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Conceptualizing Business-to-Thing Interactions - A Sociomaterial Perspective on the Internet of Things

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Abstract

The Internet of Things (IoT) is recognized as one of the most disruptive technologies in the market as it integrates physical objects into the networked society. As such, the IoT also transforms established business-to-customer interactions. Remote patient monitoring, predictive maintenance, and automatic car repair are examples of evolving business-to-thing (B2T) interactions. However, the IoT is hardly covered by theoretical investigations. To complement the predominant technical and engineering focus of IoT research, we developed and evaluated a taxonomy of B2T interaction patterns. Thereby, we built on sociomateriality as justificatory knowledge. We demonstrated the taxonomy's applicability and usefulness based on simple and complex real-life objects (i.e. Nest, RelayRides, and Uber). Our taxonomy contributes to the descriptive knowledge on the IoT as it enables the classification of B2T interactions and facilitates sense-making as well as theory-led design. When combining weak and strong sociomateriality, we found that the IoT enables and requires a new perspective on material agency by considering smart things as independent actors.

Keywords: Business-to-Thing, B2T, Internet of Things, Sociomateriality, Interaction Patterns, Taxonomy

Introduction

The Internet of Things (IoT) integrates technology-enabled physical objects into the networked society (Rosemann, 2014). The equipment of physical objects with sensors, actuators, and connectivity enables new interactions between businesses, customers, and smart things. Examples are remote patient management, smart metering, and predictive maintenance. According to DHL and Cisco, there will be 50 billion smart things installed by 2020, creating new market opportunities of USD 8 trillion over the next decade (Macaulay et al, 2015). Thus, the IoT is recognized as one of the most disruptive technologies in the market (McKinsey Global Institute, 2013).

Since the introduction of the term IoT, when RFID technology was first presented at the Massachusetts Institute of Technology in 1999, its technological requirements and engineering challenges have been comprehensively discussed (Atzori et al, 2010; Kortuem et al, 2010; Laya et al, 2014). In addition, IoT-enabled innovations have already been explored from a business-to-business (B2B) perspective, focusing on logistics and supply chain management (Qin, 2011; Geerts & O'Leary, 2014). For example, Boos et al (2013) present a theoretical framework for studying the relationship between control capabilities and the accountability of human actors in the supply chain context. Beyond these technology- and B2B-centred contributions, very few studies investigated the IoT from a business-to-customer (B2C) perspective. For instance, Porter and Heppelmann (2014) and Rosemann (2014) provide high-level insights into IoT-related challenges and opportunities, highlighting new business models and an economy of shared things as emerging topics. Turber et al (2014) as well as Dijkman et al (2015) designed a business model framework for IoT-enabled environments. Bucherer and Uckelmann (2011) elaborate on four business model scenarios, as a result of introducing IoT-enabled information flows among customers, things, and businesses. Acknowledging that real-world examples do not tap the full potential of these information flows, Bucherer and Uckelmann (2011) refrain from specifying them in detail. As such, it is still largely unclear how the IoT affects the interactions between businesses and customers.

Our analysis of extant literature revealed that the impact of the IoT on B2C relationships has been recognized, but hitherto not exhaustively investigated. However, it is vital to understand how businesses and customers will interact in an IoT-enabled future, as smart things will transform 'the relationship a firm has with its products and with its customers' (Porter & Heppelmann, 2015, p. 98). Smart things will become increasingly autonomous actors in digital value networks, facilitating business-to-thing (B2T) interactions, for which customers previously served as intermediaries. B2T interactions that seamlessly integrate into customers' processes and everyday lives will substitute mostly human-intensive established B2C interactions. As a prerequisite for sense-making and theory-led design, a well-founded classification of B2T interactions is required. Thus, our research question is as follows: *What B2T interactions can be distinguished in the B2C context?*

To answer this question, we propose a taxonomy of B2T interaction patterns in line with Nickerson et al's (2013) iterative taxonomy development method. Patterns have proven useful in generating problem-solving insights (Barros et al, 2005). Typically applied in the architecture and software design domains, they have also emerged in the information systems (IS) discipline (Alexander, 1977; van der Aalst et al, 2003). Our taxonomy draws from the theory of sociomateriality as justificatory knowledge for studying the relationships among the actors involved in B2T interactions (i.e. things, customers, and businesses) (Orlikowsky, 2007). We evaluated our taxonomy by classifying simple real-life objects and by assessing its reliability and validity via the Q-sort method (Nickerson et al, 2013). We also used our taxonomy to analyse complex real-life objects, using Nest, RelayRides, and Uber as examples.

The rest of this paper is structured as follows. First, we discuss definitions of the IoT and introduce sociomateriality as justificatory knowledge. We then outline our research method. Subsequently, we propose and evaluate our taxonomy of B2T interaction patterns. Thereby, we focus on simple real-life objects, before showing how the taxonomy can be used to analyse complex real-life objects. We conclude by discussing findings, limitations, and future research opportunities.

Background

The Internet of Things—Definitions and Characteristics

From a technical perspective, the IoT is 'a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols' (Atzori et al, 2010, p. 2788). Although its underlying concepts seem intuitive, the IoT has not yet been consistently defined in academic literature (Atzori et al, 2010; Boos et al, 2013; Borgia, 2014). The reason is that the IoT is closely related to several, almost simultaneously evolving technologies, such as ubiquitous communication, pervasive computing, and ambient intelligence (Li et al, 2012). The main discrepancies of existing definitions result from varying conceptualizations for the two constitutive dimensions of the IoT: communication and things. First, there is no agreement as to which communication standards the IoT is based on. Second, the identity and capabilities of smart things remain debatable.

Figure 1 compares 16 IoT definitions we identified in a literature review following the guidelines of Shollo and Kautz (2010). All definitions were published in 2010 or later and focus on the state-of-the-art of the IoT. As part of the literature review, we compared the communication and thing dimensions. For each dimension, we identified relevant characteristics that we use to distinguish various IoT conceptualizations. More information can be found in Appendix 1.

Dimensions	Characteristics	Atzori *et al*, 2010	Boos *et al*, 2013	Borgia, 2014	Chui *et al*, 2010	Dijkman *et al*, 2015	Gartner, 2014	Gubbi *et al*, 2013	Kortuem *et al*, 2010	Mattern & Floerkemeier, 2010	McKinsey Global Institute, 2013	O'Leary, 2013	Rosemann, 2014	Sundmaeker *et al*, 2010	Uckelmann *et al*, 2011b	Vermesan & Fries, 2014	Westerlund *et al*, 2014	Our definition
Communication Dimension	*Wired*			❍	●						●	●	●	❍		❍		●
	All Wireless Technologies	●	❍	❍	●					❍	●	●	●	❍		❍		●
	Internet-Only														❍			
Thing Dimension - Identity	*Sensors and Actuators*	●		❍								❍		❍				
	Mobile Devices and Computers	❍									❍	❍		❍			●	
	Physical Objects (with embedded technology)		●	❍	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Virtual Objects			❍					●				❍	●	●	●		
Thing Dimension - Capabilities	*Sensing*	❍		❍	❍	❍	●	●	●	❍	❍		❍	❍	❍	❍	●	❍
	Interacting	●		❍			●	❍	●	❍		❍	❍	❍	❍	❍		●

Legend: ● Characteristic is included in the core IoT definition ❍ Characteristic is not included in the core IoT definition but referred to in the rest of the paper

Figure 1 Comparison of IoT Definitions

Regarding the communication dimension, the term 'Internet' can be interpreted broadly as referring to a thing's general communication ability or, technically, to the TCP/IP protocol stack (Mattern & Floerkemeier, 2010). Most IoT definitions follow a broad interpretation that abstracts from concrete communication technologies. We identified terms such as 'technological infrastructure' (Boos et al, 2013, p. 454), 'wired and wireless networks' (O'Leary, 2013, p. 55), and 'telecommunication' (Atzori et al, 2010, p. 278). We also differentiate between definitions that include wired networks, such as Chui et al's (2010), and those that refer to wireless communication, such as that of Mattern and Floerkemeier's (2010). Only Uckelmann et al (2011) use the term 'Internet' to define communication technology as 'everything that goes beyond an extranet' (2011, p. 8).

As for the thing dimension, it is unclear what a thing actually is in the IoT context. For instance, Sundmaeker et al (2010) base their understanding on the philosopher Aristotle, stating that things are not restricted to material objects. Hence, sensors, mobile devices, physical objects, and virtual objects can be things in the IoT context. Atzori et al (2010) only view sensors (e.g. RFID tags), actuators, and mobile phones as IoT-enabled things, excluding everyday physical objects. In contrast, Gartner (2014), Uckelmann et al (2011) as well as Mattern and Floerkemeier (2010) exclude PCs, tablet computers, and smart phones, as their existence depends on communication technology. Instead, they focus on technology-enabled everyday objects. Moreover, virtual objects are virtual representations of physical objects, providing additional information such as status, history, and location as well as programming and communication interfaces (Uckelmann et al, 2011). Rosemann (2014) emphasizes the role of things' virtual representations, pointing out that 'putting the car into the Internet might have much more disruptive potential than putting the Internet into the car' (Rosemann, 2014, p. 8). Further, existing definitions disagree about what a smart thing's capabilities are, ranging from sensing to interacting. Sensing refers to the recording and passing of signals, while interaction describes participation in reciprocal request/performance relationships (Vermesan and Fries 2014).

Based on the discussion above, we define the IoT as the connectivity of physical objects equipped with sensors and actuators to the Internet via data communication technology. We also refer to such technology-enabled physical objects as smart things. We consider wired and wireless communication technologies, and set no restrictions regarding any standard communication protocols. In our understanding, a smart thing is a physical object (e.g. a car, refrigerator, or thermostat) that exists independently of communication technology. This excludes PCs, smartphones, tablet computers, and (Gartner, 2014). We also exclude virtual things without a representation in the physical world. Based on unique identification and bilateral communication, the IoT enables interactions with and among smart things, where smart things may initiate actions or processes on their own (Rosemann, 2014, p. 9). At present, not all smart things can interact, but we expect that ever more smart things will be able to do so in the future (Porter & Heppelmann, 2015).

Sociomateriality Background

B2T interactions build on the ability of smart things to interact with customers and businesses. As the theory of sociomateriality helps conceptualize relationships between social and material actors, we used it as justificatory knowledge for developing our taxonomy of B2T interaction patterns. Thereby, we combined strong and weak sociomateriality.

As one of the most popular and debated IS theories, sociomateriality aims to understand and explain the relation between the social and the material in organizational and technological contexts (Cecez-Kecmanovic et al, 2014). As an umbrella term, sociomateriality incorporates various preceding theories, e.g. sociotechnical systems, actor network, and practice theory (Leonardi, 2013). Sociomateriality is a rapidly developing field whose developments are controversially discussed. Especially the debate between Mutch (2013) and Scott and Orlikowski (2013) demonstrates that there is no common understanding of the scope and variety of sociomateriality (Mutch, 2013; Scott & Orlikowski, 2013; Jones, 2014). The two major streams of sociomateriality, i.e. strong and weak sociomateriality, differ by their ontological foundations.

Strong sociomateriality, which is based on agential realism, presumes that the social and the material are inextricably entangled. This implies that 'there is no social that is not also material, and no material that is not also social' (Barad, 2003; Orlikowski, 2007, p. 1437). Strong sociomateriality claims that social and material entities do not precede interactions, but emerge through 'intra-actions' (Barad, 2003; Cecez-Kecmanovic et al, 2014). Only through iterative intra-actions, relations between and boundaries of the social and the material become manifest. At the same time, relations and boundaries are never fixed or static, but determined by a local resolution through an agential cut (Orlikowsky & Scott, 2008; Leonardi, 2013). From a strong sociomaterial perspective, a relation of entangled entities cannot be broken down into unidirectional impacts or mutual interactions (Barad, 2003).

Based on critical realism, weak sociomateriality proposes an alternative understanding of sociomaterial entanglement. The social and the material are viewed as separate entities: one can exist without the other and both pre-exist any relations (Jones, 2014). Social and material agency can be clearly distinguished, whereby social agency is represented by human intentions and material agency is 'the way the object acts when humans provoke it' (Leonardi, 2013, p. 70). Moreover, social and material actors interact with one another, a circumstance that allows for analysing the effects of their sociomaterial interplay (Mutch, 2013; Jones, 2014).

The strict separation of strong and weak sociomateriality has already been questioned by researchers, as the ontological positions of both forms are not incompatible (Scott & Orlikowski, 2013). For example, Mikalsen (2014) emphasizes that 'sociomaterial research must cut across ontological, epistemological, and methodological borders' (2014, p. 1). Even Scott and Orlikowski (2013) see 'no reason why critical realism and agential realism cannot work alongside each other' (p. 80). Strong sociomateriality is rather philosophical, offering 'conceptual and analytical traction for making sense of the world' (Scott & Orlikowski, 2013, p. 79). At the same time, it is associated with practical problems that arise when mapping philosophical notions onto empirical phenomena (Leonardi, 2013). Weak sociomateriality translates philosophical arguments of strong sociomateriality into more practical mechanisms (Leonardi, 2013). In this sense, weak sociomateriality has methodological implications: researchers are asked to specify what they mean by the social and the material and to describe their interplay. Further, the roles of actors that create the sociomaterial over time must be determined, including 'what actors do with a world that presents itself as though it were sociomaterial' (Leonardi, 2013, p. 71).

Kautz and Jensen (2013), as well as McLaughlin (2015), suggest to better understand IS phenomena 'by investigating them in their inseparability as well as in their local separability' (Kautz & Jensen, 2013, p. 25). Following this line of thought, strong sociomateriality lets us view businesses, customers, and smart things as sociomaterial actors that are neither exclusively social nor material, but enacted through sociomaterial practices and intra-actions. Following weak sociomateriality, we view these actors as separate and stable entities that interact. By interaction, we understand two actors 'given in advance that come together and engage in some kind of exchange' (Suchman, 2007, p. 267). We provide concrete examples below when proposing the taxonomy.

Research Method

We developed and evaluated a taxonomy of B2T interactions patterns in the B2C context. Often used interchangeably with terms such as typology or framework, taxonomies are empirically or conceptually derived systems of grouping that consist of dimensions and characteristics (Nickerson et al, 2013). Taxonomies can be interpreted from two perspectives: from a theory-building perspective, taxonomies are theories for analysing, which help describe and classify real-world phenomena (Gregor, 2006). Such theories are useful if theoretical knowledge is limited (Gregor, 2006). From the perspective of the taxonomy development process, taxonomies are design artefacts (i.e. models) with the purpose of classifying existing and future objects (March & Smith, 1995; Nickerson et al, 2013). This interpretation is in line with Nickerson et al (2013), who declare their taxonomy development method as a design method. Thus, our study relates to theory-building and design science research. Further, taxonomies add to descriptive knowledge and facilitate sense-making as well as theory-led design (Gregor & Hevner, 2013).

To create our taxonomy, we followed Nickerson et al's (2013) iterative taxonomy development method. This method comprises seven steps: determination of a meta-characteristic, determination of ending conditions, choice of approach, conceptualization of characteristics and dimensions, examination of real-life objects, design or revision of the taxonomy, and testing of ending conditions. The meta-characteristic reflects the taxonomy's objective, before subjective and objective ending condition are specified. In every iteration, either the empirical-to-conceptual or the conceptual-to-empirical approach is chosen. If the conceptual-to-empirical approach is chosen, classification dimensions are conceptualized first. Then, mutually exclusive and exhaustive characteristics are determined per dimension. The conceptualization of dimensions and characteristics builds on researchers' creativity and justificatory knowledge. Subsequently, real-life objects are mapped to dimensions and characteristics. The result is an initial or revised taxonomy. The taxonomy development method terminates if all ending conditions are met. Otherwise, the taxonomy needs to be revised. After the last iteration, the taxonomy is evaluated regarding its usefulness for the intended users and purpose. This step and the iterative mapping of real-life objects to dimensions and characteristics cover the evaluation activities recommended by Nickerson et al (2013).

Following Nickerson et al's (2013) method, we conducted four iterations, grounded on the following meta-characteristic: *interactions between a business, a customer, and a smart thing as sociomaterial actors*. In all iterations, we followed the conceptual-to-empirical approach, as the IoT is an immature domain, especially in the B2C context. Grounding our study on empirical findings would not have covered all conceivable B2T interactions. In contrast, we aimed to identify generally valid B2T interaction patterns that are persistent over time. This objective could be pursued best by using the conceptual-to-empirical approach and drawing from sociomateriality as justificatory knowledge. While the taxonomy's dimensions (i.e. interactions between socio-material actors) directly resulted from the meta-characteristic, we varied the conceptualization of actors and interactions during the taxonomy development process. We terminated the taxonomy development process after the taxonomy met the following objective ending conditions: every dimension is unique and not repeated (i.e. no duplication) and at least one real-life object is classified under each characteristic (i.e. 'yes' and 'no' regarding the existence of an interaction between two actors). As for subjective ending conditions, the taxonomy development process ended after all authors agreed that the taxonomy was concise, robust, comprehensive, extendible, and explanatory. Table 1 provides an overview of the four iterations, including the respective conceptualization of actors and interactions. It also indicates how many real-life objects we considered per iteration to evaluate the taxonomy. Finally, Table 1 highlights which ending conditions were met and justifies why other ending conditions were not met.

Following the examples of Gregor (2006), Williams et al (2008), Tsatsou et al (2010), and von Briel and Schneider (2012), we evaluated the intermediate and final versions of our taxonomy by classifying real-life objects. This classification helped verify whether and how intuitively real-life objects can be mapped to dimensions and characteristics. To identify real-life objects, we followed three steps. In the first step, we searched academic papers, databases, and press releases for references to businesses whose offerings build on the IoT. A literature review along the guidelines of Shollo and Kautz (2010) revealed that Borgia (2014), Chui et al (2010), Porter and Heppelmann (2014, 2015), and Rosemann (2014) provide such references. To not only consider well-established businesses, we also identified IoT-related start-ups via the CrunchBase (2014) database. Hosted by TechCrunch, CrunchBase is 'the most influential technology blog in the USA' (Werth & Boeert, 2013, p. 244). Finally, we analysed press releases until all authors agreed that saturation had been reached in the sense that references reoccurred regularly. We selected press releases by TechCrunch (2015) and ECT News Network's (2015) TechNewsWorld technology site, as they are the largest technology news publishers in the US. Overall, we considered academic sources from 2010 to 2015, start-ups from the 2014 based CrunchBase database, and press releases from October 2014 to January 2015. In the second step, we examined the identified businesses online with respect to their topicality and whether their offerings build on the IoT in the B2C context. In the third step, we investigated the identified IoT-based offerings in detail. As the IoT landscape is dynamic and the number of real-life objects is constantly increasing, we did not aim to compile an exhaustive sample. Instead, our objective was to examine a broad range of real-life objects from various industries, ranging from established businesses to digital start-ups. We continuously extended our sample during the taxonomy development process (Table 1). Finally, our sample included 109 simple real-life objects (i.e. with one customer, one business, and one smart thing) and 33 complex real-life objects (i.e. with at least two instances for at least one actor type). For more details, please refer to Appendix 2.

Table 1 Iterations of the Taxonomy Development Process

It.	**Conceptualization** (including major changes)	**Real-life objects***	**Ending conditions** (selection, not exhaustive)
1	*Actors*: Multiple actors without further theoretical conceptualization, i.e. businesses (differentiated into groups of service providers and thing manufacturers), customers, and smart things *Interactions:* Abstract relationship, not further specified	80 real-life objects identified in academic papers	× Objective ending conditions not met: Duplication of dimensions as infinitely many actors had to be considered
2	*Actors*: Three actors without further theoretical conceptual-ization, i.e. one business, one customer, and one smart thing *Interactions:* Workflow loops with four steps, i.e. request, negotiation, performance, and acceptance (Denning, 1992; Medina-Mora et al, 1992; Denning & Medina-Mora, 1995)	Further 35 real-life objects identified from the Crunch-Base (2014) data-base; overall 115 real-life objects for evaluation	× Subjective ending conditions not met: Not explanatory as users could not draw a clear line between social and material actors, i.e. whether a smartphone is a thing or a part of the customer Not concise/useful for the intended users due to a large number of patterns emerging from the granular view on interactions
3	*Actors*: Three sociomaterial actors with either a social or a material core, i.e. one business and one customer (social core), and one smart thing (material core) *Interactions:* Two-step request/performance relationship in accordance with the language/action perspective (Goldkuhl, 2005)	Further 27 real-life objects identified from press releases; overall 142 real-life objects for evaluation	× Subjective ending conditions not met: Not concise/useful for the intended users due to an unnecessary mapping of request/performance steps to the analysed real-life objects
4	*Actors*: No changes *Interactions:* Two actors 'given in advance that come together and engage in some kind of exchange' (Suchman, 2007, p. 267) in line with weak sociomateriality	No changes	✓ Objective and subjective ending conditions met: Every dimension unique and not repeated, at least one object classified under each characteristic of each dimension; all authors agreed that the taxonomy was concise, robust, comprehensive, extendible, and explanatory

* In total, we identified 142 real-life objects, thereof 109 simple and 33 complex objects. Starting from the second iteration, we only used simple real-life objects for evaluating the taxonomy.

Having met all ending conditions after the fourth iteration, we evaluated the taxonomy's usefulness for the intended users and purpose via the Q-sort. The Q-sort is a statistical tool that has been developed to examine people's attitudes and opinions (Stephenson, 1935). Among others, it has been applied in marketing, psychology, and sociology (Thomas & Watson, 2002), and to test taxonomies. In this paper, we adopt the principles of Nahm et al (2002), who used the Q-sort to validate questionnaire items. In particular, we refer to Rajesh et al (2011), who tested a taxonomy for knowledge management, and Carter et al (2007), who proposed a taxonomy of decision biases in supply chain management. The Q-sort comprises the classification of items (i.e. real-life objects that build on B2T interactions as the Q-set) to predefined constructs (i.e. B2T interaction patterns) by two or more judges (P-set). Judges are not randomly selected, as they are expected to have a clear understanding of the subject at hand (Carter et al, 2007). In our study, one author first classified the simple real-life objects to set a reference point before selecting 20 of them as the Q-set. The selected real-life objects (at least two per pattern and one per application domain) are highlighted in grey in Table 5. After that, two other researchers (round 1) and 28 academics with an IS background (round 2) (P-set) classified the Q-set. We determined the taxonomy's usefulness in terms of construct validity and reliability. Construct validity is measured in terms of hit ratios that consider the frequency of items placed within predefined constructs (Moore & Benbasat, 1991). Reliability is measured using the Kappa coefficient, defined as 'the proportion of joint judgment in which there is agreement after chance agreement is excluded' (Nahm et al, 2002, p. 115). While Cohen's Kappa (Cohen, 1960) considers only two judges, Fleiss' Kappa refers to the agreement of more than two judges (Fleiss, 1971). A summary of the Q-sort results is shown in Table 2. More information on how we compiled Q- and P-sets can be found in Appendix 3.

Table 2 Evaluation Criteria for Two Rounds of the Q-Sort

	Round 1	**Round 2**
P-set	2 authors, not familiar with the real-life objects yet	28 academics with a background in IS
Q-set	20 simple real-life objects	20 simple real-life objects
Construct validity measure	Hit ratio(s) (Moore & Benbasat, 1991)	Hit ratio(s) (Moore & Benbasat, 1991)
Reliability measure	Cohen's Kappa coefficient (Cohen, 1960)	Fleiss' Kappa coefficient (Fleiss, 1971)

Results and Analysis

Following the steps of Nickerson et al's (2013) taxonomy development method, we here present the results of the fourth iteration. We include the final taxonomy of B2T interaction patterns, the examination of simple real-life objects, and the results of the Q-sort.

A Taxonomy of B2T Interaction Patterns

Complying with the meta-characteristic, our taxonomy of B2T interaction patterns refers to interactions between a business, a customer, and a smart thing as sociomaterial actors. From a strong sociomaterial perspective, these actors are neither exclusively social nor material. Rather, they are enacted through intra-actions in sociomaterial practices. We argue that sociomaterial actors have a social or material core. Businesses, which are the providers or manufacturers of smart things or third-party service providers, have social and material components (e.g. IS, employees, or office facilities). These components constitute businesses through intra-actions. Although these components are involved in interactions with customers and smart things, they need not be separated for the purposes of our taxonomy. The core of businesses is social, as managers and staff are human. Likewise, we view customers and their communication devices (e.g. smartphones or computers) as sociomaterial actors with a social core. Smart things, as physical objects with embedded technology, consist of various human-shaped physical and digital components. For example, the algorithms that make a thing smart are developed by humans (Orlikowski, 2007). Thus, smart things are sociomaterial actors with a material core. The three actors and their sociomaterial entanglement through intra-actions are illustrated in Figure 2b, where actors with a social core are represented as circles and actors with a material core as boxes.

In line with weak sociomateriality, the three sociomaterial actors can be separated and interactions among them analysed. Interactions are visualized in Figure 2 as double-headed arrows, showing that every actor can initiate interactions. Figure 2a illustrates how we depict sociomaterial actors and their interactions as interaction patterns. In this case, we show a traditional B2C interaction, where an interaction takes place between a business and a customer. For instance, a car, which is a thing (T), can be used by its owner, who is the customer (C) of a business (B) (e.g. the car manufacturer or third-party car service provider). Traditionally, the car's ability to interact is limited in the sense of the IoT. Hence, only the customer and the business can interact regarding topics such as maintenance services. Conversely, the IoT enables the active participation of smart things in interactions, allowing interactions to be initiated by a smart car. For instance, a Tesla car automatically identifies problems and requests a digital or physical repair service, either from the customer or directly from the business (Porter & Heppelmann, 2014).

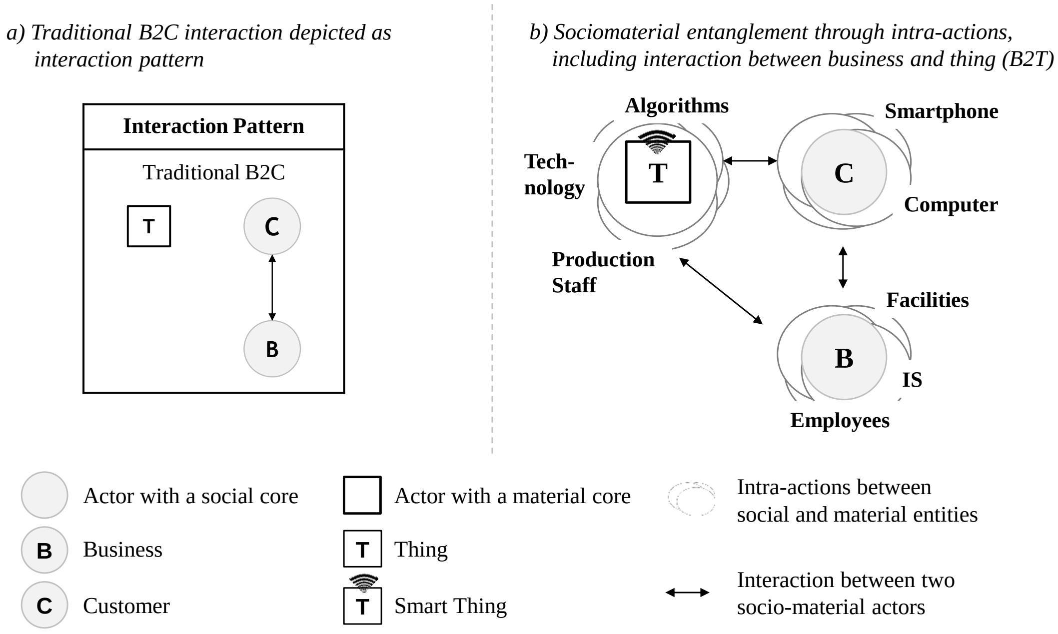
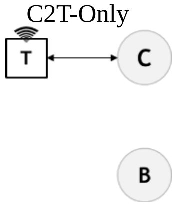
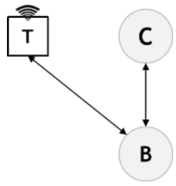
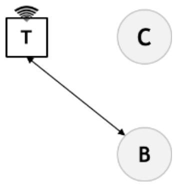
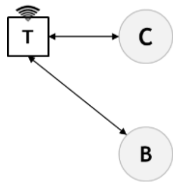
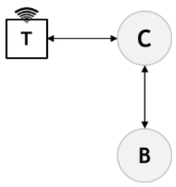
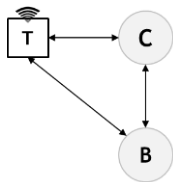


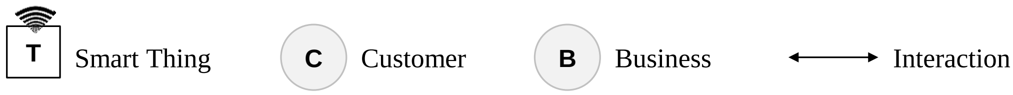
Figure 2 Interaction Pattern Comprising Sociomaterial Actors with a Social and a Material Core

Conceptualization of characteristics and dimensions: In line with its meta-characteristic, the taxonomy includes three dimensions: (1) interaction between a smart thing and a customer, (2) interaction between a smart thing and a business, and (3) interaction between a customer and a business. Per dimension, the mutually exclusive and exhaustive characteristics are ‘yes’ and ‘no’. Merely providing a platform that mediates the communication between actors is not an interaction. Moreover, interactions are considered from a post-commitment perspective (Alter, 2010).

Taxonomy design: When combining dimensions and characteristics, we derived eight interaction patterns in line with the combinatorial possibilities of three dichotomous dimensions. However, the patterns without interactions or with exclusive interactions between a customer and a business (B2C) are out of scope. This does not mean that established B2C interactions are trivial or irrelevant (Nguyen and Mutum 2012). Furthermore, there is a pattern where interactions take place only between a customer and a smart thing, bypassing the business. We refer to this pattern as *C2T-Only*. Even if not directly involved, businesses are interested in the *C2T-Only* pattern, as it creates value for their customers and affects their customer equity (Gupta et al, 2004). Therefore, we included the *C2T-Only* pattern in the taxonomy. As suggested by Gregor (2006), we visualized the taxonomy of B2T interaction patterns and compiled key characteristics in Table 3.

Table 3 Business-to-Thing (B2T) Interaction Patterns

Interaction Pattern	Characteristics	Interaction Pattern	Characteristics
C2T-Only 	▪ Interaction solely between a smart thing and a customer ▪ No interaction with a business	Business-Centred B2T 	▪ Business as the central party and gatekeeper ▪ No direct interaction between a smart thing and a customer
B2T-Only 	▪ Interaction solely between a smart thing and a business ▪ No direct interaction with a customer	Thing-Centred B2T 	▪ Smart thing as the central party and gatekeeper ▪ No direct interaction between a customer and a business
Customer-Centred B2T 	▪ Customer as the central party and gatekeeper ▪ No direct interaction between a smart thing and a business	All-In B2T 	▪ All three actors interact directly with each other



Examination of real-life objects: We used our taxonomy to classify 109 simple real-life objects in the B2C context. Table 4 shows the aggregated classification results structured along interaction patterns and application domains. Almost two thirds of the identified objects (62%) are based on the *C2T-Only* pattern. The results show that industries vary greatly in terms of IoT adoption: not only emerging digital businesses, which we expected to have advanced capabilities, but also traditional businesses started exploring the opportunities of the IoT. About one third (32%) of the identified objects are in the smart home domain. Further, traditional car manufacturers seem to react to changing customer needs by offering smart mobility services, as BMW's car-sharing model and GM's OnStar service illustrate. Healthcare and individual well-being services are often based on *C2T-Only* interactions. Finally, we found few B2T interactions in public services.

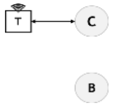
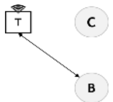
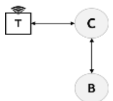
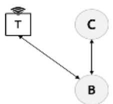
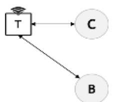
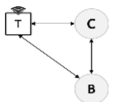
Table 4 Aggregated Classification Results

B2T Interaction Pattern	abso-lute	rela-tive
C2T-Only	**68**	62%
B2T-Only	**10**	9%
Customer-Centred B2T	**7**	6%
Business-Centred B2T	**9**	8%
Thing-Centred B2T	**12**	11%
All-In B2T	**3**	3%
All	**109**	100%

Application Domain*	abso-lute	rela-tive
Healthcare	**11**	10%
Individual Well-Being	**14**	13%
Public Services	**6**	6%
Smart Grid	**5**	5%
Smart Home	**35**	32%
Smart Home Electronics	**18**	17%
Smart Mobility	**20**	18%
All	**109**	100%

* Modified from Borgia, 2014

To illustrate the application of our taxonomy, we provide an overview of B2T interaction patterns and corresponding real-life objects in Table 5, and discuss one or two examples. Appendix 4 provides an exhaustive list including more details. The *C2T-Only* pattern describes an interaction between a smart thing and a customer. For example, smart watches and fitness trackers count steps, calories, and sleeping hours, and make this information accessible to customers (e.g. Up24). The *B2T-Only* pattern focuses on the interaction between a smart thing and a business, bypassing the customer. Schneider, for example, offers remote monitoring of home appliances without involving the customer. In the *Customer-Centred B2T* pattern, the customer is the gatekeeper between a business and a smart thing, controlling two interrelated interactions. One example is HAPILABS' coaching service. Their smart HAPIfork not only collects data about the customer's eating behaviour, but also allows him/her to send these data to a HAPI coach for personalized feedback. The *Business-Centred B2T* pattern facilitates direct B2T interactions, but requires the customer to be a participating actor. An example is Medtronic's glucose monitoring device, which is used for the masked collection of glucose data. The data are not provided to the patient, but to a physician, who discusses the results and further treatment with the patient. The *Thing-Centred B2T* pattern includes two interrelated interactions, controlled by the smart thing as a gatekeeper. For example, Tesla provides automatic software updates to cars that must be accepted by the customer. Finally, the *All-in B2T* pattern describes an interaction pattern that involves all actors. An example is Lively's Safety Watch that offers elderly people a 'help button'. When the button is pushed, the Lively Care Team contacts the patient to offer support.

B2T Interaction Pattern	Smart Thing	Service Provider	Offering Building on a B2T Interaction Pattern	Application Domain	Reference
C2T-Only 	Babolatplay	Babolat	Tennis skills analysis	Individual Well-Being	Porter and Heppelmann, 2014, p.72
	HAPI Fork	HAPILABS	Monitoring of eating habits	Healthcare	Rosemann, 2014, p.8
	Up24	Jawbone	Individual sports and health data analysis	Individual Well-Being	Rosemann, 2014, p. 13
	Connected Pillbox	Lively	Medication reminder	Healthcare	Crunchbase, 2014
	Guardian REAL-Time System	Medtronic MiniMed	Individual check of glucose patterns	Healthcare	Porter and Heppelmann, 2014, p.70
	Wearable Wristband	Sproutling	Monitoring of baby activity	Healthcare	Crunchbase, 2014
	[…]				
B2T-Only 	Building products	Callida Energy	Optimization of building control solution	Smart Home	Crunchbase, 2014
	Recycling Bin	Cities of Cleveland and Cincinnati	Improvement of garbage collection	Public Services	Chui et al. 2010, p.57
	Smart meter	City of Issy-les-Moulineaux	IssyGrid: Improvement of energy services	Smart Grid	Borgia, 2014, p.21
	Nest Thermostat	Nest Labs	Optimization of heating and cooling	Smart Home	Rosemann, 2014, p.8
	Bags	Qantas Airways Limited	Check-in and monitoring of bags	Smart Mobility	Rosemann, 2014, p.8
	Building products	Schneider Electric	Monitoring of home appliances	Smart Home	Porter and Heppelmann, 2014, p.78
	[…]				
Customer-Centred B2T 	Scale "Drop"	Drop Kitchen	Recipe-specific scale setting	Smart Home Electronics	TechCrunch, 2015
	Smart Alert Nightlight	Emergency services	Smoke detection and follow-up emergency call	Smart Home	ECT News Network, 2015
	HAPI Fork	HAPILABS	Personalized coaching service based on eating behaviour	Healthcare	Rosemann, 2014, p.8
	ThinkQ Electric Oven	LG Electronics	Recipe-specific oven setting	Smart Home Electronics	TechCrunch, 2015
	ThinkQ Washers and Dryers	LG Electronics	Professional guidance for tough stains	Smart Home Electronics	TechCrunch, 2015
	Tesla Car	Tesla Motors	Physical car repair	Smart Mobility	Porter and Heppelmann, 2014, p.82
	[…]				
Business-Centred B2T 	icomm Elite	A.O. Smith	Water heater monitoring	Smart Home	Porter and Heppelmann, 2014, p.78
	Lock: Skylock	Authorities	Emergency call and follow-up examination by authorities	Mobility	Crunchbase, 2014
	GM Car	General Motors	OnStar: Automatic Crash Response	Smart Mobility	Porter and Heppelmann, 2014, p.78
	GM Car	General Motors	OnStar: Remote car identification and car start	Smart Mobility	Porter and Heppelmann, 2014, p.78
	GM Car	GM car dealer	Dealer maintenance notification	Smart Mobility	Porter and Heppelmann, 2014, p.79
	CGM Device	Physicians	Professional check of glucose patterns	Healthcare	Porter and Heppelmann, 2014, p.70
	[…]				
Thing-Centred B2T 	BMW Cars	BMW	DriveNow: Car sharing	Smart Mobility	Porter and Heppelmann, 2014, p. 75
	Streetlights	Emergency Services	Intellistreet: Emergency Call	Public Services	Borgia, 2014, p.21
	GM Car	General Motors	OnStar: Check of key car systems	Smart Mobility	Porter and Heppelmann, 2014, p.78
	Shared Bike Dock	Hubway	Shared bike defect notification	Mobility	Porter and Heppelmann, 2014, p.84
	ThinkQ Washers and Dryers	LG Electronics	Updating with performance advances	Smart Home Electronics	TechCrunch, 2015
	Tesla Car	Tesla Motors	Automatic car software update	Smart Mobility	Porter and Heppelmann, 2014, p.82
	[…]				
All-In B2T 	GM Car	General Motors	OnStar: Emergency service and follow-up examination	Smart Mobility	Porter and Heppelmann, 2014, p.78
	ThinkQ Washers and Dryers	LG Electronics	Smart diagnosis service	Smart Home Electronics	TechCrunch, 2015
	Safety Watch	Lively	Emergency call and follow-up examination	Healthcare	Crunchbase, 2014

Classifications tested with Q-sort method

Table 5 Classification of Real-Life Objects Building on B2T Interactions

Evaluation of the Taxonomy

We used the Q-sort to evaluate the usefulness of our taxonomy. Before discussing all simple real-life objects, two of the authors who were not yet familiar with these objects created an internal P-set (round 1). They achieved an overall hit ratio of 95% (Moore & Benbasat, 1991) and a Cohen's Kappa coefficient of 94% (Cohen, 1960). These values reflect almost perfect agreement (Landis & Koch, 1977). After that, 28 participants with an IS background, all unfamiliar with the taxonomy of B2T interaction patterns, did the same (round 2). They obtained an overall hit ratio of 81% and a Fleiss' Kappa coefficient of 63% (Fleiss, 1971). These values denote substantial agreement (Landis & Koch, 1977). The pattern-specific hit ratios are depicted in Table 6. The diagonal indicates the extent to which the selected real-life objects were classified in accordance with our internal pre-classification: most objects were classified as intended and the overall level of agreement was significantly higher than for a random sorting. Only the hit ratio regarding the *Customer-Centred B2T* pattern was below 50%. Having reviewed the classification results and talked to participants, we found that the description of the HAPIfork service from HAPIfork's homepage did not sufficiently convey the central role of the customer. Considering the participants' inexperience with B2T interaction patterns, the evaluation results corroborate that our taxonomy is valid, reliable, and useful for IS academics when investigating B2T interactions.

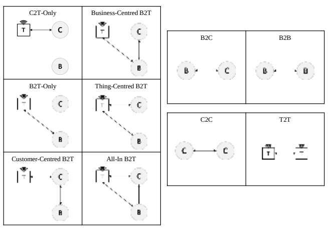
Table 6 Pattern-Specific Hit Ratios

Classification by the Authors	Classification by the Participants						
	C2T-Only	B2T-Only	Customer-Centred B2T	Business-Centred B2T	Thing-Centred B2T	All-In B2T	N/A
C2T-Only	**93%**	0%	0%	1%	4%	1%	2%
B2T-Only	2%	**79%**	2%	3%	13%	1%	2%
Customer-Centred B2T	9%	0%	**43%**	4%	18%	27%	0%
Business-Centred B2T	0%	5%	1%	**86%**	4%	5%	0%
Thing-Centred B2T	4%	1%	5%	1%	**86%**	4%	0%
All-In B2T	0%	0%	13%	0%	14%	**71%**	2%

Application of the Taxonomy to Complex Real-Life Objects

In the future, ever more complex real-life objects will emerge, as 'there are virtually endless ways of connecting […] a thing, a business, and a consumer together' (Westerlund et al, 2014, p. 7). We also refer to complex real-life objects as IoT-enabled interaction networks. To analyse complex real-life objects, B2T interaction patterns can be composed. They can also be combined with traditional interactions (e.g. B2C and B2B) and other IoT-enabled interactions such as customer-to-customer (C2C) and thing-to-thing (T2T) interactions. Further, the direction and sequence of interactions can be specified. Table 7 summarizes the necessary components for analysing complex real-life objects.

Table 7 Components for Analysing Complex Real-Life Objects

Component	Characteristic	Description
Actor	Customer single multiple 	None, one, or more customers
	Smart Thing single  multiple 	None, one, or more smart things
	Business single multiple 	None, one, or more businesses
Interaction	Direction and sequence n →	Customers, smart things, and businesses are connected via directed interactions • The direction of the single-headed arrow indicates which actor initiates an interaction, i.e., through the starting point of the arrow • Numbers (n) indicate the sequence of interactions
Interaction Pattern		Actors and interactions are grouped into the following patterns • Elementary B2T interaction patterns • Traditional B2C and B2B interactions • Other IoT-enabled interactions, i.e.. C2C and T2T

When identifying real-life objects for the evaluation of our taxonomy, we found that 33 (out of 142) objects included several B2T interaction patterns and/or more than one customer, business, or smart thing (Appendix 4). However, most examples do not reflect sophisticated compositions, but include connections to multiple customers (for comparison of peer data) or multiple things (to be connected to one control device). To demonstrate how the B2T interaction patterns support the analysis of complex real-life objects, we chose the three most complex and, in our opinion, most interesting real-life objects: Nest, RelayRides, and Uber. Thereby, we discuss how traditional businesses adapt their offerings and how newly founded digital businesses use the IoT to transform previously non-digital markets.

Example 1: Nest

In the US, energy providers are working with Nest, a smart thermostat, which enables demand-side energy management to balance network loads in times of excess demand. In so-called 'rush hours' energy providers can request the Nest thermostat as well as other smart home appliances to reduce their energy consumption until network loads are again balanced. This service is called 'Rush Hour Rewards'. It builds on a *Thing-Centred B2T* interaction pattern, multiple T2T interactions, and a B2B interaction, as depicted in Figure 3.

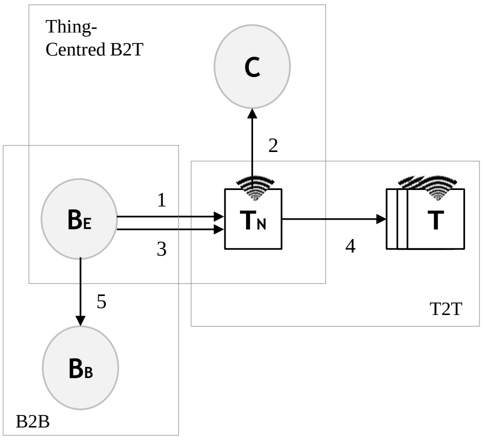


Figure 3 Nest's Interaction Network for ‘Rush Hour Rewards’

The steps involved are as follows:

(1) The energy provider (B_E) notifies the Nest thermostat (T_N) on next day’s expected rush hours.

(2) The Nest thermostat informs the customer (C) on next day’s expected rush hours. The customer can cancel the rush hour service if desired.

(3) If the customer accepts the rush hour service, the energy provider reduces and adjusts the thermostat’s activities during these rush hours.

(4) The thermostat requests that other energy-intensive smart things (T, e.g. ‘Whirlpool’ washing machine, ‘Charge Point’ charging devices) postpone or adjust their consumption.

(5) The saved energy is recorded and rewarded monetarily. Corresponding payments are processed via a bank (B_B), based on previously transmitted information by the customer.

Rush Hour Rewards demonstrates how volatile network loads can be balanced through the IoT. This form of demand-side management is more cost-efficient and eco-friendly then supply-side energy management in times of volatile renewable energy (Strbac, 2008). The collaboration between energy and thing providers not only creates value for customers and businesses, but also contributes to reducing the dependency on nuclear and fossil-fuel energy.

Example 2: RelayRides

General Motors (GM), a US-based car manufacturer, equips its cars with the OnStar system. OnStar facilitates remote interactions between car users, GM, and other businesses allowing for a new form of car sharing called RelayRides. RelayRides builds on a *Business-Centred B2T* interaction pattern, a B2B interaction, and a C2C interaction, as shown in Figure 4.

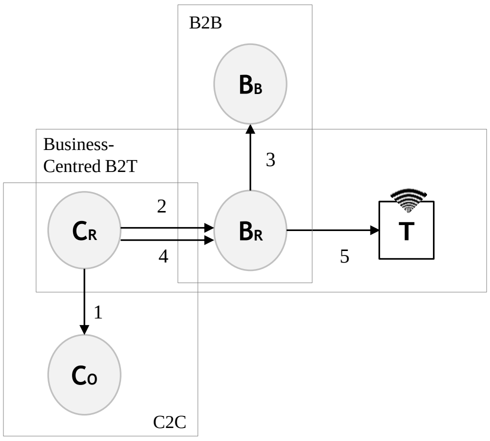


Figure 4 RelayRides' Interaction Network for 'OnStar-Based Car Sharing'

The steps involved are as follows:

(1) The renting customer (C_R) requests to rent the car owner's (C_O) car at a particular time for a particular price. Both need to be registered with RelayRides.

(2) If the request is confirmed, the renting customer books the car, initiating the payment process via RelayRides (B_R).

(3) RelayRides processes the payment through a bank (B_B).

(4) At the rental start, the renting customer requests that RelayRides unlocks the car via email or SMS.

(5) RelayRides remotely unlocks the car, and the renting customer can start his/her journey.

Steps (4) and (5) are repeated at the end of the journey to lock the car. In contrast to ordinary car sharing services, RelayRides' customers need not meet in person. Given the OnStar system and the deposit of keys in glove boxes, the renting customer only needs to contact RelayRides to open the car. Moreover, neither customer is concerned with handling payments.

Example 3: Uber

Uber's customers are looking for a ride from one location to another, and would have traditionally called a taxi. However, by connecting personal cars to the Internet via a smartphone app, Uber enables individuals to give others rides at rates often lower than established taxis.

The IS community is divided regarding the question whether Uber truly is IoT-enabled. Some consider Uber to be little more than 'a pair of smartphone apps connecting a passenger and a driver' (O'Reilly, 2015). However, we argue that an Uber car is transformed into a connected car, being virtually represented on the Internet via the Uber driver's smartphone. In line with strong sociomateriality, the car and smartphone are inextricably entangled entities, constituting a smart thing. However, we acknowledge that this might only be the first step in offering IoT-enabled ridesharing services. Uber has invested in a research centre potentially focusing on driverless cars

(Bloomberg, 2015). Hence, ridesharing without human drivers clearly is an IoT-enabled service. In Figure 5a, Uber's basic ridesharing service is illustrated with two *Thing-Centred B2T* interaction patterns and one B2B interaction.

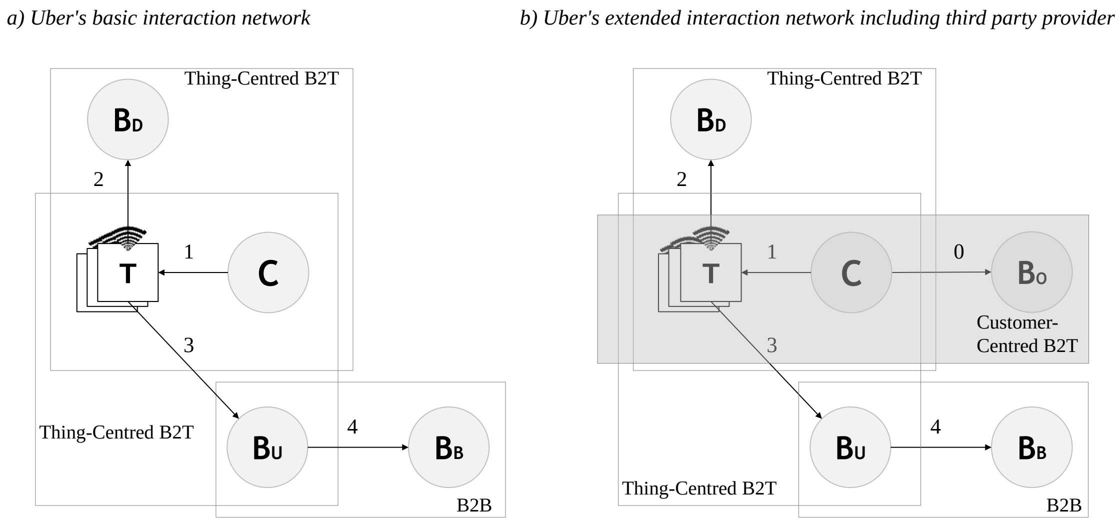


Figure 5 Two Evolution Phases of Uber's Interaction Network

The steps involved are as follows:

(1) A customer (C), who has pre-registered on Uber's website, requests an Uber car (T) via the Uber app. Thereby, the customer sends the request including destination to multiple Uber cars (T…T) nearby. The assigned Uber car informs the customer about the transfer details and provides updates on the approaching car.

(2) The Uber driver (B_D) who first accepts the customer's request is assigned the order and approaches the customer's destination.

(3) The driver starts and stops the taximeter (via the Ubaer app). The resulting data are then automatically transmitted to Uber (B_U).

(4) Based on the data transmitted, Uber determines the fare and issues a payment order to the customer's bank (B_B).

The Uber car is the gatekeeper for interactions between the customer and the driver. Direct interactions are possible, but not necessary for Uber's service offering. In contrast to traditional taxi rides, the customer does not handle payments, is updated about the position of the approaching car, and has ongoing access to the route that the Uber driver takes. While customers have traditionally interacted with taxi drivers, the Uber car handles most interactions for the customer.

By opening its application programming interface to third-party developers, Uber has taken the next step toward building a larger interaction network. For instance, after requesting a restaurant reservation via OpenTable's mobile app (B_O), the customer is offered a matching ride with Uber. The customer, who is the gatekeeper, pushes a button in the OpenTable app, and information on the restaurant's location and reservation time is directly transferred to the Uber car. As shown in Figure 5b, this adds a *Customer-Centred B2T* interaction pattern to Uber's interaction network. Ever more businesses, such as United Airlines, Starbucks, and Spotify, are working on similar IoT-enabled offerings with Uber (Bloomberg, 2014; Uber, 2014) where digital businesses benefit without providing physical hardware.

Discussion

Theoretical Implications

Although the IoT is recognized as one of the most disruptive technologies in the market, it is hardly covered by theoretical investigations. Our theoretical contribution is a taxonomy of B2T interaction patterns. This taxonomy is theoretically well-founded, as it draws from sociomateriality as justificatory knowledge. The taxonomy was also evaluated empirically by classifying real-life objects and investigating its usefulness for the intended users and purpose. As a theory for analysing and a design artefact that helps classify B2T interactions, our taxonomy adds to the descriptive knowledge on the IoT (Gregor, 2006; Nickerson et al, 2013). The taxonomy deliberately distinguishes IoT-enabled interactions not based on technology-related, but on interaction-based characteristics, which are persistent in a rapidly changing IoT-enabled environment. The proposed B2T interaction patterns introduce a novel catalytic idea that helps academics and practitioners structure the design space enabled by the IoT. The patterns also inform design decisions related to IoT-enabled services and business models. Thus, our taxonomy provides a foundation for theory-led design and sense-making (Gregor & Hevner, 2013). It also broadens the predominant technical and engineering focus of IoT research.

To the best of our knowledge, our study is the first to draw from the theory of sociomateriality when investigating the IoT. When using sociomateriality as justificatory knowledge throughout the taxonomy development process, we recognized that the IoT enables and requires a new perspective on material agency. Acknowledging that the ideas of 'sociomateriality and entanglement […] are open concepts' (Scott & Orlikowski, 2014, p. 874), we took an integrated perspective on strong and weak sociomateriality (Jones, 2014). This allowed for the simultaneous consideration of interactions between stable sociomaterial actors (i.e. businesses, customers, and smart things) and intra-actions between social and material components of these actors (e.g. customers as humans entangled with their smartphones and computers). We viewed businesses, customers, and smart things as sociomaterial entities with a social or material core, co-existing in a sociomaterial environment. Strong sociomateriality let us view actors as sociomaterial entities that are neither exclusively social nor material, but enacted through intra-actions in sociomaterial practices. In line with weak sociomateriality, actors can be separated and exist independently. These properties enable examining interactions between actors. In most sociomaterial studies, the social takes precedence over the mute material, 'typically only represented by human spokespersons' (Cecez-Kecmanovic et al, 2014, p. 816). For example, Gaskin et al (2014) only consider humans as actors, while things are seen as tools. However, the IoT empowers smart things, making them act and decide independently of human agency. Thus, the IoT requires material agency to emancipate from capturing 'the way [an] object acts when humans provoke it' (Leonardi, 2013, p. 70). This advocates to consider smart things as independent and equal actors. It also implies that social and material agency are converging. Thus, our research on B2T interaction patterns supports other researchers' calls for further developing sociomaterial theory, not only with respect to an integration of strong and weak sociomateriality, but also with a focus on material agency. We are convinced that this is a promising direction of future research.

Managerial Implications

From a managerial standpoint, our study provides practically relevant output. This is noteworthy as many studies related to sociomateriality offer little practical implications (Cecez-Kecmanovic et al, 2014). Although we do not claim to provide an exhaustive overview of all available B2T interactions in the B2C context, the identified real-life objects yield useful insights.

Managers should start thinking about IoT-enabled opportunities and capitalize on the IoT. Currently, the IoT market is dominated by *C2T-Only* interactions. Product providers have taken the first step of 'smartifying' their previously non-digital offerings. They are mainly focusing on their customers' interactions with smart things without extending their offerings by engaging in interaction networks. The two thirds of our examples that build on *C2T-Only* interactions, represent the foundation for more advanced patterns and interaction networks. Hence, the time is right for managers to actively think about the potential of B2T interactions for their services and business models. They should identify which things to connect and which network partners to involve. It will not suffice to connect things to the Internet and establish interactions with customers. Rather, managers should think about networks based on B2T interactions for sustained value creation.

Managers should learn from best practices when applying B2T interactions. We identified patterns across industries. For instance, an automatic emergency call, whether from a home (Lively), car (General Motors), or bike (Velo Labs), is based on a *Business-Centred B2T* interaction pattern. The smart thing in focus (e.g. in the form of a watch, car, or bike lock) senses an accident, informs the business, and requests a follow-up call. This pattern can be extended with traditional and other IoT-enabled interaction patterns. For instance, the Nest thermostat detects an emergency in a customer's home and contacts not only an emergency provider, but also other smart things, such as the sprinkler system via T2T interactions. Further, IoT-enabled car sharing can be extended with C2C interactions to facilitate private car sharing models where customers share private cars based on the business' ability to remotely open and control these cars (e.g. RelayRides). Hence, managers can draw upon established patterns from different industries or competitors and follow best practices.

Managers should apply different B2T interactions to address different customer segments. Businesses can build variations of their offerings based on different B2T interaction patterns. This enables addressing customer segments with varying needs, payment reserves, and value perceptions in a more target-oriented manner (Porter & Heppelmann, 2015). For example, Schneider Electric and A.O. Smith offer remote monitoring of their home appliances based on the *C2T-Only* pattern for regular customers. However, customers who desire a managed solution can choose solutions based on the *B2T-Only* or *Business-Centred B2T* pattern. A Tesla car detecting that it is due for repair sends a notification to the customer, asking him/her to organize the physical repair (*Customer-Centred B2T*). Conversely, a GM car automatically notifies the car dealer who then contacts the customer (*Business-Centred B2T*). Alternatively, businesses can exclusively interact with the car without interacting with the customer at all (*B2T-Only*).

Moreover, practitioners can use our taxonomy for various purposes. On the level of individual smart things, practitioners can use our taxonomy for comparing B2T interaction patterns used by their own and their competitors' smart things. They can also apply the taxonomy to support the design of smart things. On the level of interaction networks, practitioners can compose the proposed B2T interaction patterns and complement them by traditional and other IoT-enabled interactions. Thereby, our taxonomy of B2T interaction patterns can eventually be used in the design of innovative IoT-enabled services and business models.

Conclusion and Further Research

As any research endeavour, our work is beset with limitations. First, our study focuses on smart things that are virtually represented on the Internet. Future research should also account for virtual things without a physical representation. Second, the real-life objects used to evaluate our taxonomy do not provide a complete overview of all objects building on B2T interactions. They are restricted to a certain period and the B2C context. Due to the fast development of the IoT, future research should analyse more cases and reassess our taxonomy repeatedly. Third, the IoT will not only change interactions in the B2C context, but also in the B2B context. Hence, B2T interactions in other contexts should be investigated as well. Finally, further clarifications of customers' privacy and security demands are needed.

Our taxonomy of B2T interaction patterns also stimulates further theory development. As a theory for analysing, it provides a foundation for future research dedicated to sense-making and theory-led design. With sufficient real-life objects available, we expect future research to shift its focus to the development of theories for explaining. Sample research questions relate to understanding why B2T interaction patterns are adopted and how they transform established B2C interactions. Research should also engage in theories for design and action to provide academics and practitioners with guidance on the construction of IoT-enabled services and business models.

Finally, future research should explore how the IoT enables and requires further developing sociomateriality. Topics of interest are the integration of strong and weak sociomateriality and the evolution of material agency. Our analysis of simple and complex real-life objects corroborates that the changing nature of interactions has given rise to unforeseen opportunities driven by smart things. Becoming ever more independent from owners and users, smart things may take over negotiations from customers and communicate with businesses or other things in the future.

In conclusion, the IoT will increase global sociomaterial entanglement by equipping things with an independent agency and making them autonomous interaction partners in the networked society. We believe that this study is theoretically and practically relevant, and hope it provides fellow researchers with a foundation for continuing their research on the IoT, B2T interactions, and sociomateriality.

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