IoT enabled advanced services: exploring the IoT artefact as a socio-technical construct

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Abstract

The present study draws on the Information Systems (IS) artefact theory (Lee, Thomas, & Baskerville, 2015) to systematically conceptualize the IoT and investigate its contribution to the manufacturer's advanced services. The study employs qualitative methods to analyse the advanced services offerings of eight multinational manufacturers and identifies the specific IS artefacts, their underlying information-, social- and technology-subsystems and their enabling roles in an advanced services context. The study and its findings contribute to the development of a socio-technical IoT perspective and an enhanced understanding of the role IoT has in an advanced services context.

Keywords: IoT, advanced services, servitization

Introduction

The industry's embracing of the 'Internet of Things' (IoT) not only implies the embedding of sensors and connectivity into products but also the creation of new IoT-enabled organizational business models (Porter & Heppelmann, 2014). To effectively utilize this new technology paradigm and design solutions that fully exploit its potential it is critical to establish a detailed understanding of the IoT's enabling role within these business models. Yet, the ability to create benefits from the IoT is not only determined by the IoT itself. It is embedded within organisational process and systems which are likely to interact and affect the ability to create benefits from an IoT application. To establish the detailed understanding of the IoT's enabling role a careful investigation of its use and its interaction with the wider organisational context is required.

The importance of considering the IoT application within its wider organisational context is illustrated through the *advanced services* business model manufacturer have started to adopt (Baines & Lightfoot, 2013). Adopting an *advanced services* business model implies that the manufacturer shifts its focus from being a provider of a discrete product to being a provider of a continuous service that is based on the product's value proposition ('servitization'). Although the dedicated advanced services literature repeatedly emphasises that the IoT and the ability to monitor a product-in-use is critical for a profitable advanced services delivery (i.e. maintenance optimization, repair efficiency (Zancul et al., 2016; Zhang, Ren, Liu, Sakao, & Huisingh, 2017) little research has focused on how these benefits are created.

It is the objective of the present study to address the IoT research and theory gap and advance our understanding of how the expected business benefits are created. The research uses Lee et al's (2015) 'IS artefact' notion as the theoretical grounding to conceptualise the IoT within its organisational context and analyse its contribution. The IS artefact notion emphasises the interaction between technology, social and information subsystem as the source of an artefact's utility. The study focuses on the manufacturer's advanced services as a specific IoT-enabled business model to apply the IS artefact notion and examine the creation of business benefits from the IoT. More specifically, by drawing on the context of the advanced services business model the study seeks to establish i) the diversity and nature of contributions the IoT creates, and ii) the subsystem's enabling role in establishing these contributions.

Literature review and conceptualisation

The 'IS artefact'

The 'IS artefact' is defined by Lee et al (2015) as (i) a human-designed system, (ii) that can be characterized by its purpose, and (iii) is enabled by interacting technology, information and social subsystems. Its definition as (i) a human-designed system draws on Simon's (1996) understanding of artefacts being artificial things which are designed (i.e. synthesized) by human beings; it's purpose-based characterisation (ii) implies that the IS artefact is designed to provide a specific utility that can be described (Hevner, March, Park, & Ram, 2004). Yet, the artefact may not meet its purpose and its designer may not fully understand its underlying mechanisms. By defining the IS artefact as a composition of technology, information and social subsystems (iii) a socio-technical perspective is implied that emphasises an inseparability between technology and its context (Land & Hirschheim, 1983). Based on the subsystem's interaction the IS artefact yields a utility that is greater than the sum of its parts.

In addition to representing a theoretical construct the IS artefact notion represents an analytical framework suitable to investigate the interplay between technology, information and social subsystems and their enabling role in an organisational context (Iivari, 2017).

The Internet of Things (IOT)

The Internet of Things (IoT) describes a technology convergence of product digitalization, ubiquitous communication and real-time analytics. This convergence creates "a paradigm where everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet" (Whitmore, Agarwal, & Da Xu, 2015b, p. 261). Product digitalization captures "the practice of taking processes, content or objects that used to be primarily (or entirely) physical or analog and transforming them to be primarily (or entirely) digital" (Fichman, Dos Santos, & Zheng, 2014, p. 333). Infusing products with digital technology provides them with new communication, programmability and traceability properties (Yoo, Boland Jr, Lyytinen, & Majchrzak, 2012; Yoo, Lyytinen, Boland, & Berente, 2010). It not only changes the nature of the product (Fichman et al., 2014) but also turns product users (through use of the product) into creators of data (Kreps & Kimppa, 2015). Predictions of the IoT's substantial economic impact are based on the expected widespread integration of digitalized products through ubiquitous communication and the analytical insights that can be gained from its use (Sinclair, 2017).

Academic IoT research thus far is largely conducted within the computer science and engineering domains which approach the IoT from a predominantly technical perspective. Respective studies focus on aspects of the IoT's technical architecture including sensors, communication and actuator technologies, and protocols that bridge the physical and digital environments (for an extended review of the technical IoT literature see Madakam, Ramaswamy, & Tripathi, 2015). However, studies within these domains have also started to focus on specific IoT application areas (e.g. smart-home, health-care, manufacturing industry) and the particular contributions or security- and legal challenges created by IoT adoption (Whitmore, Agarwal, & Da Xu, 2015a).

The present research draws on Lee et al's (2015) IS artefact notion to conceptualise the IoT as a technology subsystem that, in interaction with social- and information subsystems, enables the creation of organisational utility in form of an IS artefact ('IoT-enabled IS artefact'). Its conceptualization as enabler implies that the IoT's utility creation is dependent on its interaction with the other subsystems and their enabling roles. The adoption of Lee's (2015) IS artefact notion positions the product-use data as the information subsystem. Its positioning as an information subsystem (alongside the technology and social subsystem) implies that interactions with other subsystems are required for product-use data to create utility for a particular business context. We will next review the manufacturer's advanced services as a critical business context for the IoT.

Manufacturer's advanced services as IOT application area

The manufacturer's 'advanced services' is of the business areas where the IoT is expected to create a particularly high contribution. Advanced services in the manufacturing context describe a particular kind of offering where manufacturers create complex bundle of product- and service-offerings. Such bundles often include: (i) revenue payments structured around product usage; (ii) performance incentives (e.g. penalties for product failure when in service); and (iii) long-term contractual agreements and cost-down commitments (Baines & Lightfoot, 2013). Well-known 'advanced services' examples include Rolls-Royce's *Power-by-the-Hour* offering (Ng, Parry, Smith, Maull, & Briscoe, 2012) where the product (jet engine) and the service (proactive engine health monitoring) are provided as a single offering and customers are charged for the extent of use of the product-service-bundle (i.e. numbers of passengers moved, or mileage travelled).

The servitization literature outlines several ways by which the IoT contributes to the delivery but also design of the manufacturer's advanced services offerings (Rymaszewska, Helo, & Gunasekaran, 2017). Its contributions to the advanced services delivery illustrates the range of scenarios in which the manufacturer uses the IoT to provide the benefits of the service offering to the customer, efficiently and effectively. Specifically, the IoT provides the manufacturer with detailed real-time insights on the current conditions and status of the product-in-use which enables the manufacturer to i) optimize its balancing between delaying maintenance operations (reducing cost) and the increasing risk of malfunction (incurring financial penalties); ii) better prepare for the service visit (i.e. identify skills and parts required) and optimize its spare parts logistics (Zancul et al., 2016; Zhang et al., 2017); ii) engage in remote trouble-shooting and directly advise the product operators on repair opportunities (Zancul et al., 2016); detailed real-time product in-use insights also enable the manufacturer to effectively administer usage-based pricing models and to analyse and optimize its internal service decision making and delivery process (Zancul et al., 2016).

The IoT's contributions to the advanced services design illustrates scenarios where the manufacturer uses the IoT to establish the *what* and *how* of its service offering (Goldstein, Johnston, Duffy, & Rao, 2002). It provides the manufacturer with detailed insights on the diverse product-use scenarios and customer operations to enable i) its identification of additional customer needs and formulation of specific service value propositions; the design or refinement of offerings that include specific service performance targets or gain-share agreements (Lenka, Parida, & Wincent, 2017); ii) to prototype specific service offerings and model their feasibility (i.e. pricing) based on real-world scenarios (Opresnik & Taisch, 2015).

The present study seeks to develop a detailed understanding of the contributions the IoT provides to the manufacturer's advanced services. The 'IoT-enabled IS artifact' notion conceptualised above is used as a framework to examine the IoT as a technology subsystem that (in interaction with the information and social subsystem) enables the manufacturer's advanced services and to analyse the mechanisms that underlie its enabling role. The objectives are formalized in these two research questions:

- How do the IoT-enabled IS artefacts contribute to manufacturer's advanced services?
- How do the IoT-enabled IS artefact's subsystems enable the artefact's contributing role?

Research method

The study has addressed the research questions in a three-step qualitative research method. The first step of the research sought to identify the range of advanced service offerings manufacturers provide and within these offerings elicit the specific scenarios in which the IoT contributes. To draw on relevant data that help to identify the advanced service offerings and IoT contributions the data collection focused on case organisations that i) are manufacturers, ii) operate in a business-to-business context, and iii) have experiences with advanced services provision. To obtain an early in-depth understanding of the IoT contributions the data collection in the first case organisation included interviews with five representatives. Interviews with the remaining case organisations involved 1 or 2 representatives each. The interviews lasted between 30 and 120 minutes and followed a semi-structured format with questions focusing on: i) the advanced services offerings, ii) the IoT contribution to these advanced service offerings, iii) the process and context required to create these IoT contributions. All interviews were recorded and transcribed. Overall, 14 interviews were conducted with senior managers directly involved in the advanced services and IoT initiatives of eight case organisations. The case organisations covered a diverse array of international manufacturers producing largely high value equipment for a range of industries.

The second research step sought to identify the IS artefacts through which the IoT contributes to the advanced services as well as their underlying subsystems (directly addressing RQ1). Following Lee et al (2015) an IS artefact is defined by its purpose and the interaction of technology, information and social subsystems. Hence, the analysis first focused on identifying ‘candidate IS artefacts’ (based on their purpose) before confirming them as genuine ‘IS artefacts’ (based on their subsystem identification). An iterative thematic analysis (Braun & Clarke, 2006) involving two researchers was employed to identify the artefact purposes and subsystems.

The third step of the research sought to identify the enabling role of the subsystems underlying the IS artefact (directly addressing RQ2). Lee et al (2015) argue that the IS artefact’s contribution is based on the enabling subsystems. Hence, the analysis sought to determine for each IS artefact the subsystems’ enabling role.

Findings

Advanced services propositions

The initial analysis identified the range of specific service propositions the manufacturers offer. The identified service propositions either improve the customer’s product use or directly address the customer’s business problems and are listed in table 1. Service propositions that target the customer’s product use include repair services, replacement services or diagnostic support services all offering to facilitate the customer’s interaction with the product. Service propositions that target the customer’s business problems include the optimisation and administration services which offer to add additional value to the customer’s business.

Table 1 List of IoT-related service offerings

Service propositions	Description of value proposition
Repair service	Responsive and timely product repair
Consumable/wear part replacement service	Predictive replacement of critical consumables and wear-parts
Product-maintenance service	Efficient and timely interventions to ensure the continuous product performance
Diagnostic support service	Provision of analysis to identify root-cause of product faults
Repair support service	Provision of detailed instructions to address product faults
Optimisation service	Specialist advise and consultancy on product utilization and associated business processes
Product alert service	Continuous real-time monitoring and notification of product use and status
Administration service	Provision of product-related supervisory and regulatory documentation

The initial analysis also showed how the manufacturers often offer the range of service propositions in different packages. In addition to offering the service proposition configurations in form of comprehensive advanced services packages manufacturers were found to offer individual service propositions to their customers through separate contracts. For example, while the product-maintenance service is included in the manufacturer’s pay-per-use offering customers can also draw on these maintenance services through a separate contract (without agreeing to the full pay-per-use offering).

IoT-enabled IS artefacts

The further analysis sought to identify how the IS artefacts, with the IoT in an enabling role contribute, to the above service proposition (RQ1).

Applying the utility and subsystem criteria the analysis identified 11 (IoT-enabled) IS artefacts that 1) provide a demonstrable utility within the manufacturer's advanced services problem space (e.g. address problems in the manufacturer's service propositions) and 2) are composed of information, social and technology subsystems that enable the artefact's contribution (outlined in the next section). Candidate artefacts for which no utility for the manufacturer's advanced services could be confirmed or for which no interaction between technology-, information and social subsystems could be identified, were excluded. Table 2 groups the IS artefacts into those that contribute to the manufacturer's efficient service proposition delivery and those that contribute to the manufacturer's service proposition itself.

Table 2. IS artefacts

IS artefacts that contribute to manufacturer's service delivery	
IS artifact [core utility explanation]	**IS artefact's contribution**
Repair efficiency artefact [detailed insights on product malfunction]	Contributes to manufacturer's product repair service delivery by • optimizing repair preparation (foresee required tools, spare parts, technician specialisation) which increases speed of repair and reduces risk of second visit • developing extensive training database to teach engineers on malfunction recognition
Maintenance optimization artefact [real-time insights on product maintenance needs]	Contributes to manufacturer's product maintenance service delivery by • optimizing maintenance scheduling through fine-grained identification of individual product failure risk (predictive maintenance)
Consumables/wear parts replenishment artefact [real-time insights on replenishment needs]	Contributes to manufacturer's consumable/wear part replacement service delivery by • optimizing own and customer's stock-levels (predictive replenishment)
Service contribution artefact [insights on the economic savings and contributions created]	Contributes to manufacturer's ability to visualise service value created by • benchmarking performance improvements
Operational misuse alert artefact [continuous product monitoring and alerts on product misuse]	Contributes to manufacturer's ability to ensure product-use is within agreed parameters of service contract by • identifying and alerting of product misuse.
IS artefacts that create manufacturer's service proposition	
IS artifact [IS artifact's core utility]	**IS artefact's contribution**
Customer self-repair assistance artefact [failure diagnostic and repair instructions]	Provide manufacturers with opportunity to offer customers failure diagnostics and repair support services by • creating access to automated analytics function and expert advice
Customer operational context advise artefact [product-use efficiency benchmarking and analytics]	Provide manufacturers with opportunity to offer customers optimisation services by

	• assessing the product-use context and use-performance (identify inefficiencies, use-related damages, product-choice) and advising on optimisation potential
Failure prediction artefact [prediction and alert of imminent product failure]	Provide manufacturers with opportunity to offer customers product alerts by • continuous monitoring of product status and provide risk-based alerts on imminent component failure
End-product quality advise artefact [continuous monitoring of process outcome]	Provides manufacturers with opportunity to offer customers optimisation services by • assessing real-time product details to create insights on customer's overall process performance (predict end-product-quality)
Fleet management administration artefact [product use and intervention documentation]	Provide manufacturers with opportunity to offer the customers administration services by • maintaining the product documentation (use-cycles, maintenance, compliance checks)
Location tracking artefact [tracking product location and movement]	Provide manufacturers with opportunity to offer the customers product alerts or optimisation services by • creating insights on product location and movement (geofencing)

Subsystems and their enabling role

The further analysis also sought to identify how the information, social and technology subsystems enable the (IoT-enabled) IS artefact (RQ2). The presentation of these findings outlines the specific information, social and technology subsystems that have been identified in the analysis of the IS artefacts.

While the product-use data was identified as an important **information subsystems** throughout, the analysis also identified algorithms, benchmarks and thresholds as further information subsystems that provide specific enabling roles:

- Algorithms were identified as a critical information subsystem which the manufacturers develop and continuously refine to apply specific reasoning to the incoming product-use data. Algorithms enable the IS artefacts that help manufacturers efficiently deliver its service proposition (e.g. predict maintenance needs in 'repair efficiency artefact') but also enable the IS artefacts that form the basis of some of the manufacturer's service proposition (e.g. identify root cause of failure in 'diagnostic support artefact').
- Benchmarks were identified as particularly important information subsystems that add further reasoning to the product-use data. The benchmarks are developed from the comparison of product fleets which help to establish a point of reference against which the individual product and its operation can be compared as is essential for several of the IS artefacts (e.g. identifying product-use inefficiencies in the 'customer operational context advise artefact').
- Thresholds were also identified as important information subsystems as it enables a number of the IS artefacts identified above. The thresholds are developed from monitoring of products in use and are critical to help establish at what intensity certain product-use values require interventions which is essential in several of the IS artefacts (e.g. triggering replacements in the 'Consumables/wear parts replenishment artefact').

The analysis the IS artefacts has also identified a number of **social subsystems** (relationship or interactions) and their respective enabling roles.

- Trusted relationships between manufacturer and customer were among the social subsystems most frequently identified in the analysis of the IS artefacts. Interviewees frequently described how the development of a trusted relationships (confidence that the manufacturer acts in a way that benefits the customer) was as essential for the manufacturer to retain continuous access to the product and the product-use data which underlies the IS artefacts.
- Substantial interactions between manufacturer and customer were also identified as core enablers in the analysis of several IS artefacts. The substantial interactions allow the manufacturer and the customer to exchange and align views and interpretations which is essential for several IS artefacts (e.g. provides the basis for understanding the particular customer context which is essential for the 'customer operational context advise artefact').
- Security guarantees and reputation were also identified as core enablers in the analysis of several IS artefacts as they provide the customer with the confidence that the manufacturer will maintain the latest security/compliance standards. Especially in IS artefacts which allow the manufacturer to obtain insights related to the production process (e.g. 'end-product quality advise artefact') and where the reliability of the IS artefact can have legal consequences (e.g. fleet management and administration artefact') such security guarantees and reputation have an important enabling role.

The identification of the technology subsystems that enable the IS artefact was dominated by the IoT technology (an essential criteria for considering the IS artefact). However, the analysis of the IS artefacts has also identified a further range of technology subsystems that enable several of the IS artefact identified above.

- The focused analysis of the **IoT technology** identified a wide range of IOT components; diverse sensors (capturing diverse product and environmental parameters) and communication devices (transmitting data across diverse standards) where identified as essential components for enabling the IS artefacts.
- In addition to the IoT technology the analysis identified a range of **analytic software tools that** that enables a range of IS artefacts by allowing the manufacturer to make sense of the product-use data that has been captured. Further technology subsystems that enable specific IS artefact have been identified (e.g. Shared screen technology to enable the 'Customer self-repair assistance artefact').

Discussion and conclusions

The study identified 11 distinct IS artefacts and determined a diversity of ways these contribute to the manufacturer's advanced services. Several of the IS artefacts (5) were identified with their contribution to the advanced services delivery. They were shown to specifically contribute to the efficiency of the service delivery by enabling the manufacturer to provide the service proposition profitably and at scale (e.g. maintenance optimization artefact). Other IS artefacts (6) were shown to not just contribute to the efficiency but instead to form the basis of the service offering. Hence, these IS artefacts create information resources which the manufacturer can provide as information-based service propositions to its customers. The study also identified a variety of information, social and technical subsystems that interactively enable these IS artefacts.

Despite the range of its contributions, it is important to note the study's limitations. First, the choice of method also integrates its inherent limitations. Although the study relied on a diversity of interviewees to provide a balanced and rich perspective, more interviews could still play a role. The range of subsystems that were identified for each artefact is dependent on what has been highlighted during the interview (e.g. contracts were only described in one scenario although it may be more prevalent). Also, while we focused the first interviews on five people for the organisations (to obtain more insights and depth of understanding) the remaining cases were limited to two or one participant in order to obtain insights in a wider range of scenarios with the given resources available. Second, the choice of organisation has significant impact on the outcome of the research. While we have included a wider range of manufacturers they were all a large and multinational nature. This needs to be taken into consideration when seeking to interpret and transfer the findings into an SME context.

Theoretical contributions and future research

The study broadens the predominantly technology-focused IoT research and contributes to the development of a socio-technical perspective to investigate the IoT and its implications. By drawing on Lee at al's (2015) IS artefact framework the study positions the IoT technology within a wider socio-technical context and explains its diverse contributions through the critical interaction between technology, social and information components ('subsystems'). The present study also contributes to IoT research by specifying the range and diversity of contributions the IoT creates in a specific business context. By applying the IS artefact notion the present study provides 11 distinct IoT-based contributions which helps to move the research on the IoT contributions from the abstract to the specific.

The present findings on the complexity and underlying nature of the IoT contributions creates a number of important future research opportunities. Future research should explicitly recognise and investigate the networks of shared subsystems to develop an understanding of the critical pathways organisation adopt to draw benefits from their IoT investments. Future research should also explore design approaches that include the design of the social context in order to systematically investigate, characterise or carry out the IoT solution design. Future research is further needed to develop the tools and frameworks that look at IoT design from the broader IS artefact perspective and broadens the investigative scope from the single firm (as done her) to a dyadic or even network perspective; resources dependency theory (Pfeffer & Salancik, 2003) in particular can be used to explain the dynamics that underlies future IoT strategy development.

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