A survey on event log extraction from blockchain

Ahlem Makni[1,*], Rawya Mars[1], Saoussen Cheikhrouhou[1,2], Slim Kallel[1,2] and Mohamed Sellami[3,†]

[1]ReDCAD Laboratory, ENIS, University of Sfax, Tunisia
[2]Digital Research Center of Sfax, Tunisia
[3]SAMOVAR, Télécom SudParis, Institut Polytechnique de Paris, 91120 Palaiseau, France

Abstract

To address the traceability challenges associated with inter-organizational business processes enactment, one potential solution is to rely on the blockchain technology . In such cases, establishing process traceability requires analyzing and leveraging blockchain logs. In order to contribute to the discourse on this issue, this paper presents a comprehensive review of existing literature conducted to explore the multifaceted landscape of traceability in business processes. The review synthesizes a diverse range of studies focusing on the use of blockchain logs. These logs not only capture individual events but also offer valuable insights into the entities involved in these processes . Researchers studied these entities using process mining techniques to unravel their complex lifecycles. Finally, this review of the literature has led to the identification of two categories of logs that can be linked with traceability within blockchain technology.

Keywords

Business process, Process mining, Event log, Blockchain, Smart contracts

1. Introduction

Inter-Organizational Business Processes have become an integral component of modern business practices. Essentially, IOBPs involve the collaboration between various organizations in order to accomplish mutually agreed-upon objectives. However, a considerable challenge in the execution of IOBP is the inherent lack of trust among collaborators, which can lead to disputes regarding counterfeiting activities. To address this issue, recent discussions have proposed the integration of Blockchain technology for more secure and transparent management of IOBP execution. The concepts of blockchain and distributed ledgers have gained significant attention and sparked numerous projects across various industries. One of the major challenges to Blockchain adoption [1], is ensuring seamless integration and interoperability [2] between different platforms. Two widely utilized blockchain platforms are Ethereum and Hyperledger, which play a pivotal role in advancing this revolutionary technology. In addition, other approaches [3] have been proposed to leverage the trusted smart contract execution environment provided by blockchain

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*Corresponding author.
ahlem630makni@gmail.com (A. Makni); rawya.mars@redcad.org (R. Mars); saoussen.cheikhrouhou@redcad.org (S. Cheikhrouhou); slim.kallel@redcad.org (S. Kallel); mohamed.sellami@telecom-sudparis.eu (M. Sellami)
0000-0002-5662-0140 (R. Mars); 0000-0003-4607-7452 (S. Cheikhrouhou); 0000-0002-2824-167X (S. Kallel); 0000-0002-7547-1857 (M. Sellami)

technology to enforce collaborative business processes. These can be observed or identified in Caterpillar and Lorikeet. Caterpillar [4] is the first blockchain-based process execution engine has the ability to handle process models that contain subprocesses and utilizes the Ethereum blockchain to store the current status of each process instance, while employing smart contracts generated by a BPMN [5] to Solidity [1] compiler for workflow routing. Lorikeet [6], for instance, presents an innovative approach that can seamlessly bridge the gap between business process specifications and smart contract execution, . It is a a Model-Driven Engineering (MDE) tool that incorporates the methodology proposed by Weber et al. [7] and utilizes the translation algorithm developed by Garcia et al. [8]. Lorikeet has been successfully employed in various industry projects, highlighting the practicality of generating process-oriented smart contracts. As blockchain technology continues to be adopted in various industries and its applications expand, a significant problem arises: how can we ensure the traceability between Business Process Models and their actual execution, especially in Inter-Organizational Business Processes (IOBPs) relying on multiple blockchain platforms ? One of the challenges in adopting blockchain platforms for business processes is striking a balance between data privacy and security on one hand, and transparency and trust among participants on the other. To illustrate this challenge, we refer to a pharmaceutical supply chain [9]. This particular case study aims to achieve two goals: (i) authentication of verification requests using verifiable credentials, and (ii) improved verification processes between pharmacies and manufacturers. Through analyzing event logs and transaction data recorded on blockchains, process mining provides insights into how business processes are executed in reality [10]. By reconstructing and visualizing actual processes, process mining helps identify deviations from the intended BPM, ensuring compliance and alignment in IOBPs. It should be noted that there can be variations in the format and content of extracted, as different methods may be used to record events. Some event logs focus on tracking activities within a business process, while others are specific to certain involved objects. Recent studies in this field have demonstrated a notable emphasis on event logs that are centered around objects rather than activities [11, 12]. This shift towards object-centric event logs is motivated by the difficulties related to convergence and divergence within activity-based event logs. For instance, considering a BP related to a pharmaceutical supply chain, we can notice an significant number of important object-centric interactions in addition to the activity centric ones. For instance, an object in this process, e.g., a purchase order can be created, approved, Transmitted and confirmed. Every stage, beginning with order placement and concluding with product delivery. In this paper, we aim at categorizing existing work that concentrate on both activity and object event logs.

The organization of this paper is as follows. Section 2 provides a detailed overview of blockchain logging. Section 3 presents other logs format distinct from those extracted from the blockchain. We thoroughly evaluate and discuss these works Section 4. Finally, in Section 5, concluding remarks are made along with suggestions for future directions.

[1] https://solidity-fr.readthedocs.io/

2. Blockchain logging

In this section, we provide a comprehensive review of prior research in the area of extracting logs from blockchains. Numerous studies have explored this topic, with certain works emphasizing objects and others focusing on activities. We categorize the various studies for extracting logs into three distinct groups: event-centric extraction, object-centric extraction and hybrid approaches.

2.1. Event-centric Extraction

In this subsection, we refer to approaches focus on capturing specific events or activity that occur on the blockchain, regardless of the related entities. The primary focus is to track and record events like transfers, contract invocations, consensus changes, etc. In [13], the authors present extracted data from the blockchain into event logs formatted according to the IEEE Extensible Event Stream (XES) standard [14]. This approach is based on a configuration file called Manifest, provides a set of rules for logging relevant process information into the blockchain, ensuring that all the required data is captured and after that data extractor retrieves the logged information from the blockchain and transforms it into a suitable format for process mining. By following this framework, organizations can effectively utilize their existing blockchain infrastructure to derive valuable insights into their business processes. Nevertheless, this framework is primarily centered around Ethereum and needs to be adapted when applied to different blockchain systems. Additionally, its functionality is constrained as it only supports a specific range of value builders. It also has limited capabilities for handling complex conditions in attribute and element filtering, and lacks comprehensive support for low-level logging interfaces.

The authors of [15] describe their method for extracting process data from an Ethereum blockchain ledger and converting it into a format that complies with the IEEE XES standard. They validate their approach with a proof-of-concept prototype relying on an Ethereum's public blockchain smart contracts dataset. Their methodology allows extracting blockchain process data, storing it as XES event logs, and supports data analysis through process mining techniques. Adherence to IEEE XES ensures compatibility with existing process mining tools in the ProM [2] and Disco [3] toolkit. However, this work did not consider certain key aspects. For instance, not properly aligning smart contract functions with process activities can lead to inaccuracies in process mining due to potential mismatches. Moreover, assuming that each process instance corresponds to a single smart contract may not always be valid, necessitating the use of more sophisticated reconciliation techniques and obtaining supplementary data from certified sources like oracles for precise timing information.

The primary objective of the study in [16] is to extract event logs from decentralized applications deployed and executed on the public Ethereum blockchain. The researchers utilized a tool called ELF [17] to extract the event logs, which are available in XES format. In their work, Bandara et al. demonstrated how data extraction was performed for four different blockchain

[2] https://promtools.org/
[3] https://fluxicon.com/disco/

applications: Augur [4], Forsage [5], CryptoKitties [6], and ChickenHunt [7]. It is crucial to recognize the constraints that need to be taken into account. Although ELF was primarily developed for compatibility with Ethereum, it might necessitate modifications when utilized on alternative blockchain platforms that employ distinct logging mechanisms. Moreover, while ELF provides valuable functionality, it does impose certain limitations such as partial support for more complex log extraction scenarios.

Another approach [18] specifically focused on extracting process data from smart contracts deployed on Hyperledger Fabric and Composer, which export them in CSV format. Their chosen use case revolved around vehicle manufacturing networks. In choosing to focus on Hyperledger Fabric and Composer rather than Ethereum, a pragmatic consideration was taken into account. Unlike Ethereum, which has been observed to generate empty blocks during mining operations resulting in complex and congested event logs, Hyperledger Fabric and Composer were deemed more suitable for business-oriented smart contracts that prioritize clarity and efficiency over unnecessary complexity. This decision aligns with the specific needs of their use case but may limit the direct applicability of their approach within the broader blockchain landscape. It emphasizes how crucial it is to select an appropriate blockchain platform based on the particular requirements and characteristics of each application, as different platforms offer distinct advantages and disadvantages depending on the intended use case.

2.2. Object-centric Extraction

In this Subsection, we enumerate approaches which focus on particular elements or entities extracted from blockchain. The recovery of events is closely related to these elements, their characteristics, or how they interact with one another. Identifying the entity that generates an event is essential, and events are often located in the attributes or actions associated with these objects.

A noteworthy approach [11] dedicated to extracting OCELs logs from blockchain data, with a primary focus on leveraging the capabilities of the Ethereum blockchain. In [19], authors provides an initial evaluation of the proposed methodology, rigorously assessing its technical feasibility and performance. Furthermore, this study conducts a comparative analysis by comparing the resulting OCEL-log to a prior case study that used the XES format. However, The application of Object-Centric Event Logs in blockchain applications, like Augur [8], exposes certain constraints. These constraints become evident when considering the simultaneous existence of various entities, including DApp CAs, transactions, and user accounts. These objects may undergo changes in their roles throughout a given process. It is worth noting that OCEL currently does not provide explicit support for documenting these role transitions. As a result, accurately representing the complete historical development of an object, including its changing roles over time, poses a significant challenge. For instance, a token in Augur can be assigned to the same user account as both the sender and receiver. However, OCEL currently

[4] https://augur.net/
[5] https://fr.bitdegree.org/traqueur-de-crypto/top-ethereum-dapps/forsage
[6] https://www.cryptokitties.co/
[7] https://chickenhunt.io/
[8] Augur is a peer-to-peer, decentralized exchange, enabling universal and transparent access to its markets

does not provide explicit support for documenting how an object's roles change over time.

The storage of event data has predominantly been done using "flat" formats such as XES. However, a novel and more advanced data format named XOC [20] was introduced to address certain limitations associated with previous formats. Unlike its predecessors, XOC does not rely on a case notion and also avoids flattening multi-dimensional data. Notably, there has been further progress in this area with the introduction of OCEL - an even more efficient log format that surpasses its predecessor in terms of both storage capacity and processing capabilities.

In [12], the authors introduced ACEL, a novel logging format and a novel solution for extracting blockchain data from artifact-centric applications and transforming it into a structured format tailored for process mining methods. ACEL logs offers a more comprehensive and enriching log format compared to the OCEL format. They capture data related to objects and their evolutionary journey over time, as well as their intricate relationships with other entities. As a result, ACEL logs emerge as a solid option choice for capturing event data originating from artifact-centric applications, providing a more detailed and nuanced perspective on the dynamics of these systems. This study highlights two primary constraints. Firstly, the extraction of ACEL logs from blockchain relies on a manually written configuration file. Authors acknowledges the potential difficulties users may face when writing these files. Secondly, the current extraction algorithm is tailored specifically for Ethereum and therefore restricts its broader applicability to other contexts or platforms.

A novel logging framework called BLF is introduced in [21]. This logging framework specifically caters to decentralized applications on the blockchain, offering an innovative solution for analyzing event data from these applications and facilitating the extraction and interpretation of logs. The authors emphasize that while BLF was initially developed for Ethereum and Hyperledger blockchains, it has the potential for expansion in order to support other blockchain platforms as well. The case studies employed in BLF include the widely recognized Ethereum game known as CryptoKitties, as well as Augur. To explore these case studies further, Hyperkitties an implementation of the CryptoKitties Ethereum smart contract within the Hyperledger platform, was utilized. The primary aim to extract events from HyperKitties found within various blocks and subsequently generate an event log formatted document in XES. The current work lacks the exploration of other platforms beyond Ethereum and Hyperledger. Additionally, it appears that there is room for further enhancement in the Blockchain Query Language (BcQl) language.

It is worth noting that apart from variations in log formats, several other aspects are being explored like data-awareness of object-centric event logs [22] and artifact centric event logs [12]. This particular format established a restriction on the capabilities of OCEL to handle object attributes that have dynamic values which may change over time [22]. The DOCEL format has been developed to tackle the identified concerns and improve the way process data, involving various types of objects, is represented and analyzed. Hence, it can be stated that this particular format serves as an expansion of the OCEL format. The authors present a proposed method for transforming XES logs into DOCEL logs. Consolidating multiple XES format event logs about each object involved in the process can be quite difficult. However, this algorithm effectively combines these individual XES files into one cohesive DOCEL log while maintaining the essential data flow characteristics that make XES a desirable event log format.

3. Hybrid Approaches

In this section, we provide an overview of several approaches that integrate both event-centric and object-centric strategies. These approaches enable the capturing of specific events within the context of particular objects. They are aimed at transforming conventional event logs into their object-centric counterparts.

In [23], the authors have explored a method for converting an XES log format into an OCEL log. In order to accomplish this objective, the authors integrate the process of analyzing semantic characteristics within the text with the techniques of data profiling and control-flow-based relation extraction. This method reveals additional data that was not initially recorded in the OCEL log. This entails the incorporation of additional types of objects, attributes, and connections, which enables a more comprehensive understanding of the process. However, One of the main challenges we faced in their approach was determining the relationships between objects in a 1:n relationship with the core case object. This complexity resulted in several incorrect assignments of instances to their corresponding events.

Currently,there is ongoing research focused on the automation of converting XES logs into OCEL logs. Authors of [12] propose an algorithm to extract event data and transform it into ACEL format. Also, authors of [22] propose an algorithm to transform XES logs into DOCEL logs with the primary objective to associate all attributes with their respective objects. This new format resolves the limitations of OCEL. It allows for a clear association of attributes with both events and objects, as well as tracking changes in attribute values. Nevertheless, there are certain constraints that need to be addressed in both the XES and DOCEL formats. In particular, these limitations include a lack of ability to distinguish between object roles in events and the absence of support for managing multiple objects within a single XES file. To overcome such challenges, future research could explore opportunities for developing new algorithms in DOCEL specifically aimed at object-centric process discovery and conformance checking. This would help address the identified deficiencies while also opening up new avenues for exploration.

4. Comparison and discussion

4.1. Activity vs object centric event logs

After conducting our comprehensive review of existing approaches, we identify two distinct methodology categories for extracting logs from blockchain. Our in-depth evaluation and comparison between these categories, is summarized in Table 1 which exhibits the chronological development of activity-centric and object-centric logs extraction methods and emphasises the sequential advancement of log extraction methods over time.

In recent research, there is a noticeable shift taking place: there is an increasing focus on object-centric analyses as opposed to the established activity-centric ones. Many Activity-Centric log approaches typically favor the XES format due to its versatility and compatibility with various tools and platforms for event log analysis. However, in a specific case study [18] conducted in 2021, the CSV format was chosen as the preferred format for recording logs on the Hyperledger Fabric/Composer blockchain platform. This exceptional decision may be attributed

Classification	Year	Approaches	Event Log Format	Blockchain Platforms
Activity-Centric Logs	2019	[13, 15]	XES	Ethereum
	2020	[17]	XES	Ethereum
	2021	[16]	XES	Ethereum
	2021	[18]	CSV	Hyperledger Fabric/ Composer
Object-Centric Logs	2021	[21]	XES	Ethereum/ Hyperledger-Fabric
	2022	[12]	ACEL	Ethereum
	2023	[11]	OCEL	Ethereum

Table 1
Classification of Temporal Blockchain Log Approaches: Activity-Centric and Object-Centric

to specific requirements or constraints of the platform, highlighting how log formats can adapt according to different blockchain platforms and use cases. In 2021, a significant transition occurred in research, shifting the focus from activity-centric analysis to object-centric analysis and this evolution underscores an increasingly acknowledged importance of delving into the behaviors and interactions of individual objects within intricate systems. While event logs, a mainstay in process mining, have conventionally been employed to capture sequential actions, contemporary scholars are gravitating toward object-centric logs due to their potential to offer a more thorough grasp of system dynamics. It is important to note that event logs frequently do not provide explicit information about the entities or objects involved in processes. This can lead to challenges when trying to understand and analyze complex interrelationships. In contrast, object-centric logs offer a potential solution to these challenges. By placing emphasis on analyzing the states, properties, and interactions of objects, researchers aim to provide a more comprehensive and accurate representation of system dynamics. Moreover, researchers are expected to develop novel approaches that harness the inherent structures and meanings of objects as they delve further into object-centric log analysis.
To facilitate a comprehensive comparison of activity-centric and object-centric logs generated from blockchain technology, this comparison is presented in table 2. These logging methods have unique features. The Activity-Centric approach predominantly records event sequences with accurate timestamps, whereas the object-centric approach emphasizes entities and objects, highlighting temporal relationships and semantic structures. It is important to note that scalability issues may arise with extensive event volumes in the activity-centric model, requiring domain expertise for interpretation. On the other hand, object-centric logs excel in managing large numbers of objects and promoting deeper understanding of data. This thorough analysis helps researchers and practitioners choose the most suitable approach for their blockchain-related projects.

4.2. Discussion and future work

This section delves into the research endeavors that have concentrated on addressing the challenges associated with retrieving logs from blockchain environments. Additionally, it discusses the utilization of process mining techniques to analyze these retrieved logs and obtain valuable insights.

The application of blockchain technology in IOBP can enhance data traceability, and prove-

Comparison Criteria	Activity-centric Logs	Object-Centric Logs
Fundamental Concept	Records sequences of events	Focuses on entities and objects
Data Granularity	Individual events with timestamps	Objects with attributes and relationships
Temporal Representation	Precise event timestamps	Temporal relationships among objects
Scalability	Can pose challenges with large event volumes	Better suited for managing a large number of objects
Results Interpretation	May require deep domain expertise.	Can facilitate understanding with semantic structures

Table 2
A Comparative Assessment of Activity-Centric and Object-Centric Logging

nance at different stages of inter-organizational processes. The main objective of [24] is to develop a methodology for generating event logs during the execution of IOBP, which includes data cleaning techniques. The output will be in both XES and CSV formats, making it suitable for process mining tasks such as discovery and conformance checking.However, there exist several inherent limitations that affect the extraction of event logs across various networks. An important constraint to highlight is the occurrence of empty blocks during the mining process. It is worth noting that this restriction applies not only to Ethereum but also extends to numerous other blockchain platforms. The occurrence of empty blocks in a blockchain, where there are no transactions or significant smart contract interactions present, can be attributed to different factors such as mining optimizations, network delays, and intricacies in blockchain consensus protocols. These empty blocks disrupt the smooth flow and integrity of event logs. As a result, extracting a complete and consistent history of events becomes increasingly difficult due to these sparse blocks that complicate the extraction process significantly.

Addressing the issue of cross-chain compatibility is an ongoing challenge that requires attention in the blockchain space. The seamless facilitation of communication and collaboration between different blockchain networks remains a priority. In [12], there is a focus on extracting artifact-centric event data from Ethereum using the ACEL model. This discussion prompts us to explore if there is already a standardized logging format or if extensions to ACEL are necessary for effective cross-chain analysis. Additionally, it raises important questions about whether existing process mining techniques should be adopted or adapted, or if novel methods tailored specifically for cross-chain processes need to be developed. These academic considerations contribute significantly to our understanding of this topic

Our investigation focuses on examining the practical utilization of Ethereum and Hyperledger Fabric, both well-known blockchain platforms with significant influence in the field. These platforms stand at the forefront of blockchain technology, each offering unique features that set them apart from one another. However, a considerable gap exists in terms of understanding how these platforms can be effectively applied in real-world scenarios. Future research can explore ways to facilitate cross-platform transactions in diverse ecosystems. The integration of blockchain technology and process mining holds promise in addressing the longstanding challenge of implementing blockchain in inter-organizational processes. This area of research has the potential to make a significant contribution by providing practical insights into the

real-world applications and relevance of blockchain technology.

5. Conclusion

This literature review has focused on the extraction of event logs from blockchains, with a distinction between activity-centric and object-centric approaches. An analysis reveals that recent research efforts have primarily concentrated on object-centric event log extraction methods. Additionally, we have discussed the limitations associated with these approaches in their respective categories. Our proposal presents a unique approach that leverages the integration of blockchain platforms and object-centric event logs to track the complete lifecycle of blockchain data. This integrated approach provides a solid groundwork for future research efforts, particularly in the field of Business Process Management Systems that are compatible with both blockchain technology and process mining techniques.

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