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UNDERSTANDING SERVICES IN THE ERA OF THE INTERNET OF THINGS: A SMART SERVICE TAXONOMY

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Research Paper

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Abstract

In recent years, the "Internet of Things" with so called "smart products" has obtained increasing popularity in both practice and research. By building on the capabilities of smart products, services transform to "smart services" emphasizing the value smart products can provide and how it is co-created. Even though first attempts have been conducted to conceptualize and classify smart services, there seems to be no overall consensus on the specific characteristics of smart services, which different forms they can take on and how different smart services can be described. For example, existing research on smart services does not always consider the common service design elements "service content" and "service delivery". To address this shortcoming, we develop a taxonomy of smart services by applying extant literature. We further demonstrate the usefulness of our taxonomy by classifying 50 empirical objects and presenting three cases. As a contribution, the paper enhances the understanding of the notion of smart services and strengthens the conceptual foundation for future smart service research.

Keywords: Smart Services, Intelligent Services, Taxonomy, Internet of Things, Smart Products

1 Introduction

Due to the ongoing digitalization trend, information and communication technology (ICT) is increasingly applied in service systems (Barrett, Davidson and Vargo, 2015). The use of ICT to enhance services enables improved productivity, cost reductions and innovation (Barrett et al., 2015). ICT can not only simplify coordination and cooperation activities in service systems, but can also leverage completely new digital services (Barrett et al., 2015; Ostrom et al., 2015). Such digital service innovations can allow companies to find a new position in the market and create advantages over competitors and even come up with completely new business models (BMs) (Johne and Storey, 1998; Hauser, Tellis and Griffin, 2006; Dreher, Stock-Homburg and Zacharias, 2011). Thus, innovative companies put established companies under pressure by responding to new digital trends and rethinking their value creation (Zott and Amit, 2010; Peters et al., 2016).

Recent advancements in technology enable new solutions for digital services, that is, smart services. Smart services are services made possible by smart products (Allmendinger and Lombreglia, 2005). Their capabilities range from simple monitoring and remote control (Porter and Heppelmann, 2014) to being "capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation" (Medina-Borja, 2015, p. iii). In this regard, smart services go far beyond previous digital services and promise additional and new tailored values (Allmendinger and Lombreglia, 2005; Beverungen et al., 2017b; Maglio and Lim, 2016; Porter and Heppelmann, 2014). Although the shift from product orientation toward service orientation has already been widely discussed among researchers (Tukker and Tischner, 2006; Wuenderlich et al., 2015), its importance increases even more in times of the Internet of Things (IoT) in which every physical product becomes a smart product and inherently comprises a digital service (Fleisch, Weinberger and Wortmann, 2014).

The IoT and the corresponding smart products and services emerge in many domains, such as smart farming, smart retail or smart home, and are expected to expand into all areas of business and life (Porter and Heppelmann, 2014; Georgakopoulos and Jayaraman, 2016). Gartner predicts that there will be 20.8 billion smart products installed by 2020 (Gartner, 2014). Additionally, a recent survey among service scientists revealed that the proliferation of smart products and services gives rise to an "ubiquitous, always on, always connected, smart, and global world [and] is leading to profound changes in customer experience and value co-creation; front-stage and back-stage service provision; and service organizations, networks and service ecosystems" (Ostrom et al., 2015, p. 145).

As a result of the growing importance of the IoT, research has already intensively studied technological and engineering challenges in the context of the IoT (Atzori, Iera and Morabito, 2010; Kortuem, Kawsar, Fitton and Sundramoorthy, 2010) and business-to-business (B2B) relationships with a focus on internal process optimizations (Geerts and O'Leary, 2014; Shim et al., 2017). Strategic and BM perspectives on the IoT are likewise emerging (Porter and Heppelmann, 2014; Turber, Vom Brocke, Gassmann and Fleisch, 2014; Dijkman, Sprenkels, Peeters and Janssen, 2015). The service science field has also begun to study the IoT in the form of smart service systems (Beverungen et al., 2017b; Maglio et al., 2015; Maglio and Lim, 2016; Peters et al., 2016). For instance, domain-specific smart services have been investigated in the past (e.g. Lee and Lee, 2014; Kahma and Matschoss, 2017). Further, first attempts to conceptualize and classify smart services can be found (Beverungen et al., 2017b; Maglio and Lim, 2016; Rizk et al., 2018; Wünderlich et al., 2013). Existing classifications on smart services often do not provide a holistic perspective by covering the most important elements and dimensions sufficiently in form of established service design elements like service content and delivery (Yu and Sangiorgi, 2014).

Although classifications help to better understand new research concepts (Gregor, 2006) for smart services, there is little support for structuring and analyzing the single important components and their design options (e.g. Geum et al., 2016). This is especially relevant, as many companies still have problems in adopting a new role as a service provider (Fleisch et al., 2014; Wuenderlich et al., 2015). A common descriptive language consisting of the most important attributes of smart services can help to describe, analyze and identify different possible smart services and their configuration options. Against this background, we examine the following research question: *How can smart services be described in terms of important characteristics?*

We answer our research question by proposing a taxonomy of smart services, based on the established procedure by Nickerson et al. (2013). The taxonomy is derived from existing conceptualizations in the literature and evaluated with 50 empirical cases. To support sense-making and theory-led design, this paper analyzes smart services through the lens of service-dominant logic (S-D logic). Since we are interested in general insights on important elements of smart services and how to distinguish them, we abstract from a specific domain.

The result of our research is an intuitive, applicable and reasonable classification for describing smart services along several dimensions. The classification extends previous research on smart products and, in particular, related taxonomies (e.g. Püschel et al., 2016) by explicitly focusing on smart services. In this regard, our taxonomy adds descriptive knowledge to the field of smart services and smart products and can support sense-making and theory-led design in the future.

2 Theoretical Background

2.1 Smart Products and Services

The IoT is expected to deeply influence products and services (El Sawy and Pereira, 2013; Yoo et al., 2010). The vision of the IoT is that every physical object and location in the real world becomes part of the internet (Fleisch, Weinberger and Wortmann, 2015). Following a technical perspective, the IoT is "a worldwide network of interconnected objects uniquely addressable, based on standard communication protocols" (Atzori et al., 2010, p. 2788). For our research, we refer to the IoT as smart products that consist of physical objects embedding intelligent components, such as sensors, controls, micro-processors, software and data storage, as well as a connectivity component that together enable new monitoring, control, optimization and autonomous capabilities (Beverungen et al., 2017b; Porter and Heppelmann, 2014). Smart products collect data from the environment and sometimes even interact with the environment and communicate over the internet with other objects (Fleisch et al., 2014). A model of a layered architecture is often applied to analyze the components of a smart product. For example, Yoo et al. (2010) present a modular four-layer architecture consisting of a device layer, network layer, service layer and contents layer that can be decoupled. By decoupling the single layers, several different stakeholders can contribute to each layer (Yoo et al., 2010), as they are sources of value co-creation by multiple participants in the ecosystem (Mejtoft, 2011; Yoo et al., 2010).

Following this logic, smart services are created on the top layer of a smart product. According to Allmendinger and Lombreglia (2005), smart services basically rely on two fundamental properties of smart products, awareness and connectivity, that foster new forms of value creation. Since smart services also require the resources and activities of different actors for value co-creation, they are instead smart service systems. In smart service systems, smart products are boundary objects that enable the service provider and consumers to digitally network their resources, creating an individualized, co-generated value proposition with mutual benefits (Beverungen et al., 2017b).

In this regard, smart service systems use the generated and collected data from smart products, the user and the environment to create new and enhanced customer values, such as more convenience and individualized offerings (Beverungen et al., 2017b; Porter and Heppelmann, 2014; Rosemann, 2013). Although ICT-based services have always used data and even connected devices have been used to collect data, it is the scope, granularity and velocity that has remarkably increased in recent years, along with data storage capabilities and techniques for data analysis. Since this data tends to be very large and complex, it is referred to as big data (Beverungen et al., 2017b; Manyika et al., 2011). Leveraging the potential of big data is achieved by data analytics, which applies computational processes and cognitive mechanisms to uncover patterns in the data (George, Haas and Pentland, 2014). In this regard, smart products facilitate new qualities of data revealing hidden customer actions and resources to the service provider (Beverungen et al., 2017b). Therefore, data and the resulting information is expected to become the central source for future service innovation (Maglio and Lim, 2016; Medina-Borja, 2015).

2.2 Service-Dominant Logic

Research on (smart) services (e.g. Anke, 2018; Dreyer et al., 2018) frequently applies S-D logic, stating that the customer does not simply consume a service or good but participates in the value creation by using an offering or being engaged with it. Thus, there is value-in-use. Moreover, the value generated is always in the eye of the beneficiary (Anke, 2018; Beverungen et al., 2017b; Dreyer et al., 2018; Vargo and Lusch, 2004, 2008). According to S-D logic, the participation of the user is referred to as value co-creation in the service system (Vargo and Lusch, 2004, 2008).

In the context of the IoT, service consumers are even more actively involved, as their user data is provided to the service provider (Vargo and Lusch, 2004; Yoo, Boland, Lyytinen and Majchrzak, 2012; Turber et al., 2014). Moreover, the value co-creation is often related to information and thus there is "value in information use." (Lim et al., 2018, p. 126) Therefore, the consumer has to receive and understand the information provided by the smart product and eventually put it into practice. It is essential for co-creation that the consumer can generate value of the presented information, for example, for better fitness management, better heart rate management or better driving (Lim et al., 2018). Some smart services can even perform their own actions, and thus have a larger part in co-creation of value compared to the display of simple status information on a smartphone. Nonetheless, a large part of co-creation in smart service systems always relies on the information the smart products generate.

In the light of S-D logic, which considers services as underlying all economic exchanges (Vargo and Lusch, 2004, 2008), smart products are no longer offered in terms of selling goods but serve as a carrier and platform for services, blurring traditional distinctions between goods and services (Lusch and Nambisan, 2015). This is also highlighted by the consideration of smart products as product-service systems (PSSs), since they combine physical products and digital services as a single solution to the customer (Goedkoop, Van Halen, Te Riele and Rommens, 1999; Valencia, Mugge, Schoormans and Schifferstein, 2015). Compared with traditional services (e.g. a warranty) being attached to the product, PSSs provide value through an integrated offering (i.e. both are part of the solution), which influences the interaction between consumers and the product and their experiences with it (Valencia et al., 2015).

Apart from this embedded nature of services in smart products, S-D logic also becomes more important, since the interactions between service provider and consumer are more frequent. Research highlights that smart products are not one-time offerings like in the traditional goods-dominated world, since they foster recurrent customer contacts and monetization options through new features and functionalities (e.g. upgrades, software-based updates) (Allmendinger and Lombreglia, 2005; Fleisch et al., 2014; Hui, 2014; Porter and Heppelmann, 2014). Furthermore, as the costs for exact sensing and measuring have decreased, more usage- and performance-based payments on a small scale are possible, for example, cost per printed page (Fleisch et al., 2014). Moreover, the tracked data from products, users and context facilitate new services (Hui, 2014; Chan, 2015; Beverungen et al., 2017b). Thus, the interactions between smart products, the consumer and the provider in smart service systems leverage new levels of values, which in turn can lead to new data-based services, such as the sale of data to third parties.

In the following section, we apply S-D logic to develop our taxonomy and to foster a service-oriented perspective on smart products. Beyond information as a central source in smart service systems, S-D logic facilitates a better understanding of the new collaborative value creation logic between users, service providers and smart products. In particular, the theory helps to gain a better understanding of the various new interactions with smart products leveraging new smart services and corresponding values.

2.3 Service Taxonomies

In the literature, the term “taxonomy” is often used synonymously with other structuring concepts, such as framework or typology. To structure and organize entities of interest, taxonomies combine common characteristics to group similar objects from a domain and help to explain the relations between the characteristics (Cook, Goh and Chung, 1999; Nickerson et al., 2013). Taxonomies are especially required if only little knowledge exists (Gregor, 2006). Since smart services are an evolving phenomenon, there is less support for the analysis of existing services and design of new smart service offerings (Maglio and Lim, 2016). However, the identification of service characteristics is regarded as an important step for meaningful and more detailed analyses of services, since an undifferentiated procedure is not suitable due to the vast amount of heterogeneous services (Bullinger, Fähnrich and Meiren, 2003). In this regard, classifications of services have normative implications for service design (Menor, Tatikonda and Sampson, 2002).

Consequently, various approaches in the past have been conducted to classify services. For example, Lovelock (1983), Cook et al. (1999) and Van der Valk and Axelsson (2015) provide an overview of existing classification schemes and propose their own ones. Typical attributes for service differentiation are, for example, the extent of customer contact, degree of tangible actions, continuous delivery or discrete transactions and customization in service delivery. Due to the particular nature of ICT-based services compared with traditional services, specific classification approaches have been conducted for e-services or digital services (e.g. Williams et al., 2008).

With respect to smart services, research has already provided related classifications, typologies and taxonomies for smart services, which are summarized in Table 1.

For example, Wünderlich et al. (2013) present a typology of interactive services in a four-fold table that describes the user and provider actions. Each of the variables contains two values or states, that is, low and high interaction. A similar focus is provided by Kees et al. (2015) and Oberländer et al. (2018) as they study business-to-things (B2T) interactions between service providers, users, smart things and respective products, and they present a corresponding taxonomy of interaction pattern. To highlight the information flows among the actors, Maglio and Lim (2016) also make use of a typology to differentiate the sources (people, objects) and the addresses of the smart services (people, objects).

Service of Interest	*Classification Type*	*Source*
Smart interactive services	Typology of smart interactive services	Wünderlich et al. (2013)
Smart services	Typology of big data use from and for objects and people in smart service systems	Maglio and Lim (2016)
Business-to-things (B2T) interactions	Taxonomy of B2T interaction pattern	Kees et al. (2015); Oberländer et al. (2018)
Smart products and services	Taxonomy of smart things	Püschel et al. (2016)
Data-driven digital services	Taxonomy of data-driven digital services	Rizk et al. (2018)
Industrial service systems	Taxonomy of industrial service systems enabled by digital product innovation	Herterich et al. (2016)
Smart services	Smart service design morphology	Geum et al. (2016)
Smart services	Taxonomy of the smart elements to design effective service smart services	Pourzolfaghar and Helfert (2017)
Smart services	Smart service classification	Gavrilova and Kokoulina (2015)
IT-enabled information-intensive services	Two classifications of IT-enabled information-intensive services	Lim and Kim (2015)
IT-enabled information-intensive services	Taxonomy of information-intensive services and examples of service configurations	Lim et al. (2018)

Table 1. Smart service related classifications in literature

Literature is also prevalent regarding taxonomies of smart products, things and objects (López, Ranasinghe, Patkai and McFarlane, 2011; Püschel et al., 2016). In this regard, the smart things taxonomy by Püschel et al. (2016) considers a smart service layer as well. However, this layer differentiates only between the main purpose of the service and offline functionality. Due to the focus on the smart product itself, they do not refer to the value that is provided through the product, the service value delivery, or take the monetization perspective into account, which is important for smart services (Shim et al., 2017).

With a focus on new service design, Geum et al. (2016) present a morphological analysis to develop smart services by integrating a market-pull and technology-push perspective. As their technology morphology is limited to three dimensions (technology sensor, technological activities and technological benefit), they suggest extending the morphology by aspects that cover the full user context and technological characteristics more comprehensively.

Rizk et al. (2018) classify data-driven digital services from a strong data analytics and data utility perspective. Accordingly, their taxonomy is mainly defined by data dimensions. Regarding a service perspective, they provide the “insight utilization” dimension with the characteristics visualization, secondary service, feature/recommendation and autonomous decision making (Rizk et al., 2018).

Although it is named “smart service classification,” Gavirolva and Kokoulina (2015) present a rather technical-oriented classification, which, moreover, relies on their research on enterprise information portals (e.g. considering aspects such as software-as-a-service and an organization’s own servers).

To summarize our findings, research has already started to classify smart services with a focus on specific single aspects, such as interaction (e.g. Kees et al., 2015; Maglio and Lim, 2016; Oberländer et al., 2018; Wünderlich et al., 2013) and data-analytics (e.g. Lim et al., 2017; Rizk et al., 2018), or has concentrated on the underlying smart products (e.g. Püschel et al., 2016). Therefore, with our taxonomy, we build on previous research and apply a service science lens to assess the most important smart service elements enabled by smart products.

3 Research Method

Since many classification approaches lack a profound methodology, we oriented our overall procedure toward the rigorous taxonomy development approach used by Nickerson et al. (2013). Combining conceptual and empirical work, it has been used by several researchers in the past for classification developments (e.g. Püschel et al., 2016; Gimpel et al., 2017; Oberländer et al., 2018) . According to the taxonomy development procedure, one has first to define a meta-characteristic that determines the purpose of the classification and addresses the interests of the future users. The development process often consists of several iterations: For each iteration, the researcher has to decide whether to use academic literature (conceptual-to-empirical approach) as a source for the dimensions and characteristics or to derive them from observations of empirical objects (empirical-to-conceptual approach).The iterations end when the ending conditions are met.

For our taxonomy, we first defined our *meta-characteristic*. The purpose of the classification is to provide a clear description of the main characteristics of smart services, which are based on smart products and offered to the market. Thus, we use a service-oriented view informed by S-D logic on smart products and extract the single important elements regarding smart services along the perspectives of service concept, service delivery and service monetization. The higher-level perspectives of "service content" and "service delivery" are rooted in service science literature (Edvardsonn and Olsson, 1996; Tax and Stuart, 1997; Goldstein, Johnston, Duffy and Rao, 2002; Roth and Menor, 2009; Barrett et al., 2015). "Service concept" includes the service value and components, whereas "service delivery" describes the way the service is delivered to the customer (e.g. processes, infrastructures). One part of the smart service delivery process comprises, for instance, the interactions between user, provider and smart products (Wünderlich et al., 2013). This is in line with S-D logic that promotes the importance of value co-creation between the actors (Vargo and Lusch, 2004). Often, service innovation is achieved either by changing the service concept, such as offering a new core value, or by providing a new way for delivering a core value (Berry et al., 2006). Moreover, a component regularly neglected by service design is the monetization of a service, yet it is an important aspect when designing smart services and has often been difficult for companies to realize until now (Witell et al., 2016; Gimpel et al., 2017; Shim et al., 2017; Anke, 2018; Kleinschmidt et al., 2018). Further, smart services are expected to bring forward new innovative pricing models (Fleisch et al., 2014; Chan, 2015). Therefore, this perspective allowed us to focus and analyze market-available smart services that are offered either to other companies or to the end customer. Accordingly, we framed our taxonomy with the three-overarching dimensions of service concept, service delivery and monetization, which enables us to cover the static, dynamic and financial dimension of services.

As our *ending conditions*, we adopted three of the following stated by Nickerson et al. (2013): Each characteristic within a dimension should be unique. Moreover, each dimension is unique and is not repeated. Additionally, at least one object must be classified to each characteristic and each dimension. Furthermore, we adapted the five subjective ending conditions reported by Nickerson et al. (2013).

Since the field is still emerging, we followed a conceptual-to-empirical approach, which means we built our initial classification on existing literature. Against this background, we conducted a literature search oriented toward established guidelines (Webster and Watson, 2002; Vom Brocke et al., 2009). We applied different combinations of search strings (e.g. "smart services" and "intelligent service") in five common databases (ScienceDirect, Scopus, Web of Science, EBESCOhost, AISel). To guarantee a suitable quality, we applied some exclusion criteria. For instance, we considered only peer-reviewed articles published between 2008 and 2018 and excluded literature that did not follow our smart service understanding. Therefore, we did not consider strong technical papers describing prototypes, system architectures or web services. With proper full texts, we also searched backward and forward (Webster and Watson, 2002). Ultimately, we considered 40 papers in our review.

In our *first iteration*, we selected papers proposing classifications of smart services or related services, which were presented in section 2.3. For each paper, we discussed possible dimensions and characteristics, which could be adopted for the taxonomy. However, the taxonomy was neither concise nor comprehensive, as it consisted of unstructured and partly overlapping dimensions. Thus, in the *second conceptual-to-empirical iteration*, we used the rest of the papers from the literature review mainly consisting of further conceptualizations (i.e. definitions) and empirical studies, which also enhanced the understanding of smart services. In this iteration, we mainly revised and detailed some dimensions and characteristics. During each iteration, we checked the ending conditions and reviewed the new taxonomy candidates against our meta-characteristic. By doing this, we ensured that we assessed the dimensions and characteristics of smart services sufficiently. Still, we did not meet our ending conditions and, thus, opted for a *third conceptual-to-empirical iteration*. Since smart services build on smart products, we used key literature in the closely related area of smart products and the IoT (e.g. Porter and Heppelmann, 2014; Turber et al., 2014; Oberländer et al., 2018), which ensured that we had not ignored important aspects. As we fulfilled our objective ending conditions, we checked for the subjective conditions by discussing each condition for each dimension and characteristic among the authors. With the ending conditions being fulfilled, the third iteration finally resulted in the taxonomy.

Apart from the empirical objects used during the conceptual-to-empirical iterations, we aimed to evaluate the usefulness of our taxonomy with a larger sample of real cases. The empirical objects were derived from our literature sample (Porter and Heppelmann, 2014; Püschel et al., 2016; Mittag et al., 2018) by browsing common startup databases, for example, Crunchbase,[1] and conducting a Google search. We intended to identify a broad range of different smart services in the business-to-business (B2B) as well as the business-to-consumer (B2C) sectors from various domains (e.g. smart city, smart health, smart manufacturing, smart grid, smart farming). Two researchers classified all 50 objects independently and discrepancies among the classified objects were discussed. For the dimensions with discrepancies, we extended the description, which increased the common understanding. The taxonomy dimensions and characteristics themselves proved to be useful in the current condition.

4 Taxonomy of Smart Services

Our taxonomy of smart services consists of nine dimensions with their related characteristics (Table 2). The numbers in brackets refer to the empirical objects we classified. Since the dimensions are not mutually exclusive, the numbers in one dimension can exceed 50. In the following section, we go into detail for the dimensions and corresponding characteristics and explain our rationale.

<table>
<tr><th></th><th>Dimension</th><th colspan="12">Characteristics</th></tr>
<tr><td rowspan="4">Service Concept</td><td>Value Proposition</td><td colspan="4">Hedonic Value (6)</td><td colspan="4">Functional Value (47)</td><td colspan="4">Social Value (6)</td></tr>
<tr><td>Bundle</td><td colspan="4">Digital Service (15)</td><td colspan="4">Digital and Physical Service (6)</td><td colspan="4">Smart Product-Service System (29)</td></tr>
<tr><td>Main Outcome</td><td colspan="4">Efficiency Gains (15)</td><td colspan="4">Improved/Added Value (18)</td><td colspan="4">New Offering (22)</td></tr>
<tr><td>Visibility</td><td colspan="6">Visible (44)</td><td colspan="6">Invisible (6)</td></tr>
<tr><td rowspan="3">Service Delivery</td><td>Mode of Operation</td><td colspan="3">Monitoring (25)</td><td colspan="3">Controlling (15)</td><td colspan="3">Optimizing (4)</td><td colspan="3">Autonomous Acting (6)</td></tr>
<tr><td>Interaction between Actors</td><td colspan="3">Customer Active (29)</td><td colspan="3">Interactive (4)</td><td colspan="3">Provider Active (4)</td><td colspan="3">Machine Active (18)</td></tr>
<tr><td>Main Interface</td><td colspan="4">Device-based (42)</td><td colspan="4">Smart Product-based (14)</td><td colspan="4">Human-based (5)</td></tr>
<tr><td rowspan="2">Service Monetization</td><td>Payment Mode</td><td colspan="4">Embedded in Product (31)</td><td colspan="4">Separate Service Payment (17)</td><td colspan="4">Data and Advertising (2)</td></tr>
<tr><td>Pricing Model</td><td colspan="4">Transaction-based (33)</td><td colspan="4">Subscription-based (16)</td><td colspan="4">None (4)</td></tr>
</table>

Table 2. Taxonomy of smart services

[1] https://www.crunchbase.com/

Service Concept

Value Proposition: One characteristic of smart services is that they represent border objects between the customer and the service provider with mutual benefit (Beverungen et al., 2017b). Since our taxonomy applies a customer-oriented view, we defined the value proposition for the customer. Other dimensions, such as monetization, implicitly capture the mutual benefit of the service provider (e.g. collection of customer data, payments, advertising). Beyond *functional values*, which support and improve operations, smart services can also offer primarily *hedonic value*, such as a joyful customer experience. Community building and collaboration of users, for example, in energy communities where prosumers exchange their energy (e.g. sonnenCommunity) or the sharing of vital functions of a fitness tracker in social media (e.g. Fitbit) would be examples for *social value* propositions (Huang, 2017).

Bundle: The offering can consist of a *digital service* only, such as notifications in an application or visualizations of collected data on a website (Rizk et al., 2018). A *digital and physical service* is a combined offering consisting of a digital and a physical service component. An example is a predictive maintenance service that also comprises the activation of a service technician to fix technical problems (Mittag et al., 2018). Since offered smart products always include a digital service component, we explicitly referred to this as a *smart product-service system* (Anke, 2018; Beverungen et al., 2017b; Dreyer et al., 2018; Fleisch et al., 2014) that includes the smart product beyond a digital component and an optional physical service component (Mittag et al., 2018).

Main Outcome: Every (smart) service provides an outcome constituting the service concept (Clark, Johnston and Shulver, 2000; Yu and Sangiorgi, 2014). The main outcome of a smart service can be subdivided into three characteristics: *efficiency gains*, *added value* and *new offering*. Reduced costs, time savings or increased flexibility are examples for *efficiency gains* (Wünderlich et al., 2013). According to Mittag et al. (2018), most smart services are *value-added services* that improve existing offerings (Demirkan, Spohrer and Badinelli, 2016). Fitbit's smart scale Aria 2, for instance, is a scale that is able to display body weight, which is not a new service by itself. However, sensors and health monitoring leverage added value, such as body fat analysis and body mass index determination. We also regard an enhanced customer experience, for example, based on more personalized recommendations, as an *improved offering* (Ostrom et al., 2015; Lim and Maglio, 2018). Furthermore, smart services can provide the basis for greater service innovation fostering completely *new types of offerings* (Demirkan et al., 2016), such as Tesla's self-driving autopilot.

Visibility: The way in which services are perceived can also change. For instance, instead of physically reading an electricity meter, in future it will be read digitally via smart meters and remotely by the metering point operator. This, however, also makes the meter reading service "invisible" to the customer (Beverungen et al., 2017b; Wuenderlich et al., 2015). The perceived *visibility* of a service can be important. For example, regarding monetization, a customer might be more willing to pay for a perceived service, that is, a visible service.

Service Delivery

Mode of Operation: Due to the fusion of smart products and services, products have become increasingly important in service delivery (Beverungen et al., 2017a) . Several authors (e.g. Porter and Heppelmann, 2014; Maglio and Lim, 2016; Mittag et al., 2018) describe the actions smart services can perform based on smart products. They range from *monitoring*, *control* and *optimization* to *autonomous actions* (Porter and Heppelmann, 2014). For instance, *monitoring* activities display only information, for example, the condition of a car tire, or can provide alerts and notifications in case of changes (Porter and Heppelmann, 2014; Mittag et al., 2018). *Controlling* enables the control of product functions, such as the remote control of smart light bulbs, and the personalization of smart products (Porter and Heppelmann, 2014). Moreover, *controlling* refers to both the physical and digital actions of smart products (Beverungen et al., 2017a). *Optimization* builds on the monitoring of product and environment conditions on which they perform analysis and actions, for instance, the regulation of airplane turbine velocity depending on environmental conditions. *Autonomous actions* require the smart product to perform actions without human support. They do not only provide suggestions for decision making, but also perform the actions on their own and eventually even coordinate themselves with other connected smart products (Porter and Heppelmann, 2014).

Interaction Between Actors: Smart service systems are a result of the co-creation of value between service provider and customers (e.g. Beverungen et al., 2017b; Lim and Maglio, 2018). While co-creating, the different parties interact and thus share data and information (Beverungen et al., 2017b; Carrubbo and Bruni, 2015; Kees et al., 2015; Maglio and Lim, 2016; Püschel et al., 2016; Wuenderlich et al., 2015). Since smart products are always involved in co-creation in smart service systems (Beverungen et al., 2017b; Kees et al., 2015), we emphasized the distinct ways interactions between mainly the provider and the customer take place and differentiated the interactions into *provider active*, *customer active*, *interactive* and *machine active* (Wünderlich et al., 2013; Kees et al., 2015). Services that require a high level of interactions of the service provider are *provider active*. For instance, Philips Lifeline is a smart service for elderly in which an automatic emergency call is set to a Philips representative, who then communicates with the person through an intercom (Valencia et al., 2015). We only considered smart products separately in terms of highly automated services with a low involvement of both the service provider and customer. This interactions are therefore highly *machine active*, for instance, an automatic payment in the car (Wünderlich et al., 2013; Kees et al., 2015). Smart services that require a low level of interactivity from the service provider but a high level of interaction from the customer are considered *customer active* (Wünderlich et al., 2013; Valencia et al., 2015). Following Kees et al. (2015), there are also *interactive* services that require actions from both sides, the company and the user, for example, parcel-to-car delivery or HAPIfork, a smart fork. In this regard, human interactions continue to be important for a variety of services, but are enhanced by smart services (Wünderlich et al., 2013; Valencia et al., 2015).

Main Interface: The interface of service delivery defines the type of interface the customer is confronted with for co-creating the service. For example, users can access and interact with services through diverse clients, such as mobile or web applications, which we referred to as *device-based* (Massink, Harrison and Latella, 2010; Anke, 2018; Lim and Maglio, 2018). Examples for devices are smartphones, tablets or voice-controlled personal assistants, which enable access to the smart product and are not embedded in the smart product (Spohrer, 2013; Lim and Maglio, 2018). Moreover, smart products, such as a smart vacuum cleaner, also allow accessing its smart services on the product itself, for example, via specific buttons (*smart product-based*) (Rizk et al., 2018). Although human interactions can be automated via smart services (Maglio and Lim, 2016), there is occasionally still the demand or desire for human interaction and, thus, a service client can consist of a personal, that is, *human-based* interface (Wünderlich et al., 2013; Kimes and Collier, 2015; Valencia et al., 2015).

<u>Service Monetization</u>

Payment Mode: The payment can be *embedded* in the product itself (e.g. the smart service is included), it could be a *separate service payment* or non-monetary payment through *data and advertising* (Fleisch et al., 2014; Gimpel et al., 2017; Anke, 2018). *Separate payments* are smart services, which can be bought in applications or at an Appstore, such as Innogy “Energy Control Premium.” The value for the service provider can also consist in a non-monetary form, that is, data or advertising, since the collected data of the customer could be sold to third parties, used for tailoring of advertising or product improvements (Gimpel et al., 2017; Dreyer et al., 2018). For instance, the company Diageo used a smart bottle of their “Johnnie Walker Blue Label” whisky for product- and brand-centric customer marketing.

Pricing Model: For smart service systems and their corresponding costs, the service provider has to consider different payment intervals (Anke, 2018). One-time payments or usage-based payments are *transactional-based* payments, whereas *subscription-based* payments are regular time-based payments regardless of usage. Currently, pay per function and other regular payments that are usage- and performance-based are realized beyond the basic sale of smart product (Chan, 2015; Anke, 2018). There is also the option that services do not include a payment mode (i.e. “*none*”), e.g. due to non-monetary values for the service provider, such as use of secondary data, tailored pricing models or more efficiency (Beverungen et al., 2017b).

5 Evaluation and Application of the Taxonomy

To evaluate the usefulness of our taxonomy (Nickerson et al., 2013), we classified 50 empirical objects. While classifying, we took an end customer perspective. As an illustration of the applicability, we present three smart services in detail that we selected from our sample of smart services (Appendix). The cases cover not only a broad range of taxonomy dimensions, but also range across various domains.

	Dimension	*HP Instant Ink*	*ThyssenKrupp MAX*	*Fitbit Charger 3 Fitness Tracker*
Service Concept	*Value Proposition*	Functional	Functional	Hedonic, Functional, Social
	Bundle	Digital	Digital and Physical	Smart Product-Service System
	Main Outcome	Efficiency Gains	Improved/Added Value	Efficiency Gains, New Offerings
	Visibility	Visible	Visible	Visible
Service Delivery	*Main Activity*	Controlling	Monitoring	Monitoring
	Interaction between Actors	Provider Active	Provider Active Machine Active	Customer Active
	Main Interface	Device-based	Device-based, Human-based	Device-based, Smart-Product-based
Service Monetization	*Payment Mode*	Separate Service Payment	Separate Service Payment	Embedded in Product
	Pricing Model	Subscription-based	Subscription-based	Transaction-based

Table 3. Illustration of taxonomy application

Hewlett Packard (HP) – Instant Ink: HP is one of the leading information technology companies in the world and is well-known for its office printing and scanning solutions. With Instant Ink, HP offers a complete digital personal toner assistant primarily for business customers. Customers can choose between four services plans (e.g. moderate printing: 100 pages/month for $4.99). The local printer anticipates the level of ink and every time the filling level of a toner achieves a critical level, new toner is automatically ordered. In this regard, the service includes controlling. The whole dispatchment is provider oriented, also taking care of the used toner. The service is predominantly a digital service with functional value and efficiency gains for customers, as the service controls the whole refill process.

ThyssenKrupp – MAX: ThyssenKrupp is a multinational industrial concern, which is mainly known for its steel production. Besides this, ThyssenKrupp is active in various other business areas, such as material service and the elevator industry. With the predictive maintenance solution MAX, ThyssenKrupp provides a service for real-time monitoring, breakdown prevention and lifespan forecasts based on real-world-data, which is delivered by evaluators worldwide. ThyssenKrupp's MAX represents a classic example for a hybrid service that integrates digital and physical aspects not only in its service concept but also in the delivery through a human-based interface, since a technician from ThyssenKrupp is also involved in the solution process.

Fitbit – Charger 3 Fitness Tracker: Fitbit Inc. is one of the leading providers for self-tracking-solutions worldwide, with a wide range of different tracking products (e.g. fitness trackers, smartwatches and smart scales). The Fitbit Charger 3 is a fitness tracker enabling several services for health and fitness monitoring. Accordingly, it tracks body and health parameters such as sleep, steps or heart rate frequently and automatically. Based on various parameters, the service offers further information and deeper insights for the user, such as calories burned or estimated calorie deficits for the day. The smart service provides a clear functional value in combination with efficiency gains, but also has a further value proposition with its social components, which motivate the user with sharing and comparing aspects. The tracker is sold with the smart service included.

During the classification process, we gained further insights into the relationships between the dimensions and characteristics. For instance, we experienced that the B2B services are more service-oriented, whereas the B2C services heavily build on the smart products. Accordingly, we identified 58% as smart product-service systems. In this regard, it is important to note that our sample is not divided equally between B2B and B2C services but consists of more B2C cases (58%). Generally, combinations of digital and physical services were rare. In line with the strong product orientation came the observation that many smart services are not monetized separately but embedded in the smart products, which is the case for 62% of the objects. Especially in the B2C domain, it is common to pay for a smart product with an embedded service. However, in contrast to traditional physical products, there can be a subscription fee in addition to the transactional one-time payment for the smart product. The service offerings with a separate service payment with made up 82% of the B2B-market; only three were consumer-oriented. Another observation was due to the mode of operation and visibility. As most of the services rely on monitoring and controlling operations (80%), the user is actively involved in the perception of the service and thus they tend to be visible for the users (88%). Several controlling operations were perceivable, since they offer remote control options to the user. Thus, the high customer action during the service co-creation can be explained, which was the case for 53% of the services.

6 Discussion

Our study contributes to the descriptive knowledge on smart services, as it explores the distinctive and important elements that describe smart services along several dimensions. As our main contribution, we present a theoretically founded and empirically validated taxonomy of smart services.

Since the research on smart services is an emerging topic with few theoretical insights, the taxonomy extends the extant findings on smart services and provides descriptive knowledge on how smart services can be conceptualized in form of a taxonomy. In this sense, the taxonomy is informed by S-D logic, which helps to deepen the understanding of the strong connection between smart products and services and the underlying co-creation logic. In particular, the notion of IT in the form of smart technologies as enabler facilitates a better explanation of how digitalization changes the provision of services. Further, we contribute to the research on how smart technologies affect traditional industries, especially product-based industries such as manufacturing (Porter and Heppelmann, 2014; Wuenderlich et al., 2015).

Furthermore, the taxonomy serves as a tool to describe and analyze existing smart services as well as a medium to design and configure services. Since there is a trend toward individual and tailored solutions ranging from supportive services to comprehensive “as a service” solutions (e.g. Hyytinen and Toivonen, 2015), our taxonomy can aid in the configuration of service design options. Managers can enhance their understanding of customers and the recognition of specific differences can also lead to different strategies, for instance, in terms of distribution systems, marketing or manufacturing (Lovelock, 1983). One advantage of a taxonomy is that the presented services in literature often only provide insights to already existing configurations of smart services. Hence, the taxonomy can uncover white spots for possible new service configurations, which is why we also regard it as a service innovation tool. By using the classification for the assessment of smart services of competitors, a company can identify gaps and opportunities for competitive advantage by identifying elements that are not applied by competitors and can serve to occupy (Peters, Blohm and Leimeister, 2015).

Since the field of smart services is an evolving domain, the taxonomy needs regular updates to be useful in the future. Another limitation of our paper is the assessment of market-available services, which relies on website data. In general, it is difficult to isolate single smart services which is especially difficult in terms of B2B services, as they are often unspecific. For instance, the companies offer rather generic IoT platforms with several applications, which have to be adjusted to the individual customer use case. Additionally, the websites for business-oriented smart services often provide only limited information on the services, particularly in terms of monetization. Another limitation is due to the fact that we focused on specific elements of smart services and thus were not able to address all cutting-edge topics in the area of smart service offerings such as blockchain or data privacy and security. Moreover, due to our business-oriented focus, we were not able to address societal issues, e.g. trust building measures or efforts that help individuals to find ways how to monetize their data securely and safety.

7 Conclusion and Future Research

Due to rise of the IoT, services become even more important as they are embedded in and enabled by smart products. Understanding smart services and their individual elements is essential for companies when designing new innovative services, which in turn is necessary to be competitive in the transforming market landscape. To study the single important elements of smart services, we developed a taxonomy of smart services based on a systematic and rigorous methodology (Nickerson et al., 2013) and considered theoretical findings as well as 50 empirical objects.

Although our research provides theoretical and practical implications, there is room for improvement as well as alternative and extended versions of the taxonomy. For instance, as highlighted in the limitations, the taxonomy could be more connected to technological developments (e.g. blockchain) and the societal context. A potential extension of the taxonomy could be to refine the “Mode of Operation” since within each of these stated characteristics there are numerous forms of analytics and modeling that create significant variations in the functionality and capability of the service. For future research, it might be also of particular interest to study non-monetary payments (e.g. through data and advertising), since we could identify only two cases at this time. Generally, studying more performance- and usage-based payment modes in combination with service-oriented offerings would be interesting, for instance, offering a smart product without the need to buy it. This would also decrease the high upfront costs that often accompany smart products. Furthermore, in future we expect more offerings that support machine-active interactions and products that act autonomously. In this regard, the component of visibility might become more important, as smart services will become more difficult to notice. With emerging technological progress, there might be more smart services supporting interactions between people, as well as social values through the sharing of experiences. Consequently, an analysis of the classified cases in the smart service taxonomy provides several avenues for future research. Beyond the analysis of single smart service elements, we see two further research options building on our taxonomy. As there are specific interdependencies between the service elements, forthcoming studies could also identify the relations to decrease the complexity of the possible configurations (Salah et al., 2017). Another research option are “service innovation patterns” (Chai, Zhang and Tan, 2005), which could be established similar to product patterns from the production industry (commonly known as the “Theory of Inventive Problem Solving” or TRIZ). The smart service pattern could be derived from our taxonomy.

We are convinced that the taxonomy of smart services provides new insights into the characteristics of smart services along the perspectives of service concept, service delivery and service monetization and strengthens the conceptual foundation for future research on smart services.

Appendix

No	Company	Smart Product	Smart Service	URL
1	Fitbit	Aria 2	Measuring weight and bodyfat	https://www.fitbit.com/aria2
2	Husqvarna	Automower 450X	Autonomous lawn mowing	https://bit.ly/2WgT6b1/
3	Smart Shelf (B2B)	AWM Smart Shelf	Inventory monitoring, targeted on-shelf marketing, remote changes e.g. of prices	https://smartshelf.com/retail_solutions.html#aii
4	evoz	Baby Vision Monitor	Audio, video and infrared monitoring for babies	https://myevoz.com/store/
5	car2go	car2go	Car sharing	https://www.car2go.com/DE/en/
6	Fitbit	Charger 3	Health monitoring and measuring - Fitness Tracker	https://www.fitbit.com/charge3
7	greencitysolutions	CityTree	Monitoring of environmental performance	https://greencitysolutions.de/en/
8	BMW	Connected Car - Remote Service	Remote access for BMW automobiles	https://bit.ly/2Cvx8Kd
9	Continental	Conticonnect	Monitoring and predictive maintenance of tires	https://bit.ly/2ULEOyU
10	Anki	Cozmo	Smart toy robot	https://www.anki.com/en-us/cozmo
11	Wonder Workshop	Dash Roboter	Educational toy robot	https://www.makewonder.com
12	Schneider Electric	EcoStructure Plant & Machine	Process- and machine automation	https://bit.ly/2IFw2vN
13	Recogizer	energyControl	Detection of Anomalies	https://www.recogizer.com/energycontrol/anomalieerkennung/
14	GetDrop	GE Appliances oven	Recipe-oriented remote cooking	https://getdrop.com/appliances/ge-appliances-ovens/
15	greenited	Greenited Premium	Visualize CO_2 emissions as a service	http://www.greenited.net/
16	Hapi	HAPIfork	Fork serving	https://www.hapi.com/product/hapifork
17	Beaconstack (B2B2C)	iBeacon	Proximity beacon marketing campaigns	https://www.beaconstac.com/retail
18	Würth	iBin	Automatic replenishment of c-parts in production	https://bit.ly/2HAekO3
19	Device Insight	Industrial production machines	Monitoring and Predictive Maintenance	https://www.device-insight.com/de/iot-industrie.html
20	Recogizer	industryAnalytics	Predictive Control for industrial machines and processes	https://www.recogizer.com/industryanalytics/predictive-control/
21	Innogy	Innogy Smart Home	SH Energy Control Premium App	https://bit.ly/2Flt6pv
22	Hewlett Packard	Instant Ink	Personal toner assistant	https://instantink.hpconnected.com
23	Diageo	Johnnie Walker Blue Label smart bottle	Product- and brand-centric customer marketing	https://bit.ly/2HJVkMh
24	Kärcher	Kärcher Fleet	Monitoring and predictive maintenance for cleansing machines	https://bit.ly/2FpDIna
25	LaundryView	LaundryView	Monitoring of laundry activities	https://www.laundryview.com
26	Tile	Mate	Tracking device for consumer products	https://www.thetileapp.com/en-us/products/mate
27	ThyssenKrupp	MAX	Monitoring and predictive maintenance for elevators	https://max.thyssenkrupp-elevator.com/en/
28	Michelin	Michelin Fleet Solution	Mile exact tile rental	https://www.michelin.com/eng/michelin-group/products-services/michelin-solutions
29	Mimo	Mimo Baby	Measuring of sleep cycles for babies	https://www.mimobaby.com
30	Tesla	Model S and X	Autonomous driving	https://www.tesla.com/autopilot?redirect=no
31	Moocall	Moocall HEAT	Monitoring of cow behavior for heat detection	https://bit.ly/2HGJjYB
32	Inttra	Ocean Schedules	Monitoring of vessels	https://www.inttra.com/shipper-solutions/ocean-schedules/
33	Philips	Philips Lifeline Collar	Automatic emergency call for elderly	https://www.lifeline.philips.com/
34	Picavi	Pick-by-Vision	Detects objects and optimizes logistics	https://picavi.com/
35	Evopark (B2B2C)	RFID-card	Automatic Payment for use of parking lots	https://www.evopark.de/
36	iRobot	Roomba 980	Autonomous house cleaning	https://bit.ly/2xUiGsF
37	Sonoff	S20 EU	Remote control of electrical sockets	https://sonoff.itead.cc/en/products/residential/s20-socket
38	Kinsa	Smart Ear Thermometer	Temperature measuring	https://bit.ly/2UYxeRS
39	Cardrops	Smart locker (car)	Parcel-to-car delivery	http://www.cardrops.com/
40	Tado	Smart Radiator Thermostat	Remote radiator thermostat controlling	https://bit.ly/2kGtJx3
41	LG	Smart Refrigerator	Remote control and energy saving	https://www.lg.com/us/discover/smartthinq/refrigerators
42	Owlet	Smart Sock 2	Baby heart-rate, oxygen and sleep-cycle tracking	https://bit.ly/2F96o4v
43	Sonah (B2B)	Sonah smart sensors	Routing to parking lot	http://sonah.tech
44	Sonnen	sonnenBatterie eco/ hybrid	Share of energy in an energy community	https://sonnenbatterie.co.uk/
45	MotionTag	TicketEasy App	Automatic check-in and out for public transport	https://motion-tag.com/en/
46	Rolls Royce	Total Care	360-degree maintenance service	https://bit.ly/2xPOU7F
47	Tractive	Tractiv GPS DOG	Real-time GPS-tracking for dogs	https://tractive.com/en/
48	Ring	Video Doorbell Elite	Video and audio monitoring for the front door	https://bit.ly/2UTBdyP
49	Voltstorage	Voltstorage SMART	Automatic-system optimization	https://bit.ly/2OjJtFM
50	Wiseshelf	WISESHELF	Real-time insights for standard retail shelves	https://www.wiseshelf.com/

Table 4. List of empirical objects

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