Blockchain-Based Secured Collaborative Model for Supply Chain Resource Sharing and Visibility

Tarun Kumar Agrawal, Ravi Kalaiarasan, Magnus Wiktorsson

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Tarun Kumar Agrawal[1✉] [0000-0003-4408-3656], Ravi Kalaisrasan[1,2] , Magnus Wiktorsson [1][0000-0001-7935-8811]

[1] Department of Sustainable Production Development, KTH Royal Institute of Technology, Södertälje, Sweden
[2] Scania CV AB, Södertälje, Sweden
tkag@kth.se, tarunagraw@gmail.com

Abstract. Globalization, escalating competition, and demand for sustainable practices have required supply chain and production managers to consider various capabilities and value creation strategies for the customers. Rapid technological advancement in the current production environment calls for integrative and collaborative efforts for effective resource utilization and better visibility to gain competitive advantages. However, privacy risks and trust have always been a significant barrier for organizations' efforts towards supply chain integration. Supply chain stakeholders fear these collaborate practices might weaken their bargaining power, accelerate risk of data manipulation and result in loss of information advantages. Addressing these issues, the study proposes a Blockchain-based collaborative model for production visibility and resource sharing. It demonstrates the framework for stakeholders' interaction over a central procurement system backed with blockchain technology. The study further lays down the notion of production capacity backed smart contract rules. These smart contracts will run on the proposed blockchain network to reduce the possibilities of fraudulent transactions and capacity overbooking- leading to illegitimate subcontracting. The overall network will stimulate visibility and develop a technology-based trust among partners which ensuring sustainability by effective utilization of resource.

Keywords: Blockchain, Resource Sharing, Supply chain collaboration, Visibility.

1 Introduction: Supply chain collaboration

Recent studies highlight the importance and demand for sustainable initiatives in the production and supply chain environment [1]. Constant pressure from customers, governments, and stakeholders' groups has stimulated firms to efficiently incorporate sustainability issues into their strategic and operational planning [2]. Nevertheless, these initiatives can only lead to sustainable supply and production when all the individual firms in the supply network collaborate and integrate to possess or develop the necessary resources as requisites for realizing sustainable production and supply chain. In this way, they can facilitate environmentally and ethically sound organizational and supply chain behaviors [1–3].

Numerous studies in the past have advocated the benefits of collaborative alliances and inter-organizational resource sharing [3, 4]. Collaboration has multiple advantage: ranging from network expansion to better insights and visibility in production units, from accessing new talent, skills / techniques and processes to potentially increased productivity, better utilization of resources, faster growth and increased global reach [2, 3]. These collaborations can include both material flow and information flow. Wherein information flow includes not only the process, and product transformation data but also the knowledge creation and transfer among organizations in the forms of new products, processes and technology development [2, 3].

While it is true that many managers have attempted to form collaborative alliances with other partner organizations, such strategies are tough to implement. Usually, they fail as implementation and management of an alliance is much harder than the decision to collaborate [5]. It is found that building consensus among organizations is often difficult. As collaboration involves material and information flow, partner organizations often do not trust each other and perceive a strong risk of losing strategic/competitive advantage. They believe information sharing among partners can lead to risk of manipulated data, loss of know-how and expertise, weakening of bargaining power and information disadvantage [5]. At the same time, collaboration leads to a revelation of the whole supply network and easier tracing of unethical practices, which happens to be a major concern for dishonest partners.

In fact, lack of collaboration among partners has made the supply chain quite unsustainable. There is lack of transparency in supply chain, ineffective utilization of resources, issues of capacity overbooking - leading to illegitimate subcontracting and inefficient production planning and synchronization. Hence, there is a need for further development of digital collaborative platforms that can facilitate information sharing and develop mutual trust among partners without risking their competitive and information advantage.

In this direction, the paper proposes blockchain as a potential technology that can address the above challenges. Several studies in past has advocated blockchain application for supply chain digitalization, traceability and visibility enhancement, improving forecasting, demand based supply planning, fraud prevention, reducing negative impact on environment [6–8]. Nevertheless, [9] identifies blockchain for supply chain integration as a potential field lacking substantial research contribution. Besides, it is important to consider and examine the blockchain operations based on its applications in supply chain requirements [10]. Therefore, based on literature and understanding of blockchain technology, the study introduce a work-in-progress solution contributing to improve supply chain collaboration at operational level. It follows a pearl growth search strategy to explore literature (initiating from few sources to identify and understand appropriate terminologies that could be used in search queries) [11]. Thereafter, the paper primarily focuses on information flow between actors and illustrates a blockchain-based collaborative network that can ensure privacy of individual partner, promote visibility in the network and ultimately develop a technology-based trust among partners. Finally, smart contact rules for the proposed system has been explained that can lead to efficient resource sharing and reduce fraudulent transactions. The potential effects and consequence of the proposed solution are explained in the discussion section followed by conclusions and future research areas.

2 Proposed collaborate network platform

Based on literature, the proposed collaborate platform is presented by introducing general aspects on blockchain technology, followed by an example where two key features are described: Supply chain partner integration and Capacity based smart contract.

2.1 Blockchain technology

Blockchain is defined as:

A shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, a car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved [12].

Blockchain can be public (open to anyone and everyone with access to internet [12]. Anyone can join the network and perform transactions) and private (only authorized participants can join the network and their rights are defined by network accessibility rules) [13]. Due to text limitation, the paper explains four key features of blockchain technology that makes it unique and secure. These features play a vital role in the proposed collaborative framework. Subsequently, a detailed overview of the technology and its application in logistics and manufacturing industry can be found in [14–17].

First is distributed network, which makes it ideal for multi-tier supply chain applications where the partners are usually located at large geographical distances with limited amount of trust. It encourages partners with differences in governance rule to share essential information on a shared platform. Second, smart contract, which contains transaction rules agreed among partners, written and stored as computer programs over the network. It ensures validity of transaction and trust that that everyone is playing fairly. Third, data immutability, which is achieved through cryptographic function and block linking mechanism. It ensures traceability and accountability of each transaction. Fourth, is consensus, which is the process of reaching an (automatic) agreement among all the involved partners for each transaction by verifying it with each individual copy of shared ledger. It helps in reducing fraudulent and inaccurate transactions and overcome the Byzantine fault problem [12, 13, 18].

2.2 Blockchain-based collaborative model : Supply chain partner integration

For effective communication, a simplified example of supply chain of two suppliers (A and B) and one buyer (focal firm) the framework explains partner interactions over the network. Buyer is downstream manufacturing unit in the supply chain that procures the same kind of intermediate products from supplier A and B. It can be noted that the described network can be complicated with certain modifications and following similar network rules to fit in real case examples and/or more complex supply chain networks. Production at buyer site is highly dependent on flow of intermediate products from suppliers. In usual situations, both suppliers compete to secure more orders to keep their production running and gain more profit. This lead to over-booking of capacity, irregular utilization of resources and illegitimate subcontracting. Additional, sharing information lead to security and privacy issue.

Hence, in the proposed framework, as shown in Fig. 1, the individual suppliers can be connected over different channels over a same blockchain network managed by a focal firm, in this example, the buyer. Each channel is a subnet/subnetwork of the global blockchain network, having their separate smart contract and a shared ledger that runs transaction rules as agreement between buyer and respective supplier. Individual channels also have their own-shared ledger to recode different transactions between the buyer and supplier and ensures traceability and visibility. However, on the global network scale, each channel is connected to central procurement unit that only records and maintains shareable real-time capacity data. Thus, the central procurement unit ledger can be referred for order procurement to ensure fair and efficient utilization of resources. It can be further observed from Fig 1 that each production unit (buyer and suppliers) have an internal traceability system that is connected with sensors at each work station, tracking and recording material flow at each stage of the production system. This enables better visibility within the production unit and is helpful to identify bottleneck. Nevertheless, as shown, and if administered properly, it is not necessary to link each of these data collection points directly to a blockchain network. Direct linking can make the network cumbersome.

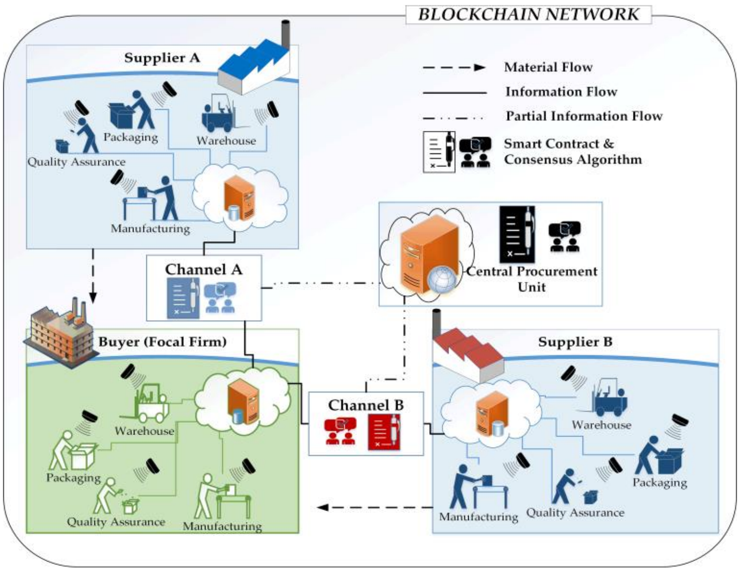

Fig. 1. A simple illustration of supply chain partners' (one focal firm as buyer and two suppliers) interactions over a blockchain-based collaborative network.

2.3 Blockchain-based collaborative model : Capacity based smart contract

A capacity-based smart contact would be an apt solution to prevent fraudulent transactions and overbooking of capacity in the proposed collaborative model. The shared ledger on the central procurement unit will connect real-time data of the capacity of individual supplier from individual channels. These real-time data, for instance, could include information related to number of operational machine, shift hours, product SAM, line efficiency, machine downtime, operators' attendance etc. Even factors related to multi criteria decisions including factors of the triple bottom line to reach the sustainability of the supply chain. In a situation of another new demand from the buyer, it will verify and distribute order according to the available resources as shown in Fig.2.

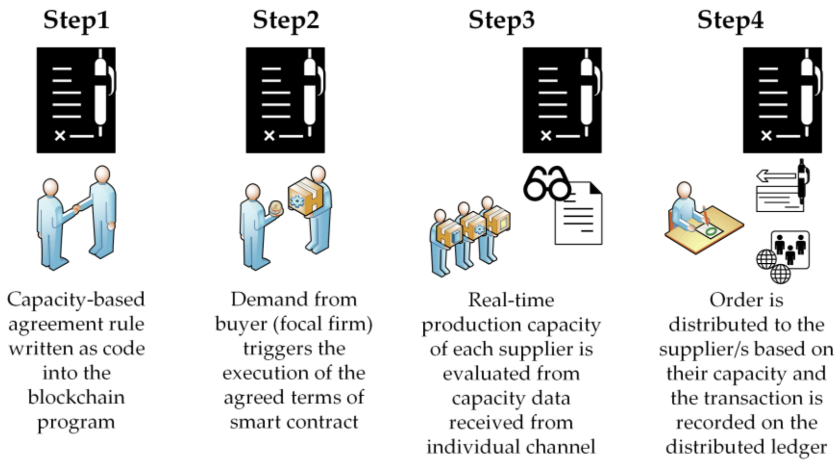

Fig. 2. Steps for capacity-based smart contract execution

3 Discussions

3.1 Characteristics of the Blockchain-based collaborative model

The proposed collaborative model utilizes the four key features of Blockchain technology, the distributed network, smart contract, data immutability and consensus. The distributed network and capacity based smart contract is explained in the previous sections. Data immutability is ensured by the cryptographic SHA function, Merkle tree and linking the chain of hashes with the newly formed block, as in case of bitcoin. A detail about the explanation about the data immutability feature can be found in [12, 13]. As the proposed model is a permissioned network, actors can only access the network based on their accessibility condition and consensus algorithm need not to be as complex as the proof-of-work in case of bitcoin. Proof-of-stake or proof-of-elapsed time can be used to test and achieve consensus among the actors. Additionally, being a permissioned network, not all actor can perform all type of task on the blockchain. For instance, an actor with read only permission can only access the distributed ledger to check the transactions, whereas an actor with write permission can read as well as record a transaction on the ledger. Similarly, only limited actors will have the permission to actually perform transactions on the blockchain. This characteristic makes the system secure but also eliminate possibility of unwanted transactions in a distributed network.

3.2 Potential effects of the Blockchain-based collaborative model

The hypothesis behind the proposed blockchain-based collaborative model is that the distributed database technology for secure data responds well to the increasing complexity of global supply chains, with high requirements on security, privacy and trust amongst actors, while still enabling high visibility and resource utilization for individual actors in the network. By the technology for secure and transparent collaboration, would the resilience and sustainability of the system as a whole increase. These performance benefits are however still left to prove, as well as specific challenges in implementing and operating the collaborative model.

By relating the blockchain-based collaborative model to the five performance dimensions of the SCOR (Supply Chain Operations Reference) model[19], performance benefits and challenges could be envisioned as briefly listed in Table 1.

Table 1. SCOR performance attribute and how the proposed model can influence them

Performance attribute	Metric description	Blockchain-based collaborative model
Reliability	Order fulfilment. (customer focus)	Develops a technology-based trust among the partners and ensure fair play. Capacity based smart contract can facilitate effective utilization of resources for on-time order fulfilment.
Responsiveness	Order fulfilment cycle time. (customer focus)	Optimum order allocation based on real time capacity knowledge can ensure quick response and shorter order fulfilment cycle.
Agility	Upstream adaptability. Downstream adaptability. Value-at-Risk. (customer focus)	Secured information sharing mechanism can enhance supply chain visibility, which facilitate swift adaptability in unforeseen situations.
Cost	Total SCM costs. Cost of goods sold.	Effective resource utilization reduces production cost.
Asset Management Efficiency	Cash-to-cash cycle time. Return on fixed assets. Return on working capital. (internal focus)	Collaboration and resource sharing helps in effective utilization of available assets and working capital (resources).Thus, helpful to attain return on investment.

4 Conclusions

Taking an example of buyer and suppliers' interaction, the paper explains a blockchain-based secured collaborative model for visibility and resource sharing. A network framework using channel /subnet has been demonstrated that can ensure security and at the same time privacy, in the blockchain network. Further, a capacity-based smart contract has been proposed that can ensure efficient utilization of resources and prevent fraudulent transactions. Thus assuring a technology-based trust among the partners in a multi-tier supply chain. The proposed model ensure effective utilization of resources, ensuring economical sustainability. It can be noted that this study is work-in-progress and in future works, the model will be complicated to include other stages of supply chain. Further, a discussion with companies could enable a first step towards validation of the still theoretical model. The proposed smart contact would be developed on an example blockchain network to test with a simulated situation of the demonstrated framework. Followed by development of a consensus algorithms that would facilitate validation and broadcasting of transactions on blockchain. Beside, further research can be carried out to identify key factors that can influence the collaborative models (including those related with social and environmental sustainability), which, can be input for the smart contract and useful for multi criteria decision making for optimum order distribution. Moreover, as data sharing among partners is a major concern due to privacy issues; therefore, the data components and their accessibility and visibility to the specific actors would be identified and segregated. Further, for coherent and seamless data communication and sharing data nomenclature would be defined.

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