Exploring Blockchain Technology to Improve Multi-party Relationship in Business Process Management Systems

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Abstract: Business Process Management Systems (BMPSs) are often used to track activities, identify inefficiencies, and streamline the workflow. Typically, BPMSs are used by a single organization for internal users and processes through a trusted central system. However, scenarios involving multiple parties present a new challenge: to ensure the reliability of registered information and strict adherence to business rules for all participants without a central authority. Therefore, we explored the use of blockchain technology in association with a BPMS to create a Distributed Business Process System (dBPMS). This integration can fulfill the requirements above mentioned, creating tamper-proof registries, allowing reliable self-execution through smart contracts, within a trusted environment for all parties, without the need for inter-party trust. The proposed solution provides a workflow encompassing all activities and parties in an efficient ecosystem.

1 INTRODUCTION

As a basic process modelling approach, workflows usually focus on the sequence of events. Thus, Business Process Management Systems (BPMSs) (Karagiannis, 1995) play a critical role to describe and track activities in the organizational environment. However, it loses the connection between the model and the developed platform as well as ignores the informational perspective (Hull et al., 2016). In order to improve the big picture of organizational business processes and the information traceability during the process execution, we have integrated to the BPMS the blockchain technology (BCT) in order to: (i) keep the historical records; (ii) guarantee that data is tamper-proof, and (iii) ensure that the processes are running precisely as planned according to the deal made between the involved parties.

In this sense, mapping the business process is crucial to guarantee the orchestration between business goals and their execution. Therefore, it is vital to check, and even redesign, the processes regularly, due to the constant need to adapt businesses workflows to attend to new demands. Furthermore, this orchestration often involves external entities (other companies), such as supply providers and regulatory entities. Therefore, to ensure the reliability of registered information and strict adherence to business rules for all participants it is crucial to use proper technology.

Blockchain technology presents many features to support such BPMS requirements, such as resources to deal with untrusted parties, tamper-proofing and traceability of information. Furthermore, the use of blockchain technology to distribute BPMS is a novel approach never presented before. Moreover, Blockchain Smart Contracts (BSCs) play a crucial role in this environment, enabling self-executed contracts that use programming language code, which do not depend on parties will to be enforced. Once deployed, the smart contract code cannot be undone, an effect derived from the immutability of BSC.

Usually, blockchain enterprise solutions are executed in a permissioned (i.e. private) blockchain, where the information is shared with a particular group of stakeholders, which is a specific feature of this kind of blockchain. Unlike permissionless (i.e. public) blockchains, the permissioned blockchains allow faster and cheaper transactions because of their limited number of participants, allowing parties to

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rapidly achieve consensus in order to approve transactions.

In this context, this paper proposes an exploratory study to analyze and create a new solution using BPMS and blockchain technology in an integrated manner. To implement such solution, twelve different workflow tools were identified and analyzed, whereas only one was selected to develop a blockchain integrated solution enforced by smart contracts. To analyze and demonstrate the benefits of this solution, we have exemplified the usage of this architecture, applying it to a real processes at an Oil and Gas company.

The paper is structured as follows. Section 2 focuses on the background, while Section 3 discusses related work. Section 4 presents the comparison of BPMS existing projects and Section 5 presents the proposed solution for distributed BPMS (dBPMS), and Section 6 shows an application scenario. Finally, Section 7 presents the conclusions and future perspectives.

2 BACKGROUND

This section describes the main concepts used in this paper, such as Business Process Management suits and blockchain technology. Both concepts are fundamental to understand how they are used together to create a dBPMS, and the benefits of this solution.

2.1 Business Process Management Systems

In general, Business Process Management orchestrate the organizational resources, informational structures and business goals (Hull et al., 2016). Moreover, BPM regulate inter-organizational relationships, and guarantee the execution of tasks and decisions that yield an outcome that adds value for an enterprise (Dumas et al., 2013).

Workflows are typically applied for process modelling approach and business coordination (van Der Aalst, 2009). They usually are focused on control flows; however, in these cases, the informational perspective is ignored. As a result, instead of improving operational innovation, business agents frequently focus on what should be done as a process, instead of aiming at issues such as the data security, transparency, and data sharing. (Bhattacharya et al., 2007). Based on this perspective, many suites were developed to deliver resources to improve business process management, such as presented in (Abdelgader et al., 2013; Van Der Aalst and Ter Hofstede, 2005; Chabanoles and Ozil, 2015; Rademakers, 2012; Cumberlidge, 2007; Fernandez, 2013).

Business Process Management Systems are software tools used to allow managing business process life cycle (Meidan et al., 2017). Moreover, they are also used as a unified solution to model, execute and monitor business processes. However, each solution present different features, and deciding which one is appropriate to a particular situation can be challenging. Besides, BPMS often proposes a centralized solution and no features to deal with the lack of trust and transparency between different parties in a specific environment.

Therefore, in the following sections, we propose a new BPMS model to distribute the information without a central authority, aiming not only to improve the execution and monitoring processes, but also to store tamper-proof information. This new approach also improves the process' data and transparency to enhance trust for involved parties.

2.2 Blockchain Technology

The blockchain technology was introduced in the Bitcoin white paper (Nakamoto, 2009) as a technology to ensure transparency of the registered data, dismisses inter-party trust, and guarantee data immutability. Consensus mechanism play an essential role on the validation of the registered transactions, which influences on energy consumption and network performance. Later, other kinds of distributed solutions used this technology to enjoy all of blockchain features, such as BSC, for instance.

Furthermore, there are two different types of blockchain: (i) permissionless, and (ii) permissioned blockchains (Peters and Panayi, 2016) (Alves et al., 2018). The former is the original purposed blockchain, with no imposed limitation of the agents that can access the network or its content, maintaining public all registered data, which is distributed to the networks' node. Conversely, permissionless blockchains only allow information to be shared with selected entities, in which access to data can either be public or private to the participants, according to previous combination. The permissioned blockchains usually presents better performance than the public ones due to the smaller number of participants involved, requiring less effort on achieving a consensus.

Based on the blockchain technology, smart contracts are a representation of a contract, roles, agreements and obligations written on programming language, which are coded throughout simple if-then-else logic (Szabo, 1994) in a distributed network. It enables auto-execution of the negotiated obligations, without the need of a central authority to enforce the agreed terms; oracles present an important role in this case (Adler et al., 2018). Thus, untrusted relationships can rely on the blockchain environment to guarantee transparency between participants, self-execution of the agreed terms and reliability of the registered data, due to its consensus mechanism. Also, trust is reinforced since data is shared between the network participants and cannot be altered by them. Besides, smart contract platforms allows the development of distributed applications (dApp), which are a kind of internet application where the backend runs on distributed, or decentralized, peer-to-peer network. Also, no single participant has complete control over the dApp on the network (Prusty, 2017).

Therefore, in the following sections we explain our Distributed Business Process Management System (dBPMS) proposal.

3 RELATED WORK

This section presents some related works regarding BPM and blockchain technology. They were categorized as follow: (i) blockchain challenges and opportunities in the BPM context; (ii) Business Process Modeling Notation Systems integration with BCT to redesign governance; (iii) BPM traceability using blockchain, (iv) BPMS tools, and (v) BPMN usage for BSC modelling and execution.

The authors in (Mendling et al., 2018) present some challenges and opportunities for blockchain abstractions and heuristics development, presenting a promising direction from BPMN choreography diagrams and data-aware workflows. The combination of these two perspectives, data and process, seems to be interesting for the top-down design of multi-organizational processes. Moreover, as blockchain technology, among others, delivers immutability, data sharing management (permissioned blockchains) and no central authority, the authors cited the importance of process redesign to consider all these features while developing a blockchain-based solution. However, (Mendling et al., 2018) only highlights the discussion, and does not present any proposals.

Moreover, the authors in (Viriyasitavat et al., 2018) argues that the main bottleneck in BPM systems is the trust management, lack of transparency and evaluation. They also present three main benefits of the use blockchain technology application in BPM: (i) trust establishment by consensus mechanism and transparency; (ii) costs reduction due to the absence of a central authority, and (iii) transaction automation by real-time update and verification of the quality of service. They developed a BPM blockchain-based approach where a Solidity smart contract represents the business processes. Although the authors created a framework from this approach, it does not guarantee that the process will be executed as planned in the modelling phase.

Some approaches (García-Bañuelos et al., 2017; López-Pintado et al., 2019; Weber et al., 2016; Di Ciccio et al., 2019), have proposed frameworks and tools to translate BPMN in a BSC. For instance, Caterpillar (López-Pintado et al., 2019) and Lorikeet (Di Ciccio et al., 2019) are tools that are used to model business process and to automatically generate an Ethereum smart contract structure. Furthermore, the authors in (García-Bañuelos et al., 2017) and (Di Ciccio et al., 2019) apply the same approach using Petri net (Murata, 1989) to translate the generated BPMN process model. Although those works have developed an Ethereum smart contract in compliance with the BPMN process model, the authors do not present a relation between the modelled process and the smart contract after its first execution. In other words, once created, the smart contract is not affected by the model anymore. Unlike their solution, we developed a persistence mode using a private blockchain; hence, the modelled process will always generate data persistence on the blockchain.

Furthermore, the authors in (Meidan et al., 2017) and (Garcês et al., 2009) presents the result of a conducted survey which organizations evaluated the benefits of open source BPMS systems. The former paper presents a detailed description of each platform, describing their modelling, design, deployment, execution and monitoring. The latter presents a comparative framework based on the Workflow Management Coalition. Although the authors proposes a general feature evaluation, many essential aspects were not considered by them, such as process interoperability, document management and process validation, for instance. Furthermore, both surveys indicates the importance of quality and optimization improvement in the BPMS environment.

Finally, Prybila et al. (Prybila et al., 2017) and Meroni et al. (Meroni et al., 2019) present the blockchain technology as a provider of BPMS decentralization and BPM data distribution, respectively. The former presents choreographies when the control over process instance is shared between different companies or organizations. Moreover, the authors developed a runtime verification for choreographies by the usage of the Bitcoin blockchain. However, the Bitcoin blockchain presents limited features in comparison with smart contract blockchain platforms;

thus, the authors lost the compliance checker and the self-executed features derived from the blockchain smart contract. In its turn, the latter presents an Ethereum-based solution to store documents and IoT data on the blockchain to improve trust in monitoring artifacts (physical objects) in a multi-party business process. However, the authors did not approach the importance of assuring business data privacy policy in a permissionless blockchain.

Thus, many different approaches are proposing solutions related to the usage of blockchain and BPM to improve transparency, data availability, and to help with the mapping of the process and its functions on smart contracts. However, a solution presenting a distributed business process management system is still missing. In this sense, we identified this opportunity and developed an approach where all the information is legitimately stored. Moreover, we present an application example of our solution in order to demonstrate precisely its execution in the Oil and Gas scenario.

4 BPM WORKFLOW PLATFORMS COMPARISON

This section describes the evaluated BPMSs and why we selected one of the investigated workflow tools to develop the solution to integrate it with a private blockchain. For this task, we analyzed twelve different platforms, among open-source and commercial solutions, looking for the following requirements: (i) business process modeling tool; (ii) workflow execution with forms support; (iii) API availability; (iv) open-source project and (v) programming language for open-source projects,

First, the modeling tool must understand and orchestrate business processes; this is the initial step towards the construction of a dBPMS. Then, in order to execute the modeled processes, a workflow execution in compliance with the modeled processes is needed; besides, this workflow needs to support manners to add data directly on the platform during its processes execution. Next, the API is required to send information to a private blockchain. In this manner, we selected a set of platforms presented on our related work and analyzed them in order to make a well-based decision regarding which platform we should use to develop our architecture. Moreover, open-source projects have increasingly presented a growing impact on the software industry and have often become primary competitors to commercial software (Fitzgerald, 2006; Bonaccorsi and Rossi, 2003).

Table 1 presents a comparison between all the analysed platforms, i.e. commercial licenses and open-source. All platforms presented an API REST to integrate services and systems to their solutions. Moreover, five of seven open-source projects presented all the five required features (Farah et al., 2014). As a commercial solution, Pipefy, Wrike, Monday.com, Kissflow, and Integrity do not present details of their solution and the language code. Thus, we decided to remove these projects from our set of possibilities.

Table 1: BPM Systems Evaluation.

Tool/ Feature	BPMN	Forms	OpenSource
Pipefy	NO	NO	NO
Wrike	NO	YES	NO
Monday.com	NO	YES	NO
Kissflow	YES	YES	NO
Integrity	YES	NO	NO
Joget	NO	YES	YES
YAWL	NO	YES	YES
Bonita	YES	YES	YES
ProcessMaker	YES	YES	YES
Activiti	YES	YES	YES
jBPM	YES	YES	YES
Camunda	YES	YES	YES

We present below an overview of the five projects that fulfilled our five requirements above-mentioned, describing more details of each open-source project.

Bonita delivers BPM automation and application projects, and is composed of two parts: (i) BPM Studio and (ii) BPM Platform. The BPM Studio is a graphical interface for process and forms development; whereas the BPM Platform handles business process execution and Bonita Portal. The latter allows visualizing tasks and tracking user activity.

ProcessMaker is based on three main components: (i) business process design; (ii) workflow engine, and (iii) adapters. The BP design presents tools to map processes and business rules. Moreover, it also allows the creation of forms and the attachment of documents as input to the process. The engine is used to automate processes. Finally, the adapters are a suite of connectors to integrating external solutions.

Activiti, as all the open-sources projects presented, Activity allows users to design BPMN 2.0 environments. The process engine was developed in Java, and distributed under the Apache license. It is composed of a modeler, and Activiti engine to execute the modeled processes.

jBPM is also an open-source project written in Java. It allows the design, execution and monitoring of the business process life cycle. Moreover, it also allows the user to model business process throughout a web-based interface. Remote APIs and tasks services are also available.

Camunda delivers process automation by a BPM java-based framework, and consists of two parts: (i) Camunda Modeler and (ii) Camunda Engine. The former is a web-based application to model business processes. The latter is an engine composed of the following components: Cockpit, Tasklist, Workflow Engine, and Decision Engine, which are used to execute and monitor processes.

Although five out of seven open-source projects attended to our requirements, we had to choose only one of them, even though we acknowledge that any of the other four projects could also be used. In this sense, we have chosen Camunda, because this project presents an architecture that supports process application event listeners, classified as (i) task event listener and (ii) execution event listeners. The former allows reacting to task events, such as creation, assignment and conclusion, while the latter allows reacting to trigger events at the same time that a move is executed further on the diagram.

Furthermore, the Camunda BPMN model API enables the extraction of data from existing process definition. Likewise, Camunda Process Engine guarantees that Events are delegated to the right process application. The combination of these features created an adequate environment to integrate Camunda BMPS with blockchain technology, allowing for the registration of immutable data, high data availability and permissioned access between organizations. In the next sections, we explain in details the usage of Camunda and its architecture when integrated with a private blockchain, thus creating a dBPMS.

5 PROPOSED SOLUTION

This section describes the main concepts used to develop the dBPMS architecture, and how such architecture will work in the business process management environment with the integration of blockchain technology, thus, guaranteeing transparency, tamper-proof information and self-executed smart contracts. This kind of architecture, used to store rules, and current state of tasks in the blockchain trough BSC, was also proposed in (Smirnov et al., 2019).

5.1 Camunda BPM

Camunda BPM is a Java-based open-source platform for Business Process Management automation. Its stack is composed of the following applications:

- BPMN Workflow Engine: Used to execute (micro-)service orchestration and human task management based on the BPMN model;
- Modeler: Used to create BPMN process diagrams and DMN decision tables and deploy these workflows to the Camunda Engines;
- Tasklist: Used to perform human task management that allows users to work on assigned tasks, such as form filling;
- Cockpit: Used to monitor workflows and decisions in production to identify, analyse and solve technical problems.

Moreover, Camunda BPM also offers a REST API to interact with the engines and allows the integration with external applications. Besides, in order to handle the workflow execution, Camunda BPM offers the possibilities to write Delegation Code, a Java Code to execute external applications, scripts or evaluate expressions when certain events occur during process execution by the Execution Listener. It can attach any event in the normal token flow, for instance, the start and end of a process instance, activity, gateway or event.

The Execution Listener is an external Java-class that should implement the *org.camunda.bpm.engine.delegate.ExecutionListener interface*. When the process, event, gateway or activity occurs, the *notify* method notifies the listener implementation to store the information in the blockchain. It allows variables manipulation and log creations of all completed steps by process instances; thus, the listener implementation can call a blockchain Hyperledger Fabric node and persists JSON objects with all the variables of any process. Therefore, the listener can make requests to external systems and manipulate the variables within the BPMN elements.

5.2 Hyperledger Integration

The integration of the proposed BPMN solution with Hyperledger Fabric is rather simple, but still powerful enough to bring forward the benefits of a blockchain distributed system.

The Hyperledger Fabric environment consists of permissioned distributed nodes that execute smart contracts. These contracts are specifically built to register and manage information created by the BPMN solution. The BPMN system communicates with the blockchain nodes using Javascript clients and the appropriate Hyperledger SDKs. These clients act as intermediaries to the blockchain network to allow interactions with the smart contracts. All execution and data generated from these interactions are distributed to the blockchain network; hence, the stored data becomes immutable and auditable.

Moreover, Hyperledger Fabric is a permissioned blockchain where smart contracts are executed on controlled and access-restricted communication channels. In other words, only specific and authorized participants can interact and access transactions on a particular channel. Thus, these channels can be used to effectively maintain private information between participants of the system, allowing for data governance and provenance.

5.3 dBPMS Proposal

Business Process Management Systems (BPMSs) are sophisticated tools that are able to model, execute, coordinate and monitor business processes. BPMS aims to handle the relationship between one or more parties as a centralized system. However, BPMSs do not provide any external guarantee of data integrity or immutable log record. All BPMS listed (see section 4, Table 1) used a traditional centralized database to store the transmitted information. Therefore, we propose a blockchain-based solution applying critical blockchain features.

The integration between Camunda BPMS and Hyperledger private blockchain result in a trusted and distributed BPMS. Figure 1 depicts the proposed solution. Initially, the Camunda Modeler is used to design the BPMN 2.0 business model in a web-based interface, available at any web browser. Then, the Camunda BPM platform orchestrate and executes the designed processes.

Furthermore, the BPM platform is composed of two main steps. The first step aims to generate tasks and assign them to users. The second aims to execute tasks according to the designed business process rules. The transmitted information is stored in a traditional database. Camunda supports MySQL, MariaDB, Oracle, IBM DB2, PostgreSQL, Microsoft SQL Server and H2 databases.

Camunda BPM developed a delegation code that allows for the execution of external Java code, scripts or the evaluation of expressions during the process execution. There are four different types of delegation code: (i) Execution Listeners, that can be attached to any event within the normal token flow; (ii) Java Delegates, which can be attached to a BPMN Service Task; (iii) Delegate Variable Mapping, that can be attached to a Call Activity, and (iv) Task Listeners which can be attached to events within the user task life cycle.

Thus, we applied the Execution Listeners to allow the blockchain data persistence. Camunda Listener is responsible for storing sensitive business information on the Hyperledger blockchain. This ensures the trustworthiness of registered information and strict

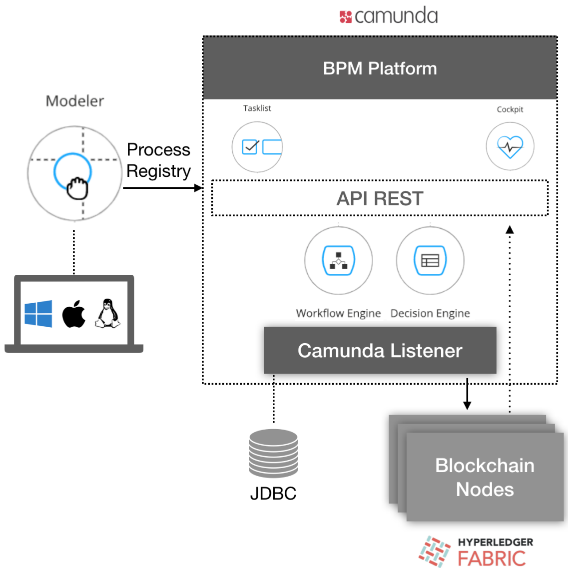

Figure 1: Distributed Business Process System.

adherence to business rules for all participants. Since Hyperledger creates and executes blockchain smart contracts in the distributed environment, there is no need of a central authority to validate the registered transactions on the blockchain.

Figure 2 depicts our Hyperledger architecture. There are three different nodes types on our Hyperledger Fabric network. The Orderer nodes maintain consensus of all information in the system and they are the pillar to the entire blockchain system. They are responsible for organizing data creation and sharing throughout the network. On the other hand, Peer nodes maintain and execute smart contracts. They are oriented by the Orderes to maintain consensus and consistency of contracts data.

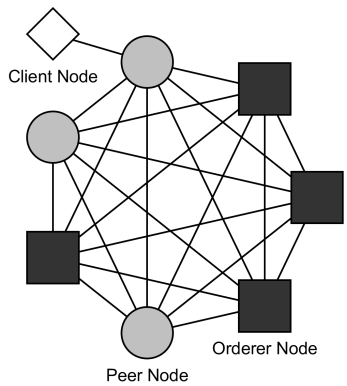

Figure 2: Hyperledger Architecture.

Our application uses smart contracts, that run on these Peers, to register BPMS log data. Moreover, Client nodes act as interfaces between the blockchain

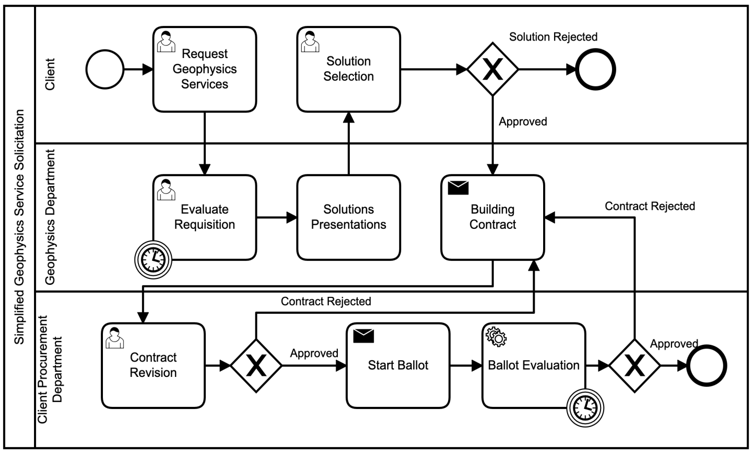

Figure 3: Simplified Geophysics Service Solicitation Process.

and external systems. They are used in our solution to provide the link between the BPMS and the blockchain. Clients interact directly with nodes to consult, call and create smart contracts. All other nodes, i.e., Orderers and Peers, can communicate freely between themselves.

Furthermore, Hyperledger Fabric implements the concept of communication channels. These channels restrict smart contracts execution and data access to specific Peer nodes. In our application, this is used to maintain private information between participants that need to interact, but do not want to expose all data transacted to everyone in the network.

Hyperledger Fabric also allows simple integration with various modern programming languages. The used integration consists of an interaction between a blockchain Peer node (through a Client node) that validates transactions and creates smart contract calls, and external applications. In this manner, the Camunda Listener is able to execute smart contracts commands in the Hyperledger Fabric network, persisting, consulting and changing data. The blockchain smart contract ensure self-execution of the agreed obligation embedded on code. Moreover, this kind of platform, private blockchains, also allows data sharing, privacy management, and fast transactions, which is often vital to the business. A positive aspect of this application is that polices related to which information should, or not, be stored on the blockchain can be defined by each application context, following the company's security guidelines.

Moreover, in order to integrate other BPMSs, we also have saved the information metadata generated from the BPMS process execution in the blockchain, the class *HyperledgerLoggerListener.kt* shows how it was made[1]. This metadata allows further different BPMSs integration, since they will be able to query the blockchain data and recreate the objects used in a Camunda BPM Platform.

In summary, the decentralized backend and the data immutability are important elements to assure high availability, secure and transparent systems. Combined with blockchain smart contracts, such systems are able to provide the ecosystem with these characteristics.

6 USE CASE: GEOPHYSICS DATA ACQUISITION PROCESS

The proposed example scenario was developed on the Oil and Gas context, specifically the geophysics data acquisition, which is a familiar scenario in this sector. In order to evaluate the pros and cons to explore a specific block, the geophysics department is requested to evaluate the project availability.

The simplified scenario involves three actors: (i) client, who is asking for the geophysics data; (ii) geophysics department, and (iii) the client purchasing department. The client and its purchasing department are untrusted external entities, so all parties actions need to be transparent, and all exchanged information must be immutable and available for auditing.

To attend to these demands, the Geophysics Department developed a standard workflow to deal with external data requisition that guarantee data reliability of registered information. Figure 3 depicts the simplified business process created in Camunda Modeler. The Camunda Tasklist was used to execute the modelled process and allow users to perform their actions,

[1]All the source code changed and created from scratch in this project are available in our repository. Repository Link: shorturl.at/etyC1 (visited on 18/03/2020).

such as fill up the forms and contracts.

As presented in Figure 3, the process starts when a client request geophysics data, by filling up a form with a detailed description of the wanted data. Within seven days, the Geophysics Department must evaluate such request and present in a workshop their solutions to acquire the data. After the presentation, the client has to fill up the acceptance form with the selected solution and confirm their interest in pursuing the acquisition data. Then, the Geophysics Department creates a service contract and send it to the client purchasing department. If all clauses comply with the requested service, a ballot is started to get the acceptance of the managers. Next, the ballot evaluation process is executed by a simple voting smart contract system in two weeks. If the managers decide to accept the contract, the process will end. Otherwise, they must send the rejection notes to the Geophysics Department to generate a new contract.

All the process information, i.e., forms, contracts, and acceptance letters, were stored on the blockchain in an encrypted manner, using many Hyperledger Fabric nodes, some inside the organization, and others outside, in the cloud. This procedure ensures data transparency and auditability. Moreover, in the Cockpit, managers are able to monitor and follow the process anytime.

Therefore, the developed scenario presents the use of the proposed solution from modelling a process to executing and storing the process data on the blockchain. Any department inside the organization can use the dBPMS solution, and more parties can be added in this process, including external ones, with no need to implement changes to the proposed architecture. Furthermore, all data transmitted and stored are immutable and available for the selected participants. This is possible due to the permissioned blockchain architecture.

7 CONCLUSION AND FUTURE WORK

This paper proposes an approach to distributed BPMS data through the use of blockchain technology to improve multiple parties process orchestration, process transparency, and allow tamper-proof registries. Moreover, the proposed architecture also ensures the reliability of business process information. In order to select one BPMS to develop our solution, we analyzed the BPMS state of art and selected the most appropriate solution, according to our goals.

The main contributions of this research are: (i) the BPM Systems evaluation, where we listed commercial and open-source platforms, and (ii) the proposal of a Distributed Business Process Management System (dBPMS) to deliver blockhain features to the business process management environment. The former is described in detail and an analysis of the core business of each application is presented. The latter is also described and exemplified by a case study in the context of the Oil and Gas industry, specifically, the geophysics service data acquisition process.

As future work, we aim to develop a middle interface layer between the Listener and the private blockchain to allow different blockchain-base solution, instead of a specific one. Although the presented work allows the storage of information on the blockchain, an interesting improvement would be the other way around, where the BPMS request information from the blockchain to rebuild the previously executed processes..

Another future work is related to the development of a data visualization tool to apply process mining techniques to improve the process performance. Moreover, despite the model design, new modelling entities considering the blockchain features could be developed to improve the BPMN representation.

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