Chapter 6
Coupling Blockchain with Emerging Real-Life Applications

This chapter discusses some real-life blockchain-based applications and describes the applicability and necessity of integrating blockchain with the existing centralized systems. Particularly, we describe some widely popular domains where blockchain can be applied, i.e., healthcare, energy, finance, agriculture, smart city, smart manufacturing, e-voting, and personal identity management. To clearly understand the applications, we present visual representations of deploying blockchain's conceptual understanding within those real-life applications. Prior works [1–6] highlight the potential areas or domains for blockchain technology. This chapter presents in detail how blockchain can be blended with those areas to provide a secure service.

6.1 Blockchain in Healthcare

Blockchain technology is considered to have a huge impact on healthcare applications, because healthcare data are sensitive and the leakage or modifications of any such data due to cyber-attacks could have a vital negative impact on hospital authorities and patients. The digitalization of healthcare service opens up the opportunity to track a patient's data and provide assistance by remotely monitoring the health conditions. For example, a senior citizen who is unable to go to a hospital due to health issues, resource shortage, or contagious virus (e.g., Severe Acute Respiratory Syndrome (SARS), Wuhan Novel Coronavirus) can be monitored (e.g., blood pressure, heartbeat, oxygen level) through wearable devices that continuously pass data to the hospital server. Such advancement creates security and privacy concerns as the patient data is directly shared with a third party, and it imposes the risk of altering any sensitive information. However, if the hospital adapts the blockchain technology, any transaction related to patient records (e.g., health data, drug information) would be protected and secured. There would be

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no possibility of data modification that may otherwise result in drug counterfeit, personal information leak, etc. Besides, blockchain can be applied for reliable storage of drug prescriptions, secure access control, supply chain management, and sharing and accessing of patient information. Different healthcare sectors can also benefit from blockchains such as medical billing, clinical trials, exchanging medical records, agreements with other hospitals or organizations, and anti-counterfeiting trade agreements. Due to the robustness of blockchain technology and secure access control over patients' health records, the security and reliability of patients' data are enhanced, particularly while exchanging medical records with different healthcare systems [7]. In Fig. 6.1, we presented some healthcare domains that can adapt blockchain for secure operations.

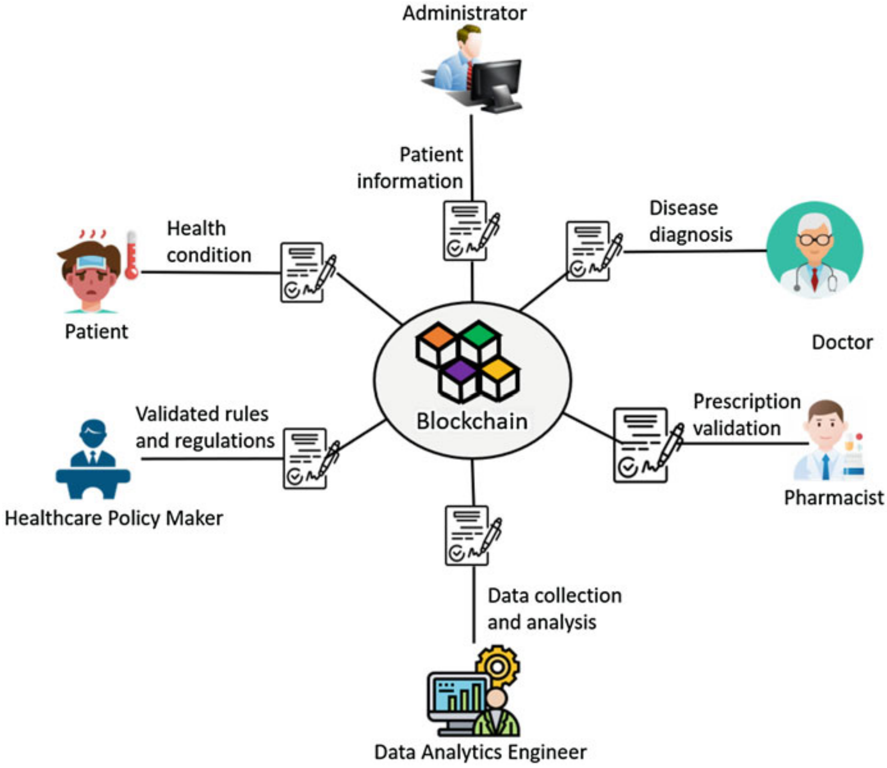

Fig. 6.1 Blockchain applications in healthcare

6.2 Energy Market Trading

It is essential to ensure fair, transparent, and trusted energy trading between two parties residing in a distributed environment in energy market trading. The power of blockchain technology provides secure P2P trading between the blockchain users of the energy network [8, 9]. For example, the energy market trading concept is applicable while designing a resilient system for smart grids. The energy status information of the energy resources can be obtained through IoT and can be stored in an immutable and secure distributed ledger. The authors in [10, 11] discussed peer-to-peer energy resource exchange for distributed grids that enables examining the matching or similarities between generation and load at a distribution level. The optimal matching between loads and generators reduces the relative cost of energy, makes effective utilization of unused power, and ensures lower transmission line congestion. Besides, blockchain can be effective in the maintenance and service purposes of electric components and machines. For instance, we can consider electric vehicles (EVs) that possess the scarce changing infrastructure and encounter complexity while deploying them [12]. Blockchain provides secure services and simplifies the charging process that makes the maintenance of EVs convenient and cheaper. The charging and discharging operations of EVs can be executed by analyzing electricity and smart contracts' requirements and can be worked as batteries to handle energy allocation. In the case of energy market trading between multiple grid agents, a smart contract or an agreement (details on the smart contract are given in Chap. 2) can be created, and we can spread that over the network. None of the parties can refuse the agreement due to traceability, and the identity of the transacted parties remains anonymous. Besides, the guarantee of immutable information about distributed energy resources can help us to discover reliable knowledge and perform efficient, intelligent decisions. In Fig. 6.2, we presented a high-level overview of a blockchain-based energy market trading scenario.

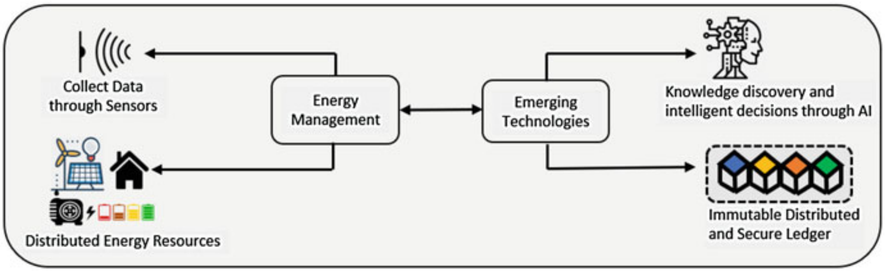

Fig. 6.2 Applying blockchain in energy market trading

6.3 Banking and Finance

The fragmented banking systems can also benefit from blockchain technology. The blockchain revolution can solve the issue related to trust, transparency, and confidentiality. Due to the intermediary regulatory process and clearance of operational trade, the customers need to wait for a long processing time to process their transactions [13]. Such delays cause trouble for the traders, brokers, regulators, and all other involved parties/stakeholders. Blockchain can resolve this issue by establishing authentication, confidentiality, non-repudiation through asymmetric cryptography and ensuring the clients' security and privacy through decentralization. Blockchain eliminates the intermediary processes and monotonous paperwork while dealing with the financial exchange and legal transfer ownership. Figure 6.3 represents the applicability of blockchain technology in the banking and finance sector.

6.4 Agriculture and Food Supply Chain

Blockchain technology has brought a revolutionary change in the notion of trust by demonstrating its improved efficiencies toward sustainable agricultural development. When the blockchain-based agricultural infrastructure is constructed with the immutable distributed record management strategy, the integrity of the baseline agricultural data is safeguarded for the participants involved in the transparent data management [14]. The agriculture sectors include farmland monitoring, secure transactions, quality assurance, trustworthy logistics support, reliable decision-making, and predictive analysis, and analyzing a product's market status. The

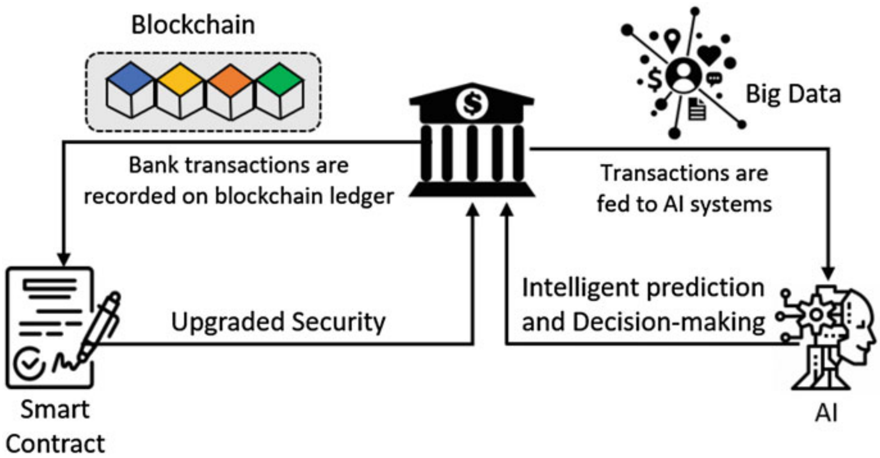

Fig. 6.3 Applicability of blockchain in banking and finance sectors

evaluation of IoT technology enables tracking agricultural products and monitoring farmland conditions, and blockchain technology protects those data by encapsulating them within secure blockchain blocks. Any predictive analysis can be performed from those extracted data, and necessary steps can be taken according to the forecasting results [15]. Besides, while dealing with customers about products, a smart contract can be signed between both parties that ensure secure and reliable asset transfer. Further, in a food supply chain, a product may consist of multiple parts supplied by different manufacturers. However, some low-quality or forged product may be included in the supply chain. It is costly to apply anti-fraud systems for every single part of a product throughout the process life-time in such a situation. The integration of blockchain and IoT concept can be used to mitigate such a high cost and identify any low-quality product. Each product can be attached with a unique ID, timestamp, product-quality status, and other necessary information. The identification of each part is saved into the blockchain, which is immutable and traceable. Later on, even any changes within the item reveal the tampered product, and the supplier can easily trace and replace that. In this way, the integration of blockchain with IoT helps to fasten production speed, reduce cost, and enable flexible operations in supply chain management. In Fig. 6.4, we illustrated the blockchain applicability within different domains of smart farming.

6.5 Smart City

A smart city's infrastructure consists of traffic management, surveillance of roads and highways, optimal road light control, monitoring environment, smart waste management, and parking, etc. All these applications of a smart city are dependent on the idea of the Internet of Things (IoT). The improved infrastructure and widespread availability of internet facility enable deploying smart city in an effective fashion [16–18]. The applications of smart cities are mostly dependent on the collected and observed data by IoT devices that are integrated with the system

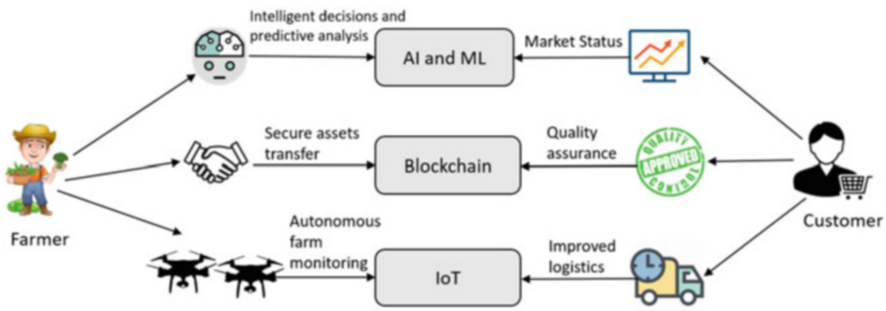

Fig. 6.4 Integrating blockchain to ensure secure and smart agriculture

environment. Any data extracted by the sensors or video data captured by the camera can be further used for analysis, decision-making, constructing a prediction model, or identifying useful information. However, due to the heterogeneous nature and resource-constrained issues, a smart city is prone to vulnerable attacks [19, 20]. To avoid such attacks, storing the collected and observed data in a secure and trustless platform is indispensable. In Fig. 6.5, we presented different blockchain applications considering smart city infrastructure. The smart city applications include smart traffic management system by monitoring vehicle activities, and traffic flows by capturing and analyzing video data. Smart security includes personal property, organizations, or roadside surveillance, while smart road light control can be operated by determining vehicles' presence. A smart environment means capturing the weather and environmental information to understand the purity of nature, and a smart waste management system refers to the waste bin status monitoring without any human involvement. Finally, smart parking helps to know about parking information of a particular area (e.g., free parking location). All these applications pass sensitive information of the users and their surroundings, and any leakage or slight modifications of the collected data can hamper any related operations or decision-making process. However, if those collected data can be handled and managed through blockchain technology, then it can accelerate the decision-making process due to its fast data validation process [21].

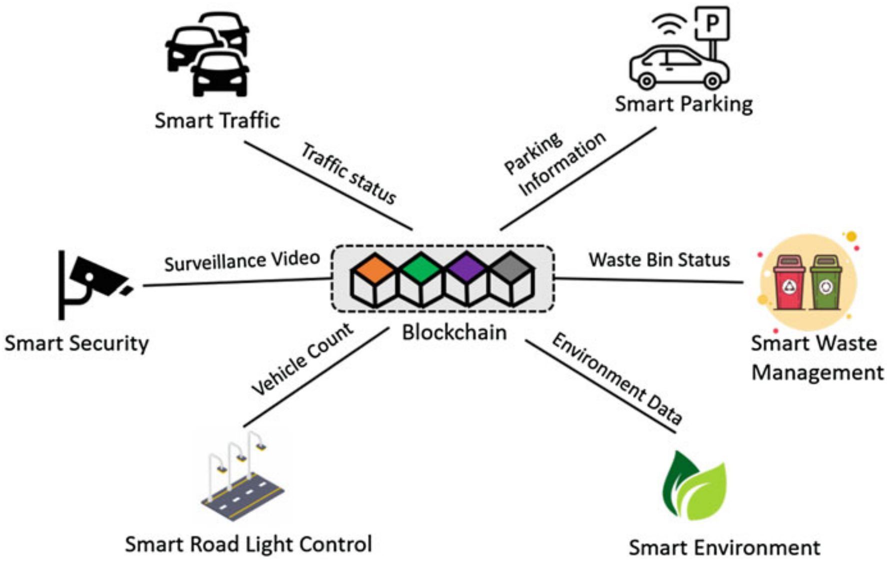

Fig. 6.5 Application of blockchain in smart city infrastructure

6.6 Smart Manufacturing

The manufacturing industries are experiencing an upgrade from automated to smart manufacturing. The analysis of manufacturing data plays a vital role in this regard. A vast amount of data is generated from the overall product life cycle, e.g., requirement gathering, product designing, supply information of raw material, production, distribution, maintenance, after-sales service [22–24]. An overview of different applications in smart manufacturing is illustrated in Fig. 6.6. The blockchain collects product information via a shared and secure record of the exchange. A product may be possessed by various actors, e.g., manufacturers, distributors, retailers, certifiers, operation management, registers, waste management, and finally, reach the customers. Each product can be attached with a tag in the form of RFID, barcode, or QR code. The tag can act as a cryptographic identifier and establish a link between the physical product and its virtual naming on the blockchain network. Each actor provides their relevant product information within the blockchain, and the information remains safe and secure. The actors can observe the product details according to their accessibility. Sometimes, a department may require the generated data from another department. We need to ensure immutability while exchanging that information among various departments or with another industry.

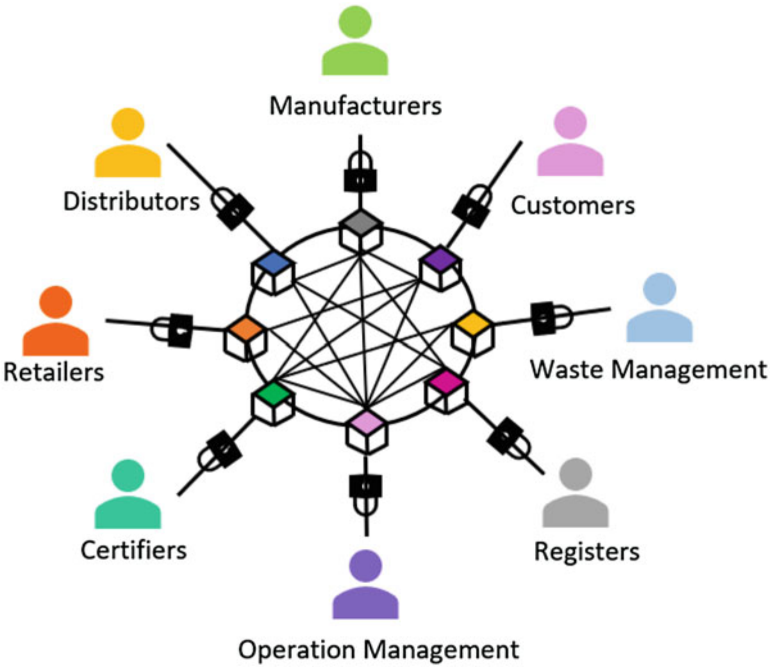

Fig. 6.6 Blockchain-based smart manufacturing process

Several blockchains can be constructed for different sections, and blockchain interoperability can be incorporated to obtain secure information exchange.

6.7 Voting

Another useful application of blockchain is constructing a voting platform. The conventional voting systems can be improved by leveraging blockchain. We need a mechanism that guarantees a vote to be counted without skipping or tampering. Blockchain can solve the matter by storing every vote in immutable and distributed ledgers [25–28]. In Fig. 6.7, we presented a blockchain-based e-voting scheme. Initially, each voter needs to provide credentials, and the respective authority examines the credentials. Further, the authenticated voter provides a signed vote in a smart contract that resides within a blockchain. The blockchain verifies the vote and generates a transaction id for that voter that is written in the smart contract. Any modifications of the vote generate a different transaction id, and hence, the block hash will be changed. As a result, the tampered block will not be a part of the chain anymore. Therefore, there is no chance of voting manipulation, and the voters are guaranteed that their vote would be counted.

6.8 Personal Identity Management

In today's world, personal identity is verified by matching an identity card (e.g., passport, driving license) of a person with the data stored on the server. However, it is possible to forge those private data, and any slight modification of data can bring a lot of trouble for that user. In such applications, blockchain can be an effective mechanism to secure the online identities of the users. Blockchain can allow a user

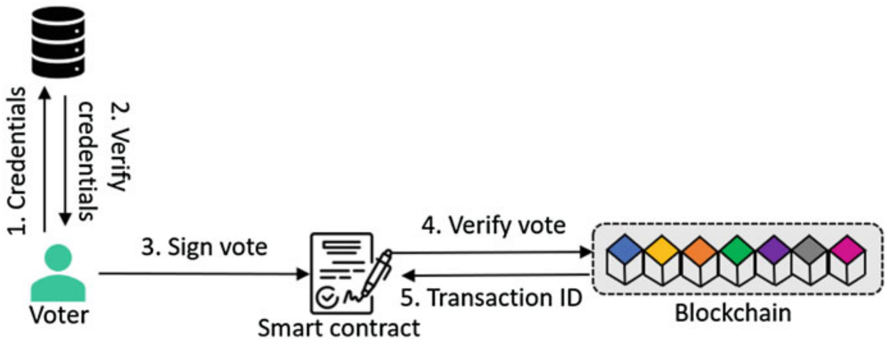

Fig. 6.7 Blockchain-based smart manufacturing process

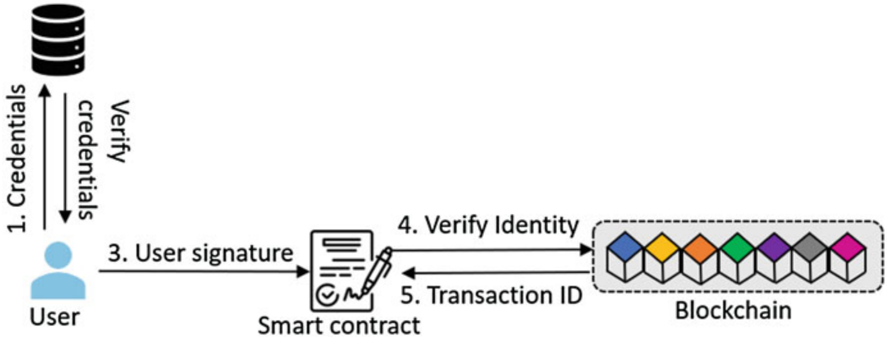

Fig. 6.8 Blockchain-based personal identity management

to create an encrypted identity without revealing its sensitive information and also can trace or identify any fraudulent activities of the systems [29]. A digital ID can be generated after adapting the blockchain principle, and any sensitive activities (e.g., payment, appointment) can be accessed and verified. It eliminates the risk of changing any user information, as any change would alter the block hash that results in isolation of the forged block from the main chain. In Fig. 6.8, we presented how a user identity can be signed, verified, and stored within a blockchain.

6.9 Discussion

In this chapter, we discuss various real-life blockchain applications and explain how the integration of blockchain technology has brought revolutionary changes, particularly in ensuring the security of those substantially popular applications. Throughout this chapter, we present high-level visual representations of the working mechanisms of different blockchain application domains with proper explanations that help the reader perceive a clear conception about the working process and the necessity of coupling blockchain technology emerging real-life applications.

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