Blockchain Technology as Enablement of Industry 4.0: Perspective from e-Delphi Panel

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Abstract. Industry 4.0 (also known as smart manufacturing or Industrial Internet of Things (IIoT)) refers to a major change in the way products are manufactured and delivered, with a focus on industrial automation and the flexible factory-backed with several technologies that include the Internet of things (IoT), cyber-physical systems, and artificial intelligence. Industry 4.0 gave birth to a new age of smart manufacturing, automated supply chain, and personalized goods and services. Meanwhile, the rise in the application of blockchain technology (BCT) in different sectors propels the industry 4.0 model to extend its scope. This chapter discusses the impact of BCT as the enablement of Industry 4.0. The modified e-Delphi methodology aimed at gathering the opinions of recognized experts was used. The findings present the potential that BCT brings, uses case along with emerging issues. Emerging issues such as BCT security, interoperability, smart contract issues, digital twin issues, and ethical issues are discussed and solutions are proposed.

Keywords: Blockchain technology, Cyber-physical systems, Industry 4.0, Smart contracts

1 Introduction

Industry 4.0 is transforming the way industries produce, develop, and sell their goods. Manufacturers are incorporating enabling technologies such as the Internet of Things (IoT), cloud computing and analytics, artificial intelligence (AI), cloud computing, big data analytics, smart sensors, location detection technologies, adaptive robotics, and machine learning into their manufacturing operational activities [1-5]. The real strength of Industry 4.0 lies in the integration of technologies in the network of industrial machines that generate, exchange information, and make decisions based on that information. Industry 4.0 pushes the impact of digital transformation to a whole new stage by leveraging interconnectivity via IoT, accessibility and decision making based on real-time data, and the integration of cyber-physical systems [6, 7]. Put, Industry 4.0 transforms traditional factories into “smart” factories.

As manufacturers embrace Industry 4.0, evolving smart factories deliver several potential opportunities. Smart factories, for example, can analyze large quantities of data collected from industrial sensors and machinery in real-time, offering real-time tracking of manufacturing properties and conducting predictive maintenance based on the data to minimize downtime.

“Block-chain” has been a common buzzword since Satoshi Nakamoto leveraged the technology as the data structure for Bitcoin in 2008 [10]. The focal point of blockchain technology (BCT) was on financial applications [8]. As a result, it's unsurprising that it's fairly well-employed for handling financial operations where trust can be gained by the use of blockchains. The blockchain's role in Industry 4.0 is unleashing a slew of emerging innovations. For instance, BCT can guarantees that the Cyber-Physical Systems (CPS) that make up smart factories can order a required spare part independently and safely, streamline the manufacturing processes to reduce power usage, predict future supply chain defects before they occur, and many other benefits [9]. As a result, BCT is a promising enabler in the evolution of Industry 4.0.

Because of blockchain's efficiency in handling transactions, industries are now looking for it to solve other issues, including a variety of manufacturing-related issues. A blockchain, for instance, can link ledgers across a production process to increase the accuracy and reliability of product traceability. By enhancing tracking capabilities, a cumbersome, multi-day operation can be turned into an automated process that takes just seconds. For instance, if you employ BCT between smart Enterprise Resource Planning (ERP) and parts supplier, as well as the cyber-physical infrastructure that makes up the industrial plant, machines can procure spare parts securely and fully autonomous.

Besides that, blockchain's ability to allow secure and open transactions between any range of smart devices makes it critical for the economic changes that industry 4.0 implies. In a smart factory, automated controllers exchange data from a complex network of equipment, parts, and processes. Designers, distribution firms, and equipment suppliers are among the many players in the value chain. As it transforms a series of components into a finished product, blockchain can track and record every step of the process. Risk factors such as locating defective parts may be mitigated with BCT.

In this chapter, the author provides a detailed discussion of the potential of blockchain technology for Industry 4.0. The organization of the chapter is as follows: Section 2 presents an overview of blockchain technology and industry 4.0. In this chapter, the blockchain generations and the role of CPS in industry 4.0 are presented. Section 3 describes the enablement of blockchain technology in industry 4.0 along with use cases. Section 4 introduces emerging issues that impact the deployment of blockchain technology in industry 4.0 and the chapter is concluded in section 5.

2 Blockchain Technology and Industry 4.0

2.1 Blockchain Technology

The blockchain platform was first conceived in the financial sector in 2009 when it was referred to as a peer-to-peer electronic cash system [9]. It began as the basis for a completely distributed crypto-currency unit (bitcoin), but currently, it is spreading into other fields, including healthcare, banking, agriculture, as well as e-commerce. Although concepts for the blockchain were circulating in computer science spheres for some time, it was Satoshi Nakamoto, the anonymous founder of Bitcoin, who presented the blockchain as we recognize it in the white paper for BTC [9].

The bitcoin network, also known as blockchain 1.0, launched the 1st generation of the technology in 2009. The formation of the first cryptocurrencies occurred during this generation. The concept revolved around payment and how it could be used to produce cryptocurrency [10]. Blockchain technology has been dubbed the "internet of money" since its ability to allow the peer-to-peer transaction without depending on the oversight or approval of an intermediary such as a state or financial regulator.

In 2010, smart contracts and financial services for different purposes were implemented as the second stage of BCT [11]. Smart contracts were perhaps the most significant breakthrough in the second generation brought on by Ethereum. This era introduced blockchain architecture using the Ethereum and Hyperledger systems. In simple terms, Ethereum suggests that BCT can be used to make digital asset management possible without demanding platform ownership. For the very first time, Ethereum offers a solution to the internet's "centralization" (which has assisted companies like Google and Facebook) by essentially incorporating BCT in their platform.

The 3rd generation is predominantly concerned with real-time services on public ledgers and distributed databases [12]. At this level, Industry 4.0-based technologies are seamlessly incorporated. A range of emerging technologies is integrated with machinery and BCT. In this generation, scalability is one of the most significant challenges that blockchain faces [13-15]. Although many newer cryptocurrencies claim to be able to handle more transactions in a second, one of the most important features a third-generation blockchain would need to provide is a reliable scaling solution – whether that means changing the features of the blockchain itself or using a ‘second-layer solution to handle more transactions.

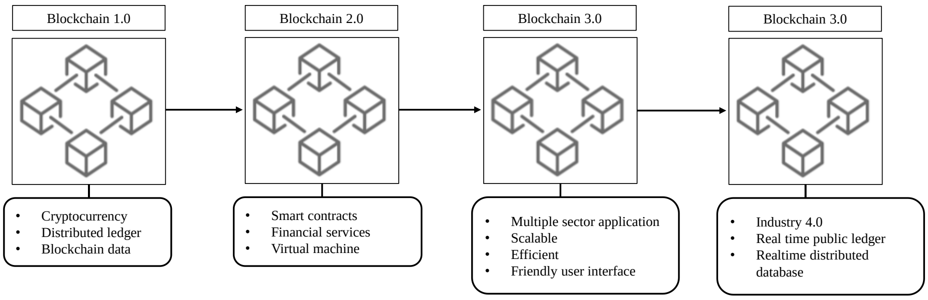

Fig. 1. Evolution of blockchain technology

Even though blockchain technology is still in its infancy, it has made considerable progress in the last five years [16, 17]. BCT makes transaction tracking and processing much more open and stable. In BCT, any time a service transaction is completed, a new block of data is recorded on the blockchain, which will remain there indefinitely and be visible to all parties. The details in the BCT are extensively encrypted to prevent tampering with the transactions.

Since the ledger is permanent and distributed throughout the network in different locations, blockchain provides greater security. This means it can keep working even if a network unit fails or if one of the chain's participants exits. Moreover, there is no involvement from a third party (middlemen). Blockchain removes middlemen and removes the need for the central system, making operations quicker, effective and safe [18].

Transactions are used to send and receive digital assets such as money, financial data, personal data, health information, computer activity records, and just about any other digital asset that can be sent. The block contains transaction information which is connected to the chain using hash values, forming a blockchain with full data integrity. Each additional block is connected to the one before it. Every one of the system's actors is in charge of distributing and verifying new transactions, as well as encoding them into new blocks (Figure 2).

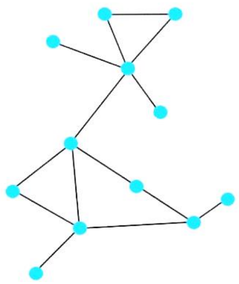

Fig. 2. Decentralization in blockchain technology

The BCT decentralization feature enables stable, open, persistent, and reliable data sharing with nodes taking on the position of the current center point. Every node possesses a copy of blockchain at about the same time. As a result, the data stored in the blockchain cannot be manipulated by a single entity since all other nodes must agree.

2.2 Industry 4.0

Industry 4.0 also known as smart manufacturing or Industrial IoT (IIoT), is the current state which encompasses the 4th industrial revolution that employs the Internet of Things (IoT) as well as other technologies to digitally boost manufacturing lines and transform them into "smart" lines [19]. In industry 4.0, improved performance in the manufacturing process is optimized through real-time huge data analysis which results in almost real-time autonomous decision making.

In the 3rd industrial revolution, companies started to integrate Information and Communication Technologies (ICTs) in their industry through the advancement of industrial computers, workstations, sensors, automation, and the Internet in manufacturing plants. Unlike past revolutions, the primary idea of Industry 4.0 is not fueled by a particular technology. Industry 4.0 features the interconnection of multiple technologies present in the industrial world, allowing for data collection, analysis of big industrial data, and making the right decisions based on the information collected from the industrial processes.

Cyber-Physical Systems (CPS)

Cyber-physical system (CPS) is a crucial component in the application of Industry 4.0. CPS refers to an Industry 4.0-enabled manufacturing system that allows real-time information collection, analysis, and visibility in all aspects of the manufacturing process. With CPS, means of production becomes networked and able to ‘share information,' allowing for new production processes, value creation, and real-time adjustments [20]. CPS offers integration of various systems of diverse natures with the primary goal of controlling a physical process and adapting to new circumstances in real-time through feedback [21]. Equipped with computing capability, control modules, sensors, and actuators, CPS can be IP address-assigned entity that self-monitor, generate information about its activity, and communicate with other related entities or even the outside world.

CPS allows both computational and communication technologies to be integrated into a wide range of physical structures. CPS is centered on a large computational capacity and certain characteristics that grant freedom to make decisions based on the integration of disruptive technology and acquired data from the surrounding in which it is incorporated. As a result, extreme integration between the physical and digital worlds is feasible, for example, sensors or machinery can send data to the CPS, which then takes action based on its database of information. Besides that, CPS is the potential for breaking down the industrial hierarchical levels, facilitating the so-called horizontal and vertical integration of the industrial world, allowing any computer at any industrial scale to communicate and interoperate with just another device from every other place. With this, data from different industrial processes can be integrated and used by any other party in the industrial chain.

3 Methods

The modified e-Delphi method was used in this study [60]. The Delphi method is an iterative process that employs a series of data collection and analysis techniques in response to expert decisions at regular intervals [61]. The Delphi method is a method for gaining individual consensus on issues where there is little to no conclusive proof and where consensus is relevant. The traditional Delphi method intends to elicit group opinion through an anonymized, multi-level group interaction, with several rounds monitored by a mediator to find agreement [3]. The anonymity factor prevents issues arising from influential experts, community influence, and status, which are often more noticeable in the hierarchy of professionals.

The electronic Delphi (e-Delphi) technique utilize online tools. Researchers may use this approach to develop expert consensus using the World Wide Web's tools for simplicity, ease of use, and intensity of the discussion. The internet research tools used in this analysis were Google Drive and Gmail. The number of "rounds" or iterations is generally decided upon at the start of the analysis and varies from 2 to 4. As shown in Figure 3, there were 3 rounds of information and consensus building in this study.

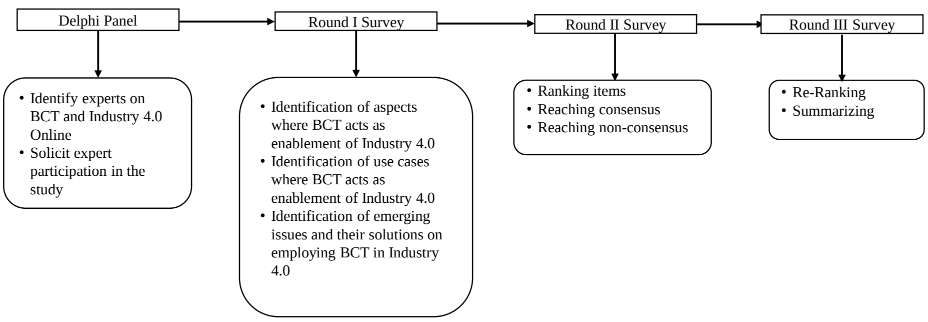

Fig. 3. Modified Delphi web-based methodology employed in this study

3.1 Delphi Panel Selection

Potential panel participants were chosen based on a study of the literature, with top scholars who have researched in the fields of BCT and industry 4.0 in reputable international journals were considered. Potential panellists were contacted by email after the selection process to request their approval. Following approval, a follow-up letter is communicated to the experts who approved the invitation to participate, along with the necessary research forms. The method for selecting panellists in this study is tabulated in Table 1. 31 experts were approached and invited to participate in the study using the table 1 procedure (between November 2020 and January 2021). Those who wanted to take part in the study were asked to provide an email address to which all research correspondence would be used.

Table 1. *Procedure for the panel selection*

Phase	**Process**	**Result**
Phase I	Review the literature to assemble a list of	Expert names

	possible panel members based on BCT and industry 4.0 publications.	compilation
Phase II	Look for evidence of BCT and industry 4.0 expertise in books and journal articles by the same researcher.	Record evidence
Phase III	Examine the total number of citations of the reseatcher.	Record number of citations
Phase IV	Determine the value of the experts' contributions to the academic discussion of BCT and industry 4.0.	Rate on the scale of 1-3 (1-not useful, 2-moderately useful, 3-very useful)
Phase V	Make a final list of possible expert members.	The final list of experts
Phase VI	Communicate with the final list of experts through email	Email invitation to participate in the study

The survey was sent via Google Drive to protect the privacy and confidentiality of the responses. The questions were developed using the Google Drive form application and then sent to the panellist via e-mail addresses. This system benefits from quick responses and immediate analysis, and it encourages the use of technological advances to reach consensus among experts who often most of them have limited time. There were three Delphi iterations in total. The degree of consensus is typically defined before the analysis and is determined by the study's goals and implications for practice [58, 59]. In this study, we set a threshold level of 70% consensus.

3.2 e-Delphi Round I

The first Delphi iteration participants were asked to identify (1) what aspects of BCT be considered as enablement of industry 4.0? (2) What uses cases can describe the BCT enablement on industry 4.0? (3) What are the emerging issues arising in employing BCT in industry 4.0? and (4) What are the proposed solutions to the arising issues? The panellists were given four weeks to finish and send their responses at first, but this was extended by one week to enable all 21 panellists to complete the survey. The researcher was able to aggregate the responses together due to the use of repetitive themes in the responses. Themes were derived from the formal responses after a thorough examination of the collective comments and careful consideration of the concepts used in the responses by the panellists. The list also included remarks that did not fit into any of the other groupings.

3.3 e-Delphi Round II

The Round 1 responses were emailed to the panellists in the second Delphi iteration so that they could revisit their responses and adjust or strengthen their Round 1 responses (Franklin & Hart, 2007). In the second round, each email address received the list of responses from round one. On a scale of one to nine, each panellist was asked to rate the item's significance. On a 9-point scale, scores 1-3 suggest that panellists believe the item is not significant, 4-6 indicate equivocality and 7-9 indicate that the item is significant. If all ratings fall under one of these ranges, there is absolute consensus; if ranks fall within each of the scale categories, there is a broad concept of agreement. Points for which 70% of panellists did not score within the scale of 7-9 were omitted after analysis. The panellists were then given the results for round three.

3.4 e-Delphi Round III

In round 3, panellists used the same 9-point measure to rate the components, however this time with an awareness of the group's ratings. As a result, participants may focus on their score and make adjustments in light of the group's score while remaining anonymous to the rest of the panel. Each round had seen a decline in the number of participants, with the last round having just 16 responses. Round 3 results were evaluated in the same way as round 2 results were, and a final number of points was settled upon. This list was then divided into major themes.

4 Findings and Discussion

The section of the chapter presents the findings of the study particularly on how blockchain acts as enablement of industry 4.0 Based on the findings of the modified web-based Delphi methodology employed in the study, the author presents and discusses several ways on how BCT can impact industry 4.0, emerging issues and proposed solutions.

The aspects were BCT acts as enablement which was identified as of very high significance by 70% of the expert panel were: 1) Trackability with Smart Contracts, 2) End to end visibility 3) Quality 4.0, 4) Intellectual Property (IP) Protection, 5) Product safety, 6) Fraud prevention, 7) Data & Communication Security and 8) Neighborhood Microgrid.

3.1 Trackability with Smart Contracts

Smart contracts are simply computer code that can perform complex functions automatically and operate with a basic “if x then y” logic [22-24]. For instance, a smart contract can be coded so that when it gets the data verifying that a shipment of cargo has been delivered by the buyer, the data is checked for authenticity, and the smart contract immediately transfers payment that has been held in escrow.

Compared with traditional contracts where human confirmation is required for the operation of a contract, to review the terms of service and determine the next steps by the signed agreement. With smart contracts, information is shared reliably, and safely across complex supply chains. Smart contracts offer unalterable, persistent digital records of items, components, and goods, fostering transaction openness between all participants [25]. By using smart contracts, the transaction is marked with a special tag which is beneficial due to (1) lack of trust among members beneficial (2) the supply chain includes several parties with their different IT systems, or (3) new party can be inducted into the chain.

Smart contracts minimize payment delay, mitigate billing and payment inconsistencies, and connect processes to real-world physical experiences. A smart contract's purpose is to make contracts self-executing and actionable, in other words, automatic. Since smart contracts are stored on a single, distributed ledger, anybody with the proper authorization can access them. This implies that all participants in the supply chain will see all smart contracts at any time [26]. They can also see the contract's conditions, as well as how near it is to being met along with the contract's records

It's worth remembering that smart contracts aren't just digital copies of paper contracts; they're pieces of code. They're established as "if-then" conditions in programmatic coding, thus, if one condition happened, another happens. Depending on the contract and the number of parties involved, these conditions may require one or more steps. Aside from offering a method to increase transaction performance, advocates of smart contracts promote its potential to remove non-enforced terms in conventional contracts. For example, if two parties agree to procedural code language in a contract but find that implementing one element of the contract is economically unviable or impractical, they can simply exclude the phrase in a smart contract.

Use Case I: Logistics 4.0

Numerous operations in the logistics industry, such as agreement terms, fraud prevention, records management, transactions, cash flow, and more, are simplified and secured by smart contracts [27]. Smart contracts can track deliveries from the start to the end of their journey — as they exit the factory and find their way to the customer [28]. The blockchain stores all of the details about its journeys, and when the terms are met, smart contracts are executed.

Trucking companies are now attempting to invest in good tracking technology, but the security of these systems is doubtful. Furthermore, since these technologies lack a secure authentication mechanism, cybercriminals or bad actors can still access the network's data. The blockchain can radically offer the solution in these situations.

Blockchain can verify all of the driver records for every new carrier, much as it can validate a used vehicle. Many companies are increasingly concerned with data being tampered with, duplicated, or even full of inaccuracies on their load boards. This can contribute to a distorted portrayal of customer needs. with the BCT for logistics tracking feature, importers can directly update the blockchain with timestamps. There is no risk of mistake or replication since all of the data in the blockchain is checked.

3.2 End to End Visibility

Within complex supply chains, industries may use BCT to share data instantly, efficiently, and safely. Blockchain can provide an unchangeable, persistent digital record of items, pieces, and goods, fostering end-to-end visibility and providing all parties with a single source of reality [29]. Transactions can have a unique tag added to them in the blockchain records. These real-time activity logs can be used by manufacturers to monitor the movement of source parts and finished products. All orders, sales, and inventory can be tracked by all parties, allowing them to stay on top of things. Consider the effect that complete supply chain visibility would have on businesses. They'll be able to see where parts were sourced, who was involved in the manufacturing process, and how the product went from one end of the supply chain to the other. This provides complete accountability for industries and aids in the strengthening of corporate relationships.

Use Case: Aircraft Industry

A completely operational commercial plane needs millions of small and large parts, many of which come from different sources. As a result, knowing the history of each component of the aircraft is crucial. Despite developments in sensor technology, IoT, data analytics, and cloud computing, there is still a lack of real-time access to details such as components, settings, and service schedules. In reality, obtaining comprehensive, real-time details of an airliner, let alone an entire fleet is incredibly difficult. And there's the blockchain. By balancing openness and security on a distributed ledger, it has the potential to resolve this.

Not only can blockchain trace the origin of various parts, but it also has the potential to record the setup of a plane for any flight during its long operational life by providing a snapshot of all the pieces and processes. BCT keeps the capacity of creating a digital record for each component mounted in a plane and updating it after each service or inspection. Tail numbers, part positions on planes, suppliers, part admissibility, the name of each mechanic who worked with the part, and the service location are all examples of data that could be captured. Besides that, blockchain enables users to see the entire digital record of a product while hiding those details from others to protect confidential information and trade secrets.

3.4 Quality 4.0

Quality 4.0 is the extension of the fourth industrial revolution to the field of quality [30]. The central principle of Quality 4.0 is to integrate quality management practices with evolving Industry 4.0 capabilities to help industries achieve operational excellence. The rapid, efficient aggregation of data from different sources, which enables informed and efficient decision-making, is a major aspect of Quality 4.0 [31]. Furthermore, automatic assessment reduces the possibility of human error in interpreting the data. Non-contact inspection automation also allows for the processing of even larger volumes of data for more in-depth research. With BCT, blockchain provides immutable records of quality checks and manufacturing process details, in addition to assisting clients in tracking and tracing shipment parts through a supply chain. Any transaction, adjustment, or quality check is automatically entered on the blockchain database, which tags each product differently. The development setup typically includes automated quality checks that produce and document measurements directly to the blockchain. The quality assurance/check ensures that industries track machines for signs of potential failures and repair them making sure high efficiency all of the time, rather than waiting for them to break down [32].

Moreover, current quality metrics are largely analytical – they offer information about what occurred, why it occurred, and use predictive analysis to simulate what would occur as a result. Industry 4.0 technologies such as big data, machine learning, and artificial intelligence allow the inclusion of the fourth category of models: prescriptive models that can predict failure and advise on the best course of action.

Use Case I: Pharmaceutical industry

3.3 Product Safety

For decades, it has been a challenge to find out how to build a (traceability) scheme for the complete product supply ecosystem such as food [33]. Due to its emphasis on trust, integrity, and openness, BCT is considered a good fit for this issue. Retailers and companies have begun to use BCT to improve the product supply chain's security and traceability. Aside from food safety, another reason for using Blockchain in the product supply chain is to reduce document processing and create an efficient billing and payment system.

Use Case I: Tracking food from the field

From time-to-time people have been getting sick from infected lettuce or other products. When this happens, supermarkets and other retailers do as we would expect: they remove the product from the shelf to be safe. Walmart, on the other hand, has been at the forefront of reforming this strategy in recent years. Walmart revealed in 2018 that it will be using BCT to monitor every package of spinach and head of lettuce after a 2-year pilot scheme [34]. Then, Walmart requested that more than 100 farms from which it procured enter precise information about its goods into a blockchain database.

The people managing the Walmart supply chain make an entry on the blockchain at each step in the supply chain, signing when they acquire the food product and when they send it on to the next individual in the chain. Food is tracked from the farm, through cleaning and processing facilities, to the factory, and finally to the supermarket, using BCT.

Treum is a BCT-based supply chain business that, in collaboration with the World Wildlife Fund, is now using the technologies to assist revolutionize the tuna industry [35]. To show how it functions, a tuna fish is fitted with an RFID tag as soon as it is captured, and its address is sent to the Ethereum blockchain. This demonstrates how technology can be used for product traceability and ensures that the fish was captured lawfully and sustainably. The fish can be monitored to the store, consumers can use their phone to scan a QR code to check where, when, and by whom the fish was captured.

3.5 Intellectual Property (IP) Protection

When it comes to monetizing digital assets, blockchain is one of the technologies that can help a business secure and retain ownership of its intellectual property (IP) [36]. IP protection is a must for companies in all manufacturing industries. In the event of a patent dispute, a corporation may use blockchain technology to help prove the ownership of IP [37]. Bernstein Technology [38], for example, has created a web service that allows users to register IP addresses in a blockchain.

Nevertheless, since Blockchain is still in its early stages of growth, we will see many more advanced Blockchain applications for intellectual property in the coming years. Brand owners may use a ledger that shows who owns what as a point of reference for their rights and the degree to which those rights are being used in the market. This may be especially useful in jurisdictions where evidence of first or genuine use is needed, or where the scope of use is critical, such as in trademark disputes or other disputes involving well-known marks, or in defending trademarks. A ledger that shows who owns what, who is an approved licensee, and so on will allow everybody in the supply chain, including customers and customs officials, to verify a real product and tell it apart from a counterfeit.

Among the most compelling use cases of BCT in IP protection is attaching scannable blockchain-connected tags, tamper-resistant seals, to goods, which could play a vital role in combating counterfeit goods. If a brand owner tells customs officials of the security features that legitimate goods should have, then the lack of such features is an easy way to identify fakes. The ability to communicate with and inform consumers about the dangers of counterfeits and the ability to check if the goods they have bought are authentic is also strengthened by the inclusion of these features communicating with the BCT. These blockchain solutions are quickly becoming popular, allowing users to check a product's authenticity while also providing trust and affirmation to companies, governments, customers, and insurers.

Use Case: 3D Printing Industry

IP theft is a major issue in the 3D printing industry, for example. Traditional methods of moving files with designs to vendors and their printing machines leave designers susceptible to theft. To combat this, the blockchain system provides an automated audit trail, allowing users to monitor the proper use of the 3D model, as well as the materials used in the production.

3.6 Fraud Prevention

The manufacturing sector is the most susceptible to fraud. Since supply chains are complicated and typically include a large number of people and moving parts, there are many opportunities for fraud to occur and go unnoticed [29]. Goods may be counterfeited to the point that they are indistinguishable from the real thing. Inventory fraud is one illustration of a pervasive problem that undermines consumer and distributor trust in producers.

Manufacturing entrepreneurs can suffer significant financial losses as a result of ineffective regulation, improper record-keeping systems, and other weaknesses in the industry's architecture. Besides that, the manufacturing industry is vulnerable not just to inventory, vendor, and procurement fraud, but also cyber threats, shady middlemen, and billing schemes [39]. For example, with BCT, if a buyer has questions about a gold seller's credibility and origins, he or she may check the data collected, which contains information archived from the time the mineral was mined until the last supplier, ensuring its validity and the sellers' integrity. Similarly, it could be used to ensure the consistency of a product, such as in the case of a high-priced product buyer who wants to ensure not just the sellers' authenticity, but also the authenticity of every particular raw material used to produce the product.

Use Case: Anti-Money Laundering

Digital exchanges and financial institutions all over the world are currently designing mechanisms to improve enforcement and enforce higher standards of regulation in their systems to comply with know you the customer (KYC) and new AML (Anti-Money Laundering) standards, as the old ones have been criticized as inadequate [40, 41]. The global financial model is changing, partly as a result of creativity and partly as a result of necessity. The previous AML guidelines and policies are inadequate, leading to poor management and low enforcement, placing customers at risk of fraud. To conform to KYC regulations, a distributed ledger could minimize errors through automation, avoid duplication, and create a database of all checks performed for each client.

3.7 Data & Communication Security

BCT enables parties to have full control over data and privacy without depending on a single point of control, making it incredibly cost-effective and productive. This presents the potential to use blockchain to build a safe and trustworthy, management and sharing system, which will speed up the data-sharing process.

For a hacker to tamper with the data in the blockchain, the hacker will have to delete the data stored on every user's device in the global network. Thousands of computers may be involved, everyone holding a copy of all or most of the data. Undamaged machines, also known as "nodes," will keep operating to check and keep track of all the data on the network unless the hacker could take the whole network down at that point (which is almost unfeasible).

Enforcing blockchain technology will also decentralize the domain name system (DNS), disseminating its contents across a vast number of nodes and making hacking nearly impossible. Domain editing privileges would be given only to those who need them (domain owners), and no other user would be allowed to make adjustments, minimizing the possibility of data being accessed or altered by unauthorized parties substantially. To prevent distributed denial-of-service (DDoS) attacks, few companies have been deploying blockchain in this region. Blockstack [42], for example, offers a completely decentralized DNS option. The company's philosophy is to decentralize the entire global network by eliminating all third-party management of web servers, ID systems, and databases.

IBM's Watson IoT platform, for instance, includes the ability to control IoT data in a private blockchain ledger that is incorporated into Big Blue's cloud services [43]. App developers using GE's Predix PaaS platform can use Ericsson's Blockchain Data Integrity service to get completely auditable, compliant, and reliable data.

Use Case: Hospitality Industry

Smart healthcare involves remotely monitoring and diagnosing patients' health via wireless communication. It gathers vital information from a variety of patients using a variety of electronic devices and sensors. For a significant number of patients, enormous amounts of data are gathered. Analyzing and storing this data in a safe manner is a major challenge. Hospitals, patients, physicians, and medical supply stores should all have secure access to this information. The secure transmission of these data is crucial because it impacts important decisions such as the preparation of future hospital facilities, recommending physicians, and assessing symptoms of various diseases or health problems [44]. Traditional access control policies are insufficiently secure to allow highly confidential patient information to be exchanged from one party to another. Furthermore, most people do not tell their physicians about their medical background. Patient history is required in the event of a medical emergency, but they are not accessible due to poor record management. While smart healthcare has the potential to solve many of the industry's major problems, there are some obstacles to overcome. These problems can be solved with the help of blockchain technology. Indeed, the distributed ledger between different users such as patients, physicians, medical shops, and insurance providers can transform smart healthcare. Despite ongoing academic studies [45-50] and a high level of interest from the industry, BCT-based healthcare data management systems have yet to be implemented.

3.8 Neighbourhood Microgrid

Microgrids are small-scale power stations with their output and storage resources. Among the first "blockchain microgrids" are systems that use an integrated blockchain to exchange neighbourhood power generated by rooftop solar [51]. The use of blockchain technology allows for the purchasing and sale of renewable energy produced by neighbourhood microgrids [52]. Smart contracts based on Ethereum can instantly allocate surplus power produced by solar panels. In the distributed energy space, blockchain is being used to create a slew of fresh concepts and solutions. For all types of transactions and ledgers, blockchain has certain inherent advantages. Since microgrids and smart grids would be highly transactive, providing an efficient, well-validated, and safe ledger of these transactions would be extremely beneficial.

However, while blockchain may make this possible, it does not address the underlying issues of pricing, control, and decision-making. Agreements between larger facilities and utilities are now getting more complicated, and figuring out the dynamic economics of complicated systems with multiple decisions is proving to be difficult.

Use Case: Consensys

Consensys [53], headquartered in Brooklyn, is one of the leading companies developing Ethereum applications around the world. Transactive Grid, a project they're collaborating on with LO3, a distributed energy firm, is one of the projects they're working on together where Ethereum smart contracts are currently being used in a pilot project to automate the control and distribution of microgrid resources.

4 Emerging Issues

In this chapter section, the author presents the emerging issues that arouse in employing blockchain technology with industry 4.0. This section discusses emerging issues that have been identified as a result of the research conducted for this chapter.

4.1 Issues in Smart contract

Since smart contracts and distributed ledgers are still in their early growth stage, there are several challenges to consider in addition to the benefits. First is the issue of compatibility. Industries should determine if their current technology is compatible with the technology needed to completely implement a smart contract. For instance, is freight forwarders' existing shipment tracking equipment capable of digitally interacting with the smart contract code without human intervention? Or does it necessitate any human involvement?

Moreover, computer coding is used to create smart contracts. This is specialized expertise that few companies would have on staff. Hence, industries need to hire programmers to code and manage smart contracts compared to traditional contracts where only attorneys were hired.

There are some restrictions on what a smart contract can do. Smart contracts are often referred to as "unalterable." That is, when the smart contract has been incorporated into the distribution ledger, what's been coded cannot be modified. As a result, if the parties change their minds at a later time, the smart contract cannot be changed to reflect the new conditions. As previously mentioned, the code operates on an “if y, then x” basis. As a consequence, if the parties' agreement allows for a price change to be resolved at a future date, this cannot be coded into the smart contract. The smart contract will be unable to carry out an instruction such as "if y, then the parties will agree on a price variation collectively."

Another thing to note is how the parties will be able to rewrite the smart contract if the law changes and made the commitments coded illegal. Smart contracts can pose issues about their lawfulness, validity, and governing law status. Besides that, smart contracts can effectively remove some legal options, such as the right to halt the execution of contract agreements or cancel the contract.

4.2 BCT Interoperability

The resurgence of interest in blockchains has sparked a slew of research and development projects. As a result, today's blockchain ecosystem is extremely diverse, with users having access to a variety of incompatible technologies. Since interoperability between BCTs is rarely planned in current protocols and standards, functions such as transmitting tokens from one party to another or triggering and implementing smart contracts are limited to a single blockchain [54].

When developing a blockchain, developers often neglect standards to achieve more flexibility, but this often led to interoperability and communication issues. Various blockchain networks with various criteria such as consensus models, smart contract features, and transaction mechanisms are the most emerging challenge to interoperability [55]. Making two separate blockchains interoperable, that is, allowing one to send data from one blockchain to another, may be of interest. A few standardization projects are underway to resolve this issue. To establish an interoperable blockchain, IBM and Microsoft are relying on an existing GS1 standard [56]. In certain cases, such as “atomic exchanges” and hash-locking, the problem of interoperability is addressed by using game theory [57]. Even then, the general issue of trustless interoperability remains unanswered. Hence the need for blockchain interoperability is crucial to help to spur a paradigm change from today's restricted blockchains to an open framework where devices and users can communicate without blockchain barriers.

4.3 Blockchain, Digital Twin and Altering of Information

The most difficult aspect of using blockchain for quality checks is establishing trust by connecting a physical entity to its digital replica (known as a digital twin). Any human interference that can alter information must be prevented or revealed. Likewise, the blockchain record is appended with immutable proof of the maintenance history. These applications, which are still in the early stages of growth, increase industrial machinery durability, make tracking of machinery health simpler, and establish fully transparent health assessments of machinery. Furthermore, in the case of in-house teams performing repairs, the blockchain record will serve as evidence to equipment suppliers that the team followed the conditions outlined in the warranty and guarantee agreements.

4.4 BCT and Autonomous Vehicle Technology

Since BCT enables automated industrial robots and vehicles to communicate with other parties via smart contracts, blockchain is significant in this field. As a result, blockchain-based robots and vehicles will work together and transact business with one another and with third parties in a fully autonomous manner. There have been concerns regarding the potential for connected vehicles to be hacked. This challenge could be resolved by employing BCT. BCT provides natural protection which makes it virtually impossible for malicious actors to hack because it is not easy to access or modify data in a block after it has been stored and a degree of encryption is applied to each transaction. This encryption, though, isn't without disadvantages. Since processing time is a major bottleneck in practical uses, careful consideration is needed. However, due to BCT complexity, is argued that it will not be effective in an environment where autonomous cars communicate with networks in microseconds.

4.5 Ethics in BCT

The ethical implications of BTC have yet to be identified, unlike other fields of tech ethics (AI ethics, biomedical ethics). Building the area of blockchain ethics is challenging. People, businesses, and devices are all considering using blockchain to store their digital identities. The underlying transparency and immutability of blockchain truly distinctive value propositions. However, when it comes to handling confidential identity data, these very strengths can be disadvantageous. There are some legal issues to consider. Is it appropriate to give the general public access to classified information? What if this information leads to people being persecuted? Is it possible for data miners or validators to exploit the information? Furthermore, some countries forbid the collection of confidential data outside of their borders. Blockchain is a global ecosystem of participants from all over the world. How do we guarantee that the knowledge does not cross a particular jurisdiction? People may request that businesses remove their personal information under data privacy laws. How will Blockchain-based businesses react to this request?

According to some experts, storing the same data through several systems protects the data from attacks. However, on the other hand, hackers now have many likely targets. How do we keep these systems secure all over the world? State-of-the-art encryption techniques can be used to encrypt the data stored. Post-quantum cryptography and other futuristic approaches can be used. However, this leads us to the next point. One individual with all the keys is a tragedy waiting to happen. It's a good idea to use multi-party computational keys. The data-lock is unlocked by using a set of keys. Multi-party keys also ensure that no one party can access the data without the permission of all relevant parties. If one of the parties loses their key, the others will authorize the development of a new key, which is a fail-safe choice.

While smart contracts automate processes, they are written by humans. When humans are involved, the mechanism is contaminated with prejudice. A socioeconomic stigma toward smaller businesses exists when a billion-dollar company is chosen as attractive to investors. How do we infuse ethics with anti-bias characteristics and lead to an ethical blockchain?

5 Conclusions

Blockchain's implementation and usage have long outgrown its original intent as the foundation of the world's first decentralized cryptocurrency. Other industries have recognized the importance of a trustless, decentralized ledger with historical immutability, and are looking to adopt the key principles to their current business processes. Existing major technology firms are investing in this technology, and numerous attempts are being made to build publicly open-sourced platforms. These activities demonstrate the promise of blockchain technology and its convergence with Industry 4.0.

Even though both Industry 4.0 and Blockchain technology has strong prospective applications, both trends are still too immature to be applied on a wide scale in a real-world setting. If we just look at the Industry 4.0 model, we can see that there is a lot of work to be done to find solutions that go beyond the networking, safety, privacy, and performance of devices, processes, and industries. In a progressively commoditized and global environment, manufacturers and technology professionals must collaborate to find out how blockchain can rejuvenate factories. A new way of thinking, as well as a creative and agile approach, is needed to fully realize blockchain's potential.

This study used e-Delphi to address the enablement of BCT in Industry 4.0. The e-Delphi method and online surveys were found to be cost-effective in terms of the researcher's time and finance, as well as promoting rapid contact between experts from various fields. The decrease in response rate over the Delphi rounds is a shortcoming. This is believed to be due to respondents losing interest as they are asked to rate the very same issues several times. Despite the decrease in response rates, the final results revealed a variety of aspects where consensus was reached. The e-Delphi technique, on the other hand, proven to be a method enriched in qualitative data and an effective way of getting experts together to examine, argue, and coordinate a body of data to develop a validated instrument, reach consensus on a topic, discover common causes, or forecast patterns.

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