Enterprise Resource Planning System and Blockchain Functioning Synchronization

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Enterprise Resource Planning (ERP) systems are modular software packages with a single database and designed to be used in various environments. In the face of numerous challenges in supply chain management, new technologies are being implemented to overcome obstacles and improve overall performance. Among these technologies, blockchain, a part of the distributed ledger family, offers several advantages when integrated with ERP systems, such as transparency, traceability, and data security.

Keywords: blockchain ; supply chain ; ERP system ; decision-making framework

1. Introduction

Enterprise Resource Planning (ERP) systems are modular software packages with a single database and designed to be used in various environments. They enable the management and integration of all internal functions of a company [1].

ERP systems have proven themselves over the years by providing numerous benefits, including improved financial performance [2][3]. However, ERP systems do face some challenges, in particular, when different ERP systems need to communicate with each other within a supply chain [4]. Additionally, ERP systems are centralized systems with a single database. This means that ERP systems are controlled by a single entity. This entity has administrative rights, allowing it to add, modify, or delete certain data. When this entity proves to be dishonest, it can create problems for the various partners in the supply chain [5].

Indeed, the various partners in the supply chain, such as suppliers, customers, service providers, and manufacturers, interact and collaborate with each other to have access to certain data in order to better manage their processes and sub-processes [6]. Consequently, ERP systems must interact with each other in real-time to ensure data availability and transparency for all partners in the supply chain.

However, this approach faces some challenges. The data configuration needs to be performed as cross-references, which is not always straightforward due to the unavailability of certain data; data maintenance must be performed regularly; data standardization needs to be performed as unstructured data can have a negative impact on data transfer; and finally, this architecture must be integrated into several systems since each company has its own data system [6].

Blockchain can be a solution to these problems of data transfer, accessibility, and transparency [6], thanks to its ability to interact with multiple companies and its features, including immutability, the use of smart contracts, and cryptography. The principle is to connect all supply chain partners to a secure and reliable network and consequently integrate the ERP systems of each company in the supply chain into a single blockchain network. As a result, blockchain can only be beneficial to the supply chain if it is used by all its partners. In this case, it is not about integrating blockchain into a single company but into a consortium that allows for the management of the entire supply chain [6].

Blockchain technology can be conceptualized as an organized assembly of data entities conjoined in a series of interconnected blocks. The data within these blocks are safeguarded using cryptographic methods. Each block encompasses a cryptographic hash pertaining to the preceding blocks, in conjunction with a temporal identifier. Additionally, a block may incorporate data pertaining to several transactions. Blockchain constitutes a component of a broader category denoted as Distributed Ledger Technology (DLT) [1][2][3][4].

The integration of blockchain with the various ERP systems in the supply chain would then be the next generation in information systems. Blockchain would be a complementary technology to ERP systems to improve supply chain performance and a company's internal performance. The integration of blockchain into ERP systems will enable true data

interoperability for various business and banking services. This interoperability will result in real-time, transparent data accessibility for all partners in the supply chain [6].

This data accessibility would serve as a foundation for decision-making support. As a result, ERP systems integrated with blockchain would also be a means to prepare companies for an uncertain future. Blockchain could also accelerate the flow of goods, services, information, and financial exchanges between different supply chain partners. Tracing these flows through the blockchain will increase customer satisfaction [6]. Blockchain can bring other performance improvements to the supply chain, such as minimizing transportation costs, reducing errors and delays, increasing trust between partners, enhancing logistics activities, increasing supply chain sustainability, and improving the traceability of physical and information flows [7].

2. Blockchain Technology

Blockchain technology is a system comprising structured data organized into blocks that are interconnected. Cryptography is employed to secure this data. Each block possesses a cryptographic hash of the preceding blocks, in addition to a timestamp [7]. This characteristic grants the blockchain its immutability. Furthermore, a block can hold information pertaining to several transactions [8].

The blockchain network is comprised of numerous nodes that collectively maintain a shared collection of states and execute transactions that alter these states. Transactions necessitate validation by a majority of the network's nodes prior to being organized and encapsulated within a temporally-indexed block [4]. This mining procedure is contingent upon the consensus mechanism employed by the blockchain network [9]. Before the integration of the proposed new block into the chain, all nodes within the network must ascertain the validity of the transactions contained within the block and confirm accurate referencing of the antecedent block through a cryptographic identifier.

Blockchain belongs to a more extensive family called DLT. DLT is distinguished by its distributed registers [10]. As a result, blockchains are structured as peer-to-peer networks following a shared protocol that enables communication between nodes and the validation of new transactions [11]. After being recorded, data cannot be altered without the agreement of most network participants [12]. This framework prevents data manipulation, modification, or deletion [10].

M. Iansiti and K. Lakhani defined blockchain based on five characteristics, as summarized in the following points [13]: distributed database, peer-to-peer network, system immutability, and digitalization of the ledger.

These characteristics make blockchain a secure, transparent, and immutable data structure, ensuring the integrity and trustworthiness of the information stored within it.

The current literature classifies blockchain networks into several categories based on network management and permissions [14]. However, there are three main categories of blockchain:

- Public (permissionless);
- Private (permissioned);
- Federated (permissioned).

3. Blockchain for Consortium

To explore and exploit the use of blockchain, companies tend to form a consortium where members can benefit from shared costs, risk mitigation, accelerated learning, and influencing standards [15]. Most enterprise blockchain solutions will be implemented by a consortium of companies developing one or several applications on a blockchain platform. The creation of a platform implies the creation of an ecosystem, demonstrating interconnectivity and interdependence among supply chain partners [16]. The concept of a platform tends to be treated as a technological subsystem of a business ecosystem and a specific type of business model [17].

Several consortia have already begun to emerge, implementing blockchain technology, as is the case with TradeLens and the shipping giant Maersk. They created a consortium for various supply chain partners to securely share information and access real-time shipping data, reducing transit times by 40% [18]. Other examples include the BitA consortium in the transportation industry and the pharmaceutical supply chains under the MediLedger project [19]. Some blockchain initiatives are led by a dominant company, as in the case of Walmart's project [4]. Despite this dominance, there is still a

need to include relevant actors from the supply chain [20]. Consequently, the implementation of blockchain for businesses goes beyond an individual organization and focuses more on the collective action of a group of actors.

4. Blockchain as a Service (BaaS) for Consortia

Blockchain as a Service (BaaS) is a combination of cloud-based hosting services that enable various consortia to develop, host, and manage their own applications, nodes, smart contracts, and distributed ledgers in a cloud ecosystem [9]. BaaS can be seen as a bridge between the blockchain platform and the information systems used by the company, such as Enterprise Resource Planning (ERP), Business Warehouse Management, Customer Relationship Management (CRM), or Supplier Relationship Management (SCM). BaaS offers multiple advantages for the consortia, including reduced deployment costs, improved scalability, and project support. However, the decision to adopt BaaS must be based on several criteria. Certain sectors are governed by strict regulations that compel them to not opt for a cloud solution.

In cases where the consortium chooses to adopt BaaS, the main BaaS providers in the market include Microsoft, IBM, Oracle, Amazon, and SAP [9]. The choice depends on the services offered by each provider and the blockchain platform used by the consortium.

Figure 1 illustrates the connection between the information systems of each company within the consortium (such as ERP, CRM, SRM, WMS, etc.), the platform adopted by the consortium (Hyperledger Fabric, Ethereum, R3 Corda, EOS, Stellar, etc.), and the BaaS services (Amazon Blockchain, SAP Leonardo, IBM Blockchain Platform, Azure Cloud Computing Blockchain, Oracle Blockchain Cloud Service, HPE Mission Critical Blockchain, etc.).

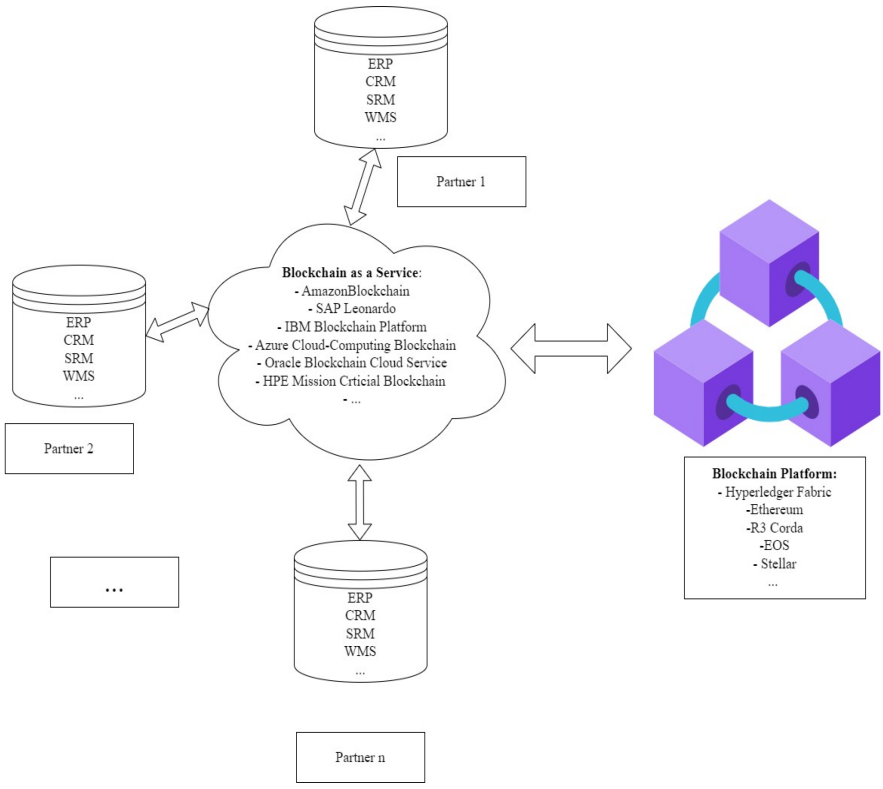

Figure 1. The connection between the BaaS, the Blockchain platform, and the information systems of the supply chain partners.

5. Synchronization of ERP System and Blockchain Functioning

This section describes how blockchain synchronizes with ERP systems to validate transactions and update the state of the ledger and ERP system database. This synchronization is referred to as a blocker [5]. Each company can make its own choices with its architecture depending on its context of blockchain usage, but to clarify the operation of ERP systems with blockchain, the researchers have presented the model proposed by Aslam et al. and some theoretical concepts [5]. This operation can be described in several stages:

- **Transaction Initiation**: A user can send a request to the database to initiate the transaction; however, the transaction can be initiated in different ways, such as using an oracle. This request is first processed by the database with pre-established management rules, including access control mechanisms, artificial intelligence algorithms, and neural

networks to filter out erroneous information and users without access control. Selective data, important for the supply chain, are sent to the blockchain through the application interface. However, some companies choose to only store metadata on the blockchain to avoid storage problems [21].

- **Preparation Stage**: Once sent through the application interface to the blockchain, transactions are placed in the pool as unprocessed transactions. A second verification at the blockchain level is initiated to control access and the veracity of information transmitted to the blockchain. These transactions are grouped into packets of 'N' transactions and updated as blocks.

- **Consensus and Propagation Stage**: The block containing 'N' transactions is transmitted to the validator nodes. After the block is validated by a validator node, the validation is complete. The block is added to the blockchain and propagated to all nodes in the network.

- **Database Update Stage:** When the transaction is validated and placed in a block, the corresponding data in the ERP system database are updated in accordance with the validated transaction. The relevant parties then receive a notification of the transaction confirmation.

The architecture proposed in [5] operates with several hierarchical levels of the blockchain.

- **Level 1**: Transaction Journals or Data (Data Restoration). The first level provides the possibility of restoring data in the case of an error during a transaction. There might be a misconception about the immutable nature of the blockchain, amplifying the perception that errors are irreversible. Initially, it is advised to apply artificial intelligence algorithms and neural networks to filter the data and detect errors before they are introduced into the system [19]. However, in the event of an error, there is a way to restore the system's integrity. Data reversibility in a blockchain can be achieved by restoring the system to a state prior to the error using the immutable information stored in the blockchain. The immutability of the blockchain ensures the permanence of the recorded data, preventing any alteration once they have been added to the chain. In the case of an error, it is not possible to directly delete the transaction from the blockchain. However, it is possible to restore the state preceding the erroneous transaction. This restoration can be performed by executing an inverse transaction, thereby canceling the effects of the incorrect transaction. However, it should be noted that companies have the flexibility to decide whether they store the entirety of transactions on the blockchain, including transaction journals, or only the corresponding metadata.

- **Level 2**: Access Management and Business Rules The second tier of the blockchain focuses on business rules and access management aspects. At this stage, we find information related to access rights granted to users within the ERP system and the activities of authorized users who have access to the system.

- **Level 3**: ERP Data Validation At this level, the integrity of transactions is ensured, and the same records are placed in the ERP and blockchain databases. This level establishes rules by which the ERP and blockchain can communicate with each other at any time for mutual synchronization.

6. Synthesis

Numerous studies have been conducted on integrating blockchain into existing information systems. For instance, Thantharate and Thantharate have introduced a blockchain framework named ZeroTrustBlock, which is a comprehensive, secure, and private system for health information. Beyond blockchain, additional technologies like Trusted Execution Environments (TEEs) and Zero-Knowledge Proofs (ZKPs) were adopted to further bolster the proposed system's security [22]. Despite blockchain's reputation for enhancing information security, it is not without vulnerabilities, hence the strong recommendation for its combined use with complementary technologies [19][20][21].

Other research has focused on architectural models for integrating blockchain into ERP systems. Several researchers have also emphasized the importance of coupling blockchain with emerging technologies like the Internet of Things or RFID [8][22] to strengthen the security of the data processed by the Internet of Things [23].

Further studies highlighted the benefits of employing blockchain within a consortium, i.e., a group of supply chain actors, to fully leverage its advantages [20]. Undoubtedly, integrating blockchain into a supply chain can improve various performance aspects, notably in terms of cost reduction [24], security enhancement [19][20][21][22][23], and transparency [6].

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