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On IoT-services: Survey, Classification and Enterprise Integration

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***Abstract*—This paper presents the results of a recent survey we conducted on the usage of services and service oriented architecture (SOA) within Internet of Things (IoT) related public funded projects and the research community, in general. We identified the lack of a coherent definition and classification of IoT services, as it would be necessary to contribute to service science in general. We therefore present a definition of IoT services and classify them based on the relationship to a physical entity and their lifecycle. The usefulness of this is abstraction is then shown on the example of business process modelling and Enterprise SOA integration.**

I. Introduction

As part of our work on actuator and sensor integration into Enterprise IT systems we identified services as one of the main building blocks of the Future Internet. Nonetheless, we were surprised that there is still no common nomenclature and especially the term ”IoT-service” has different meanings among different projects. One of our goals is to merge ideas from the Internet of Services (IoS) and the enterprise IT world [1] for describing and provisioning IoT-services. Therefore it is a necessity to have a good understanding of what an IoT-service is, what its relationships to existing concepts is and how these concepts can be brought into the IoT world.

This paper will first describe services in general and as a main building block of the Internet of Things. Furthermore, we will survey existing definitions of services in an IoT-context and afterwards present our own coherent classification. Additionaly, we will show how this abstraction can help a business domain expert in working with IoT services.

II. Services

Services are a very suitable abstraction for building complex software systems and are the fundament of most of todays enterprise systems [2]. In the same way they play a cruical role in nowadays IT, it is suggested that they will also play a cruical role in the Internet-of-Things [3]. They are part of many domain and reference models. Furthermore, there is currently a lot of research in the areas of IoT and SOA [4].

Nonetheless, service is a somewhat heavily overloaded term which can have many meanings. For example, one wide-spread use of the term service is to use it as a synonym for what we call a *technical interface*, or software functionality provided by a defined service interface (e. g. Web-Services). In [5] a service is defined as a ”commercial transaction where one party grants temporary access to the resources of another party (...)”. In service science and in Internet of Services (IoS) research there were and are many efforts to establish one single definition of service, a comprehensive discussion of several ways to define service is given by Ferrario [6]. Nonetheless, no definition has been accepted by a wider community yet ([7], [5], [6]). Furthermore, it is questionable if there will ever be the one and only definition, as there are way too many different scenarios and usages need to be considered and even if there would be only one definition it would most likely be too general, so that specialized service definitions will continue to persist.

III. Survey

To get a clear picture what currently is considered as an IoT-Service we surveyed more than 30 past (e. g., SIRENA [8], SOCRADES [3], SENSEI [9], RUNES [10] and OASiS [11]) and ongoing ([12]) EU projects and did a comprehensive search through the ACM and IEEE literature databases for service concepts in the realm of the Internet of Things, Web of Things (WoT), cyber-physical systems (CPS) and related terms. Most papers were in the realm of IoT (≈52%), followed by CPS (≈40%). For consistency and ease of reading we will solely use the term IoT-service, sometimes there are also named real-world services or cyber-physical service. The search returned more than 620 documents with a high probability of being of interest. These were automatically downloaded, analyzed with a full-text search engine (pdfgrep) and ranked according to their likelihood of discussing services and SOA concepts using a weighted mean algorithm based on selected keywords. Only publicly available material was used, for example no internal reports were taken into consideration. We selected the top 110 documents according to our ranking to conduct our analysis. A vast majority of all projects used or mentioned SOA principles (>90%). This is not a surprise, since we were searching for services related papers. What is surprising is that only very few papers and projects dealing with IoT-services defined precisely what they consider an IoT-service (<10%) and what the differences to traditional services are, and how to deal with combining IoT and non-IoT services.

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This is even more astonishing since there are a lot of IoT-middleware and IoT SOA frameworks around, which claim to bridge the gap between the Enterprise SOA world and the physical world. Mainly papers from the realm of IoT ($\approx$ 70%) dealt with SOA or services. This can be explained by a slight bias towards the term by explicitely include EU projects on one hand and that CPS concerns more about real-time systems [13], than IoT does. Most papers ($\approx$ 80%) had a mere implicit definition of IoT-service, or gave just a general definition of service.

It is acknowledged that in a technical sense, there are differences between traditional services and IoT-services, like special QoS-parameters, and the fact that devices running these services are often resource-constrained with respect to computing, storage, communication and energy capabilities. Furthermore, IoT services might only occasionally be connected to a network (for example in [14], [15]). The findings here are inline with a comprehensive survey on IoT in general, done by [4]. That survey also noticed a tendency towards SOA. Nonetheless, IoT services are not explicitly covered by them.

Karnouskos et. al. [15] define "Real-world SOA", as a SOA were each device *offers its functionality in a service-oriented way; is able to discover other devices and their hosted services dynamically at runtime; can invoke actions of the discovered services dynamically; and is able to publish and subscribe to typed, asynchronous events* [15]. A specific discussion of what a real world (or IoT) service is, is missing though.

The very similar term "real-world service" is used by De et. al. [16] *The Internet of Things envisions a multitude of heterogeneous objects and interactions with the physical environment. The functionalities provided by these objects can be termed as real-world services as they provide a near real-time state of the physical world.*. Nonetheless, the term "real-world service" is ambiguous as it is also used for explicitly non IT services provided in the real world (for example, the transportation of goods) [17]. This is why we stay with the term "IoT-service", which has no predefined meaning in other domains.

A very similar definition has been given by Debaty et. al. [18]: *To computer applications, the incarnation of a Web presence is a set of Web services to learn and interact with the physical entity.*, where a web presence *is the virtual representation of a physical entity as an integrant part of the Web*.

Some research projects (e. g. [19], [9]) differentiate between sensing and actuation services. Nonetheless, the definitions of these two kinds of services, which are essential for the Internet of Things, are only implicitly given. The term IoT service is used for describing interfaces to devices, which perform the actual sensing or actuation task ([9]).

IV. Definition and Classification

As it has been shown in section III most people use the term IoT-service for accessing the functionality (for example: sensing) of a device (a sensor) or resource via low level services. It is rarely used as a high level concept, and if so, the relationship to general purpose services as known from Enterprise IT or the Internet of Services is not completely clear. We take a perspective based on the physical entity. The physical entity (sometimes just called *Entity* or *Thing*) is the object in which state we are interested in. Furthermore, we will use the term resources for means to get information about the environment. Resources are usually computational elements which provide the technical link to the physical entities. This can be more than just "dump" sensors. For example, the temperature of a room (the physical entity we are interested in), could be observed by one ore more mobile phones of people who are actually in the room. In this case, the resources are the mobile phones. The resources then access temperature sensors on the phone which are the devices.

As service is an ambiguous term, we give a definition that is not too limiting (for example, by defining a service as a software component only), but still restricting enough, so that IoT-services can stand as a field of their own. We therefore used the term *transaction* as introduced in [5], but do not limit ourselves to commercial transactions.

> An *IoT-Service* is a transaction between two parties, the service provider and the service consumer. It causes a prescribed function enabling the interaction with the physical world by measuring the state of entities or by initiating actions which will cause a change to the entities.

In the following we propose a simple but comprehensive classification of services along two dimensions: (1) Relationship with the Entity and (2) based on the life-cycle. We defined IoT service as services enabling interactions with the real world, and thus as the superset of the more specifically defined services outlined in Table I. Integrated services are conceptually used to bridge between IoT specific services and external services non IoT specific services. The service classification is an outcome of the IOT-A project [20], while the service definition originates in our work on extending the Unified Service Description Language (USDL) for sensors and actors within the FI-WARE [21] project.

TABLE I
Classification based on relationship with the Entity

Low level service	The low level services make the capabilities of the devices or the resources accessible to entity services or integrated services
Resource service	Resource Services provide the observations the Resource is capable to make or provide the actions a resource is capable to execute.
"Entity"-Service	Entity services are the heart of IoT systems. These are the services provided by the entities and are often, but not necessarily, compositions of low-level services.
Integrated service	Services that work with "Entities", they usally work with Entity services and compose them with non IoT services.

When we classify along the relationship with the Physical Entity (see Table I), one of the key concepts we explicately introduce are the *Entity service* and *integrated services* as higher level of abstraction that utilize simple resource/device and other (IoT-external) services as primitives, thereby hiding the complexity of dealing with them from modeling experts, developers and users. This is the most natural way to look at an IoT-thing entity, because it is more intuitive for domain experts as they do not with to work with some low-level sensor service interface. This has to be abstracted for being usable, for example, in Enterprise environments. Additionally this, of course, also reduces the complexity for development in general and allows the integration into SOA environments.

TABLE II
CLASSIFICATION BASED ON THE SERVICE LIFE-CYCLE

Deployable	A service which is not yet in the field, but is generally deployable. The according service description exists in a service repository, but an appropriate runtime environment is not yet assigned. Thus a service locator is not available in the service registry.
Deployed	A deployed service is already in the field, but not yet ready to use. There are further steps necessary to make it operational. This further steps could be technical, as well as economical (like paying for the service)
Operational	An operational service is, as its name suggest, already deployed (if applicable) and ready to use. The service is associated to an Entity and the association is known to a resolution inftrastructure.

Another important classification is according to the service lifecycle as shown in Table II. Apart from the different Quality of Information (QoI) and Quality of Service (QoS) constraints of IoT-services, the other very special thing is that they are bound to and running on a large variety of devices, thus complicating the service management a lot. In an Enterprise context it is therfore a necessity to have a closer look at the different states in the service lifecycle. This is a necessary precondition for the service management and binding in Enterprise service orchestration and service cheography engines ([22], [23]).

V. INTERNET OF THINGS, INTERNET OF SERVICES AND ENTERPRISE IT

One of the main challenges in the integration of IoT and Enterprise IT systems is that, in the enterprise world many stakeholders with different roles, different skillsets and different backgrounds participate in creating a complex system. Usually, business process experts with profound business domain knowledge start to specify processes of Enterprise Resource Planing (ERP) system applications. “Business Process Model and Notation” BPMN 2.0 (BPMN) [24] is the current and most IoT-aware industry standard providing a business and technical process level [25]. On the lower levels the needed technical expertise generally is much higher. BPMN combined with a SOA based approach is used to close the gap between the business domain experts and the highly specialized engineers working on the lower levels [7]. In the following scenario we apply the entity service concept to the business process world. We demonstrate the usefulness of the different IoT service granularity levels by presenting the different concept elements in terms of a business process. We are following the idea of Business Process Decomposition [22], that means decomposing a business process into distributed executable tasks including edge-node processing. This edge-node processing is done within the services.

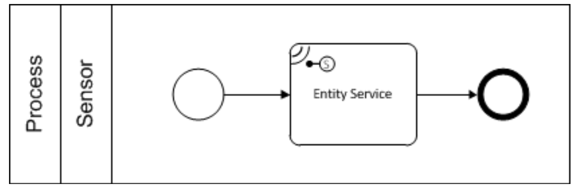

Fig. 1. Resource Service in Business Process Model

To give an example for the different classes of IoT services we will describe the inter- and intra-company tracking of goods, which is a very common scenario within enterprises. Measuring the temperature is necessary in cold chain tracking, for example in life sciences, for perishable goods like certain pharmaceuticals. In current day enterprises this is done via RFID and process anomalies are detected only at special measurement points. Future sensor network based solutions will allow real-time tracking and monitoring of this data, which then can be processed by ERP systems [26].

The low level service of such a temperature sensor comprises the technical interface consisting of the bit patterns for request and response, which have to be sent over a serial line or a wireless connection. For using this service the service consumer has to know these bit patterns and how to create, send, receive, and parse them. Therefore this service is usable for a technically experienced developer, but not for a business domain expert, who focuses on the result-oriented and fundamental integration of operational details of the temperature service into the process model [27].

The resource service abstracts the described low level service by wrapping its technical interface with a higher level interface, which is described with well-known technologies like SOAP or REST. An IoT extended BPMN 2.0 compliant process model [28] foresees the direct usage of such a SOAP web service by specifying a process activity of the type sensing task. A technical process expert can directly integrate such a resource service to the process model (Fig. 1) by refining the service details such as the address and specification of the service endpoint [28]. In comparison to the low level service a dedicated programming knowledge for the resource service is no longer needed.

The entity service is a stronger abstraction, because it is not defined in terms of a pure technical interface, but by its interaction with the entity itself. An example is that it is a box, which is located in the area of a port, with pharmaceuticals in it. They have to be transported within a specified temperature limit and the description of the interaction is ”get temperature”. In a business process model two ways of using an entity service can be distinguished: First, a technically skilled process modeler can directly integrate the entity service by specifying its technical details as in the case of resource services. Optionally, additional parameters of the entity process elements can be specified. Second, a business process expert can specify the

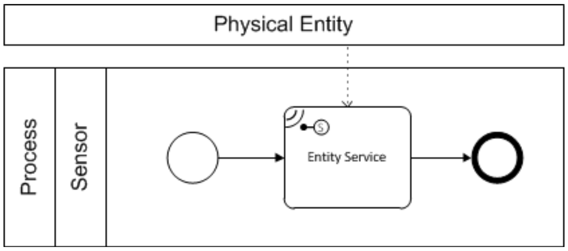

Fig. 2. Entity Service in Business Process Model

entity with which the process is supposed to interact and the means of interaction. For this less technical knowledge is needed than for the first case, but the engine that executes the process must resolve the endpoint of an appropriate resource service in order to fulfill the entity service. Based on [28] both options share the same grafical model, shown in Fig. 2.

An example for an integrated service is the composition of an entity service, which senses the temperature of the goods, with a non IoT service, which stores the sensed temperature value in an ERP system or a business warehouse, where eventually further business analytics can be conducted.

VI. Conclusion

The classification and the sourrending concepts are centering around the entity and not that much around the technical representations or means of realization through low level services. We introduced a conceptual view on IoT-services, which allows easy integration of IoT entities into the SOA world and into service science. While it might sound obvious that there are specific differences between services in a classic sense and services allowing interaction with the physical world, a conceptional frame defining them is necessary. Our objective was to close this gap and foster a discussion on what kinds of services do exist in the IoT world, what makes them special and how they can be integrated into existing conceptional frameworks which already do exist in the SOA and IoS domains. Furthermore, we have shown the usefulnes of our abstraction for BPM modeling and Enterprise SOA integration.

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