Tweeting in IIoT Ecosystems – Empirical Insights from Social Media Analytics about IIoT Platforms

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Abstract: The market for the Industrial Internet of Things (IIoT) platforms remains highly dynamic and is rapidly evolving regarding the growth of the platform-based ecosystems. However, digital platforms, used in the industrial business-to-business setting, differ significantly from the established platforms in the business-to-consumer domains and remain little researched. In this study, we apply a data-driven approach and conduct bottom-up and top-down content analysis, exploring social media data on the current state of IIoT platforms. For a top-down analysis, we draw on the theoretical concept of platform boundary resources. Specifically, we apply descriptive analytics and topic modeling on the Twitter data regarding the market-ready IIoT platforms Adamos, Cumulocity, Watson IoT, MindSphere, Leonardo, and ThingWorx, thus conducting an exploratory multiple case study. Our findings generate descriptive insights on the currently discussed topics in the area of IIoT platforms, contributing to the knowledge of the current state of digital platforms used in IIoT, highlighting the different focuses in ecosystem communication.

Keywords: Industrial IoT, IoT Platform, Platform Strategy, Boundary Resources, Twitter Analytics

1 Introduction

Industrial Internet of Things (IIoT) platforms build an interoperable and modularly extendable digital infrastructure to connect heterogeneous industrial assets, enterprise information systems, and other networked objects across the borders of a single company [Gu18, Bo18]. Industrial companies show a growing interest in IIoT platforms to capture value from the connected assets, either to make their production more efficient or to develop new business models. IIoT platforms, as a domain-specific type of digital platforms, foster generativity, and change the organization of traditional supply-chains. Thus, the platformization of manufacturing and mechanical engineering industries causes intense competition between incumbent enterprise software providers (e.g., Microsoft, SAP, Software AG, IBM) and industrial companies (e.g., Siemens, General Electric, Hitachi, Bosch, ABB). Both types of actors launch platforms and establish IIoT ecosystems, with the numbers of platform providers increasing year after year [PEM20, En19]. Building upon the competitive advantages from their traditional business fields,

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such companies have become platform owners, offering extensible codebases to the heterogeneous types of third-party complementors through regulated access routines [BW09, TKB10, PH20]. The complementors use the platform to contribute their unique capabilities and create platform-based IoT solutions. These complementary solutions rely on the network effects and increase the value of the platform and help the platform companies to manage the variety of use cases and to profit from the generativity [En19, BW09, Ga14, MP20]. Therefore, IIoT platforms also act as an innovation architecture for complementors, fitting the concept of digital innovation platforms, and transforming the innovation processes [CGY19, PVJ17]. Accordingly, the possibilities to achieve platform-based growth and the collaboration in platform-based ecosystems determine the present research objectives within the platform research [SP21, He20]. One of the relevant concepts to explain the process of enabling third-party innovation are the platform boundary resources (BR), which define the interfaces between the platform provider and the complementors [GH10, KGL18]. Prior research recognized multiple aspects of benefit in the provision of BR, which range from the control to the attractiveness [GH10, Ea15, PH20a]. The concept of BR is even recognized as an appropriate research lens to study advanced topics of digital platforms [DSB18].

Although previous research has already shown that digital platforms in business-to-consumer (B2C) differ in various aspects from platforms in the enterprise domains such as IIoT [MP20, PH19, Sc19], and highlighted the multitude of existing BR in the IIoT domain, the is not much research work studying the IIoT platforms, the inherent ecosystems and the used BR in this domain. Even though digital platforms represent popular research directions in information systems (IS) research [He20, DSB18], many existing papers study the transactional platforms and not the innovation platforms. Furthermore, most of the studies on innovation platforms set the software platforms in business-to-consumer (B2C) domains as the research object. Overall, the majority of the prior research articles do not entirely comply with the enterprise IIoT context that is for instance defined by the differences in the impact of network effects [Sc19], the maturity of the platforms or the criticality of the data processed on the platform. Additionally, compared to the mature B2C platform-mediated markets, the competition-driven dynamics in the market for IIoT platforms remains high, despite the ongoing consolidation [Tu18]. Accordingly, IIoT platforms represent an exciting research object in a rapidly changing enterprise environment, providing an under-researched application domain for digital platforms in a business-to-business (B2B) setting.

Against this background, our goal was to shed light on the current topics connected to IIoT platforms and the possible BR used to leverage ecosystem dynamics [TKB10, MP20]. Currently, only one IIoT ecosystem, based upon the Siemens MindSphere platform, has been closely analyzed, taking into account the BR offered and their potential to create attractiveness in the platform-based IIoT ecosystem [PH20a]. Hence, to bring the research platform dynamics in IIoT ecosystems forward, we use social media data from Twitter that represents the voices of the ecosystem participants (i. e., platform providers and platform users), including multiple platform providers. This data helps to identify current topics in IIoT the practitioners talk about concerning the IIoT platforms. We utilize the

BR as a theoretical framework [CGY19, My13] since the projection of these platform-complementor interfaces on the gathered Twitter data helps to appraise the relevance of the concepts related to platform dynamics in the extensive set of raw data.

RQ1: *What are currently discussed topics in the domain of IIoT?*

RQ2: *What can we learn about the use of boundary resources in IIoT?*

In particular, we use social media data from Twitter and derive empirical insights from six popular IIoT platforms: MindSphere (Siemens), Adamos and Cumulocity (Software AG), Leonardo (SAP), Watson IoT (IBM), and ThingWorx (PTC). To address RQ2, we utilize the concept of boundary resources (BR) as a research lens to reduce the data noise and improve the understanding of social media data, supporting the interpretative analysis of the extracted tweets [DSB18, De17]. Thus, by examining a large amount of Twitter data and applying BR as a research lens, and a theoretical framework, we complement the field with descriptive insights regarding BR-related strategies in IIoT ecosystems (e.g., which BR are present in corporate communication and how for instance influencers are used to promote specific IIoT topics) and therefore provide an additional perspective that distinguishes from current IS studies dealing with platform-based ecosystems [PEM20, En19, Sc19, Ma20].

2 Theoretical Background and Related Work

2.1 Digital Platforms and the Industrial Internet of Things

To get a comprehensive understanding, IIoT platforms should be considered from the technical and economic perspectives. Adding the ecosystems, the organizational perspective completes the understanding of the concept. From the technical perspective, IIoT platforms provide scalable middleware, offering interfaces for the connected smart devices, cyber-physical systems, and enterprise software systems. Thus, IIoT platforms provide interoperability and help to overcome the connectivity-related challenges, which are grounded in the variety of used and incompatible industrial protocols.

Usually, IIoT platforms are understood as scalable multi-layered architectures. Supplemented by the modularity, the functionality of the platform core is connected with the periphery to extend its capabilities, matching the requirements for the vast amount of the industrial use cases [Gu18, Bo18, PH14]. Due to the usual complexity of the industrial use cases, companies are required to collaborate on the IoT solutions [Ga14, Sc19]. Thus, offering a digital infrastructure, IIoT platforms bridge the distance between multiple solution providers. Acting as multi-sided markets, they leverage access to new industrial customers for the complementors [PEM20, He20].

However, despite connecting heterogenous market-sides, due to the variety of the use cases, IIoT platforms are not generating strong indirect network effects, which argues

against the application of the multi-sided platform definition, provided by Evans and Schmalensee [Sc19, EHS06]. Nevertheless, IIoT platforms usually foster the building of ecosystems consisting of complementary and industrial companies. The IIoT platform provider is usually an incumbent company with a background either in industry or enterprise software. It can use its power to design the ecosystem in a way, to fuel generativity created upon its platform [IL04, JCG18]. Intermediating the various stakeholder types and increasing their collaboration, IIoT platforms may also foster generativity and create unforeseen value [NWF19]. The value is achieved by interacting actors who depend on each other's activities and use the IoT platform to create IoT applications [Gu18, Ad06]. In order to maximize the value of the whole platform-based ecosystem, the platform provider should also pay attention to the balancing effects achieved through BR to attract and foster third-party innovation [PH20a]. Prior research already acknowledged that if the ecosystems are left ungoverned, the balance in the ecosystem can be disturbed by the dominance of certain complementors [SLS19]. That is why we explain the concept of BR in the next section.

2.2 Platform Boundary Resources in the Internet of Things

BR represent a concept to explain how the platform providing companies can stay in control of the external innovation, contributed by the ecosystem participants, simultaneously sourcing the complementors with the required tools and routines [GH13]. Conceptualized by Ghazawneh and Henfridsson, the BR concept consists of technical (TBR) and non-technical or social (SBR) platform resources. Application programming interfaces (APIs) or development tools represent exemplary forms of TBR, while the platform documentation, the license agreements, or the platform-related events represent exemplary forms of SBR.

Prior research recognized how BR are used by the ecosystem to create the complements [GH13]. Platform providers usually shape the BR design after their initial release, while the ecosystem can exercise power to affect the BR design during the platform cycle [PH20b]. Consequently, BR were conceptualized as a governance model for platform providers, which use alternating sourcing and restricting actions to tune the BR and change third-party innovation [GH13]. This view of BR comes primarily from the B2C perspective, where the aim is to guide the innovation focus in the desired direction with regard to the complements. Due to the criticality of the data to be processed on the IIoT platform, the control aspect of BR is a sensitive issue for platform users in IIoT and therefore, the sourcing aspect predominates in the industrial use of BR. Accordingly, different IIoT platform providers maintain various BR [PH19, Sc17] and use them, even more, to enable the complementors to contribute, instead of governing them, since the B2B complementors are much more sensitive to the dependencies caused by the platform provider's lock-in. Despite this fact, we do not know much about the perception of IIoT platforms by the enterprise complementors and especially about the effect of BR in IIoT on platform dynamics. The numerous BR types used in IIoT create even more complexity for the platform provider in an already highly competitive and fragmented market. The

quality of the offered BR is valued by the complementors and affects the complementor satisfaction with the IIoT platform and the ecosystem [PH20a, PH19, PH20b]. Lastly, BR can be used in competition, e.g., for closing the gaps of new market entrants in platform-mediated markets [KR20]. Taken together, BR can be considered as mechanisms from the platform provider perspective, which in turn, also need to be communicated via different corporate channels, such as Twitter, Facebook, GitHub, etc. The perception of this communication by the ecosystem participants plays a crucial role to position the platform, including the promotion of BR for active complementary involvement. However, the mentioned social media platforms allow public discussions about the IoT, so a platform provider usually has little control over this public communication. Thus, different aspects are discussed and communicated by different ecosystem participants. Thus, in order to gain a better understanding about recently discussed topics and the strategic use of BR in IIoT ecosystems, the present research focuses on the analysis of a social media channel as a pre-dominant communication platform, where aspects related to TBR and SBR are frequently discussed in public.

3 Research Method

3.1 Twitter Analytics and Applied Methods

Social media platforms provide a rich, steadily growing, and valuable source of user-generated content and interaction data. Since the data is highly diverse and interdisciplinary, and it can readily be extracted from online platforms, it is of particular interest for research purposes [St14, At12]. The social microblogging platform Twitter offers enormous amounts of publicly available data, which can be studied in different ways. Compared to the analysis of scientific literature, published tweets offer current data without much delay. The tweets may include key trends and moods of communities or offer insights on the corporate strategies if the official statements are being studied. In addition, Twitter offers various metrics, which can be included for analysis purposes as well [St14, At12, JKI17].

Hence, social media and especially Twitter can be used by practitioners to support decision making, and likewise, it can be used successfully by researchers to enable studies of mass data [De17]. Relevant techniques include descriptive analysis, content analysis, or network analysis, whereby the choice of the technique depends on the research goal. This paper presents the results of the descriptive metrics analysis and content analysis, incorporating bottom-up and top-down analysis techniques [St14, JKI17]. With descriptive analysis, Twitter data can be analyzed concerning the users, their tweets, and related metrics such as the numbers of followers, tweets, and retweets. Tweets can be grouped by their hashtags, as these are used to mark tweets on a specific topic. Moreover, hashtags also allow tweets to reach a wider audience since they can be found more easily using hashtags as search terms. Descriptive analyses are suitable for obtaining a basic knowledge of the tweet data in the initial phase of the investigation. After becoming

familiar with the basic properties of the tweets, a content analysis provides detailed results about specific topics. For this purpose, text categorization is a central element. With manual coding, one can choose between a bottom-up and a top-down approach. Top-down investigations are based on existing pre-defined categories, while bottom-up methods generate these categories during the analysis [De17]. The bottom-up approach was chosen due to the open research questions of this paper. This procedure should guarantee a holistic examination of the platforms, discussed on Twitter. Concerning the topics that are known in advance (i.e., BR), a top-down approach was used to investigate IIoT platforms specifically through a specific lens to get a focus on the desired objects of investigation. To master the challenges posed by large amounts of text data, we rely on a topic modeling approach using the Latent Dirichlet Allocation (LDA) technique [De17]. LDA is suitable for automated text categorization as a form of unsupervised machine learning. It is based on the theory that documents contain a random set of topics defined by a certain word combination. Overall, the use of LDA in the context of topic modeling was successfully used in IS research before, for instance, to analyze social media posts, job advertisements, mobile app stores, and many more [De17].

3.2 Case Selection

Since the market for IIoT platforms is still highly fragmented, currently no platform provider has yet been able to significantly assert its platform in the competition and capture a dominant position. This situation is indicated by the steadily increasing numbers of platform companies in the domains of IoT and IIoT [PT19]. The latest market report on IIoT platforms was conducted by ForresterWave in Q4 2019. It contains a benchmark to define the research object and select suitable platforms. Thus, instead of focusing on a single platform, our case study selection includes six IIoT platforms of leading platform providers [Ti12] summarized in Table 1.

Platform	***#hashtag***	***Platform characteristics***
Adamos (Software AG, DMG Mori, Dürr, Zeiss, ASM PT)	#adamos	Availability: since 2017 Background of the platform provider: IT and mechanical engineering Software AG 2018 revenue: 865.7 million EUR
Cumulocity (Software AG)	#cumulocity	Availability: since 2012 Background of the platform provider: IT Software AG 2018 revenue: 865.7 million EUR
Watson IoT (IBM)	#IBMWatson	Availability: since 2014 Background of the platform provider: IT Turnover IBM 2018: 79.6 billion USD
MindSphere (Siemens)	#MindSphere	Availability: since 2016 Background of the platform provider: Manufacture/ Production

Leonardo (SAP)	#SAPLeonardo	Siemens 2018 sales: 83 billion EUR Availability: since 2017 Background of the platform provider: IT SAP 2018 revenue: 25.96 billion EUR
ThingWorx (PTC)	#Thingworx	Availability: since 2014 Background of the platform provider: IT PTC 2018 sales: USD 1.24 billion USD

Tab. 1: Overview of the studies IIoT platforms

We have specifically focused on leading platforms as it can be assumed that, due to their gained maturity within the field, they have already established various successful mechanisms in the sense of BR, and created ecosystems, thus provide valuable insights about their platform scope, the discussed topics and the possibly used BR in this particular B2B segment. All the platforms match the definition of platforms as "the extensible codebase of a software-based system that provides core functionality shared by apps that interoperate with it, and the interfaces through which they interoperate" [6]. Furthermore, all of the six platforms offer openly accessible documentation for third-party complementors to develop applications and provide extensive documentation on the connectivity of assets. Therefore, the six platforms represent attempts to create IIoT ecosystems and lead open communication on Twitter, also being represented on Twitter by specific hashtags.

3.3 Data Collection and Preparation

For our study, a python-based scraping and analytics program was developed and launched through a command-line interface of Anaconda, an open-source distribution for Python and R. Utilizing the Twitter scraping script, we crawled the tweets using the hashtags (see column #hashtag in Table 1) within a defined range and saved the extracted tweets and their metadata as a .csv file. As an interim step, we built word clouds to perform our LDA analysis. Our implementation was based on several libraries, such as twitterscraper, matplotlib.pyplot, sklearn, wordcloud. Our source code can be retrieved online: https://github.com/Kypez/Twitter-Scrap-IoT-Platform.

The tweets collected and analyzed were posted between 01-01-2015 and 31-08-2019. There is no limit to the number of tweets. Instead, start and end dates were used as a time limit. To ensure a comparable and uniform analysis of the terms, we included only tweets posted in English. During data cleansing, we deleted stop words (as they have no relevance to the context and distort the frequencies), retweets (as they are considered as duplicates), and irrelevant tweets that were scrapped mistakenly by the script (e.g., "How many of these have you ever been to?" or "Write in the comments which costume you like best"). Furthermore, the hashtags of the individual platforms were removed as they are the most common terms of the tweets. Table 2 depicts some descriptive statistics on the collected and analyzed data:

Platform	*# of the collected tweets*	*# of tweets after data cleansing*
Adamos	415	201
Cumulocity	813	438
Watson IoT	136673	134677
MindSphere	12737	11416
Leonardo	8470	7330
ThingWorx	4922	3132
Sum	164030	157194

Tab. 2: Number of tweets after data collection and cleansing

4 Results

4.1 Descriptive Analysis

In order to get an overview of general information of the data, descriptive analyses are first carried out using the bottom-up method. The cleansed files from the previous section are used. It is noticeable that the hashtag #IBMWatson with 134,677 (85.3%) of a total of 157,869 tweets has a significantly higher number of tweets than the other hashtags, suggesting a possible distortion of the results in further data analysis. Therefore, the tweets about this platform are not considered in further analyses, apart from the LDA analysis. Without the consideration of IBM Watson, it is evident that the MindSphere, the Leonardo, and the ThingWorx platforms were responsible for the generation of the most tweets. The MindSphere community on Twitter is responsible for 49% of the examined tweets. Almost one third (32%) of all tweets were published on the SAP Leonardo platform. In total, the ThingWorx, the Cumulocity IoT, and the Adamos platforms only share 6% of the remaining tweets. The second descriptive evaluation tackles the frequency of tweets to show how used hashtags are distributed over the years, as shown in Table 3. Most of the tweets were published in 2018, whereas a continuous increase of tweets can be observed from 2015 to 2018. Since the study was conducted in August 2019, the figure from that year cannot be compared in absolute terms with the figures of the other years. If the platforms are examined individually, a similar distribution for Cumulocity IoT and MindSphere becomes evident. Adamos and ThingWorx show the most tweets for 2017, and later the numbers drop similarly as for the other platforms. The Leonardo platform has an equivalently high number of tweets in 2017 and 2018. However, one can expect a smaller number of tweets for 2019. It is also revealed that there are no tweets for Adamos and Leonardo for the years 2015 and 2016.

Platform	*2015*	*2016*	*2017*	*2018*	*2019*
Adamos	0	0	94	71	36
Cumulocity	9	15	76	232	106
MindSphere	10	617	3110	5299	2380
Leonardo	0	0	3094	3264	972

ThingWorx	550	769	862	588	363
Sum	569	1401	7236	9454	3857

Tab. 3: Frequency distribution of tweets from January 2015 to August 2019

If we look at the frequency of tweets over time, it becomes clear that the annual number will increase from 2015 to 2018. In this four-year period, the annual number of all tweets examined rises from 569 to 10010, i.e., the frequency increases by a factor of 17.59. Although on average, the number of Tweets of each platform increases over the years, the results suggest that the tweets of the MindSphere platform show the highest growth. By contrast, there are no tweets for the SAP Leonardo platform for the years 2015 and 2016. A high number of tweets was posted one year later, with only a slight increase in 2018, whereby a drop can be predicted for Leonardo in 2019. In total, no complete data was available for the year 2019, and the period under investigation contains only about 2/3 (3857) of the year. An extrapolated development for all platforms indicates a drop in the tweet intensity resulting in a total predicted number of 5785 tweets that would be posted in 2019. This figure is significantly lower than in the previous year's figure. This decline is more strongly reflected in the Leonardo, MindSphere, and Cumulocity IoT platforms. Extrapolated, the frequency of tweets on Adamos and ThingWorx would be only slightly below the previous year's figure.

The next descriptive analysis deals with the user profiles, investigating which types of user accounts publish the largest number of tweets. Table 4 provides a summarized overview.

Platform	***Number of private accounts***	***Number of corporate accounts***	***Account type with the most tweets***
Adamos	1	9	Corporate
Cumulocity	4	6	Private
MindSphere	7	3	Private
Leonardo	8	2	Private
ThingWorx	5	5	Corporate

Tab. 4: Number of private accounts and corporate accounts with the most tweets

The results provide some insights into the activity within the ecosystems. A sufficient number of tweets posted by private accounts indicate the existence of an organic ecosystem. On the opposite, a majority of tweets posted by corporate accounts indicate a coordinated strategy for the ecosystem development, orchestrated by the platform provider. Among the top 10 users of the examined IIoT ecosystems, we observe an equal share of 25 private accounts and 25 corporate accounts. For #adamos and #Thingworx, the users with the most tweets are corporate ones. Private accounts show the highest activity for the other four ecosystems.

In the case of the Adamos, there is only one private account among the top 10. For Cumulocity IoT, the list also includes more corporate accounts than private ones. With the platform ThingWorx, the number of private users and corporate accounts is equal.

Focusing on the top 10 users, we can see that with regard to SAP Leonardo, mainly private users publish a more significant number of tweets for the platform. There is only one official SAP account in the top 10 (i.e., "SAP Intelligent RPA"), ranking 8th position with 73 tweets in total. First, this indicates that the company is active on Twitter from 2017 onwards (cf. Table 3). Second, it indicates that a vibrant ecosystem of platform users was created. It remains striking that the popularity of the platform without the development of the tweet frequencies, especially among private users, suddenly reaches a very high level, suggesting that SAP actively promoted the platform when it was launched. In contrast, the Adamos platform is mainly represented by the corporate accounts of the Adamos shareholders (e.g., Software AG, DMG, Duerr, and Carl Zeiss). The small number of 201 tweets for Adamos suggests that the platform is comparatively unknown and, therefore, only a few private users participate in the Twitter discussion regarding Adamos.

4.2 Content Analysis

The following tweet evaluations are part of the content analysis. In the run-up to the identification of topics, we study common words using word clouds to identify ten most frequent terms. This is followed by the evaluation of the terms using the LDA approach. For this purpose, the number of topics and terms must be determined. An initial test with five topics and ten terms revealed that this number of topics and terms is too high for platforms with few tweets, and therefore, the topics only differed by a few single terms. After adjustments, we decided to set three topics with ten or twelve terms each or four topics with twelve terms each, depending on the total number of tweets and the result of the test evaluation. Overall, the application of the LDA method shows that, in many cases, the tweets use specific terms to highlight a certain topic, as seen in Table 5, although not all terms are necessarily required to access a certain topic.

The identified topics, which are reflected by their respective terms, reveal a heterogeneous picture. For example, some topics primarily refer to specific domain orientations (e.g., IBM Watson topic 3 healthcare), while others refer to technological directions (e.g., Leonardo topic 1 data analytics). Moreover, the identified topics within a platform cannot be clearly distinguished from one another. However, between the various platforms, relatively clear topics can be identified.

The Adamos platform, for example, deals with hackathons in two out of three topics and mentions partners of the platform particularly often. In two of three topics of the platform Cumulocity IoT, the term "softwareaginfluencer" is included. MindSphere deals with terms such as "industrial", "manufacturing" or "industry40" in several topics. The SAP Leonardo topics contain the term "sapphirenow" in two of three cases. The tweets of the ThingWorx platform contain the term "Liveworx" in all three topics. One of the topics deals with terms such as "manufacturing" and "connectivity", another with "training and "certification". The evaluation indicates that especially tweets with the hashtag #IBMWatson refer less to the IIoT area than tweets from other platforms. Several terms in the word cloud refer to personality analyses (e.g., "personality similar", "personality

insight") and health care (e.g., "treat patient", "doctors treat", "disease doctors", "patient care"). At least two topics contain the terms "ibm", "cognitive", "ai" and "new". It is noticeable that no topic contains terms related to IIoT, but instead analogous to the word cloud, terms such as "personality", "cancer", "health", "healthcare" and "care". It seems that the tweets on IBM Watson do not address specifically the industrial field of application of the platform, which is an interesting insight for practitioners to categorize the platform.

Platform	*Most probable terms*	*Topic*
Adamos	new, iiot, machine, platform, duerrag, zeiss_group, softwareag, iot engineering, partners	Partnership
	softwareag, iiot, iot, platform, hackathon, duerrag, zeiss_group digital, team, adamosgroup	Shareholders
	hackathon, digitization, strongertogether, teams, industrial, iot, challenges, motto, crosscompany, interdisciplinary	Teamwork
Cumulocity	iot, softwareag, wire, business, build, solutions, test, team, solution, fast	Development
	iot, softwareag, free, iiot, 30, softwareaginfluencer, days, platform, trial, solution	Sales Promotion
	ot, softwareag, platform, iiot, global, softwareaginfluencer, partnership, innovation, leading	Influencing
Watson IoT	ibm, cognitive, iot, help, ai, new, bluemix, services, using, apps	Portfolio
	ibm, ai, cognitive, new, bigdata, personality, analytics, machinelearning, similar, learning	Analytics
	ai, ibm, data, cancer, like, health, world, help, healthcare, care	Healthcare
MindSphere	siemens, iot, digitalization, business, iiot, atos, hm18, siemensindustry, use, new, digital, digitaltransformation	Digitilization
	siemens, iot, data, industrial, iiot, industry40, digital, new, lounge, partner, cloud, atos	Industry
	siemens, iot, iiot, platform, manufacturing, cloud, ai, aws, solutions, just, open, apps	Openness
	iot, iiot, siemens, bigdata, atos, industry40, siemensindustry, cyber security, digital, analytics, sps live, siemensusa	Partner
Leonardo	iiot, blockchain, machinelearning, ai, sap, bigdata, cloud, analytics, s4hana, industry40, innovation, internetofthings	Data Analytics
	sap, iot, digital, new business, intelligent, blog, erp, sapphirenow, post, innovation, iiot	Digitilization
	sap, iot, learning, sapphirenow, machine, learn, sapteched, help, join, data, ai, business	Portfolio

ThingWorx	Ptc, iot, iiot, tips, liveworx, platform, digitaltransformation, manufacturing, connectivity, free	Digitilization
	iot, ptc, liveworx, learn, new, data, platform, partner, solution, analytics	Unspecified
	iot, ptc, certification, ar, blog, training, things, liveworx, using, internet	Education

Tab. 5: Identified topics and related terms of the LDA analysis

In addition to the above-described bottom-up procedure of content, we also applied a top-down approach, which specifically investigates to what extent TBR and SBR are mentioned in the tweets. For this purpose, two BR are selected for each category and their frequency in the tweets is examined. As TBR the terms "API" and "SDK" are examined, as SBR the terms "Hackathon" and "Documentation". We used the same preparation steps as for the LDA analysis, except for the creation of a "string". Since the term "API" is often part of other words, we defined it as an independent word in the analysis. The results of the top-down analysis of the selected BR show that the SBR "Hackathon" with 124 citations is the most frequently discussed BR. Hackathons are the most frequently mentioned BR for Adamos, Cumulocity IoT, and MindSphere. For Leonardo and ThingWorx APIs are mentioned most often. The results of the top-down analysis are presented in Table 6.

Platform	*API*	*SDK*	*Hackathon*	*Documentation*	*Sum*
Adamos	0	0	45	0	45
Cumulocity	1	1	12	0	14
MindSphere	0	0	55	2	57
Leonardo	22	6	10	0	38
ThingWorx	10	6	2	0	18
Sum	33	13	124	2	172

Tab. 6: Frequencies of mentions of selected BR in the analyzed tweets

5 Discussion

5.1 Descriptive Analysis

The first descriptive analysis examines the tweet frequencies and how the tweets are distributed over different platforms. The study shows that IIoT platforms have different levels of awareness among the Twitter community and potential customers. The data indicate that MindSphere is more popular than the other platforms, and the last three platforms are relatively unknown. There is no clear relationship to the platform providers' financial data, but the tweet frequencies go in line with the financial power of the respective platform providers. Siemens has the highest total revenue of €83 billion for the year 2018 of all the platforms examined, which is significantly higher than the revenue of

a company like Software AG, which is only €865.7 million. The observed activity on Twitter indicates that the MindSphere platform attracts more platform users than financially smaller platforms (i.e., Adamos). The only surprise is the massive over-presence to IBM Watson IoT on Twitter, with IBM's revenue for 2018 being similar to that of Siemens. However, the observed frequencies do not allow any conclusions about the platform's actual penetration rate.

The declining tweet numbers indicate the overall fading of the IIoT hype. This initially surprising result goes hand in hand with the findings of the yearly Gartner hype cycle for emerging technologies. The hype cycle for 2018 shows that IoT platforms are then in reaching the peak of exaggerated expectations, i.e., expectations for IoT platforms are saturated, and attention is slightly decreasing. The reasons for the significant decrease in tweets about SAP Leonardo should be further investigated in order to derive possible reasons for activity stagnation, as observed in this single case. Currently, based upon the figures for SAP, a general recommendation for practitioners regarding the decrease in the ecosystem activity is to **actively promote the awareness of the platform** and the ecosystem activities in order not to fall behind the competition.

Furthermore, we investigated when the platforms were available and when tweets were posted for the platforms. It becomes clear that for most platforms, the first tweets were posted in the year of release or one year after. In terms of the development of frequencies, SAP Leonardo is an exception compared to the other platforms. While most platforms show a gradually increasing trend, the number of tweets for SAP Leonardo in the first year is above 3,000 tweets, which will hardly increase next year.

The analysis of the account types suggests that platforms with few tweets are more likely to be represented by involved corporates than by private accounts. On closer inspection of the users, four names, in particular, stand out: Ywan van Loon, Dean Anthony Gratton, and Sarah-Jayne Gratton. Further exploration revealed that these users are influencers in the area of IoT. Own statements on the website of Sarah-Jayne Gratton, according to her, she is a member of the Siemens Influencer Community. Her account is also among the top 10 of MindSphere on Twitter. In the typology of Twitter users, according to Tinati et al., influencers can play different roles, such as idea starters, amplifiers, or curators of certain contents [Ti12]. These findings indicate that **platform providers are deliberately influencing the IIoT topics and use Twitter strategically to leverage the ecosystem activity and awareness**. The influencers' function is to facilitate communication of products and present specific opinions since influencers appear credible with regard to statements about the products [Ti12]. PTC goes even further, installing for ThingWorx multiple accounts, while among the first two official accounts of PTC, the account "PTC University" takes the first place. The account was created to address academic user types with targeted information and educational opportunities and indicates **strategic efforts to attract a specific market-side**.

5.2 Bottom-Up Analysis

The LDA technique is intended to provide information on which topics are discussed in connection with the platforms. Thus, the ten most frequently used terms were examined. The term “iot” and the company name of the respective platform are the most often used terms. For Adamos, Cumulocity IoT, MindSphere, and ThingWorx, the term "iiot" is also frequently used, among the top five ranks for these platforms. These results validate that the **IoT and its industrial application are in the focus** of the Twitter-based strategies of four platforms out of six. We clearly see that the most frequent terms in the tweets of the SAP and IBM platforms have no explicit mention of the IIoT range. The top 10 terms describe general, current topics of IoT, such as "ai", "machinelearning", "blockchain", "cloud" or "bigdata". Thus, IBM obviously advertises domain-agnostic intelligent technologies. Additionally, this leads to the assumption that **SAP and IBM, in comparison to the other platforms, rather have IoT or other business processes in their scope, instead of the industrial instantiation of the platform**.

Regarding Adamos, the most frequently mentioned terms are also reflected in those used for topic formation. One of the three topics suggests that new partners of the IIoT platform are announced in the tweets, which are mostly from the mechanical engineering sector. The other two topics both contain the term "hackathon". This suggests that this specific SBR has a high value for the platform and therefore appears frequently in the Twitter discussion. One identified topic includes more general terms such as "team", while another topic provides more insight. We assume that this message focuses strongly on the interdisciplinarity of cross-company teams and emphasizes that companies are stronger when they join forces. These findings suggest that **small platforms, in particular, such as Adamos, form alliances with other companies and rely on less standardized relationships** with the complementors. At the same time, these partnerships are interdisciplinary. It is likely that joint events are used by Adamos to meet new potential partners or to deepen the relationship with existing partners. Certain tweets also indicate the cooperation between Adamos and Cumulocity IoT.

5.3 Top-Down Analysis

The top-down approach enables the specific analysis of the BR topic. As a clear result, it was identified that especially the technical BR "API" and "SDK" are hardly mentioned in the tweets. This contrasts with the scientific literature, which mainly focuses on TBR. The SBR "Documentation" is also a very rarely mentioned topic on Twitter. These are surprising results since the APIs, and the documentation are mentioned as the most important resources from the complementors’ perspective [PH20a, PH20b]. The most frequently mentioned BR is "Hackathon" with 124 mentions of 172. Judging the frequency solely, the tweets suggest that hackathons clearly represent an important BR in the IIoT domain. This result is consistent with the results of the conducted LDA analysis. Especially for Adamos, hackathons seem to build an essential part of the platform strategy, fueled by this type of SBR. For other platforms, social events such as trade fairs and

conferences are also important for communication on Twitter. This insight offers potential for further research on corporate events and their influence on driving the platform dynamics. For the MindSphere-related tweets, we discovered some cloud-related terms, such as "cloud" and "aws", indicating at least some mentioning of the TBR (e.g., “How Siemens launched #MindSphere the open #IoT platform on AWS in just 8 weeks #unlockthepotential”). We assume this to be a **controlled strategy to advertise the platform’s developer orientation**. Hence, advertising an effortless integration for IoT developers, this concrete example shows how platform companies can communicate certain platform features on Twitter. Surprisingly, SAP was the only platform provider to communicate the term "cloud" for Leonardo. From this, it can be assumed that IIoT platforms facilitate the provision of TBR without an appropriate advertisement, despite their relevance to implement IoT use cases. The results reveal a connection between SBR and the establishment of strategic partnerships. It can be seen that with regard to IIoT platforms, **strategic partners are more in focus than application developers**. Further, the data confirms that Twitter is largely used to communicate resourcing platform strategies. However, it is also apparent that some BR serve both resourcing and securing. An example of this is the controlled publishing of platform-related information. Hence, these measures can be used by the platform owner in a targeted manner to control the capabilities of complementors via shared information. This can also be considered as securing actions. The use of Twitter, in general, can be rather defined as a resourcing strategy since tweets serve as a communication medium. Targeted content can be published, either through official channels or even be promoted by influencers. These, in turn, can be strategically positioned to foster contact with users.

5.4 Limitations and Outlook

To sum up, the paper conducts exploratory research of different IIoT ecosystems, examining Twitter as a rich data source. Applying a data-driven approach to the domain-specific platform research, we extract knowledge on the BR-related strategies in IIoT. We could also identify different platform scopes (e.g., blockchain for SAP or academics for ThingWorx). After applying the BR concept as a research lens, we see that TBR-related activities are rarely communicated on Twitter compared to the SBR. A complementary analysis of the IIoT TBR discussions on portals such as GitHub could also provide valuable insights about the design and the impact of TBR on the developers’ choice of IIoT platforms. It would also help get a more complete picture of the current challenges and problems in the use of BR in IIoT. Across platforms, the slightly decreasing number of IoT-related tweets is also interesting, and exploring the exact reasons for this offers exciting directions for future research. Following the analysis of the Twitter account types, a social network analysis of entire IIoT ecosystems and their connections with each other should be conducted in the future. We believe that the use of influencers and controlled communication by IIoT platform companies may be used to support the perceived rule adequacy within the respective ecosystem [7]. However, the influence of Twitter on this construct has not yet been investigated and offers another research opportunity. In addition, the study reveals some evidence on the current alliancing strategy focus [Ma20]

across the relevant IIoT ecosystems, despite its lower degree of scaling [7]. Due to page limitations, further data analysis techniques such as sentiment analysis could not be applied and represent a limitation of the present study. Tweets in IIoT ecosystems can be converted into positive, neutral, or negative groups and sorted according to their emotion-based allocations, thus enabling opinion mining [Th10]. Furthermore, the derived findings are interpretative and, therefore, of limited validity. Our current results stay at a descriptive level in this course and should be regarded with caution as they do not allow any causal conclusions. Consequently, a future validation by investigations with additional data sources is necessary to bring forward the research on platform dynamics in the enterprise IIoT context.

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