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Conceptualizing the Internet of Things Data Supply

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Abstract

By enmeshing the digital and physical worlds, the Internet of Things is envisioned to generate a wealth of real-world data which enables new ways of creating value based on data. Organizations and researchers in the Information Systems community have already begun to transform existing approaches by applying concepts such as Nonownership Business Models that use data as the new main resource to create value. However, as our critical literature review shows, there has been limited attention to the actual characteristics and challenges of data supply in the IoT. Based on the critical review, two distinct themes were identified regarding the conceptualization of data and Things. Data is conceptualized either as Shallow Data or as Provenance Data, whereas things are conceptualized in terms of Things as Sensors or Things as Agents. Based on these themes, two research implications are developed. Firstly, things are more than sensors, they inherit agency and intention from their respective owners. Secondly, the provenance of data is essential. Data is considered a resource, quality control, assessment of legality are essential to securely rely on data to create value.

Keywords: Internet of Things; Data Supply; Value Capturing

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1. Introduction

The Internet of Things (IoT) is envisioned as a key driver that enables the provision and consumption of digital services that will change the way we work, live and socialize in the future [1]. Minteer et al. [2] estimate that IoT-enabled business models and IoT-enhanced processes will open up an annual revenue opportunity of $2.6T to $6.2T [2]. By 2030 organizations could generate value by using the data that is generated by 8 billion people and 25 billion connected devices [3] for purposes such as monitoring remote production facilities [4] or for prediction of future demand [4] [5].

With data becoming a main resource for novel digital services and changing industrial models [6] new challenges as well as opportunities arise for organizations [4]. For example, organizations such as Uber do not need to own any physical products or assets to create value [7]. In essence, Uber creates value by sharing the position of customers and service providers (the Uber drivers) with each other. These new ways of creating value from data, such as Data Driven Business Models (DDBM) [8] Nonownership Business Models (NOBM) [9], digital services and platforms [10] [11] and digitalized products [12] are enabled by or heavily benefit from the wealth of data that the IoT offers. The field of Information Systems (IS) research has, to date, been interested in understanding how organizations are leveraging the opportunities offered by the abundance of real-world data. In particular, new business models have been explored [13] [14], methods and tools to transform to organizations developed [11] and IoT related challenges and requirements assessed [15]. However, the IoT is more than a network of sensors which provide real world data. Williams et al. [16] argue that the IoT is more complex than a sensor-network and can be considered as a new Information Infrastructure (II), spanning across borders and domains, having no fixed notion of "user" and involving multiple stakeholders [4] [17] [18]. However, the definitions of IoT in most research studies, especially in the IS field, simply define the IoT as a global sensor network [e.g. 20 36 38]. Based on the insight that the IoT offers value that is contained in the real-world data it offers, and the observation that collecting data from the IoT is more complex than querying a sensor network, we argue that building a system or business model on top of the IoT must consider the characteristics of data supply in the IoT to ensure a solid foundation.

The aim of this paper is to shed light on these characteristics and derive research implications for incorporating the specific criteria relating to the use and reliance on IoT-Data in future developments. In order to do so, we firstly conduct a critical literature review [22] to identify the current themes and focus on IoT in the IS field. Based on this review, we then discuss the potential consequences of overlooking the complexities of relying on IoT-Data. We identify that the IS field has paid limited attention to the characteristics of the IoT in terms of data supply and argue that by not taking these characteristics into account, future developments that rely on IoT-Data to create value may be built on unstable foundations. The remainder of the paper is structured as follow. IoT in general and Value capturing methods as well as the research method are discussed in section 2 and 3 respectively. Section 4 presents the newly identified concepts regarding data and things. Section 5 concludes the paper and discusses potentials for future work.

2. Theoretical Foundation

Since the subsequent literature analysis is heavily influenced by the definition of IoT and related concepts used by the authors, this section presents the definition of IoT used throughout this paper as well as existing value capturing methods in the IoT.

2.1. The Internet of Things

From a technological standpoint, the IoT consists of interconnected objects, Things, that are able to sense, process and communicate [23]. Things, one core component of the IoT, are embedded in everyday objects and sense and influence their surroundings. The plethora of interconnected, sensing and communicating devices create an ocean of heterogeneous real-world IoT-Data. Before IoT-Data can be used to create value, the IoT-Data-Supply process translates, transforms, categorizes, understands and ensures sufficient data quality. Developing this global network poses many technological challenges. Hence, the IoT is often considered as technology driven [24].

However, the technological aspects of IoT will arguably have a smaller effect on the aspects of our everyday life than the possibilities that these networks offer. Various studies and reports claim that at any time we will be surrounded by numerous ubiquitous devices [25]. Furthermore, many consider that these devices are additionally capable of collaborating to achieve individual or common goals [26]. These devices will likely maintain a relationship with other devices, for example with the devices they have successfully collaborated with in the past [15] [27]. The Social Internet of Things (SIoT) is a further evolutionary step in the development and conceptualization of the IoT. Essentially, it envisions that Things maintain social relationships with other things or humans, forming a social network [27]. The quality or property of these relationships could be of various kinds, ranging from "success collaborators" to "data consumers", which might be other Things or even humans [27]. However, it is unquestionably the case that all things will have some form of ownership relationship. Since, these devices require someone who is responsible for maintenance and the availability of the device's data, all of which requires certain effort and likely compensation [15]. It is envisioned that the IoT will connect more than 30 billion devices to the internet [6].

That all these devices will belong to the same owner is unlikely. Likewise, these devices can be seen as an extension of their respective owners, since they behave on behalf of the owner's interest and offer data according to the owner's interest [5]. In this work, we consider the IoT as a network of heterogeneous things, each having the capability to sense, actuate communicate and collaborate; each aiming to follow the behavior imposed on them by their different owners.

2.2. Value capturing in the IoT

Developments in Big Data have generated numerous methods and technologies to gain insights from large amounts of data [28]. By creating, optimizing and validating models based on vast amounts of data, it is possible to verify the present and predict, more or less reliably, the future. One way for the IoT to generate value is by fueling big data efforts [29]. In reality, leveraging value from IoT will always incorporate some form of data analytics [30]. However, there are also other ways to capture value from data.In contrast, Data Driven Business Models (DDBM), intend to support data-related ventures to capture value by aiming to monetize data [8]. Hartmann et al. [8] define that DDMBs rely on data as a key resource to capture value. Where a key resource is considered as "*all assets, capabilities, organizational processes, firm attributes, information, knowledge controlled by a firm*" [8, p. 1386]. A company employing such a business model is not limited to only conducting analytics but can also sell traditional products that additionally rely on data as one key resource. For example, smart speakers can add value through the capability to interface with online retailers [31], relying on data-sets to enable natural language understanding as well as customer data that is collected and likely shared with partners.

Nonownership Business Models (NOBM) are existing concepts [9] in which companies retain the ownership of their physical products and instead offer the performance of their product as a service. For example, Rolls Royce charges their jet engine customers for the flight hours of their engine while retaining ownership of the engine itself [32]. Bock and Wiener [9] consider NOBM, in context of the manufacturing domain, as a novel manifestation of a Servitization strategy [9]. Due to the ability of the IoT to enable remote monitoring and further using this data to predict maintenance cycles it significantly improves and extends the efficiency and potential of these business models.

As approaches such as DDBM and NOBM show, IoT-Data is envisioned to carry significant potential for capturing new value, monetize data and improve existing products and services. However, before being able to instantiate these new approaches, the viability of the IoT as a reliable supplier of real-world data must be considered.

3. Research Method

In order to explore how the IoT data supply is conceptualized in the literature we undertook a critical review of the IS literature [22] with the focus on identifying how and to what extent the concept of Things and data are used in relation to IoT.

The critical review was conducted using the search phrase "(`Internet of Thing~`OR `IoT`)" matching in title or abstract, a broad search of the literature was conducted, including sources such as: AIS Electronic Library database and leading IS journals, including: EJIS, ISJ, ISR, JIT, JMIS, JSIS, MISQ and MISQE. Further, results from 2005 to 2020 were selected, since enabling technologies such as Wireless Sensor networks and consequentially the IoT started to gain significant interest by 2005 [33]. The review includes conference proceedings and top IS journals to represent the IS field´s interest in IoT in sufficient depth. Further, the review is focused on the IS field in order to explore how the new form of real-world data provided by IoT impacts people, tasks, structures and the technology of organizations. The search phrase yielded a corpus of 144 publications, which were then reduced to 63. In the initial screening we filtered out publications that do not directly address IoT or creating value from IoT. However, the critical review is not constrained by the nature of the primary data sources and the corpus contains articles based on empirical data, conceptual information as well as quantitative and qualitative studies. Additionally, descriptions of use cases have been included, regardless how these use cases were used in the respective publication. The publications included in the review span various areas, such as encryption [34], the presentation and analysis of use cases [35] [36] and studies dealing with the transformational effect of IoT [37] [38].

In our review we focus on Things as well as IoT-Data, since they have been identified as key components and resources respectively. Therefore, we review each selected publication in terms of conceptualization of data and things. The individual core topics of publications regarded in this review are considered as supplemental information. However, we acknowledge that the primary topics of the publications are related to the depth that data and things are covered in. For example, publications addressing security and privacy tend to consider data more in depth [39] as publications focusing on business models [40] [41]. The individual themes of data and things are developed as follows. First, attributes of things and data were collected from the literature. For example, Goul [30] describes that contracts, formed by stakeholders of Analytics of Things assemblages (AoT/ AoT assemblage), should clarify what kind of compensation is provided for data. By applying this approach to descriptions and concepts of things and data in the literature, different themes for data and Things have been identified and will be discussed in the subsequent section. Since critical literature reviews are prone to subjectivity [22], we make our further approach and argument by having presented our definition of IoT in section 2.

4. Thing and Data Themes of IoT

Drawing from the literature review described in section 2, two distinct themes were identified regarding the conceptualization of data and things used throughout the literature. Data is conceptualized either by the Shallow Data theme or by the Provenance Data theme (see table 1), whereas things are conceptualized using the Things as Sensors theme or the Things as Agents theme (see table 2).

4.1. Shallow Data

The Shallow Data Concept characterizes IoT-Data as being reliably related to a physical context, generally available in large volumes, varying velocities and increasing variety. The purpose and scope of the data has been defined before collection, the collection itself requires little effort apart from establishing a network connection and deploying the device. Data is, due to the fact that it is measured and collected for an intended purpose, of sufficient quality and can be used without further assessment apart from typical data preparation carried out in data analytics. Furthermore, the legality of the data or the process of its acquisition is not considered to be an issue, since it is expected that the user of the data is also the owner. Data is also not expected to leave the boundaries of the IoT application and purpose it is collected for [12]. This concept of data is typical for applications in an industrial context where IoT is used to improve shop floor performance, monitor manufacturing processes or supply chain activities. For example, Wortmann and Flüchter [14] describe that the “Thing-based” function of bins is to provide storage capacity. However, by enhancing these bins with IoT technology, they could detect their own levels of stock and offer automatic replenishment services, which are then considered the “IT-based” function of the bin [14]. This could lead to cost reduction in the company utilizing this approach. However, they consider the data created and transmitted in their examples to not have value other than supporting the process [14].

4.2. Provenance Data

The Provenance Data Concept generally extends the Shallow Data Concept in that it not only considers data in terms of Volume, Velocity and Veracity but also critically assesses the Veracity of data as well as defines that data on its own has a Value before it is used to provide digital services or analytics. Additionally, data is not considered to be exclusively collected for a specific purpose. Therefore, data needs to be assessed for its suitability to the intended purpose in terms of its quality specifically as well as being treated as a valuable resource in general [42]. Based on the insight that data contains value in itself, expenses to acquire data, such as the deployment of IoT infrastructure or the costs of establishing a network connection must also be taken into account. The actual cost of the data must be determined and compensated for. Expenses to collect data also incorporate incentives or compensations relative to the value of data. Since sensing the data is not necessarily related to the intended purpose or an existing system or platform, this concept considers the fact that ownership can vary between individual sources (Things) is of relevance. In addition to this, the legality of the collection process and the data itself needs to be critically assessed. Further, due to the imbued value of data regardless of its purpose, it is likely to be shared between systems. For example Goad and Gal [15] attribute Things with various relationships such as ownership, among others. Furthermore, they suggest that Things should be able to behave socially and require incentives to participate in the network. By doing so, they characterize Things not only as more than sensors, they also expect that data has value prior to its use within a system based on the requirement that Things should require incentives to collaborate and share data [15].

Table 1. Conceptualization of Data in IoT

Data properties	**Shallow Data Concept** (39 publications)	**Provenance data Concept** (24 publications)
Acquisition Expenses	Data does not need to be acquired; no expenses considered	Data needs to be acquired, either internally or externally
Assessment/ Fit for purpose	Data is considered to be fit for purpose; Data is collected specifically for intended use	Data is not necessarily collected for intended use and needs to be assessed before being used.
Volume, Velocity, Variety	Data is attributed with Volume, Velocity and Variety depending on intended use	
Veracity, Value	Not considered.	Data is considered as an external resource that has value and needs to be acquired. Value of data depends on veracity, among others.
Data Quality	Data is always fit for purpose; data quality is not considered.	Data is considered as an external resource; data quality must be considered to determine data value.
Data Legality	Not considered.	Data is considered as an external resource; legality of data collection must be considered to determine data quality.
Ownership	Not considered. Implicitly adjudged to the organization using the data.	Data is collected, transmitted and shared by different stakeholders, each having different degrees of ownership.
Data sharing	Not considered	Data is rarely shared between stakeholders or platforms.

4.3. Things as Sensors

The Things as Sensors concept is rooted in Atzori et al's. [43] Thing Oriented Vision of IoT. The main aspect of Sensors, embedded into everyday objects, is to sense their surroundings, communicate with other things, forming Sensor Networks and connect to the internet [33] [43]. Things are considered as providing data without compensation, e.g. due to the fact that they are deemed to be tied to a product and its respective ecosystem [23]. The ownership of a Thing is not explicitly addressed in this approach. However, Things are implicitly owned by the owner of the object it is attached to or part of. Alternatively, it is owned by the owner of the "Sensor Network" which the Thing is part of. Furthermore, Things do not exist apart from the object they are attached to or the ecosystem they are embedded in. For example, Ives et al. [12] explore how and in which phases and stages of the Customer Service Life Cycle (CSLC), which has been used for decades to understand customer service and provide managers with strategic guidance [12], can benefit from IoT-Data. They analyze IoT initiatives in relation to the CSLC to determine which initiative addresses which step and stage of the CSLC. They characterize things as being tied to physical objects, having identifying, sensing, communication and computing capabilities. However, Things are neither attributed with ownership nor intention. Further, the IoT initiatives being analyzed are considering Things as a component of a system in which Things serve no purpose without said system.

4.4. Things as agents

In the Things as Agents approach, Things are considered to act with intention, which is inherited by their owners. Furthermore, things are not existentially relying on their relationship to a product or ecosystem. In contrast to the Things as Sensors approach, the existence of Things depends on their owners, who can be individual persons, organizations or governments [5]. Furthermore, Things are able to act autonomously within the boundaries of the intentions and goals inherited by their owners. For example, they can collaborate with other things to fulfill the task their owners have set for them, essentially forming a network of collaborating agents, each following their own agenda but benefiting from each other. The concept of the Social Internet of Things (SIoT), where things are considered as social objects [44] describes this approach best. Based on the inheritance of their owners' intentions, Things may or may not require some form of compensation for providing data depending on the intention of the owners. For example, Oberländer et al. [7] evaluate business-to-thing (B2T) interaction patterns, building on sociomateriality. Through developing a taxonomy of B2T interactions and combining weak and strong sociomateriality they identify that smart things can be considered as independent actors [7]. Hence, Things are characterized as more than data providing sensors.

Table 2. Conceptualization of Things in IoT

Thing properties	**Things as Sensors** (48 publications)	**Things as agents** (15 publications)
Ownership	Not considered. Implicitly adjudged to the organization using the data of the thing.	Each thing can potentially have a different owner, each with different interests.
Agency/ intention of action	Things act as data sources or actuators in strictly predefined contexts.	Thing inherit agency and intention from their owners, e.g. amount of compensation for providing data.
Compensation of access	Not considered.	Based on owner´s intentions, compensation for access, e.g. to data, is required.
Existential Relationship	Things are created for predefined purpose and are not expected to exist outside their respective application or context.	Things are *components* of owners and inherit the intention of these owners. Their existence is tied to owners.

Using these themes, we identified that the current focus of the IS field is primarily to explore future and potential value of IoT and the data it provides. However, the details of the actual data supply are neglected. To date, research in the IS field, is directed towards exploring the transformational IoT related requirements and challenges as well as developing tools and methods to facilitate IoT related transformations and changes [10] [11]. The majority of research studies identified in our analysis employ the Shallow Data Concept in conjunction with the Things as Sensors concept. These studies aim to project the potential value of exemplary IoT applications or use cases. However, most often these use cases and experimental IoT applications are either simple, small in scale or both [45]. Since these use cases and applications are simple and manageable, usually consisting of a proprietary or closed network of sensors, sometimes dubbed as "Intranet of Things" [46], concerns regarding the veracity or value of data rarely arise. The conceptual details of data provided by IoT or how things in IoT are considered, are largely treated as out of the scope in these studies that aim to explore the value of IoT-Data, or that examine the organizational challenges involved in being able to leverage this data. This lack of a detailed view of IoT-Data and the nature of things may lead to future problems and base further developments using IoT-Data on a weak foundation as cases of canceled or failed data initiatives show [47].

5. Conclusion and Research implications

Based on a critical literature review, we identified two different themes of data and Things in the IoT. Firstly, IoT-Data is regarded as either being shallow or having provenance. The Shallow Data Concept characterizes IoT-Data as readily available and fit for the intended purpose as well as not requiring expenses to acquire IoT-Data. Studies employing this concept focus on novel possibilities of value creation with IoT-Data [14] and the associated challenges with increased volume, velocity and variety of this new form of data. In contrast, the Provenance Data Concept additionally considers aspects such as veracity, legality, ownership and value of data [15] [27]. This concept further defines that acquiring IoT-Data requires organizations offering digital services to compensate the data-owners as well as to request their consent to ensure the legality of data.

Secondly, Things are either considered as sensors or agents. On the one hand, the Things as Sensor concept defines that the existence and purpose of a Thing is tied to the object it is attached to, or to the system the Thing belongs to [23]. Further, the ownership of a Thing is generally not relevant for studies utilizing this concept because Things are generally considered to belong to the application-owner or the owner of the object. On the other hand, the Things as Agents concept envisions Things as being able to follow the intentions of their respective owners [26] [27]. In this concept, owners impose their own intentions and characteristics onto Things. Further, things are then envisioned to be able to act on behalf of their owners, e.g. by taking over negotiations with other things or businesses [26] [27].

5.1. Things are more than sensors

By incorporating the concept that Things are more than Sensors that simply sense and provide data into the design of IoT applications and business models, additional opportunities can be exploited. Acknowledging that Things have owners, who in turn impose their individual agenda and intentions on their Things, opens the opportunity for new approaches to value creation. Furthermore, considering that Things do not need to be part of an organization's own ecosystem from the beginning, this may allow organizations with limited hardware and product capabilities to leverage the IoT. As Atzori et al. [44] envision, an individual could willingly trade their ice-cream consumption via a smart fridge with an ice cream manufacturer. The individual may receive discounts, while the manufacturer can use the consumption data to streamline production [5], neither one needs to be able to produce a smart fridge or grocery tracking system. Additionally, by acknowledging that Things derive their intentions from their owners, organizations may consider Things more as Customers or Partners. Therefore, future research needs to consider that Things are more than sensors and incorporate this notion into the development of IoT solutions.

5.2. The provenance of Data is essential

Taking into account that data has value that is detached from the purpose it is gathered for, opens several opportunities. Firstly, this implies that data can be used to generate multiple types of value. For example, monitoring of production machinery [9] may improve maintenance and utilization in the near future. However, in the more distant future a wealth of historical machine utilization data might yield additional value that is unknown at the time of data collection. Secondly, while it might be possible to leverage existing Things to collect data, the consumption data still requires compensation. Judging from the wealth of studies looking at incentive mechanisms for the IoT, this might be an important aspect for future applications. Further extending on the aspect that things have owners with intentions, assessing the quality and legality of collected data must be incorporated into the design of future IoT applications. Thus, critically assessing the circumstances IoT-Data has been measured in as well as paying attention to the route the data takes from sensing to its use must be considered when designing applications and business models relying on IoT-Data.

6. Limitations & Future Work

The topic of Internet of Things (IoT) has been studied in many other research fields; this study focuses on the Information Systems field. Hence, this study examines in-depth how the IoT and IoT-Data-Supply is used and conceptualized in the IS field by conducting a critical literature review. One limitation of critical reviews is that they are prone to subjectivity. However, this method is especially suited to pointing out topics that have received less research interest and require more attention to deepen knowledge and close emerging research gaps [22]. In this study, we viewed IoT as being more than an emerging technology, essentially as being an information infrastructure that allows us to unveil the complexities of IoT. Topics, such as security and privacy, governance and social impacts, are considered relevant but are not addressed in our study. We propose that future studies develop a consolidated transdisciplinary view of IoT. As we have shown, there are opportunities and challenges in the space between things collecting data and organizations consuming this IoT-Data to fuel data driven business models.

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