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Utilization Of Blockchain Technology In Distributed Manufacturing Resource Scheduling

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Abstract:

In today's world, collaborative production networks are quickly becoming the norm rather than the exception. The questions of how and where data from Internet of Things devices is saved, as well as the manner in which communication is carried out between organisations, have not been entirely answered. In this context, systems that are decentralised provide potential in comparison to ways that are centralised, particularly in terms of confidence and the security of data. One technology that has just come into existence is known as the blockchain technology. Despite the widespread awareness of the possible benefits, there is a paucity of research on the use of blockchain technology in supply chain management and manufacturing. The use of blockchain technology in distributed manufacturing is the topic of this study, which proposes a notion for such an application. The manufacturing operations are carried out on shared resources inside distributed collaborative production networks thanks to the use of smart contracts. It has been determined what the benefits and drawbacks of the suggested technique are. A case study involving various different firms that participate in dispersed manufacturing serves as the conclusion of the article.

Keywords: Blockchain Technology, Distributed Manufacturing, Distributed Scheduling.

Introduction:

Key developments in contemporary manufacturing and supply chain management (SCM) include digitalization and Industry 4.0. These trends make it possible for new technologies to be developed and lead to a full reengineering of production strategies and configurations (Kagermann et al. 2013; Rossit et al. 2018). These new arrangements are also a response to the unpredictability of the market and the extreme volatility of demand over the last several years. Enterprises in the manufacturing sector are increasingly banding together to build collaborative production networks, which allow its members to share resources inside the network (Lou et al. 2010; Renna and Argoneto 2011; Tao et al. 2017). This dynamic configuration in distributed manufacturing (DM) enables a flexible reconfiguration at any moment in response to the requirements of the market and production. However, communication and negotiation procedures in production networks continue to be a difficult challenge, and they often come into conflict with the need to swiftly react to changes in market demands. Research is ongoing in many areas, including but not limited to: where and how to store production data created by new Internet of Things (IoT) devices; how to manage safe and reliable communication between IoT devices; and how to decide where and how to store production data (Makhdoom et al. 2019). The Internet of Things (IoT) data and other complicated supply chain setups, such as collaborative manufacturing, might considerably benefit from the blockchain technology's provision of a service that could significantly boost trustworthiness. The blockchain, as a system, enables the storing of information and data in a way that is both immutable and decentralised (Nakamoto 2008). The open and decentralised design of the blockchain presents an alternative to both centralised and decentralised systems that is already in use, and it is something that should be investigated further in the context of the manufacturing industry (Li et al. 2018). Manufacturing procedures might be carried out automatically by businesses that are linked in a peer-to-peer (P2P) network using smart contracts that are stored on a blockchain. This would eliminate the need for human intervention. Although the potential advantages of using blockchain technology in business are generally recognised, there is a dearth of written material on blockchain's use in supply chain management and data management.

Theoretical Background:

Distributed manufacturing in the Industry 4.0 era:

As a collective phrase, "Industry 4.0" refers to a shift in the mindset of manufacturers toward the adoption of a more adaptable approach to the design of their production processes. Entities that operate on their own are able to communicate with one another in decentralised systems using real-time data (Kagermann et al. 2013; Tao et al. 2017). In the smart manufacturing idea, cyber-physical systems, also known as CPS, play a vital role. CPS incorporate both hardware and software aspects, have their own distinct identities, and are able to observe and interact with their surrounding environment (Bartsch et al. 2018). Within the more expansive framework of cyberphysical production systems, the shop floor is in direct connection with higher-level decision support systems. To interact, machines and their component pieces scarcely need human control (Rossit et al. 2018). The smart systems have a framework that is more dynamic than the supply chains that are already in use. This dynamic is also mirrored in the current propensity of businesses to investigate virtual manufacturing networks that integrate powerful computer systems with coordinating tactics. These networks bring both of these elements together. It is common practise to construct these networks in tandem with the more general idea of DM, which stands for geographically dispersed manufacturing in flexible networks. According to Tuma (1998) and Rodrguez Monroy and Vilana Arto (2010), these tendencies are a response to the concentration of key competencies and the intense global rivalry. It is possible to differentiate between two primary categories of virtual collaborative networks: networks that focus on short-term project-based cooperation and networks that focus on long-term collaboration with primarily independent businesses that are able to join and leave the network on their own (Tuma 1998; Srai et al. 2016). The networks are built to facilitate the quick and flexible collection of knowledge and resources, as well as the exchange of resources and skills among members of the network. The level of cooperation with businesses that are outside of the organisation itself is directly proportional to the virtual component of the system (Shi et al. 2005; Tao et al. 2017).

Issues in collaborative distributed manufacturing networks:

The functioning of collaborative DM networks is a situation that is mostly seen in capital-intensive sectors, such as semiconductor or additive manufacturing (Renna and Argoneto 2011). The high level of demand volatility causes valuable equipment to sit idle for longer periods of time, forcing them to be shared around the network. When putting together a network for collaborative manufacturing, there are a few choices that need to be made. These include deciding how and where to store production data that is generated from shared resources, as well as how to ensure that communication between entities is both secure and reliable. Both centralised and decentralised information technology systems may be used to facilitate the transfer of data and the transmission of ideas. In a network with a centralised design, one of the partners collects and keeps all of the production data, while also providing other partners with the ability to access the data. Solutions that rely on centralised data processing, whether they do so via cloud computing or more conventional information technology systems, are susceptible to a number of hazards and vulnerabilities. There are several variables to consider, but two of them are data security in relation to a centralised point of vulnerability and trust in relation to data corruption (Makhdoom et al. 2019; Casino et al. 2019). Connecting each partner to a single platform takes a lot of time and money, which is a problem that is particularly problematic for small and medium-sized businesses. The resources of the central authority are the most important factor in determining the system's availability, and they are also the one that most heavily influences the system's adaptability. In addition to this, it is very impossible to run centralised networks without creating disparities and injustices (Korpela et al. 2017; Reyna et al. 2018). When it comes to productivity and scalability, relying on third parties (such as cloud service providers in cloud manufacturing) or intermediaries might be detrimental (Yang et al. 2014; Ren et al. 2017). The Internet of Things makes these flaws even more obvious due to the fact that machines as cyberphysical systems are essentially capable of perceiving and reacting with their surroundings in whatever way they see fit. The essential benefit of the Internet of Things, which is the open connection with the surrounding environment in real time, is lost when this communication is routed via a mediator in a centralised information technology system or in cloud manufacturing (Reyna et al. 2018). In order to overcome these disadvantages, decentralised solutions are often used. Each actor is responsible for his or her own choices, and a coordinating method is used to accomplish shared objectives. The vast majority of techniques described in the research literature make use of game theory or negotiation processes; multiagent architectures are especially prevalent (Renna and Argoneto 2011). One of the most significant drawbacks of multi-agent systems is that all of the communication that takes place between agents takes place on a sublevel, making it impossible to monitor in a transparent manner. Again, trust is the most important thing, since decentralised systems in use today often lack transparency (Li et al. 2018). The frequency with which businesses say, in surveys, that a general lack of data interchange and high-quality information in networks is seen as a key issue underlines the relevance of trust and security. This is a problem because it indicates that there is a widespread problem (KPMG 2016). According to the findings of yet another poll conducted by Cognizant, just one quarter of businesses consider the level of trust among ecosystem partners to be "strong" (Das 2017). In order to provide a concise summary of the findings made, the difficulties associated with collaborative production networks and DM may be broken down into five primary categories: trust, integrity, availability, agility, and security. The currently available decentralised networks do not offer a foolproof remedy for these problems. At the very least, the concepts of security and agility, which are fundamental to the idea of DM, are most accurately represented by a network composed of dispersed nodes (Kohtala 2015). The blockchain technology allows for the management of this network of nodes as a peer-to-peer network.

Blockchain Technology:

The blockchain is basically a decentralised ledger that maintains a single record of data at a time in the form of blocks and is saved on the nodes of the network. The general public is more familiar with it due to its use in the process of doing transactions using cryptocurrencies such as Bitcoin (Nakamoto 2008). A P2P network is used for the secure communication that takes place between the individual nodes that make up the network. The nodes are spread out around the map, and there is no one node that has an advantage over the others. Transactions and other aspects of encryption are used to manage the communication. The members in the network work together to create an immutable and comprehensive ledger that is then copied across the network. Each node in the network is responsible for synchronising the data and propagating the transactions. Every time there is a communication event, a new transaction is added to the ledger. This transaction must include at least two addresses (one for the sender and one for the recipient), the message itself, and signatures. Blocks are used to store accumulating lists of transactions. Each block also includes a hash pointer that may be used to reference the block before it as well as an immutable timestamp. By organising the blocks in this fashion, a "chain" of events may be reconstructed. The blockchain makes it possible for entities for the very first time to interact and trade values and information with other entities that they do not need to trust without the need of a third party that mediates the transaction. The use of robust cryptographic techniques protects the confidentiality of all information transfers (Abeyratne and Monfared 2016; Bahga and Madisetti 2016).

To identify the current state of the ledger and come to an agreement on which transactions should be added to the ledger, a consensus method is carried out on each node of the network rather than a central authority or a mediator. This allows the network to operate more efficiently. The Proof-of-Work (PoW) consensus method, the Proof-of-Stake consensus mechanism (PoS), and the Proof-of-Authority consensus mechanism (PoA) are all widely used (Zheng et al. 2017; Makhdoom et al. 2019). The most widely used implementation of PoW requires users, known as miners, to work toward the solution of a cryptographic method in order to add a new valid block to the chain and be eligible for a reward in the form of digital currency credit. This incentive guarantees that data are constantly validated and consistent throughout the network, as well as a consistent level of performance across the network. It is important to place an emphasis on PoA within the framework of dispersed manufacturing. PoA regulates itself based on the amount of processing power used in the network, which allows for more equitable involvement among all partners (Casino et al. 2019). To generate new blocks, PoA relies not on miners but rather on a network of nodes that have been granted the appropriate permissions (also known as "authorities" or "validators"). Each new block and the consequent new blockchain are need to be signed by a plurality of authority nodes in order to be valid. Because the identification of each authority is tied to its reputation, the authorities have an incentive to ensure that the transaction process continues to operate normally and is not compromised in any way. PoA is fundamentally superior than PoW in terms of security, cost, and operational efficiency due to the fact that computationally intensive mining is unneeded and transaction acceptance latency is reduced. In addition, blocks are generated at predetermined intervals, which contributes to an increased level of predictability and stability (Parity 2019).

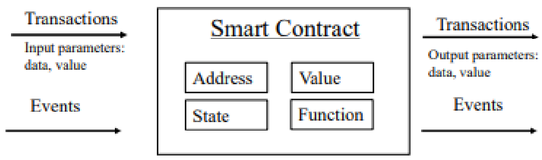

Fig. 1. Smart Contract – Structure and content (based on Bahga and Madisetti, 2016)

A Blockchain System For Resource Scheduling In Collaborative Production Networks:

A idea has been developed for the exploitation of blockchain technology in order to plan resources in collaborative production networks.

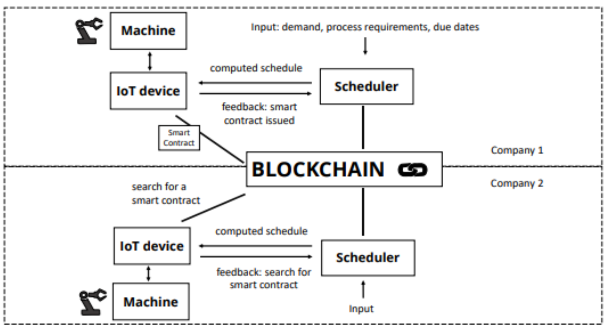

Fig. 2. IoT scheduling process using the blockchain

We are thinking about creating a production network that would collaborate with independent network partners. Manufacturing machines, Internet of Things devices, software, computer nodes, and human beings are some of the entities that are engaged. A one-of-a-kind address is assigned to each and every participant in the network. Every partner in the network has their own manufacturing facilities, which they run regardless of whether or not they are part of the network. The establishment of a P2P network amongst the machines themselves is the primary characteristic of our technology. This gives the machines the ability to interact and collaborate directly with one another. Over time, demand from customers is reflected in each organisation as an accumulation of orders. The schedule is then delivered to the machines to be processed, and the available machines are scheduled in accordance with the new timetable. Each actual machine has a connection to an Internet of Things (IoT) device, which acts as the equipment's digital counterpart. The Internet of Things device has the capability to detect the operational condition of the equipment as well as analyse the data that has been gathered. In addition to this, it is in charge of the transfer of data with the scheduling system. Each individual process capacity that must be present in a corporation is represented by an Internet of Things device that is part of the network. If an available time slot on a machine is not utilised in accordance with the schedule that was generated and the time slot is not blocked for maintenance, then the machine itself contributes to the capacity of the network. It publishes a smart contract on the blockchain that contains information on the processing capabilities available, the available time for processing, and an anticipated reimbursement for usage. The available time is the amount of time that exists between the completion of one work and the beginning of the next job that is scheduled to be executed, taking into account any necessary setup periods. Processing capabilities may be characterised in two ways: first, as the setup configuration of the machine, and second, as all sorts of processing that are executable. The consortium is responsible for determining the calculation basis for the anticipated remuneration; this basis may be relatively fixed, such as rates based on machine hours, or it may be demand-driven. In the event that a business does not have the machine capacity to carry out a process step associated with an order, the machine that is responsible for the step, functioning as an IoT device, will automatically look for an accessible smart contract that has the necessary critical data. The process of utilising the external machine capacity may be activated immediately by a transaction to the address of the smart contract if the detected data satisfies the internal requirements. This is the case only if the data matches exactly. The smart contract may also be used to begin the transportation of goods. In the event that a smart contract that was published by a machine is no longer realisable, for instance because of a flaw in the machine itself, the machine is able to generate a new smart contract in the same manner as it does when it releases capacity. Through a transaction, the new contract has the ability to activate the prior smart contract, which will result in the contract being removed from the system. The capacity of machines is only made available for collaborative use in the network if there is no demand for them on the internal side. This guarantees that each partner will be able to accomplish its own objectives and satisfy all of the stakeholders. Every business keeps complete control over its machines; the only information that must be disclosed is regulatory-mandated information on available machine capacity. The capacity-providing computers are able to begin processing immediately since it is guaranteed that they will get the agreed-upon remuneration as soon as the transaction has been confirmed (e.g. by using the underlying cryptocurrency).

Conclusion:

In this article, we provide a technique for constructing a blockchain system with the usage of smart contracts in a distributed collaborative production network by using the method of design science. This study makes use of the method of design science to achieve so. We evaluated the problems that are still present in collaborative production networks and demonstrated how the blockchain can contribute to the solution of these problems as a means of ensuring that the methodology we developed is relevant. This was done in order to provide an answer to our first research question. After that, we provided a solution to our second research question and suggested a technique for using blockchain technology in distributed manufacturing. In accordance with this, the capabilities of the approach as well as any possible advantages and hazards are provided. In order to show the usability of blockchain as a tool to schedule resources in a P2P network with maximal transparency, trust, and Internet of Things readiness, a case study is utilised in which multiple linked organisations make use of a shared resource. The proof of concept is an important phase in the research process, as it paves the way for determining the optimal conditions.

References:

[1]. Abeyratne SA, Monfared RP (2016) Blockchain ready manufacturing supply chain using distributed ledger. Int J Res Eng Technol 05:1–10

[2]. Angrish A, Craver B, Hasan M, Starly B (2018) A Case Study for Blockchain in Manufacturing: “FabRec”: A Prototype for Peer-to-Peer Network of Manufacturing Nodes. Procedia Manuf 26:1180–1192

[3]. Bahga A, Madisetti VK (2016) Blockchain Platform for Industrial Internet of Things. J Softw Eng Appl 09:533–546

[4]. Bartsch F, Neidhardt N, Nüttgens M, et al (2018) Anwendungsszenarien für die Blockchain-Technologie in der Industrie 4.0. HMD Prax der Wirtschaftsinformatik 55:1274–1284

[5]. Benkler Y (2006) The Wealth of Networks. Yale University Press.

[6]. New Haven and London Blossey G, Eisenhardt J, Hahn GJ (2019) Blockchain Technology in Supply Chain Management : An Application Perspective. In: Proceedings of the 52nd Hawaii International Conference on System Sciences | 2019. pp 6885–6893.

[7]. Casino F, Dasaklis TK, Patsakis C (2019) A systematic literature review of blockchainbased applications: Current status, classification and open issues. Telemat Informatics 36:55–81

[8]. Das S (2017) Blockchain Global Analysis. In: Cogniz. - Blockchain Glob. Anal. https://www.cognizant.com/Resources/cognizant-blockchain-globalanalysis.pdf. Accessed 10 Jan 2019 evan

[9]. GmbH (2019) evan.network. https://evan.network/. Accessed 9 Jan 2019

[10]. Feng Q, He D, Zeadally S, et al (2019) A survey on privacy protection in blockchain system. J Netw Comput Appl 126:45–58

[11]. Hevner A, Ram S, March ST, Park J (2004) Design Science In Information Systems Research. MIS Q 28:75–105

[12]. Hyperledger (2018) Hyperledger – Open Source Blockchain Technologies. https://www.hyperledger.org/. Accessed 20 Dec 2018

[13]. Kagermann PDH, Wahlster PDW, Helbig DJ, et al (2013) Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0. https://www.bmbf.de/files/Umsetzungsempfehlungen_Industrie4_0.pdf. Accessed 20 Dec 2018

[14]. Kim H, Laskowski M (2017) A Perspective on Blockchain and Smart Contracts. IEEE Work Work Privacy, Secur Trust Blockchain Technol 6

[15]. Kohtala C (2015) Addressing sustainability in research on distributed production: An integrated literature review. J Clean Prod 106:654–668

[16]. Korpela K, Hallikas J, Dahlberg T (2017) Digital Supply Chain Transformation toward Blockchain Integration. In: Proceedings of the 50th Hawaii International

Conference on System Sciences | 2017. pp 4182–4191

[17]. KPMG (2016) Global Manufacturing Outlook - Competing for growth: How to be a growth leader in industrial manufacturing. https://home.kpmg/content/dam/kpmg/pdf/2016/05/global-manufacturingoutlook-competing-for-growth.pdf. Accessed 8 Jan 2019 Li Z,

[18]. Barenji AV, Huang GQ (2018) Toward a blockchain cloud manufacturing system as a peer to peer distributed network platform. Robot Comput Integr Manuf 54:133–144

[19]. Lou P, Ong SK, Nee AYC (2010) Agent-based distributed scheduling for virtual job shops. Int J Prod Res 48:3889–3910

[20]. Makhdoom I, Abolhasan M, Abbas H, Ni W (2019) Blockchain's adoption in IoT: The challenges, and a way forward. J Netw Comput Appl 125:251–279

[21]. Nakamoto S (2008) Bitcoin: a peer-to-peer electronic cash system. https://bitcoin.org/bitcoin.pdf. Accessed 10 Jan 2019

[22]. Pai S, Sevilla M, Jerome B, et al (2018) Does blockchain hold the key to a new age of supply chain transparency and trust? https://www.capgemini.com/wpcontent/uploads/2018/10/Digital-Blockchain-in-Supply-Chain-Report.pdf. Accessed 20 Dec 2018

[23]. Parity (2019) Parity Technologies: Proof-of-Authority Chains - Parity Tech Documentation. https://wiki.parity.io/Proof-of-Authority-Chains. Accessed 28 Jan 2019.

[24]. Tao F, Cheng Y, Zhang L, Nee AYC (2017) Advanced manufacturing systems: socialization characteristics and trends. J Intell Manuf 28:1079–1094

[25]. Tuma A (1998) Configuration and coordination of virtual production networks. Int J Prod Econ 56–57:641–648

[26]. Wang L, Shen X, Li J, et al (2018) Cryptographic primitives in blockchains. J Netw Comput Appl 127:43–58

[27]. Yang X, Shi G, Zhang Z (2014) Collaboration of large equipment complete service under cloud manufacturing mode. Int J Prod Res 52:326–336

[28]. Zheng Z, Xie S, Dai H-N, et al (2018) Blockchain Challenges and Opportunities: A Survey. Int J Web Grid Serv 14:1–25

[29]. .Zheng Z, Xie S, Dai H, et al (2017) An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. In: Proceedings - 2017 IEEE 6th International Congress on Big Data, BigData Congress 2017. pp 557–564