

REQUIREMENTS FOR A META-MODEL TO REPRESENT PRODUCT-SERVICE SYSTEMS (PSS) THAT INCORPORATE INTERNET OF THINGS (IoT) SOLUTIONS

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ABSTRACT

The Internet of Things (IoT) infrastructure of networked objects presents potential to enable new value proposition for PSS offering, due to its ability to intensify and aggregate different levels of intelligence; interaction; and perception of real world events. Furthermore, these levels can be represented by a combination of attributes of design objects. Moreover, the described IoT's "abilities" have the potential to emulate human actor's activities that support PSS Operations. However, the behavioral perspective of activities performed by IoT's design objects, while emulating human behavior must be better understood. Therefore, the objective of this work is to identify requirements in the literature to define a meta-model to represent both PSS's and IOT's design objects. This work is based on the Design Research Methodology (DRM), which is used to help to improve the design research process. The partial result so far is represented by the identification of five models in the literature, with different behavioral perspectives and attributes, able to represent the initial requirements to compose a meta-model of a PSS that comprises IoT solutions. Next steps will be to analyze, merge and consolidate the final set of behavioral perspectives and attributes.

Key words: product-service system; internet of things; design dimension; design object; meta-model.

Área: Potencial da Internet of Things (IoT) e soluções de TIC para o desenvolvimento de produtos e serviços.

1. INTRODUÇÃO

The Internet of Things (IoT) is able to support new offerings based on the aggregation of its objects abilities of intelligence, awareness, and interaction (KORTUEM et al., 2010, p.30). Moreover, the evolution of both sensing enabling technology and associated processing will result in “systems-of-systems that synergistically interact to form totally new unpredictable services” (STANKOVIC, 2014, p.1).

The “smart products” that comprise IoT design objects may be understood as a bundle of core equipment, sensors, communication devices, hardware and both local and "cloud" based software applications. This kind of complex offering may be supported by delivering the proposed value as a group of services rather than a package of products, thus configuring a “productless” offering (PORTER; HEPPELMANN, 2014, p.11).

The transformation of the traditional business model of manufacturing companies from delivering value to the customer by selling products, to the value delivered by the provision of services and infrastructure represents an evolving trend (MONT, 2002, p.239). It is possible to find in the literature other names for this approach, such as: Industrial Product-Service Systems (IPS2), and others. Nevertheless, these terms are based on the same approach of service orientation (PIERONI, 2017). Thus, the present work uses the term Product-Service Systems (PSS).

The PSS business model has been used in various successful offerings, where value is provided to customers through service provision, such as: The Rolls Royce's aircraft engines "Power-by-the-hour", JCDecaux shared bicycles' self-service rental schemes, Caterpillar, Xerox, and other (TAN, 2010, p.13). Moreover, Aurich et al. (2006, p.1481) define the structure of a PSS in which the design framework will be applied as a combination of physical and non-physical components, which can be represented as physical product core "enhanced and individualized by a mainly non-physical shell", which provides the customer with "life cycle oriented benefits".

As stated by Valencia et al. (2015, p.13), "Smart Product-Service Systems (Smart PSSs) integrate smart products and e-services into single solutions". Moreover, the previous author states that there is a need to identify a first set of characteristics of Smart PSS to enlarge the existing knowledge regarding PSSs. These characteristics are needed to support the understanding of opportunities in terms of new dynamics related to providers and customers interactions, as well as new value proposition to be delivered during the Smart PSS use phase.

The literature search for PSS and IoT joint approach was expected to indicate a relevant number of references, because the large number of both PSS and IoT references found in separate during the first search step, but the result did not comply with what was expected. There were found very few joint works related to PSS and IoT conceptualization, and these references found were focused just on monitoring and control capabilities, thus not comprising more complex IoT solutions.

The design of more complex smart PSSs must deal with attributes such as: "autonomy, adaptability, reactivity, multi-functionality, the ability to cooperate with other devices, the human-like interaction of the product, and personality" (VALENCIA et al., 2015, p.15). Furthermore, a complex "smart product", such as an autonomous driverless car, comprises attributes that emulates human activities based on different perspectives, which must be considered during the PSS design.

Therefore, because the large amount of different design perspectives that will affect both customer and business actor's network activities, it is important to investigate which are the requirements regarding characteristics and attributes necessary to represent the IoT in a PSS, during the design process (AURICH; FUCHS; WAGENKNECHT, 2006; KORTUEM et al., 2010; MORELLI, 2003; TAN, 2010).

The PSS' and IoT's models found in the literature comprise characteristics and attributes that must be better understood, to compose a meta-model able to represent PSS that comprises IoT solutions. Moreover, each group of similar characteristics and attributes within the meta-model will be consolidated in different groups named design dimensions. Therefore, the objective of this work is to identify requirements in the literature to define a meta-model able to help designers to answer the following research question: How to represent a PSS that comprises complex IoT solutions?

This study is structured in 6 sections, where: Section 1 introduces the content of this work and presents the context and justification as well as the research objective; Section 2 presents the literature review of the main themes approached by this work; Section 3 describes the methodology applied in this research; Section 4 presents the research results; Section 5 presents the final considerations; Section 6 discuss future work.

2. PSS AND IOT DEFINITION AND DESIGN

The literature review was focused on both PSS and IoT definitions and models that support design, to understand the main themes and improve task clarification.

2.1 PSS definition and design

The study of Boehm and Thomas (2013), performed a comprehensive literature review of PSS concept and definitions with 265 articles, which corroborate that PSS offering is focused on the customer capability to perceive value through the activities performed during the use phase. The previous authors propose a common definition for PSS as being “an integrated bundle of products and services which aims at creating customer utility and generating value” (BOEHM; THOMAS, 2013, p.252).

Besides generating value while creating customer utility, the PSS offer has also to be competitive and satisfy customer needs continuously in a multi-dimensional business environment (MONT, 2004, p.71). Moreover, as stated by Morelli (2003, p.98), a design of a new PSS “requires an extension of the traditional designer’s competence into new logical domains”, originated from the interaction between the designer and customers.

PSS can also be understood as a system that continuously provide resource optimization in which the client satisfaction is based, thus being able to produce new business opportunities and competitiveness (MANZINI; VEZZOLI, 2003, p.856). Furthermore, PSS design represents a new challenge for designers because “the focus of the design activity shifts from the definition of new products to the re-organization of existing elements on the basis of new needs and values” (MORELLI, 2003, p. 75).

The VAN Halen et al. (2005) Methodology for Development and Evaluation of PSS (MEPSS), is a detailed and structured methodology that is broadly used to evaluate PSS using different dimensions, while covering key issues related with PSS concepts generation and evaluation phases. The MEPSS Sustainability Design-Orienting Toolkit provides a set of PSS design dimensions and attributes, depicted in Figure 6, that represent important source of information for the present research (DESIGN-ORIENTED, 2017). The proposed design dimensions and attributes of MEPSS are:

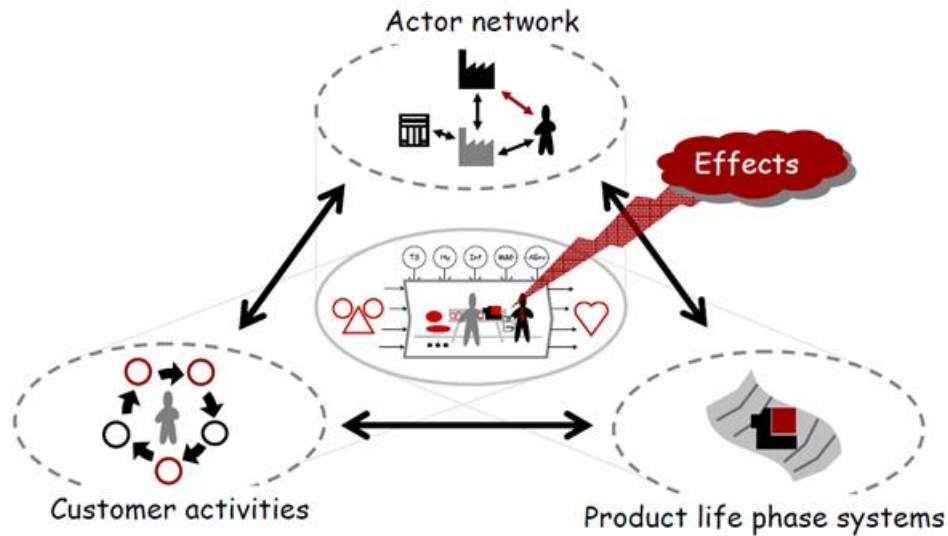
- Environmental Sustainability design dimension, with attributes such as: System life optimization; Transportation/Distribution reduction; Resources reduction
- Socio-Ethical Sustainability design dimension, with attributes such as: Working conditions; Sustainable consumption; Empower local resources
- Economic Sustainability design dimension, with attributes such as: Profitability; Long term Business Development/Risk; Partnership/Co-operation.

Tan (2010, p.172), proposed a meta-model for PSS conceptualization considering the approach of PSS as a design object, as depicted in Figure 1. The meta-model for PSS conceptualization comprises three PSS design dimensions whose behavioral properties when integrated define the effects of the entire system, in special regarding the value proposition that is delivered based on the customer activities within he PSS during its life cycle. The three essential design dimensions to support PSS conceptualization are:

- Customer Activities: allow designers to consider the activities that customers must go through to get the PSS value, representing the “user/customer “needs dimension”.
- Product Life Cycle Systems: allow designers to consider the design of the system and channels that incorporates the product, representing the “product and supporting technologies dimension”.

- Actor Network: allows designers to consider all the actors involved in delivering the life phase systems and supporting the customer activities, representing the related “business dimension”.

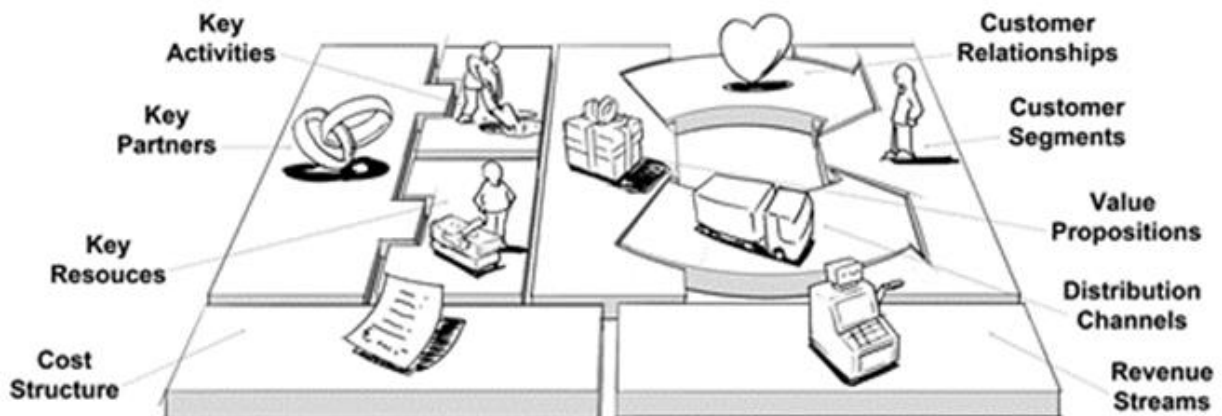
Figure 1 – Meta-model for PSS conceptualization. Source: Tan (2010, p.172)



The Tan (2010, p.172) meta-model’s design dimensions, structural characteristics and behavioral properties, which were developed using case studies based on action research, represent important source of information to support this work. However, as stated by the author, the three proposed design dimensions “do not fully describe a PSS concept” (TAN, 2010, p.211).

A broadly used generic design model found in the literature that can provide information regarding design dimensions and attributes is the Canvas Business Model Canvas (OSTERWALDER; PIGNEUR, 2010). As defined by Osterwalder and Pineur (2010, p.14), “a business model describes the rationale of how an organization creates, delivers, and captures value”. Therefore, the previous authors proposed nine “building blocks” that compose the Business Model Canvas, which is depicted in Figure 2.

Figure 2 – Business Model Canvas. Source: Osterwalder and Pigneur (2010, p. 18, 19)



Furthermore, Barquet (2015, p.38) developed a method to guide the creation of PSS proposals that adopt the Business Model Canvas as a tool to compose the “Configurator of PSS

Proposals” (BARQUET, 2015, p.18). The previous author developed a very comprehensive study regarding the identification of attributes that should support a PSS proposal creation, and related each identified attribute with one of the nine building blocks of Business Model Canvas, named as “dimensions” by the author (BARQUET, 2015, p.92; OSTERWALDER; IGNEUR, 2010).

2.2 IoT definition and design

As stated by Atzori et al. (2010, p. 2787), the basic idea of the Internet of Things (IoT) concept is based on “the pervasive presence around us of a variety of things or objects that are able to interact with each other and cooperate with their neighbors to reach common goals”. The pervasive presence of objects that can be grouped in time and space in order to provide value to customers, have high potential of impact on the behavior of potential users and on the design of new products.

As described by Stankovic (2014, p.1) there are five research communities that are researching the “smart world” of mobile phones, cars, cities and so on: Internet of Things (IoT), Mobile Computing (MC), Pervasive Computing (PC), Wireless Sensor Networks (WSN), and most recently, Cyber Physical Systems (CPS) where the study of Industry 4.0 theory is evolved. However, as the theoretical knowledge of all five research communities evolves, it is possible to identify an increasing overlap of principles and research questions, which are based on the same research focus on enabling technologies, such as: real-time computing, machine learning, security, signal processing, big data and other.

This literature review uses references and terms that emerge mainly from the Internet of Things (IoT) research community. Nevertheless, as discussed in the Stankovic (2014, p.1) work, it must be reinforced that the literature generated by any amongst the five research communities involved in the “smart world” trend, would be able to support the present research

According to Atzori et al. (2010, p. 2790) the main IoT enabling technologies are:

- Identification, sensing and communication technologies, where passive and active sensors support sensing, computing, and communication capabilities within the network of things or objects;
- Middleware, which represents a software layer comprising a set of sub-layers, interposed between the technological (objects) and the application levels;
- Applications, which communicates with the middleware exporting the system’s functionalities to the final user, and grouped by the authors in the following domains: transportation and logistics, healthcare, smart environment (home, office, plant), and personal/social;

Porter and Heppelmann (2014, p.4) highlights the IoT applications potential of adding new value proposition to the society, because of products that “become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in myriad ways” named “smart products”. The capabilities of smart products can be grouped into four categories: monitoring, control, optimization and autonomy, where each category of smart product category uses the preceding one as prerequisite.

According to Miorandi et al. (2012, p.1497), a big leap around the internet as a social and business enabling platform is related to “the use of the Internet as a global platform for letting machines and smart objects communicate, dialogue, compute and coordinate”, where “interconnected smart objects will form pervasive computing environments”. The smart

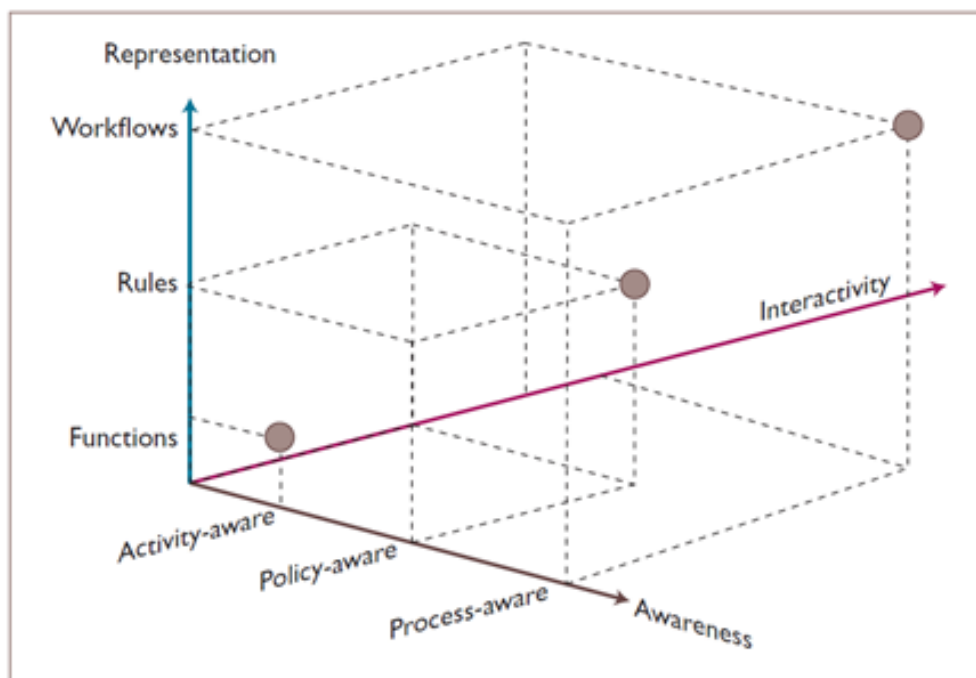
objects must present the following abilities: to be identifiable, where anything must identify itself; to communicate to anything; and to interact to anything.

Moreover, a critical issue regarding the IoT research context is to define “architectures and methods for ‘virtualizing’ objects by creating a standardized representation of smart objects in the digital domain”. The smart object representation is needed to seamlessly integrate the functionalities and resources, provided by heterogeneous smart objects into value-added services for customers (MIORANDI et al., 2012, p.1499).

Kortuem et al. (2010, p.31) proposed an IoT’s object model for smart objects that comprises three design dimensions, which seems to comply with Miorandi et al. (2012, p.1499) and Atzori et al. (2010, p.2792), depicted in Figure 3, as follow:

- Awareness: represents a smart object’s ability to understand the context of events and human activities occurring in the physical world; such as plain activities, domain-specific policies, and work processes.
- Representation: represents the core applications model ability to support activities, such as: aggregation of information function model, rules based model and workflow based model.
- Interaction: represents the smart object’s “ability to interact with the user”; such as: threshold warnings and context-aware task guidance.

Figure 3 – Smart Object Model. Source: Kortuem et al. (2010, p. 31)



2.3 PSS and IoT

The search for references regarding a PSS and IoT design process joint approach was performed combining the search for PSS with the search for IoT references, resulting in just 46 references within Scopus database and just 61 references within Web of Science database. Furthermore, the references found were mainly related with the potential new value proposition of a joint PSS and IoT approach.

The search for references regarding a PSS' and IoT's design process joint approach resulted in just 46 references within Scopus database and just 61 references within Web of Science database. Furthermore, the references found were mainly related to the potential new value proposition of a joint PSS and IoT approach.

As stated by Michael et al. (2010, p.1663), instead of selling RFID solutions as a bundle of hardware, software and service, it is more suitable to sell the RFID technologies capabilities as services that will deliver the value, as proposed in the PSS Business Model. Furthermore, IoT technologies may also improve PSS as described in the study of ZANCUL et al.(2016, p. 305, 306). The previous authors proposed a method to use the potential of IoT technologies available to minimize potential product failures, and evaluate the impact of these IoT technologies on key PSS Business Process Areas, such as: remote machine setup; corrective and predictive maintenance; and information reporting.

Moreover, the “productless” offer of smart products described by Porter and Heppelmann (2014, p. 13, 14) where a product system provide core value instead the product itself, correspond to the Smart PSS characteristics thus being able to be considered as a PSS and IoT jointly offer. In that sense, Seregni et al. (2016, p.2) also cites Porter and Heppelmann (2014, p. 8) smart product categorization based on the capabilities of smart, connected products, and the categorization of IoT services described by Gigli and Koo (2011, p.1), in order to discuss the impact of IoT technologies on PSS.

3. Methodology

This study adopted the Design Research Methodology (DRM), proposed by Blessing and Chakrabarti (2009), that aims “to help design research become more effective and efficient” (BLESSING; CHAKRABARTI, 2009, p.14). This study uses DRM’s framework to help the design research planning, and follows the DRM’s guidelines to help the development of a more rigorous research, while improving the chances of reaching valid results.

This study is compliant with DRM’s “research type 1” framework, which comprises a Research Clarification stage based on literature review, and a comprehensive Descriptive Study stage comprising the literature review, content analysis, and empirical studies (BLESSING; CHAKRABARTI, 2009, p.28).

The DRM’s framework was used to help a better understanding regarding the behavioral characteristics and attributes of both PSS’ and IoT’s models, which were found in the literature. It was used also to help to verify which group of results could be considered as requirements to compose a meta-model able to represent a PSS that comprises complex IoT’s solutions, after a content analysis that must be further validated by empirical studies.

The DRM stages adopted in this study are described below:

- **Research Clarification (RC):** At this stage, the literature review was performed to better understand the definitions and models related to PSS’s and IoT’s design. As a result, the research objective and methodology were defined;
- **Descriptive Study I (DS-I):** At this stage, it was performed a comprehensive literature review and content analysis to improve task clarification, related to the characteristics and attributes of both PSS’s and IoT’s models, to help the proposition of a meta-model able to represent PSS with embedded IoT solutions.

The themes that were considered in the literature review and content analysis were scrutinized within both Scopus and Web of Science databases, from where the references that were used in this research were selected.

4. RESULTS

To provide information to support design of PSS that comprises complex IoT's solutions, it is necessary to understand which are the relevant characteristics and attributes that should be considered by designers. Therefore, to fulfil this need different models were scrutinized to identify sources of knowledge to clarify this activity.

This work's partial result is represented by the identification of five models, which comprise behavioral characteristics and attributes aligned with the research objective. This partial result emerged from literature references that presented validation of their results in practice, while applying "action research" evaluation method in their own work (BLESSING; CHAKRABARTI, 2009, p.193). The five models, behavioral characteristics, and attributes identified as requirements are:

- MEPSS methodology sustainability assessment tool (DESIGN-ORIENTED, 2017), comprising 15 attributes from 3 design dimensions;
- Business Model Canvas (OSTERWALDER; PIGNEUR, 2010), comprising 45 attributes from 9 design dimensions
- "Configurator of PSS proposals" (BARQUET, 2015), comprising 41 attributes from 7 design dimensions
- "Meta-model for PSS conceptualization" (TAN, 2010) comprising 3 design dimensions;
- "Smart Objects Model" (KORTUEM et al., 2010), comprising 3 attributes from one design dimension.

However, the evidence found in literature presents several overlaps, as well as lack of needed information, when comparing the different dimensions, attributes and behavioral perspectives. Therefore, there will be a need to regroup and eliminate redundancy of the identified design dimensions and their set of attributes, to compose a meta-model able to orientate the designers.

5. FINAL CONSIDERATIONS

The PSS-IoT related literature is usually focused on the opportunity represented by a combined PSS and IoT offering. The few references found in literature that generated knowledge about the design of a PSS with embedded IoT solutions, correspond to the "monitoring" category type of smart products, described by Porter and Heppelmann (2014, p. 4). This type of smart product usually does not interact with user, and just aggregate low level of information to support monitoring activities.

Therefore, the attributes and behavioral characteristics identified in this work may be considered as useful requirements to compose a future meta-model, able to support design of PSS that comprises more complex IoT solutions, thus representing a contribution to theory.

6. FUTURE WORK

The identified models, as well as its design objects characteristics and attributes, may be considered as input to future analysis to verify its compliance with this study objective, as well as eliminating redundant information. Moreover, it will be needed to validate the initial group of design dimensions, behavioral characteristics and attributes, by means of industry's expert focus group meetings.

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