourly, daily), or data may be delivered upon request or upon certain events	e-Health	FR
UNI.019	The system shall support user-initiated communication	Providers can initiate communication with the patients health monitoring device for a number of reasons. Examples of this include a provider querying the device for a reading or for configuring such a device	e-Health	FR
UNI.020	The system shall support real-time monitoring of radio usage of devices and gateways	The application knows the current radio transmission activity of the M2M device	e-Health	FR
UNI.022	The system shall support secure communication	Patients are able to initiate communication to the providers Electronic Medical Record (EMR) or health database application using the secure messaging tool for a variety of purposes. Examples include providing manually gathered information on existing self-monitoring and/or chronic care regiments.	e-Health	FR

ID	Description	Rationale	Originating Business Scenario	Req. Type
UNI.023	The system shall provide access to external information sources, e.g. health databases	Patients are able to initiate communication to the providers Electronic Medical Record (EMR) or health database application using the secure messaging tool for a variety of purposes. Examples include providing manually gathered information on existing self-monitoring and/or chronic care regiments.	e-Health	FR
UNI.026	The system shall support time-critical message handling and delivery	In case of emergency the RMD has to send or receive time critical messages	e-Health	FR
UNI.027	The system shall support prioritization of services	In case of time-sensitive services the system needs to assure that important services are prioritized	e-Health	FR
UNI.028	The system shall provide a message-priorisation mechanism	Not every message has the same priority	e-Health	FR
UNI.029	The system shall provide a support for routing of data based on content	A system may be provided which is operable to determine a routing node for a data object. The system can comprise an identifier generator operable to generate an identifier for the data object on the basis of data content thereof, and a lookup engine operable to compare the identifier for the data object to a routing table to determine a routing node for the data element.	e-Health	FR
UNI.030	The system shall provide a resolution infrastructure for naming, addressing and assignment of virtual entities and services	A system may be provided which is operable to determine a routing node for a data object. The system can comprise an identifier generator operable to generate an identifier for the data object on the basis of data content thereof, and a lookup engine operable to compare the identifier for the data object to a routing table to determine a routing node for the data element.	e-Health	FR
UNI.031	The system shall enable centralized or decentralized automated activities (control loops)	Today, due to sub-optimal processes, a lot of time and money is wasted. This situation could be improved a lot by tracking all the items/things, providing context data on them at any time and location, allowing for automated evaluation of the collected data and reacting immediately on a dangerous situation to protect against the break down of items.	Transportation/Logistics	TBD

ID	Description	Rationale	Originating Business Scenario	Req. Type
UNI.032	The system shall enable the planning of automated tasks	Today, due to sub-optimal processes, a lot of time and money is wasted. This situation could be improved a lot by tracking all the items/things, providing context data on them at any time and location, allowing for automated evaluation of the collected data and reacting immediately on a dangerous situation to protect against the break down of items.	Transportation/Logistics	FR
UNI.036	The system shall enable the retrieval of the self-description of things	My wish is to retrieve the capacity of a thing. Thus, I can plan a change maintenance of all my bulbs if they can said when they should be changed	Smart city	FR
UNI.040	The system shall provide ways to ensure security and resilience	Road users and energy providers want to avoid shortages/ blackouts	Smart city	NFR
UNI.041	The system shall provide historical information about the physical entity	A method for clarification whether the Cold/Hot Chain has been violated or not is required. To be able to do this, the continuous context information (e.g., temperature) of the things needs to be collected. This is for example of major importance to avoid any damage to the pharmaceutics during the transport and storage process.	Transportation/Logistics	FR
UNI.042	Both user and device must be able to exchange information about their state	Both the M2M server and the M2M device must be able to provide information about the current state	e-Mobility	NFR
UNI.043	The system shall enable the composition of entity-related services	The costs for complex logistics and healthcare processes need to be kept on a low level. A modular setup of the applications and services is one important ingredient to achieve this. Therefore it should be very easy to integrate things together with their atomic services into other services, and it should be easy for things to use services provided by others.	Transportation/Logistics	FR
UNI.045	Services shall be accessible through semantic interfaces	The mobile phone of the consumer can and should be used for interacting with product centric services	Retail	FR
UNI.046	The system shall support storage of user data	The mobile phone of the consumer can and should be used for assisting the user in all purchase relevant aspects	Retail	FR

ID	Description	Rationale	Originating Business Scenario	Req. Type
UNI.047	The system must ensure interoperability between objects or between applications	As an example, CCTV system could inform traffic management of the length of the waiting queue at a crossroad. Having smart traffic lights receiving such input from the CCTV system could, could help changing the schedule of green/red light to optimize the traffic.	Smart city	NFR
UNI.048	The system shall provide interoperable naming and addressing	IoT-A will play a role in terms of providing a kind of novel resolution infrastructure. We need to understand how best IoT could be served by scheme regarding the naming of objects, the addressing and assigning problems.	(none specific)	FR
UNI.049	Any system shall provide interoperability with other systems, including legacy ones	Citizens do not want to use several city systems	Smart city	NFR
UNI.050	The system shall support mobility of the physical entity	The use of M2M Devices for monitoring health related information is not confined to the residence of the patient.	e-Health	FR
UNI.051	The system shall support mobility of the human user	Citizens want to access all areas of a city	Smart city	FR
UNI.058	The system shall provide high availability	Communication blackouts are not accepted from client side and particularly if they are paying for premium services	e-Health	NFR
UNI.060	The system shall support different SLA	Communication blackouts are not accepted from client side and particularly if they are paying for premium services	e-Health	NFR
UNI.062	The system shall provide trusted and secure communication and information management	A method for clarification whether the Cold/Hot Chain has been violated or not is required. To be able to do this, the detailed context information (e.g., temperature) of the things, which have been collected in some database need to be easily made available. This is for example of major importance to avoid any damage to the pharmaceutics during the transport and storage process.	Transportation/Logistics	DC
UNI.064	The system shall provide security through resilience	Security, why? Simply because the IoT - I am sure you will demonstrate it - is a kind of critical information infrastructure which means that if ever for whatever reason there is a failure somewhere on the IoT the impact will be so high that it would be a social loss, like if we do not have more electricity.	Transportation/Logistics	NFR

ID	Description	Rationale	Originating Business Scenario	Req. Type
UNI.065	The system shall provide reliable services	In order to accommodate certain scenarios, support of a certain degree of reliability might be necessary	Smart city	NFR
UNI.066	The system shall provide integrity validation of virtual entities, devices, resources, and services	In certain life-critical applications the device may be required to perform a secure start-up procedure that includes integrity checking.	e-Health	FR
UNI.067	The system shall provide different access permissions to information	Sensitive data of patients must be kept secure in order to assure trust between the patients and to allow access to certain people	e-Health	FR
UNI.070	The system shall handle semantic interoperability between different semantic levels	I would like a way to create and exchange semantics between objects in order to design new applications	Smart city	FR
UNI.071	The system shall provide standardized and semantic communication between services	Standard communications between objects, from a communication channel point of view but also from a semantic point of view. (Standardization of object semantic is somehow similar to the standardization of MIB (Management Information Base) of telecommunication equipments).	Smart city	DC
UNI.073	The system shall allow the semantic description of physical entities and services by a user	I would like a way to create and exchange semantics between objects in order to design new applications	Smart City	FR
UNI.087	The system shall support service lifecycle management	Road users want to use one service over a service life cycle	e-Mobility	FR
UNI.089	The system shall support reliable time synchronization	Services which depend on a precise time need a guarantee that the devices they are communicating to have the right time.	e-Health	FR
UNI.092	Remote services shall be accessible by human users	The mobile phone of the consumer can and should be used for interacting with product centric services	Retail	NFR

2.4 Traceability regarding views and perspectives

Unified Requirement ID	Views				Perspectives			
	Functional	Information	Deployment	Operational	Security and Privacy	Performance and Scalability	Availability and Resilience	Evolution and Interoperability
UNI.001					X		X	
UNI.002					X		X	
UNI.003								X
UNI.004		X						
UNI.005	X							
UNI.008						X		
UNI.010								X
UNI.012								X
UNI.014			X					
UNI.015			X	X				
UNI.016	X	X						
UNI.018	X							
UNI.019	X							
UNI.020	X							
UNI.021	X							
UNI.022	X							
UNI.023	X							
UNI.026	X							
UNI.027	X							
UNI.028	X							
UNI.029	X							
UNI.030	X							
UNI.031	X							
UNI.032	X							
UNI.036	X							
UNI.040					X		X	
UNI.041	X	X						
UNI.042								X
UNI.043	X							

Unified Requirement ID	Views				Perspectives			
	Functional	Information	Deployment	Operational	Security and Privacy	Performance and Scalability	Availability and Resilience	Evolution and Interoperability
UNI.045	X	X						
UNI.046	X							
UNI.047								X
UNI.048	X	X						
UNI.049								X
UNI.050	X							
UNI.051	X							
UNI.058							X	
UNI.060						X		
UNI.062					X		X	
UNI.064					X		X	
UNI.065							X	
UNI.066						X		
UNI.067	X							
UNI.070		X						
UNI.071								X
UNI.073	X	X						
UNI.087				X				
UNI.089						X		
UNI.092							X	

3. Second and third stakeholder workshops

The second stakeholder workshop (SW2) took place within the IoT week in June 2011. Its priority objective was twofold (see Figure 6). First, the stakeholders were asked to comment on the previously conducted requirements process, giving a review of the outputs by then. Second, the initial validation approach was discussed, so that the stakeholders were aware about the future work and the implications of their contributions. Both discussions led to stakeholder comments which were recorded as raw notes by several project partners as well as in the form of audio material.

The post-analysis of SW2 included a usable structuring of the collected materials. Thus, all the stakeholder comments were divided into four categories related to preceding as well as to future work, these are:

- New requirement
- Process

- ARM
- Validation

Stakeholder comments tagged with “New requirement” contain (potential) new input to the unified requirements list while the category “Process” refers to the requirements process undertaken hitherto. Expressions in terms of the development of the ARM were classified in the category “ARM”. The last category (“Validation”) enfolds remarks related to the validation process.

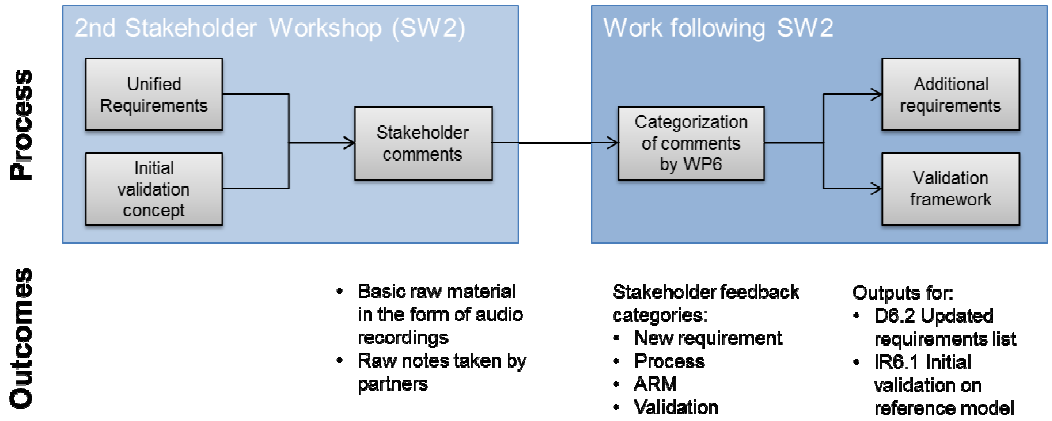

Figure 6: Unified requirements evaluation by stakeholders leading to second requirements gathering process

Stakeholder workshop 3 (SW3) was hold one day before IoT International Forum in Berlin, 22nd of November 2011. During this event the objectives included to conduct open discussions with the goal to obtain new requirements as well as to discuss the further developed validation process. By means of showing a set of visionary IoT videos the stakeholders were encouraged to evaluate the feasibility for the future and to identify possible issues (e.g. security or privacy) to infer new requirements based on their statements. The post-processing was similar to the post-processing of SW2 that is all stakeholder comments were collected, extracted and transcribed in order to categorize them into the categories mentioned above.

3.1 Comments on the existing requirements list

A survey about the external requirements was submitted to the stakeholder with the intention to verify their pertinence against their concerns and the vision they had of an architectural reference model for the Internet of Things. The survey has been set up before SW2 and the stakeholders were invited to participate. Six stakeholders responded and participated in the survey. The results can be seen in [Appendix C – Survey]. These results were then presented and also discussed at SW2.

The survey structure comprised the views and perspectives indicated in [Walewski_D1.2 2011]. For each of the requirements tagged with one the views or perspectives the stakeholders were requested to answer a survey. They were asked to assess the importance of a requirement for which a [Likert_scale] was used from “Very unimportant” to “Very important”.

It turned out that almost all evaluations of isolated requirements were at least “neutral”.

But looking at the overall result the views and perspectives “Evolution and Interoperability”, “Information” and “Security and Privacy” had the highest priority for the stakeholders while, the views and perspectives “Operational” and “Performance and Scalability” had the lowest priority. To highlight the resulting relative importance between all requirements a weighted result was

generated [Appendix C – Survey]. This result was achieved by multiplying the single requirement result with the view or perspective result of which the respective requirement is assigned. Consequently, due to the very high importance of the perspective “Evolution and Interoperability”, the pertaining requirements have higher ranks while requirements of the “Performance and Scalability” perspective have lower ranks - even though their single results were higher. The complete result of the survey is reported in the Appendix C.

In summary, it can be stated that even though there couldn’t be reached a significant number of participants to get a statistically valid result, the survey gives a good indication of which views and perspectives have a greater importance to the stakeholders, facilitating the validation of the ARM against stakeholders’ concerns.

3.2 Emerging new requirements

In the following, we list new requirements derived from the stakeholder workshops 2 and 3. These were extracted from the transcription of the audio recordings and confronted to the initial list of requirements to avoid duplication.

ID	Description	Rationale	Originating Business Scenario	Req. Type
STW.027	The system shall be extendible for future technologies.	The reference architecture shall provide an integral approach that combines legacy aspects as well as an imaginating vision on the Internet of Things.	(none specific)	NFR
STW.029	The system composition shall be driven by business scenarios.	The reference architecture shall provide the building blocks in a creative way coming from a business perspective.	(none specific)	NFR
STW.036	The system shall include an interface to IP communication protocols.	The reference architecture shall consider that we have gateways to IP everywhere, so we must have a global addressing system with protocol and so on. That would be an evolution of IPv6. Or we need an integration package for existing addressing systems.	(none specific)	DC
STW.042	The system shall support the autonomous and dynamic selection of protocols without human intervention.	Future systems implementing the reference architecture shall allow for a dynamic selection of protocols and layers without any human intervention.	(none specific)	FR
STW.311	The system shall support information (data) lifecycle management.	Deal with the lifecycle of information (how to distinguish, if information (tag) is temporary not available or not valid any more?)	(none specific)	FR
STW.319	The system shall have a semantic understanding of distance and location.	It is necessary to make the system know what defines a distance.	(none specific)	FR
STW.321	The system shall guarantee correctness of resolutions (data).	When searching for a certain object you need an implemented system that actually gives you the correct result.	(none specific)	FR

ID	Description	Rationale	Originating Business Scenario	Req. Type
STW.327	The system should include means to wake-up sleepy devices.	We must look out also for some way to wake up sleepy communications in order to manage energy consume.	(none specific)	FR
STW.328	The system should include means to manage the energy consumption of devices.	We must look out for a highly energy efficient system.	(none specific)	NFR
STW.331	The system should take into account external computing resources, e.g. 'the cloud'.	Maybe there should be some part of processing information in the cloud.	(none specific)	DC

New Requirement ID	Views				Perspectives			
	Functional	Information	Deployment	Operational	Security and Privacy	Performance and Scalability	Availability and Resilience	Evolution and Interoperability
STW.027								X
STW.029								X
STW.036	X							
STW.042			X					
STW.280		X						
STW.311				X				
STW.319		X						
STW.321	X							
STW.327	X							
STW.328								X
STW.331						X		

4. Stakeholders feedback for next iteration on the ARM

Part of the focus of the stakeholder workshops 2 and 3 was the collection of feedback to the IoT-A ARM. This is valuable input for validation and the further refinement of the ARM. In the following, we document and discuss this feedback.

4.1 Selection of stakeholder comments related to the ARM

As starting point we used all the material compiled from both SW2 and SW3, a list of 334 possible comments. According to the criteria introduced in Chapter 3, the comments were classified into four categories (new requirements, process, ARM and validation).

The following section focuses on the comments to the IoT-A architectural reference model (ARM),

which left a subtotal of 90 comments. Those are further discussed in the next section and the most relevant comments are listed.

4.2 Suggestions for further refinement of the ARM

For this second refinement we took the comments related to IoT-A ARM and through internal discussion taken place within WP6 and other interested WP's (mainly WP1), a list of 16 comments was obtained. Many of the comments excluded in the list below are valid in general, but are obviously already taken into account in the IoT-A ARM. They are omitted, since they do not aim at modifications of the ARM. As a consequence of these comments, the communication of background information on the IoT-A ARM needs to improve for future stakeholder workshops.

The following table presents the remaining stakeholder comments and a first approach for a refinement of the IoT-A ARM or IoT-A as project for each of the selected comments.

ID	Stakeholder Comment	Suggestion
STW.014	So far a truly imaginative vision on IoT is missing. There is a fragmental set of use, but not an integral approach that is both respectable of the legacy, but primarily looking ahead.	The development of the usecases should bring the imaginative vision to light. Starting from existing technologies, and applying an evolutionary approach makes the result look fragmented at first sight. Avoiding this issue with a clean-slate approach, though, would have brought more problems than solutions, as discussed in the proposal. We will monitor at SW4 and in future interaction that our vision will be well reflected in the WP7 achievements.
STW.015	Start to ask the right questions like "What is the Internet of Things?", "What are the objects?" and "What do we mean if we talk about the connections of objects?" Even though the project might not be able to answer it within 2 years. Be remembered for the asked questions and not for the given answers.	A remarkable work has been done regarding terminology and understanding the IoT domain. Obviously, we need to increase the visibility of this work through a more aggressive dissemination strategy.
STW.020	There are principles I would expect this IP to answers like "Do we really expect n to n communication between all objects?" "Is that the need?" "Do we expect one unique super-architecture with one numbering system abstract from all existing ones?"	This comment is related to reference architectures. There is likely not a single solution for this, but one depending from the context and the specific requirements. Solution to this comment is twofold: first of all, we need to define precisely what reference architectures we will study, which will be done in D1.3, and then proceed with an aggressive dissemination strategy in order to make these results known to the IoT community.

ID	Stakeholder Comment	Suggestion
STW.073	Is the RM taking into account legacy systems (e.g. EPoSS) and is it a model that can be used even if there is no unique identifier (e.g. through a camera with a localization device, with augmented reality)?	The whole project is built over existing systems, and our main objective is to go from Intranet-of-Things to Internet-of-Things. Therefore, all our theoretical and abstract models do take into consideration legacy systems. If this has not been perceived by the stakeholders, we need to reinforce the communication strategy towards them, or else ask a specific example that we did not take into account, so that future iteration of our ARM will include those specific legacy systems today ignored.
STW.072	It is important to identify which services could be common between the different IoT architectures and then the business model will follow. Furthermore an IoT architect has to know what is necessary from the RA, not just a picture on the wall but have real services, models and usable things to build a certain architecture.	The consortium decided to modify the workplan in order to accommodate a task on best practices and methodologies. The purpose will be to guide innovation managers from the higher abstraction models to the development of a concrete architecture, given specific requirements. The connection with IoS is studied within WP2, and the results of WP2 need to be widely distributed.
STW.097	The RA should be some sort of one-stop-shop where to look at the existing options and solutions and by drag&drop facility to build a new architecture. The test cases will NOT be just represented by the developed IOT architectures, but the process to derive an IOT architecture by the RA is the essential part to be designed, monitored and evaluated not just against time-cost-quality issues but also non-functional properties like interoperability, scalability, privacy, resilience.	
STW.100	Guidelines for the RA should be published, lines of conduct, best practices, advices in order to build an IOTA-compliant architecture. An IOT Architecture Building Wizard should encompass all the above by providing architects with the right suggestions on how to build an IOT-A compatible architecture, including suggestions to solve compatibility, interoperability, privacy, scalability problems.	
STW.082	When talking about business models a firs t question is: Why to use the RA to realize a business model?	RA should not realize a Business model. RAs are simply patterns that show the technological feasibility of certain solutions. Therefore, Business models exist independently, and RAs are just enablers. In the best practices section, we will need to clarify precisely the relation between business models and RA, and how to implement a specific architecture given a target business model.

ID	Stakeholder Comment	Suggestion
STW.102	The overall functional model (and also in part the domain model) seems exclusively service-oriented, as well as all the upper parts of the stack: once we model and virtualize things like services, then our task is finished, as it is the IoS which will be able to self-manage the services, orchestrate them, build proper business processes and run enterprise/citizens applications.	IoT-A encompass the whole range of IoT technologies, from services to devices. Clearly, the way an expert looks at our modelling is often from his point of view, therefore there could be the impression that the work is service-oriented. We need to make clear, both in the WP1 deliverables and in the publications stemming from the technical workpackages, that the effort is not only towards services, but on developing sustainable technologies for the interoperability of IoT systems.
STW.104	In synthesis, I see the current approach too service-oriented and not IOT specific. By absurd, we could say that we should focus just on the real world because on top of it we will have just services and IOS will manage it. This is absolutely not true.	
STW.116	If you build an architecture on the basis of the requirements of today this will be not normative at all.	IoT-A does not aim to build a architecture, but a Architectural Reference Model. Abstracting the specific requirements we have today we envisage building the necessary modelling foundation to provide Reference Architectures for future concrete implementations. Similarly to the ISO OSI 7-layers model, which enabled the development of advanced web architectures, our ARM aims at providing the base on which to build future products. We need to pursue a more aggressive dissemination strategy in order to clarify what are the objectives of IoT-A and how our modelling work can be used in the future.
STW.117	You should make a reference architecture for the systems of tomorrow and the day after tomorrow.	
STW.262	How does the RA combine all the UC scenarios?	The best practices section should clarify how from an abstract model some practical use-cases can be developed.
STW.267	Privacy and Security should only taken into account where necessary, not for everything	The notion of privacy is context-dependent, as security. Currently, the Security Officer is coordinating efforts through all the WP in order to develop security and privacy policies that could be used whenever specific requirements indicate that certain vulnerabilities or risks exist. The result of this coordination will result in publications and in specific sections in different deliverables.
STW.305	Definition of trust model?	The definition of trust model will be done within the security effort.
STW.310	Life span of information?	The information lifecycle is tackled within the Information model. We need to pursue an aggressive dissemination strategy on all different aspects of the ARM, including Information model, and gather feedback for the last iteration of the ARM.

5. The internal requirements

This chapter presents the internal requirements gathered from the technical work packages. The concept and structure of gathering requirements within the project follows a two step approach. In a first step, the technical work packages were asked to formulate requirements towards the IoT-A architecture in such a way that the architecture would support, facilitate, or enable a set of typical system use cases that the technical work packages would specify based on the particular idiosyncrasies of their individual work package. This first step would help ensuring that the overall architecture could serve as a reference for deriving concrete architectures in the individual work packages. The format and structure of this initial gathering of requirements was similar to the compilation of the stakeholder requirements. No views or perspectives were introduced to cluster the requirements. In order to provide for the opportunity of evaluating the internal requirements towards the end of the project not only a description and rationale where provided, but also a fit criterion.

In a second step the raw data initially collected will be clustered and structured according to the views and perspectives introduced for the unified requirements. This process is currently ongoing and therefore it is not part of this deliverable. The results will be reported in the forthcoming deliverable D6.3.

As written above, within step one a set of technical requirements were acquired from the partners spanning the entire IoT-A project, in all of IoT-A's different aspects: this includes specialists in orchestration, communication, discovery & lookup, and in IoT-objects. These topics also correspond to the internal subdivisions of the IoT-A project by work package, so that requirements were provided from all of the technical work packages 2, 3, 4 and 5.

5.1 Approach and methodology

The approach taken was to ask each work package (which corresponded to the areas of orchestration, communication, discover and devices) to analyze the state-of-the-art work which was carried out in D1.1, and formulate best practices by writing requirements for the IoT-A reference model. This task was undertaken in February 2011 and continued until June 2011.

Additionally, as part of the work in developing the architecture reference model, the technical work packages had to generate system use cases for their areas of expertise. Upon completion of the system use cases, each work package was requested to extract the requirements for certain functionalities which an IoT system should have, and give these requirements to WP6. System use cases related to typical processes and functions that would be relevant for the respective work package. For example, work package 2 deals among other topics with process modeling and process execution, and effectively bridges the gap between the Internet of things and higher levels of the future Internet. Consequently, a work package 2 system use case involves process execution and the binding and orchestration of respective services. An internal requirement derived from this system use case would then relate to the modeling concepts necessary in order to reflect the Internet of things within the domain of business process modeling. As we can see below, most of the internal requirements gathered directly relate to the functional blocks found in the work package specific system use cases. The whole approach is summarized in the following figure.

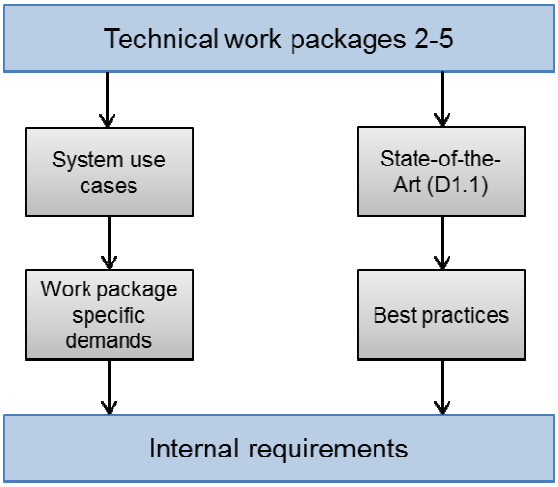

Figure 7: Approach by which internal requirements were obtained

The first iteration of the internal requirements appeared in D1.2 Initial Architecture Reference Model; these requirements were checked internally for consistency with the terminology and concepts defined in D1.2, by an expert group of partners who had roles in both WP6 and another technical work package. Some of the requirements listed below are currently being questioned by work package 1 with respect to the fact that they might be more relevant to the individual technical work package than to the overall reference architecture. This will probably result in a reduction of the nearly 100 requirements listed below to only those that are strictly relevant for the reference architecture. Nevertheless, as step two of the internal requirements processing is currently being performed and is therefore not reported in this deliverable, we still list all of the requirements initially gathered. The following table thus reflects the state of the internal requirements as it was published in the annex of D1.2.

5.2 Table of the internal requirements

ID	Description	Rationale	Req. Type
IR2.1	The process editor must be able to create BPMN 2.0.D25	BPMN 2.0 was evaluated to be the most IoT-aware process notation.	FR
IR2.2	The process editor must be extendable.	The reuse of a comprehensive tool allows to focus the effort.	FR
IR2.3	The process editor must provide facilities to model on business level.	A business user is not able to specify an executable process model.	FR
IR2.4	The process editor must provide facilities to model on technical level.	A technical user is not able to specify the business frame of a process.	FR

ID	Description	Rationale	Req. Type
IR2.5	The process editor has to be enduser-friendly.	A business user needs to be able to model a process.	NFR
IR2.6	The process editor must be able to verify the syntax of the process model.	The technical user needs information about the correctness of the syntax before the execution.	FR
IR2.7	The process editor must be "easily and fastly" extendable.	First project results should be presentable in a small time frame.	NFR
IR2.8	The process editor has to provide an attractive graphical user interface.	The project results need to be representable in a research review.	NFR
IR2.9	The process editor must be interoperable with developments of other WPs and Tasks.	The projects results should be combinable to reach the common project goals.	FR
IR2.10	The process editor must support BPMN 2.0 completely (in particular the IoT-aware parts)	The development effort should focus on the BPMN IoT extension.	DC
IR2.11	The process modeling notation has to be extensible in terms of the definition of new stencils, the specification of new syntax, the definition of serialisation and execution semantics.	The reuse of an existing process modeling notation allows to focus the effort on the IoT-extension.	FR
IR2.12	The process modeling notation has to be executable.	The projects task 2.2 and 2.3 should closely work together and represent a hand in hand solution.	FR
IR2.13	The process modeling notation has to be IoT-aware.	Due to the DOW the project focuses on IoT processes.	NFR
IR2.14	The process modeling notation has to offer a graphical representation.	A graphical process notation offers a symbolism to easily model and document business processes.	FR
IR2.15	The process modeling notation has to be a standard.	A common standard maximizes the potential application of industrial stakeholders.	NFR
IR2.16	The BPMN extension must support an entity based approach defined by the domain model of WP1.	The domain model is one key result by WP1 and should fit to the business modeling approach of WP2.	FR
IR2.17	The BPMN extension must support the process execution distributed over several devices.	In the IoT the execution of process steps can be distributed over several devices.	FR
IR2.18	The BPMN extension must support the modelling of different IoT specific interaction types.	The interaction between different devices, the integration of information about physical entities, and the interaction between services characterizes the IoT.	FR

ID	Description	Rationale	Req. Type
IR2.19	The BPMN extension must support to arrange data distribution over several data storages (resources) of devices.	Business Processes in the IoT distribute data objects in resources of many devices.	FR
IR2.20	The BPMN extension must provide means to scalably model and execute processes independently of the number of involved process components.	In IoT processes multiple physical entities, devices, resources and services can appear, which could negatively effect the performance of the execution.	FR
IR2.21	The BPMN extension must support the abstraction of individual process components.	In the IoT multiple devices, resources and services can appear. The accuracy and availability of accumulated data can be of much higher importance for the process than the data of individual components. The extension shall provide abstractive individual process components.	FR
IR2.22	The BPMN extension must support means to express the availability of a process component.	Due to the mobile nature that physical entities, devices and its services and data often have, a business process can have a different availability depending on its involved components.	FR
IR2.23	The BPMN extension must provide means to express the tolerable error rate of a process.	Depending on the process, a process result is still acceptable as far it stays under a tolerable error rate.	FR
IR2.24	The BPMN extension must provide means for designing context-aware business processes.	Depending on occurring events the IoT processes need to be highly flexible.	FR
IR2.25	The BPMN extension must provide means for expressing the uncertainty of process components.	The uncertainty of individual process components can influence the process creation on model and execution time.	FR
IR2.26	The BPMN extension must provide means for expressing real-time constraints.	As the process interact with augmented entities real-time constraints apply to these processes	FR
IR2.27	The process execution engine must be able to execute processes described in BPMN 2.0 format.	The graphically defined BPMN 2.0 process model can be executed without mapping the process model to another notation.	FR
IR2.28	The process execution engine must be able to execute defined BPMN 2.0 extensions.	The execution demonstrates the benefit of the graphical extension.	FR
IR2.29	The process execution engine must be "easily and fastly" extendable.	The development should focus on the IoT related extension.	NFR
IR2.30	The process execution engine must be interoperable with the results and development of the other WP task.	The projects results should be combinable to reach the common project goals.	FR
IR2.31	The process execution engine must support BPMN 2.0 completely.	The development effort should focus on the BPMN IoT extension.	FR

ID	Description	Rationale	Req. Type
IR2.32	The process execution engine must support the integration with a Complex Event Processing (CEP) component.	One WP central process execution engine including the CEP enables a bigger research contribution.	FR
IR2.33	Mobile entities must be able to provide events to the platform	Many physical entities such as mobile phones, products in a retail store, etc. are mobile and IoT-A must be able to detect changes related to those entities	FR
IR2.34	Events are processed on a set of distributed nodes	A distributed architecture provides more flexibility in the way events are processed, saves energy and allows minimal functionality if there is no network connectivity	NFR
IR2.35	Processing of events must take quality of information (QoI) into account	QoI may have an impact on applied processing and varies processing steps (e.g. mean calculation),	FR
IR2.36	Quality of information related to virtual entities can be retrieved from the system	Different devices provide information with varying quality. An application may have certain quality requirements.	FR
IR2.37	The IoT-A reference architecture shall provide events that can be related to augmented entities	Augmented entities are the key concepts in IoT-A with which the applications will deal with.	FR
IR2.38	The IoT-A reference architecture shall provide event templates that can be related to types of augmented entities	Events can be defined for a class of augmented entities at design time, but evaluated for every augmented entities of the same type at runtime. Otherwise Events must be defined for every particular augmented entity.	FR
IR2.39	The IoT-A architecture shall provide a shared memory of the observable phenomenon	Due to services could not be online all the time it could be necessary to incorporate a shared memory in order to store this information.	FR
IR2.40	The IoT-A architecture shall provide unified interfaces to access and query the resource/entity meta data	This will enable WP4 discovery and identification and also reasoning mechanisms to access the required descriptions	FR
IR2.41	The IoT-A architecture shall provide unified interfaces to access and query the observation and measurement data emerging from resources	This will enable integration of IoT data into business layer and high-level applications; this will be also related to requirement IR2.39	FR
IR2.42	The IoT-A architecture shall provide standard query end-points and generic reasoning mechanisms to infer the emerging data and to process the stored meta-data related to resources/entities	This will provide generic interface to query the stored meta-data and to enable high-level applications/services to perform query and reasoning upon the existing/emerging data	FR
IR2.43	The IoT-A architecture shall provide mechanisms to publish and present the resource/entity/service description meta data as linked-data	This will enable linking the published description to other domain knowledge and also location models described by third party ontologies or open linked data concepts and will also support reasoning the data based on high-level concepts and entities defined in domain ontologies	FR

ID	Description	Rationale	Req. Type
IR2.44	The orchestration engine shall interpret service descriptions	service orchestration is done based on service descriptions	FR
IR2.45	The orchestration engine shall support creation of new applications	Higher level services should create new functionality	FR
IR2.46	The orchestration engine shall create new service descriptions	The newly created service must be registered with service discovery	FR
IR2.47	The orchestration engine shall support flexible composition	Services involved in compositions can fail and need to be replaced by some serving equal needs	FR
IR2.48	The orchestration engine shall handle scopes for selecting services for composition	Scopes selected for composed service must be applied to the atomic services as well	FR
IR2.49	The orchestration engine shall increase quality of information by service composition	QoI can be increased by using additional information as reference	FR
IR2.50	The orchestration shall access service resolution	Orchestration depends on service descriptions provided by discovery	FR
IR2.51	The orchestration shall provide a feedback to the user who sent a composition request	The feedback should contain a message about the success of the requested composition	FR
IR2.52	The orchestration engine shall provide feedback within a reasonable amount of time (<5sec)	A time out must be set for request/response loops	NFR
IR2.53	The orchestration engines shall support setting preferences for selecting services involved in composition	Users can have the possibility to prefer one service over another for any reason	FR
IR4.1	Discovery and lookup service of IoT systems shall allow the locating physical entities based on geographical parameters	Confirms our present plan of having some geographical representation. This requirement is derived from SmartProducts (SP) requirement "A SmartProduct should be able to locate another SmartProduct in the same environment w.r.t. their environment"	FR
IR4.2	A geographical location attribute shall exist for virtual entities	Confirms our present plan of having some geographical representation. Derived from SP requirement "A SmartProduct should be able to access the location information of other SmartProducts"	FR
IR4.3	IoT-A shall support a standardized location model and location-information representation.	Derived from SP requirement "Smart products shall support a standardized location model and location-information representation."	FR
IR4.4	IoT-A shall support a hybrid location model, that is, it shall support symbolic coordinates as well as local and global	Derived from SP requirement "Smart products shall support a hybrid location model, that is, it shall support symbolic coordinates as well as local and global	FR

ID	Description	Rationale	Req. Type
IR4.5	The location model shall allow programmers to add new coordinate reference systems and shall support the transformation of coordinates among them	Derived from SP requirement: The location model shall allow programmers to add new coordinate reference systems and shall support the transformation of coordinates among them	FR
IR4.6	The location model shall enable the implementation of the following	Derived from SP requirement: "The location model shall support the following common location queries: position queries, nearest neighbor queries, navigational queries, and range queries"	FR
IR4.7	The look-up service of IoT-A shall withhold or grant information depending on context such as application involved, requesting entity, and security permissions	Needed for fulfilling security requests of stakeholders. Derived from BRIDGE requirement: "A broad set of data from enterprise applications MAY be requested depending on context, industry, application, etc"	FR
IR4.8	Services (and information providing services) connected with the IoT system can indicate what information can be found by a Discovery/Look-up service	Opting out of being found in a data search was indicated in the BRIDGE requirement and also in the IoT-A stakeholders. The BRIDGE requirement was "Data that companies are willing to provide to the Discovery Services are mainly URL addresses of databases / EPCIS repositories"	FR
IR4.9	The Digital Entity History Storage should allow for storage of aggregation changes	This is a main functionality of the BRIDGE system which applies to RFID/assets tracked in the EPCGlobal framework	FR
IR4.10	The Digital Entity History Storage shall be restricted in who can call delete and update functions	The integrity and trust in the history storage block depends on how "unaltered" it is. The BRIDGE SoTA justifies the present use of the "history storage" component. They expressed it as "Discovery Service security policies may be set to restrict update and delete actions on DS records to provide a journal functionality"	FR
IR4.11	Clients requesting data via the Discovery/Lookup services shall be uniquely identifiable	BRIDGE mentioned that the unique client identification at the DS is required to control access to data stored on the DS (particularly EPC number and link).	FR
IR4.12	Data owners should be able to set access-control rights/ policies (set up by data owners) to their data stored on resources	This addresses privacy by putting the control in the hands of the data owners (or certain external groups)	FR
IR4.13	Access-control rights/ policies (set up by data owners) shall not be published publicly.	Access control policies themselves, if known, can give away information.	DC
IR4.14	The IoT system must enable the dynamic discovery of relevant virtual entities and their related services based on respective specifications.	Augmented entities are the core concept proposed for IoT and to enable applications that do not have to be a-priori configured for a fixed set of augmented entities, discovery at runtime must be possible.	FR
IR4.15	The IoT system must enable the dynamic discovery of relevant physical entities and their related services based on a geographical location scope.	Geographic location is one of the most important aspects for finding relevant physical entities. Spatial relations are of prime importance in the physical world.	FR

ID	Description	Rationale	Req. Type
IR4.16	The IoT system must enable the lookup of service descriptions of specified services for an augmented entity with the augmented entity identifier as key for the lookup.	It is important to find the services related to an augmented entity that may provide information about it, allow to actuate the augmented entity or enable interaction with the augmented entity.	FR
IR4.17	The IoT system must enable the resolution of service identifiers to service locators.	Due to the heterogeneity, dynamicity and mobility in the Internet of Things, the communication endpoint may change or different endpoints may be suitable for different applications. Therefore, services should be uniquely identified by a service identifier, but this identifier should not be used for locating the service, so a resolution step is necessary.	FR
IR4.18	The IoT system must be able to discover dynamic associations between an virtual entities and services related to the virtual entities	Due to the mobility of physical entities as well as devices whose resources are accessible through services, changing services may provide information, allow actuation or enable interaction with physical entities. In order to provide the currently relevant services for a corresponding virtual entity, the dynamic associations must be discovered	FR
IR4.19	The IoT system must be able to track dynamic associations between an augmented entity and services related to the augmented entity to determine whether they are still valid.	Due to the mobility of augmented entities as well as devices whose resources are accessible through services, changing services may provide information, allow actuation or enable interaction with augmented entities. In order to provide the currently relevant services for an augmented entity, the dynamic associations must be tracked to determine whether they are still valid.	FR
IR4.20	The IoT system must be able to discover dynamic associations based on geographic location and other context information.	Mobility is one of the key aspects for changing associations. By monitoring the location of physical entities and area for which resources can provide information, possibly in combination with other context information, dynamic associations between physical entities and services providing access to resources can be discovered.	FR
IR4.21	The IoT system must be able to track dynamic associations between an virtual entity and services based on geographic location to determine whether they are still valid.	Mobility is one of the key aspects for changing associations. By monitoring the location of physical entities, e.g., using location services, it can be determined when associations become invalid due to the geographic distance of physical entities and possibly other aspects.	FR
IR4.22	The IoT system shall enable the discovery and lookup of associations across multiple administrative domains.	The Internet of Things will consist of multiple administrative domains with different owners. To develop its full potential interactions, including lookup and discovery, across domain boundaries must be possible.	DC
IR4.23	The IoT system must respect the privacy aspects when performing discovery, resolution and lookup	Privacy is a key aspect for the IoT.	DC
IR4.24	The IoT system must provide privacy protection for users accessing information about physical entities or services	For acceptance of the Internet of Things privacy during usage must be guaranteed	DC

ID	Description	Rationale	Req. Type
IR4.25	The IoT Service Identifier shall use the service/resource description for retrieval	The IoT System must consider the description of a service/resource for the semantic indexing on which the search will be performed	FR
IR4.26	The IoT System shall be able to accept and manage semantic queries from the user and return Resources/Services	Necessary for the match in the VE Semantic Retrieval	FR
IR4.27	The Discovery Service in local search, is required to find service/resource based on (rough) semantic description	Because the discovery service in local search combine the peer to peer discovery with the white search (no semantic filter) in the geo-localization context.	FR
IR4.28	The IoT system shall have a service to obtain a new identifier to the new VE registered resource/service and to save the description of its services	VE Service Identifier manages the ID (VID) and the semantic description, for the Global Discovery Search.	FR
IR4.29	The IoT system shall have a service to insert the operational specifications of the new registered resource/service	VE Service Specification manage the association ID(VID) to the operational specification for the LookUp Service	FR
IR4.30	The IoT system shall have a service to register the proper URI and the locator of the new registered resource/service	To managed by dynamic linker, uses for the Resolution Service by return the last address/locator	FR
IR4.31	A VE that is associated with a PE that changes geolocation shall update coordinates/address/locator through IoT system service	IoT Service Monitoring is a service that manages the coordinates/address/locator and uses for the Resolution Service by return the last address/locator	FR
IR4.32	IoT system should define a common virtual identification system (virtual-ID)	An universal identifier should be defined as standard ID in order to map it to the specific ID used in every type of system (TCP/IP, RFID, ...)	FR
IR5.1	The communicated messages must not be spied by an unauthorized person or device	Confidentiality must be ensured	NFR
IR5.2	The device (contactless card for example) must not be activated without the consent of the owner	To avoid unsolicited scanning of people	NFR
IR5.3	The identifier of the device (ID of an RFID tag for example) must not be tracked by unauthorized entities	The tracking of items and then people raise the problem of privacy	NFR
IR5.4	Connected objects shall be able to do energy harvesting	Maintain operation in harsh environments	FR
IR5.5	Connected objects shall be able to communicate with each other through the network via standard communication interfaces	Enhance wide use potential	FR
IR5.6	Data security & privacy should be enabled at atomic level		NFR

ID	Description	Rationale	Req. Type
IR5.7	Communication with the objects must be intermittent and command-based	Avoid traffic overhead	NFR
IR5.8	Each object should have a universal ID, part of it read-only and part of it read/write	Enable object recognition and setup/configuration in the context of particular applications development	NFR
IR5.9	Object capabilities may be universally defined at HW-level	Enable plug n'play operations at user services level	NFR
IR5.10	Atomic-level protocols must implement only functions related to data acquisition (e.g. DSP-level), crypto and security	Avoid overlap with user-level communication protocols (WP3)	NFR

5.3 Analysis of internal requirements

As the numbering scheme used in the table above shows, more than half of the requirements initially gathered were collected in work package 2 alone (53 requirements). Work package 4 contributed 32 requirements and 10 requirements were collected in work package 5. The number of requirements coming from work package 2 is expected to decrease in the next report, as a significant part of the requirements relate to business process modeling functionality that is not regarded as a core output of the project. Another focus of work package 2 is service orchestration that is reflected in a significant number of internal requirements that are picked up by work package 1. Work package 4 is closely related to work package 2 in the sense that it primarily deals with services that are bound to processes defined in work package 2. At the same time, it is also more centrally located in the functional view of the IoT-A project, mediating between the higher levels of the WP2 business systems relevant for the future Internet and the lower levels of the Internet of things stack dealt with in WP3 and WP5. Consequently, the requirements formulated in work package 4 deal with the association of virtual entities with services that e.g. are used to monitor them or access their resources. From fundamental questions such as the ownership of data or privacy issues, the range of requirements from WP4 includes the discovery, look up and resolution of services, as this closely matches the functional blocks relevant for work package 4. A further focus of the requirements of WP4 is also the location of entities, as location is one of the most important contexts in the domain of the Internet of things. Finally, as work package 5 is concerned with the “things” in the Internet of things, the requirements from WP5 mainly focus on the capabilities and communication means of devices and core operating objects that need to fulfill certain functionalities within an Internet of things.

While the selection of internal requirements already provides a beneficial input to the architecture work in WP1, the list as presented here is still rather heterogeneous in terms of the degree of abstraction and the perspectives that are addressed by the requirements. Also, some of the requirements are more related to the reference model than others. It is therefore planned to restructure and reorganize the internal requirements in a similar way as the unified requirements presented in this document. The results of the second phase of internal requirements processing will consequently be reported in D6.3.

6. Conclusion and outlook

The content of the deliverable D6.2 is twofold – primarily, we present an update of the initial requirements list presented in D6.1 and secondarily use the deliverable to document the interaction with stakeholders in the last year and their feedback for the IoT-A ARM.

6.1 Update of the requirements list

The work with the requirements can be summarized in three different activities. First, the initial list of stakeholder requirements has been taken into account during the development of the IoT-A ARM and thereby been reflected and discussed by the IoT-A architects. This process included a reshaping of requirements to make the specific and domain driven expressions more general, understandable and applicable to architectural modeling. The necessary diligence was taken to keep the intention of the stakeholder rationales during this process. As side effect to this cross WP work, also the list of fields for characterization of requirements was further elaborated. The results of this first step are documented in Chapter 2.

The results of the stakeholder workshops 2 and 3 were evaluated for new requirements, and the results of this process are explained in Chapter 3. Some new requirements were successfully identified, while most statements of stakeholders have been evaluated to be already represented in the list of requirements. These requirements are communicated to the WP1 for consideration in future iterations of the ARM.

Finally, a collection of internal requirements was conducted within the technical work packages. This collection is presented in Chapter 5 and contains the requirements as seen for the development of new mechanisms for the IoT. These internal requirements stem from the expertise of the involved partners and the state of the art. Currently, these requirements undergo a similar revision as applied to the initial stakeholder requirements, with the goal to derive requirements applicable on the architecture level.

6.2 Stakeholder feedback to the ARM

For the documentation and further iterations of the IoT-A ARM the feedback of stakeholders collected on stakeholder workshop 2 and 3 is presented in Chapter 4. Many statements of stakeholders confirm the work IoT-A is addressing in the ARM. Thus we restricted the list to issues we evaluate to give new ideas and directions to the modeling of the ARM.

6.3 From requirements to validation

The requirements collected in the first stage of the project provided a strong basis for the development of the ARM and the WP7 use cases. Now that the development is in progress and requirements have been “guiding development”, we will start to use the requirements also for “inspecting development“ during the validation.

The requirements impact the validation process directly in terms of the technological validation and indirectly in terms of the business and socio-economic validation. The direct impact results of the development of the ARM on the basis of the requirements. The indirect impact is recognizable as the ARM provides the foundation for each application-specific concrete architecture and thus for each use case. In order to reach this a possibility of measuring the fulfillment of requirements is required.

Therefore a so-called “fit criterion” will be added to both the unified and internal requirements. This fit criterion allows verifying, that the requirements are not only collected, but also taken into account and corresponding mechanisms are implemented in the development.

Figure 7 depicts this validation step in terms of the technological validation. As can be seen from the figure the requirements build the foundation for both the reference model (RM) and the reference architecture (RA). Both of them will be used to create a domain-specific application (UC) for what a concrete architecture (CA) is necessary, however this process is not available yet. The link to validation is the following. If one can claim that a requirement is reflected in the concrete architecture a valid cycle starting from requirements over the ARM and concrete architecture is identifiably. In this case the traceability from requirements to concrete architecture is established and verified. In the other case a requirement is not reflected in a concrete architecture the cycle is broken and thus the traceability is not existent.

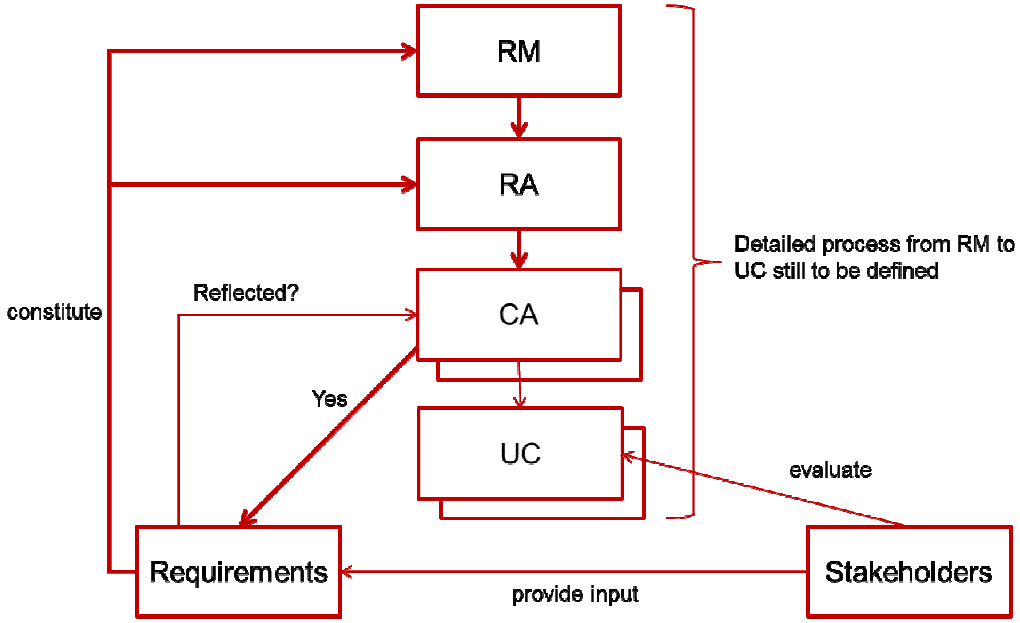

Figure 8: Technological validation approach

The scope for the upcoming stakeholder workshops will shift from collecting new requirements to validate the developments in IoT-A. From this time on the focus lies on refining the ARM, for what new requirements won’t influence significantly, rather than developing entirely new features. For this purpose it is planned to expose the IoT-A demonstrators implemented in WP7 to the stakeholders and to evaluate the above-mentioned cycle.

The validation will be subject to the upcoming stakeholder workshops in June 2012 and May 2013.

7. References

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Appendix A – Acknowledgments

Workshops

This report is based on the outcome of the Second and Third IoT-A Stakeholder Workshops which took place within the IoT week in June 2011 and one day before the IoT International Forum in Berlin, 22nd of November 2011. The workshops were initiated and organized by the partners involved in the work package 6: Requirements, Validation and Stakeholder Interaction.

Workshops participants

A particular recognition goes towards the workshop participants who dedicated their knowledge and time to this event. The following experts participated in the workshop with the privilege to be moderated by Rob van Kranenburg.

Name	Organization	Domain
Gérald Santucci	European Commission	
Francesco Tangorra	University of Milan	End User / Veterinary Sciences for Animal Health and Food Safety
Patrick Guillemin	ETSI	Technology / Standardization
Christoph Thuemmler	Edimburgh N. University	End User / Health
Alain Berne	Groupe Casino	End User / Retail
John MacGregor	Bosch Corporate Research	Technology / Automotive
Amine Mohamed Houyou	Siemens AG	Technology / Technology Integrator
Thomas Jell	Siemens IT Solutions	Technology / Technology integrator
Julien Mascolo	Centro Ricerche Fiat	End User / Automotive
Stefania Leonardi	University of Milan	End User / Veterinary Sciences for Animal Health and Food Safety
Henri Barthel	SG1	End User / Standardization

Name	Organization	Domain
Dr. Simon Huettinger	Siemens Audiologische Technik GmbH	End User / Hearing Aids
Mirko Ross	Echolot digital worx GmbH	End User / Internet
Cristiano Storni	Interaction design centre - university of limerick	End User / Health
Filippo Visitainer	Centro Ricerche Fiat	End User / Automotive
Sergio Gusmeroli	TXT	Technology / ELLIOT
Rob van Kranenburg	IoT Council	Moderator
Alessandro Bassi	Hitachi Europe	IoT-A
Edward Ho	University St. Gallen	IoT-A
Alain Pastor	Alcatel-Lucent Bell Labs	IoT-A
Ralf Kernchen	University of Surrey	IoT-A
Carsten Magerkurth	SAP	IoT-A
Alex Salinas	University of Würzburg	IoT-A
Laure Quintin	VDI/VDE-IT	IoT-A
Norbert Vicari	Siemens AG	IoT-A
Gregorio Martín	Telefonica	IoT-A
Francois Carrez	University of Surrey	IoT-A
Sebastian Lange	VDI/VDE-IT	IoT-A
Martin Bauer	NEC Europe Ltd.	IoT-A

Special thanks to Eleni Kosta (Faculty of Law, Katholieke Universiteit Leuven) who could not attend the workshops but who was kind enough to answer the survey.

Appendix B – Stakeholder Use Cases

This section lists new stakeholder use cases as presented on stakeholder workshops. The use case below extends the use cases on, Health Care, Technology Integration, Retail, Automotive, Service Integrators, Telecom Operators, Standardization, and Veterinary Medicine as described in D6.1.

E-Health: Audiologic devices

Stakeholder: Dr. Simon Huettinger, Siemens Audiologische Technik GmbH

Background

Hearing aids are medical assistive technologies that utilize a large share of electronic processing. Within the last 10 years, hearing aids have made the step from the analogue to the wireless digital world. This means, that both sides of the hearing aid are interconnected as well as are connected to a remote control to see the battery state and to parameterize the hearing aid.

Use cases for IoT enabled audiologic devices

Currently, hearing aids are primarily a closed system with very little external digital communication. There are hardware extensions for the TV or audio set, that serve a relay to provide connectivity to the hearing aid, as well as similar connectivity to the mobile phone as it is provided by Bluetooth head sets.

a) Binaural signal processing

Both sides of the hearing aid communicate for collaboratively filtering environmental noise and enhance the hearing perception of the user. This could also help in increasing the awareness of the current user situation and to adapt the hearing profile to this situation.

b) No-relay-station connectivity

The hearing aid may directly recognize TV or audio systems and use the audio of those systems directly. Interconnecting hearing aids may enable communication where the real world does not allow talking directly, similar to a phone call but less disturbing.

c) Integration into audio-streaming-infrastructure

Currently audio information in public places and churches may be transmitted by magnetic loops. This is costly and allows for only one channel. Future systems may directly plug into some audio streaming infrastructure, which can have better cost efficiency and may also provide translated language versions according to the preferences of the user. This might also be of interest to travelers without hearing handicap.

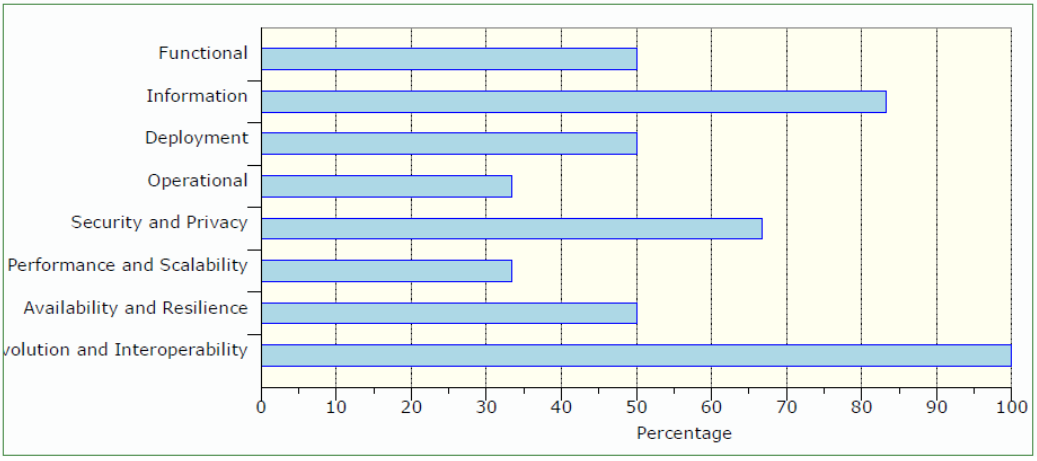
d) Benefit from ambient intelligence

The hearing aids may be completely integrated into the IoT. This might provide a big advance in context awareness and therefore better adaption to the current situation of the user. External computational resources may provide the power to solve complex tasks of the hearing aid without quickly draining the battery.

Appendix C – Survey

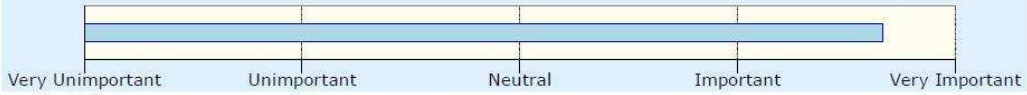
General | Functional | Information | Deployment | Operational | Security and Privacy | Performance and Scalability | Availability and Resilience | Evolution and Interoperability | Weighted Reqs

This graph shows the percentage of selection for each viewpoint/perspective.

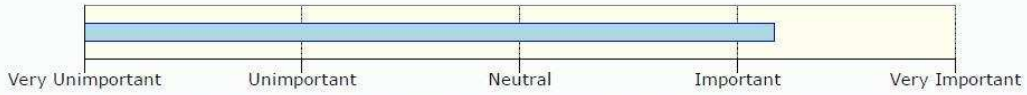


General | Functional | Information | Deployment | Operational | Security and Privacy | Performance and Scalability | Availability and Resilience | Evolution and Interoperability | Weighted Reqs

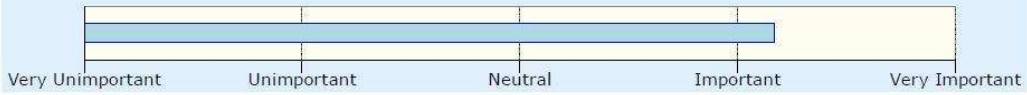
UNI.47 - The system must enable interoperability between Devices/Resources/Services and Applications



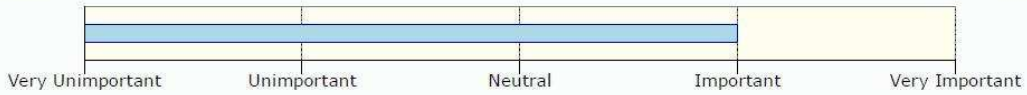
UNI.49 - The system shall provide interfaces with legacy systems



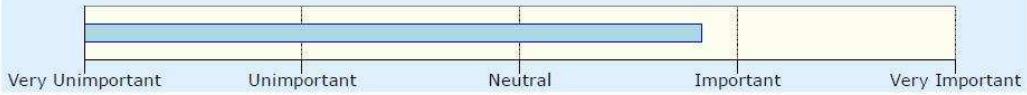
UNI.70 - The system shall handle semantic interoperability between different semantical levels



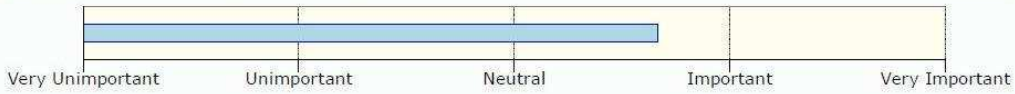
UNI.48 - The system shall provide an interoperable solution at the naming and addressing level



UNI.71 - The system shall provide standard communication between EoI-related Services



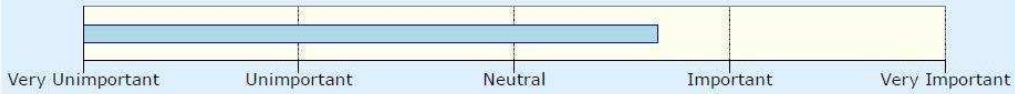
UNI.18 - The system shall support data processing (filtering, aggregation/fusion, ...) on different IoT-system levels (for instance device level)



Comments

Finding the balance between the collection and processing of data, which is essential for the various IoT systems, on the one hand and the protection of the privacy of individuals and the respect to the data protection legislation on the other.

UNI.16 - The system shall support EoI location tracking (geo spatial and/or logical location)

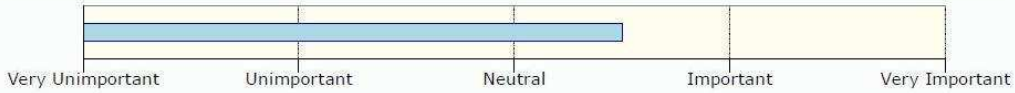


Comments

Very important if IoT is applied to Intelligent Transport Systems

Although this would be very useful for the deployment of specific applications, it is extremely important to pay attention to HOW location information is collected and processed, so that the user is always protected (especially in terms of privacy)

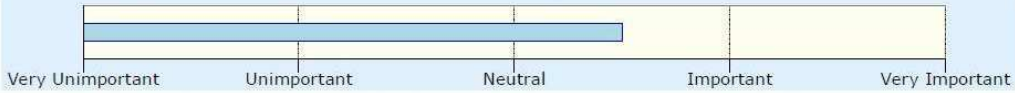
UNI.24 - The system shall provide secure communication, e.g. for health information



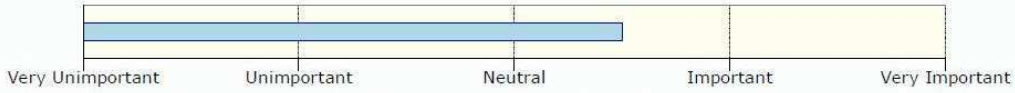
Comments

Indeed, although the transmission of such information should be limited to the utmost minimum.

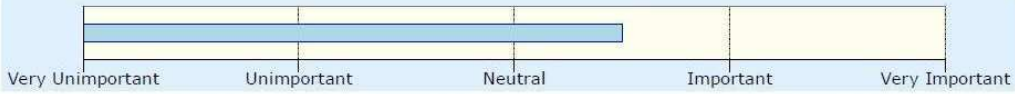
UNI.67 - The system shall provide different access permissions to the information



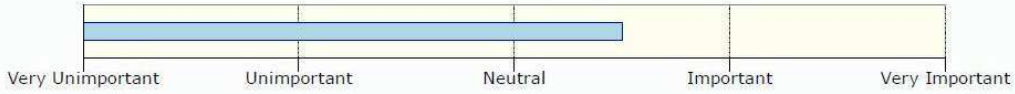
UNI.62 - The system shall provide highly trusted and secure communications and information management



UNI.22 - The system shall support secure communications through secure messaging tool



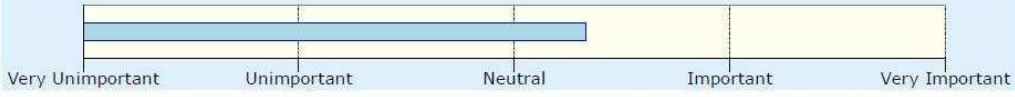
UNI.23 - The system shall provide access to external information sources, e.g. health databases



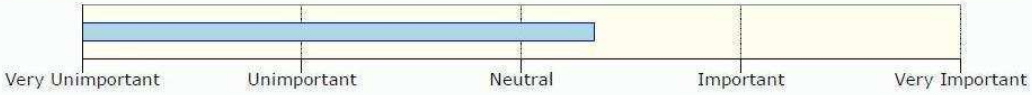
Comments

This should only be done if it does not jeopardise the security of the system and the external database. Enhanced linkability creates additional security requirements.

UNI.6 - The system shall propose means to design applications taking into account the semantical decriptions of Devices/EoIs



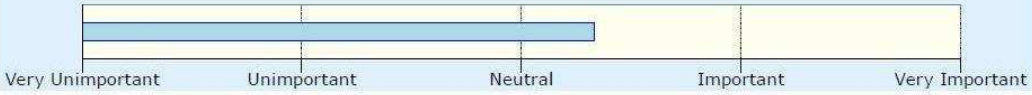
UNI.1 - The system shall provide a means to allow people to use Internet of Things Services anonymously



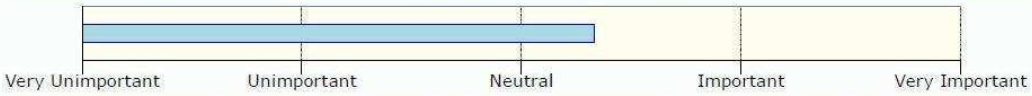
Comments

This is extrtemely important. However, in view of specific legal obligations of the data controller (such as data retention), it may not be always possible to do this. Usually, a control mechanism in case of fraudulent actions is also required.

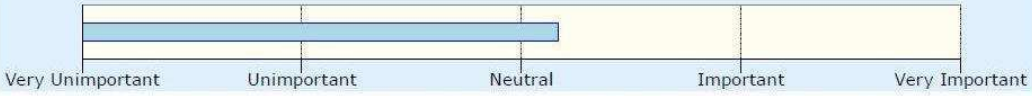
UNI.4 - The system shall provide a model for describing an EoIs semantically



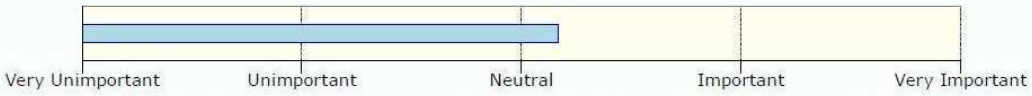
UNI.66 - The system shall provide integrity validation of EoI, Services and Platform



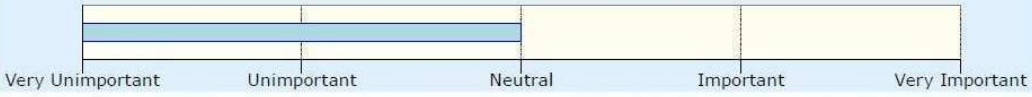
UNI.41 - The system shall provide a historical information of the EoI monitoring



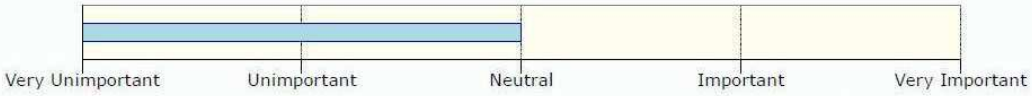
UNI.74 - The system shall make comprehensive semantic information about EoIs and services accessable to Human Actors and software agents



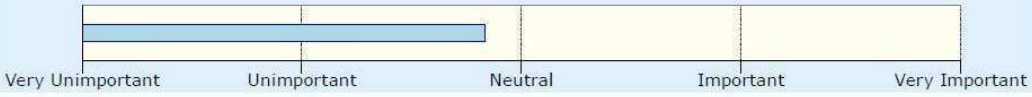
UNI.42 - The system shall inform the Service Client about its status and vice versa



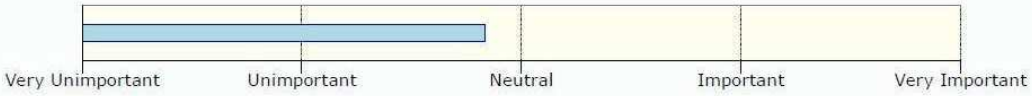
UNI.73 - The system shall allow the semantic description of EoIs and Services by an actor



UNI.40 - The system shall provide technical ways to ensure security and resilience



UNI.46 - The system shall support user profiling

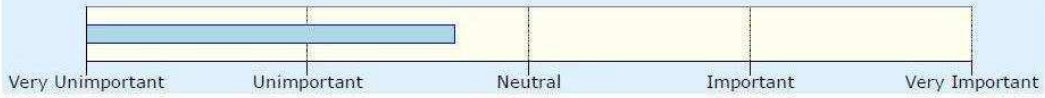


Comments

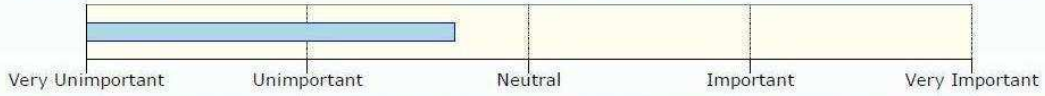
Very important for automotive applications

It depends what it is meant by this. Allowing the profiling of users entails societal and legal dangers.

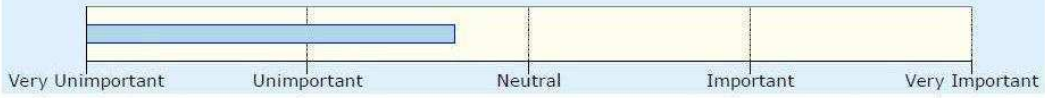
UNI.89 - The system shall support secure time synchronization



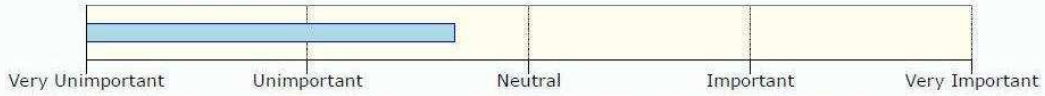
UNI.65 - The system shall be fault-tolerant and support always-on Services



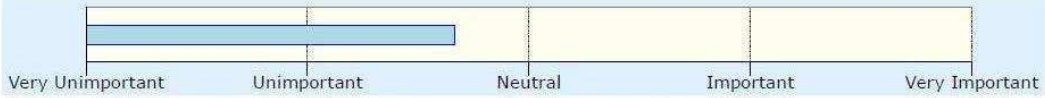
UNI.59 - The system shall provide different types of Services with different QoS associated to them



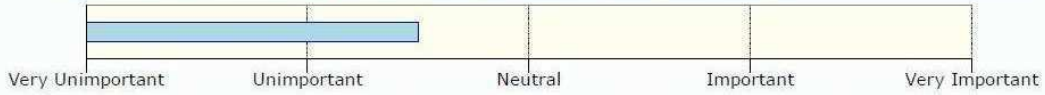
UNI.30 - The system shall provide a resolution infrastructure for naming, addressing and assignment of EoIs and Services



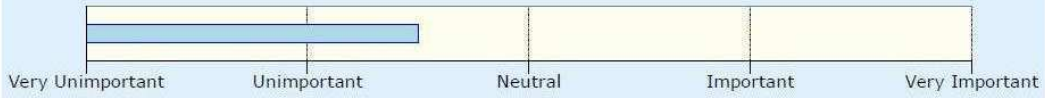
UNI.45 - The system shall provide interfaces in order to allow the access using Mobile Devices



UNI.51 - The system shall support mobility of Devices/Services/EoIs



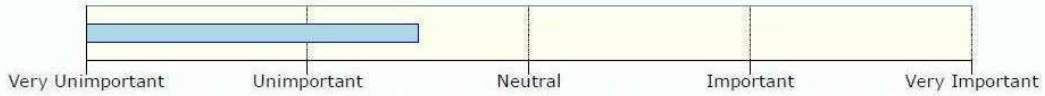
UNI.36 - The system shall provide means for linking entity specific user data of many users to one EoI



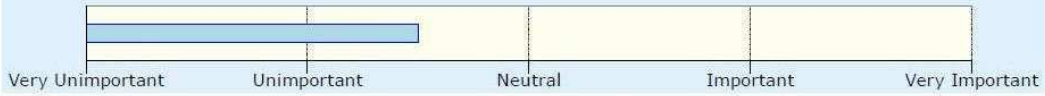
Comments

This can be very privacy intrusive

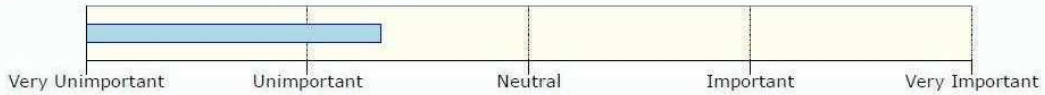
UNI.5 - The system shall provide interfaces for accessing the semantical descriptions of entities



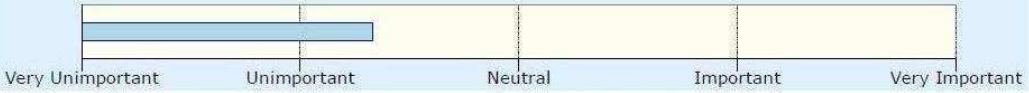
UNI.88 - The system shall provide alarm signalling to indicate initialization failure on Services and Platform



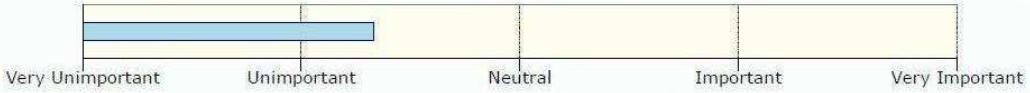
UNI.32 - The system shall provide means for IoT-entities to react autonomously on context data (e.g. by using a rule language)



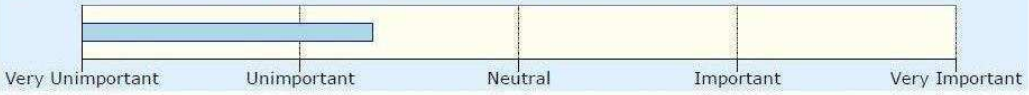
UNI.43 - The system shall enable the composition of EoI-related Services on devices and cloud services



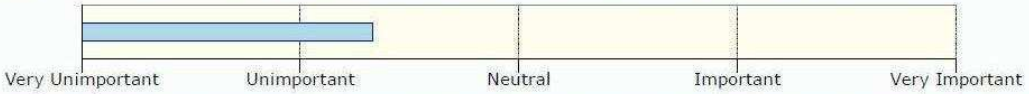
UNI.56 - The system shall support an energy aware architecture



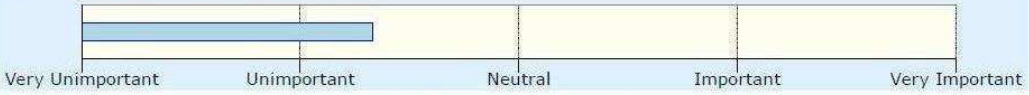
UNI.19 - The system shall support provider-based Device management



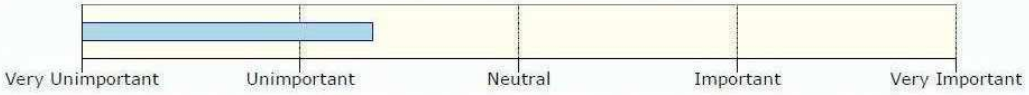
UNI.29 - The system shall provide a support for routing of data based on content



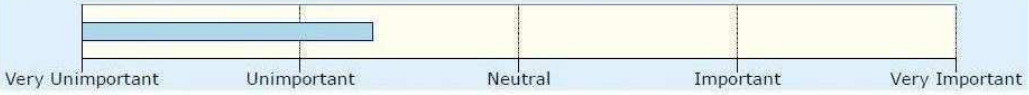
UNI.31 - The system shall provide functionality that allows the specification of business processes that autonomously monitor information related to EoIs and controls the respective aspects of the EoI



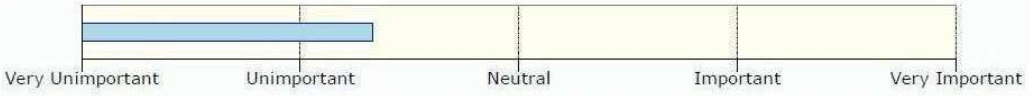
UNI.50 - The system shall provide mobility at the networking level



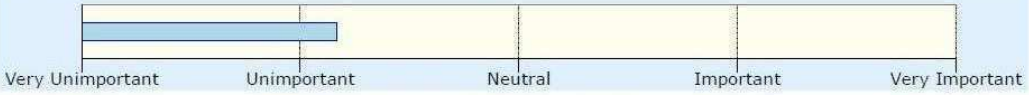
UNI.14 - The system shall support Devices to activate themselves into a collaboration



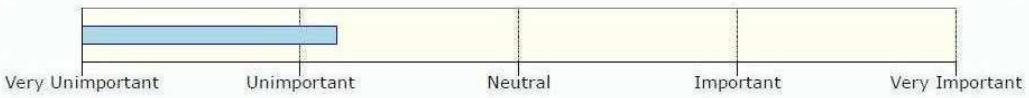
UNI.12 - The system shall be able to handle interference between IoT Devices (avoidance and detection)



UNI.21 - The system shall support the management of the radio transmitting Devices in real-time



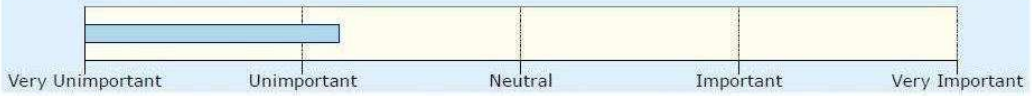
UNI.20 - The system shall support the real-time monitoring of the radio usage of Devices and gateways



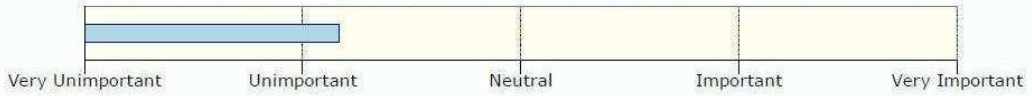
Comments

Monitoring of any kind, should be conducted only under specific safeguards.

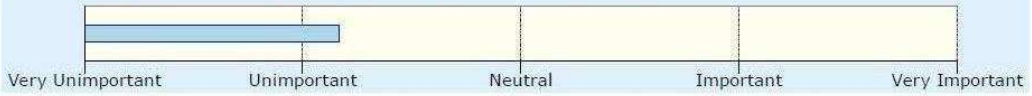
UNI.10 - The system shall enable autonomous goal-driven (task-driven) collaboration between Devices or Services



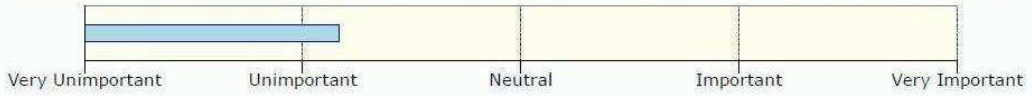
UNI.58 - The system shall provide high reliability and low latency communications



UNI.27 - The system shall support priorization of Services



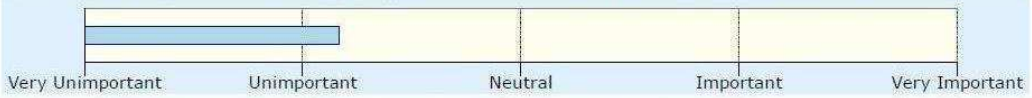
UNI.26 - The system shall support time critical message handling and delivery



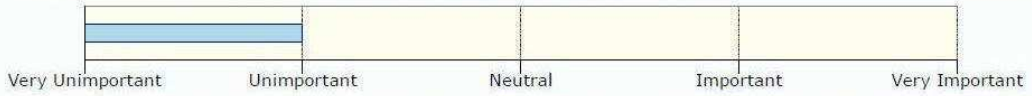
Comments

"Important for the application of IoT to Intelligent Transport Systems"

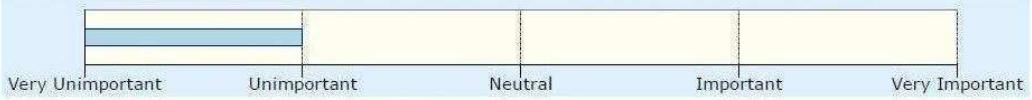
UNI.28 - The system shall support some mechanism of messages priorization



UNI.87 - The system shall support Service lifecycle management



UNI.8 - The system shall be able to run Applications and Services concurrently



UNI.60 - The system shall provide different SLA