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PROPOSED SOLUTIONS IN INDUSTRY 4.0 FOR SECURE DATA STORAGE BASED ON BLOCKCHAINS - AN OVERVIEW

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Rezumat. *Dezvoltarea și interesul pentru Industry 4.0 au creat oportunități remarcabile de a îmbunătăți atât unele procese cât și calitatea sistemelor, perspectiva ajungând la un nivel cu totul nou. Procesele simple care sunt abordate în prezent, manual sau în mod separat, vor fi asigurate într-un model integrat folosind tehnologia Blockchain. Industria 4.0 va fi conectată pe un registru de încredere distribuit care elimină nevoia de intermediar. În cadrul acestui articol, autorii revizuiesc potențialele tehnologiilor Blockchain din Industria 4.0 , dar și unele aplicații ale acestora. Obiectivul principal este de a avea o viziune și cunoștințe despre soluțiile Blockchain și beneficiile care ar putea fi obținute de către practicieni și cercetători.*

Abstract. *The development and the interest in Industry 4.0 have created unbelievable opportunities to improve some processes and the quality of the systems to a totally new level. Simple processes that are currently approached, manually or in a segregated way will be ensured in an integrated model using Blockchain technology. Industry 4.0 will be connected on a trusted distributed register that eliminates the need for an intermediary. In this article, the authors review the potentials of Blockchain technologies in Industry 4.0 and some of their applications. The main objective is to have a vision and knowledge about Blockchain solutions and the benefits that could be achieved by practitioners and researchers.*

Keywords: blockchain, secure data, maintenance, supply chain, electric vehicles battery

1. Introduction

During the last years, more and more enterprises are considering analyzing the application of decentralized blockchain systems. Nowadays, the blockchain technology can be seen as a step in the development of the new networking paradigm and opens a window to an innovative platform for transparent transactions in industries. Blockchain is a technology which promises to guarantee security, anonymity and integrity without a trusted third-party organization

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controlling transactions. The new technologies have the capability to improve the supply chains, maintenance strategies, productivity, energy industry (power purchasing, coal and solar-power trading, electric vehicles battery refueling) [1]. This article describes how this technology may improve efficiency, traceability in the supply chain, maintenance activities and accountability for quality control, provide new business opportunities and improve security, transparency and visibility in battery refueling procedure of the electric vehicles. The main objective of this paper is to provide the reader with an overview and also, to offer knowledge about blockchain solutions and the benefits that could be achieved by practitioners and researchers.

The structure of this paper is as follows: Section 2 presents the methodological approach for secure data storage based on blockchain, including the theoretical framework concerning blockchain technology and a blockchain coding. Subsequently, Section 3 overviews the proposed solutions and tackles blockchain technology applications to Industry 4.0. We conclude in Section 4, provide a general review of the research and mention future work ideas.

2. Secure data storage based on blockchain

2.1. Blockchain – general description

Blockchain is a network ledger that allows various parties to come to an agreement. A network is a collection of nodes, which are altogether connected in order to share some data or resources between them. More than that, blockchains are distributed networks (Fig. 1) [2], i.e. the case of absolute zero centralization and the security is based on every node which is responsible for its data and therefore is able to spread forgery data.

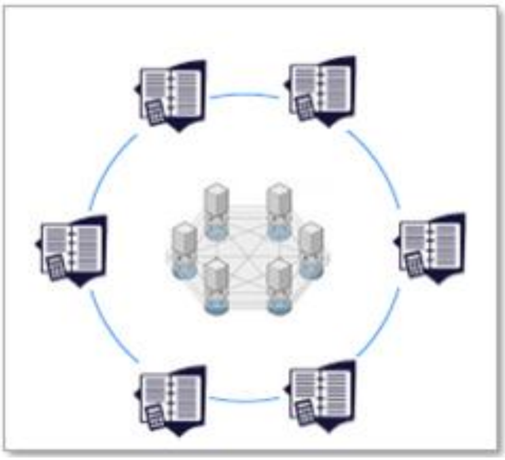


Fig. 1. Blockchain - distributed network

A blockchain is a cumulative list of data, named blocks that are connected and secured using cryptography. As a data structure, a blockchain is a simple chained list, in which the connections between elements are built through a hash function. Thus, each block usually includes a link with the previous block (a hash of the previous block), a timestamp and transaction data. By design, blockchains are resistant to changing data.

Blockchain technology utilizes well-known computer science mechanisms and cryptographic primitives (cryptographic hash functions, digital signatures, asymmetric-key cryptography) mixed with record-keeping concepts. Also, it is used the public key cryptography whereby each agent is assigned a private key, which is kept secret like a password [3].

Hashing is a method of applying a cryptographic hash function to data, which, based on an input string (theoretically of infinite length) provide a fixed, unique value to the output (digest). The Secure Hash Algorithm (SHA) with an output size of 256 bits (SHA-256) is the hash function used in many blockchains. The hash function SHA-256 is part of the SHA-2 family, a set of cryptographic hash functions published by the National Institute of Standards and Technology (NIST) [4]. For example, the input text "blockchain" has the corresponding SHA-256 Digest values:

SHA256(blockchain)=ef7797e13d3a75526946a3bcf00daec9fc9c9c4d51ddc7cc5d
f888f74dd434d1

Another term used in blockchain technology is the cryptographic nonce, which is an arbitrary number used only once in order to obtain different digest values maintaining the same data. The process of determining the nonce value necessary for generating valid hashes is called *Mining*. The mining process starts with the value of "0" and this nonce is incremented by "1" until a Valid Hash is found. This technique is used in the proof of work consensus model. The proof of work (PoW) model is like a designed puzzle that is, solving the puzzle is difficult, but checking if a solution is valid, is easy. For example, the text string "blockchain" is appended with a nonce value such that Hash Digest starting with "000000". To solve this puzzle, it took 10,730,896 guesses:

SHA256(blockchain10730895)=**000000**ca1415e0bec568f6f605fcc83d18cac7a4e6
c219a957c10c6879d67587

The blockchain technology utilizes asymmetric-key cryptography, private and public keys in order to digitally sign transactions, to derive addresses, to check signatures. A digital signature is a one-way function, which is easy to calculate, but whose inverse is very difficult to calculate. When a transaction is created, the owner of the transaction signs it with its private key: this generates the signature. It is then used its public key to verify that the original transaction generated exactly the same hash of the signature. As a matter of fact, only a couple of public and private key can generate the same signature [5].

2.2. Blockchain Coding

A chain of "blocks" is a distributed ledger, where each block contains valid encrypted transactions, i.e. anyone can add data to the chain of blocks, anyone can review this data at any time, but no one can change it without adequate authorization. Every Blockchain starts with the Genesis Block. Then it is adding new blocks of data (mining notion) onto the ongoing chain through validation by each node on the network (Fig.2.) [7,8].

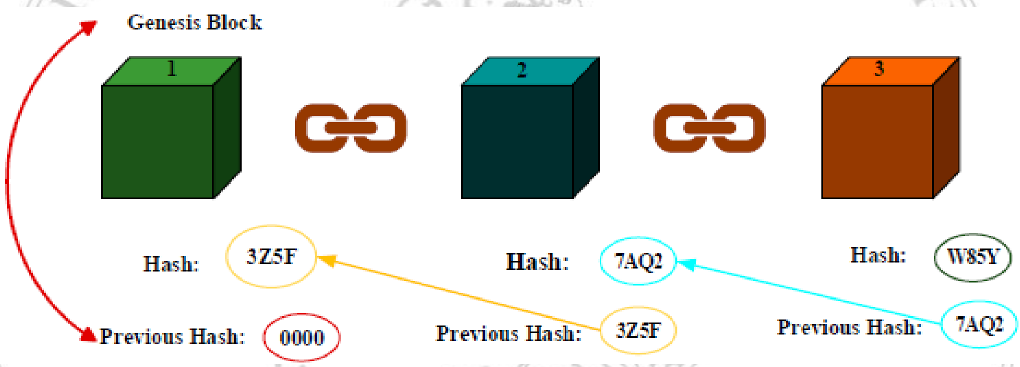
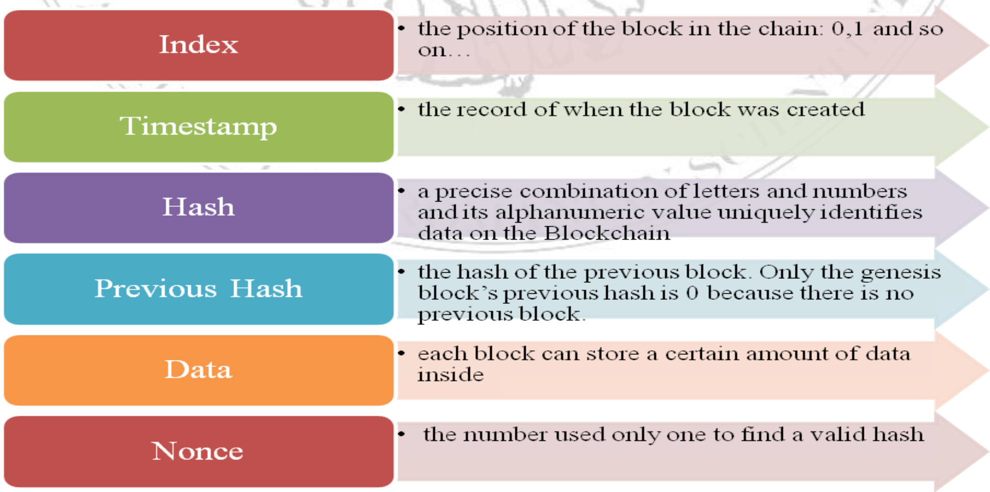


Fig. 2. Blockchain reprezentation [6]

Each block contains the following information [7]:



Coding the Blockchain in Python [9], starts by creating a new object class called *Block*. It takes as input an index, a timestamp, and the previous hash as initial variables, then simply combines them all in a plaintext string.

```
class Block:
    def __init__(self, index, timestamp, data, previous_hash):
        self.index = index
        self.timestamp = timestamp
        self.data = data
        self.previous_hash = previous_hash
        self.hash = self.hash_block()
```

Then, it runs them through the hashing function.

```
class Block:
    def hash_block(self):
        input_ = (str(self.index) + str(self.timestamp) + str(self.data) + str(self.previous_hash))
        hashed = hash(input_)
        return (hashed)
```

Next, it is created a helper function called *create_genesis_block()*.

```
class Block:
    def create_genesis_block():
        return (Block(0, date.datetime.now(), "Genesis Block", "0"))
```

Then, another helper called *next_block()* is added which just iterates to a new block with a new date-time and message. Afterwards, it creates the first block, next puts it in a list and finally iterates for as many blocks as we want to create. Now we have a cryptographically linked list which may technically be a blockchain (Fig.3.) [6].

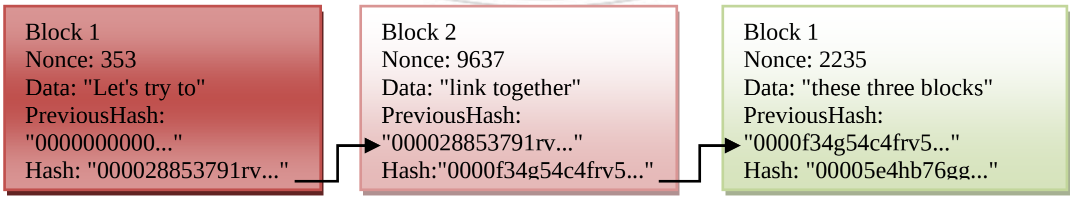


Fig. 3 Cryptographic linked list

In order to get the right to add the next block, we will replace the *next_block()* function with a function called *mine()*.

```
class Block:
def mine(previous_block):
print ('Mining blocks . . . ')
index = previous_block.index + 1
timestamp = str(date.datetime.now())
data = "Mined block " + str(index)
last_hash = str(previous_block.hash)
target = 280
while True:
nonce = random_string(6)
new_hash = hash(str(index) + timestamp + data + nonce + last_hash)
summed = hash_sum(new_hash)
if summed <= target:
print ('Mined a block!!!')
break
print ('Mined at ' + timestamp)
return (Block(index, timestamp, data + nonce, last_hash))
```

This function allows a decentralized proof of work blockchain. Proof of Work (PoW) implements two important elements: computational power and randomness. The computation power makes sure that miners are generally acting with trust because they confirm the next block. The randomness helps to keep things decentralized and rightful [8].

3. Applications of blockchain technology in Industry 4.0

Applying blockchain technologies in the industry brought the focus to many areas, such as: Supply Chain Management, Predictive Maintenance and is needed to capitalize Just-in-Time production, to track position in supply chain, to prevent poor quality control, to predict at which point in the future and which kinds of maintenance activities will be required and, also, for security of intellectual property [3,10,11].

3.1 A proposed solution for preventive maintenance scheduling

In the production industry, manufacturers must publish technical manuals of their products to be assigned inside the repair and maintenance departments. These technical records need to be released and updated promptly, which is a very laborious process and involves a lot of paperwork. Using the blockchain technology, technical publications can be based on such a framework and is accessible to blockchain users without worrying about version changes or latest data loss [12,13].

Fig. 4. Preventive Maintenance on Blockchain

The transfer of machine health parameters is made by means of the Internet of Things (IoT) (Fig. 4). The Internet of Things represents the implementation of sensors of all types that are integrated into the manufacturing process and ensures the collection of data. These sensors can measure phenomena, like, movement, heat, pressure, humidity, vibration, etc. The information can be collected, stored and analyzed on a real-time basis or in batches of statistically relevant quantities. With these data stored in a blockchain based on many transactions, it can be predicted future failure and repair rates of the machines in the manufacturing system [10].

3.2 A proposed solution for Supply Chain Industry

In many supply chain systems, anti-fake demand could be realized using RFID (Radio Frequency Identification) chips and NFC (Near Field Communication) technology. These techniques are centralized and a person with authority may modify it at will. To solve these problems, a decentralized method is proposed, blockchain technology. Supply chains are getting increasingly more complicated and it is very hard to have an overall frame of all transactions within the chains. Supply chain in manufacturing systems comprises a series of system entities that facilitate moving a product from supplier to customer. Blockchain technology will be a powerful tool to improve supply chain solutions. The adoption of the blockchains in the Supply Chain can be a solution for Cost-saving or the generating frauds or errors, to reduce forgery, to product recalls, to enhance supply chain transparency and process tracking, regulatory compliance and reporting, enable efficient ownership and licensing [2,11,12,14].

3.3 A proposed solution for electric vehicle battery refuelling

For the electric vehicles, a mechanism based on a blockchain could resolve the trust-lacking between electric vehicles owners and swapping station. Thus, electric vehicles owners get a guarantee about the battery information and transaction's correctness, openness, traceability and immutability. Using blockchain, battery's life-cycle data and all operations histories are permanently saved. Also, a permanent record of the refuelling, repairs, and payments would be recorded on the blockchain and shared by participants including vehicle owners, manufacturers, repair facilities, and financing firms. Song Hua et al. [15] proposed a blockchain to evaluate the quality of battery automatically implemented with smart contracts. They present a simple battery swapping scenario: an owner of electric vehicle buy and then register a battery and invokes the discharging action to simulate energy-consuming until the battery energy is low. In a station, the owner can select a full energy battery from station battery list and submits a swapping request. Next, a station operator checks swapping request and confirms it. Using a smart contract, the prices of the two batteries are automatically calculated. Battery price is estimated based on the assessment result of battery quality. If there is a price difference, it will charge coins from one side with lower price battery, and compensate to the other side. However, the blockchain solution needs continuous improvements, for example, the monitoring of battery's physical RFID (Radio-frequency identification), and the logging and synchronization of various discharging current for different drivers [16].

4. Conclusions

The usage of the blockchain technology is still in its untimely etapes. Many companies are trying to apply Blockchain due to its promised advantages: decentralized network, safe data, anonymous transaction. However, as a new technology, the practitioners would like to know whether it would be profitable in some real cases. Therefore, in this paper, we presented an overview of the proposed solutions in Industry 4.0 for secure data storage based on blockchains. This paper was divided into two main phases. Firstly, the paper discussed the need to study deeply the Blockchain technology and Industry 4.0 respectively. Secondly, the paper consisted in the development of a framework for the identification of the potential Blockchain applications in a different field. In this article we generally described blockchain from the cryptographic point of view. We shortly explained the corresponding cryptographic primitives step by step (hash functions SHA256, nonces, proofs of work, timestamps, private and public keys, as well as digital signatures). A Python coding is created in order to get a cryptographically linked list which may technically be a blockchain. Industry 4.0 requires new applications for smart manufacturing, supply chain solutions, autonomous vehicle solutions, manufacturing plant asset management, including security, trust, traceability and reliability. Several of these issues can be addressed using blockchain and IoT solutions. For the supply chain, the IoT platform invokes transactions that contain the shipment container location and timestamp and they are proof of shipment and proof of delivery for container shipments. Thus, the shipment delays would be minimized, the lead times could be more accurately predicted and the inventory could be better aligned with just-in-time practices. In the manufacturing systems, a blockchain and IoT solution would enable the prevention and prediction of failures for manufacturing plant equipment. The repairman could monitor the blockchain for preventive maintenance and record their work on the blockchain. The needed resources for the blockchain maintenance are: the servers from the network which run without problems at any time, the nodes form peer-to-peer (P2P) network, the files stored in databases, the unchanged blocks, the mining mechanism of decentralized security, the security that ensure to update any type of security on every software and hardware. Autonomous vehicle manufacturers could use IoT platform in order to emit data such as fueling, charging, parking and repairing. Blockchain and IoT solutions will bring business value, more timely and visible data and security in the Industry 4.0.

An interesting future work would be to evaluate a real case study from a manufacturing line in order to create a blockchain for secure maintenance data storage in a month and then the failure and repair rates will be modeled statistically thorough distribution fitting and finally a regression model wil be developed to predict the next failures.

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