(Short Paper) Developing a smart storage container for a Blockchain-based supply chain application

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Abstract—**Blockchain and Internet of Things are supposed to have big impact on logistics. This study presents a prototypical smart contract using smart storage containers in order to investigate the potential and the maturity of Blockchain and Internet of Things for logistical processes. A smart storage container is developed and connected to an Ethereum-based smart contract. The smart contract is based on a multi signature wallet of three parties to process the payment and arbitrate disagreements. Further research implications for the development of smart contracts for supply chains are derived from the experiences of this prototype study.**

Keywords-component; Blockchain, Ethereum, logistics, smart storage containers, material supply, supply chain, Internet of Things

I. INTRODUCTION

Logistics, transport and material supply have been named frequently as potential areas of application for Blockchain. A wide range of ideas have been proposed, such as tracking and tracing of goods [1], simplification of customs procedures [2] or detection of counterfeit products [3]. In particular, so-called 'Internet-of-Things' (IoT) devices raise high expectations to positively influence processes of logistics [4]. A DHL study estimated a potential of 1.8 trillion $ of value increase worldwide through the use of smart objects in logistics [5]. An often presented use case for these objects is the application for warehouse operations. It is expected that it will improve the tracking of inventory and accelerate the supply with new material. However, most concepts are rather ideas than existing prototypes and even less empirical evidence is available for Blockchain applications. Therefore, the purpose of this study is to build a prototype for using smart storage containers in combination with Blockchain. The objective is to investigate the difficulties and further directions for research on IoT objects for Blockchain. The study presents the existing prototype of smart storage container, which is used for triggering an Smart Contract. This provides insights into hurdles and potentials how to integrate IoT and Blockchain for logistical processes.

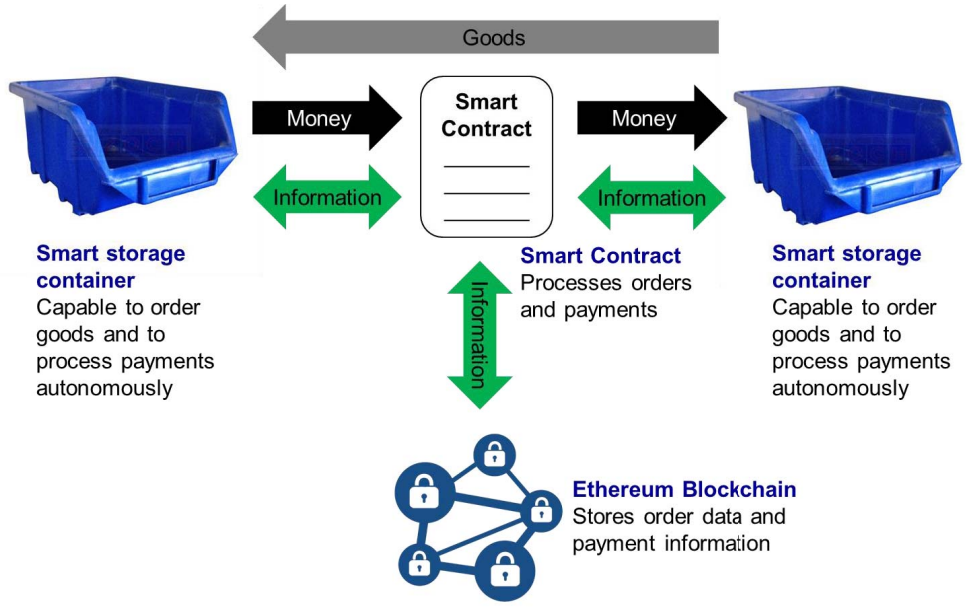

Figure 1: Concept of Blockchain application.

978-1-5386-7204-4/18/$31.00 ©2018 IEEE
DOI 10.1109/CVCBT.2018.00017

II. Related Literature

The popularity of Blockchain has led to a growing number of ideas and proposals how to use Blockchain and Smart Contracts for logistical processes. The European Parliament identifies Blockchain as a technology with impact on a number of sectors and processes; with supply chains being an important area of application [6]. A European research project, called SmartLog, investigates the application of Blockchain for the tracking of containers, but the results have not been published yet [7]. Great attention is also paid to well communicated projects, such as the collaboration of Maersk and IBM to use Blockchain for maritime transports [8]. However, especially technical details, have not been published and not all experts are convinced from the usefulness of Blockchain for the management of sea containers [9]. A study about the utilization of Blockchain in procurement processes from [10] also shows the expected potential for process improvement, but it also names a number of hurdles to be taken. The Fraunhofer Society, a German research organization, sees IoT in relation to logistics as a particularly important field for Blockchain applications [11]. IoT under the perspective of logistics is understood as a network of material flow objects, which enables the objects of this network to communicate, partly over the internet [12]. Those IoT objects are often called 'cyber-physical systems', because they combine usual logistical objects, such as containers, with computers, sensors and software to enable data collection and processing. Therefore, these IoT objects are also sometimes called smart, which will be used throughout this study. The combination of IoT objects with a Blockchain is often claimed as a good measure to improve logistical processes [13][14]. The description of a Blockchain with IoT use case can be found in [15], who present a tracking system for cold goods. However, most of the papers do not describe technically how to integrate IoT and Blockchain. This lack of experimental evidence and practical experience makes it difficult to identify obstacles and potential for further development. Therefore, the objective of this study is to investigate a prototypical Blockchain application for using smart storage containers to supply material. The result is a list of necessary developments and research topics for successfully combining Blockchain and IoT objects.

III. Developing a Conceptual Blockchain Application with Smart Storage Containers

A prototypical concept for testing a Blockchain application for material supply with smart storage containers is required. Figure 1 displays a concept, which models the flows of information, goods and money in this logistical process. Two smart storage containers are used as end-points of the process. Both containers are capable of determining and broadcasting information about its content. This enables the containers to order and to pay goods autonomously. When the content of a containers falls below a certain threshold, it orders goods from the other container. After receiving the correct quantity of goods, the payment is processed. All information about order, delivery and payment are stored in the Blockchain.

It all starts with the smart storage containers, which determine and broadcast data about its content. A photo of these containers is displayed in Figure 2. A container can take up to 10kg of weight, preferably small goods. Four weight sensors are deployed under the container. The weight signals of the sensors are summarized and processed using an Arduino MKR 1000 microcontroller. Screws were used as content of the containers. The number of screws within a container is calculated through dividing the weight by the average weight of a screw. This information is

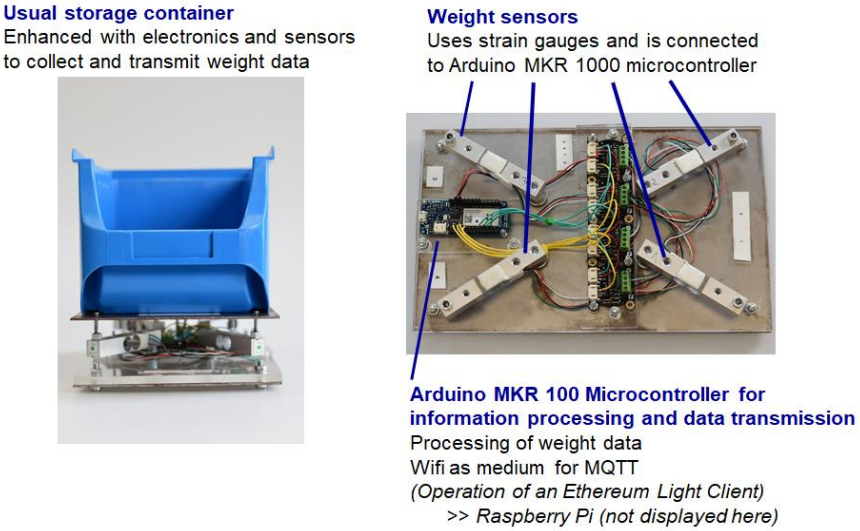

Figure 2: Prototype of smart storage container. [16]

transmitted using the Wifi sender of the Arduino MKR 1000. Later in the project, this Arduino board became a problem, because of its limited performance. At the time of the project, it is not possible to run an Ethereum Light Client on this Arduino MKR 1000, because it does not provide sufficient storage and processor performance. To overcome this, a Raspberry Pi computer was installed to the container.

The overall architecture of the concept, including the smart storage containers, is displayed as a UML diagram in Figure 3 and shows all building blocks and the relationships among each other. MQTT is used as a protocol to transmit these information. It is a publish / subscribe protocol, which allows network participants to broadcast information under certain topics, which can be subscribed from other parties. MQTT is standardized under OASIS and further information about the technical details can be found in the official documentation [17]. Suppliers can now subscribe to the topic of several containers, which broadcast order requests over MQTT. These broadcasts are fed into the supplier backend, which can manually or automatically accept and process orders. Once an order is accepted, this information is transferred to the smart contract, which is stored in the Ethereum Blockchain. The Ethereum Blockchain nodes are set up manually on virtual servers in a test-network and one for each smart storage container, all separated from the internet. The smart contract receives information about (1) the acceptance of an order, (2) the planned delivery date, (3) the order amount of goods and (4) the recipient of the goods. The payment is triggered, when the reception of an order is detected in the weight data of the ordering smart storage container.

The payment of the order is organized using the multi signature function of the Ethereum Mist wallet. Once the buying container receives the delivery of the ordered goods, it sends money to the multi signature wallet. Three parties participate in this wallet; the buying container, the selling container and a so-called Trustee. The money for the payment is released, when at least two of the three participants agree on the payment. The role of the Trustee is to observe the payment, to mediate in case of discrepancies, like quality differences. In doing so, this Trustee acts as an intermediate to moderate the business case in the real world. Up to now, further rules and regulations for the Trustee have not been formulated. This multi signature wallet forms the prototype of the Blockchain-based supply chain application.

IV. Learnings from the Prototype

Several learnings can be drawn from the experience made during developing this prototype:

1. Suitable IoT hardware is required for Blockchain applications. Existing IoT hardware, the Arduino MKR 1000 board in this case, does not satisfy the requirements for storage and processor performance to run Blockchain nodes. This counts for Ethereum full nodes as well as for Ethereum light client. This requires roughly 350 MB of storage, which exceeds the 256 kB of Flash storage of the Arduino MKR 1000. To overcome this problem, a Raspberry Pi computer has to be added to the container, which increases costs beyond a reasonable level. Therefore, particular IoT hardware for Blockchain applications has to be developed.
2. Suitable software is required for Blockchain applications. As described above, already Ethereum Light Clients exceed the requirements of an Arduino MKR 1000 board. It would have been possible to develop an Ethereum Ultra Light client, but the necessary cryptographic libraries do not exist for Arduino. Hence, Ultra Light client software is

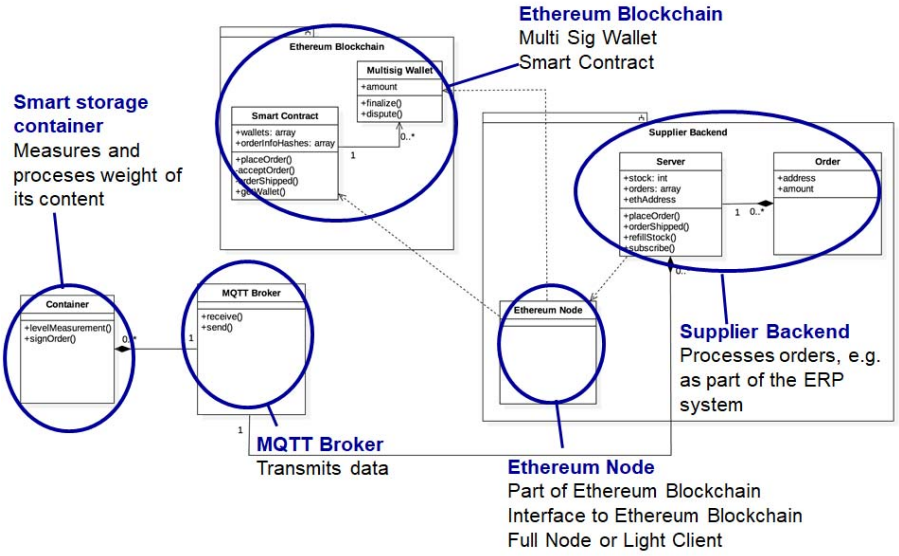

Figure 3: Architecture of Blockchain application. [18]

needed for integrating IoT devices into Blockchain applications.

3. Existing communication protocols are insufficient for IoT Blockchain applications. MQTT, which is a rather popular communication protocol for IoT, is used for this prototype. However, it requires a central MQTT broker, which is a single point for distribution of information. It makes systems vulnerable against attacks and break-downs. Blockchain-based, decentral communication protocols are needed, such as Ethereum's Swarm or Whisper [19], which are under development.
4. Blockchain applications have to be formally verified. A misuse of a smart contract for material replenishment can create a lot of damage in the supply chain. Recent hacks have shown that attacks on the overall Blockchain application can be dangerous and costly. Therefore, it is necessary to develop techniques for formally verifying Blockchain applications for supply chains.
5. The role of intermediates for Blockchain–based supply chain applications has to be redefined. The management of the multi signature wallet requires an intermediate, which is called Trustee. This Trustee decides on the payment of the delivery. However, the requirements, rights and duties of this Trustee remains undefined at the moment. More interdisciplinary research between engineering and jurisprudence is needed.
6. Scalability is still not sufficient for supply chain applications. The number of potential transactions of the Ethereum network is still too low. The throughput of the network is roughly 15 transactions per second at the moment. A complete supply chain with several thousand smart storage containers and hundreds of suppliers potentially needs more transaction throughput. Potential solutions for this problem are under development from Ethereum [20]. However, the benefit needs to be evaluated once they are available.

Putting it altogether, this study shows a prototypical implementation of a Blockchain-based supply chain application. The prototype shows both how smart storage containers and smart contracts could be coupled and which developments are needed in order to make it a use case, which is interesting for logistical companies. The potential for application of Blockchain to logistical processes is there, but there is still a lot of work to be done to make it work.

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