

Blockchains for Business Process Management - Challenges and Opportunities

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Abstract

Blockchain technology promises a sizable potential for executing inter-organizational business processes without requiring a central party serving as a single point of trust (and failure). This paper analyzes its impact on business process management (BPM). We structure the discussion using two BPM frameworks, namely the six BPM core capabilities and the BPM lifecycle. This paper provides research directions for investigating the application of blockchain technology to BPM.

Keywords: Blockchain, Business Process Management, Research Challenges

1. Introduction

Business process management (BPM) is concerned with the design, execution, monitoring, and improvement of business processes. Systems that support process execution are extensively used by companies to streamline and automate *intra*-organizational processes. Yet, for *inter*-organizational processes, challenges for the joint design and a lack of mutual trust have hampered a broader uptake.

Emerging *blockchain* technology has the potential to drastically change the environment in which inter-organizational processes would be able to operate. Blockchains offer a way to execute processes in a trustworthy manner even in a network without any mutual trust between nodes. Key aspects are specific algorithms that lead to consensus among the nodes and market mechanisms that motivate the nodes to progress the network.

In this paper, we investigate how blockchain technology creates new challenges and opportunities for BPM. This leads to directions for research activities to investigate both challenges and opportunities. Section 2 discusses the background and an illustrative example. Sections 3 and 4 use the *six core elements* [8] and the *BPM lifecycle phases* [3] to structure the discussion. Section 5 concludes with a brief reflection.

2. Background

2.1. Blockchain

Blockchain is the technology underlying Bitcoin and other cryptocurrencies. It is a distributed database technology that builds on a tamper-proof list of timestamped transaction records. Its innovative power stems from allowing parties to transact with others they do not trust over a network in which nobody is trusted. This is enabled by a combination of peer-to-peer networks, consensus-making, cryptography, and market mechanisms. Blockchains ensure data integrity and transparency, such that the network stays operational even under byzantine faults. A copy of the entire blockchain is held on every node on

the network and consensus is achieved either by proof-of-work or proof-of-stake algorithms [6].

Blockchain technology is more broadly applicable than for cryptocurrencies: in essence, it is a peer-to-peer database that offers access to the history of all previous states. Furthermore, several blockchain networks offer the possibility of executing user-defined scripts, so-called *smart contracts*. For instance, the *Ethereum* blockchain supports Turing-complete programming languages for smart contracts¹. The code is deterministic and relies on a closed-world assumption: only knowledge from blockchain transactions is available in the runtime environment. Like any other transaction, the deployment of smart contract code to the blockchain is immutable. Once deployed, smart contracts offer a way to execute code directly on the blockchain network, for instance to transfer money if a certain condition is fulfilled. In this way, untrusted parties can establish trust in the truthful execution of the code. Smart contracts can be used to implement business collaborations in general, and inter-organizational business processes in particular. The potential of blockchain-based distributed ledgers to enable collaboration in open environments has been successfully tested in diverse fields ranging from diamonds trading to securities settlement [9].

We put the proposition forward that blockchains enable a fundamental rethinking about how one particular corporate asset can be managed, namely its business processes. Recent work [10] shows that specific aspects of inter-organizational business processes can be compiled into smart contracts that ensure the joint process is correctly executed. So-called *trigger* components allow connecting these inter-organizational process implementations to Web services and internal process implementations. These triggers serve as a bridge between the blockchain and enterprise applications. The cryptocurrency concept enables the implementation of conditional payment and built-in escrow management at defined points within the process. All these different facets of blockchains help organizations to implement and execute business processes across organizational boundaries even if they cannot agree on a trusted third party. Overall, the core aspects of this technology will enable support of enterprise collaborations going far beyond asset management, including managing supply chains, tracking food to increase safety, or sharing personal health records in privacy-ensuring ways.

2.2. Motivating Example: Supply Chain

To illustrate our proposition, Figure 1 shows a simplified supply chain scenario, where a bulk buyer orders goods from a manufacturer. The manufacturer, in turn, orders supplies through a middleman, which are sent from the supplier to the manufacturer via a special carrier. Without global monitoring each participant has a restricted visibility of the overall progress. This may very well be a basis for misunderstandings and shifting blame in cases of conflict.

If executed using smart contracts on a blockchain, typical barriers complicating the deployment of inter-organization processes can be removed. (i)

¹<https://www.ethereum.org/>

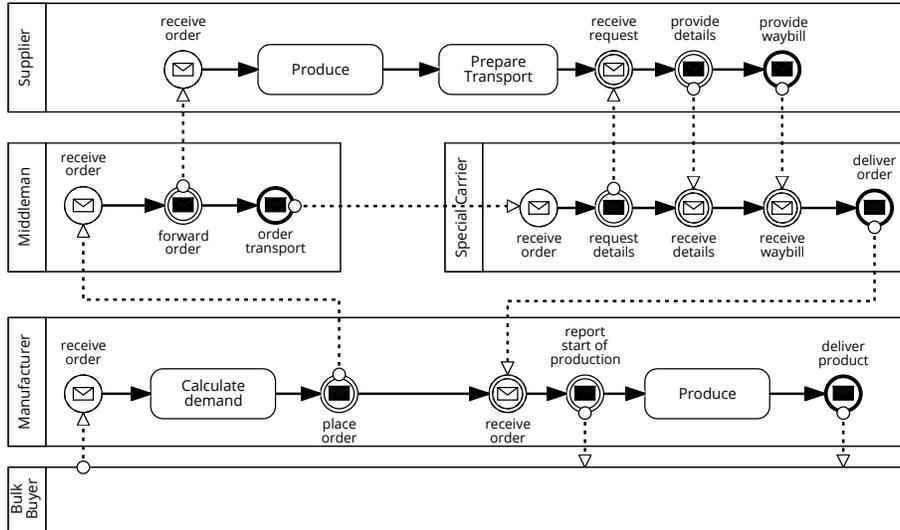


Figure 1: Supply Chain Scenario from [10]

The blockchain can serve as an immutable public ledger, so that participants can review a trustworthy history of messages to pinpoint the source of an error. This means that all state-changing messages have to be recorded in the blockchain. (ii) Smart contracts can offer independent process monitoring from a global viewpoint, such that only expected messages are accepted, and only if they are sent from the player registered for the respective role in the process instance. (iii) Encryption can ensure that only the data that must be visible is public, while the remaining data is only readable for the process participants that require it. Partially, smart contracts that enforce a process execution in a trustworthy way can be generated from process models [10].

3. Blockchain and BPM Capabilities

We now discuss challenges and opportunities that arise from blockchain technology in terms of six BPM core capability areas [8], namely strategic alignment, governance, methods, information technology, people, and culture.

3.1. Strategic Alignment

Strategic alignment refers to the active management of connections between organizational priorities and enterprise processes [8], which aims at facilitating effective actions to improve business performance. Blockchain technology calls for research on how systematic analyses of the strategic implications of its use on certain processes can be conducted. More broadly, blockchain as a disruptive technology raises questions if the traditional process-follows-strategy paradigm

could be flipped upside down with new blockchain-based processes challenging entire industries such as accounting. For many companies, a potential disintermediation, which can be enabled by the use of blockchain-based systems, might pose more of a threat than an opportunity for their business.

3.2. Governance

BPM governance refers to appropriate and transparent accountability in terms of roles, responsibilities, and decision processes for different BPM-related programs, projects, and operations [8]. Blockchain technology changes governance because it enables cooperation as a new management mode for processes. This calls for research on the definition of dedicated roles that liaise with internal and external partners for setting up blockchain support for processes. Also, policies are required that define where and when blockchain technology can be used or must not be used for supporting processes. For instance, cryptocurrencies have highly volatile exchange rates to traditional currencies – gains and losses of 10-50% within a single day are not uncommon. It is expected that this volatility will decrease with broader uptake [6]; as of today, it is a roadblock for many applications.

New attack scenarios on blockchain networks are difficult to foresee [4]. Therefore, guidelines for using private, public, or consortium-based blockchains are required [6]. Finally, smart contracts promise to facilitate self-governance of not only processes, but of entire organizations, such as currently role-modeled by the Decentralized Autonomous Organization (DAO) ². Deciding which participants should have visibility of which parts of the transaction history also poses challenges in trade-offs: on the one hand higher privacy and confidentiality will increase acceptance of the technology; on the other hand more transparency supports trustworthiness, compliance checking, and optimization based on reliable data.

3.3. Methods

BPM methods refer to tools and techniques that support management activities along the process lifecycle and throughout an enterprise-wide BPM program [3]. Blockchain technology will require novel analysis methods, specifically with a focus on risk assessment and cost/benefit analysis, and collaborative engineering methods. These require formal reasoning capabilities about the correctness and privacy preservation of smart contracts. Furthermore, blockchain will arguably redirect attention from analyzing pain points back to searching unexplored new opportunities, which might revive some of the process re-engineering concepts discussed in the early 1990s.

²<https://daohub.org>

3.4. Information Technology

BPM-related information technology subsumes all systems that support process execution. Blockchain technology requires novel solutions, software components and integrated development environments to implement business processes with blockchains. Also new challenges arise regarding security and privacy issues, such as how to prevent confidential business data leakage. While the visibility of encrypted data on a blockchain is restricted, it is up to the participants in the process to ensure that these mechanisms are used according to their confidentiality requirements. Some of these requirements are currently investigated in the financial industry ³. Finally, inherent limitations of blockchains have to be considered including computational power, data storage, throughput, and processing costs. Rather than using an existing blockchain, an alternative could be to adopt only the corresponding design principles, like replicated transaction history.

3.5. People

People in the context of BPM refers to all individuals in different roles who engage with BPM [8]. The adoption of blockchains and the design of smart contracts will require new ways of thinking about people, because the focus shifts from processes within a sphere of control to collaboration between organizations. Also, people must be willing to design business collaborations within the frame of existing regulations to enable adoption. This implies that research into blockchain-specific technology acceptance is needed. Finally, the openness of blockchains makes it easy to offer incentives for third parties to contribute to ongoing processes, with implications for work relations.

3.6. Culture

Organizational culture is defined by the collective values of a group of people in an organization [8]. Specifically relevant for BPM is corporate culture, which can generally vary in its support of BPM. Blockchains call for research into the organizational factors that facilitate early and successful adoption. Organizational culture is likely to be one of these factors, because the blockchain concept challenges classical organizational structures.

4. Blockchain and BPM Lifecycle

In this section, we discuss blockchains with respect to the traditional BPM lifecycle [3] including: identification, discovery, analysis, redesign, implementation, execution, monitoring, and adaptation. These partially overlap with the *information technology* and *methods* capability areas.

³<https://gandal.me/2016/04/05/introducing-r3-corda-a-distributed-ledger-designed-for-financial-services/>

4.1. Identification

Process identification is concerned with the high-level description and evaluation of a company from a process-oriented perspective, thus connecting strategic alignment with process improvement. Blockchain technology is a relevant focus for evaluating high-level processes in terms of their strengths, weaknesses, opportunities, and risks in relation to the emergence of blockchain technology. Research is needed on how these perspectives can be systematically integrated into the identification phase. Because blockchains are prone to support inter-organizational processes, process identification may need to encompass not only the needs of one organization, but broader known and even unknown partners.

4.2. Discovery

Process discovery refers to the collection of information about the current way a process operates and its representation as an *as-is* process model. Various process mining techniques are available to support, among others, process discovery [1]. Blockchain technology defines new challenges for process discovery techniques: the information may be fragmented and encrypted; accounts and keys can change frequently; and payload data may be stored partly on-chain and partly off-chain. This fragmentation might require a repeated alignment of information from all parties operating on the blockchain. Work on process matching could represent a promising starting point to solve this problem. There are also opportunities for reverse engineering business processes, among others, from smart contracts.

4.3. Analysis

Process analysis refers to obtaining insights into issues of a business process as to how it currently operates. Records of processes executed on the blockchain yield valuable information that can help to assess the case load, durations, frequencies of paths, parties involved, and correlations between unencrypted data items. These pieces of information can be used to discover real processes, detect deviations, and conduct root cause analysis [1], ranging over small groups of companies or over an industry at large. Such analysis can be utilized on processes in which one is involved or processes that other parties are working on when blockchain data is accessible.

4.4. Redesign

Process redesign deals with the question of how a process can be systematically improved. So-called redesign heuristics formulate proven solutions for specific issues a process might face. Blockchain technology might offer novel ways of improving specific business processes or resolving specific problems. The question is where blockchains can be applied for optimizing existing interactions and where new interaction patterns without a trusted central party can be established. A promising direction for developing blockchain-appropriate abstractions and heuristics may come from data-aware workflows [5] and BPMN choreography diagrams [2]. It might also be beneficial to formulate blockchain-specific

redesign heuristics. These could mimic how Incoterms [7] define standardized interactions in international trade. Specific challenges for redesign include the joint engineering of blockchain processes between all parties involved. This has been an ongoing problem for choreography design. Balancing the trade-off between blockchain benefits, transaction cost, risk, delay, and other factors is a major open question.

4.5. Implementation

Process implementation refers to the procedure of transforming a *to-be* model into software components executing the business process. Because blockchain opens many possibilities for business collaboration in more efficient and trusted ways, it is crucial to develop approaches to identify existing collaboration processes, so as to create analogous blockchain-based collaborations. This raises new challenges, because only the interaction portions of overall collaborative processes will be visible. Also the discovery of existing blockchain processes faces challenges, as discussed above. An important engineering challenge is the definition of abstractions, including modeling primitives like BPMN extensions, libraries, connectors or tailored execution engines. Several ideas for generating parts of executable processes from choreographies can potentially be lifted to this setting, e.g. [2]. Software patterns and anti-patterns will be of good help to engineers designing blockchain-based processes. In particular, model-driven software engineering and code generation offer specific benefits in the blockchain setting. Smart contract code is in principle accessible to all participants of a blockchain - there are no firewalls and no perimeter security in front of it. Code generation, e.g. from process models, provides advantages including better boilerplate code, avoiding known security vulnerabilities across all generated code, making use of latest best practices for smart contracts, and the option to regenerate the code from the original model in case more threats become known after deployment. There is also a need for new approaches for quality assurance, correctness, and verification. These can build on existing notions of compliance, reliability, or quality of services, but will have to go beyond these in terms of consistency and consideration of potential payments. Furthermore, dynamic partner binding and rebinding is a challenge that requires attention. Process participants will have to find partners, either manually or automatically on dedicated marketplaces using dedicated look-up services. For instance, the property of inhabiting a certain role in a process might itself be a tradable asset, e.g., a supplier may auction off the role of shipper to the highest bidder as part of the process. Also, directories for smart contract templates will emerge. All these characteristics emphasize the need for specific testing approaches.

4.6. Execution

For the actual execution of a process deployed on the blockchain, several differences with the traditional ways exist. First, during initialization, (partial) binding of roles to participants needs to take place. If this binding is partial, or if rebinding is allowed, the mechanisms for further/re-binding need to be defined

a priori. For the actual execution, messages between participants need to be passed as blockchain transactions to the smart contract; resulting messages need to be observed from the blocks in the blockchain. Both of this can be achieved by integrating blockchain technology directly with existing enterprise systems, or through the use of dedicated integration components, such as the triggers suggested in [10]. The main challenge here is ensuring correctness and security, especially when monetary assets are transferred using this technology.

4.7. Monitoring

Process monitoring refers to collecting events of process executions, displaying them in an understandable way, and triggering alerts and escalation in cases where undesired behavior is observed. Here we face issues in terms of data fragmentation and encryption as in the analysis phase; e.g., the need to integrate local off-chain data with decrypted local copies of on-chain data. With such tracing in place, the global view of the process can be monitored independently by each involved party. This provides a suitable basis for continuous conformance and compliance checking and monitoring of service-level agreements.

4.8. Adaptation

Runtime adaptation refers to the concept of changing the process during execution. This can for instance be achieved by allowing participants in a process to change the model during its execution. In the setting discussed here, blockchain is used to enforce conformance with the model, so that participants can rely on the joint model being followed. Thus, adaptation is by default something to be *avoided*: if a participant can change the model, this could be used to gain an unfair advantage over the other participants. For instance, the rules of retrieving cryptocurrency from an escrow account could be changed, or the terms of payment. Therefore, in the blockchain setting process adaptation must strictly adhere to defined paths for it, e.g., any change to a deployed smart contract requires a transaction signed by all participants. More abstractly speaking, in order to preserve trustworthiness it must be clear who can change what, until when and under which circumstances.

5. Summary and Outlook

Blockchains will fundamentally shift how we deal with transactions in general, and therefore how organizations manage their business processes within their network. The BPM community has a unique opportunity to help shape this fundamental shift. With this paper we aim to provide clarity, focus, and impetus for the research challenges that are upon us.

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