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Supply chain management by blockchain

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Abstract. This paper first presents a formal model of the transactions activated in a blockchain used to manage a supply chain composed by Small-Mid Enterprises (SME). Such a formal model is based on a correspondence between the decision to be taken by a SME each time a new order is arrived from a downstream stage of the supply chain, and the formulation of a transaction in a blockchain. Based on this correspondence, a model of the blockchain management of all SMEs included in a supply chain is formulated according to the basic concepts of an event-driven production scheduling problem. The resulting blockchain model can be represented by a table showing the interactions between a provider and a consumer in terms of smart contract, thus connecting two stages of the supply chain. The transaction security is assured by secret codes of both the contract and the two actors, namely the provider and the consumer. Applications of blockchain to two SMEs operating in the agro-food sector is briefly described, thus showing the real impact of blockchain-based management in practice situations.

Keywords: Supply Chain Management, Event-Driven Scheduling, Blockchain.

1 Introduction

Recently, blockchain application appears to be a powerful tool for management in industrial sectors of particular importance for the industrial world, mainly if applied to Small-Mid Enterprises (SMEs) supply chain management. The reason for the growing industrial interest for this blockchain application is that in a supply chain a huge number of movements of materials and information take place within a network of pairs of actors, being the upstream one the “provider or supplier” and the downstream one the “customers”, and daily transactions must be managed via a very large number of contracts [1, 2]. Blockchain should guarantee the safe management of this mass of movements and relations among said actors [3].

In order to have a clear view of the two types of applications mentioned above, first it is necessary to recognize and state an industry-oriented model of how a SME, included in a supply chain, takes decisions concerning the schedule of orders received

from other SMEs belonging to the downstream stages of the supply chain itself. According to a theoretical point of view, the considered SME decision problem corresponds to an “event-driven production scheduling” one [4].

Then, a model of the blockchain transactions between two considered SMEs in the supply chain, based on the concept of digital ledgers, as well as a model of data and contract transfer in a network of SMEs (i.e., blockchain nodes) must be stated and its application be analyzed.

These two statements introduce a strong correspondence between event-driven scheduling at a SME inside a supply chain stage, and the management of the nodes of a blockchain.

Based on this correspondence, the following Section 2 will describe the event-driven scheduling problem to be solved by a SME at the arrival of a new order (i.e. from the supply chain downstream stage), when some previous orders (now denoted “jobs”) are under processing; some jobs have already been finished; other jobs are waiting to be loaded for work. Then, at the arrival of a new order, the SME has to decide which order - among those queueing - must be completed and delivered to downstream stage: this means which transaction must be activated with a downstream SME.

This aspect, in the development of any blockchain oriented to a simple application, is of particular importance, because it refers to the identification, even if approximate, of the critical reaction time for a given event [5]. In addition, the difficulty of this evaluation is increased by the desire of the blockchain manager to tend to the implementation of a zero-defect production or delivery strategy, particularly in the case of multi-stage productions [6].

Section 3 gives a new simple model of the “transaction” between a consumer and the provider. For sake of presenting a scheme of transaction easily understood by SME manager, first a basic comparison between a traditional ledger and a blockchain-used ledger is illustrated. Then, a new detailed scheme of a transaction between the two above mentioned actors is shown.

Since a blockchain transaction is represented on-line by a “block”, Section 4 will give a simplified scheme of the block transfer in the network, its approval and its linkage to a chain, such that the transaction will be registered and remain protected and permanently in the blockchain.

Section 5 discusses how the blockchain can impact supply chains by referring to two types of applications, by which a brief analysis the main problems that may arise in real situations of blockchain utilization will be shown.

Finally, Section 6 will outline some remark on the interest – but also the difficulty – of applying blockchain in industrial practice.

2 Simplified Model of the Event-Driven Scheduling at a SME in a Supply Chain Stage

In industrial practice, a SME belonging to a supply chain stage has to satisfy the orders of downstream stage customers as soon as possible, mainly taking into account

the “importance” of each customer itself. Then, it must be able to assure prompt product delivery by an effective event-driven re-scheduling of production, but without any information on the occurrence of the next event, i.e. the acceptance of customer orders for any type of products that the SME is able to manufacture. This is the case of the problem widely discussed in the paper [7], to address the re-scheduling caused by unexpected events, as well as in the paper [8], discussing re-scheduling in semi-automated assembling lines in front of rush orders events. In this second case, it would be really important to have at disposal a good procedure for predicting rush orders, such as the possibility of regulating the capacity reservation mechanism in advance [9].

Indeed, since the production of any order (denoted also job) from downstream in the supply chain requires the execution of a sequence of operations by the production resources, at the arrival time of a new order only some operations of a job have already been completed. Therefore, at that time, the “state” of any job has to be updated, where the term “job state” indicates the number of operations to be still executed to complete the job itself.

At each event time, the production reorganization at the considered SME has to be based on the new state of each jobs, then characterizing the event-driven dynamics of the production scheduling problem, as formally stated in [4].

Given any job under processing (i.e., order already received):

- to the operations already started and completed for this same job, an operation time equal to zero will be assigned;
- for the set of all the other operations, both the ones previously scheduled but not yet completed and the ones required to complete the new job, a new re-scheduling problem must be solved.

The difficulty to apply a job-shop rescheduling procedure in a SME pushes any manager to allocate jobs in the production plant by using very simplified logic, whose application seems him to be apparently useful and clear, even if frequently inefficient.

From the analysis of about 100 SMEs, settled in different Italian regions, within the PMInnova Program [10], it has been recognized the following event-driven scheduling rule [4]. Any arrival of a new order forces the manager to re-schedule by adopting one of the following criteria:

1. to decide to not modify the schedule under use, and insert the new job as the last in the queue to be processed; this rule is usually mentioned by SME managers as “weighted FIFO” or simply “FIFO” and, in some cases, as “JIT-type”, if their internal movements of parts are managed by using cards;
2. to insert the new job as soon as one of those under processing will be completed, if the customer has a good level of importance; this is denoted as “weighted clients”;
3. to allocate only biggest jobs, also considering some weights depending on the client importance and include smaller lots in a random way (denoted “random entry of new orders”).

Each one of these decision-making criteria corresponds to a type of formulating a transaction in a blockchain used to manage order-driven interactions between two stages of the supply chain.

3 Model of a Blockchain Transaction Based on Digital Ledger

In practice, blockchain is a single master book for collecting and storing the transactions of a large number of Providers (upstream stage SMEs) and Consumers (downstream stage SMEs).

Traditionally, each pair of Providers and Consumers recorded the transaction that remained indefinitely in each book on their personal ledger. In the blockchain managing a supply chain, this happens for the unique decentralized distributed “Ledger of Blockchain” with the condition that each transaction (which became a block) is associated with the Provider & Consumer pair.

An individual traditional ledger will include, for any transaction, all data referred to a purchase or a sale. A unique general Ledger managed by a blockchain will contain, besides the transaction data, also a number of keys and signatures of both the Consumer and the Provider, as well as “secret key” associated to the transaction/contract itself.

The following Table 1 illustrates a comparison between the traditional ledger of either the consumer or the provider (in the left column), and the unique ledger managed by blockchain (in the right column).

Table 1. Comparison of transaction data registered in a traditional Ledger, and data/info’s detailed in a transaction in a Blockchain.

Transaction’s information and data contained in....	
Traditional Ledger	Blockchain-used Ledger
N° transaction	Transaction code
N° document	Contract code to be stored in the blockchain
Date	Data set
Paid	
Received gain	
Transaction description/type	Transaction type
Balance (everyone has their own)	Transaction balance:
	A. Provider and Consumer public keys , as actors operating on the unique ledger
	B. Provider and Consumer signatures to identify a one-to-one transaction
	C. Secret key (Hash) computed by Provider, to make the transaction readable by the Consumer

The following Table 2 is represented in a form similar to a flow chart, where the arrows illustrate the sequence of interactions between Consumer (C) and Provider (P) for activating a transaction in a blockchain.

Table 2. Interactions between Consumer (C) and Provider (P) for activating a transaction in a blockchain.

<i>Consumer (C)</i>	<i>Provider (P)</i>
Once the desired service and the Provider have been selected by the Consumer:	
C creates: - its Signature SigC and its Public key PubC	Provider creates its Public key PubB and the digital signature SigP
1) C sends its Public Key PubC to P	2) Provider P creates a <i>smart contract</i> (SCo) and P creates a Secret Key of the contract (K)
	3) Then, Provider P compute the hash (SH) used for authentication of consumer feedback
SH is the commitment to the consumer to verify the correctness of the transaction	4) Provider P sends SH to the consumer
	5) Provider P creates the message mc (PubC, SigP, SH)
	6) Then, P appends the smart contract SCo and the message mc into the blockchain
Blockchain: Please note: This step notifies to all the other nodes of the blockchain that Consumer C asks for the service defined by the small contract SCo	
7) Consumer C checks the smart contract and approve it, by recognizing the smart contract by using mc	
	8) Provider P sees that the Smart Contract SCo is approved and send Secret Key (K) associated to the smart contract SCo
9) The contract's service type can be read, and a feedback message is created fmc (K, PubP, SH, FV) , where FV is the feedback value created together with SigC	
10) Then, Consumer C sends the feedback value Fv for the service supplied by the smart contract SCo to the Provider P	11) Provider P receives the feedback value Fv
Blockchain: For the Smart Contract SCo it will be verified:	
<ul style="list-style-type: none"> • The transactions indexed by SH; • The signatures SigC and SigP 	
And the feedback transaction is included in the Blockchain, together a time mark (Timestamp), being represented on line as a “ block ”	
<ul style="list-style-type: none"> • The smart contract SCo is closed. 	

Specifically, each arrow represents a transfer of information from one to the other actor of the transaction, thus showing the interaction between the Consumer C and a Provider P in stipulating a smart contract [11], with the additional scope of loading their contract on a unique distributed ledger, thus assuring their security through use of keys. The transaction is represented online as a “block”.

The question now is how to manage a very large number of blocks, assuring them security and immutability.

4 Models of Blocks Transfer in Network of Blockchain Nodes

Blockchain is a set of blocks, each one archiving a set of validated and timestamp related transactions. Each block includes its own hash, i.e., a non-invertible algorithmic computer function that uniquely identifies the block and allows connection with the previous block by identifying the latter.

Each transaction can be practically managed by a Smart Contract (SCo) between a Consumer and a Provider, sent to blockchain as illustrated in Table 2, and reported in the following steps:

- A. a new block to be chained is created upon the execution of the smart contract SCo;
- B. this block (i) is chained to a previous one and includes:
 - the previous block hash BH(i-1);
 - the timestamp of the transactions contained in the block;
 - the transaction;
 - the hash of the transactions (SH) referred to the Smart Contract and the book sign, i.e., BH(i) done by the block creator.
- C. the inclusion of a new block into the Blockchain it must be approved.

A simplified scheme of the transaction approval in the blockchain, as well as of the block connection to other blocks, such to create a “blockchain”, is the following:

1. Customer C wants to pay a desired service to the Provider P for the considered smart contract SCo.
2. The transaction is represented as a “block” (which could also contain other transactions to be verified and accepted in the blockchain).
3. The block is broadcast to several other “nodes” of an internet network; each node could be a server or a simple computer, all connected.
4. A selected group of nodes, or the majority of nodes in the network, will approve (or not) if the transition is valid.
5. The considered block is then added to other blocks, previously created, thus obtaining a secure record of transactions, denoted “blockchain”.
6. Provider P will then receive the payment for the transaction.

5 Blockchain Applications in Real Supply Chains

According to the previous Section, blockchain applications have undoubtedly the potential to improve the supply chain sector because they provide an infrastructure

that records, certifies and maps an asset that is transferred between often distant parts, connected between them through a chain of distribution between parties that are not necessarily bound by a bond of trust [12]. In this way, assets would be pawns that can be transferred along a chain of control that verifies over time, in an encrypted and transparent process, a transaction. The terms of each transaction would remain irrevocable and immutable, open to the control of anyone or only authorized users.

This has been verified by the blockchain application for two Small-Mid Enterprises (SME) operating in the agri-food sector, registered in the PMInnova Program [10]. For the two companies AGROCOMPANY (www.agrocompany.it) and the Consorzio dei Produttori di Piccoli Frutti (www.ciacuneo.org/frutta_verdura_piccoli_frutti.htm), the main problem is to manage a "short" supply chain to be able to implement a retail sale via e-commerce, but with a large number of small transactions.

On the other hand, if many analyses believe that one of the sectors that will benefit the most from the point of view of the consumer is the food industry, unfortunately there are examples of cases of mass contamination of food chains due to poor control on suppliers and other reasons related to production, such as excessive use of herbicides, fertilizers and various ways of storing products through incorrect freezing.

One of the most interesting initiatives to create transparent supply chains for food products in every part of their life cycle is the company Project Provenance Ltd (<https://www.provenance.org/>), which is developing a platform that, for each product or component it manages, at each point in the supply chain it details the nature (what it is), the quantity, the quality and the property [13].

With reference to the above mentioned two Italian SMEs, producing valuable agri-food products, those with a "controlled designation of origin - DOC", the applied blockchain could help to counter frauds in the sale of controlled-source Italian goods. An accurate product record could also make the managed supply chain more efficient and send food to stores faster, thus reducing waste and waste, especially by using "smart contracts" [13].

6 Concluding Remarks

The blockchain represents a new system of data distribution, extremely innovative and still little used as it is little known and detailed without a real standard, if not that of the bitcoins that have made it known. Although it is an innovative concept, it presents limits due to the lack of standards and, moreover, uses cryptographic systems that are dated and need to be evolved. Today, the cryptography of twenty years ago is still used, and the real problem is not its vulnerability but rather recognizing its authenticity of origin. In fact, it is almost impossible to attack a blockchain, but it is possible to create a false one. The problem of web security has never grown like the power of the web itself. Blockchain could distort the current concept of many servers also replicated that still contain data that are centralized and therefore very vulnerable.

However, there are some resistances to the adoption of this technology. What seems to be the biggest concern on the part of business owners is the fact that this technology is based on a public and shared ledger, which means that companies must

freely allow others to have access to information. But the fact that there is a public register does not mean that one must necessarily share everything with everyone. Blockchain technology allows to manage information in a private way, making only the directly involved parties participate. Only those authorized can access the information of a contract. Furthermore, the blockchain is a chain where the past is always a recognizable trace ("inviolability of the past"), and the blocks are always sequential and maintain the history of the whole chain ("ordering of events"), as well as being available in each node and therefore also replicated ("competition and information retrieval").

It must also be said that there is currently no standard and perhaps it is the main problem of the blockchain. It will take years, and in the meantime, each application will follow a proprietary path by dirtying the data network. To protect the privacy of the chains, the risk is of overload of the transport band and one will have to think also of a useless or obsolete chain cleaning system. The comparison that comes to mind is that of plastic: a beautiful invention but people must be able to dispose of it.

Within few years, many communication technologies will disappear, will change the professionalism, and will change the life of man as well as it has happened from the 90s to today with the introduction of the World Wide Web (www). We must remember that technology is ready: blockchain is an integral part of this technology. Keep in mind that even today a small or large reality that is without connection presents very large problems. In the near future, the connection will be essential for any small or large business, so the hope is that it is powerful but, above all, safe.

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