Chapter 12
BlockTwins: A Blockchain-Based Digital Twins Framework

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12.1 Introduction

Recently, digital twin has gained significant interest from academia and the industry due to its considerable impact on increasing productivity. DT is the digital replica of an actual-world physical asset, product, or a system around us. Digital twin concepts employed in previous works demonstrate two important features: (1) Every idea explores the relation between the actual system and the consequent simulated system [1], and (2) this relation is proven by producing real-time information from sensors [2]. The idea of a digital twin can be linked with other ideas such as cross-real worlds or co-spaces and mirror prototypes, which aim to, by and large, synchronize part of the physical world with its cyber representation [3, 4].

The digital twin comprises of different modules: actual device, simulated product, and communication between the actual product and virtual product. A digital twin for a car product is depicted in Fig. 12.1. The communication between the physical and the virtual product is important for preserving the vitality of digital twins. The data transmission from a virtual product to a physical product can be utilized to observe and support the execution of the actual product.

Recently, with the appearance of blockchain technology, digital twins have been redefined in its various applications in the Internet of Things. It can be used for transferring data and value onto the Internet with full transparency and security. Conservatively, to build a digital twin system, it needs a central intermediary that

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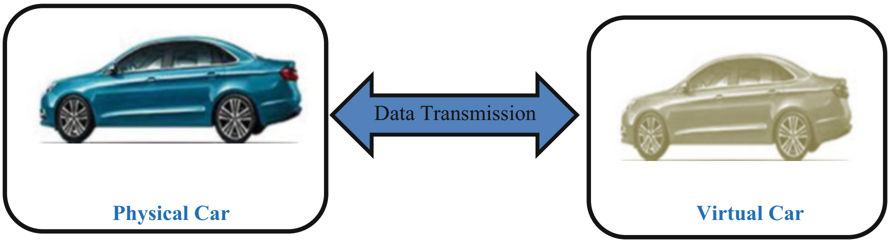


Fig. 12.1 A digital twin of a car product

is dependable in performing analytics and holding data. To generate and monitor digital twins in a secure and immutable manner, blockchain can achieve this aim. Likewise, to monitor the various stages in the construction of DTs, there is a need for a secure, reliable, robust, and consistent method.

Likewise, linking digital twin and blockchain will support businesses and brands to protect their products from being counterfeited and prevent financial losses. Hence, this work aims to propose a decentralized blockchain-based digital twins framework. Concisely, the main contributions of this work are as follows:

- Explore the basic concepts of blockchain and digital twin technologies
- Present a blockchain-based digital twin framework that assures secure and reliable traceability, convenience, and accessibility of transactions and data provenance of its creation process as well as governing and tracking connections initiated by applicants engaged in the digital twins system

The rest of this work is organized as follows: Sect. 12.2 presents the concept of the digital twins, while the blockchain terminology and its concepts are provided in Sect. 12.3. Section 12.4 provides the importance of combining the digital twins with blockchain as a perfect pair, while the proposed framework is introduced in Sect. 12.5. Finally, the conclusion of this work is provided in Sect. 12.6.

12.2 Digital Twins

Thanks to tremendous development in communication and information technology in the last decade, digital twins has become a dynamic topic recently and has been applied in different fields such as manufacturing, smart cities, biomedicine, and aerospace [5–9]. DT can be defined as a replicate or twinning the real system, product, and/or assets using a computer-based model based on collected data and information from the system [10]. Likewise, there are various definitions of DT as tabulated in Table 12.1. The advantage of DT is that it can simulate and model a simple or more complicated process ranging from vehicle parts to homes, cities, and even humans [8].

With the proposed digital twins technology by Grieves in 2002, its purpose is to simulate the system to increase productivity, optimize the operation, and reduce

Table 12.1 Definitions of digital twins

References	Definition
Grieves & Vickers [14]	"The Digital Twin is a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level. At its optimum, any information that could be obtained from inspecting a physical manufactured product can be obtained from its Digital Twin"
Glaessgen & Stargel [15]	"A Digital Twin is an integrated multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin"
Tao, Sui [16]	"Digital twin is a real mapping of all components in the product life cycle using physical data, virtual data and interaction data between them"
Bolton [17]	"A dynamic virtual representation of a physical object or system across its lifecycle, using real-time data to enable understanding, learning and reasoning"
Söderberg [18]	"Using a digital copy of the physical system to perform real-time optimization"

the cost of the productions. The main three parts of DT are the physical system, the virtual model, and the connections between the physical and virtual [11] It is important to understand the behavior and characteristics of DT. DT has some characteristics which discriminate it from other technologies:

- Connectivity
- Reprogrammable and smart
- Digital traces
- Modularity
- Homogenization

The digital twin persistently monitors and observes data from several supplies that support to forecast product safety and recognize the defect in working condition and then send the information to the physical systems to drive prime result. Precisely, if an issue happens in one system and is perceived and regulated, then that solution and operation is not only applied in that system but likewise in other identical systems across the world to provide optimized operation and service [12]. Similarly, predictive modelling is employed in DT to prognosticate the upcoming changes in the real system such as failures in the product's life cycle [8]. Thus, DT can be installed on the device itself or the cloud or edge computing, and the data from the sensors are transferred to the virtual model [13].

There are many applications of digital twins, from the production process, aviation, and agriculture to smart city applications and healthcare systems. Any digital twin platform must be designed and built with special care because it must be resilient to malware and viruses due to the usage of IoT and cloud computing. Important data and relevant information can be damaged because of hacking. Consequently, safety and privacy should be taken very seriously, particularly when it comes to biomedical and healthcare fields [8]. Through technological developments such as blockchain, there are many ways to improve privacy and emphasis on seeking approaches that support securing digital twins' data.

12.3 Blockchain

In the last decade, a new technology called blockchain was developed by Nakamoto [19] to operate as the decentralized transaction ledger of the digital currency called Bitcoin. Blockchain is constructed by a collection of blocks connected by cryptography. The structure of the blockchain network is considered as an ordered list of blocks shown in Fig. 12.2 where each block belongs to a prior block, providing a blockchain. When a block has been generated and connected to the blockchain, the operations in that block cannot be altered or returned [20].

The blockchain core is the coordination process that certifies that all compromise nodes on the network agree on a single global state of the blockchain. A blockchain network typically consists of data producers, consensus nodes, and data pool. When data producers want to write the data on the blockchain, they first submit their data to the data pool as presented in Fig. 12.3. Then the data will be collected by

Fig. 12.2 Blockchain connected network [20]

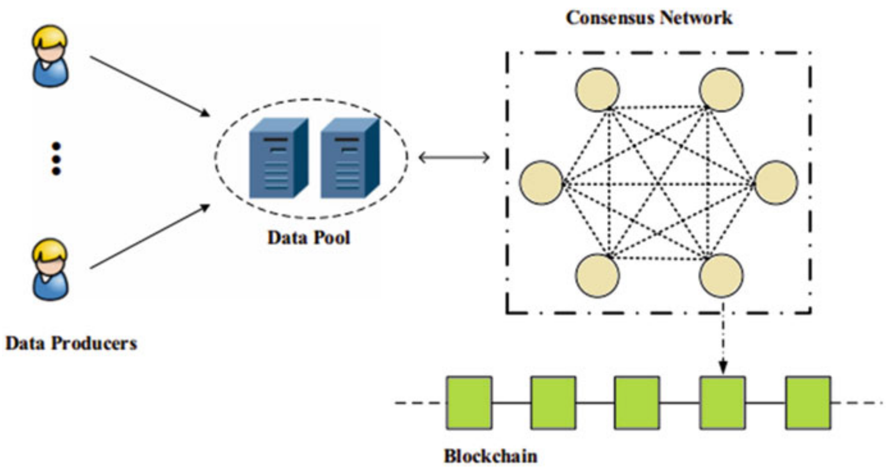


Fig. 12.3 The working process of the blockchain network [20]

compromise points in the consensus network from the data pool. After validating the collected information, the consensus protocol is run by the consensus node, and the bookkeeping node will be picked. The bookkeeping node shall submit the data to the blockchain [20].

The blockchain system is a decentralized and public digital ledger where every engaged history cannot be changed retroactively, without the change of all subsequent blocks. There are several types of blockchain as tabulated in Table 12.2. Currently, blockchain is used in different fields, such as transportation, healthcare, electronic voting, logistics, and so on.

12.4 Blockchain and Digital Twins Pair

Digital twins and blockchain can be leveraged together for their security features and assist businesses to thwart instances of fraud and duplication of their products and services. In the last days, businesses always have been counterfeiting their products. Technology is universal and is advancing at a quick step. Therefore, it has become much easier for fraudsters to create replicas and sell it to unsuspecting customers. These fraudsters not only cause financial losses for reputable brands but may also cause permanent reputational losses. The combination of digital twin and blockchain can provide us with a solution to prevent frauds and help businesses to maintain the authenticity of their offerings.

In 2020, the approximated IoT devices are about over 20 billion. These devices will be able to support millions of digital twins. Digital twins will form one of the fundamental pillars of the digitization of physical objects. Blockchain technology, on the other hand, with its decentralized framework, will bring in transparency, further strengthening the security of the digital data. The concept of combining digital twin and blockchain can be applied in various applications such as in logistics and the medical field. The benefits of using blockchain for digital twins are shown in Fig. 12.4.

12.5 Blockchain-Based Digital Twins Framework

In this section, we describe our proposed blockchain-based digital twins framework called BlockTwins to secure a digital twins system. Transactions would not have to rely on third-party verifications to ensure the security of each transaction in the twins' system during the communication between the virtual and physical assets. Instead, each transaction would be timestamped and then hashed into an ongoing chain of hash-based proof of work. This can prevent any external malicious tampering and modifications by criminals and illegitimate users.

In the industrial control system and manufacturing, the product life cycle contains the strategy, production, servicing, and so on, in which tremendously various

Table 12.2 Types of blockchain systems

Type	Features					
	Access to data	***Network expansion***	***Proof of transaction***	***Identifiability***	***Transaction speed***	Transaction maker
Private	Authorized users	Very easy	Central agency	Possible to identify	Fast	Only authorized users
Public	Anyone	Difficult	Verification algorithm	Anonymity	Slow	Everybody
Consortium	Authorized users	Easy	Previously agreed rule	Possible to identify	Fast	Only authorized users

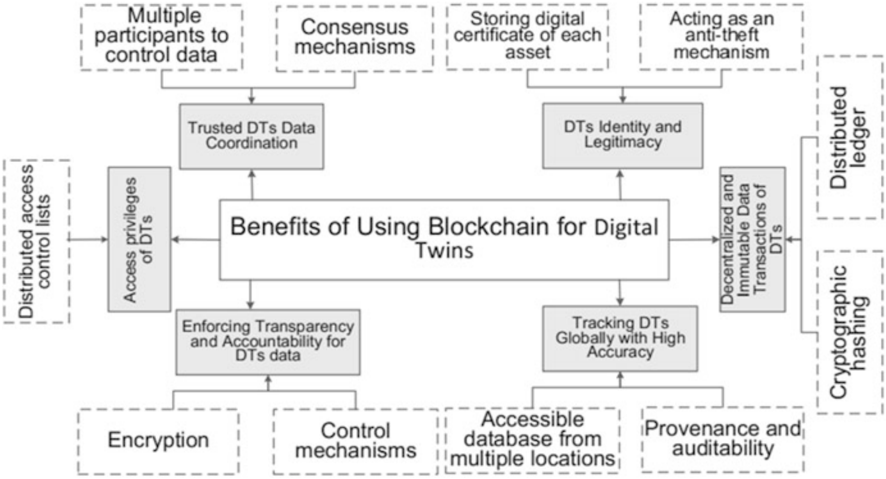


Fig. 12.4 Benefits of using blockchain for digital twins [21]

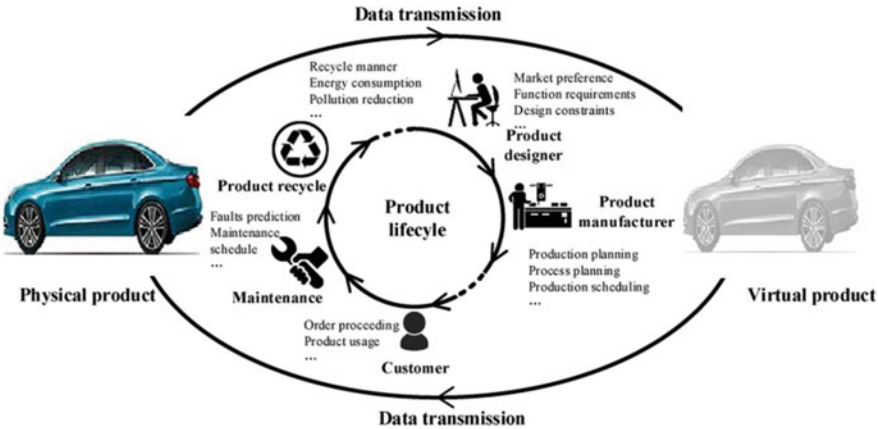
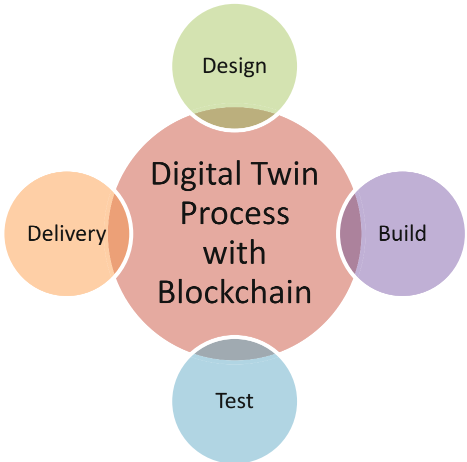


Fig. 12.5 Product life cycle management based on a digital twin

product data are produced and termed as product life cycle data. It is a complex task that should be focused on complicated details in each cycle. The product life cycle management is required to guarantee that all the processes within the product design phases are under control. The advent of DT supports a method to supervise every action of the device inside the whole life cycle and improve the performance of the device based on the virtual model of the digital twin, as demonstrated in Fig. 12.5. Thus, blockchain can be used to handle the problems in the data management of digital twins for all phases of device production securely and efficiently. These problems involve data storage, data sharing, data access, and data authenticity.

To paradigm the proposed system, it is required to build a blockchain network to connect all components within the product life cycle. Every activity of the DT of the product between contenders is logged by the transaction. The transaction will also record the sensor data between the real product and the digital model. All transactions are saved in the linked blocks by hashing algorithms along with timestamp involves the entire processes to mark the time of occurrence. These blocks are connected to establish a blockchain-based product management network. Likewise, blockchain is used to handle the main phases involved in the creation process of DTs as shown in Fig. 12.6. The proposed product life cycle management-based blockchain is shown in Fig. 12.7.

Fig. 12.6 Blockchain as the managing entity for the DT creation process



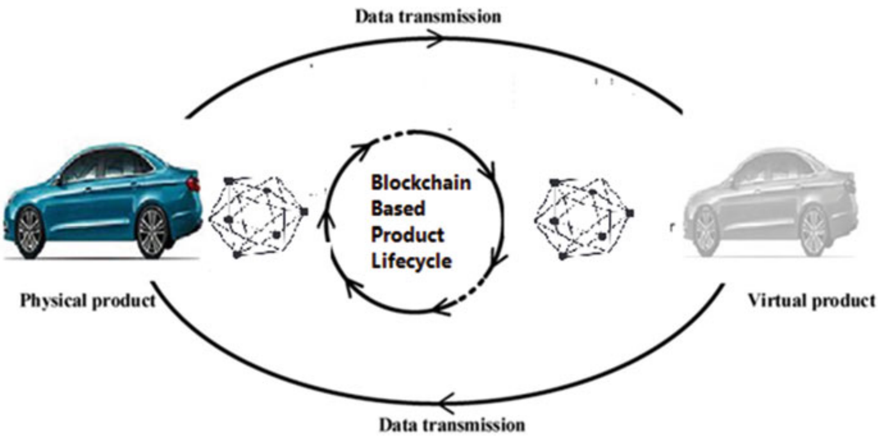


Fig. 12.7 Blockchain-based product life cycle management

12.6 Conclusion

The concept of digital twins can be redefined with the advent of blockchain. It became a decisive technology to aid the IoT-based digital twin's applications for transferring data and value onto the Internet with full transparency, accessibility, trusted traceability, and immutability of transactions and data provenance. Therefore, this work presents a framework of blockchain-based digital twins.

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