Using Blockchain Technology for Cross-Organizational Process Mining – Concept and Case Study

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Abstract. Business processes in companies lead to an enormous number of event logs in their IT systems. Evaluating these event logs using data mining can provide companies with valuable process analysis information which can uncover process improvement potentials. However, media breaks frequently occur in these processes, so that there is a risk of optimizing isolated sub-processes only. Blockchain technology may avoid these media breaks and thus create the basis for complete event log analysis. The focus of our paper is to investigate existing requirements and to identify a blockchain based solution scenario evaluated by experts.

Keywords: Blockchain · Process mining · Data science · Process analytics

1 Introduction

Multinational companies (MNEs) have increased their global trade significantly in recent years [1]. A multinational (MNE) is characterized by distributed value creation in factories outside the home country [2]. Due to highly-developed division of labour, value creation in a multinational corporation takes place in various decentralized units. There are numerous intercompany supply relationships within a multinational company in the production of goods, semi-finished goods and intermediates. The transport of goods around the globe today requires a great deal of time and money and is therefore the subject of a continual search for opportunities to reduce both time and costs. Data that can help with this can be found in the intercompany business processes of the various ERP and IT systems of the group. Process mining is where this data is collected, analysed, weaknesses identified and optimization potentials determined. The challenge today is that heterogeneity in ERP and IT systems, common in multinational corporations, makes consistent process analysis by a central authority much more difficult [3]. In such cases, weak points in processes can be determined by means of process mining carried out on results from data science coupled with the real-time data of the blockchain [3]. The blockchain is the gateway to connect the processes and deliver the relevant data for the process mining. It has against traditional databases the advantage, that in additional to internal units, external parties like customers or suppliers can be integrated, without the development of a further technology. All the process participants are equal partners and can therefore trust the neutral blockchain

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technology. At the end, after the integration of all participants of the process, the end-to-end process analysis with process mining is possible and brings all the participants a competitive advantage.

The purpose of this paper is to examine whether blockchain technology is a solution to the challenge of transparency of multinational companies' intercompany business processes. Our research question is therefore:

How can blockchain technology be used for Cross-Organizational Process Mining in a multinational corporation to meet the challenge of transparency of intercompany processes?

In order to answer our research question, we design and develop an artifact, following the design science research paradigm of Gregor et al. [4]. We therefore adapt existing knowledge about the blockchain to new operational problems. We develop the artifact in a case study based on a real-world problem at a multinational company in the commercial vehicle industry and evaluate it by interviewing experts.

2 Theoretical Background

2.1 Process Mining

The analysis of processes based on their event data is a process mining technique used for checking compliance, identifying and analysing bottlenecks, comparing process variants within a benchmark and identifying potentials for improvement [3]. Process mining closes the gap between data mining and process analysis and describes activities related to searching large amounts of data for relevant or significant information [5]. The idea behind data mining is that companies create huge amounts of automatically generated homogeneous data every day, which can generate decision support issues for decision makers [6]. Process analysis, on the other hand, deals with the course of a business process [7] and consists of a series of functions in a specific order, ultimately providing value for an internal or external customer [8]. Cross-functional end-to-end processes within a multinational company should be considered as a whole to avoid improving only isolated sub-processes. Process analysis is based on event logs that are generated during process execution and is thus adapted to the real-word situation [8]. Currently, process analysis is mostly based on data available within organizations [9]. For cross-organizational process mining, for example, in the analysis of supply chains, data can even be spread across multiple organizations [3]. Today's information systems log enormous amounts of events, but such information is usually unstructured, for example, event data in SAP R/3 is spread across many tables or must be retrieved from subsystems that exchange messages. In such cases, event files are present, but some effort is required to extract the data. Data extraction is an integral part of all process mining efforts and is not possible without corresponding event logs [3] which allow process-level process analysis to be performed and the setting up and calculation of indicators based on process execution traces [8]. However, dependency on the event logs limits the process mining techniques to identifying activities that are

not included in the event logs, such as manual activities performed in the process [10]. The reality is that event data is typically distributed across different data sources, and often some effort is required to gather the relevant data [3]. The blockchain keeps records of executed processes and can provide valuable information to assess case load, duration, frequency of paths, parties involved, and the correlation between unencrypted data elements. This information can be used to detect processes, detect deviations, and conduct root cause analysis [3], ranging from small business groups to an entire industry.

Process Mining, with its combination of event data and process models, enables both a data-driven and process-oriented view. It can be used to answer numerous compliance and performance questions. Control of conformity is achieved by comparing observed behaviour with modelled behaviour [3]. In this way, compliance violations can be identified as well as detected for other inconsistencies in the processes [11]. The investigation of weaknesses and the detection of bottlenecks belong to performance questions about processes in a company [3].

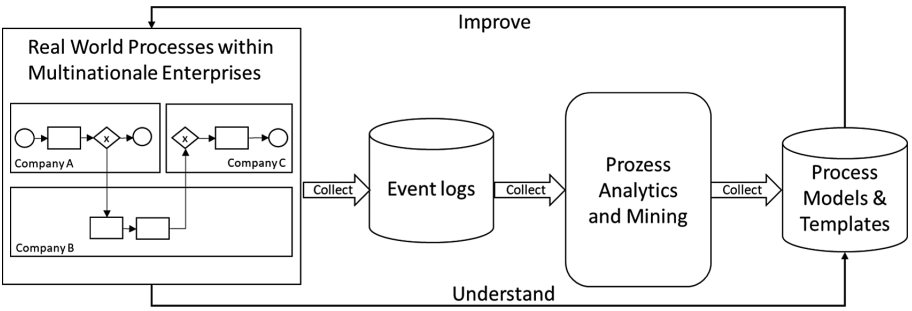

Fig. 1. The basic process of Process Mining, based on Hof (2018) [27].

Basic Process Mining begins with the transfer and extraction of event data from the various IT systems into an event log database. Then this data is adapted to the company needs and to take into account both syntactic and semantic requirements. Finally, the data is loaded into a data warehouse system [3] and is available for analysis [12]. The knowledge gained can be used to adapt and improve processes.

2.2 Blockchain Technology

Blockchain technology became popular with the introduction of the crypto-currency Bitcoin 10 years ago and is now used in numerous use cases. A blockchain as distributed ledger is a concatenation of data based on transactions between subscribers that are aggregated into individual blocks and stored on all users' computers in a peer-to-peer network. The data is concatenated using cryptographic methods, creating a chronological chain of immutable data. The inclusion of a new record in the blockchain

requires the passage of a so-called consensus mechanism that runs across the network of all subscribers and is used to reach an agreement between all members of the blockchain network about the correct status of the data. This ensures that the data is the same on all nodes in the network [13]. The best-known consensus mechanism is a proof-of-work method that requires the computer to perform a complicated mathematical algorithm at great expense. Only after successful execution, a new data block can be generated in the blockchain, which must be checked by the other computers in the peer-to-peer network before being included in the blockchain [14]. In addition to the data, each block contains a timestamp as well as the hash value of the previous block. The blocks are protected by cryptographic methods against subsequent changes, so that a coherent chain of linked data blocks forms over time [14]. The data exchange between a blockchain and an ERP system could, for example, be done via the Unibright Connector. The Unibright Connector (UBC) is based on a Microsoft .NET class library and establishes a connection between the blockchain and external systems [15]. The Unibright Framework cross-blockchain and cross-system connections provide a blockchain-based business integration process [16].

2.3 Methodical Approach

To answer our research question, we first use the results of a qualitative content analysis of interviews that we carried out a year ago as part of our research into the blockchain for business processes in purchasing. Qualitative content analysis allows words to be classified into content categories [17]. We have developed a case study based on current problems and challenges as well as the advantages of using blockchain. This case study addresses real-world company problems and challenges and attempts to solve them using blockchain technology. The evaluation is carried out by interviewing experts using a standardized questionnaire.

2.4 Related Works

We were able to find related studies based on a previous review of the literature. Mendling et al. (2018) suggest that blockchain technology has the potential to drastically change inter-organizational processes. The need for drastic change arises, among other things, from the lack of a global view of processes today. The fragmentation of processes across countries and their systems leads to misunderstandings and blame if there is a conflict. The reason is that companies often use systems for the implementation and execution of processes only for intra-organizational processes [7]. Rbigui and Cho (2018) perform performance analysis on a process mining process and come to the conclusion that process mining yields good results only where processes are complete [18]. In our work we develop a concept to integrate the blockchain technology with existing IT-systems in firms as the basis for a inter-organizational process mining. The concept sees the blockchain as the bridge to close the gap between different steps in a process. Therefore, the process mining is able to analyse the whole process.

3 Analysis of Interviews

It was important for our concept to record the existing challenges in logistics processes of multinational enterprises (current situation) as well as recording the possible results of improvements by the integration of a blockchain into the logistics process (target situation). For the assessment of the current situation, we entered the search string "Blockchain" and "Interview" and "Supply chain" or "Logistics *" in Google for the period 01.01.2017 to 31.01.2018 and received 35,400 results. Based on our assumption that the results of the first pages reflect the relevance of Google's search algorithms [19], we used the titles and short texts to analyse the results in order to filter out the interviews relevant to our research question.

The data from the first 20 interviews was transferred to an Excel file and analysed on the basis of the following questions:

- What problems or challenges are seen in logistics or in supply chain management?
- What are the advantages of using the blockchain in the logistics industry?

Due to the fact that not all analysed interviews were able to provide the necessary information to answer our questions, we then transferred and analysed further interviews from our Google search results.

Table 1. Results of the interviews with classification.

Problems/Challenges (current situation)		C	P	Advantages (target situation)		C	P
Class	No	No	No	Class	No	No	No
Process	9	2	7	Process	36	13	23
Trust	5	2	3	Transparency	28	10	18
Conditions	4	2	2	Fraud	8	7	1
Data	2	2	0	Costs	5	0	5
IT-Security	2	2	0	Organization	4	2	2
Fraud	1	1	0	IT-Security	4	3	1
Costs	1	0	1	Collaboration	3	0	3
Standards	1	0	1	Trust	3	2	1

C = Conformance questions; P = Performance questions

We were able to evaluate 35 interviews about current challenges and future expectations and analyse them against the classes shown in Table 1. In a second step, we categorised the answers according to the relevance of process mining as either "performance questions" or "conformance questions". The results show that the processes are very important in this context, both in terms of the current challenges and future expectations. The current problem definition of the interviewees' processes shows a clear focus on the performance of the processes. In addition to the high demands of documenting process steps, the interviewees also mentioned the numerous participants in a process with the associated media disruptions as well as the associated

lengthy waiting and idle times. With regard to the future expectations of blockchain-based solutions, the requirements for the processes also predominate. Time plays an important role in the Processes class. The perceived benefits of using blockchain technology are the timely processing of process steps.

4 Case Study

To answer our research questions as defined above, we conduct a case study that, according to Ridder (2017), offers the advantage of detailed description and detailed analysis so that the questions "how" and "why" can be answered more easily [20]. Our case study is suitable for our research topic because a current phenomenon (blockchain) is examined in a real and practical context (MNE) [21]. According to Brüsemeister (2008), a case-by-case study is also helpful if it provides information about a previously under-researched social area aimed at using process mining of blockchain data to improve cross-organizational processes [22].

The company in our case study is Europe's leading manufacturer of semi-trailers and trailers for temperature-controlled freight, general cargo and bulk goods and has an annual production of around 61,000 vehicles with around 6,400 employees. In the 2017/2018 financial year, sales reached over € 2.17 billion [23].

In addition to several production sites in Germany, the MNE also has factories in Lithuania, Turkey, China, Russia and Spain. Sales in Europe are made through the company's own distribution companies in almost every country [24]. Since 2004, the production facility in Germany has produced their own axles with an annual output of approx. 150,000 units [25]. The procurement volume for raw materials, consumables and supplies, for purchased goods and services, amounted to € 1,460.6 million in the financial year [26].

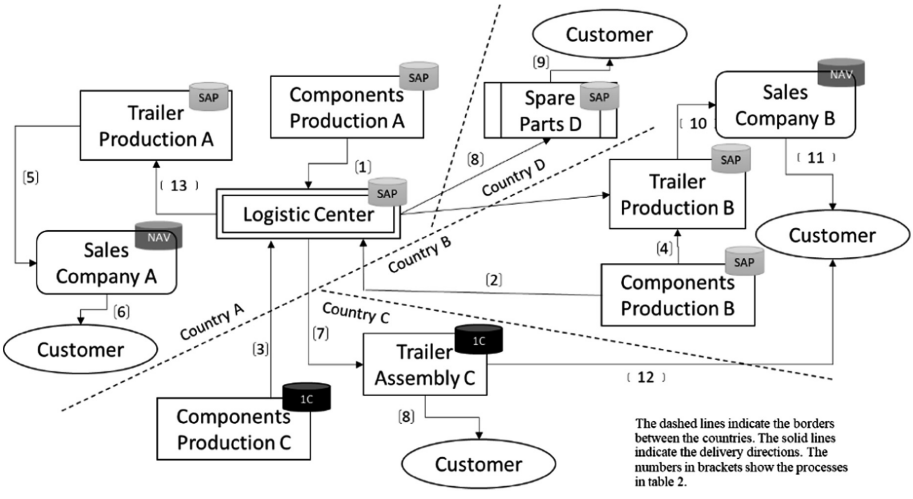

Fig. 2. Supply relationships in the case study.

Figure 2 shows an example of part of the complex performance relationships within the multinational company for five different countries. The headquarters of the multinational is in Country A.

The previous picture shows the factories for the production of components of a trailer (Components Production) and the logistics center (Logistic Center) as a central warehouse for the supply of factories in the group, for example with the Axle from Components Production A. Furthermore, the Factories producing Trailers (Trailer Production) are essential components of value creation. For reasons of customs law, Country C has only a trailer assembly for the assembly of components and kits for trailers. The trade in spare parts at workshops takes place via the spare parts trade (spare parts). In addition to the companies, the IT system used for processing supply relationships is listed.

Table 2. Supply relationships between the entities in the group

No.	Supplying unit	Received unit	IT-System supplier	IT-System receiver	Process
(1)	Components Production A	Logistic Center	SAP-R/3	SAP-R/3	I
(2)	Components Production B	Logistic Center	SAP-R/3	SAP-R/3	S
(3)	Components Production C	Logistic Center	1C	SAP-R/3	S
(4)	Components Production B	Trailer Production B	SAP-R/3	SAP-R/3	S
(5)	Trailer Production A	Sales Company A	SAP-R/3	Navision	S
(6)	Sales Company A	Customer	Navision	Unknown	S
(7)	Logistic Center	Trailer Assembly C	SAP-R/3	1C	S
(8)	Logistic Center	Spare Parts D	SAP-R/3	SAP-R/3	S
(9)	Spare Parts D	Customer	SAP-R/3	Unknown	S
(10)	Trailer Production B	Sales Company B	SAP-R/3	Navision	S
(11)	Sales Company B	Customer	Navision	Unknown	S
(12)	Trailer Assembly C	Customer	1C	Unknown	S
(13)	Logistic Center	Trailer Production A	SAP-R/3	SAP-R/3	I

No.: shows the process step from the Fig. 2/Process: I = Integration; S = Segregation

Table 2 shows the example supply relationships between the companies in the multinational group. The Process column indicates whether the business process between the supplier and recipient IT systems is integrated into a system (I) or whether a media break occurs between the systems (S).

Real integration can only be seen today in the companies with SAP-R/3 in Country A, because this is where the headquarters of the Group is located and where integration efforts are the most advanced. Crossing a border usually results in segregation of processes, even if both companies work with the same SAP R/3 system. Between different IT systems, such as e.g. SAP R/3 and Navision, there is no process integration with interfaces.

Based on the current situation in our case study and the requirements of the analysed interviews, we design a solution based on blockchain technology. Blockchain technology connects the processes that were previously segregated in our solution (see Fig. 3). For example, in the case of a delivery from the SAP R/3 system, the data record is written to the blockchain via a connector and forwarded via a smart contract to the receiving company. The connector then picks up the record and translates it into the local IT system, e.g. Navision. Due to the real-time processing of the blockchain, both the supplying company and the receiving company are always able to provide information about the status of the process.

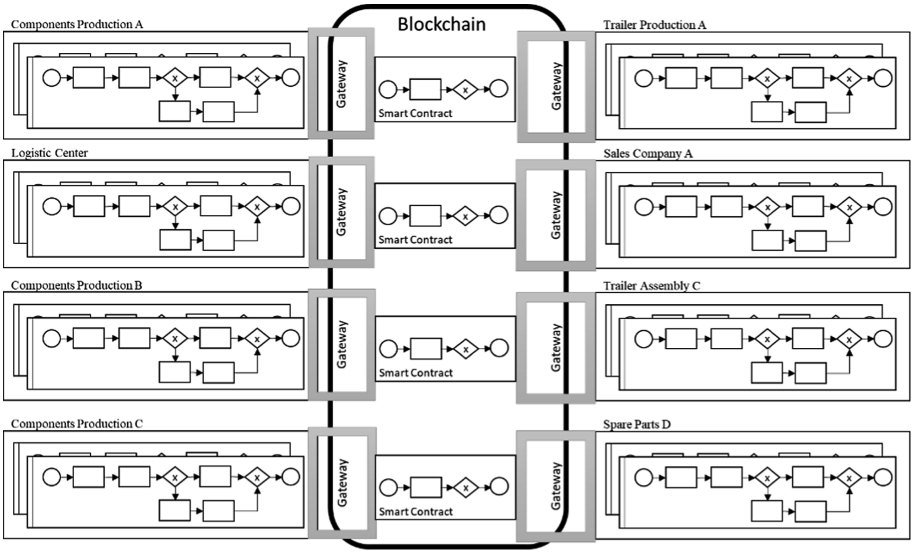

Fig. 3. The blockchain connects the cross-organizational processes.

The blockchain technology can connect processes that were previously separated by media breaks, so that the event logs can be used as part of a data mining process to analyse the processes (see Fig. 4). The blockchain is based on the concept in Fig. 1 applied to the processes in decentralized IT systems such as e.g. SAP R/3 and Navision and database event log implemented. The acceptance of the blockchain solution for all the process participants can reach with a permissioned blockchain. All the process relevant data are secure and can only viewed from the participants with the concrete rights. A permissioned blockchain runs without a consensus algorithms.

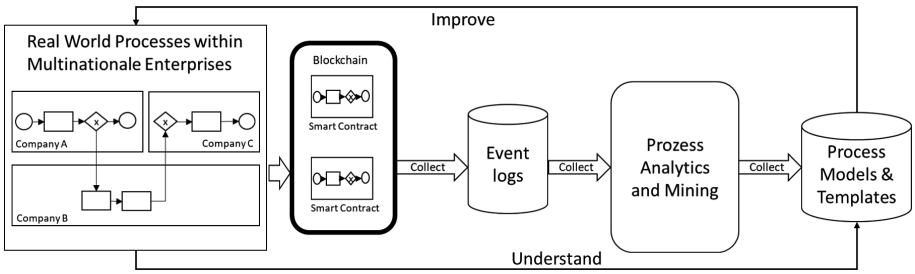

Fig. 4. The integration of the blockchain into process mining, based on Klinger (2018) [28].

5 Discussion of the Results

Our solution is based on blockchain technology and generates event data based on the integration of cross-system processes. It would also be possible to use a relational and distributed database solution. This could take up data from the processes of the distributed systems via interfaces and consolidate it into an overall process. Technically, process mining is also possible using a relational database. However, it should be remembered that in some industries, such as the food industry, pharmaceutical industry and the chemical industry higher requirements of traceability for deliveries is necessary and must be provable. For these increased requirements, the blockchain, because of its immutability, decentralization, and cryptography, could offer a tremendous advantage over a traditional database. In addition, concerns about the integration of third parties, such as easier to clean out suppliers with the blockchain because all parties have access to the same data.

We interviewed experts from industrial practice and process consulting and asked them to complete a standardized questionnaire in order to evaluate our concept. The selection of participants took place via social media contacts in Xing, Linkedin and Facebook with the requirement that the participants have appropriate professional knowledge as well as occupational status. We invited 60 participants to complete the survey in November/December 2018 and received 56 responses by the end of December 2018 - a response rate of 93,3%. Participants are divided into 32 from industry (62,75%), 10 from consulting (19,61%) and nine from other (17,65%). Out of these 56 responses, 35 belonged to a multinational firm. When asked if they could confirm the problem described in our case study regarding process breaks in transitions between different IT systems, 83,67% answered yes. Furthermore, we wanted to know from the participants on the basis of a Likert scale from 1 to 5, how far they regarded our concept as realistic for overcoming the process breaks. The arithmetic mean of the responses is 2,72 with a standard deviation of 0,94. This indicates some uncertainty about a successful implementation. The participants see, among other things, the maturity level of blockchain technology as a hindrance to implementation as well as deficits in the performance of mass data processing. Furthermore, the participants mentioned a lack of risk-taking and the courage to invest in new technologies as a hindrance.

6 Summary and Outlook

Process Mining requires the seamless event data of processes in a multinational company, so as not to improve weak points only at partial process steps in the part of the process in which, for example, due to an SAP system, complete event data is available. Blockchain technology could bridge the gap between different IT systems, closing the existing process gap and generating event data through the use of smart contracts. This event data, which is analysed using data mining techniques because of the high volume of procurement in our case study of more than € 1 billion, could thus serve as the basis for the analysis of cross-company processes. Because of the immutability of the data in the blockchain, this event data could be used for processes in industries with increased requirements for transparency and traceability. By using blockchain technology, the involvement of third parties such as suppliers and downstream value creation stages could succeed. Furthermore, auditors and inspectors could gain access to the blockchain. In the case of cross-border supplies between companies within the group, the tax authority has an important role to play because of transfer pricing rules. The substantive over form principle in tax auditing means an assessment is based on real processes, not on the basis of contracts or agreements. The immutability, cryptography, and chronological order of the data make the blockchain ideal for process mining to control compliance.

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