Development of Architecture for Digital Supply Chain (DSC) using Blockchain, IoT and AI Technologies

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Abstract: To synchronize data and transactions in a supply chain network, blockchain technology was developed. This study illustrates how blockchain technology can increase the adaptability and agility of supply chain operations. With the use of blockchain and other recently developed technologies, supply chain uncertainty and other problems affecting the industry can be resolved. Issues in the supply chain are categorized, and a solution is offered by fusing blockchain technology with the Internet of Things (IoT), Artificial Intelligence (AI), and other technologies. Integration shows how tasks are completed utilizing blockchain and several supply chain technologies. Digital supply chains(DSC) are setting standards in a wide range of sectors because they are effective and lean. The creation of sustainable and environmentally friendly supply chains benefits from the use of intelligent technology. The study paper covers the challenges of implementing a digital supply chain. This will serve as a foundation for studying supply chain technology.

Keywords: Smart Contracts, Digital Supply Chain(DSC) Operations, Blockchain Technology, Artificial Intelligence, Internet of Things

I. INTRODUCTION

The actions involved in the production of goods and their distribution, from the stage of procurement to the stage of the final product, are all included in the supply chain. In all sectors, the supply chain architecture and foundation are quite complicated. To increase productivity and profitability in business, all sectors must strengthen their supply chains. Stakeholder trust, clarity, and efficiency at every stage of the supply chain[3] are just a few of the challenges that come with maintaining a healthy supply chain.

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The supply chain may become more agile and flexible due to blockchain. Blockchain enables all stakeholders in the ecosystem to engage, exchange, and validate all information and data. For centralized brokers managed by a single trusted authority, blockchain may be viewed as a transactional data storage that only accepts appends. This article analyses traditional supply chain difficulties and categorizes them based on a viable technology solution[3]. There are several benefits to using and using modern technology for issue solving, including blockchain, the Internet of Things (IoT), and AI. Using the blockchain technology architecture and its integration with other newly developed technologies, the research provides theoretical work for identifying supply chain challenges and generating feasible solutions. The whole supply chain, from raw materials to the product's lifecycle and finally to the client, is taken into account in the research. The study's goals include some of the following:

1. Identifying typical supply chain issues.
2. Problem classification and technology selection.
3. Examine how blockchain can be used in conjunction with other technologies to boost supply-chain operations' efficiency and agility.
4. Creation of an integrated architecture that incorporates blockchain and other modern technologies to increase transparency across the entire process.

This paper provides a process flowchart that illustrates the integration of blockchain and additional technologies, such as IoT and AI, with blockchain. A discussion and conclusion follow a demonstration of some of the supply chain members' problems, followed by the delivery of solutions utilizing blockchain and the integration of contemporary technologies.

II. LITERATURE REVIEW

For the transfer of inventory, Walmart[5] Canada has started using blockchain technology in partnership with logistics firms. Without having to alter their operations or IT infrastructure, logistics companies may synchronize and monitor shipments, logistical data, and payments using a shared node on a blockchain server.

According to the UN Environment Programme's Food Waste Index Report 2021, retail accounts for 13% of worldwide food waste. To address these issues, Walmart[6] employs blockchain technology to maintain a record of temperature in the transportation unit throughout food transit. This enables the tracking of food provenance in minutes rather than days using paper-based procedures.

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Blockchain technology is being used by Maersk and IBM to digitize trade operations and procedures, create a tamper-proof global network, and track shipments and deliveries from start to finish, including pricey point-to-point connections. Blockchain gives businesses a real-time digital record of all transactions and movements for every participant in their supply chain network.

IBM and Samsung[1,2] took a step towards blockchain-based energy management by including IoT devices that use electricity. If all supply chain participants use blockchain technology correctly, it may be extremely profitable and stable to boost supply chain security and transparency.

Ford Motor Company said in late January 2020[8] that it is planning to use Blockchain to track cobalt supply. Cobalt is regarded as a crucial component in electric vehicle batteries. Ford and IBM intend to track raw minerals such as cobalt from sources. The motor firm wants to use Blockchain to verify that they are receiving a genuine product to preserve its quality. The ledger is updated as cobalt is mined, allowing the firm to follow its progress after that.

To monitor every natural diamond from the mine to the retail counter, De Beers, the largest diamond manufacturer in the world by the value of its jewels, is also using Blockchain technology. The Tracer blockchain technology aids in authenticating diamonds and ensuring they are not from conflict areas where they may be used to fund violence.

De Beers CEO Bruce Cleaver once remarked that the blockchain-based network Tracer[7] can follow a diamond across the supply chain, providing asset traceability assurance in a way that was not before feasible.

III. METHODOLOGY

Supply chain operations encompass the execution of all procedures as well as the connection of all systems. To improve their financial and operational success, all businesses must improve their supply chain operations. The involvement of a large number of parties in the supply chain leads to operational problems while reducing one-on-one communication between different participants.

The picture below shows the steps involved in implementing blockchain technology along the whole supply chain. To gather, process, verify, and store data, a blockchain server comprises four layers: a ledger layer, a smart contract layer, a transaction layer, and a layer for data input. Every participant/stakeholder in the supply chain is a node connected to a blockchain server.
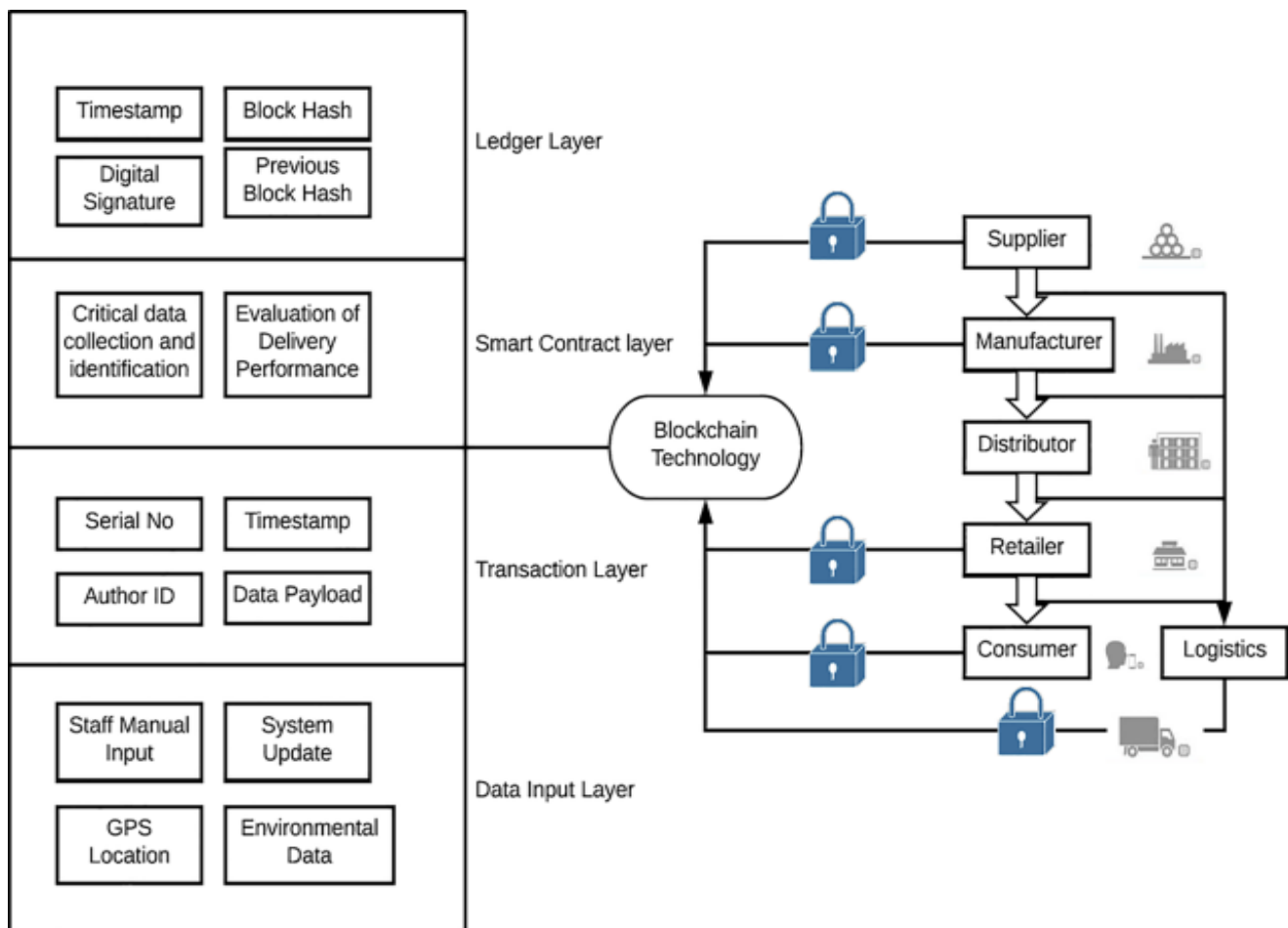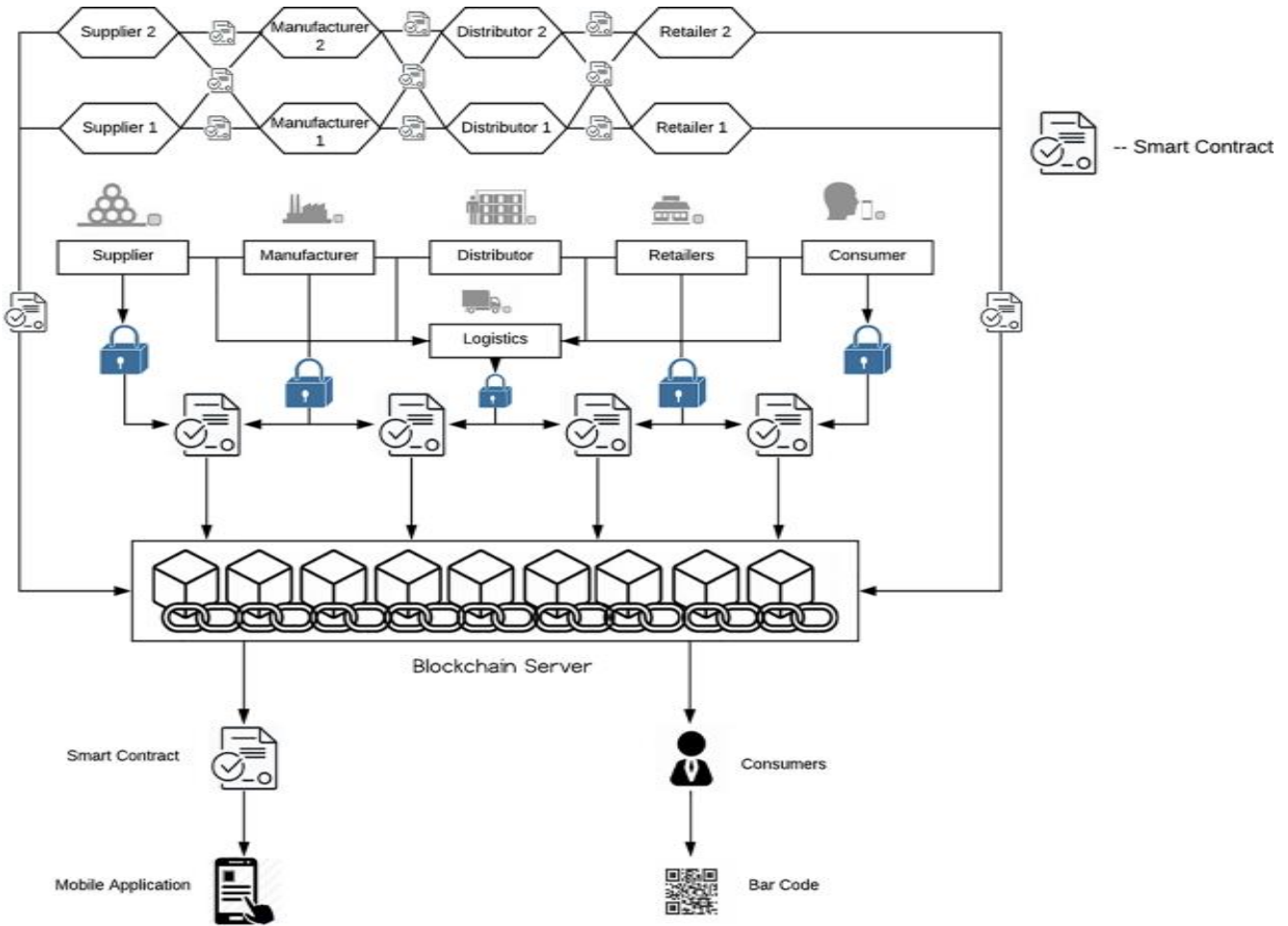

Figure 1 Implementation Route of Blockchain Technology Throughout the Supply Chain

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A. Blockchain and Smart Contracts

The non-tampering software programs known as smart contracts are kept on a blockchain server. They may be designed in the Solidity programming language and are distributed, immutable, self-executing, and self-executing. They can create function libraries, authenticate, and self-manage and self-execute payments. Blockchain technology has the potential to transform many sectors and enterprises by integrating delivery platforms and payment systems into digital contracts, cutting down on the time and money delays associated with processing and creating the contract manually. Every component of the product is registered via smart contracts on the ledger. The supply chain is a multi-faceted process with several players. Copyrighted material, store shareholder and investment contracts store employee and land contracts, ownership and registry of all assets or goods, peer-to-peer transactions, and copyrighted content are all protected by smart contracts[5]. Additionally, they can assist firms in reducing fraud and forging while reducing legal penalties and tax deductions for late payments. Protecting copyrighted information, storing employee and land contracts, storing shareholder and investment contracts, ownership and registry of all assets or goods, and peer-to-peer transactions are just a few of the uses of blockchain and smart contracts in the supply chain[6].

Figure 2 Smart contract implementation in DSC

B. Technologies for Integration with Blockchain

Blockchain technology may be used with IoT and AI to increase the flexibility and agility of supply chain operations. Neither technology is integrated by many firms, and both are employed individually in various industries. The parts that follow go into further detail about the information flow and the integration of IoT and AI with the blockchain network.

I. Blockchain and IoT

IoT is the term used to describe IoT that downloads data from a server and stores it online so that an administrator may access it from any location at any time. The finest illustration of the fusion of blockchain with IoT is the digital supply chain (DSC). Sensors and actuators, Internet gateways, edge IT analytics, and data center administration are the four essential processes via which IoT operates in the supply chain[3,4]. The most important component of blockchain IoT in the supply chain is asset tracking, which is accessible to all chain participants thanks to a decentralized blockchain server. The biggest benefit of blockchain-IoT integration is for distributors, who may utilize RFID tags to track every item in the huge warehouse.

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Increased trust and issues with dispersed data sources are solved by integrating blockchain and IoT into the supply chain. Additionally, it assists in reducing the workforce needed for conventional supply chain management, which results in cost savings. Real-time data is uploaded on the blockchain server and is tracked by RFID and barcodes on commodities and items. To detect product damage and upload information to the blockchain server, sensors, and machine learning can also be employed. These linkages contribute to the development of a new supply chain and the improvement of current traditional supply chain operations.
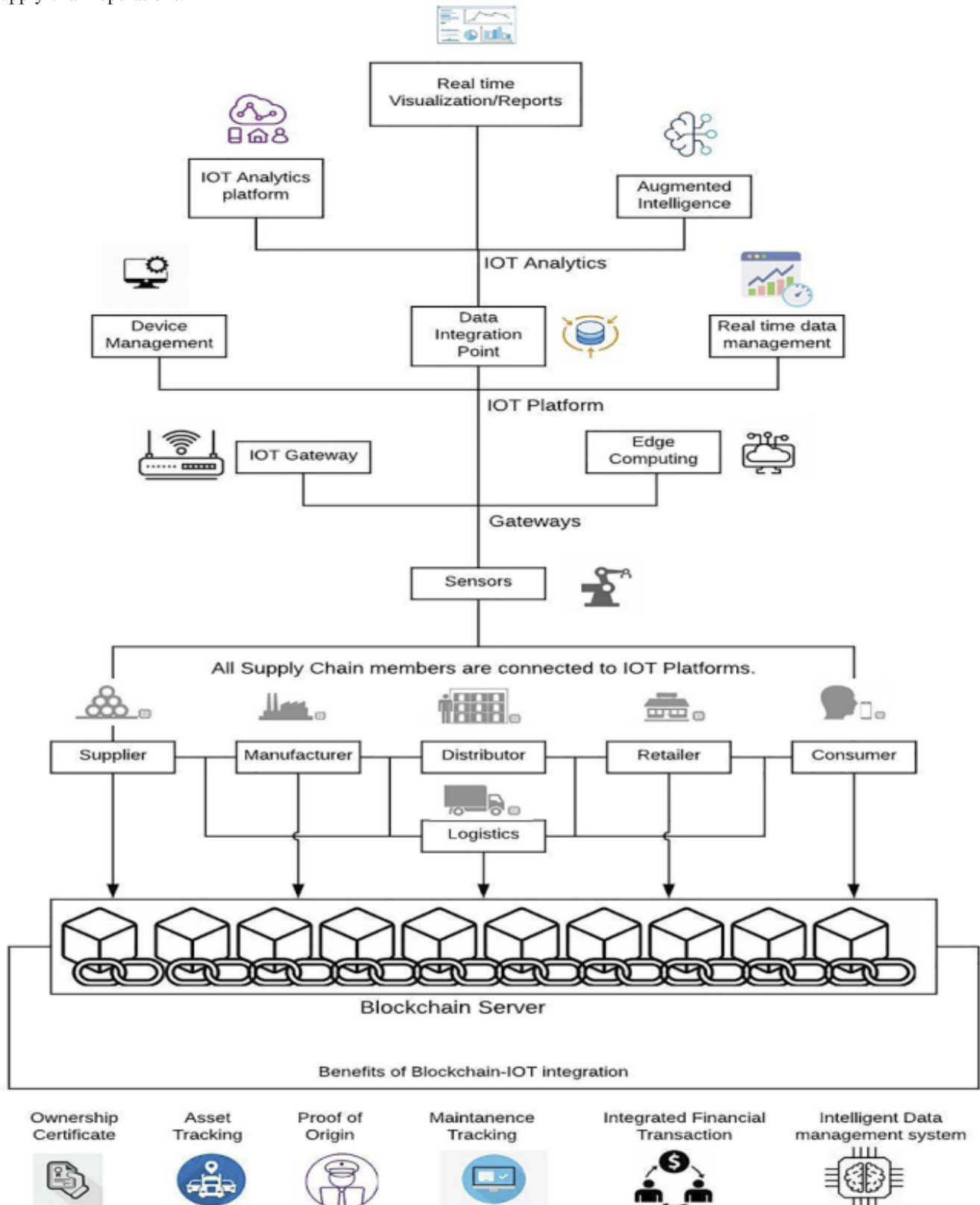

Figure 3 Blockchain-IoT integration in DSC

Due to their real-time data, effective operations, and secure real-time data storage, blockchain, and IoT integration can revolutionize manufacturing supply chains. It may assist with inventory management, quality control, raw material management, equipment maintenance, and production planning and control, among other things. On the blockchain server, real-time information is posted to assist businesses in planning and strategizing their operations.

II.   *Blockchain and AI*

Computers and other devices that behave like humans are made intelligent through the usage of AI. The supply chain may benefit by using it to store data more securely, use data more effectively, and make wise decisions. With its supply chain management suite, IBM has joined the field of blockchain-based AI management. Intelligent Decentralized Autonomous Agents (DAOs)[7] are made possible by the combination of blockchain and AI technology, which also helps to improve data security. By automating the whole process, the use of AI in blockchain-based business transactions can help the supply chain be improved. To find patterns and improve SCM, AI-enabled NLP examines supply chain records. Data trends, predictive analysis, inventory management data, and demand forecasts may all be identified by integrating blockchain with AI. For components and parts used in personalized goods, it can help lower supply chain delays. AI aids in the management of operations and the monitoring of costs and financial performance. The supply chain may benefit from AI algorithms and blockchain integration by automating the process and identifying new income streams.
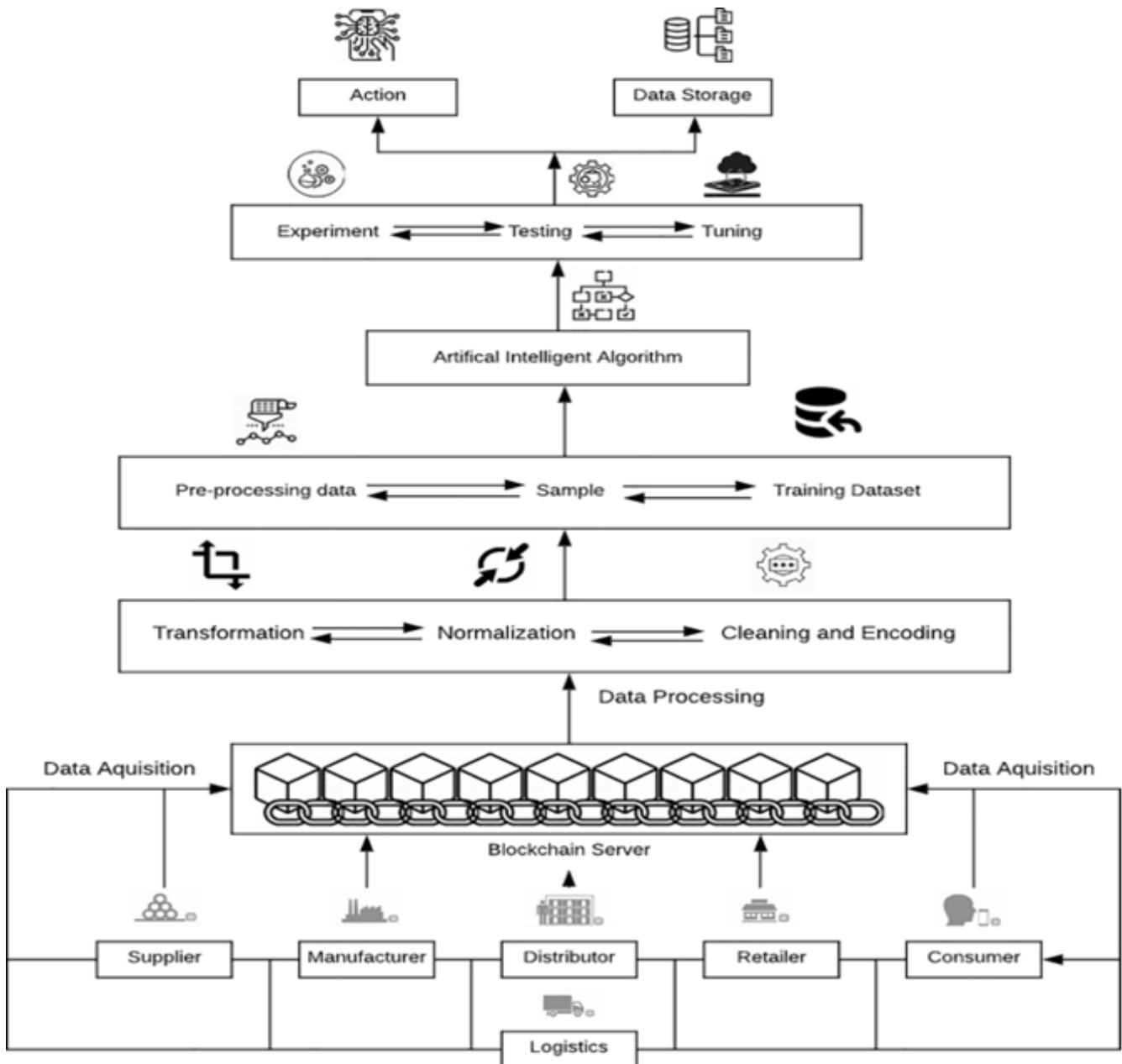

Figure 4 AI agents -IoT device integration in DSC

Suppliers, manufacturers, logistics companies, and distributors can use predictive analysis to help suppliers, manufacturers, and IoT devices enhance supply chain processes[8]. The banking industry may also employ AI algorithms and blockchain integration to safely store data and make judgments. Regular smart contracts may be made more effective and have less maintenance uncertainty by using AI-driven smart contracts.

IV. RESULTS

Adopting all current technologies may increase the effectiveness of operations, personnel, and organizations. One example is the integration of blockchain with IoT and AI. It also imposes several obligations and rules on the organization and its supply chain actors. Some of the criteria that supply chain participants in their organization must follow are as follows:

1. Each company has its operational strategy, with its manner of tracking operations and completing duties. It is advised that companies first look at all of their business practices before developing an implementation plan if they want to make the most of technology in their supply chain operations.

2. The supply chain contains several internal and external stakeholders, thus, before implementing any technology, it is crucial to create a good technology usage flow that includes and benefits all supply chain stakeholders.

3. A strong financial plan and accurate unit economics should be created before deploying any technology in the company since adopting new modern technology in a traditional supply chain is expensive. A company needs to be long-term focused when it comes to technology investment and return.

4. The aforementioned technologies are all fairly cutting-edge and challenging for older workers to master, yet they all increase the flexibility and agility of supply chain operations. All businesses must set up training sessions and seminars for staff members, laborers, managers, and other stakeholders involved in the operations to employ technology effectively and seamlessly.

5. To implement new technology, organizations, and supply chain participants must analyze all legal papers and legal compliance requirements. Smart contracts, blockchain servers, and IoT legislation may all have a lot of legitimacy because data is at the core of all these technologies.

V. CONCLUSION AND FUTURE SCOPE

This article addresses blockchain technology research findings and applications that might improve supply chain agility and efficiency. Blockchain technology and its integration with other modern technologies are being investigated for implementation to address the challenges faced by industries in the conventional supply chain. The chart lists issues and their particular remedies when combined with blockchain technology, based on literature reviews and polls of a few industry specialists. In the future, blockchain technology has the potential to rank among the most significant instruments for supply chain management. Some of the issues raised in this research are addressed by the supply chain architecture created for blockchain technology and its integration with the supply chain. In addition to addressing the issues in the conventional supply chain, blockchain technology and its integration with smart contracts, IoT, and AI may also open up new revenue streams and improve the business model financially and operationally. This design can act as a road map for businesses wishing to convert their supply chain from a conventional supply chain to a fully digital supply chain by using blockchain technology. The layout emphasizes the usage of blockchain technology and its fusion with cutting-edge innovations like IoT, AI, and smart contracts for all supply chain operations. By implementing these technologies, services are enhanced while also building stakeholder, legal, and financial confidence. Supply chain operations face several challenges despite the availability of contemporary technologies. The major problems for supply chain operations are time, consistency, transparency, and confidence among all stakeholders. Even if blockchain technology and its integration with AI and IoT are state-of-the-art technologies for dismantling barriers, companies might not be prepared to share information on a platform that all stakeholders can see and access. Globally varying government legislation results in different international procurement criteria for all supply chain partners from diverse nations. To properly integrate these technologies into the supply chain network, standard operating procedures (SOPs) must be established for all supply chain activities, processes, and operations. Due to a lack of technical expertise and resources, smaller companies and firms with lower wealth may find it challenging to deploy this technology. The company's objectives, assets, and personnel must all be in line with the transformation of the digital supply chain.

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AUTHOR'S PROFILE

Dr. Rashmi Sharma, Ph.D. (Computer Science), M. Tech (CSE), MCA, Sun certified Java 2 programmer. She is an Assistant Professor in the Department of Information Technology of Ajay Kumar Garg Engineering College, Ghaziabad. Research and interested area are but not limited to Machine Learning, Soft Computing, Artificial Intelligence, Machine/Computer Vision, Data sciences, and Blockchain. She has published approx. 30 papers in Scopus-indexed international journals, IEEE and Springer international conferences, etc. She is the reviewer of renounced journals and conferences. She had 5 patents to her credit also.

Gauri Tripathi is a driven researcher and aspiring author specializing in the field of technology. Pursuing a B.Tech degree from Ajay Kumar Garg Engineering College, her primary focus lies in Blockchain technology. With a strong interest in cutting-edge domains such as Artificial Intelligence, Data Science, and Machine Learning, Gauri aims to explore the potential applications of Blockchain in various industries. While still early in her academic journey, Gauri's commitment to research and her diligent efforts in understanding the complexities of Blockchain is evident. With aspirations to contribute to the academic community, Gauri aims to publish insightful works, collaborate with fellow researchers, and drive innovation in the field.

Pranjali Sharma, pursuing a Bachelor of Technology from Motilal Nehru National Institute of Technology, Prayagraj. Her pursuit of academic excellence shines through her dedicated focus on Blockchain technology. She also maintains a profound fascination for groundbreaking fields like Artificial Intelligence, Data Science, and Machine Learning. Her dedication, enthusiasm, and contribution to this innovative research have propelled us to the forefront of these rapidly evolving domains. Her valuable insights on modern-day problems have the potential to revolutionize various industries. She is determined to publish more papers as a testament to her passion for advancing her frontiers of knowledge and her dedication to contributing to the field of blockchain and machine learning.

Vani Tripathi is a dedicated researcher and aspiring author in the realm of technology. Currently pursuing a B.Tech degree from Ajay Kumar Garg Engineering College, her primary focus lies in exploring the fusion of Blockchain technology with Artificial Intelligence, Data Science, and Machine Learning. With a keen interest in cutting-edge advancements, Vani is driven to understand the transformative potential of Blockchain across various industries. As an emerging author and researcher, Vani aims to contribute valuable insights, collaborate with fellow scholars, and make a meaningful impact in the field of technology.