Improving Vendor-managed Inventory Strategy Based on Internet of Things (IoT) Applications and Blockchain Technology

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Abstract—Vendor-managed inventory (VMI) is a widely used collaborative inventory management policy in which manufacturers/vendors manage the inventory of retailers and take responsibility for making decisions related to the timing and extent of inventory replenishment. There exist several prerequisites for a successful VMI strategy implementation like information sharing, trust, systems integration and long-term collaboration. However, in nowadays logistics flows, complex processes, high number of participants and complex distribution channels impede the successful adoption of VMI strategies. In this paper, we propose a new interaction framework based on smart contracts and blockchain for governing the relationship between the vendor and the buyer. A use-case VMI scenario is presented along with a functional smart contract. Tests performed using a local private blockchain illustrate the applicability of the proposed architecture along with the significant benefits for each participant.

Keywords—Vendor Management Inventory, Supply Chain management, Blockchain, Smart Contracts

I. INTRODUCTION

The Fourth Industrial Revolution is characterized by the convergence of various disruptive technologies such as the Internet of Things (IoT), artificial intelligence and blockchain. Similar to many other industry sectors, logistics is in the midst of a major technological shift. Global SC networks are being re-shaped to an unprecedented degree and at an unprecedented pace, and they are being transformed into almost complete digitized ecosystems [1], [2]. SC digitization offers unprecedented business velocity and agility as well as the creation of SC networks that are interconnected, inclusive, trustworthy and secure.

Vendor-managed inventory (VMI) is a supply chain (SC) management approach for improving multi-firm SC performance while establishing a mutually beneficial relationship between a vendor and a retailer. The key concept of VMI is that the vendor is authorized to oversee product inventory for the retailer. The adoption of VMI approaches may have significant benefits for retailers, vendors and the supply chain as a whole [3]. For retailers, VMI provides a more efficient framework for order processing while reducing operating and administrative costs. For vendors, VMI offers the necessary visibility for better demand forecasting and, therefore, more accurate inventory management. Although VMI has become a widely used tool for SC performance improvement, not all VMI implementations are successful. In fact, there exist several barriers for successfully implementing a VMI model such as SC complexity and the difficulty in information sharing and opportunistic behavior among key SC participants (which participant will reap the most benefits from VMI implementation). Other important barriers for VMI implementation may relate to security issues attributed to systems integration and inherent cost involved in managing SC intermediaries and relevant VMI processes. The paper addresses this gap in the literature by providing a distributed trustless and secure architecture for VMI implementation based on blockchain technology. In particular, an autonomous and effective back-end data sharing architecture based on smart contracts and blockchain technology for governing the relationship between a vendor and a buyer is used. A use-case VMI scenario is presented illustrating the applicability of the proposed architecture along with the significant benefits for each participant. Finally, some limitations of the developed architecture are discussed, and several fruitful areas for future research are proposed.

II. LITERATURE REVIEW

VMI has been extensively studied within the SC literature [4]–[9]. Several authors have also tried to determine the importance of critical success factors for actually implementing VMI strategies [10]–[13] along with the value of information [14] and information exchange [15] in VMI implementation. In particular, VMI has been used for optimizing market strategies within SC networks [16], reducing the bullwhip effect [17], measuring performance [18], establishing better pricing strategies [19], [20], managing backorders [21], better retailer service [22] and, finally, for improving environmental performance [23]. Some authors have also used VMI as a driver for suppliers’ selection [24] and better SC coordination [25]. An important aspect of VMI strategy relates to determining the significant benefits the various SC members enjoy for actually implementing VMI strategies [26], particularly in terms of cost [27], [28] and inventory reduction [29]. Various decision support systems have also been developed related to VMI implementation [30], [31]. VMI-related frameworks have been developed across a wide variety of sectors, like the automotive industry [32], groceries industry [33], healthcare [34] and e-commerce [35]. Regarding the methodologies applied, several authors use optimization techniques [36]–[39], simulation [40], [41] and fuzzy systems approaches [42], [43]. In addition, several frameworks include disruptive technologies like IoT applications in VMI application [44], [45].
III. INFORMATION SYSTEM ARCHITECTURE FOR VMI BASED ON IOT AND BLOCKCHAIN

Figure 1 shows the overview of the VMI-based blockchain architecture. The main actors of the system are the following:

**Vendor:** Manages inventory by proposing replacement orders or deploying smart contracts in the blockchain.

**Retailer:** Interacts with the vendor via blockchain and smart contracts, places orders or lets the vendor manage his resources.

**Delivery companies:** Their main role is to provide quality delivery according to some parameters (established in the smart contract or defined by quality policies). In addition, they can interact with blockchain to update information about products.

Therefore, a standard procedure in the case of direct vendor-retailer connection is described as follows:

1) The retailer keeps an updated track of its inventory in two ways: (i) it sends its inventory status to the blockchain periodically (e.g. daily) using well-known off-chain storage such as the InterPlanetary File System (IPFS) [46] to enable scalability, or (ii) it stores the inventory in a local database.

2) The vendor checks the inventory of the retailer via blockchain or directly accessing the local retailer DB (if they have the permission to do so, depending on the VMI model). These options are compatible with the retailer requesting an order to the vendor, like in traditional VMI.

3) The vendor detects a series of needs and deploys a smart contract with a new order to refill the retailer, according to specific conditions, periods and other information. Other participants (declared in the smart contract) such as delivery companies may update and change the status of products.

4) The retailer checks the smart contract’s contents and accepts it, confirming the transaction.

5) The vendor delivers the products to the retailer. The status of the products (e.g. location, transportation conditions, delivery times, temperatures) will be updated throughout all the SC to keep track of events.

When the products reach their final destination and are verified by the retailer, the transaction is completed. The structures, descriptions and available information can be adapted to be compliant with some directives, and thus, efficient auditability may be provided. For example, in the case of food supply, risk management systems that identify, evaluate, and control hazards related to food safety could be easily embedded within the smart contract as described above.

We provide experiments using a local private blockchain to show the feasibility of the proposed architecture. More concretely, we created an ethereum-based blockchain using [node] and ganache-cli [48], and we used truffle [49] to deploy a functional smart contract. In this regard, contents can be retrieved and/or modified only by participants with specific roles (each function is implemented with concrete permissions, e.g. using the require clause of solidity and variables such as msg:sender to check account authenticity). The code implementation is available on GitHub [50].

IV. DISCUSSION AND CONCLUSIONS

Blockchain enables a set of SC stakeholders to maintain a safe, permanent, and tamper-proof digital record of transactions, without the interference of a central trusted authority. This makes blockchain a candidate building block for a distributed SC management system, which will ensure the integrity of the SC itself. Due to its distributed nature, blockchain may simultaneously assure the availability and resilience of the SC management system efficiently. In this paper, we propose a novel VMI architecture based on blockchain and smart contracts for improving inventory policies between a vendor and a retailer. The purpose of using blockchain is to overcome certain impediments traditional VMI approaches present like lack of security, integration difficulties and opportunistic behavior. Moreover, we use a local private blockchain and a smart contract, which implements a set of functions that enable different characteristics/benefits of VMI. The proposed blockchain-enabled architecture presents other benefits, such as efficient storage management, verifiability and reduced interaction and communication between vendor and retailer, features that are translated into a notable cost reduction. Despite the aforementioned benefits, some limitations should be kept in mind. For example, our approach addresses a relatively simple SC relationship (one buyer and one retailer). Therefore, it would be very interesting to create some use case VMI scenarios in which multiple vendors interact at the same time with multiple retailers. In this case, it is expected that features of trust and visibility would be further exemplified by the use of smart contracts. In addition, despite the improvements of the blockchain and its heterogeneous applications [51], it is still not currently suitable (albeit appropriate) for storage of vast amounts of data, and many recognize that scalability is one of the main challenges to solve. In this regard, the implementation of a multiple-participants VMI approach would necessitate the processing of a large number of transactions in a relatively short period, therefore, scalability issues may arise. We expect this study to be of significant value for practitioners and researchers interested in the field of blockchain and SC applications.

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