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Event-Driven Business Process Management enhancing IoT – a Systematic Literature Review and Development of Research Agendas

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Abstract. The integration of high frequency event data from Internet of Things (IoT) devices into existing complex and mature Business Process Management Systems (BPMS) constitutes a major hurdle for many organizations. Event-Driven Business Process Management (EDBPM) is a paradigm to tackle this hurdle and to lever the enhancement of industrial IoT applications. Existing literature regarding EDBPM and its underlying technologies and methods form a heterogenous set of approaches, frameworks and applications that lacks standardization and maturity. In this context, the literature review of the work at hand conducts a survey about EDBPM focusing on its capabilities to be a lever for the scale of IoT applications. First, we perform an extensive literature research on EDBPM and related topics. Second, a literature analysis and synthesis are presented by summarizing and clustering the discovered publications. Furthermore, a future research agenda is formulated that addresses the main existing research gaps and challenges of EDBPM.

Keywords: Event-Driven Business Process Management, Internet of Things, Complex Event Processing, Event-Driven Architecture.

1 Introduction

The widespread of the Internet of Things (IoT) led to a great variety of different applications in almost each sector of private and professional life [1]. One major focus of applications in the last decade lay on the smart home, smart grid, and smart healthcare market [2]. But especially industrial companies are progressively using IoT technology for efficient management and controlling of industrial processes and assets to increase productivity and reduce operational costs [3]. However, most companies already have matured and sophisticated process landscapes and IT system architectures that often prevent an easy implementation of IoT technologies [4]. One inherent cause for this situation is the need for enterprise IT systems to adapt to the flexible and near real-time continuous data flow that is generated by IoT devices. The high availability of IoT-related business operations data leads to a high scale transmission of event data that needs to be received, correlated, and processed before exploiting it for business processes [5]. A business process is a collection of events, activities, and decisions that involves several (human) resources [6]. To support processes at an operational level, a Business Process Management System (BPMS) can be used. A BPMS deals, a.o., with the enactment of models that define the interplay between environmental circumstances and activities to be executed. The emergence of IoT is a big challenge for traditional BPMS that are responsible for managing the increasing number of data coming from heterogenous sources. Event-Driven Business Process Management (EDBPM) now constitutes an interesting approach that combines two different disciplines, namely Complex Event Processing (CEP) and Business Process Management (BPM) to tackle the challenges of high-volume event integration. This combination leads to a system that can deal with event-driven behavior and can process real-time data from distributed sources. Having implemented EDBPM into the enterprise IT landscape, a more effective and efficient integration and usage of IoT devices is possible [7].

This paper aims at *a)* describing the importance of EDBPM for the proliferation of IoT applications, *b)* synthesizing and interpreting the current state of EDBPM research and *c)* proposing a possible research agenda. According to Hart [8], through a structured literature review, the current state of research can be systematically reproduced, summarized, and interpreted. In this way, research gaps can be uncovered and new incentives for future research can be created. Especially by synthesizing and interpreting the overall picture, a further gain in knowledge is possible, which is not achievable by only studying a single publication [9]. Therefore, the authors hope to provide a structured entry point, overview, and motivation for further research on EDBPM that paves the way for a larger scale of IoT technologies in process-oriented businesses. The paper is organized as follows. Section 2 provides an overview about the theoretical foundations of EDBPM and related work. In section 3, the applied research methodology is presented. Section 4 presents the results of the literature review by analyzing and synthesizing the considered publications. Section 5 proposes a future research agenda based on the main research gaps, concluding with a summary and outlook in section 6.

2 Theoretical Background and Related Work

2.1 Theoretical Foundation

The research of BPM has already come up with several methods to perform data processing or data analysis. For example, Business Process Intelligence solutions provide tools for the analysis, prediction, monitoring, control, and optimization of business processes [10]. But Business Process Intelligence is mostly used for ex post analysis of process or event data and lacks capabilities of processing enormous amounts of real-time data from heterogenous sources [11]. Business Activity Monitoring (BAM), however, is able to monitor and process event data online in real-time. But traditional BAM does not provide a specific engine to identify rules or create patterns that are essential for the correlation of high-volume event data generated by IoT devices, besides their inflexibility regarding heterogenous data sources [12]. The concept of an Event-Driven Architecture (EDA) constituted an important progress as events turned to a central structural element within the corporate IT environment [5]. Based on this message-driven architecture, further methods like CEP enabled obtaining understandable and usable information on the basis of high-volume event streams generated by heterogenous data sources [13]. EDBPM now comprises and combines several disciplines including CEP and BPM to make use of the acquired data and represents a central paradigm for high volume event integration [14]. A working definition of EDBPM could be the enhancement of traditional BPM by Service Oriented Architecture, EDA, Software as a Service, BAM and CEP to make optimal use of events for process integration [12].

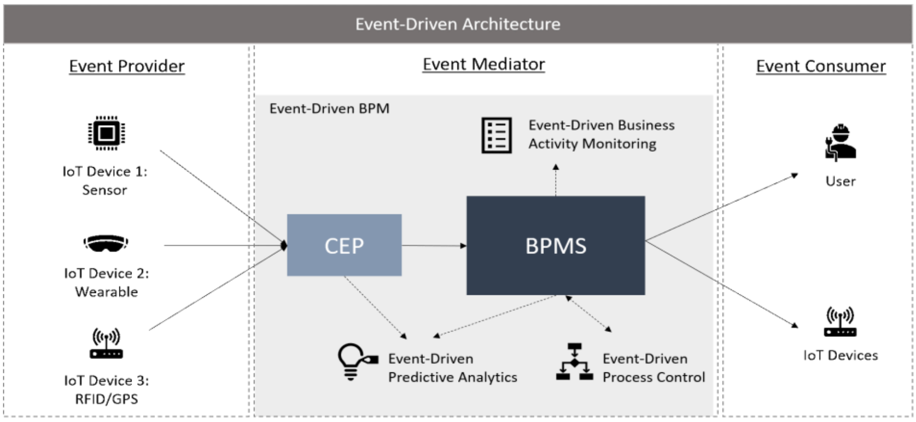

Figure 1. EDBPM architecture and interfaces

Figure 1 illustrates the main components and interfaces of an EDBPM based on an EDA. An EDBPM serves as an event mediator with its main components CEP and BPMS including interfaces to the event provider and event consumer. Event-Driven Business Activity Monitoring has the capabilities to capture and process events with minimum latency for providing real-time access to business performance indicators. By adding reactive capabilities using Event-Driven Process Control, the system is not mandatory limited to human intervention. Beyond the monitoring and active control of business processes, there is a strongly growing market for further analytics to gain even deeper insights in the operational process data. One of the main interests lies in active, real-time decision support or even predictive tools such as Event-Driven Predictive Analytics.

2.2 Differentiation from Related Work

There are already existing studies on EDBPM and related topics, which mostly focus on various independent aspects including EDA and CEP (see Table 1). However, the few publications performing a comprehensive review on EDBPM are either outdated or pursue a different survey objective. Krumeich et al. [15] for example, investigated the status quo of EDBPM in the year 2014 and proposed a possible research agenda.

Yet, in the past six years, the research field of EDBPM has experienced significant growth and needs to be reinvestigated. 25 of the 55 publications presented in section 4 have been published after 2014, confirming the progress of that field of research. Several of the formerly existing challenges have already been solved or at least tackled, as illustrated in subsection 5.1. Moreover, the paper at hand underlays EDBPM as a lever to enhance the implementation and scaling of IoT applications and therefore differentiates itself from other similar publications. This mostly becomes apparent both at the formulated clusters of section 4 and the proposed research agenda in section 5 that have a distinct IoT reference. Therefore, the publication focuses on literature that leads to improved EDBPM solutions or EDBPM components with beneficial character for IoT event data processing. Furthermore, the literature review lays a focus on the rather technical aspects of EDBPM without concentration on management or process related publications.

3 Research Methodology

The underlying methodology to survey the current state of research in the field of EDBPM is a structured literature review. Vom Brocke et al. [16] proposed an established procedure that allows a rigorous literature analysis based on a five-step framework. This framework comprises *(i)* the definition of the review scope, *(ii)* the conceptualization of the topic, *(iii)* a literature search, *(iv)* an extensive literature analysis and synthesis, and *(v)* the formulation of a research agenda. In combination with the structured taxonomy by Cooper [17], the main characteristics of the review could be concretized. This review mainly focuses on the current state of research regarding EDBPM in the function of a technology enabler for IoT. The main goal is the identification of clusters within the current research contributions and to detect research gaps aiming at the formulation of a research agenda. To cover all important research directions, a neutral perspective needs to be maintained. The coverage can be considered as representative, as an adequate number of publications has been selected in different eminent databases that cover most of the journals and conferences relevant to the topic. The organization of the review follows a conceptual approach and is designated to a specialized scholar.

The literature search itself was conducted according to the Preferred Items for SLRs and Meta-Analysis (PRISMA) statement. The PRISMA statement is a method to help authors to improve the reporting of systematic reviews and includes a structured checklist and flow diagram [18]. Especially the flow diagram is capable of illustrating the procedure and results of the literature search and analysis. Composed of four phases, “Identification”, “Screening”, “Eligibility”, and “Included”, the method gradually reduces the number of publications by assessing the eligibility using predefined criteria. Figure 2 shows the resulting four-phase flow diagram including the incorporated databases and number of considered publications. Several fundamental papers about EDBPM have been analyzed by their title, abstract, and keywords to find suitable search terms. Eventually, the search string *(“EDBPM” OR “EDA” OR “CEP” OR “BPM”) AND (“IoT”)* as well as the written-out terms have been used for abstract queries in the relevant databases. To incorporate and consider preferably all relevant journals and top conference proceedings of that research area, ACM Direct Library, IEEE Xplore, ScienceDirect, Scopus, Springer Link, and Wiley Online have been queried. According to the PRISMA statement, four criteria have been formulated which a paper needs to achieve to be eligible for this review. The publication must *i)* be a peer-reviewed original research paper, *ii)* be a full-length paper, *iii)* propose novel and relevant scientific findings, and *iv)* propose an evaluated solution or method. As criterion *i*) and *ii*) can be easily and objectively examined for each publication, the assessment of both latter criteria represents a rather subjective procedure based on the authors' capability to estimate the contribution and significance of each publication.

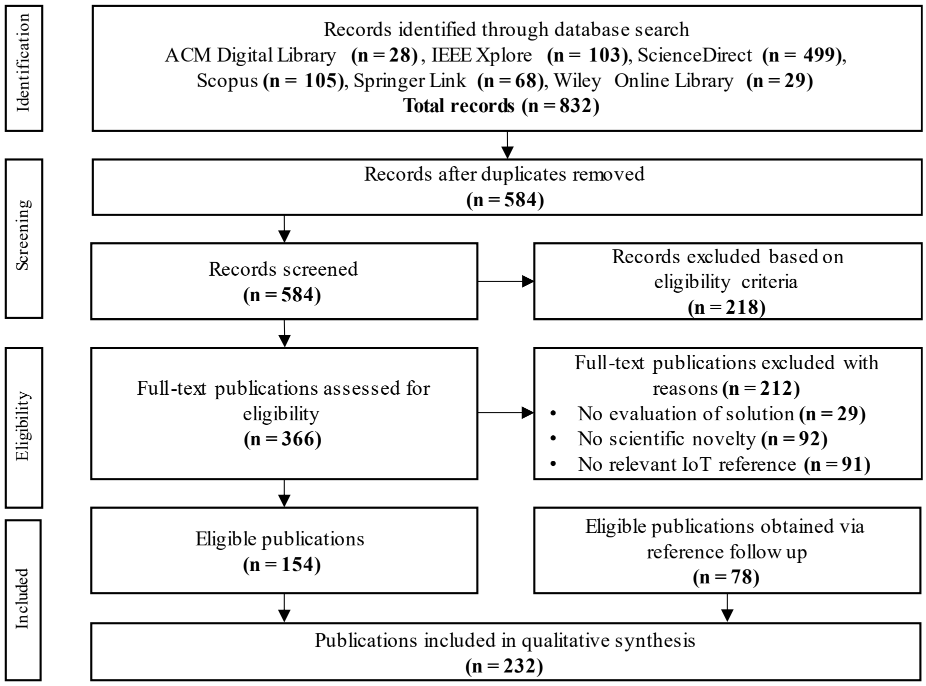

Figure 2. PRISMA flow diagram

For the initial abstract queries, 832 publications have been found in all utilized databases. After removing duplicates, a first manual review of the remaining 584 records was performed. The authors therefore performed an assessment on title, abstract and keywords based on incongruity with the eligibility criteria. Another 218 papers were discarded based on incongruity with at least one criterion. Eventually, the full texts of 366 articles were analyzed in detail resulting in another discard of 212 articles. Among them, 29 publications did not provide an evaluated solution, 92 could not add significant scientific novelty in comparison with existing contributions, and 91 had no relevant reference to the IoT paradigm. In addition to the 154 remaining publications, 78 further relevant articles were found during forward and backward search or expert recommendations.

4 Literature Analysis and Synthesis

All 232 publications have been analyzed and summarized in detail. Subsequently, the main contribution of each publication could be extracted. These contributions were now used to derive five different clusters that comprise all the relevant research topics of the considered publications. It became evident, that the main topics of EDBPM research focuses on the development of EDBPM architectures, CEP engines and rule identification methods, CEP modeling and the improvement of its usability, advanced predictive CEP capabilities or general applications, and industry use cases.

Table 1 shows a selection of 55 papers representing a minimum viable number to illustrate the current state of research. The publications were chosen by means of significance of the contribution, number of citations, and actuality to hereinafter present the five formed clusters. To translate this into quantitative criteria, publications with more than 50 citations and a publication date after 2014 were preferred. However, if a specific publication is assessed relevant and necessary for describing the state of research, a violation of one or both quantitative criteria is accepted. Each of the stated publications addresses one or several topics of the formulated clusters and can be taken as a representative example.

Table 1. Clustering of publications by main contributions

Reference	EDBPM architecture	CEP engine and rule identification	CEP modeling language and usability	Predictive capabilities	Application
[7, 18-24]	✓	X	X	X	X
[25-31]	✓	X	X	X	✓
[31-33]	✓	✓	X	✓	X
[34-37]	✓	✓	X	X	X
[38]	✓	X	X	✓	✓
[39]	✓	✓	X	✓	✓
[40-47]	✓	✓	X	X	✓
[48]	✓	X	✓	X	✓
[49]	X	✓	X	X	✓
[50-54]	X	✓	X	X	X
[55-59]	X	✓	X	✓	X
[60]	X	✓	X	X	✓
[61]	X	✓	✓	X	X
[62]	X	✓	X	✓	✓
[63-71]	X	X	✓	X	X
[72]	X	X	✓	X	✓

These five clusters are now illustrated and summarized in the following subsections using the 55 publications as representative and current instances.

4.1 Cluster 1: Fundamental EDBPM Architectures and Approaches

The field of EDBPM has been subject of research for several years and resulted in multiple different approaches and architectures. Early reference architectures and concepts for EDBPM mainly focus on monitoring business processes and including performance metrics or similar KPI based systems [20]. With only limited or non-existing reactive capabilities, these approaches are designed to improve the awareness about the business process environment [25, 31]. These systems are often used in combination with IoT technology for tracking and tracing use cases. In addition, there have been several implementations of viable prototypes at major companies that comprise BAM combined with CEP engines [14, 21]. However, there has been an increasing level of advanced EDBPM approaches that feature improved reactiveness and Event-Driven Process Control [22]. Furthermore, there are architectures that enable even case management engines, e.g. Chimera, that are used for knowledge-intensive business process modeling and execution, to incorporate external events [35, 36]. Several approaches are based on reference models and architectures that enable communication between different acting systems or at least have simple rudimental process control features [19, 32, 34, 37]. Recently, more papers emerged that pay more attention to Event-Driven Process Control elements by enhancing CEP to have a more intelligent and collaborative character [23, 24]. Also, the extended integration of edge devices by addressing CEP engines that leverage the edge computing environment is becoming an important challenge, which is tackled by research. By developing collaborative system architectures and providing capabilities to process the events at the edge of the network, the challenge of including data coming together from several heterogenous IoT devices can be faced [24, 39].

4.2 Cluster 2: CEP Engines and Advanced Rule Identification Methods

The main task of CEP is the detection of event patterns in continuous data streams from heterogenous sources such as IoT devices. The core of each CEP system is the CEP engine which is able to operate on a basis of temporal, spatial, or semantic correlation of event data [49]. To detect event patterns, a set of specific rules needs to be predefined which, again, is characterized by several parameters. As the definition of optimal parameter values is very challenging, there are different approaches to automize this task [49]. Early CEP systems are based on a manual detection of event patterns or the predefinition of rules and parameters by experts [50]. Gradually, several semi-automated CEP engines have been presented by researchers including algorithms that perform a prescriptive analysis that consists of detecting event patterns and making automatic decisions [40]. Pielmeier et al. [49] suggested three ways to define rules. They described a manual definition by domain experts and two semi-automated definitions by rule mining or optimization. Other approaches perform an advanced rule definition by rule mining algorithms, clustering, or a Fuzzy Unordered Rule Induction Algorithm [50, 51].

Besides CEP research regarding event pattern detection, some papers directly address the challenge to improve the interfaces between IoT devices and CEP systems.

The collection, integration, and appropriate and consistent representation of complex and high frequency sensor data is a rather complex task. Common CEP engines involve various analytical procedures for data fusion and require high computational resources [53]. Still, most of the established CEP systems remain job-specific and are limited to the integration of a few data sources, dependent on specific interface standards. Possible solutions suggest a combination of CEP technologies and stochastic models or semantic annotation processes or adapted CEP system architectures [52, 53]. Advanced CEP systems are therefore able to integrate multiple related sensor data streams coming from distributed sources [55].

4.3 Cluster 3: Usability and Modeling Languages for CEP

As already mentioned, the main task of CEP is to detect relevant events from continuous data streams, process them, and provide the information to further systems or activities, such as Event Processing Workflows. It therefore acts as a major driver for the integration of sensor data from IoT sources and the diffusion of EDBPM. One big challenge for the implementation of CEP is the lack of usability, which is caused by the high complexity of its management [63]. It is a substantial challenge for users to define event patterns and rule sets, especially, when they are non-technical experts [64]. In general, the definition of event patterns and detection of complex events is implemented with a specific Event Processing Language (EPL), which is similar to SQL for databases. There have been several efforts to create a standard for EPLs, such as Esper [63], domain specific languages [65], or other conceptual or graphical modeling approaches [66-69]. Recently, there have been further research activities regarding the integration of CEP elements within the BPMN or BPMN 2.0 representation of business processes [61]. These approaches represent EPL statements through BPMN elements [63, 70] or even map whole EPL syntax elements to existing BPMN artifacts [67, 71]. Besides the representation of CEP, there also exist approaches that try to facilitate programming of whole Wireless Sensor Network by using BPMN artifacts [48]. Alongside BPMN, there has also been a focus on the Event-driven Process Chain standard, which is another widely used process modeling notation [72]. In general, modeling event patterns in an established modeling notation and transforming it into an executable EPL could be a major field of research to decrease the inhibition threshold for using CEP [33, 69]. As most enterprises already have specialists for common business process notation standards, the implementation and integration of CEP and eventually EDBPM would be simplified.

4.4 Cluster 4: CEP with Predictive Capabilities

Current EDBPM approaches and CEP systems provide almost real-time detection and processing of complex event data. However, for specific applications, events should better be anticipated and e.g. proactively prevented before they occur. Examples for such events could be credit card fraud or various issues in the manufacturing industry such as disruption events. There are already several CEP applications in use, that have a predictive character. Krumeich et al. [33] exploited the potentials of CEP in combination with predictive analytics at a steel company and stated the vision of proactive process execution. As a result, process activities can be triggered much sooner as they would have been triggered in traditional BPMS by anticipating events. Another paper introduced an architecture of prescriptive enterprise systems, that is able to predict events from multi-sensor environments and therefore comprises several other systems on a higher-level approach [38]. There are multiple concepts, frameworks, and reference architectures for combining CEP with predictive analytics methods. Besides established prediction methods, such as logical and probabilistic reasoning [55] or Bayesian networks [56], there have been domain specific algorithms [57-59]. These algorithms are particularly designed to predict possible future events by deeply analyzing previous event patterns, that can be predicators for certain occurrences.

4.5 Cluster 5: Applications for IoT Technology meeting EDBPM

IoT technology meeting EDBPM and CEP systems are already in use in many different areas. Besides of applications in the private sector like smart home technologies and fitness wearables [43, 44], there have been projects in possibly every business sector including manufacturing, logistics, or even agriculture. Using CEP for monitoring complex event data from elders via wearables to create a virtual health profile can relieve the workload of doctors in rural regions [45]. In addition, RFID-enabled hospitals can model surgical events and critical situations via CEP and trigger specific processes [46]. Smart grids are another area of interest, where real-time CEP and Event-Driven Predictive Analytics can e.g. improve the distribution and planning of energy flows [47]. Especially for developing countries with critical air quality situations, novel CEP-based prediction frameworks based on IoT networks can lower people's exposure to pollution [26]. The logistics sector is one of the industrial branches that can benefit most from real-time BAM and the collection and processing of event data [41, 42]. Emmersberger et al. [27] introduced an EDBPM architecture that can be applied for logistics companies and identified several crucial challenges that need to be tackled. While the integration of IoT technology is rather easy for the private sector and small to medium sized logistics companies, it becomes a major challenge for huge corporations in the manufacturing industry with complex operations and processes. For these major enterprises, IoT technology is often used for the whole supply chain including multiple suppliers and customers. This leads to extraordinarily complex environments of IoT devices, IT systems, and interfaces. Several papers address the topic of event processing in the manufacturing industry [28, 60] and describe the status quo and existing hurdles for further scaling of IoT technology [73]. But there have also been publications that propose whole bidirectional communication architectures of IoT systems, which enable an IoT-based BPM with high scalability of devices [29]. These novel use cases show the diverse possibilities of EDBPM and the transferability of current research topics to actual industry applications [30].

5 Findings and Research Agenda

The analysis and synthesis of all relevant publications provided an overview over the major research topics regarding EDBPM. This section now formulates the main findings and research gaps that were identified and proposes a research agenda, which addresses the most relevant identified challenges.

5.1 General Findings and Research Gaps

One main finding of the literature review is, that the publications can be categorized into five distinct clusters which contain specific areas of research. For each of these clusters, relevant scientific progress has been made in the last years that tackled and, in some cases, resolved open challenges formulated by prior publications such as Krumeich et al. [15]. One major challenge, that was mentioned, is the need for further experiences with EDBPM in industrial applications. However, in recent years, industry-related [29, 30] and domain-specific [41, 47] experiences with integrating IoT technology into business processes based on the EDBPM paradigm have been made. This led to an improved maturity of industrial IoT applications and provided blueprints that can be adapted by other companies. Also, the integration of large amounts of high-volume event data in the context of Big Data was identified as a major challenge for further research. There have been concepts and prototypes by Guo and Huang [53] and Flouris et al. [54] that address this topic and enable a capable handling of massive event data. This improves the integration of IoT devices with high data rates in the context of Big Data and enables more efficient and effective handling of massive event data. In addition, several new methods and tools for the management of CEP rules and systems have been suggested [40, 50, 51], that also improve the usability and therefore acceptance in the industrial context [64]. However, several challenges remain unresolved or lack a mature and practical solution. Early applications almost exclusively focus on pure monitoring of business processes or tracking and tracing of transportable goods. This may be explained by the divergence between existing enterprise software systems and the system architectures required by EDBPM. In addition, the complexity of integrating multiple heterogenous IoT devices into a network and defining rule patterns for the detection and processing of continuous event data is a big hurdle. Most corporates lack specific domain experts for CEP and therefore need solutions which are easy to use and maintain. Also, the focus on EDA is still not quite common in many industries. Just recent research activities show a more advanced use of IoT in combination with EDBPM. As the usability of CEP solutions is improving through the representation of statements by established modeling languages, also the integration of reactive capabilities and predictive analytics is levered. These reactive capabilities and prediction components are rather limited features that still lack an adequate level of automation and often only serve as a basis for a human-centric decision support [42]. Moreover, the sheer bandwidth of different proprietary concepts for EDA, CEP engines, and modeling languages constitute a deterrent for many corporates. As companies have high requirements for the quality and stability of their information systems, most contemporary approaches regarding EDBPM do not have the required maturity, as also mentioned in other publications [73].

5.2 Research Agenda for IoT meeting EDBPM

Based on the main findings and existing research gaps, a research agenda is provided in this subsection by analyzing the main challenges of each cluster, as seen in Table 2. To guarantee an objective and representative overview of the most important and relevant challenges and opportunities, the research agendas and challenges of the reviewed publications have also been analyzed and incorporated into the following agenda, if still contemporary. The focus of the agenda proposal is the capability of itself to act as a lever for the integration and scaling of IoT technology. Therefore, this paper does possibly not consider all crucial challenges of EDBPM, as they are not considered as a major hurdle for the scaling of IoT applications. For this reason, the provided research agendas are neither prioritized in a certain way nor represent a complete listing. Table 2 states the formulated research agenda and links it to the respective clusters of section 4.

Table 2. Proposed research agenda

No.	Research agenda	Cluster
1	Establishing mature EDA frameworks and CEP reference models	1, 2, 5
2	Automating and simplifying rule pattern definition and modeling languages	2, 3
3	Standardization of interfaces and data formats	3, 5
4	Developing CEP systems with increased reactive and predictive capabilities	2, 4

5.3 Establishing Mature EDA Frameworks and CEP Reference Models

Current EDAs and CEP approaches lack standardization and proven maturity [19, 34]. It is necessary to develop reference architectures and design patterns, that can be easily adopted and broadly scaled. Having mature and proved frameworks and reference models that meet the business requirements and expectations, may have a beneficial influence on the exploration of complex IoT applications. Using architectural blueprints may also reduce the invest and maintenance costs for adapting EDBPM and its components which could also increase the relevance for enterprises.

5.4 Automating and Simplifying Rule Pattern Definition and Modeling Languages

The high complexity of detecting and processing relevant event data from heterogenous IoT devices is a major hurdle for businesses. As most companies do not have specific experts for CEP, the operation and maintenance of related systems needs to be as simple as possible. Future research activities should address the automation of rule pattern definition and examine possibilities for self-improving systems. This incorporates also the standardization and simplification of EPLs which could be done based on existing concepts like Event-Driven Process Chain or BPMN 2.0 [61]. This would lower the inhibition threshold of companies for the technological adoption of IoT applications and improve the general usability of EDBPM related systems.

5.5 Standardization of Interfaces and Data Formats

To fully exploit the benefits of EDBPM, there is a strong need for standardized interfaces to existing information systems [34]. The current systems do not offer sufficient alignment to established formats and interfaces and collectively lack appropriate data formats for events [15]. As major companies are operating heterogenous facilities, IoT devices, and IT systems, the integration and combination of those through flexible interfaces needs to be facilitated. This could also enable a more efficient integration of heterogenous and distributed IoT devices.

5.6 Developing CEP Systems with Increased Reactive and Predictive Capabilities

As the benefits of reactive CEP systems, and therefore process automation, have an enormous value for companies, research on these topics should have a high attention. Many companies already use passive IoT technology such as RFID tags for pure monitoring tasks and express the desire for a deeper integration of these technologies with the physical world. In addition, the prediction of events could have disruptive effects on businesses and even influence their business models. By avoiding unwanted events through predictions, negative consequences could be prevented. But also, the prediction of minor events can be beneficial, as companies may gain time to prepare for them and therefore reduce uncertainty.

6 Conclusion

This paper gave a representative overview over the current state of research regarding EDBPM and its related technologies and paradigms. The main goal was to identify major challenges and opportunities of EDBPM that have a strong influence on the expansion of IoT technology at businesses. In particular, the authors focused on the recent progress and developments of this research area, as it is gaining importance due to increasing numbers and types of IoT devices and technologies. As the majority of IoT applications require advanced complex data processing systems and proper alignment of the system architecture towards an event-driven paradigm, EDBPM can be an enabling technology. It became evident, that there is a great bandwidth of research activities that address CEP, EDA, EDBPM, and corresponding topics. Some of the once formulated challenges and hurdles have already been tackled and resolved but several are still requiring further effort. There are many concepts, frameworks, and reference models that have a mainly theoretical character and lack maturity and standardization. As the integration of heterogenous data sources in IoT networks requires flexible and stable working systems, the existing and mainly proprietary solutions cannot fulfill the needs of possible users. To cope with this fundamental issue, future research should focus on establishing standards and adaptable real-life applications, that can act as a blueprint for other use cases. Also, improved future approaches with reactive and predictive character could act as a lever for the integration of EDBPM and eventually IoT technologies as they could imply major benefits for enterprises. Further research activities and applications are required to outline the capabilities and possibilities of these systems. By proving the beneficial character of event-orientation and sophisticated EDBPM, companies and other institutions might pay more attention to IoT technologies and the inhibition level could be lowered significantly. This survey may serve as a representative overview, starting point, and motivation for further research activities regarding EDBPM.

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