Blockchain-based Information Ecosystems*

Francesco Salzano[1,2,*], Remo Pareschi[2,3], Lodovica Marchesi[1,*] and Roberto Tonelli[1]

[1]Dep. of Mathematics and Computer Science of University of Cagliari), Palazzo Delle Scienze, Via Ospedale, 72, 09124 Cagliari CA, Italy
[2]Stake Lab, University of Molise, Campobasso, Italy
[3]BB-Smile Srl, Rome, Italy

Abstract
This study proposes a high-level architecture for deploying blockchain-based information ecosystems (BBIEs) by leveraging and expanding the Blockchain-as-a-Service (BaaS) concept. The proposed architecture integrates blockchain with the overall information ecosystem to enable trust management and coordination systems in inter-organizational contexts. An Identity Management System (IMS) ensures scalability and security. A case study is presented from the field of fiber cabling of urban centers involving building companies, a monitoring company, and a BaaS provider. The architecture offers a promising approach to prevent the risks of a "blockchain winter" by going beyond the limited scope of the traceability applications so far pursued in industrial deployments of the blockchain and to break the traditional domination scheme of a leading company in business consortia.

Keywords
Information system, Blockchain, Blockchain Oriented Software Engineering (BOSE), Blockchain as a Service (BaaS)

1. Introduction

Information systems have marked the history of the organizational transformations of companies from the second half of the twentieth century to the present day [17, 14]. The concept of an information system, which in its basic version is a collection of technologies, processes, and people who work together to produce information that supports the goals and objectives of the organization, has evolved and has been shaped by advances in technology, changes in the business environment, and new theories about how information can be used to support decision making and problem solving [6].

Information systems have a long story that begins in the 1950s and 1960s when mainframe computers were used to automate business processes such as payroll and accounting. They evolved in information ecosystems involving multiple businesses with the coming of age of a global communication infrastructure that can connect different enterprises through the internet, the Worldwide Web, mobile computing, and cloud computing [28]. Amazon and

DLT 2023: Distributed Ledger Technology, May 25–26, 2023, Bologna, Italy
*Corresponding author.
francesco.salzano@unica.it (F. Salzano); remo.pareschi@unimol.it (R. Pareschi); lodovica.marchesi@unica.it (L. Marchesi); roberto.tonelli@unica.it (R. Tonelli)
0000-0002-1029-4861 (F. Salzano); 0000-0002-4912-582X (R. Pareschi); 0000-0002-0627-5043 (L. Marchesi); 0000-0002-9090-7698 (R. Tonelli)

Walmart are examples of information ecosystems that manage and coordinate the flow of goods, materials, and information across multiple supply chain stages, from suppliers to customers. Their integrated supply chain capabilities involve inter-enterprise components connected and coordinated to ensure an efficient and effective flow of goods and information. However, while such information ecosystems involve multiple business partners, decision-making power is almost entirely in a single company, such as Amazon and Walmart.

In this scenario, blockchain and distributed ledger technologies (DLT) can lead to more balanced and democratic ecosystems [13]. Unlike traditional information ecosystems in which the dominant company manages the trust relationships among partners, these are automatically managed thanks to the intrinsic characteristics of DLTs, leading to a *trustless* scenario [26].

In fact, these technologies provide the infrastructure for decentralized systems that enables a more balanced and transparent decision-making process and more equitable power distribution and benefits by not being controlled by a single entity. Moreover, the distributed infrastructure provided by DLTs and blockchain allows enterprises to share business logic taking profit from the Smart Contracts (SCs) execution [12].

In this work, we propose the definition of the concept of a blockchain-based information ecosystem (BBIE), an information ecosystem in which blockchain technology is used to provide a trust mechanism among parties and to manage shared business logic, breaking the traditional scheme of information ecosystems dominated by a leading company. A research effort in this direction was already made in some previous articles [8, 9, 10] where an algorithmic optimization of the profit mechanisms in supply chain management is illustrated and implemented in the form of a smart contract to enable supply chains to keep balanced in terms of information and decision-making power while boosting business results similarly to vendor vertical integration systems managed by dominant corporate players. In this article, the same philosophy is generalized to any inter-organizational application area where the blockchain can guarantee trust and shared governance. A specific focus is given to enabling technological components.

In a BBIE, for example, decisions about the management and flow of information could be made collectively through a consensus mechanism [23], such as a vote of the participating nodes. This could give each participant a voice in decision-making and help ensure that the ecosystem is run fairly and equitably. Similarly, transactions could be validated and processed by a decentralized network of nodes rather than a single central authority, thus increasing transparency and security and reducing the risk of a single point of failure.

The purpose of this paper is to propose and define a high-level architecture to deploy a BBIE. Such architecture includes both blockchains and non-blockchain components shared among several companies.

An important contribution to enhancing the adoption of this kind of information ecosystem comes from the availability of solutions based on the Blockchain-as-a-Service (BaaS) concept [8, 32]. BaaS is a cloud-based service that allows organizations to build, host, and use their blockchain applications, smart contracts, and functions without requiring infrastructure investment or in-house expertise in blockchain technology. Following this concept, companies can build decentralized applications (dApps) to provide specific functionality and interact with the underlying ledger. In this way, companies that want to set up and share an information ecosystem can do it without overhauling their existing information systems, seamlessly scaling up to the ecosystem dimension. With this in mind, BaaS is figured as a facilitating component of a BBIE for companies and enterprises. Interoperability and integrability are essential to combine BaaS with information ecosystems (IEs). In fact, most ISs are legacy systems. Indeed, according to the Legacy Dilemma, *we must trade off the cost of continuing to cope with the legacy system against the investment needed to improve it and the benefit of easier subsequent maintenance [5].* As the dilemma may suggest, both the cost of the system improvement and the cost caused by the system's lack can be unaffordable. Therefore, blockchain integration in IEs can leverage the BaaS paradigm.

Other components that should be considered in building blockchain-based information ecosystems are off-chain data storage (storing much of the data in standard databases) and Identity Management Systems (IMS), managing participants' identities in the information ecosystem across the different system layers. Another optional component to be considered as an add-on is a digital twin management system [11]. In fact, with the advent of the Metaverse and its connection to Blockchain technologies, this component may enable and enhance the anchoring of real world objects into Blockchain hashes or NFTs [15]. We will illustrate this component in a particular use case.

The remainder of the paper is organized as follows. Section 2 presents the background; section 3 describes the proposed solution, highlighting the decomposition among off-chain and on-chain components. Section 4 shows a real case study for a BBIE involving different companies in the construction site works for cabling an urban area. Section 5 discusses the advantages and limitations of the proposed architecture. Finally, section 6 concludes the paper.

2. Background

Since the introduction of blockchain and Bitcoin by Satoshi Nakamoto [27], blockchain applications have spread to fields other than cryptocurrencies [36], combining their infrastructure with the possibility of running business logic coded in Smart Contracts [12, 34].

The blockchain is a database technology that replicates data in a network and stores information in blocks, written using transactions. Any node on the network can read or write information to the database. Each transaction must be verified before being written to the nodes using consensus algorithms [29, 23]. Also, the deletion of data is not allowed. Therefore, the data stored in the blocks are immutable; each block points to the previous one, maintaining its hash, and creating a chain.

There are two typologies of blockchains, such as private or permissioned and public o permissionless [19]. The differences between them are in accessibility and authorization; indeed, in a public blockchain, everyone can interact with the infrastructure; conversely, in a private blockchain, only authorized participants can read and write on the distributed ledger. However, the two blockchains can be integrated to get the best of both worlds [25].

Smart Contracts are *event-reactive* programs replicated on a distributed or decentralized network, which execute transactions according to specific conditions that simulate the constraints of a legal contract [34]. Thus, by deploying SCs over a blockchain network, developers can build *dApps* granting typical blockchain properties, such as immutability and transparency [26].

Schneider et al. created a theoretical framework to look at how blockchain impacts ecosystems and business models. They discovered that blockchain resembles a symbiosis of technology and human actors from organizations and/or society as a whole who work together to create a new kind of agency that is separate from that of humans or machines [33].

Blockchain technology offers businesses numerous chances to modify and develop new company models. In a recent research Taherdoost and Madanchian, examined the state of new blockchain-based business models. In their survey, they highlighted how the use of blockchain can bring several benefits to companies, including cost savings due to faster transaction times, disintermediation, less record keeping than customers due to distributed ledger technology, and better data tracking and verification. Moreover, using blockchain technology enhances a company's interactions with its customers, rivals, and suppliers [35].

Blockchain technology was first utilized in the banking industry, but is now used by businesses to share digital data among partecipants. A blockchain can give organizations new capabilities by changing how participants interact with digital transactions [21]. Blockchains have broad implications when used in business operations. For instance, disintermediation can be simplified, transactions can be authenticated, and efficiency and trust among ecosystem participants in an organization can be increased [16, 30, 1].

A digital twin is a virtualized representation of a physical object, system, or process that utilizes real-time data and other pertinent information [11]. It represents a digital clone of the physical entity that facilitates analysis, monitoring, and simulation. Digital twins are extensively utilized across diverse fields such as manufacturing, engineering, construction, and healthcare, among others, to improve efficiency, optimize performance, and decrease costs [7]. By simulating the functioning of a physical entity, its digital twin can aid in identifying potential issues, streamlining operations, and making informed decisions based on data analysis. In a BBIE, digital twins are an ideal component to allow the tracking of real-world physical entities into Blockchain records. Their use can enable predictive maintenance, reduce downtime, and optimize operations, leading to cost savings and improved performance. Conversely, digital twins may raise privacy concerns, especially when it involves personal or sensitive data.

3. Blockchain-based Information Ecosystem

The increasing complexity of industrial business flows led to the need to share business data and information between participants in the business flow. In the current information ecosystem, trust is managed by the leading company involved, thus being centralized. Introducing blockchain technology as a trusted part allows for providing transparent, reliable, and tamper-proof data sharing, acting as an inter-enterprise data keeper. In fact, blockchain applications are widespread in commercial companies, such as supply chain management, health care, and collaborative economic optimization of businesses [4, 9, 13]. Despite the innovation and advantages, keeping the blockchain-based application isolated in an industrial context, composed of several inter-operating modules in most cases, can be limiting. Addressing this restriction, the solution we propose in this work integrates the blockchain-based application with the information system as an ecosystem module. Thus, the blockchain integrated with the information ecosystem creates what we define as BBIE.

In the following of this section, we present a high-level solution of a BBIE architecture. Before diving into the detailed description of the architecture, we clarify the key concept involved.

3.1. Kinds of Blockchain

There are different types of blockchains. In general, blockchains can be classified on the basis of how they grant permission to read and write data on the blockchain and the right to add new validators or simple nodes in the network. The interaction with the various components strongly depends on the type of blockchain.

Public blockchain: are open to anyone who wants to join the network. No restrictions exist on who can participate, and anyone can view the blockchain's contents. A high level of transparency characterizes them, even compared to private ones; anyone can view the transactions and the current state of the ledger. Integrating the two blockchain typologies, BBIE can provide scalability, efficiency, and permissioned access granted by the private one, with the transparency a public blockchain provides.

Permissioned blockchain: everyone can add a node and download the blockchain. Nevertheless, validator nodes need to be approved, either automatically through a vote among current validators, through the use of an appropriate SC, or by consortium members. Only those who have been granted authorization are able to deploy a new SC on the blockchain. Everyone is able to send transactions to the blockchain, but, just like with public ones, the SC that receives the transaction must decide whether to accept it or not.

Private blockchain: requires permission to access and participate in the network. Only certain parties are allowed to join the network, and their identities are verified through various means, such as digital signatures or a centralized authority. Permissioned blockchains allow customizable governance models; this means that the rules and procedures for operating the network can be tailored to the specific needs of the participants. The network can be run by a consortium of organizations, with each member having a say in managing the network. In a BBIE, we propose a private blockchain as the entity that runs the consortial business logic, leveraging on the low costs, scalability, and high-level security because of the restricted access to the network.

3.2. Architecture

Figure 1 shows the proposed architecture. The components of the architecture include both on-chain and off-chain components.

3.2.1. Off-chain components

All the entities running outside the blockchain environment. Therefore, all modules that are part of traditional information systems are included in this set.

- *Storage*: the storage module of industrial ISs is a critical component that enables the capture, processing, and retrieval of large volumes of data generated by industrial processes. This module comprises hardware and software designed to store and manage data from different sources, such as human input, sensors, and automated processes. The advancements in cloud computing and big data technologies have facilitated the development of highly scalable and adaptable storage solutions that meet the demands of modern industrial information systems [20]. In a BBIE, deciding what data must be stored in off-chain and on-chain storage is necessary. In our vision, the *ratio* should be based on the need to share the data, grating the tamper-proof transparently. Furthermore, the traditional storage module is in care to persist the intra-enterprise data, guaranteeing the information isolation from the other parties participating in the business. Large volumes of data, including documents and photos, also must be kept off-chain. The integrity and date of the document can be guaranteed by storing the hash digest of the document together with a link to retrieve it on the blockchain.

- *Business layer*: given that transactions can incur high costs, resource-intensive computations are frequently recommended to take place *off-chain* rather than *on-chain.* According to this, *off-chain* business logic is responsible for the execution of the internal operations of the IS of a single company. Within an off-chain context, computations are performed externally to the blockchain-based system, such as on the server of an intermediary service. Conversely, in *on-chain* scenarios, computations are executed and verified within the blockchain-based system [22].
- *User Interface*: typically the interaction with the business layer is regulated via web/app interfaces or via a dedicated API layer. This is not explicitly marked in the figure.

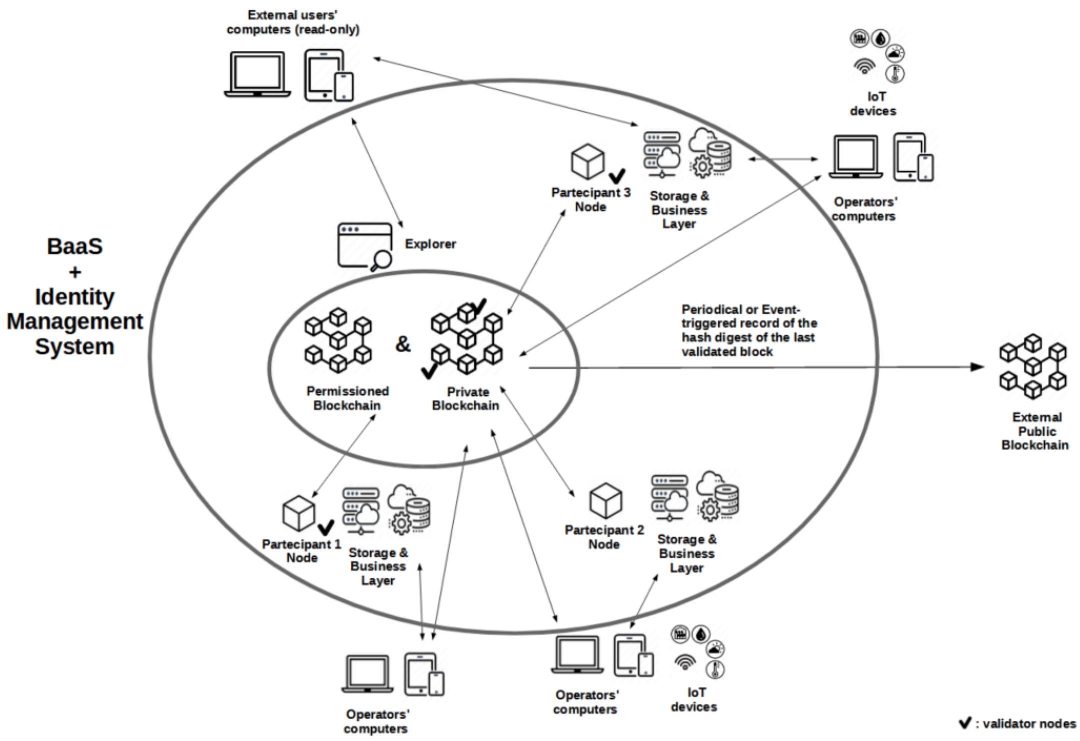

Figure 1: Blockchain based information ecosystem architecture.

3.2.2. On-chain components

On-chain modules are components of the BBIE that are executed within the blockchain network itself, leveraging the native functionalities of the blockchain, such as smart contracts and transactions. The companies involved could decide either to create their own blockchain or to use a BaaS. In the image, we show the second case, and the on-chain components are collected in the BaaS component. The BaaS provider deploys a hybrid system of private and permissioned blockchains.

- *Private Blockchain*: shown as a network of regular and validator nodes. Some of the nodes, both validators and regular, can be run by the participant companies.
- *Permissioned Blockchain*: can be either accessed by anyone or only by authorized users.
- *Shared business logic*: managed through smart contracts execution.
- *Identity Management System*: in charge of managing the identities of participants and preventing unauthorized access to systems and resources.
- *An explorer*: running on one or more nodes holding a copy of the blockchain, to browse the actual state of the blockchain without the mediation of the user interface. The explorer can be used by anyone and enhances transparency.
- *A link to an external public blockchain*: to write the hash digest of the last block mined locally. This anchoring guarantees the BBIE the same immutability as a public blockchain. It can be done periodically (i.e. every 24 hours) or event-triggered.

3.2.3. BBIE component interactions

BBIE components can execute their services according to specific needs and interactions are event-reactive, i.e., HTTP calls and some met conditions, such as a period passed by last anchoring, as discussed in 3.2.2. Services may be called not following a defined order, making BBIE modular respect industrial needs. Furthermore, in order to clarify interaction in the information ecosystem, off-chain business logic and BaaS services are requested by calling the API endpoints. Public blockchain services, such as certification transactions and private and permissioned block anchoring transactions are requested using the application binary interface (ABI). Contract ABIs are the primary components for interacting with Ethereum smart contracts, both from outside the blockchain and for contract-to-contract interaction [24]. ABI interface is also used by external users to get information regarding the anchored state of data managed by BBIE. Remainder interactions, such as database querying and user interface with the business layer are in common with the operation performed by traditional information systems.

3.2.4. Actors

The proposed architecture has four types of actors:

- *The participants*: each manages and runs a node of the private blockchain on the one hand, and on the other hand, has its storage and business layer managed off-chain. We only show three participants for simplicity, but there could be more.

- *The validators*: particular participants, shown with a bold V in the figure, which are the nodes of the key participants in the ecosystem. These keep a copy of the blockchain and validate the transactions through a consensus mechanism.
- *The Operators*: who can talk to both their storage and business layer and the blockchain. Each participant has its operators.
- *The External users*: who communicate with the blockchain only in read mode via an explorer. But they can access the documents contained in the participants' archive if authorized.

There may be a channel that puts the participants in direct communication, but it is not indicated in the figure. The solution showed integrates the blockchain-based application with the information system as an ecosystem module. The blockchains shown in the image are intentionally generic.

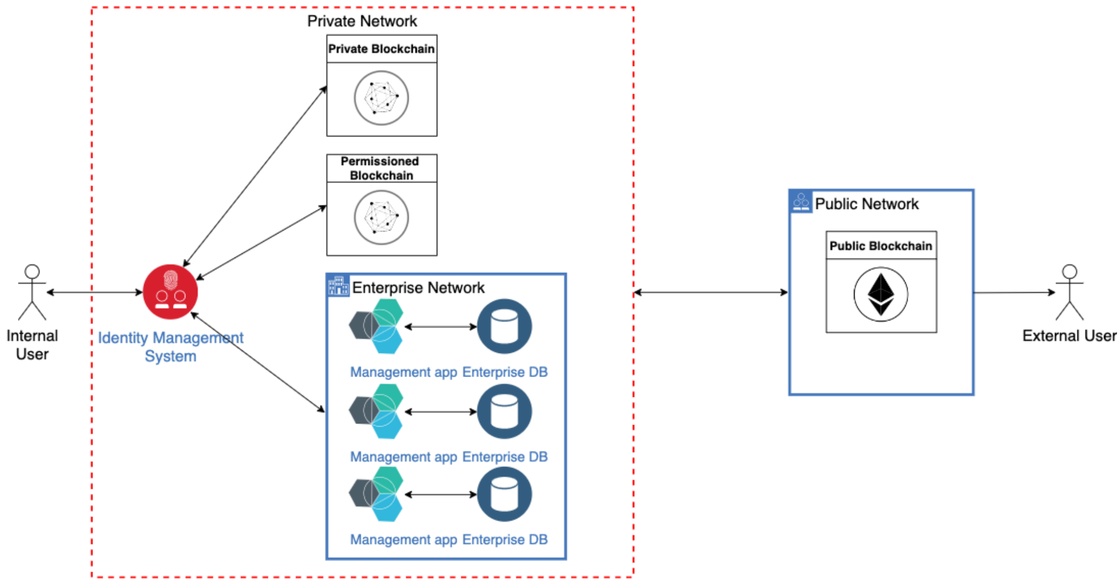

Figure 2: Blockchain-based information ecosystem model.

Figure 2 shows the BBIE model, which comprises two environments, namely, an internal environment that interacts with the private network and an external environment that interacts with the public network. Private and Permissioned blockchains with the addition of the off-chain business layer are included in the private network. Access to this network is restricted to individuals affiliated with the companies involved in the BBIE, who are authorized by the identity management system. External users who are not associated with the companies involved in the shared business may access certified data and traceability information by interacting with the public network, which provides data stored on the public blockchain(s). There may be challenges in integrating different technologies granting interoperability, however, leveraging communication standards such as REST APIs and ABI interfaces allow BBIE to integrate heterogeneous components.

4. Case Study – Cabling an Urban Area

As a case study for a BBIE, let us consider an information ecosystem for the construction site works for cabling an urban area, with the involvement of building companies, a survey company, and a BaaS provider:

1. **Building Companies**: The construction companies involved in excavating and laying cables record the progress of their works on their databases and management applications. These databases store information about the construction site, such as the site's location, the progress of the excavation and laying works, and any issues or delays that arise during the construction process.
2. **Monitoring Company**: A monitoring company uses digital twin technologies to acquire images of the construction site to certify the correspondence between the progress recorded by the construction companies and the state of the construction site as virtually reconstructed by the digital twin. Through these images, the survey company verifies that the construction works are progressing according to plan and that any issues or delays are correctly recorded and addressed.
3. **BaaS Provider**: The BaaS provider deploys a hybrid system of private and public blockchains to enable authenticating data and images relating to intermediate progress on a private blockchain as well as about closing jobs on both public and private blockchains. It thus ensures their integrity and security by enabling the construction companies and the survey company to store hashes of data and content about work-in-progress on the private blockchain. The BaaS provider also gives access to public blockchains to store hashes of the data documenting the completed construction works, which are accessible to external parties, such as regulatory bodies or auditors.

An essential aspect of this BBIE is implementing and making the blockchain accessible as BaaS. Hence, its integration occurs as a service provided externally and independently from the other applications. Entering and accessing the information on the blockchain is done through REST APIs exposed by a server that communicates with the blockchain services. In this way, the tracking and notarization capabilities provided by the blockchain platform are seamlessly integrated with the other components of the BBIE; in particular, the three-dimensional models obtained through the digital twin are inserted and managed with complete autonomy. Therefore, the monitoring company, which plays a pivotal role in the process, decides how and when to interface with the blockchain service during its operations, choosing which data to track without detracting anything in terms of dynamism and flexibility from the functioning of the ecosystem as a whole.

A further enhancement of this BBIE is through a blockchain-based Identity Management System (IMS) to let construction companies, monitoring companies, and BaaS providers authenticate their identities and grant access to specific information and functionalities on the blockchain network, including databases, management applications, and blockchain nodes. This includes granular access control, so stakeholders only have access to the specific information and functionalities they require for their role in the construction process. To this end, the IMS relies on a decentralized and trustless approach; thus, each stakeholder has a digital identity stored on the blockchain network verified by consensus, while smart contracts are used to automate the access control process, allowing stakeholders to set their access policies and rules.

5. Discussion

The primary requirement that an information system must fulfill is to furnish precise, secure, readily available, and pertinent information to facilitate decision-making and assist organizations in realizing their objectives. ISs must incorporate traceability systems, authentication protocols, and analytics tools to meet these requirements. We next discuss how the industrial adoption of a BBIE is feasible and provides clear advantages for all requirements presented above concerning former Information Ecosystems.

5.1. Managing Identities in BBIEs.

An Identity Management System facilitates efficient and secure management of access to resources and applications within organizations, thus mitigating the risk of security breaches and streamlining the management of user and device identities [18].

In the context of identity and access management, blockchain technology can provide a distributed and immutable ledger for identity data, reducing the need for centralized authorities to manage identities. However, it is essential to note that blockchain technology does not replace traditional identity and access management systems. Instead, blockchain technology can complement existing systems by providing an additional layer of security, transparency, and trust. *OAuth2* is the standard *de facto* protocol for authorization; it is designed to authorize and authenticate users with numerous applications without sharing their credentials. However, OAuth2 can be used with identity management systems, providing information regarding the user, such as role and permissions [2], as discussed in Section 4. In this sense, *OAuth2* can be seen as a valuable tool for identity management in BBIE; for instance, the token which encompasses the data for the *OAuth2* protocol can be sent in the calls to the BaaS, directed to the private or permissioned blockchain. Private or permissioned blockchains can use enterprise-level security features like encryption and access controls to enhance security further. Indeed, blockchain SCs can handle the token to verify the identity and apply management logic, granting compliance with enterprise policies. When anchoring the private blockchain blocks on the public ones, the identities are already managed and verified and, thus, safe to be part of the blockchain.

The scheme can be further integrated since blockchain services requester may interact directly with the blockchain, and blockchain addresses might be managed to define an access control list. For example, in Ethereum, smart contracts are executed on the blockchain and their code is readily accessible to all parties. However, the contract owner can exercise authority over who is authorized to interact with the contract and write data to the blockchain. By default, any individual can interact with a deployed smart contract and call upon its functions, modifying its state and writing data to the blockchain. Yet, the contract's code may be structured to implement access controls that limit those who can execute certain actions. For instance, the contract owner may create a modifier function that verifies the sender's Ethereum address, only permitting certain addresses to execute specific actions. Moreover, the contract owner may establish a whitelist of authorized addresses that are allowed to perform specific actions while refusing any transactions that originate from an unauthorized source.

5.2. BBIE integration with legacy or pre-existing systems.

Blockchain applications following the BaaS concept can expose their infrastructure and the SCs function as a service. The BaaS service interface can be implemented to meet different requirements dictated by the communication mechanisms of the systems with which it needs to be integrated. Nowadays, most inter-enterprise information systems are based on Service-Oriented-Architecture or Microservice Architecture [3]; in both architectures, the entities communicate using messages. Hence, it is enough to allow blockchain application service providers to handle requests according to the communication protocol, for instance, REST APIs. This way, pre-existing systems or even legacy systems can easily interact with the BBIE regardless their internal organization or communication protocols.

5.3. Advantages of Blockchain Integration with Enterprise Information Ecosystem.

Blockchain integration enables the shared control of the information allowing a transparent and more fair balanced division of rights, profits, and control. An infrastructure not controlled by a single entity and supported by a blockchain component enables enterprises to share consortial business logic in the shape of SCs. SCs code is run by every node and can be read transparently, as well as the ledger's state, providing organizations with visibility of the consortial state. Taking advantage of these properties, blockchain and SCs are already widely adopted in many contexts (e.g., supply chain management [31]) to solve the visibility problem and ensure equitable profit distribution, when dealing with collaborative business. In addition, other advantages brought by the blockchains to Enterprises regarding transparent information verification in Information Ecosystems are achieved following these steps:

1. Clients such as other entities of the ecosystem, front ends, and devices call SCs exposed by private BaaS;
2. SCs perform requested operations and interact with the distributed ledgers, once obtained consensus, giving transparency among the business parties;
3. Periodically, or by Event Controlled triggering, the last block of the private or permissioned blockchain can be anchored on an external public blockchain, for instance, using *ABI interfaces* (an example found in the appendix), to grant public access to the processed data. Recording data on the public blockchain can also be performed during the process or job closure to make it accessible to the public while managing the sender and contract addresses.

6. Conclusion and Future Work

In this paper, we proposed a new paradigm to leverage the advantages of blockchain technologies in information ecosystems. The integration of the two is represented through a high-level architecture defined by interacting components such as Identity Management Systems (IMS), Information Ecosystems, and Blockchain as a Service (BaaS). In the case study that we have presented, an important role is played by a different component given by a digital twin, demonstrating that BBIEs are structured with variable geometry so that additional features can be flexibly added as needed. As per definition, a blockchain-based information ecosystem (BBIE) is an information ecosystem in which blockchain technology is used to provide a trust mechanism among parties and to manage shared business logic, breaking the traditional scheme of Information Ecosystems dominated by a leading company and leveraging the decentralization of data management, information flow, and business logic. Identity management can be distributed, and identity data can be permanently and immutably recorded in the ledger integrating the OAuth2 protocol. The BaaS component can be tuned to interact with legacy systems, mitigating the legacy dilemma and enabling shared control of information flow and business logic.

We believe that BBIEs can offer an interesting perspective to get out of the impasse of the exhaustion of the push, albeit initially powerful, that propelled blockchain technology in the industrial field, namely traceability applications, a spot that could be the prelude to a "blockchain winter," at least in the industrial sector. Without detracting from the validity of the traceability applications, which remain valid and effective in their limited area, the broadening of the perspective given by the BBIE allows for fully exploiting the possibilities offered by technology in supporting innovative multi-organizational business models. Of course, we are still at the beginning. We must go a long way in deepening and refining this framework to be contiguous and synergistic with inter-company processes in global communication infrastructure. BBIEs can contribute substantially to paving the way in such a direction.

References

[1] Yawar Abbas, Alberto Martinetti, Jan-Jaap Moerman, Ton Hamberg, and Leo AM van Dongen. Do you have confidence in how your rolling stock has been maintained? a blockchain-led knowledge-sharing platform for building trust between stakeholders. *International journal of information management*, 55:102228, 2020.

[2] Nuha Alshuqayran, Nour Ali, and Roger Evans. A systematic mapping study in microservice architecture. In *2016 IEEE 9th International Conference on Service-Oriented Computing and Applications (SOCA)*, pages 44–51. IEEE, 2016.

[3] Agustinus Andriyanto, Robin Doss, and Purnomo Yustianto. Adopting soa and microservices for inter-enterprise architecture in sme communities. In *2019 International Conference on Electrical, Electronics and Information Engineering (ICEEIE)*, volume 6, pages 282–287. IEEE, 2019.

[4] Augusto RC Bedin, Miriam Capretz, and Syed Mir. Blockchain for collaborative businesses. *Mobile Networks and Applications*, 26:277–284, 2021.

[5] Keith Bennett. Legacy systems: Coping with success. *IEEE software*, 12(1):19–23, 1995.

[6] R. Boaden and G. Lockett. Information technology, information systems and information management: definition and development. *European Journal of Information Systems*, 1(1):23–32, 1991.

[7] Diego M Botín-Sanabria, Adriana-Simona Mihaita, Rodrigo E Peimbert-García, Mauricio A

Ramírez-Moreno, Ricardo A Ramírez-Mendoza, and Jorge de J Lozoya-Santos. Digital twin technology challenges and applications: A comprehensive review. *Remote Sensing*, 14(6):1335, 2022.

[8] Paolo Bottoni, Claudio Di Ciccio, Remo Pareschi, Domenico Tortola, Nicola Gessa, and Gilda Massa. Blockchain-as-a-service and blockchain-as-a-partner: Implementation options for supply chain optimization. *Blockchain: Research and Applications*, page 100119, 2022.

[9] Paolo Bottoni, Nicola Gessa, Gilda Massa, Remo Pareschi, Hesham Selim, and Enrico Arcuri. Intelligent smart contracts for innovative supply chain management. *Frontiers in Blockchain*, 3:535787, 2020.

[10] Paolo Bottoni, Remo Pareschi, Domenico Tortola, Nicola Gessa, and Gilda Massa. Distributed ledgers to support revenue-sharing business consortia: a hyperledger-based implementation. In *2021 IEEE Symposium on Computers and Communications (ISCC)*, pages 1–6, 2021.

[11] Diego M. Botín-Sanabria, Adriana-Simona Mihaita, Rodrigo E. Peimbert-García, Mauricio A. Ramírez-Moreno, Ricardo A. Ramírez-Mendoza, and Jorge de J. Lozoya-Santos. Digital twin technology challenges and applications: A comprehensive review. *Remote Sensing*, 14(6), 2022.

[12] Vitalik Buterin et al. A next-generation smart contract and decentralized application platform. *white paper*, 3(37):2–1, 2014.

[13] Stefano Dalla Palma, Remo Pareschi, and Federico Zappone. What is your distributed (hyper) ledger? In *2021 IEEE/ACM 4th International Workshop on Emerging Trends in Software Engineering for Blockchain (WETSEB)*, pages 27–33. IEEE, 2021.

[14] W.H. DeLone and E.R. McLean. Information systems success revisited. pages 2966–2976, 2002.

[15] Marco Di Francesco, Lodovica Marchesi, and Raffaele Porcu. Kryptosafe: managing and trading datasets using blockchain and ipfs. In *2023 IEEE/ACM 6th International Workshop on Emerging Trends in Software Engineering for Blockchain (WETSEB)*. IEEE, 2023.

[16] Ashutosh Dhar Dwivedi, Gautam Srivastava, Shalini Dhar, and Rajani Singh. A decentralized privacy-preserving healthcare blockchain for iot. *Sensors*, 19(2):326, 2019.

[17] B. Farbey, F. F. Land, and D. Targett. A taxonomy of information systems applications: the benefits' evaluation ladder. *European Journal of Information Systems*, 4(1):41–50, 1995.

[18] Md Sadek Ferdous and Ron Poet. A comparative analysis of identity management systems. In *2012 International Conference on High Performance Computing & Simulation (HPCS)*, pages 454–461. IEEE, 2012.

[19] Dominique Guegan. Public blockchain versus private blockhain. 2017.

[20] Ibrahim Abaker Targio Hashem, Ibrar Yaqoob, Nor Badrul Anuar, Salimah Mokhtar, Abdullah Gani, and Samee Ullah Khan. The rise of "big data" on cloud computing: Review and open research issues. *Information systems*, 47:98–115, 2015.

[21] Qile He, Maureen Meadows, Duncan Angwin, Emanuel Gomes, and John Child. Strategic alliance research in the era of digital transformation: Perspectives on future research. *British Journal of Management*, 31(3):589–617, 2020.

[22] Florian Idelberger, Guido Governatori, Régis Riveret, and Giovanni Sartor. Evaluation of logic-based smart contracts for blockchain systems. In *Rule Technologies. Research, Tools,*

and Applications: 10th International Symposium, RuleML 2016, Stony Brook, NY, USA, July 6-9, 2016. Proceedings 10, pages 167–183. Springer, 2016.

[23] Bahareh Lashkari and Petr Musilek. A comprehensive review of blockchain consensus mechanisms. *IEEE Access*, 9:43620–43652, 2021.

[24] Ruidong Li and Hitoshi Asaeda. Fscc: Flexible smart contract interaction with access control for blockchain. In *ICC 2021-IEEE International Conference on Communications*, pages 1–6. IEEE, 2021.

[25] Lodovica Marchesi, Michele Marchesi, Roberto Tonelli, and Maria Ilaria Lunesu. A blockchain architecture for industrial applications. *Blockchain: Research and Applications*, page 100088, 2022.

[26] Michele Marchesi, Lodovica Marchesi, and Roberto Tonelli. An agile software engineering method to design blockchain applications. CEE-SECR '18, New York, NY, USA, 2018. Association for Computing Machinery.

[27] Satoshi Nakamoto. Bitcoin: A peer-to-peer electronic cash system. *Decentralized business review*, page 21260, 2008.

[28] J. Peppard and J. Ward. *The strategic management of information systems: Building a digital strategy*. John Wiley Sons, 2016.

[29] Arun Sekar Rajasekaran, Maria Azees, and Fadi Al-Turjman. A comprehensive survey on blockchain technology. *Sustainable Energy Technologies and Assessments*, 52:102039, 2022.

[30] Paul Rimba, An Binh Tran, Ingo Weber, Mark Staples, Alexander Ponomarev, and Xiwei Xu. Quantifying the cost of distrust: Comparing blockchain and cloud services for business process execution. *Information Systems Frontiers*, 22:489–507, 2020.

[31] Michael Rogerson and Glenn C Parry. Blockchain: case studies in food supply chain visibility. *Supply Chain Management: An International Journal*, 25(5):601–614, 2020.

[32] Mayra Samaniego, Uurtsaikh Jamsrandorj, and Ralph Deters. Blockchain as a service for iot. In *2016 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, pages 433–436, 2016.

[33] Sabrina Schneider, Michael Leyer, and Mary Tate. The transformational impact of blockchain technology on business models and ecosystems: A symbiosis of human and technology agents. *IEEE Transactions on Engineering Management*, 67(4):1184–1195, 2020.

[34] Nick Szabo. Formalizing and securing relationships on public networks. *First monday*, 1997.

[35] Hamed Taherdoost and Mitra Madanchian. Blockchain-based new business models: A systematic review. *Electronics*, 12(6), 2023.

[36] Pinyaphat Tasatanattakool and Chian Techapanupreeda. Blockchain: Challenges and applications. In *2018 International Conference on Information Networking (ICOIN)*, pages 473–475, 2018.

A. ABI Interface

```
const axios = require('axios');
// address of the smart contract
```

```javascript
const contractAddress = '0x123...';
// name of the smart contract function
const functionName = 'transfer(address,uint256)';
 // arguments of the smart contract function
const functionArgs = ['0x456...', 100];

// hash of the smart contract function
const functionSignature = web3.eth.abi.
encodeFunctionSignature(functionName);

const requestBody = {
  "jsonrpc": "2.0",
  "method": "eth_sendTransaction",
  "params": [{
    "from": "0x789...",
    "to": contractAddress,
    "data": functionSignature + web3.eth.abi.encodeParameters(
    ['address', 'uint256'], functionArgs).substring(2)
  }],
  "id": 1
};

axios.post('https://mainnet.infura.io/v3/<projectID>', requestBody)
  .then(response => {
    // result of the smart contract function call
  })
  .catch(error => {
    // handle error
  });
```