Governing Platforms in the Internet of Things

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Abstract. The ambivalent paradigm Internet of Things (IoT) is gaining importance in today's industries. To manage the various devices built on different technologies and to apply complex event-triggered business rules to the data streams, platforms are necessary tools for almost all use cases. In the recent years, hundreds of vendors entered the intransparent IoT platform market, from small startups focusing on niches, to large enterprise vendors offering professional solutions. These platforms need tools to orchestrate the interactions between the different sides involved, so-called platform governance mechanisms. The purpose of this multiple case study analysis is to explore the platform governance mechanisms applied in IoT platforms. To achieve this goal, we explored the governance concepts of eight selected platforms in a multiple case study analysis, resulting in a description of the important aspects and differences regarding platform governance. Moreover, the four main trade-offs that platform vendors must be aware of are subsequently discussed. In a last step, an evaluation and discussion of the contribution to theory and practice is provided.

Keywords: Platform · Software ecosystems · Platform governance · Internet of Things · IoT platform · Openness · Control · Boundary resources

1 Introduction

In the uprising Internet of Things (IoT), the concept of platforms has received a significant amount of attention in the recent years, leading to a large number of solutions that emerged with the purpose: to interconnect smart objects. In 2015, Amazon presented their "AWS IoT Platform" and IBM opened the new Watson IoT headquarter in Munich. Analysts state that the market for IoT platforms will grow to $1.6 billion by 2021 [1], underlining the economic importance of IoT. Beyond the context of IoT, platforms have transformed the way products and services are being consumed and managed to attract and lock-in large numbers of participants [2]. Today's most influential businesses are those that bring together two or more groups of entities in a platform ecosystem [3]. Governing the platform ecosystem, i.e. managing the collaboration of the different actors, has emerged as a key challenge and has thus been well discussed in recent literature on IT platforms [e.g. 4, 5].

Various studies compared platform governance mechanisms mainly in business-to-consumer (B2C) markets, such as in the field of mobile applications [6, 7] or digital payment [8, 9]. Nevertheless, there is no systematic research available regarding the

adfa, p. 1, 2011.

governance structures of IoT platforms, even though their current high popularity and potential impact on the future Internet. Although, the IoT is a suitable empirical context to provide theoretical insights on some understudied issues in the literature on platforms. In the context of the IoT in general, the research and development challenges to create a smart world are enormous. Compared to other markets, the IoT is still in the very beginning when it comes to industry standards and established business models. Other unique characteristics of the IoT ecosystem are the particularly heterogenous actors (e.g. end-users, device manufacturers, complementors, etc.) an unusual large number of 'sides' (see chapter 4), and its proneness to platform-to-platform partnerships (see chapter 5). Those characteristics underline the specialty of this ecosystem and are of both theoretical and practical importance. Due to the fact that existing governance models do not always fit for this strongly diverse market, further research on the governance mechanisms in the IoT market is needed to determine the most important factors that most likely guarantee success to its provider.

The goal of this paper is to focus on this research gap by describing the ongoing development and to evaluate differences of the governance mechanisms in the emerging market of IoT platforms. Moreover, the strategic trade-offs that must be considered when those mechanisms are implemented will be analyzed. With the help of a multiple case study we identify exemplary causes and effects of those design decisions and help to underline the most important trade-offs of the governance implementations in the field of IoT platforms.

2 Background

This chapter provides the theoretical background for digital platforms, platform governance and platforms in the IoT.

2.1 Digital Platforms and Platform Governance

Platforms often serve as a core element of a larger business ecosystem which is built around it by the platform owner or vendor [10]. In this context, producers of complementary products and services are termed "complementors" [11], and all stakeholders interacting on the platform (the users or contributors) are commonly referred to as sides [12]. Thus, multi-sided platforms (MSPs) generate value by connecting two or more different parties who want to exchange products, services or information, in most cases complementors and customers [5].

The platform owner and the various sides involved form the platform ecosystem, which is typically characterized by indirect network effects: The attractiveness for its end-users is strongly correlated with the participation or the availability of offerings from the other side. Simply said, "the more users who adopt the platform, the more valuable the platform becomes to the owner and to the users" [10 p. 418]. A mall with no shops will not attract any customers, and a mall lacking customers will not attract any shops to open a subsidiary in it.

Organizations where platforms play a very important role are information technology-driven businesses. All major player from the IT industry like Microsoft, Apple, Google, Amazon, IBM, Intel, Cisco, ARM and many other firms, build hardware and software products around platforms. They provide services for computers, smartphones or consumer electronic devices that serve as platforms in the regarding industry, forming business landscapes led by the platform owner [3]. From this technology-oriented perspective, platforms can further be defined as “a set of stable components that supports variety and evolvability in a system by constraining the linkages among the other components” [13p. 3].

In contrary to the technical design, the functionalities for its users or the IT architecture of platforms, the goal of the platform governance is to orchestrate the communication between the different actors [14]. The interplay of the actors is orchestrated by the platform owner by means of platform governance, the “partitioning of decision-making authority between platform owners and […] developers, control mechanisms, and pricing and pie-sharing structures” [5]. Governance has been identified as what holds ecosystems together at its core, beside the technical features it offers [15]. The right governance strategy brings together the actors on a platform and aligns their incentives making the ecosystem flourish [4]. However, as shown in recent literature reviews as for example by Sun, Gregor and Keating [16], IS research does not yet provide conclusive insights on how software platform ecosystems can be successfully governed, leaving practitioners to trial and error when they set up and run platforms. In an earlier studies [17, 18], we have identified and applied platform governance concepts (Table 1) which we will use as starting point for the analysis of the multiple case study in this paper. Applying these concepts often results in tradeoffs that have to be solved for specific platforms. For example, by enabling openness, a platform owner gives up control and thus needs to balance openness with suitable control mechanisms [4]. The concepts are therefore a first try to structure platform governance concepts and are reflected in the discussion.

Table 1. Concepts of design and governance of platform ecosystems [based on 17]

Concept	Aspects		Literature
Roles	• Number and order of sides • Ownership	• Distribution of power • Relationship to stakeholders	[3, 19]
Pricing and Revenue Sharing	• Achieving network effects • Barriers to market entry	• Subsidizing of one or more sides	[20, 21]
Boundary Resources	• Software tools (API, SDK) • Documentation	• Data	[6, 22]
Openness	• Granting access to technology	• Giving up control over technology	[4, 9]
Control	• Informal control mechanisms	• Formal control mechanisms	[23, 24]
Technical Design	• Modularity • Interfaces	• Compatibility	[13, 25]
Competitive Strategy	• Competition • Co-opetition, collaboration	• Absorption & Envelopment • Public Relations	[26, 27]
Trust	• Relationship complementor – platform owner	• Relationship end-user – platform	[28, 29]

2.2 Platforms in the Internet of Things

In the IoT, communication takes place among devices of multiple types. Already twenty years ago, machines have been connected via dedicated leased lines to allow communication between the different apparatuses. Back then, every single project has been an individual customer-specific end-to-end project, lasting six to twelve months, resulting in enormous costs. Hence, there was a need for a common standard application platform which hides the heterogeneity of the devices by providing a common working environment to them [30]. The fast-growing IoT market has not yet brought up a champion in the fight for the IoT software platform standard, even though Schlautmann, Levy, Keeping and Pankert [31] stated that the service enabler (i.e. platform provider) will likely occupy 30 - 40% share of the total value in the IoT value chain.

In the recent years, a lot of companies from different industries claimed to offer an "IoT Platform". But a closer comparison of those products and the concepts behind them reveals vast differences. Newcomer in the field of IoT platforms are confused by those complex offerings and dissimilarities, especially when confronted with so called "platforms" that only include single elements of a mature IoT platform.

In this paper, we define IoT platforms based on their capabilities. So called IoT Application Enablement Platforms (AEP) consist of seven building blocks [10]:

- **Connectivity & Normalization:** Device interface services that provide the needed abstraction and normalization to ensure that all devices can be interacted with.
- **Device Management**: Ensuring that functions like activation, configuration, device monitoring, and provisioning software updates are able to be fulfilled and maintained cost effectively.
- **Database**: Providing the foundation for applications and analytics, should be scalable for big data.
- **Event Processing & Action Management**: Set of business rules and logics defining what processes are triggered in response to specified events.
- **Analytics**: Both to extract the value from the data and to keep the user from drowning in too much monotonous information.
- **Visualization**: Enabling the users to recognize patterns and observe trends from dashboards.
- **External Interfaces**: Helping to connect to enterprise or consumer applications and third party systems.

3 Methodology and Cases

To provide an overview of the existing governance structures in the IoT, we apply the platform governance framework (Table 1) to eight different IoT platforms. To yield a robust and generalizable understanding of the platform governance concepts in the IoT, we aimed for a heterogeneous sampling [32] along the dimensions size (big players such as IBM vs. startups such as Cumulocity), target group (industrial such as Carriots vs.consumer oriented such as Arrayend) and breadth (industry specific such as TankTaler vs. generic such as Cumulocity). It was conducted with data collected from

117 publically available sources: archival data from existing case studies and publications, press releases, online news and information available on the company websites. In four cases where further information was needed, semi-structured interviews with the regarding IoT companies were used as additional sources. The guidelines for the interviews not only contained questions related to the research questions, but also covered topics that were derived from the business model canvas in order to get a full understanding of the platforms business strategy [33].

For analyzing the data from the interviews, the statements about different characteristics of the IoT platforms were systematically structured according to the platform governance framework. During the iterative coding procedure, the framework has been updated several times to fit this unique market. Finally, the data for each of the selected platforms has been compared in a qualitative data analysis in order to identify the similarities and key differences between them [34].

The eight platforms in the multiple case study are as follows. **Arrayent Connect Platform** was founded in 2005 and is the platform with the longest history in the multiple case study. Its customers are consumer brands, mostly from the smart home area, which are implementing IoT solutions in their products and systems. **AWS IoT** is a further module for Amazon’s cloud services AWS (Amazon Web Services). Amazon takes a broad, industry-independent approach towards its users and heavily relies on the development expertise of its customers and their partners. **Carriots** is a proprietary cloud-based application enablement platform specially designed for the IoT. Since Carriots was one of the first movers in the IoT platform market, it holds expertise in almost all industry verticals. **CloudPlugs:** Even though the vendor markets its product as an industry-independent solution, almost half of their customers are settled in the telecommunications industry, using CloudPlugs for energy management, security or home automation solutions. **Cumulocity** is a platform that takes a horizontal approach in the market and focuses on enterprise customers that are looking for solutions to link and manage their connected machines or products. **TankTaler** is specialized in the Connected Car segment. The platform is the largest connected car platform in Europe and the only Hardware-specific IoT platform in the multiple case study. **ThingWorx** is a platform that has been merged by PTC with other solutions like Axeda or KepWare after their acquisition in the recent years. The IoT AEP is available either from cloud, on premise, federated or embedded, to fit the needs of any scenario in various industry segments. **Watson IoT Platform** is IBM’s comparably young solution in the IoT market. The platform owner is offering extensions for the platform in the Bluemix catalogue.

4 Results on Governance Mechanisms

The analysis of the governance mechanisms of IoT platforms will be presented according to the dimensions from Table 1.

Roles. The number of sides varies between all analyzed platforms. One side that all platforms have in common is the end-user or customer side, since this is the focus group of all vendors that generate revenues. To promote their product and bring it closer to the potential customers, all platforms take advantage of their extensive partner networks. Hence, all platforms must not only deal with the customers, but also with the intermediary sales partners on the demand side. For example, Arrayent needs to convince customers that the Arrayent IoT platform for smart homes creates value for them. At the same time Arrayent needs to engage with sales channel partners to market the platform.

On the supply side, the side that potentially offers further functionalities or services to the customers, the strategies of the platforms vary dramatically. At present, most of the analyzed platforms do not offer a marketplace that enables trade between those two sides. Nevertheless, the platforms all use modules or services from partners and integrate them in their own product. As a peculiarity for IoT platforms, we identified the devices and device partners as an additional platform side. Many platform vendors work together with device manufacturers in order to guarantee a smooth integration and connection of the users' devices, or even provide their own specialized devices. Accordingly, Arrayent partners with device manufacturers such as Osram and Whirlpool.

It is difficult to say if the IoT platforms in the multiple case study are real MSPs. According to Hagiu and Wright [35], the direct interaction between the multiple sides sets MSPs apart from other business models like resellers or fully vertically integrated firms. Fig. 1 depicts this theoretic description of the MSP model and compares it with the two platform models that we identified: A "standard" and an "advanced" IoT platform model.

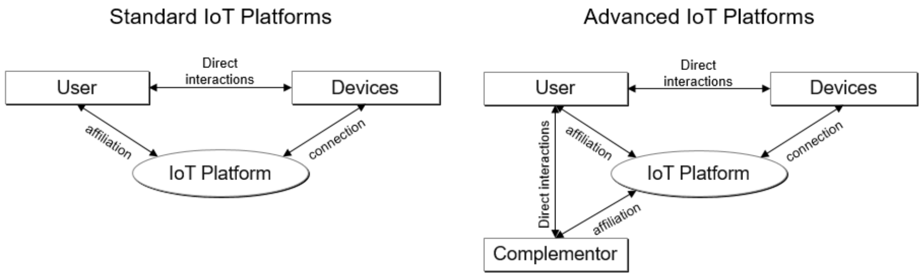

Fig. 1. The multi-sided platform model in theory and IoT practice [see also 35].

In this context, standard IoT platforms are those without marketplaces. Hence, complementors do not have access to the platform, and cannot offer further services for the platform user. The two sides of the standard IoT platforms are the users and the devices, but it is arguable if devices represent a side, since they are not humans or organizations and the interaction between the two sides needs to be evaluated completely different. Advanced IoT platforms involve marketplaces. Here, complementors can directly interact with users, and offer additional services to the demand side. We therefore categorized them as an MSP.

Regarding the order of sides, most platform vendors try to focus on the demand side first, before they open the platform for further developers. According to the mentioned lack of marketplaces on most IoT platforms, those platforms are still in the phase where they try to foster the user base, before opening their platform to the supply side.

Depending on the use case, the state of the ownership of the platform differs from case to case. For example, one platform vendor offers a “Private Edition” of his plaform where customers deploy the platform in their own data center, and use the so called “white-labeled” platform to offer their own solutions under their own brand. In such cases, the ownership is passed over to the client in a special licensing model. In other, more prevalent cases, the customers can sign up to use the platform with all its services, but the ownership stays with the platform vendor the whole time.

Boundary Resources. All of the analyzed application enablement platforms offer APIs and SDKs as technical boundary resources for the platform users to enable a fast and smooth integration of their devices. Additionally, most of the platforms also have starter kits available. Regarding the social boundary resources, we identified an online documentation for all IoT platforms in the multiple case study. Most documentations also include step-by-step tutorials, guides and code samples that help developers to connect their devices, gateways or existing systems to the platform. Some platforms also offer video tutorials or webcasts. All platforms also offer a support or help center that serves as first point of contact in case a customer needs assistance. Besides two of the analyzed platforms, all platforms offer forums to support the exchange of information among their users and to make use of their technical knowledge by letting them reply to other users’ questions.

Pricing and Revenue Sharing. Besides two of the analyzed platforms, all platforms offer a free trial of their platforms as part of their pricing model to achieve network effects and strengthen trust among their potential customers. For example, Cumulocity has introduced a 30 day trial access in 2016. Besides the free platform trials for the users, a subsidization of the sides could not be identified among the IoT platforms. The price for the end-users of the platforms depends on various factors, like the hosting option (cloud vs on-premises, if available), the number of devices or gateways that are connected, the amount of data traffic and data storage used, the application area, as well as subscriptions to further optional functionalities and applications. The individual and industry specific solutions that Cumulocity offers, illustrate that pricing is also specific to customers and their deals rather than standardized. The governance mechanism of revenue sharing is only applicable for platforms that either offer a white-labeling or that have a dedicated application marketplace. Here, third-party developers can sell their own applications for the platform and share the respective earnings with the platform owner that is responsible in setting up and maintaining the marketplace.

Openness. The openness of IoT platforms can be analyzed among two dimensions: The openness of the platform towards its users and towards third-party developers. The former highlights the platforms’ degree of openness by granting access to new users. All platforms except one allow the self-registration of new users, upon which they can directly start using the platform. Only one platform is more restrictive concerning the accessibility of the platform, since the vendor must be contacted first.

In terms of openness towards third-party developers, each platform takes a different approach. TankTaler is not open for external developers to sell platform extensions to the platform users. The Cumulocity platform enables the extension of the platforms' functionalities through applications uploaded by the users, but does not offer a marketplace. Other vendors such as Carriot and CloudPlugs offer dedicated application marketplaces for platform extensions or plan to do so.

Control. For an AEP without an application marketplace, the examination of the applied control mechanisms as proposed by Tiwana, Konsynski and Bush [36] is rather problematic: Since there is no input or output on the platform but the data streams from and towards to the devices, the control aspects applied on the platforms are not related to the traditional platform governance mechanisms. Among the IoT platforms that offer a marketplace, we identified formal control mechanisms such as output control, input and process control. For example Amazon's AWS platform implements customer ratings as output control.

Technical Design. All platforms that offer an application marketplace require a possibility to integrate additional applications. On the contrary, there are platforms available that allow the extension of its functionalities by external applications, but do not offer a dedicated marketplace for such. Besides the APIs, some platforms even offer more dedicated interface solutions in order to integrate the platform to existing systems or other ecosystems. For example, Cumulocity's solution can be integrated with other SaaS products via Zapier, a service that connects diverse SaaS web applications. On the identified application marketplaces, a variety of applications is available that supports the communication of the regarding IoT platform with external systems. All platforms in the multiple case study analysis offer a wide range of device connectivity. Next to the communication via Ethernet or Wi-Fi, other types like cellular, satellite or low power/short range communication (e.g. Bluetooth, ZigBee, etc.) are regularly supported. Common communication protocols among these platforms include HTTP and MQTT.

Competitive Strategy. To promote their IoT platforms and to publish news and updates, all of the analyzed vendors use an array of media channels for advertisement. Social media accounts, blogs, and e-mail newsletters are among the most common ways to raise the attention of potential clients. Furthermore, all listed platforms use specialized trade fairs to get in touch with their users and to sell their solutions to potential customers. All identified application marketplace vendors situated themselves in the conflict of absorption by offering their own extensions and applications on their marketplaces. For example, IBM offers various own applications such as analytics applications on the BlueMix platform. Those applications stand in competition to the third-party developers' offerings, and hence lead to direct competition between the platform owner and the complementors. On the other hand, absorption might be an important part of the monetization model of the platform vendors, as observed on other platforms (e.g. Android, see [37]). All platform owners underline the high importance of their strategic partnerships. Collaboration seems to be of much higher importance in the IoT platform market than fighting against the competitors.

Trust. All IoT platforms in the multiple case study analysis provide information regarding the security of their solutions (e.g. data security, security certifications or redundancy) separately. For most IoT platforms, reference cases of well-known customers are a good measure to strengthen trust among potential future users and to show-off expertise in the industry. For example, Cumulocity offers rich descriptions of existing use cases on their website. The free trial of the platform, as well as the available starter kits are further instruments that aim on reducing the perceived risk and strengthen the trust in the offered solutions. Enabling customer ratings and user reviews of the platform extensions are two instruments to strengthen trust, and have been identified on one platform marketplace.

The trust between the user and the complementor is also an important factor with a high influence on the platform's success. Anyhow, the platform owner can only support the sides to help build this trust at the most, therefore this issue has not been further examined in this study.

5 Discussion on Governance Trade-offs

In the previous chapter, the platform governance mechanisms identified in the multiple case study analysis have been explained in detail. In this chapter, the four main strategic trade-offs of IoT platform providers will be examined to get a better understanding of what impact the strategic decisions in the governance models have on the business model (Table 2). The relevant literature for each of the trade-offs is provided in the following discussion.

Table 2. Governance trade-offs in IoT platforms (Source: own analysis based on [17]).

Trade-off	Description
Vertical vs. horizontal market approach	Focus on use cases across different industries with less specialized functionality or on industry-specific use cases with highly specialized functionality.
Degree of openness	Degree to which the platform is open to third-party contributions in terms of technological openness as well as mechanisms applied to control the third parties.
Complexity of partner networks	Balance between keeping power within a complex network of partners and expanding the network through building trust in reliable business partners.
Compatibility to IoT standards	Approach to either embraces as many standards as possible or to focus on single or even a self-developed standard for IoT data and processes.

Vertical vs. horizontal market approach. All IoT platforms in the multiple case study can be categorized as either horizontal or vertical platform regarding their market approach. A vertical market is one in which all customers are in one particular industry [38]. Some IoT platforms specialized on particular IoT segments and market their services towards the regarding focus group. In contrast, a horizontal market is one in which all customers use a product with a common goal, regardless of what industry they are operating in [38]. In the case of IoT platforms, the common goal of the platform users is to connect their "things" with the IoT and to profit from the resulting enhanced opportunities. The most platforms in the multiple case study follow a horizontal market approach. They try to reach customers from different industry segments with various problems and requirements.

"While a lot of the action is happening at the vertical application level, the ultimate prize for many ambitious players in the space is to become the software platform upon which all vertical applications in the Internet of Things will be built" [39]. Hereby Turck [39] emphasizes the high aim for IoT platforms to not only address customers from one vertical, but several or all verticals to become the platform leader in the IoT. The eight platforms in the multiple case study directly compete against each other, since they are all open to mostly all IoT segments. Thus, the potential market is bigger, compared to the specialized, vertical IoT platforms. In the same time, competition for horizontal platforms is tougher due to the high number of competitors.

Degree of openness. The degree of openness towards the platform complementors is another strategic governance trade-off that IoT platforms must deal with. According to the preceding findings, we derived four stages of openness towards platform complementors:

1. **Closed**: In terms of openness towards third-party developers, closed platforms do not allow any kind of participation of complementors in the platform ecosystem.
2. **Participation possible**: In the second stage of this model, a participation for external developers is not precluded on the platforms, but an open marketplace is not (yet) available. Hence, the degree of openness is higher compared to the closed platforms, but not as high as on platforms that offer an application marketplace.
3. **Marketplace with tight control**: IoT platforms that include a marketplace on which third-party developers can offer additional services. The restrictions for platform complementors to offer and sell extensions can be categorized as tight control mechanisms on all examined IoT platforms.
4. **Marketplace with loose control**: An even higher stage of openness is imaginable in the model with more loose control mechanisms towards the platform complementors.

In IoT platforms, reasons to opt for openness differ from standard MSPs. Positive network effects that represent one main reason to open MSPs [4] are not as strong in the IoT market due to the market's high degree of fragmentation. Still, openness helps to co-create value within the partner network and trigger innovation. Since this strategic choice might change in the future, the degree of openness is not a fixed value, but rather an evolution in the lifecycle of IoT platforms.

Complexity of partner network. The IoT platform owner must deal with various stakeholders in his ecosystem. Platform providers form the core of the ecosystem and supply the critical building blocks for their partners [10]. Understanding the roles of business partners in the platform ecosystem is important for understanding the ecosystem development [12]. Among the various IoT platforms in the multiple case study analysis, we identified four distinct groups of partners in the platform ecosystem.

Platform partners can act as resellers. Resellers offer another company's platform to potential customers and get a share for the generated revenue. In some cases, the customers do not even notice that the platform is from another company, as some platform vendors offer so-called "white-labeling" solutions. In such cases, the platform will be rebranded and gets a new look and feel per the reseller's corporate identity. For some companies, this is the only sales channel for the platform, since there is no way for end-users to subscribe to the services of the platform directly.

The second group of potential partners in an IoT platform ecosystem are the **device integrators.** Those can either be device manufacturers, building devices especially for the platform or helping IoT platforms to connect their devices with the platform. Device integrators can also be third-party developers that program device-unique interfaces or platform extensions that make it easier for the platform users to connect their devices to the platform. In some cases, the platform owner directly offers such interfaces, in other cases such extensions are offered by external developers.

The third group of partners in the IoT platform partner ecosystem identified during the multiple case study analysis are the **platform complementors**. Those partners help the platform owner to build features as services for the platform users. Usually, those applications are then offered (for free or paid) on the platform's marketplace to the demand-side of the platform.

Finally, the **infrastructure providers** form the fourth group of partners that are relevant to an IoT platform vendor. In most cases, the data of IoT platforms is hosted on external servers of the platform vendors' business partners. Often other components of the IT infrastructure are not part of the core business of the platform vendor and are therefore sourced from partners.

Keeping this complicated partnering network stable comes with a difficult balance between keeping power (by holding the number of partners on a low level) and trust in reliable business partners and expanding the network. This is an important trade-off for every analyzed IoT platform.

Compatibility to IoT standards. It is a complex task to decide which of the competing technologies in the IoT fits best for a specific (business) goal and almost impossible to predict which standard will evolve and will be future-proof. Researchers even claimed that the lack of standardization and device heterogeneity is keeping the IoT from further growth [12]. Especially for horizontal platforms, which promise to be open for all possible IoT devices, keeping track of all available interfaces and connection types is a very hard to manage task. Those platforms need to offer a wide range of interfaces for their users and to apply to new standards in order to stay competitive and to satisfy their customers' needs. Possible strategies for platform owners to tackle this problem are described in the following.

One way to address the mentioned problem of volatile standards in the IoT is to integrate all technologies through interfaces and the support of all possible communication protocols. This would satisfy all platform users and lead to a superior competitive position of the platform in the market. Unfortunately, this is an almost impossible task, since new IoT-related standards and updates for existing technologies are published almost daily. Keeping track and supporting all of those different interfaces would require a massive amount of manpower and hence result in very high personal and maybe also licensing costs.

Another possible strategy for platform owners is to specialize on one or more IoT industries or use cases. Especially in the industrial IoT, the amount of used protocols is still very large, but the customer requirements are at least more similar.

Partnering with experts and specialized companies in the addressed IoT segment (e.g. SIs in the regarding industry) might also be a solution to outsource the problem of the volatile IoT standards. On the downside, this might lead to a high dependency on the business partners and experts.

In order to create more power to enforce the global adoption of specific already supported standards, IoT platforms already form or join alliances. The downside of this strategy is that unwanted knowledge transfer to competitors could happen due to the strong cooperation that is needed to reach the common goal.

The acquisition of specialized competitors is another strategy for platform owners that helps companies to acquire not only experts but also knowledge about specific IoT standards within a very short time. This strategy is intimately connected with high costs and therefore high risks.

Last but not least, the introduction of marketplaces for interfaces is another approach to outsource the problem of the changing IoT standards. Third-party contributors could develop fitting interfaces for the platform and would get a revenue share for each sold extension. Initial high setup costs for the marketplace and the support around it are a disadvantage of this strategy.

Contributions to theory and practice. The trade-offs we derive contribute to literature on platform governance and help practitioners in the IoT market. In literature, platform governance has been analyzed for various different platforms mainly in B2C markets such as mobile applications [6] or digital payment [8, 9]. However, B2C markets exhibit a simpler structure than the heterogeneous, multi-layered IoT market. It is therefore worthwhile to analyze how established mechanisms of platform governance can be applied and what trade-offs arise in their implementation.

We confirm trade-offs that are discussed in the B2C context and extend existing findings. First, we show that the trade-off between vertical and horizontal integration [35] is even more relevant in the IoT market than in standard MSPs as the IoT technology is highly complex extending to different layers from the devices to the applications. Second, we contribute to the ongoing discussion on the right degree of openness that platform owners need to identify [4, 9]. We not only confirm the relevance of the trade-off but also define specific degrees of openness for IoT platforms, referring to both the technology and provider level [9]. Future research could compare different IoT platforms that focus on a specific degree of openness and compare their success. Third, we discuss the value of partner networks in IoT markets that has rarely been analyzed for B2C markets [27]. The findings might prove useful for markets that are less complex but also prone to value cocreation on platforms through partnerships such as in the area of enterprise research systems [40]. Lastly, we open up the discussion on how to handle the issue of complex and heterogeneous standards in the IoT markets. As standards will dynamically evolve over the next years, future research could engage in longitudinal case studies on successful strategies to cope with standards.

Other issues for future research projects are, first, the comparison of the analyzed governance mechanisms in different markets and to focus on each of the four trade-offs to deepen the understanding of the governance challenges. This could be done with in-depth case studies that provide richer insights than a multiple case study does. Second, it would be worthwhile to reconsider the initial structure of governance mechanisms that we used as basis for our study. For example, Gulati, Puranam and Tushman [41] provide a framework that differentiates governance along the dimensions open vs. closed boundaries and high vs. low stratification. This would also be applicable to the IoT context and could help to generalize our findings. Third, our study does not specifically focus on governance of infrastructure providers and device manufacturers in IoT platforms as greater access to the cases would be necessary. This is a follow-up question for exploratory case studies which grant deeper access to the technological ecosystem of the IoT platform in focus. For practice we first show how established governance mechanisms such as boundary resources or control are applied in the IoT market. We thereby provide an overview on relevant decisions a platform owner has to make when establishing an IoT platform. Second, we illustrate main trade-offs that emerge when making these decisions. Our discussion on these trade-offs provides starting points for practitioners how to resolve them for their platform.

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