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Toward a blockchain cloud manufacturing system as a peer to peer distributed network platform

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ABSTRACT

New emerging manufacturing paradigms such as cloud manufacturing, IoT enabled manufacturing and service-oriented manufacturing, have brought many advantages to the manufacturing industry and metamorphosis the industrial IT infrastructure. However, all existing paradigms still suffer from the main problem related to centralized industrial network and third part trust operation. In a nutshell, centralized networking has had issues with flexibility, efficiency, availability, and security. Therefore, the main aim of this paper is to present a distributed peer to peer network architecture that improves the security and scalability of the CMfg. The proposed architecture was developed based on blockchain technology, this facilitated the development of a distributed peer to peer network with high security, scalability and a well-structured cloud system. The proposed architecture which was named as the "BCmfg" is made up of five layers namely; resource layer, perception layer, manufacturing layer, infrastructure layer and application layer. In this paper, the concept of its architecture, secure data sharing, and typical characteristic are discussed and investigated as well as the key technologies required for the implementation of this proposed architecture is explained based on demonstrative case study. The proposed architecture is explained based on a case study which contains five service providers and 15 end users with considering 32 OnCloud services. For evaluation purpose, the qualitative and quantitative methods are utilized and the results show that the proposed methodology can bring more advantages to CMfg than the security and scalability.

1. Introduction

In the twentieth century, a collaboration between the Internet of Thing (IoT) and information technology, was identified as the key technological and developmental trends that are necessary for re-molding the global manufacturing enterprises [1]. Recently, IoT has been fussed into the manufacturing industry and has brought about a new type of manufacturing such as the IoT enabled manufacturing and one step forward to cloud manufacturing (CMfg) [2]. With respect to a recent scientific paper [3], IoT enabled manufacturing is explained as an advanced principle in which typical production resources are converted into smart manufacturing objects that are able to sense, interconnect and interact with each other in order to automatically and adaptively carry out manufacturing logics that are used in the cloud-based system. Recently, researchers have forecast that IoT will have a trillion-dollar impact in the industrial and manufacturing sectors. Therefore, on-demand usage and sharing of resources can be made possible by the use of the IoT technology in the manufacturing industry. The IoT enabled manufacturing was developed based on modern manufacturing concepts under the Industrial 4.0 standard and incorporated advanced technologies such as the multi-agent system, cutting-edge technology, service-oriented paradigm and other advances in artificial intelligence, and as such, highly influenced the outperformance of the manufacturing industry. The key advantages of this new manufacturing paradigm are real-time data gathering and data sharing amongst the enterprises and consumers [4].

In this way, the IoT connects more industrial equipment and parts together which leads to more data's generation; as a result, more comprehensive work data will help to ease the process of decision making within the factory. However, by expanding the boundaries of IoT and information technology-based manufacturing, an increase in connectivity will occur as well as a higher level of complexity in the computing infrastructure. As a result, many researchers have proposed CMfg as a measure to be used to cover existing drawbacks of manufacturing, this includes the complexity of computing infrastructure and service sharing by taking advantage of cloud computing, service-

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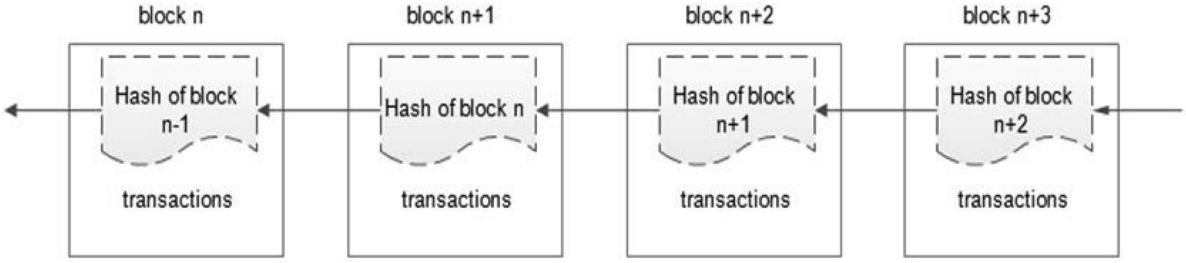

Fig. 1. Blockchain and hash of block.

oriented system and the IoT [5]. CMfg is a new service-oriented manufacturing mode that utilizes the internet and service platform to arrange manufacturing resource as well as provide service according to the end users demand [6]. Based on this definition, CMfg is a manufacturing paradigm that utilizes cloud computing and IoT to transfer manufacturing resources into the cloud environment, aiming to provide everything as a service. Therefore, on-demand service provision is a main advantage of CMfg [7]. However, this paradigm like the existing solutions uses a centralized network for communication purpose and third parts for managing. As a result, centralized network not only reduced the productivity of the CMfg but also bring flaws include scalability and a broken communication model and thus, opens the door for more vulnerabilities in the system such as cyber-attack [8]. On the other hand, in the manufacturing industry some of the physical devices are located in unsecured environments and as such, can easily be tampered with by hackers [9]. Also, data travels over a wireless network to the centralized based database which could also be a loophole in the architecture [10]. Moreover, the existing HPC and cloud-based manufacturing data sharing systems are very complex [11]; so existing HPC isn't feasible for the small and medium-size company. Hence, centralized based system support small-scale IoT networks in the manufacturing enterprise, which lack of answer to the emergent needs of an enormous IoT in the manufacturing ecosystems of tomorrow [12].

Therefore, in order to deal with these challenges, we proposed a decentralized network platfrom for a CMfg based on the blockchain technology (BC) which could be considered as the next generation of intelligent manufacturing. BC is a digital, decentralized ledger or in a simple way is peer to peer network. The concept of BC was proposed by Satoshi Nakamoto in 2008 [13]. This technology developed a distributed digital ledger of transactions that was shared amongst the nodes of a network instead of being stored on a central server. BC is capable of providing an effective solution to new manufacturing paradigms such as CMfg system, due to its abilities as follow [14,15]; A) BC stores data in the shared database as well as in the distributed and fault-tolerant database; based on these capabilities, participants in the manufacturing system are able to nullify their adversaries by harnessing the computational capabilities of the honest nodes. This makes the information that is exchanged between the parties to be resilient to foreign manipulation. B) BC is a robust architecture ward off attacks due to its decentralized network. C) BC relies on a public key infrastructure which allows the contents to be encrypted in such a way that is expensive to crack. Therefore, the proposed platform can be provided a secure and innovative data sharing solution by utilizing a decentralized and permission BC for CMfg which is accomplished by using a channel formation schema, enhanced service provision, systematic encryption and data sharing system with membership service support. The proposed methodology is developed based on the recent advancement in CMfg and fully supported to achieve a scalable, flexible and distributed network, in order to avoid the problems associated with a centralized framework. Furthermore, the proposed methodology can provide standards and protocols for implementing the new manufacturing approaches as well as resolves security and identity issues based on its advanced data cryptographic algorithms.

Therefore, this paper contributed to the following aspects: Firstly, a trusted and robust distributed network framework for whole product life cycle (PLC) was proposed; this robust distributed network framework would be used for future manufacturing systems, providing the ability for self-trust, data integrity audit and data resilience. Secondly, existing drawbacks on the new manufacturing paradigms and data sharing were highlighted. And thirdly, a secure data sharing by considering big-data in CMfg based on the proposed methodology explained and a key technology for implementation of the proposed system was defined.

In this paper, the sections are organized as follows: In Section 2, works related to the blockchain, IoT enabled manufacturing and cloud manufacturing will be discussed. Section 3 presents the proposed methodology and key characteristic of the system. While Section 4 presents the key implementation of the proposed system and example-based implementation. Section 5 focus on the evaluation of proposed methodology and last section conclusion and discussion.

2. Related work

2.1. Blockchain

A BC is a distributed data structure (ledger) which can hold any information (transaction, record and etc.) that is simulated and shared between the memberships of a network. BC created new types secure and trustable peer to peer communication platform. In the BC, each block is identified by its cryptographic hash and connected with another block for making chain [16]. Therefore, each block connected with other block based on hash information, which improves the security of BC [14]. This mechanism is illustrated in Fig. 1. As a matter of fact, any membership with access to the BC Network (BCN), block-linked list of blocks can read it and Figure out what is the world state of the data that is being exchanged on the network. Therefore, a block in the chain carries a list of transactions and a hash to the previous block [17].

Three types of BCN exist namely public BC, consortium BC and private BC which are explained and follow:

- Public BC: is a BCN that anyone in the world can access, and send transactions to network expect to see them included if they are valid, and anyone in the world can participate in the consensus process. The main disadvantages of public BC are public but no means isn't secure, it is secure by the power of cryptography. The public blockchain is considered to be a fully decentralized blockchain. Bitcoin is an example for public BC.
- Consortium BC: in this type preselected a set of nodes control the consensus process in the system. So consortium BC is partly private. For an instant, ten manufacturing industries created one BCN for communication between members, each of members must control a node and for block validation at last five members must be validated of that block. The right to read the BC may be public, or restricted to the participants, and there are also hybrid routes such as the root hashes of the blocks being public together with an API.
- Private BC: is BCN where write authorizations are kept centralized to one organization. Read authorizations may be public or limited to