Smart Contracts for supply chain applicable to Smart Cities daily operations

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***Abstract*— In Smart Cities, an era of technology and on-demand offerings, being able to have a signed contract in the least amount of time possible can significantly benefit business operations. This project focuses on the Document of Understanding (DOU) contract oriented to supply chain operations, which forms the basis for the relationship between a consumer service and the provider of that service. The sign off of this process is currently too long; opening an opportunity to apply Blockchain as a solution. For this task, we have used local resources, applying design thinking and agile practices to create a local Blockchain Ledger. Consequently, we created a proof of concept Blockchain demo, which holds the complete detailed history of the agreement, with immutable transactions and transparency, adding security and privacy of the participant's information. With this demo, we registered the time needed to have the DOU contract signed off by everyone involved in the process, and it was drastically improved. The innovative contribution of this project is the application of Blockchain to our business activities, improving business operations, and giving us a real-time view of all the information. As a result, when combining our work methods with the latest technology, we have all-around improvements in business operations. Now with a successful trial run of the application, we can confidently apply smart contracts in day to day activities in a Smart City; it can be replicated in other areas that manage sensitive information and financial reports.**

Keywords*— *Blockchain, Smart Cities, Smart Contracts, Document of Understanding, Design Thinking, Agile

I. INTRODUCTION

In today's era of technology and on-demand offerings, being able to have a signed Document of Understanding (DOU) in the least amount of time possible, before the due date has passed, can significantly benefit business operations. A DOU forms the basis for the relationship between a consumer service and the provider of that service, the current process causes long loops of emails requesting changes, approvals and generates a large number of DOU versions, that can result in distrust for the client and confusion for the Team [1].

Within the business operations of today, we know that a well-executed DOU would positively impact areas like Logistics [2] and supply chain, tackling some of the perceived pain points; by improving this contract, we can improve the supply chain business process by taking advantage of the new technologies and opportunities that come with Smart Contracts processed by the Blockchain [3]. The Blockchain is a decentralized, distributed, digital ledger that generates transparency of the transaction records, and enhances security by having the information updated through consensus. It also improves the traceability of all items back to its origin and increases efficiency and speed versus traditional paper-heavy and email processes. It will improve customer service by enhancing supply chain visibility, and customers always want full transparency of their deliverables at all times.

Blockchain enhances security and confronts the problematic of cyber-attacks and security threats, by conciliating security and privacy of personal sensitive information. Now more than ever, it is essential to have the privacy of all information, and Smart Contracts helps get us there. Having the DOU signed off as soon as possible in a Smart Contract setup, making sure to not exceed contract deadlines, helps to comply with Government Regulation as well, these imposed by federal, state and local authorities; and once in full compliance in time and form, the doors to operating within Smart Cities open, enabling the application of Smart Contracts at all business levels [4].

Now in our workplace, a group of volunteers gathered together to create a Blockchain Guild. And in our sessions, we explore areas of opportunities in which we can apply this technology. First, we took into consideration the difficulty of the event, then brought into account what we can deliver with the local resources at our disposal. As a result, we found a great opportunity working with smart contracts, particularly with the

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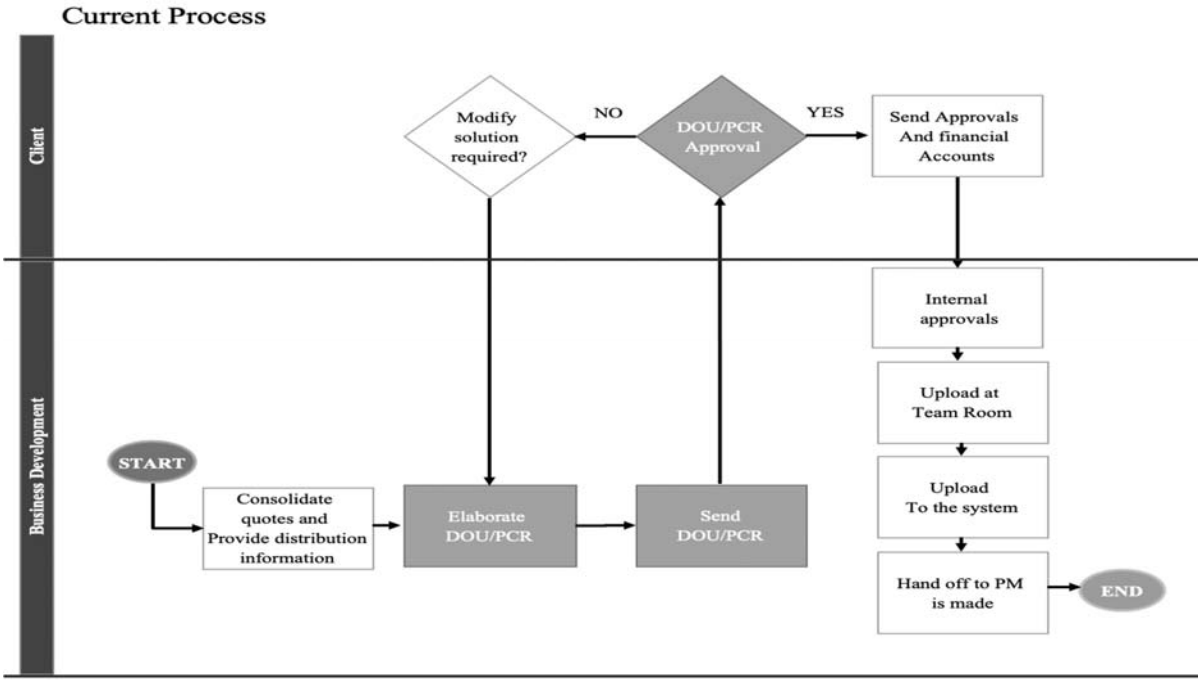

Fig. 1. Flow chart of the current contract signoff process.

Document of Understanding. In our deep dive into Blockchain education, we have discovered numerous papers and publications regarding this technology, which has helped us and guided us to understand the dos and don'ts within this environment.

II. Problem Statement

In this work, we are interested in showing that the DOU can be supported by small business and commerce, such as services, restaurants, and supermarkets in the Smart Cities. To do so, we are presenting our methodology to manage the DOU's development as well as the tests to realize.

As previously mentioned, we only used local resources to create our Blockchain solution, along with Design Thinking [5] and the Agile Methodology [6]; these are our day to day tools, and so we decided to use the tools we know and that delivers results. To better understand the complexity of the current process, we mapped the process out in the following flow chart, seen in Fig. 1.

We first start with consolidating quotes and the rendering of the distribution information. With this input, we continue with the elaboration of the DOU, and depending on the client's request, we also incorporate product change requests within the contract. In the following step is where we have our most significant pain point, a long cycle of reviews, modifications, and approvals. Once we can exit this cycle, the process becomes straight forward and less time-consuming. The contract flows to the final approvals phases and is then handed off to project management, reaching the end of the process.

III. Materials and Methods

To build our Blockchain network, we installed Hyperledger Fabric on Intel-based servers running Red Hat Enterprise Linux 7. These servers are equipped with the necessary resources to start our Blockchain network, with two cores running at 2.60 GHz, four terabytes of hard drive storage, and connected to a 1 Gbps local area network for fast transactions for the interaction with the cloud [7]. By adopting cloud computing, all the participants involved in this process will always have quick, secure, and easy access to the latest version of the contract [8]. It is essential to mention that these are dedicated servers for performing Blockchain operations; we have isolated all other factors that would interfere with the run results of our application. Adding that this Blockchain network will not have a central point to store and control information, because the servers share the responsibility on the network. We have created a Blockchain decentralized network where the devices are working together to help the ecosystem function, and have information recorded and interchanged between participants.

For the methodology, we implemented design thinking, to identify the specific problem and opportunity, which are the most critical factors for success. We targeted the time it took to have a signed and approved Document of Understanding. As a Blockchain guild, we gathered in multiple meetings, studying the situation, understanding the real problems of the DOU's end-users, the consumer service, and the provider of that service. As a group, we converged on a single point of view, to make the best decisions. We had to understand the situation, as well as the

purpose, and how to make a difference for the end-users. In doing so, we started getting results; the ideas took form with the collaboration of the group, and the set goals were reached.

Our focus is on the user's outcome, making sure that the end-user is always in first place; this is how we measure our success, by user satisfaction. To reach success or even failure, we needed to have a multidisciplinary team, some members have a strong project management background, others have skills in communication, and other members are skilled in coding. By collaborating as one unit, we moved faster and worked smarter; we had empathy first we each other, then with the end-users; by doing so, we build our foundation of mutual trust and respect across all disciplines within the guild. These values then brought us to a restless reinvention to develop a bias towards action, to view everything as a prototype; to pursue perfection, with the humility of knowing that nothing is perfect.

Continuing with the application of Offering Management, we knew that the key to reaching the goals is a combination of Hills, Playbacks, and Sponsors, all disciplines within Offering Management. Hills are statements of intent written as significant user outcomes; they show us where to go, not how to get there. In our case, the alignment of the Hills is with intent, and by doing so, we can deliver excellent outcomes because of the shared understanding. Playbacks are times for the guild to reflect together [9], to meet and go over ideas and proposals.

In a safe and inclusive space, we gathered the extended team and stakeholders to bring them up to speed, and the intention is to have everyone on the same page. And considering that not everybody has time to attend all the meetings, we worked on not letting the teams get out of sync. It was essential to have Sponsor users who bring their lived experiences and domain expertise to the team. They help break empathy barriers, to look at it from a different point of view. Empathy can only take the guild so far since the team are not the end-users of the DOU; the guild does not specialize in filling out these contracts and run through all the approval process.

We then proceeded with design thinking and followed up the activities with Agile practices. To have a shared vision with the guild, we worked with light project charters, and worked on the backlog of stories, having a flexible scope based on the evolving requirements of the project. The involvement of the team is a crucial requirement, direct business participation, and dedicated resources is always a priority for any project, and in particular, this project, since it is a proactive goal; consequently, we came up with creative collaborations to satisfy these needs.

IV. Results

Before we started the development of the project, we had to research the technical details of Blockchain; first, we needed to understand, from a technical point of view, what Blockchain is, and how we could develop an application that uses this technology [10]. After all that investigation, we went through; we decided that Hyperledger Fabric [11] and Hyperledger Composer [12] were the two blockchain frameworks we would use to build our project. We came to this determination because they fit our project's requirements, and also, they are projects in which our organization is putting a lot of work and efforts, highlighting that Hyperledger is an entirely open-source initiative.

The next phase was choosing the architecture of the project, and we decided to have the Hyperledger Fabric and Composer platforms run on Linux servers [13], one for development and testing and the second server for production. In these servers, we installed all the images of Hyperledger Fabric and Composer in Docker containers, and all the software needed for each environment. The application itself, the User Interface (UI), would be hosted in the dedicated Cloud environment [14]; access to this Cloud platform is only within the company's intranet (private company network).

From our design thinking workshop, we started the development process and the project requirements; we generated the smart contract on Blockchain using Hyperledger Composer, this smart contract is our "Business Logic" or the rules that our blockchain platform (Hyperledger Fabric) will need to follow for our specific project, see Fig. 2.

The previous method for the DOU's approval was via email. All participants receive this email containing the contract, and when a participant had an unconformity with the DOU, this person would send an email to everyone, repeating this action every time the agreement was modified, or a participant approved the DOU. All of this was time-consuming, the chain of emails was disorganized, and the information was not precise, see Table I.

We tested the Business Logic in Hyperledger Composer Playground, with a simulated Blockchain Ledger, this lets us improve the code of our smart contract, assuring the application can perform as we planned.

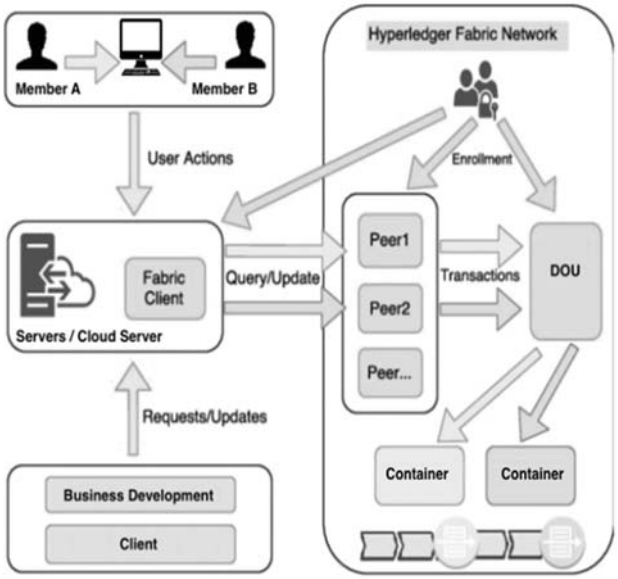

Fig. 2. Contract signoff and Collaboration Using Hyperledger Fabric and Channel for members of the DOU process.

TABLE I. CURRENT DOCUMENT OF UNDERSTATING SIGNOFF. THIS TABLE SHOWS THE PROCESS FOR SIGNOFF OF THE DOU AND THE TIME (DAYS) IT TAKES TO COMPLETE.

Consolidate quotes	Elaborate DOU	Send DOU	Modification required	DOU Approval	Send Approvals	Handoff to PM
Business developer consolidates quotes and provides distribution information	Business developer elaborates DOU	DOU is sent internally for review and approval from Project Manager, Operations Manager, and Financial Accounts	Request to modify and update the DOU	DOU received internal approval	Approved DOU is sent to Client (Project Manager, Solution Architect/Consultant, Operations Manager, and Financial Accounts) for final approval	Approved DOU by Client is sent to Product Management
3 Days	2 Days	1 Day	2 Days	2-4 Days	1 Day	1 Day

The time it takes when the DOU is sent out and is handed off to PM; up to 9 days.

With the smart contract completed and tested, we started designing and building the user interface for the application, which is an Angular 4 application with Node JS APIs as backend [15].

After deploying the smart contract in our blockchain platform, we can confirm the configuration of the Blockchain environment with the rules for our use case.

We then connect our UI to the Blockchain, so they can interact with each other, the tools provided by Hyperledger Composer lets us create a Representational State Transfer Application Programming Interface (REST API) with only one command, this API is our point of communication to the Blockchain, and we can utilize it from our Angular web application.

When we evaluated that the UI was complete and had basic functionality, we started testing the application. The tests consisted of emulating the entire approval process of a DOU many times and the usage of the different features of the application to acknowledge that every detail was operating correctly.

With the implementation of our new blockchain application, we have obtained improvements in the process listed below; these are results conducted in our test environment simulation of the production line, the improvements can be found in Fig. 3. and they are:

- *The record of transactions or changes. Thanks to the Blockchain, the record of transactions is now more precise and better organized. Additionally, any amendment, approval or modification of a DOU is only submitted to the ledger when it is a valid transaction (based on the network rules proposed and agreed by all the process participants beforehand, in consensus).*
- *Data gets isolated. Having the entire approval process handled by email caused the data to be challenging to find in an inbox full of different chains of notes. Now all the process data is in one place and well organized.*
- *Easy to audit. Since the record of all transactions is in one secure, clear, and transparent site, it's easier to audit the entire process.*
- *Traceability. Accessible to see all the transactions made to a DOU.*
- *Time. As of the reasons that have been pointed out in the previous lines, the complete process of DOU approval is faster. Approval from one participant alone takes just a few instants; see Table II.*

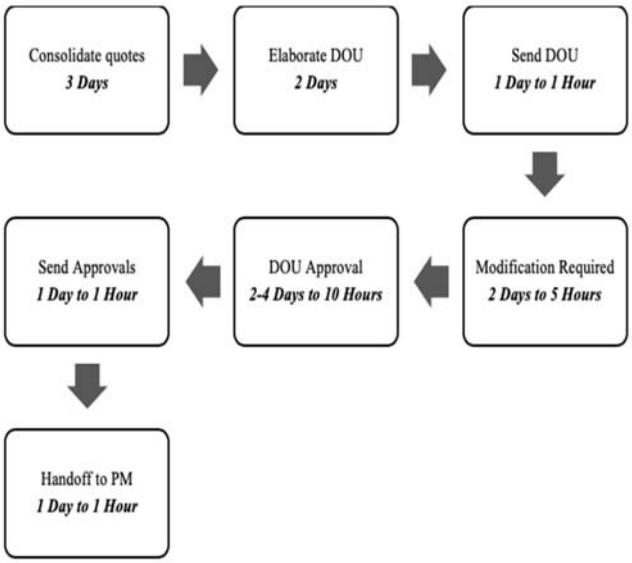

Fig. 3. Diagram with the contrast of the process for signoff, the previous method versus the implementation of the new application; we can see the improvements in times (hours/days) within each phase.

TABLE II. NEW BLOCKCHAIN DOCUMENT OF UNDERSTATING SIGNOFF. THIS TABLE SHOWS THE PROCESS FOR SIGNOFF WITH BLOCKCHAIN APPLIED TO THE DOU; WITH IMPROVED TIME (HOURS/DAYS) RECORDS.

Consolidate quotes	Elaborate DOU	Send DOU	Modification required	DOU Approval	Send Approvals	Handoff to PM
Business developer consolidates quotes and provides distribution information	Business developer elaborates DOU	DOU is sent internally for review and approval from Project Manager, Operations Manager, and Financial Accounts	Request to modify and update the DOU	DOU received internal approval	Approved DOU is sent to Client (Project Manager, Solution Architect/Consultant, Operations Manager, and Financial Accounts) for final approval	Approved DOU by Client is sent to Product Management
3 Days	2 Days	1 Hour	5 Hours	10 Hours	1 Hour	1 Hour

The time it takes when the DOU is sent out and is handed off to PM; 18 hours.

This internal benchmark is conservative, operating on only one contract permitting a higher degree of data collection. Our experiments are designed to capture the DOU process and automate it with a Smart Contract process by the Blockchain.

After we performed our due diligence, the outcome was the creation of a DOU demo. With the execution of this demo, the time typically required to review and approve the contract has shortened. We confirmed that the application of Blockchain improved traceability and efficiency of the "Modification required" phase. The request to modify and update the DOU went from various emails and numerous draft versions to one consensus contract on the ledger. Another improvement is the speed of the process for signoff; it went from over a week-long assignment to a 24-hour process, trackable with the timestamp of the operations registered on the Blockchain ledger. Due to the confidentiality of the DOU and the clients that signed this contract, we cannot share more precise details and time efficiency for the operations taken into the study.

V. CONCLUDING REMARKS & PERSPECTIVES

We derived that with the execution of the demo, the process for obtaining a signed and approved DOU is significantly reduced compared to the current process. This new timeframe has decreased from taking several days for approval to just hours. Adding to the benefits of using Blockchain, it will hold the complete provenance details of signoffs [16], modifications, and comments made by each person involved in the agreement. And these agreements are immutable because once a transaction has received an adequate level of validation, it cannot be reversed nor replaced nor edited [17]. We are also taking a step forward by providing to all participants with a clear view of a contracts' history to improve transparency in supply chain logistics for internal stakeholders [18].

All these components produce a significant improvement, although we have to take into consideration that this is a tool created by a group of enthusiasts for Blockchain, and for this demo to be picked up and implemented into production, more tests and approvals are required.

We will continue to advocate for our demo and pursue buy-ins from different areas in production. The goal is to implement our tool in a control area so that we can track and monitor performance. For this stage, we will splitter our team so that each unit is in charge of a test scenario, and this way can observe results and performance.

Once this tool is certified and approved, we can implement this application in a Smart City environment. An area of opportunity is to enhance the rental process for bicycles and scooters with Smart Contracts. One key benefit will be protecting your sensitive personal information. In every rental transaction, you share your personal information and credit card data. There is information that is not required to present in these transactions but is shared anyway.

With the Smart Contract application, you will limit the information needed and exhibit it to the small group that required such data [19]. Successful implementation of Smart Contracts in the rental process of bicycles and scooters in a Smart City will open the door to endless applications and procedures that with Blockchain can be modernized.

Considering that we have a running blockchain tool, with passing grades, we still need to go through various filters for approval to get this application into production, as previously mentioned. It is understandable, we are in a great company and have many customers and legal obligations, we cannot afford to cause downtimes for all relying on this tool and assure the delivery of services that business operations are dependent on. In the end, we will continue to endorse our tool, implement it in one scenario at a time, push to get it into production and have it as an offering for all clients. After succeeding in creating an offering of this tool, we can then move forward, targeting the implementation in Smart Cities and beyond.

In conclusion, we will work on adding more contract types and options to our tool, also making it an available to all departments interested in applying Blockchain, first improving the experience in our internal domains with a trusted method and fast application of the DOU contract, approval process, stakeholder notifications, repository, version tracking, and participants selection. Our next goals are to have an extensive option of smart contracts aimed at Smart Cities, to apply to everyday activities and with accessibility through the cloud, reducing the need to acquire more hardware and software.

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