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A Broker-based Manufacturing Supply Chain Integration with Blockchain: Managing Odoo workflows using Hyperledger Fabric Smart Contracts

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Abstract.

Nowadays, Blockchains are considered the go-to solution when it comes to secure and trust-ensuring platforms for critical data exchange. However, integrating this technology with existing systems is quite a challenging task as there is an unclear path to achieve the integration. Usually, the main motivation behind integrating blockchain with information systems is the fact that it ensures trustworthiness, security, and traceability by design. In this paper, we investigate the integration of this technology from an information system perspective in the context of manufacturing supply chains. We propose a proof-of-concept of a manufacturing supply chain scenario integration between Odoo (Supply Chain processes) and Hyperledger Fabric (blockchain development platform). We demonstrate how Odoo workflows can be optimized, secured, and made trustworthy using smart contracts and highlight the impact of this solution on current and future applications especially in the Industry 4.0 context where data is an abundant and critical resource.

Keywords: Product Lifecycle Management, Blockchain, Supply Chain Management, Odoo, Hyperledger Fabric

1 Introduction

Product design and manufacturing involve a lot of actors interacting with each other in a supply chain scenario to manufacture a product. These manufacturing supply chains are designed to be used both to exchange goods as well as services between these actors. However, complexity often increases exponentially, and effectively managing the smooth communication between these actors and securing their transactions becomes a rather complicated task. Often, issues related to traceability, transparency, sustainability, trustworthiness, and efficiency arise in highly collaborative scenarios involving many actors.

Blockchain Technology, which has proven itself in the financial technologies sector and logistics, is a collaborative platform that ensures transaction security by design using advanced consensus and cryptographic mechanisms. It has the particularity of enabling peer-to-peer trust without having to rely on a third party or a regulatory body. Blockchains come in a lot of types where we can find fully public blockchains often used with cryptocurrencies and permissioned (private or consortium) blockchains used frequently in enterprise and industrial applications.

The particularity of these supply chains is that they often involve a lot of participants interacting with each other to manufacture a product. Issues such as intellectual property, delays, product quality are directly tied to the efficiency of collaboration with these actors. In traditional systems, it is often exceedingly difficult to track and pinpoint communication issues. However, the blockchain has proven itself as an architecture that solves such challenges by design.

Blockchain technology has a lot of benefits but lacks the ability to easily adapt with existing collaborative platforms especially in the industrial sector where it is often considered disruptive and having a lot of potential [1–3]

Blockchain is being integrated into a lot of applications related to supply chain, manufacturing, etc. However, the general observation is that this integration is not a straightforward task due to the nature and the complexity of existing platforms. Indeed, most of the platforms were design using a centralized architecture and shifting to decentralized ones is cumbersome and difficult.

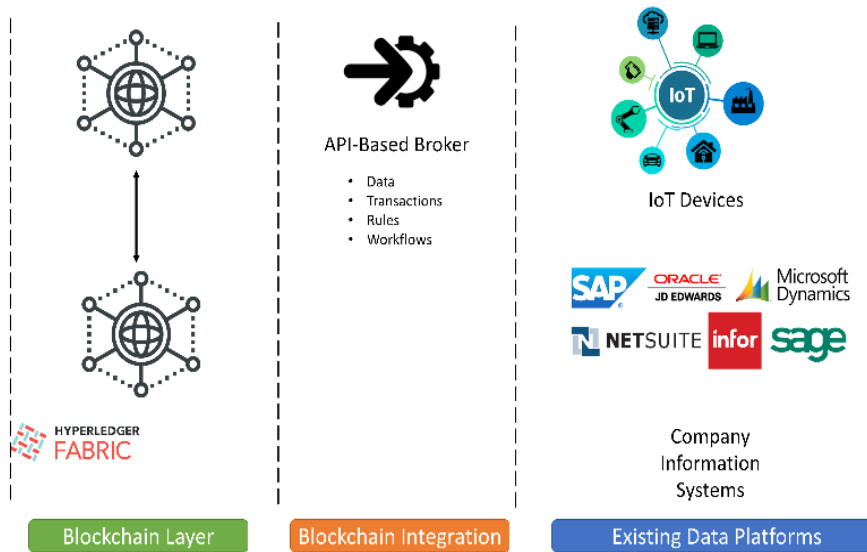


Fig. 1. Integration of Industrial Information systems highlight

In this paper, we investigate the integration of the blockchain technology through Hyperledger Fabric Smart Contracts with industrial applications focusing on the Odoo Framework under which PLM and Supply Chain processes and activities could be developed and personalized. We mostly focus on a broker-based integration which

consists of a software component that is integrated with the Odoo interface and communicates with the blockchain network to manage Odoo workflow processes using customized smart contracts. We present our proof-of-concept which is based on an exemplar small-scale manufacturing supply chain and demonstrate how can blockchain be integrated into this scenario (See **Fig. 1**).

The remainder of this paper is structured as follows. In section 2, we present a state-of-the-art overview of related works on blockchain integration in the context of industrial applications. In section 3, we present our integration method for integrating blockchain through Hyperledger smart contracts with the open-source Supply Chain/PLM platform Odoo. The choice of this platform was mainly due to its openness and the availability of its documentation. However, such integration should also be possible with platforms allowing API integration. We draw our conclusion in section 4 and highlight a set of future challenges.

2 Related Work

Since its success in FinTech, blockchain has been considered a disruptive technology in many fields due to its benefits which come by design. In industrial applications, it has been successfully used as a platform for IoT device management as it ensures the security of sensor and device data from end to end [4, 5]. Blockchain had been the subject of many contributions related to smart manufacturing and industry 4.0. Indeed, blockchain is now considered as an enabler to effectively implement and enforce the united nation's sustainable development goals in modern companies [6].

Numerous contributions studied the integration of blockchain with various aspects of supply chain management. A review of recent applications involving blockchain in the context of supply chain management was presented in [7]. In [8], the authors present a novel blockchain-based application to maintain productivity in the context of automotive spare parts manufacturing. The authors of [5] study the integration of blockchain, Internet of Things, and machine learning for enhancing quality control in smart manufacturing. The authors of [9] study the impact of blockchain integration with supply chains in the context of additive manufacturing. In [10], the authors perform an empirical study involving blockchain integration on operation management and manufacturing and present a detailed analysis of potential drawbacks and obstacles that prevent its effective integration. From a more practical point of view, the authors of [11] present a novel blockchain-based service composition model called Block-SC in the context of cloud manufacturing aiming at providing an efficient collaboration platform of service composition. In [12], the authors present a new blockchain-based shared manufacturing framework enabling peer-to-peer resource sharing while preserving trust using a smart contract network and a proof-of-participation consensus mechanism. A blockchain-based architecture of cyber-physical systems in the context of manufacturing was presented in [13]. A contribution name "ManuChain" investigated the combination of a permissioned blockchain model with a holistic optimization model.

In the context of supply chain management, numerous applications have been proposed. The authors of [14] presented the use of design tools and ontologies to develop

blockchain-based supply chains where they translated traceability information into smart contracts to enforce the domain constraints. In [15], the authors proposed a model of integration between supply chains and blockchains. The authors of [16] proposed applying blockchain technology to architect an industrial platform powered by a product-centric information management system. A study of blockchain integration with aircraft parts supply chain was presented in [17]. The authors used a blockchain, not only for traceability, but also for parts usage and performance monitoring which positively impacted safety and data integrity.

Blockchains are very resilient platforms that have multiple advantages in collaborative applications. Unfortunately, a lot of work has to be undertaken in order to achieve a smooth and seamless integration. There seems also a lot of interest to integrate this technology in manufacturing and supply chains as it enables a whole wider spectrum of applications and opens the way for peer-to-peer trust. The usual direct benefits of integrating and using this technology in an enterprise environment are:

- *Privacy*: If the solution is not designed properly, making the data public could result in data leaks.
- *Negative impact*: the integration with blockchains has the potential to improve performance and secure the data. However, the failure to integrate properly can result in opposite outcomes if the risks are not addressed.
- *Stakeholder resistance*: stakeholders using traditional supply chain platforms may resist the adoption of blockchains.
- *Local regulations*: in some countries, the usage of blockchains can be restricted to some domains or types of applications.

3 Broker-based manufacturing workflow management through smart contracts

In this section, we present our proposed architecture as well as a proof-of-concept integration between an established small-scale manufacturing supply chain and a permissioned blockchain. As it is known, most industrial information systems are based on a client/server architecture where information and processing are centralized. This has some advantages but presents various risks related to security, availability, and trust. Indeed, systems such as ERP, PLM, WMS and TMS are some of the highly collaborative industrial applications and yet their information is somehow centralized [18, 19]. Blockchain, since its revolution in the financial sector, was considered a disruptive technology as it renews or redefines the concept of trust between peers and introduces new mechanisms for establishing peer-to-peer transactions while ensuring security among other benefits through concepts such as consensus, etc. Our solution shifts the management of business workflows from a centralized ERP platform (Odoo) to a distributed blockchain platform (Hyperledger). This means that the tracking of a transaction is more robust and also all transactions are final (See **Fig. 2**). In the following, we present details of our solution by presenting its design principle, architecture, studied proof-of-concept as well as some tests and evaluations.

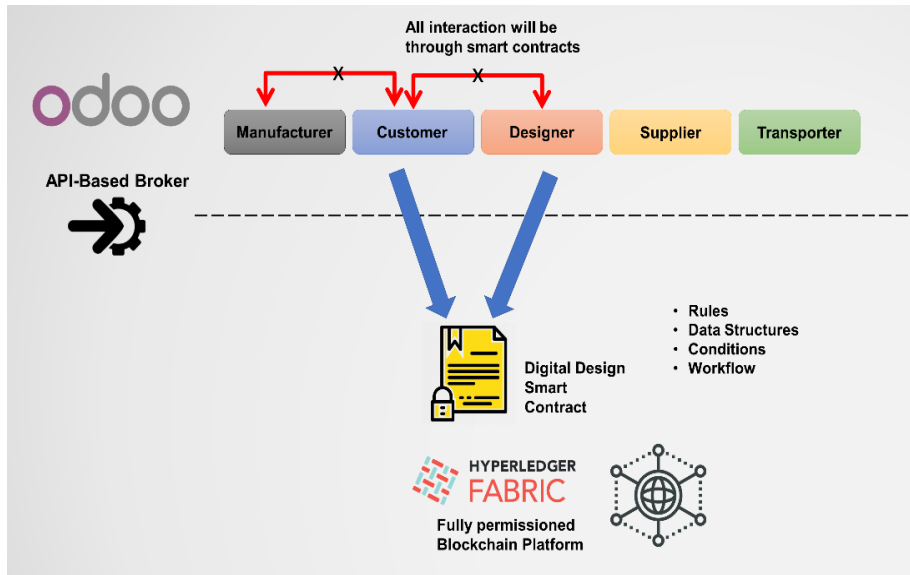


Fig. 2. Integration higher-level architecture

3.1 Architecture and Design

When analyzing blockchain frameworks such as Ethereum and Hyperledger, it turned out that these frameworks, in addition to providing core blockchain transaction concepts and data storage, provide a rich and a well-established programming interface allowing to run the decentralized transactions through smart contracts performing changes to blockchain data.

Our goal through this paper is to manage the supply chain workflows as well as the transaction in the Odoo ERP/PLM framework using Hyperledger Fabric smart contracts. However, to ensure the soundness of the system and to guarantee the integrity of data when combining both platforms, there needs to be a one-to-one mapping between the data and the business logic in both platforms. This can be achieved using one of our proposed integration strategies. The first strategy (see Fig. 3) assumes that a fresh implementation of an industrial information system such as an ERP will be established and thus maintains interoperability between both platforms by design. It uses a common data model regrouping rules and data structures written in a markup language such as XML or JSON. A translation module is implemented in each platform, a library written in Python is used in our example with the Odoo ERP platform, and another one written in JavaScript for Hyperledger.

The second strategy (see Fig. 4) assumes that both platforms are independent from each other and a software component called an “Integration Broker” acts as a messaging platform between both systems. This broker can be compared to an API but it implements advanced functionality and does not perform actions by itself. Instead, it connects to the blockchain via the Hyperledger JavaScript SDK and provides a RESTful API which is used by Odoo to interact with the Hyperledger smart contracts.

In our proof-of-concept, we only included our second integration strategy based on the Integration Broker. The first strategy is currently under development and will be subject to our future work.

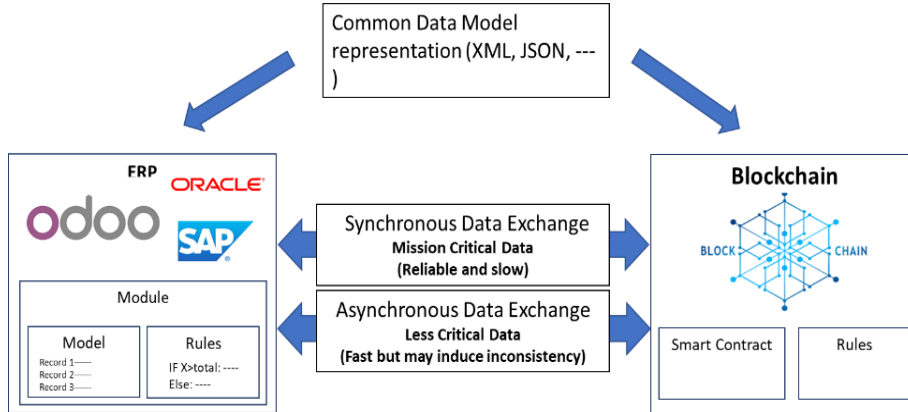


Fig. 3. Common Model Integration Architecture

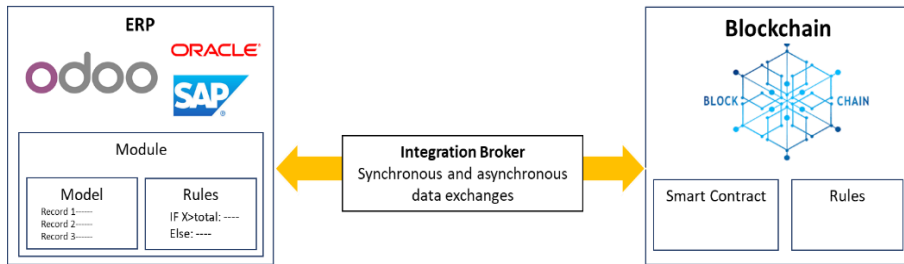


Fig. 4. Existing ERP Integration Architecture

As per the workflow management, we concluded that managing workflows in both platforms can be risky and might induce errors due to communication issues and trust challenges. In our integration, all critical workflow management happens through the blockchain using smart contracts. For each workflow, a smart contract involving the collaborating actors and making all necessary data controls is established and instantiated following the steps highlighted below:

- 1- Assuming that transaction or workflow processes have been already established and coded in a smart contract template (JavaScript used in our experiments with Hyperledger), the smart contract is instantiated between the collaborating actors.
- 2- Following instantiation, the information is naturally broadcasted to all blockchain nodes (by design). All participating nodes have the same blockchain data (Data + Smart contracts). A strong consensus mechanism manages the consensus of the data. No further modifications are possible to the structure of the contract other than the ones defined before the instantiation.

- 3- The workflow process is managed using the methods and procedures defined in the smart contract template. These methods, when triggered, are executed in all nodes, and the consensus is preserved by design.
- 4- When the workflow is completed, the contract will be still instantiated in the blockchain, no further action can be performed including the deletion of the contract or the data, as all blockchain transactions and data are final.

The following figure (**Fig. 5**) summarizes the data flow between the integration framework components.

Following the definition of the design principle and the establishment of a small supply chain to develop our proof of concept, we established the integration using the broker-based solution as it is more suitable for existing ERP installations and is more straightforward in terms of implementation. Although we already started working on the Common meta model solution, it turned out to be much harder than the broker-based one in terms of implementation and will be subject to our future contributions.

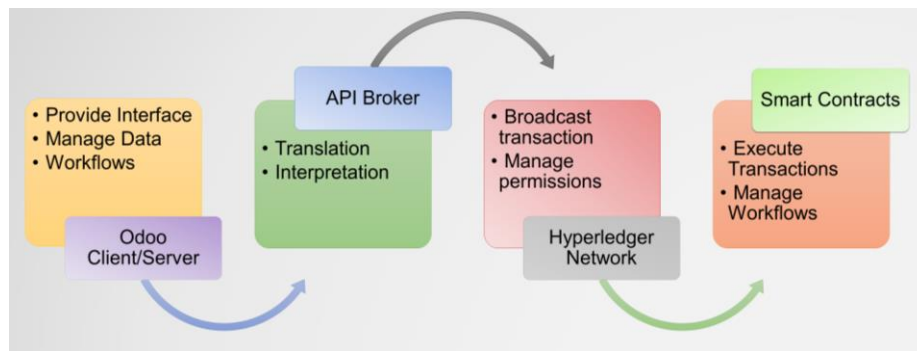


Fig. 5. Integration data flow

3.2 Proof-of-concept

As discussed before, we selected the Odoo open-source platform as an industrial information system and the Hyperledger Fabric as the blockchain platform. We established a small manufacturing supply chain scenario involving 5 actors being: Customer, Manufacturer, Designer, Transporter, and Supplier. These actors are collaborating in order to make a product. **Fig. 6** represents a diagram of this supply chain.

All actor interfaces are implemented in Odoo. However, the transactions that are undertaken between actors, which traditionally should be undertaken in Odoo, are performed in the blockchain using smart contracts. Odoo only interacts with the blockchain and triggers critical transactions. All communication between Odoo and HyperLedger is performed using A broker component implemented in Node.JS which conveys all the transactions that will be executed in the blockchain using smart contracts from Odoo. The broker relies on the Hyperledger JavaScript SDK for connecting the broker to the blockchain network. A RESTful API was established to allow secure and reliable

communication between Odoo and Hyperledger Fabric. This API implements all the necessary security tools to allow communication between both platforms.

All client interfaces for workflow management were adapted to get use of the API broker. **Fig. 7** shows the Odoo Interface for the design contract between the customer and the Designer. The interface implements all the usual UI elements such as lists etc. The Transaction state is the most obvious data field that only gets changed following an invocation of the smart contract associated with the task.

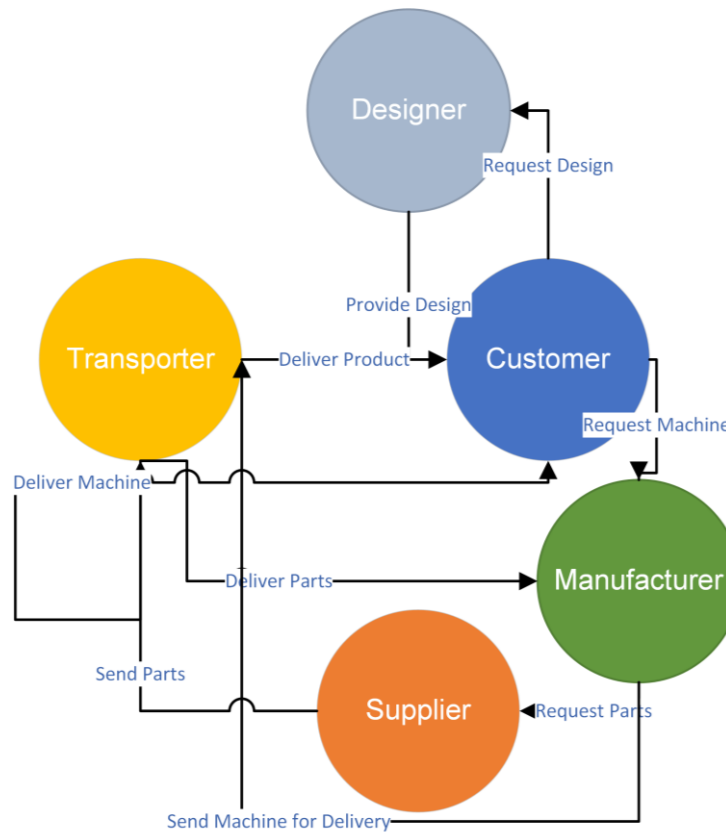


Fig. 6. Proof-of-concept supply chain

The screenshot displays the Odoo Designer interface. At the top, a navigation bar includes 'Designer' and roles: 'Customer', 'Designer', 'Manufacturer', 'Transporter', and 'Supplier'. Below this, the page title is 'Provided Designs / customer.design,103'. A toolbar contains buttons for 'Edit', 'Create', and 'Action', along with a page indicator '13 / 13'. A secondary toolbar features colored buttons: 'Notify ack' (blue), 'Start Working on design' (yellow), 'Send Quotation' (orange), 'Send Invoice' (red), and 'Deliver design' (green).

Design details are shown in a grid:

Currentstate	4: Started working on the design	Designer	New Design
Description	A ticketing machine	File Name	
Customer	Housseem	Design Code	AU-1234567
Resquest Date	23/04/2021		

Below the details is a table with columns 'Item ID', 'Description', and 'Quantity':

Item ID	Description	Quantity
Softcopy design	A softcopy of the design	1
Hardcopy design	2 hard copies of the design	2

The bottom portion of the image shows a PDF viewer displaying a document titled 'Product Design Specification (PDS)'. The document includes revision history:

- Revision 00: Original specification released for Glasgow SUS summit (RAJ, Aug 03)
- Revision 01: Updated specification following comments from LIGO SUS group and LIGO 1 alignment team (Jan 04)

A photograph of a complex mechanical structure is visible in the center of the PDF document.

Fig. 7. Odoo Interface

As depicted in **Fig. 7**, we can see the interface allowing interaction with the design workflow. The current state of the design is a value that is controlled by the smart contract deployed in the blockchain. The colored buttons control the state of the design contract. Switching from a state to another is conditioned by business logic rules that are enforced in both Odoo and the Smart contract to ensure the soundness of the system. As an example, the design cannot be moved to the delivered state unless a file is attached. This is enforced in Odoo to notify the user before the action is sent to the blockchain, and if by any chance the restriction in Odoo is not enforced due to an issue or due a tampering attempt, the smart contract will not shift to the delivered state if a file is not attached. Additionally, as can be seen in **Fig. 7**, it is worth noting the UI element displaying the PDF file of the design was customized by us. **Fig. 8** shows the Kanban view of the designs organized by their status.

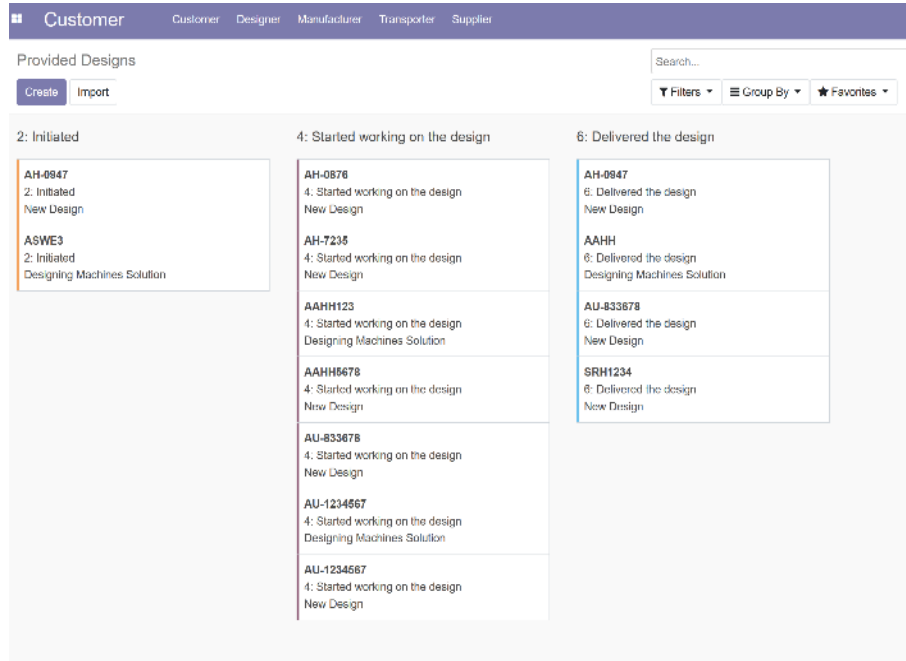


Fig. 8. Designs Kanban View (Status from the blockchain)

3.3 Tests and evaluations

To test and evaluate our proof-of-concept, we implemented the complete workflow of the interaction between the Customer and the Designer in our small-scale supply chain. In the following, we present the typical workflow of providing a design between the designer and the customer following a request to issue a design coming from the Customer. The actor performing these actions is the Designer. The contract which is named "Design contract" has 6 states, 3 of which are highlighted in this example (2: initiated, 4: Started working on the design, 6: Delivered). The other states are intermediate states or exceptions. A rule stating that the contract cannot move to the final state (6) unless the design includes a file is included in the smart contract.

1. The **first** step highlighted in Fig. 9 is the initiation of the contract by the customer.

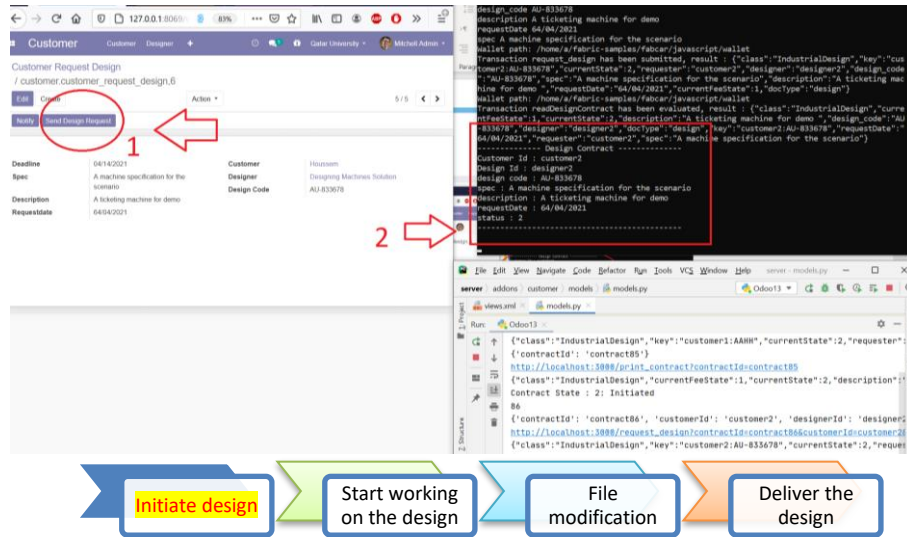


Fig. 9. Customer initiates the design

- The **second** step highlighted in Fig. 10 is the contract state from the perspective of the designer after he acknowledges it and clicks “Start working on the design” button.

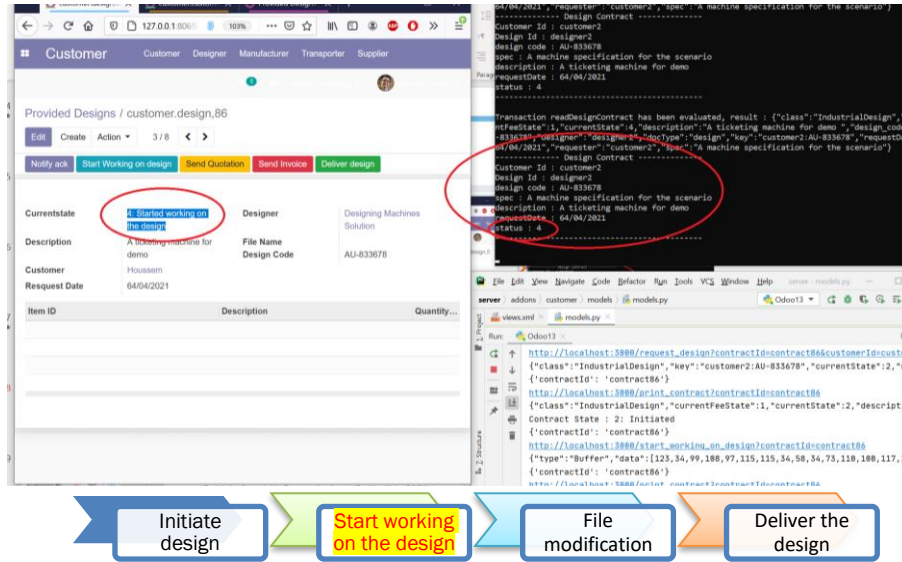


Fig. 10. The Designer starts working on the design

- The **third** step highlighted in Fig. 11 is the design edition interface is where all the information, as well as the file, are added.

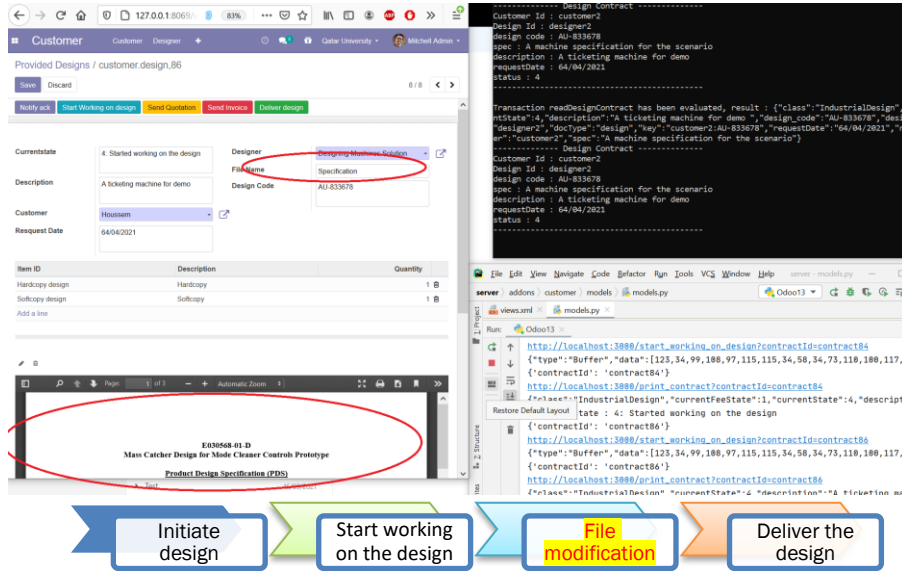


Fig. 11. The Designer edits the design and add the file

4. The final step which is highlighted in Fig. 12 is the final step where the designer delivers the design.

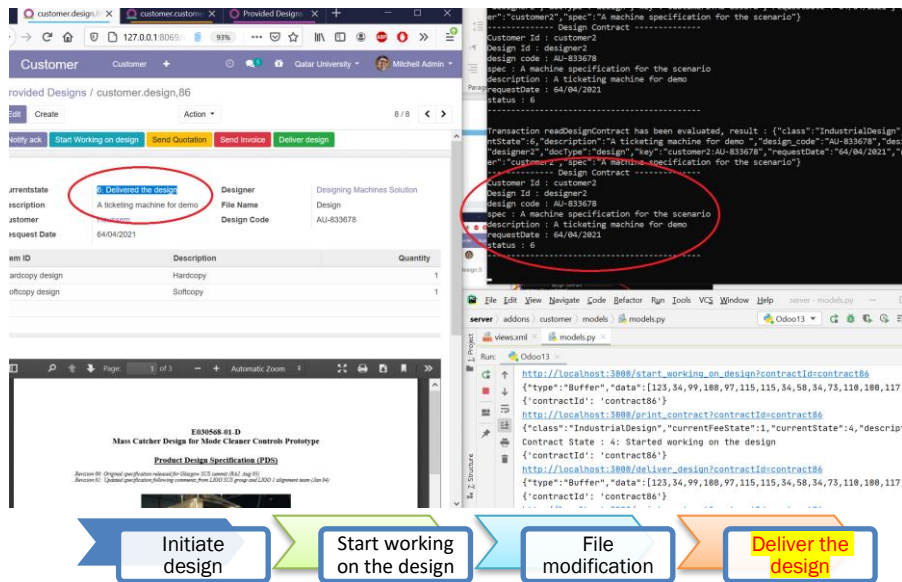


Fig. 12. The Designer delivers the design

As per the evaluation in terms of time. Adding an extra software component indeed adds more complexity. In the synchronous mode and depending on the integration strategy in the API broker, the average delay to get a commit from the blockchain in Odoo (Bidirectional path) takes between 0.5s and 2.0s. This can be seen as tolerable in some cases but in other cases, it cannot be acceptable. In asynchronous mode, the system has the same transaction execution time as by default. However, Odoo will commit transactions independently from the blockchain. Data integrity checks comparing the state of the data between Odoo and blockchain are used to spot any synchronization issues. We concluded that synchronous mode, which commits data in the blockchain making Odoo depend on 100% from the blockchain, is suitable if the additional wait time of 0.5 to 2.0s is tolerable or if the application is very critical. The asynchronous mode does not provide the same level of confidence as actions are committed in each platform independently although a data integrity checking component is present to check the synchronization between each platform.

4 Conclusion

Blockchain's impact on manufacturing and industrial applications was compared by some people to the wheel invention. This disruptive technology showed its potential in revolutionizing product design and manufacturing in many ways. In this paper, we were interested in ways to integrate this technology with industrial information systems such as PLM, ERP, WMS, etc. We presented a broker-based integration of blockchain smart contracts with industrial workflows. We used Hyperledger Fabric as a permissioned blockchain platform to store the transaction data and manage the lifecycle of smart contracts. Hyperledger Fabric was mainly selected as it is an open-source platform used extensively in the enterprise environment. As for the information system, we used Odoo which is an open-source framework written in Python. We presented our proof-of-concept integration with a scenario of a small-scale manufacturing supply chain involving a limited number of actors and demonstrated that the Odoo workflows can easily be adapted to be fully managed using smart contracts thus increasing the security, enhancing the traceability and trust of critical business transactions. We highlighted the fact that we have two main integration strategies although we only presented a broker-based one. The integration based on the common meta-model (Interoperability) will be subject for our future works.

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