Business Models for Internet of Things Platforms: Empirical Development of a Taxonomy and Archetypes

Daniel Hodapp[1], Gerrit Remane[2], Andre Hanelt[1], and Lutz M. Kolbe[1]

[1] University of Göttingen, Chair of Information Management, Göttingen, Germany
daniel.hodapp@stud.uni-goettingen.de
{andre.hanelt, lutz.kolbe}@wiwi.uni-goettingen.de
[2] FH Wedel, IT-Management, Wedel, Germany
gerrit.remane@fh-wedel.de

Abstract. A wide range of Internet of Things platform providers operate diverse business models to cater for the manifold requirements of the IoT. This paper contributes to a more precise understanding of IoT platforms as an essential building block of the IoT based on the characteristics of its business models. Even though research listing technological dimensions according to which IoT platforms differ, they have neither been systematically derived nor been linked to the business model concept. In turn, they lack descriptive power on the heterogeneous value creation mechanisms of the platform providers. Within our research, we first analyzed 195 IoT platforms and systemically developed a taxonomy allowing the characterization of IoT platform business models. Second, based on this taxonomy, we identified nine archetypes of IoT platform business models and illustrated typical combinations of business model characteristics. Equipped with such an understanding, practice and research can analyze existing IoT platforms more accurately.

Keywords: Internet of things, IoT platforms, Taxonomy, Business model, Archetypes

1 Introduction

There are 20 billion connected devices forecasted by 2020 [1]. For connecting all these heterogeneous physical products to the digital world, IoT platforms are essential. They act as a central backbone connecting the heterogeneous device landscape, different data sources, developers and end-users [2]. To give an illustrative case: The cloud company Amazon operates an IoT platform and provides the functionality to manage millions of devices. Other companies can build on these functions and develop IoT applications. For instance, Miovision, a company offering a variety of devices for measuring air quality and noise builds on Amazons platform to connect its physical devices and to develop applications that support cities in improving transport capacity, safety, efficiency and performance [3]. However, in order to take advantage of the economic opportunities more than 450 firms have entered the market for IoT platforms [4]. While all platforms are offered under an IoT related platform label, they vary considerably as they focus on different aspects of the IoT technology stack and correspondingly include diverse functionalities in their offerings, leading to different types of value creation [5].

14th International Conference on Wirtschaftsinformatik,
February 24-27, 2019, Siegen, Germany

So far, academia has highlighted different technological characteristics of IoT platforms. Some researchers stress the integrative role of IoT platforms and describe them as an abstraction service for smart objects, i.e. a digital representation of physical objects equipped with sensors, actuators and communication technology is available on the platform [6, 7]. Thereby, the IoT platform can be operated on the cloud level and provide the functionalities in a platform as a service manner or in a local environment running on a gateway or other devices[6]. In addition, some researchers include the role of end-users and characterize platforms as interaction enablers between end-users and smart objects by providing the necessary infrastructure [2]. Later on, the understanding of IoT platforms as instantiation of a digital platform emerged, i.e., a software-based system that provides core functionality shared by the interoperating modules [5, 8]. These core functionalities include integration, management and monitoring of smart objects, that can be utilized to build applications for the IoT [6]. In sum, IoT platforms can be understood as a specific type of digital platforms that are (i) operated in a cloud or local environment, (ii) enable the interaction between smart objects and end users (iii) by providing a core functionality to third party developer to support the development of modular applications (iv) on the basis of an abstraction service that is integrating underlying infrastructure and different data sources.
To advance the understanding of the IoT, existing technological considerations must be complemented by a business perspective [9]. Against this backdrop, we argue that a business model-focused view on IoT platforms is necessary, as it provides just the right perspective for relating rather technological aspects (e.g., platform openness) to essential business decisions (e.g., pricing model), thereby making these interdependencies explicit and thus manageable as part of a systematic business model design process. Considering this need, the paper strives to answer the following two research questions: *(1) How can instances of IoT platform business models be characterized?, (2) What are the IoT platform business model archetypes that can be differentiated?* To do so, we briefly provide the necessary background to digital business model frameworks before we proceed in four phases: (1) We develop a representative database of IoT platform providers. (2) We carry out a systemic literature review to identify publications that introduce specific dimensions along IoT platforms. (3) We deconstruct the business model of platform providers into a classification scheme that serves as a taxonomy and thus, a theory for analysis [10]. (4) Lastly, we empirically identify business model archetypes from this taxonomy.

2 Digital Business Model Frameworks

The term business model describes how an organization creates, delivers, and captures value [9]. In literature, the concept mainly serves as a classification basis for emerging value drivers, as performance indicator, or as foundation for business model innovation [11]. Several authors have introduced business model frameworks that provide design options for specific business model components e.g., [9]. This component-based view on the business model concept i.e., a system comprising a set of interacting components, is dominating the current scientific discussion [11]. However even though an intense scholarly discourse, there is no consensus on what a business model actually is, nor on what specific set of relevant components are included[1] [12].

With respect to our research questions, we focus on frameworks that were developed explicitly for digital business. This is necessary as IoT platforms (as well as many other platforms) rely heavily on digital technologies to create value and can therefore be considered digital business models [13]. We identified several specific business model frameworks describing the generic dimensions of digital business models, most importantly [14], [15] and [16]. In addition, other authors have also introduced business model taxonomies for specific digital domains. These approaches are more precise as they not only describe the component and dimensions of digital business models in a certain domain, but also specify the potential characteristics for each of these dimensions. Therefore, they are not only useful for analyzing existing business models but are also a powerful tool for business model innovation [17]. Therefore the first objective of this research is to develop a business model taxonomy for IoT platforms.

3 Methodology

In prior publications, the taxonomy development was conducted for two reasons: first, to provide the fine-grained approach to re-structure a comparatively young research domain (e.g. 17), and second, to set the ground to extract archetypes (e.g., 18). We included central elements from these studies in our four-phase research design.

3.1 Phase 1

In the first phase, we created a database of IoT platforms that were operational between May and June 2018 following three steps: first, we combined a variety of sources, starting from IoT platforms mentioned in the literature review (54 platforms), continuing with a tag search for "IoT platform" in the world's largest tech database CrunchBase (221 platforms), and finally adding the platforms of the leading IoT database Postscapes (123 platforms). By pooling the sources, we obtain 398 platforms. Second, we excluded providers who occurred more than once, went bankrupt, got acquired, ceased operation or offered no market-ready product. As a result, we have a reduced data set of 237 IoT platforms. Third, to have a consistent understanding of an IoT platform, we excluded platforms that did not follow the introduced understanding of an IoT platform (see introduction). The database contains all the leading platforms according to multiple market analyses (e.g., [1]). Further commercial reports indicated the presence of more than 450 IoT platforms [4]. However, we consider our database with 195 operating platforms as a sufficiently representative sample of the overall IoT platform market to identify the most relevant business model dimensions as well as archetypical combinations of these dimensions.

[1] For further theoretical details on the business model concept, see [12]

3.2 Phase 2

In the second phase, a systematic literature search and analyzes was carried out [19]. To identify all potentially relevant publications, we conducted a keyword search using the databases ScienceDirect, IEEE, AISEL and Google Scholar in the title, abstract and keywords by using the following search strings[2]: "IoT”, "Internet of things", “platform”, “middleware“, “cloud”, “classification", "types", "typology", "taxonomy", "business model” resulting in an initial sample of 327 publications.

Table 1. Literature based dimensions

Author	Conceptual dimensions	Literature-based taxonomy dimensions
[20]	• Core capabilities • Platform openness	Context awareness, Device management, Interoperation, Platform portability, Security and privacy
[21]	• Core capabilities, • Platform integration • Partner system • Degree of support	Access, Architecture, Data store, Documentation, External integration, Fault tolerant, Finality, Languages, Last update, License, Load balancing, Memory, Official Companies, Programming, Replication
[22]	• Core capabilities • Platform openness	Analytic tool, API/library, Connection type, Database type, Data formats, Energy efficiency, Messaging protocol, Notification/alert, Open Source/commercial, Platform resource requirements, Programming Language, Security, Software Development Tool, Storage Space, Visualization
[23]	• Platform integration • Degree of support	Device Management, Conversion Security, Decentralization, Enterprise integration, Event-Management, Filtering & enhancement, Information, Maintenance, Technology abstraction, Visualization
[2]	• Device support • Application sales channel • Partner system • Degree of support	Data ownership, Data processing and sharing, Developer support, Ecosystem formation, IoT marketplace, Support of heterogeneous devices
[24]	• Core capabilities • Device support • Degree of support	Availability, Developer Friendly, Plug and Play, Provision of Support, Real time data, Scalability, Security & Privacy Provisioning, Solution Type, Storage of data
[25]	• Core capabilities • Device support • Transaction based revenues	API protocols, Application, Cloud model type, Data analytics, Data visualization, Device configuration, Real time data capture capability, Usage costs / developer costs
[26]	• Core capabilities • Platform openness	Integration to Cloud, Mostly Used applications, Security, Supporting Protocols, Type of Analytics

To further systematize the review process we proceeded in three steps. First, we screened the abstract with regard to our research question (sample size 147). Second, we solely included publications in peer reviewed journals or conferences to ensure scientific rigor (sample size 96). Third, we conducted an in depth analyzes were each publication had to contain technical or other business model related dimensions that support the description of IoT platform business models (sample size 7). We than conducted a forward-backward, resulting in sample of eight publications (table 1).

In the next step, we systematically analyzed the literature corpus and identified three limitations: (1) The literature based dimensions are not systematically derived, but were rather developed ad-hoc, and lack details regarding the origin of each dimension and the associated characteristics, resulting in lack of transparency. (2) The presented dimensions were mostly developed in a technical context and not linked to the business model concept, thereby neglecting important components of a complete business model. Possibilities to capture value remain largely unexplored. (3) The introduced taxonomy dimensions are only sporadically evaluated on a representative real world sample of IoT Platforms. In addition, we have derived eight conceptual dimensions

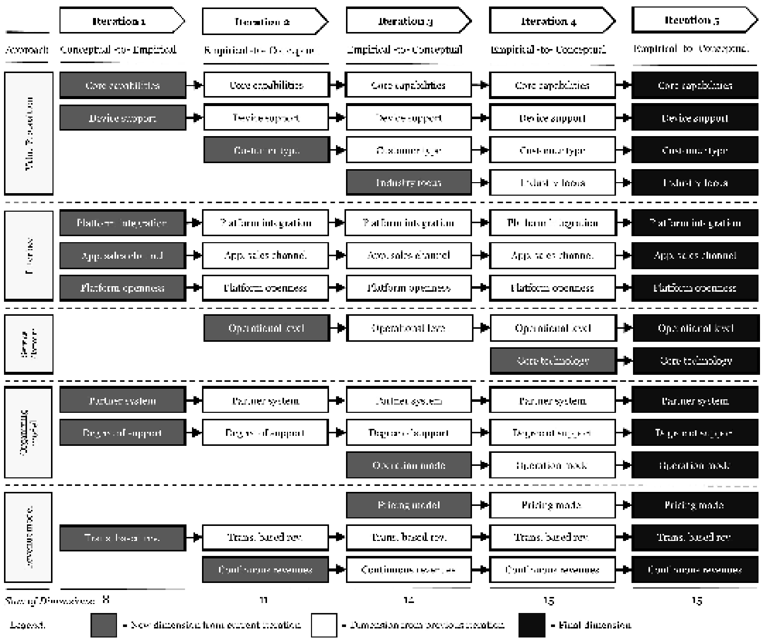
[2] Some contributions use platform [2], middleware [20] and cloud [21] interchangeable thus we included them in the key word search.

from the literature, which serve as a starting point for the taxonomy development and provide researchers with initial notions of how IoT platform business models differ.

3.3 Phase 3

In the third phase, a taxonomy of the IoT platform business models was systematically developed. The process was guided by the taxonomy development method of [27]. The method is rigorous, since the necessary steps and ending conditions are clearly defined and proven in numerous applications. In addition, the method enables the combination of already identified dimensions with new dimensions from the research of real objects.

Figure 1. IoT platform business model taxonomy development



In the first step of the process, we casted our meta-characteristic within the VISOR framework from [15], similar to [17], to assure that all relevant components of digital business models are covered. The VISOR framework is the most adequate one for decomposing the business model of IoT platform providers, as it emphasizes the importance of the customer interface, the central role of digital platforms, and the need to orchestrate complex digital ecosystems. The VISOR framework consists of five components: value proposition, interface, service platform, organizing model and revenue model. Second, our taxonomy development process is based on the eight objective and four subjective ending conditions proposed by [27]. Third, we ran through five iterations until all IoT platform providers from the database were classified and the ending conditions were met (figure 1). In the first iteration, we opted for a conceptual-to-empirical iteration and integrated the taxonomy dimensions identified during the literature review (table 1). For the second, third, fourth, and fifth iterations, we conducted empirical-to-conceptual cycles, leading to successful classification of all IoT platform providers in the data sample. To reduce the complexity of these cycles, we classified the providers according to their company size i.e., multinational companies (MCN), small and medium companies (SME), startups and project settings (e.g., open source projects). At this point, all providers from the database were classified, seven further dimensions were added (i.e., customer type, industry focus, operational level, core technology, operation mode, pricing model, continuous revenues) and all objective and subjective ending conditions were fulfilled, thereby ending the iterations.

3.4 Phase 4

In the fourth phase, we conducted a cluster analysis to empirically derive IoT platform business model archetypes from the taxonomy. Based on the work of [28], a two-step approach delivers the best results. They indicate that using Ward's method to identify the optimal number of clusters represents the first step. Therefore, the clusters must be further specified using an iterative partitioning procedure. In accordance with this recommendation, we first applied the Ward’s clustering algorithm (all analyses were conducted in SPSS, version 22). The similarities between the two organizations (objects) were calculated by the number of identical characteristics along the taxonomy dimensions and measured as square Euclidean distance, which is suitable for binary data. These results indicate that five or nine cluster solutions would be most useful for a k-means in depth analyses.

We then applied the k-means method to the five and nine cluster solutions. In both cases, the algorithm ran through five iterations until no significant improvements were achieved in the last iteration. Subsequently, we evaluated the resulting clusters manually for their explanatory power. A closer look reveals that the five cluster solution is largely similar to the seven core capabilities of the IoT platforms neglecting some important differences between underlying business logics. The nine clusters, on the other hand, were more fine-grained and reflected some essential differences, particularly regarding value capture. In short, the nine-cluster solution has more explanatory power because it provides important distinguishing characteristics. Therefore, we will only explain the results of the nine-cluster solution in this article.

4 Results

4.1 Taxonomy

The resulting taxonomy contains 15 dimensions, each with two to seven different characteristics (table 2). Each of the 195 platform providers from the database are represented by exactly one characteristic per dimension. The taxonomy contains the most important dimensions according to which IoT platform providers differ i.e., business model components that are identical for all providers are not listed here [27].

Value Proposition

Core capabilities: What are the core capabilities offered for developers by the IoT platform? First of all, the capabilities of IoT platforms greatly vary. Where some platforms focus on things by providing operating systems to develop embedded software for smart devices, other platforms enable the connectivity of things by offering telecommunication hardware such as sim cards and the infrastructure to manage the connections (e.g., Ciscos Jasper Platform). Some others focus on the management of devices by allowing remote firmware updates and configuration management of the connected devices (e.g., Echelon). Another group of platforms offer cloud storage options for the incoming device data or running code (e.g., GroveStreams) whereas others mainly provide analytic capabilities including means to extract insights from the data (e.g., SenseIoT) or capabilities to develop and deploy IoT applications through a developer environment (e.g., Ayla). A last type of IoT platform provides multiple capabilities such as, application development environments and cloud storage to provide an all-in-one IoT platform approach (e.g., ThingWorx).

Table 2. Taxonomy of IoT platform business models

VISOR	Dimension	Characteristics of the dimensions						
Value proposition	Core capabilities	Embedded device operation	Connectivity enablement	Device management	Device data storage	Analytics	Application development	Multiple capabilities
	Device support	Selected 3rd party devices	Exclusively provider´s devices	Selected 3rd party devices and provider devices	Any device, if provider's standards are used			
	Customer type	Consumer	Business	Business and consumer				
	Industry focus	Single-industry platform	Cross-industry platform					
Interface	Platform integration	In enterprise system	In web services	In multiple diverse systems	No integration opportunities			
	Application sales channel	Marketplace functionality	External marketplace necessary					
	Platform openness	Fully proprietary	Hardware proprietary	Software proprietary	Open source			
Service platform	Operational level	Operated on device	Operated on cloud	Operated on device and cloud				
	Core technology	Telecommunications	Sensors and microcontroller	Cloud technologies	Other technologies			
Organizing model	Partner system	Open partner system	Proprietary partner system	No partner system				
	Degree of support	Non personal technical support	Personal technical support	Personal technical and business support				
	Operation mode	Operated by platform provider	Operation by 3rd party possible					
Revenue Model	Pricing model	Developer projects are free and enterprise projects are priced	Developer and enterprise projects are priced	Free for use				
	Transaction based revenues	Per connected device	Per API call	Traffic based	Combination of multiple sources	Per request	Free for use	
	Continuous revenues	Time based (monthly / yearly) minimum fees	Pure pay as you grow (no continuous fees)					

Device support: What are the devices supported by the platform? Some platform providers allow selected third-parties to connect their devices to the platform, whereas others exclusively support platform provider devices. Several platforms support all types of connected devices when the platform standards (libraries) are implemented on the device and the predefined API is used.

Customer type: What is the customer type of the platform? Even though a majority of the platform providers are focused on business customer types (e.g., General Electrics), some providers also address the platform (e.g., IFTTT) to the consumer segment. *Industry focus:* What is the operating industry of the platform? Some platforms are designed to operate in a single specific industry, e.g., home or manufacturing, whereas others are designed as a cross-industry platform.

Interface

Platform integration: Does the platform offer integration functionality for other systems? While some platforms offer a strong functionality to connect to enterprise software like ERP, CRM or SCM systems, other platforms provide integration frameworks to enable rapid connectivity to web services, e.g., like AWS.

Application sales channel: Does the platform offer a marketplace to publish IoT applications? Some providers offer a marketplace (e.g., Libelium) to support developers in publishing applications. On other platforms, the developers rely on external marketplaces e.g., Arktik (Samsung), Pega 7 (Pegasystems).

Platform openness: To what extent is the platform open for modifications? Some platform providers follow the open source approach, i.e., the platform code can be modified and is open to run on any third-party device (e.g., KAA IoT platform). In contrast, there are platforms that are hardware proprietary and run exclusively on specific devices (e.g., Siemens Mindsphere), or software proprietary, which means that they can operate on any device with no access to the platform code. Some platforms are also fully proprietary, meaning that developers cannot run the platform on third party devices or change the platform code (e.g., Ayla IoT platform).

Service Platform

Operational level: On what level is the platform operated? IoT platforms run on different operating levels. Some run on a central cloud and manage millions of devices (e.g., Grovestreams), whereas others can be operated on edge devices such as a local gateway or small single-board computers (e.g., Phao, Fosstrack). Furthermore, some other platforms have a flexible structure and can run on both levels (e.g., Nimbits).

Core technology: What core technology does the provider supply along with their platform? The core technology may include sensors and microcontrollers (e.g., Siemens, General Electrics), telecommunications technologies (e.g., Cisco, Huawei, Vodafone), cloud infrastructure (e.g., Amazon, Google), or other technologies.

Organizing Model

Partner system: How is the access to the partner system organized? Some providers operate a proprietary partner system which does not allow the direct participation of complementary providers. Other providers offer direct registration for the partner program, taking into account complementary competencies and services. Some providers do not operate a partner system at all.

Degree of support: What kind of support does the platform provider offer? Some platform providers offer non-personal technical support e.g., via documentations or an online forum, whereas others run personal technical support teams. Some providers give additional business support, for example, in finding an IoT business strategy.

Operation mode: Who operates the platform? Some providers exclusively operate the platform on their own, whereas others also allow operation by third parties, for instance, on the customer's infrastructure or an external cloud service provider.

Revenue Model

Pricing model: What pricing models does the platform provider follow? Platform providers mostly distinguish between restricted developer projects (e.g., including

limited connected devices) and professional enterprise projects (e.g., large scale projects). Some platform providers do not charge the developer projects and solely price enterprise projects whereas others charge both kinds of projects. A few providers offer their platforms free of charge (e.g., KAA, Node Red, Paho).
Transaction based revenues: What are the transaction based revenues received by the platform provider? Platform providers make revenues on different kinds of transactions: e.g., per connected device, per API call, or per generated traffic. Other providers combine different sources or calculate the price per specific request.
Continuous revenues: Is the platform provider receiving continuous revenues? Some platform providers charge a fixed fee regardless or in addition to the actual transactions (hybrid pricing). Others follow a pure "pay as you grow" approach and charge no minimum fees.

4.2 Archetypes

The analysis identified nine clusters, each cluster covers between 15 to 32 IoT platforms of the 195 data samples. The extracted clusters have different centers along the dimensions and characteristics of the IoT platform business model taxonomy. As the taxonomy is mutually exclusive and collectively exhaustive, the results can be presented as percentages (table 3). For instance, in the sixth Cluster, 94% of the platforms offer application development as a core capability for developers, whereas 6% of the IoT platforms provide analytic capabilities for incoming device data. In the following, we present the characteristics that differentiate the nine clusters.

Cluster 1 - Embedded Device Operation Platform: Platforms in the first cluster provide capabilities to develop and operate embedded software on devices. As devices are equipped with more sensors, data processing power and increased connectivity, developers must manage the emerging complexity. Embedded device platforms support developers in overcoming the underlying device complexity, as the platforms ensure the integration of diverse hardware components and provide the functionality to develop add-on applications on the basis of the platform's core. RIOT OS, is a typical example for such an embedded device platform and represents an operating system (similar to Linux or Windows for the personal computer) that can be operated on any connected device. Other embedded device platforms in the first cluster are Amazon (FreeRots), Microsoft (Windows IoT) and Googles (Android Things).

Cluster 2 - Device Connectivity Enablement Platform: Platforms from the second cluster enable and manage the connectivity of devices via telecommunication technologies (e.g., sim cards, router and gateways). The Cisco Jasper platform, with 40 million connected devices is probably the largest provider of this cluster. The platform ensures that all devices used by developers are connected in a reliable and secure manner. It also provides the software environment for efficiently managing the connectivity to all devices that are equipped with a cisco global sim. The platform is addressed fully to large scale business customers and operates in several industries (e.g., smart security). Other representatives of the second cluster are Telekom (Cloud of Things), or Ericsson (Device Connection Platform).

Cluster 3 – Device Management Platform: The third cluster describes platform providers who ensure that the connected devices are working accurately on a device level by running patches, updates for software as well as changing embedded configurations. For example, the Helix Device Cloud operated by the technology provider Wind River (Intel subsidiary). The platform supports developers in device monitoring, bidirectional file transfer, remote access as well as in the detection and diagnosis of device problems mainly for devices included in Wind Rivers partner system (e.g., ARM, Intel). The Helix Device Cloud is focused on business customers who develop solutions in several industries (transportation, building automation, street lighting) and provides integration opportunities in existing ERP and CRM systems. Other well-known industrial platform providers in the third cluster are Sierra Wireless (AirVantage), Siemens (MindSphere) and Relayr.

Cluster 4 - Device Data Storage Platform: The fourth cluster consists of platform providers who deliver scalable cloud infrastructure for the storage of device data and operating codes to developers. The SenseIoT platform, launched in 2015 and a spinoff of Sense OS, offers a storage platform where any device can connect to, by using the SenseIoT API and store streamed device data. As storage platforms are designed in a universal manner, they address consumers as well as business customer and run in multiple industries (no restrictions). SenseIoT is a fully proprietary platform that is operated on a cloud level. SenseIoT, as it goes for the fourth cluster, is a pure "pay as you grow" provider. Other prominent providers offering cloud storage platforms include Sales Force (IoT Cloud) or Pentaho IoT.

Cluster 5 - Device Data Analytics Platform: The fifth cluster includes platforms that perform various device data analyses based on millions of incoming device data sets, from data clustering to machine learning up to predictive analysis. GroveStreams, a platform on which IoT analyses run, offers a range of tools for analyzing and visualizing IoT device data and operates a typical business model from this cluster. Similar to the fourth cluster (cloud storage platforms), Grovestreams allows any device to be connected to the platform, and allows developers to use it in multiple industries. Other representatives of the fifth cluster are Uptake, DataRPM or Cloudera.

Cluster 6 - Application Development Platform: The sixth cluster describes platform providers offering IoT application enablement through a software development kit to enable rapid development and deployment of IoT applications. These platforms offer a set of tools that incorporate language-independent support for programming-in-the-large tasks. The platform provider, Ayla Networks, operates the Ayla IoT platform that is a typical representative of the sixth cluster. The platform contains a variety of APIs that can be used to rapidly develop iOS and Android applications based on incoming device data. Ayla operates the platform and charges enterprises as well as developer projects per customer specific request. Other platforms belonging to the sixth cluster are DeviceHub, Arktik (Samsung) and Temboo.

Cluster 7 - Application Development, Market Place Platforms: The seventh cluster covers platforms that offer application development capabilities (similar to the sixth cluster) for developers. A typical business model from this cluster is operated by IFTTT. The platform is a free cloud service that allows application building on the basis of the if-this-then-that logic (IFTTT). For instance, if a user possesses an intelligent lighting system, it can be linked to the users' location. If the user leaves the house, the light switches itself off. And when the user gets back home, the lights turn on by themselves. IFTTTs support all devices if the platforms standards are used and is one of the few platform providers who offer, a market place functionality that allows developers to publish their if-this-then-that applications. Other examples of the seventh cluster are the more business focused IoT marketplaces of Libelium, PTC or Telus, where hardware components are also offered in addition to applications.

Table 3. Cross cluster analysis

Dimensions	Characteristics	Cluster 1	2	3	4	5	6	7	8	9
Number of platform providers per cluster		19	15	25	25	27	*32*	*22*	*15*	15
Core capabilities	Multiple capabilities	0%	0%	0%	0%	0%	0%	0%	13%	100%
	Application development	0%	0%	4%	0%	0%	94%	100%	87%	0%
	Analytics	0%	0%	8%	0%	100%	0%	0%	0%	0%
	Device data storage	0%	0%	0%	100%	0%	6%	0%	0%	0%
	Device management	0%	0%	88%	0%	0%	0%	0%	0%	0%
	Connectivity enablement	0%	100%	0%	0%	0%	0%	0%	0%	0%
	Embedded device operation	100%	0%	0%	0%	0%	0%	0%	0%	0%
Device support	Selected 3rd party devices	0%	0%	0%	8%	7%	0%	0%	0%	0%
	Exclusively provider's devices	0%	0%	4%	0%	0%	9%	0%	0%	0%
	Selected 3rd party devices and provider devices	5%	67%	76%	8%	19%	0%	0%	20%	13%
	Any device, if provider's standards are used	95%	33%	20%	84%	74%	91%	100%	80%	87%
Customer type	Consumer	0%	0%	0%	0%	0%	0%	9%	0%	0%
	Business	100%	100%	88%	20%	100%	94%	14%	0%	87%
	Business and consumer	0%	0%	12%	80%	0%	6%	77%	100%	13%
Industry focus	Single-industry platform	0%	0%	12%	4%	0%	9%	0%	13%	0%
	Cross-industry platform	100%	100%	88%	96%	100%	91%	100%	87%	100%
Platform integration	In enterprise systems	0%	87%	80%	76%	0%	0%	0%	0%	20%
	In web services	16%	0%	0%	8%	15%	97%	100%	33%	0%
	In multiple diverse systems	0%	0%	20%	16%	85%	0%	0%	0%	80%
	No integration opportunities	84%	13%	0%	0%	0%	3%	0%	67%	0%
Application sales channel	Marketplace functionality	0%	0%	0%	0%	0%	0%	100%	0%	13%
	External marketplace necessary	100%	100%	100%	100%	100%	100%	0%	100%	87%
Platform openness	Fully proprietary	0%	100%	88%	100%	15%	94%	86%	0%	80%
	Hardware proprietary	0%	0%	4%	0%	85%	0%	9%	0%	20%
	Software proprietary	37%	0%	4%	0%	0%	6%	5%	0%	0%
	Open source	63%	0%	4%	0%	0%	0%	0%	100%	0%
Operational level	Operated on device	100%	0%	0%	0%	0%	0%	0%	0%	0%
	Operated on cloud	0%	100%	12%	80%	93%	100%	95%	33%	100%
	Operated on device and cloud	0%	0%	88%	20%	7%	0%	5%	67%	0%
Core technology	Telecommunications	0%	93%	8%	12%	7%	9%	0%	0%	20%
	Sensors and microcontrollers	5%	0%	76%	4%	7%	3%	0%	0%	27%
	Cloud technologies	16%	0%	8%	72%	74%	13%	5%	0%	27%
	Other technologies	79%	7%	8%	12%	11%	75%	95%	100%	27%
Partner system	Open partner system	95%	20%	88%	96%	11%	97%	86%	0%	93%
	Proprietary partner system	5%	80%	4%	0%	89%	0%	9%	0%	7%
	No partner system	0%	0%	8%	4%	0%	3%	5%	100%	0%
Degree of support	Non-personal technical support	100%	0%	4%	16%	96%	78%	0%	93%	0%
	Personal technical support	0%	100%	96%	76%	0%	6%	9%	7%	0%
	Persona technical and business support	0%	0%	0%	8%	4%	16%	91%	0%	100%
Operation mode	Operated by platform provider	0%	100%	100%	100%	100%	97%	95%	13%	93%
	Operation by 3rd party possible	100%	0%	0%	0%	0%	3%	5%	87%	7%
Pricing model	Dev. projects free and enterprise projects priced	0%	0%	0%	0%	0%	100%	77%	0%	7%
	Dev. and enterprise projects priced	0%	100%	96%	100%	100%	0%	23%	7%	93%
	Free for use	100%	0%	4%	0%	0%	0%	0%	93%	0%
Transaction based revenues	Per connected device	0%	13%	4%	4%	4%	6%	5%	0%	0%
	Per API call	0%	0%	4%	16%	7%	3%	9%	0%	0%
	Traffic based	0%	0%	0%	60%	11%	6%	5%	0%	0%
	Combination of multiple sources	0%	20%	68%	8%	78%	0%	0%	0%	0%
	Per request	0%	67%	12%	12%	0%	72%	0%	0%	93%
	Free for use	100%	0%	12%	0%	0%	13%	91%	100%	7%
Continuous revenues	Time based (monthly/ yearly) minimum fees	0%	87%	96%	20%	4%	0%	9%	13%	100%
	Pure pay as you grow (no continues fees)	100%	13%	4%	80%	96%	100%	91%	87%	0%

Cluster 8: Application Development, Open Source Platforms: The eighth cluster also describes IoT application development platforms. However, in contrast to the sixth cluster, providers from this cluster typically offer an open source freeware IoT platform for developers. A well-known example and a typical platform of this cluster is Nimbits, launched in 2014. Nimbits supports developers in application building by providing an easy to use web server that connects things to each other. Based on the open source approach, Nimbits can be operated on any device (from a single-board computer to a cloud service) and hence, by third parties. Other freeware open source application development platforms in this cluster include KAA Project and DeviceHive.

Cluster 9 - Multi Capability Platforms: Platforms of the ninth cluster comprise multiple capabilities, such as an environment to rapidly build frontend applications (cluster 6), to manage devices (cluster 3) as well as to analyze incoming device data (cluster 5). A typical example of this all in one platform approach is ThingWorx that was acquired by PTC in 2013. ThingWorx supports all devices that use the provided code library and covers several businesses mainly in the industrial area. ThingWorx provides strong integration capabilities in existing enterprise systems (e.g., of SAP and web services as AWS). Furthermore, platforms from this cluster typically offer personal technical as well as business support, e.g., ThingWorx employs an "IoT university" to support developers in monetizing their IoT applications. Other platforms belonging to the ninth cluster are OceanConnect (Huawei), Bosch IoT Suite or Microsoft Azure IoT.

5 Discussion

5.1 Implications for Research and Practice

Our study is the first to focus on IoT platforms as an essential building block of IoT by using a business model lens and empirically deriving archetypes of an IoT platform business model. Thus, our taxonomy presents an overview of the phenomenon by combining the most important dimensions mentioned in existing research e.g., device support, application sales channel, or the degree of platform support [2, 21] with newly identified dimensions that are essential to structure and compare the business logics of IoT platforms (e.g., customer focus, core technology, and pricing model). By abstracting beyond the business model of individual platform providers, our taxonomy helps to identify different types of IoT business models based on their dimensions and characteristics. In addition, the taxonomy as well as the archetypes allow for a quick understanding of important differences, and assist researchers in anchoring their contributions more precisely within these types. The iterative taxonomy development process devised by [27] allows other researchers to extend the presented taxonomy when new IoT business models arise in the future. In short, our taxonomy and archetypes provide new insights into the design options of IoT platform business models and help systematize and synthesize previous fragmented research at the IoT.

Our archetypes provide findings regarding the issue of how different hardware (e.g., telco and device manufactures) and software firms (e.g., cloud providers) strategize in a platform environment [8]. As business model archetypes can conceptually be viewed as linkages between the business strategies of the platform providers and their operational strategy implementation [12], our results contribute to the emerging body of work regarding digital business strategies [29]. For instance, hardware manufacturers (cluster 2, 9) and telecom operators (cluster 3, 9) have been implementing a bottom up strategy by positioning their IoT platforms on top of their existing device offerings. By launching their platforms, those firms extend their existing offering (telco hardware, sensors, and microcontrollers) and add another opportunity for digital value creation while simultaneously shifting away from a hardware-centric business model. In contrast, software based companies have been following a top down approach by providing platforms for analytics, storage and application enablement or combining a bottom up (embedded device platform) as well as bottom down (multi capability platform) approach. For instance, Microsoft and Amazon have been providing an embedded device platform (cluster 1) as well as multi capability platforms (cluster 9) and can therefore provide the capabilities to operate, connect and build applications on top of existing devices, without manufacturing any. Third, there are startups that mainly operate IoT platforms within single product strategy. Their IoT platforms typically emerge with a system centric approach, often focusing on a top down strategy that incorporates capabilities to develop applications or managing devices based on code library's which is a facilitator for building up scalable, extensible, heterogeneous systems (e.g., Thing Worx) often supported by acquisition or funding of incumbent firms (e.g., PTC). However, as the interconnection of people and things progresses and numerous companies exploit the economic potentials, our archetypes provide a fruitful starting point of how different actors strategize in the IoT platform ecosystem.

Our research also provides important contributions for managerial practice. First, our database, taxonomy and archetypes offer managers a comprehensive overview of the fast moving IoT platform market. Furthermore, the taxonomy and the archetypes facilitate a quick understanding of the most common business model configurations of IoT platform providers. Second, our taxonomy serves as a concrete tool for business model innovation as it allows the necessary abstraction needed to identify unoccupied business models, as reflected by combinations of characteristics currently not offered by competing firms. We acknowledge that the taxonomy serves as a tool for simulating creativity but is not the key to reveal the perfect business model.

5.2 Limitations and Future Research

Our study is not free of limitations. First, [27] describe a taxonomy as never truly perfect, but in the best case useful. We argue that our developed taxonomy is useful in dissecting the business models of IoT platform providers. It also helps researchers and practitioners to identify differences within a business model configuration. Additionally, it is necessary to note that there is no perfect number of clusters and they are at best useful for a specific purpose. Second, the results of our research are limited to the business model configuration of the IoT platform providers at the time of data collection. As the IoT platform market was almost non-existent a few years ago and changes quickly, the database and the classification of individual providers will therefore become obsolete soon. However, the taxonomy and the archetypes of the IoT platform business models reflect the constituent elements of these instances and make them relevant for a longer period. Third, as we build our taxonomy within the empirical to conceptual cycles on the database, our study is inherently limited to the IoT platform providers contained in our sample and the respective information given at the provider's website. Though our database is quite large, following a consistent understanding of the research object and containing leading platform providers, not every platform provider has been listed in our dataset, nor can the reliability of the stated information be ensured. Fourth, given absence of a standard description of IoT platforms, the provider's information is often distributed across the entire website, using an inconsistent terminology and forcing the researchers to derive the complete information. However, as the study progressed, researchers became more experienced in handling this information and deriving complete datasets.

Given the current dynamic of the IoT field, a need for deeper and future-oriented investigations in the field is evident. Thus, the archetypes and corresponding characteristics can serve as starting points for studies on the transformation of the identified business model archetypes (e.g., extending core capabilities). In addition, when linking the identified business model archetypes to financial figures, they support the analyses of IoT platform providers with regard to aspects such as the probability of long-term success or the funding received, or the acquisition patterns of individual archetypes vis-à-vis others. Furthermore, the consideration of platform operating costs (not covered by the VISOR framework) in a future analysis will result in a more comprehensive understanding of the identified archetypes. However, based on the generality of our approach, following the aim to fit different types of IoT platforms, we had to compromise on the level of granularity. Future research can elaborate on precise taxonomies, by focusing on specific archetypes of IoT platform providers.

References

1. Gartner: Competitive Landscape of IoT Platform Vendors, https://www.gartner.com/doc/3730917/competitive-landscape-iot-platform-vendors (Accessed 27.10.2017)
2. Mineraud, J., Mazhelis, O., Su, X., Tarkoma, S.: A gap analysis of Internet-of-Things platforms. Computer Communications 89-90, 5–16 (2016)
3. Amazon: Miovision Case Study – Amazon IoT, https://aws.amazon.com/solutions/case-studies/miovision/ (Accessed 12.09.2018)
4. IoT Analytics: IoT Platform Comparison: How the 450 providers stack up, https://iot-analytics.com/iot-platform-comparison-how-providers-stack-up/ (Accessed 25.08.2018)
5. Wortmann, F., Flüchter, K.: Internet of Things. Bus Inf Syst Eng 57, 221–224 (2015)
6. Borgia, E.: The Internet of Things vision. Key features, applications and open issues. Computer Communications 54, 1–31 (2014)
7. Püschel, L., Schlott, H., Röglinger, M.: What's in a Smart Thing? Development of a Multi-layer Taxonomy. In: Proceedings of the 37th International Conference on Information Systems, pp. 1–19, Dublin (2016)
8. Reuver, M. de, Sørensen, C., Basole, R.C.: The digital platform: a research agenda. J Inf Technol 89, 1–12 (2017)
9. Osterwalder, A., Pigneur, Y., Clark, T.: Business model generation. John Wiley & Sons, Hoboken, New Jersey (2010)

10. Gregor, S.: The Nature of Theory in Information Systems. MIS Quarterly 30, 611–642 (2006)
11. Foss, N.J., Saebi, T.: Fifteen Years of Research on Business Model Innovation. Journal of Management 43, 200–227 (2016)
12. Zott, C., Amit, R., Massa, L.: The Business Model. Recent Developments and Future Research. Journal of Management 37, 1019–1042 (2011)
13. Fichman, R.G., Dos Santos, B.L., Zheng, Z.(E.): Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. MIS Quarterly 38, 329–353 (2014)
14. Al-Debei, M.M., Avison, D.: Developing a unified framework of the business model concept. Eur J Inf Syst 19, 359–376 (2010)
15. El Sawy, O.A., Pereira, F.: VISOR. A Unified Framework for Business Modeling in the Evolving Digital Space. Springer, Berlin, Heidelberg (2013)
16. Weill, P., Woerner, S.L.: Optimizing Your Digital Business Model. MIT Sloan Management Review 54, 71–78 (2013)
17. Remane, G., Nickerson, Robert, C., Hanelt, A., Tesch, J., Kolbe, Lutz, M.: A Taxonomy of Carsharing Business Models. In: Proceedings of the 37th International Conference on Information Systems, pp. 1–19, Dublin (2016)
18. Peters, C., Blohm, I., Leimeister, J.M.: Anatomy of Successful Business Models for Complex Services: Insights from the Telemedicine Field. Journal of Management Information Systems 32, 75–104 (2015)
19. Webster, J., Watson, R.T.: Analyzing the Past to prepare for the Future: Writing a Literature Review. MIS Quarterly 26, xiii–xxiii (2002)
20. Bandyopadhyay, S., Sengupta, M., Maiti, S., Dutta, S.: Role of Middleware for Internet of Things. International Journal of Computer Science & Engineering Survey 2, 94–105 (2011)
21. Díaz, M., Martín, C., Rubio, B.: State-of-the-art, challenges, and open issues in the integration of Internet of things and cloud computing. Journal of Network and Computer Applications 67, 99–117 (2016)
22. Emeakaroha, V.C., Cafferkey, N., Healy, P., Morrison, J.P.: A Cloud-Based IoT Data Gathering and Processing Platform. In: Proceedings of the 3rd International Conference on Future Internet of Things and Cloud, pp. 50–57, Rome (2015)
23. Lempert, S., Pflaum, A.: Towards a Reference Architecture for an Integration Platform for Diverse Smart Object Technologies. In: Proceedings of the 6th conference on Mobile and Ubiquitous Information Systems, pp. 53–66, Kaiserslautern (2011)
24. Nakhuva, B., Champaneria, T.: Study of Various Internet of Things Platforms. International Journal of Computer Science & Engineering Survey 6, 61–74 (2015)
25. Ray, P.P.: A survey of IoT cloud platforms. Future Computing and Informatics Journal 1, 35–46 (2016)
26. Sruthi, M., Kavitha, B. R.: A survey on IoT Platforms. International Journal of Scientific Research and Modern Education 1, 1-29 (2016)
27. Nickerson, R.C., Varshney, U., Muntermann, J.: A method for taxonomy development and its application in information systems. Eur J Inf Syst 22, 336–359 (2013)
28. Punj, G., Stewart, D.W.: Cluster Analysis in Marketing Research. Review and Suggestions for Application. Journal of Marketing Research 20, 134–148 (1983)
29. Bharadwaj, A., El Sawy, O., Pavlou, P., Venkatraman, N.: Digital Business Strategy. Toward a Next Generation of Insights. MIS Quarterly 37, 471–482 (2013)