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Effective Precision Development of Blockchain Technology on Agricultural Field: a Review

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Abstract:- Blockchain technology (BT) functions as reorganized and dispersed digital record that documents dealings among several workstations to guarantee data safety, fixity, and immutability. The technology that underlies cryptocurrencies such as Bitcoin will apply to the reluctance of currency under digital appearance that extend to further development. This paper undertakes an extensive review of academic literature to examine the present research landscape concerning the agriculture-based BT implementation. Moreover, the primary objectives include pinpointing the specific agricultural domains where blockchain is deployed, analyzing the blockchain technologies applied, examining the stored data, assessing its integration with external databases, scrutinizing the underlying motivations, and surveying the array of agricultural products involved. Additionally, the study assesses the maturity level of these various approaches. Furthermore, this paper delves into recent trends in blockchain research within the agricultural sector and subsequently offers insights into potential future research directions.

Keywords: agriculture; precision; blockchain; review; research; challenges.

1. Introduction

Currently, BT is the utmost extensively discussed as well as potentially transformative technologies. It is often regarded as one of the most disruptive innovations in recent times. In initial days of 2008, conceptual development of blockchain has been discovered by "Satoshi Nakamoto". Furthermore, the functionality to record the dealings within the bitcoin network is supposed to apply in the public format under necessary actions. Blockchain, in essence, applied to secure the cryptographic developed with the dealings developed under the history. Within the developed system of blockchain, each individual user (stakeholder) preserves a replicate for every dealing conducted in the practice. Importantly, there is no single party or node that possesses ultimate control, demonstrating its decentralized nature. This decentralized approach creates a foundation of trust, as all activities on the network are visible and auditable by all participants. To execute a transaction, a consensus algorithm is followed, requiring the agreement of nodes to validate and authorize the transaction. New technologies are constantly changing the way we live and work, making our lives more convenient and productive under the developed blockchain system that diminishes with third party intermediaries that will result to lessening the cost of transaction, resulting to the irreversibility and necessity terms for the institutions under public and private scenarios that are diminishing to make the system more efficient [2]. Participants need not trust each other individually; rather, they trust the system and the code, which are highly secure. Blockchain can be defined in three primary ways:

- Technically, it functions as a backend database that continues a distributed ledger, subject to openly inspectable.
- As of a business perspective, it serves as a peer-to-peer network to value with transferring value, possessions, and contracts without agents.

- With authorization, it authenticates transaction record, restoring earlier entities being reliable.

Generally, the finite limit can be resident to the dealing with the individuals envisioned to the gathering of subjecting platform attained with the dealing to each village [3]. The transaction takes place in full view of everyone, and each individual takes clear understanding of the personal analysis under the recording of note. Furthermore, each party's associate to dispute or deny the transaction, they couldn't, as everyone in the village possesses an original record of the transaction. Furthermore, attempting to falsify this information would require altering the notes in every individual's replicate within the area which is invalid in practical knowledge [4]. Basically, the transactions happening electronically through computers, with each computer representing a different villager and storing records. Such secured transactions can be cryptographical with the approves associated as verified into the anonymous miners behind the environment of the blockchain necessitate to the record and information built with the connection of blocks and links formed into the continuous chain of information recorded into safety [5].

1.1 Key aspects of blockchain:

Decentralized Ledger: Making the central note of distribution under the ledger maintained digitally, involving the transaction lists attained with the system. These transactions are recorded and stored across multiple computers (nodes) in a network [6]. Moreover, the authority can be maintained with control over individual reason for resisting the manipulation and tampering.

Transparency: Every dealing under the blockchain can be networked with the participants ensuring over the accountability and trust. Such case can be verified based on the transactions deal with the system efficiency.

Immutability: When blockchain is additive to the dealing, then deleting or changing can be invalid. Further, the fixity can be guarantee with integrity of the historical record of transactions, making it highly secure against fraud and unauthorized changes.

Security: Usage of techniques oriented with cryptographic is associate with the secured dealing with the data access which can authenticate the mechanism of ledger under tampering the difficulty with each validation.

Cryptocurrencies: Widely applied application for BT that include bitcoin under the secured transaction associated with currencies virtually within the banks can be priority connected to the system resulting with the technology.

Smart Contracts: With pre-defined stage of conditions within the contracts built under the execution of intermediate action developed for the agreements of the contract of written information.

DApps (Decentralized Applications): Developers can create decentralized applications that run on blockchain platforms. These applications can have greater use cases, incorporating supply chain management, finance, healthcare, so forth.

Use Cases: Various applications that are under this association understands withins finance (for cross-border payments and clearing/settlement), supply chain management (for tracking the provenance of products), healthcare (for securely managing medical records), voting systems (for secure and transparent elections), and more.

Challenges: Blockchain technology encounters confronts scalability concerns, power utilization in some networks (for instance; Proof-of-Work, Proof-of-Stake), regulatory concerns, and networking related to interoperability. These encounters are actively addressed through ongoing research and development.

This potentiality can disrupt and innovate diverse regions through increasing security, precision, and competence in data management in addition transactions. It continues to evolve and expand, with new use cases and improvements to address its limitations [7].

1.2 Applications of blockchain technology:

Cryptocurrencies: Currencies associated under the bitcoin can be associate with the transactions being fed to peer-to-peer service built-in to the system.

Smart Contracts: Contracts region with the self-execution develop with the conditions execute automatically under meet of certain knowledge shared towards the management.

Supply Chain Management: Movement towards the execution and province can be interconnected to the chain developed by the user organized.

Healthcare: To securely manage medical records and facilitate interoperability between healthcare providers.

Voting Systems: For secure and transparent elections and voting processes.

Financial Services: To streamline cross-border payments, settlements, and clearing.

Tokenization of Assets: Demonstrating assets within the real-time scenario developed further to the commodities, estates, and as a virtual basis of digital world.

Identity Verification: Verifying and protecting user identities in a secure and privacy-enhanced manner.

While blockchain technology offers many advantages, develops issues which count for the consumption of energy, scalability correlated within the networks being fed to the concerned interoperability between different blockchain networks [8]. It maintains ongoing evolvement which subject to the addressing applications for those challenges expand for the built of development.

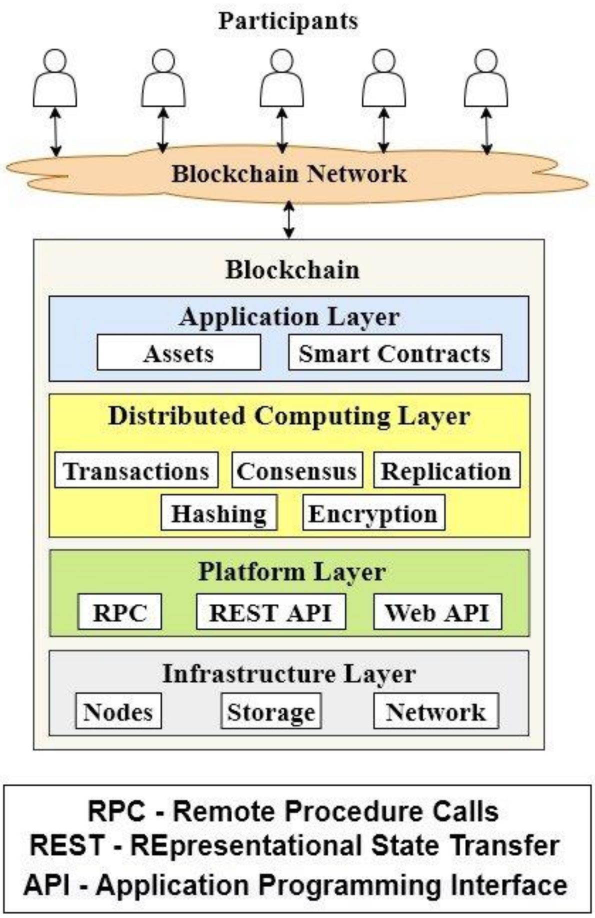

Figure 1. Blockchain structural designTop of Form

Figure 1 depicts the concept of blockchain can be described peer-to-peer fashion within the distributed management associated for the record of the count subjected to the organization. Its primary purpose is to ensure the immutability of recorded data, preventing retroactive tampering [9]. This technology empowers users to independently and transparently audit and verify transactions. In its essence, a blockchain functions that continuously develop the records in stack process, referred to as "blocks," with each block interconnected through cryptographic techniques. Every block is required to include coding under hash practice within the block subjected to preceding nature that collets the transaction authentically over discrete structure. In simpler terms, envision a blockchain as an innovative method for organizing information objective to the decentralization team resembling to the unlimited count of data decentralization way accommodating the dealings systematically. Crucially, the record activates autonomously via a peer-to-peer (P2P) arrangement then associate to the server stamped by the public authentication. Within the BT, respectively block occupies value developing with the identity of hashing with the system. Primarily, each chain of block is subjected with genesis under the parent block lacking. Individual block comprising essential development of each coding unit under the header and body of blocks [10].

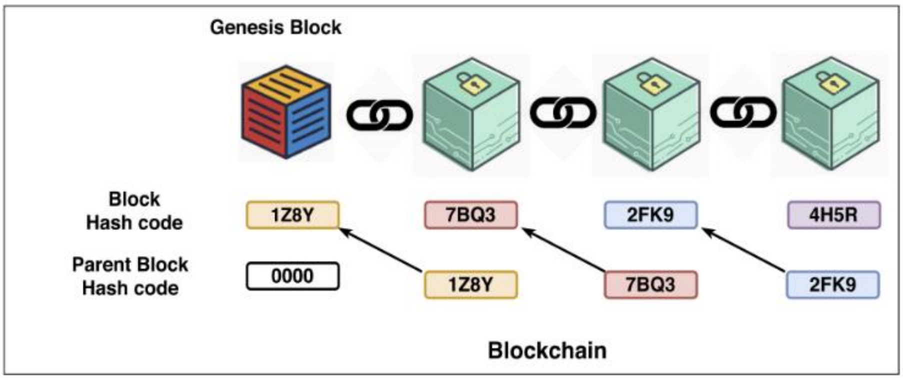

Figure 2. Hashed block sequence as a component of blockchain

Figure 2 illustrated a hashed block sequence is a foundational element of blockchain technology, necessary towards into organization and data protection within the BT. Within the system, the structured set of record can be involved into the dealings built for the system associated under the hash. The critical concept here is hashing, which is a cryptographic process that takes the data within a block and transforms it for fixed dimension of characters referred to hash count [11]. The uniqueness of this hash value is crucial for data integrity. What truly sets blockchain apart is the way blocks correlated. Individual block surrounds value in relation to the prior block subjecting hash count as an order. Nevertheless, the link can be ensured to the infeasible task guaranteeing to the block summing up with the network built to the data changing with the computation associated for the attempt to protect the data which can form with the resultant checking to the system being developed with the blockchain by cross-checking hash values, making blockchain a trustable and tamper-proof ledger [12].

1.3 Blockchain Protocols:

Blockchain protocols are the rules and standards that define how blockchain networks operate and how communications are supported as well as summited to the BT technique. These protocols guarantee the security, consensus, and functionality of the blockchain. Several key blockchain protocols include:

Proof of Work (PoW): Applied to Ethereum and bitcoin blockchain networks. Moreover, the puzzles can be solved within the miners associated for the transaction being developed further matched in the additional result in intensive nature.

Proof of Stake (PoS): An alternative to PoW; used in networks like Ethereum 2.0 and Cardano. Validators selected to develop the block dependent with the cryptocurrency tokened with the collateral to stake consider with the efficient within PoW.

Delegated Proof of Stake (DPoS): Variant to PoS; into the delegates limited for the communal nature validated to the block created for aiming to the speed of transaction and scalability improvement.

Proof of Space (PoSpace) and Proof of Space-Time (PoST): These are emerging consensus mechanisms that utilize storage space as a resource for validating transactions. Chia is an example of a blockchain network using PoSpace.

Proof of Authority (PoA): With limited range of nodes approved for the transaction associated under development. It is often used in private or consortium blockchains for faster transaction processing.

Byzantine Fault Tolerance (BFT): BFT is a class of consensus algorithms that focus on network security and resilience. Networks like Hyperledger and Corda use BFT-based consensus.

Tendermint: Tendermint is a consensus algorithm used in blockchain projects like Cosmos. It employs a BFT-based approach to achieve high security and scalability.

Raft: Raft is another consensus algorithm used in private blockchain networks. It's designed for simplicity and is often chosen when scalability and public access aren't priorities.

IOTA's Tangle: IOTA uses a directed acyclic graph (DAG) rather than a traditional blockchain. It employs a unique consensus mechanism in which participants validate previous transactions as they make new ones.

Hashgraph: Hashgraph is a distributed ledger technology that uses a consensus algorithm based on gossip and virtual voting. It's known for its high throughput and low latency.

These are just a few examples of blockchain protocols and consensus mechanisms. The choice of protocol depends on the specific goals of a blockchain network, including security, scalability, energy efficiency, and decentralization. Different blockchain projects may use a combination of these protocols or develop their own to suit their needs.

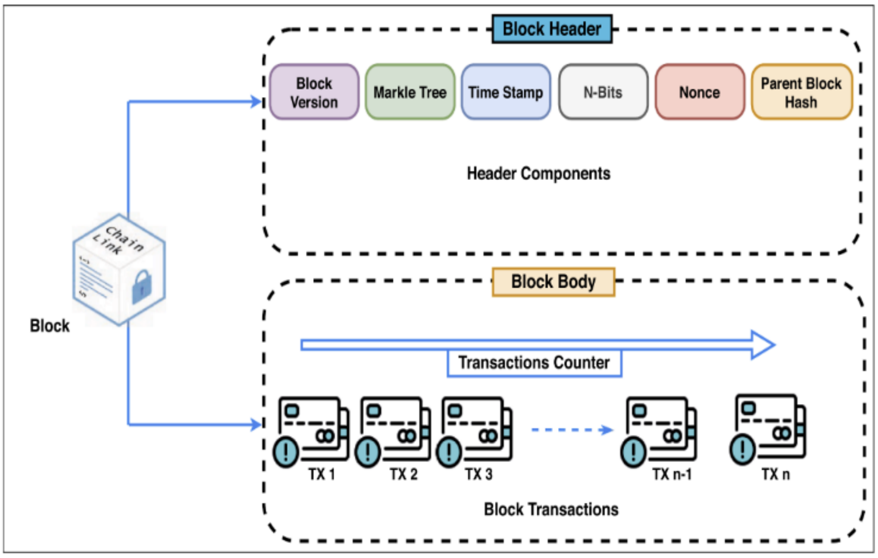

Figure 3: Design of block

Block design as demonstrated in figure 3 finds application in a wide range of fields, from art and graphic design to architecture and web design. At its core, block design involves creating a structured and organized layout within a designated space. This can be a canvas, a webpage, a room, or any area where the arrangement and presentation of content or elements are critical. The process typically starts with dividing the space into distinct sections or blocks, which serve as containers for different content. Within these blocks, content is strategically placed, considering factors like visual hierarchy, consistency, and whitespace [13]. Maintaining consistency in design elements, such as color schemes, typography, or alignment, is vital. Block design also ensures adaptability, particularly in contexts like web design, where content must adjust to different screen sizes. Achieving balance in the layout is a primary objective, creating a harmonious and functional composition. The choice of how to employ block design depends on the audience and the intended purpose. Whether it's a magazine layout, architectural design, or a website, block design contributes to an effective and aesthetically pleasing arrangement while keeping the goals and context in mind.

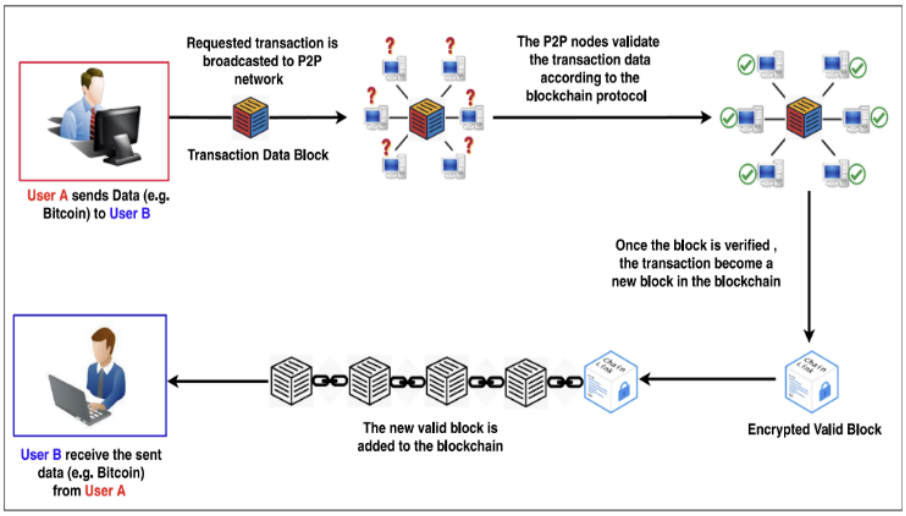

Figure 4. Functional process of blockchain

Figure 4 illustrates the functional process of a blockchain can be described as a series of well-defined steps that illustrate how this innovative technology operates. It commences with the creation and entry of data, which, in the case of cryptocurrencies like Bitcoin, represents financial transactions. These transactions are then broadcast to the network, where nodes (computers) undertake the critical task of validating their authenticity and verifying that the sender possesses the required funds. PoS and PoW is employed in public blockchains to agree on the transactions that should be included in the next block. This involves miners or validators competing to solve complex puzzles or staking cryptocurrency to create a new block [14]. Validated transactions are then grouped together in a block, which includes a reference to the previous block, a timestamp, the transactions, and a unique hash value. The new block is subsequently propagated to all nodes in the network, and consensus is confirmed, leading to its addition to the blockchain as the latest block. The blockchain, a distributed ledger, securely records all transactions in a decentralized manner, providing an immutable and transparent record that cannot be altered. This process ensures the ongoing maintenance and security of the blockchain, which remains accessible and accountable to all participants. The blockchain's functionality is built on the principles of decentralization, transparency, security, and consensus, making it a trusted and tamper-proof platform with applications extending beyond cryptocurrencies, including supply chain management, healthcare, and voting systems.

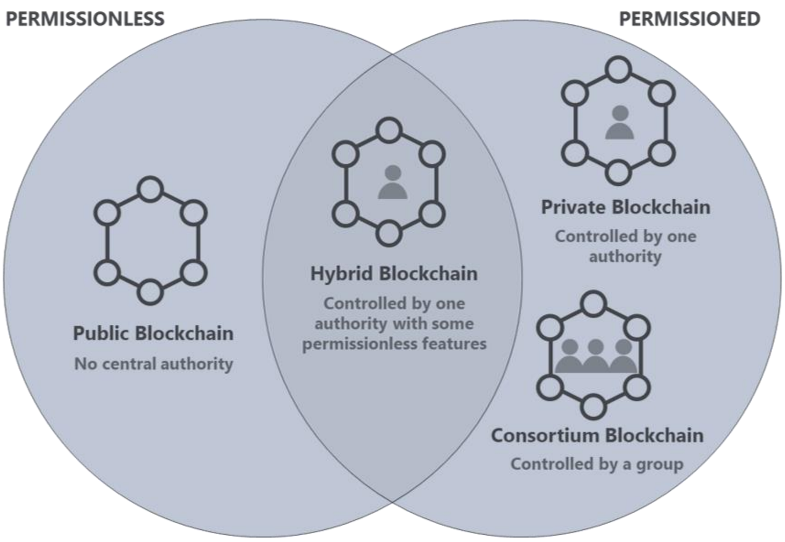

Figure 5. Various blockchain

Blockchain technology has given rise to various types of blockchains as depicted in figure 5, each designed to address specific needs and use cases [15]. Public blockchains, exemplified by Bitcoin and Ethereum, are open and permissionless, enabling anyone to join, read, and participate in the network. Contrarily, the restrict access to a select group of participants, often within an organization, ensuring greater control and privacy. Consortium blockchains offer a middle ground, being semi-private and operated by a pre-selected group of organizations [16]. Hybrid blockchains combine elements of public and private networks, allowing for both transparency and privacy in transactions. Permissionless blockchains, often associated with public chains, don't require permission to join and use consensus mechanisms like Proof of Work and Proof of Stake. Permissioned blockchains, common in private and consortium networks, require participants to seek permission to join and use consensus mechanisms tailored for known and trusted entities. Specialized blockchains include those designed for executing smart contracts, managing supply chains, identity management, or achieving energy efficiency. Furthermore, cross-chain blockchains facilitate interoperability between different blockchain networks, enabling seamless asset and data transfer [17].

Table 1: Comparison of various blockchain

Authority	Public	Private	Consortium
Validation	Every peer	Individual Corporation	Chosen peers
Retrieve permissions	Public	Private or public	Private or public
Efficiency	Less	more	more
Immutability	Alteration difficulty	altered	altered
Authority	permissionless	Permissioned	Permissioned
Centralization	no	yes	partial
Protection	High, due to decentralized consensus and public participation	High, controlled by a known group	High, shared among known participants

Table 1 lists the blockchain types. Public blockchains are often associated with open and trust less systems, private blockchains with enterprise applications, and consortium blockchains with collaborations among organizations.

2. Related of Works

Recent developments in blockchain technology have showcased the continued evolution of this innovative field. Notably, DeFi (Decentralized Finance) has witnessed substantial innovation, with decentralized lending, borrowing, yield farming, and automated market makers gaining prominence [18] [19]. Scalability solutions, such as Layer 2 protocols like Optimistic Rollups and zk-Rollups, aimed to enhance the transaction throughput of blockchains like Ethereum. The rise of Non-Fungible Tokens (NFTs) has allowed creators to tokenize and monetize their digital content, leading to the growth of NFT platforms and marketplaces. Cross-chain interoperability solutions have gained traction, enabling communication between different blockchains. Additionally, blockchain's applications in supply chain management and healthcare have advanced, offering greater transparency and traceability. Governments worldwide have explored blockchain for public services, identity management, and voting systems, emphasizing transparency and fraud reduction [20]. These are just a few areas where blockchain technology has seen significant progress, reflecting its ongoing impact on various industries. Comparing various blockchain protocols involves evaluating their key features and characteristics, such as consensus mechanisms, scalability, security, and use cases [21].

1. Bitcoin (BTC):

- Scalability: Relatively limited scalability, leading to slower transaction processing.
- Security: High security due to the extensive PoW network and long track record.
- Use Case: Primarily digital currency and store of value.

2. Ethereum (ETH):

- Consensus Mechanism: Transitioning from PoW to Proof of Stake (PoS) with Ethereum 2.0.
- Scalability: Working on improving scalability with Ethereum 2.0, which aims to enhance transaction throughput.
- Security: Security features are evolving with the transition to PoS.
- Use Case: Smart contracts, decentralized applications, and token issuance.

3. Binance Smart Chain (BSC):

- Consensus Mechanism: PoS-based with a smaller set of validators.
- Scalability: Faster transaction processing compared to Ethereum.
- Security: High security but more centralized due to fewer validators.
- Use Case: DeFi, smart contracts, and Binance ecosystem projects.

4. Polkadot (DOT):

- Consensus Mechanism: Nominated Proof of Stake (NPoS) with a relay chain and parachains.
- Scalability: Designed for scalability and interoperability between blockchains.
- Security: Strong security with a unique parachain structure.
- Use Case: Interoperability between blockchains and enabling new use cases.

5. Cardano (ADA):

- Consensus Mechanism: PoS-based with the Ouroboros protocol.
- Scalability: Focus on scalability with a layered architecture.
- Security: Emphasis on security and formal verification.
- Use Case: Smart contracts, dApps, and financial services.

6. Tezos (XTZ):

- Consensus Mechanism: Liquid PoS with on-chain governance.
- Scalability: Designed to be self-amending and upgradeable.
- Security: Strong security with a focus on on-chain governance.
- Use Case: Smart contracts, digital assets, and dApps.

7. Avalanche (AVAX):

- Consensus Mechanism: Avalanche consensus, a new family of consensus protocols.
- Scalability: High scalability with subnets.
- Security: Strong security due to Avalanche's consensus design.
- Use Case: DeFi, custom blockchains, and interoperability.

8. Solana (SOL):

- Consensus Mechanism: PoS-based with the unique Proof of History (PoH).
- Scalability: Extremely high transaction throughput.
- Security: High security with novel consensus and architectural design.

- Use Case: Fast and scalable dApps, DeFi, and NFTs.

Table 2: Comparison of blockchain protocols

Quantity	PoA [22]	PoW [24]	Pol [26]	PoS [28]	PoAss [29]	PoB [30]
Mining	puzzle + wager	puzzle	luck algo.	wager	hashcodes	burn coins.
Scalability	high	high	high	high	low	high
Center Development	Coin	Coin	Intel SGX	Coin	green mining	Coin
Access	public	public	public/private	public	private	public
Power Conserve	No	No	yes	partial	yes	yes
Authentication	< 100.0s	>100.0s	< 10s	< 100.0s	< 10s	< 100.0s
Management	partial	No	yes	partial	yes	No
Construction	P2P	P2P	P2P/central	P2P	central	P2P
Platform	Coin Proz [23]	Bitcoin-NG [25]	Hayekcoin [27]	Peercoin [28]	IOTW [29]	Slimcoin [31]

Table 2 tabulates the block protocols comparison based on the recent works. These protocols cater to a range of use cases, reflecting the evolving landscape of blockchain technology. These comparisons provide a high-level overview of some key blockchain protocols. It's important to note that blockchain technology continues to evolve, and new protocols and upgrades to existing ones are regularly introduced, impacting the landscape of available options. Kamilaris et al. [33]

highlighted the application of BT that contributes for the exchange, collection, and analysis that leads to the support of farmers in the making of decision to initiate the efficiency and sustainability. Within the real-time information the resultant agricultural products can be enable with the development of the quality and quantity attained within the objective of information including factors like fertilizers, machinery, pesticides, and weather conditions as presented by Su et al [34].

With the increase of the consumers with certain conditions acquired to the details associated with the ascertainment with the perception correlated to the trajectories stated by Astill et al [35].

Through the data-driven methods, the productivity can be captured with the BT for users helping with the schedules developed by optimal reach of plan associated with the system dealt with logistics [36].

Agriculture-based blockchain system as depicted in the figure 6, also known as AgriTech blockchain, is a specific application of blockchain technology in the agriculture sector. It offers innovative solutions to address various challenges in the agricultural industry. Here are some key aspects of agriculture-based blockchain: Supply-Chain-Traceability, Provenance and Quality Assurance [37] [38] and Reducing Food Fraud, This helps in identifying and preventing the distribution of counterfeit or adulterated agricultural products. Efficient Payments and Transactions: Blockchain facilitates transparent and efficient financial transactions within the agricultural ecosystem. It can enable quicker and more secure payments to farmers, reducing the need for intermediaries.

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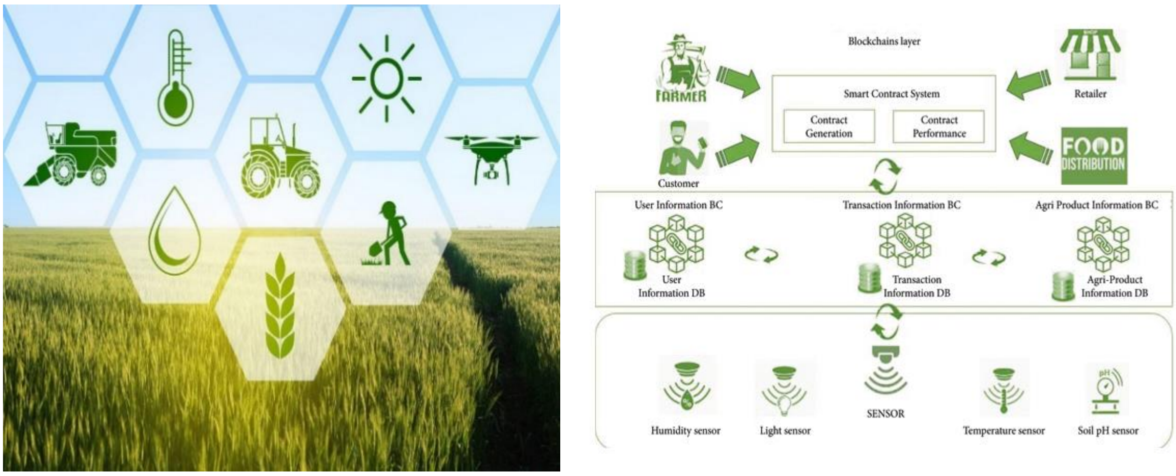

Figure 6. Agriculture based blockchain system

3. Applications of blockchain in precision agriculture:

BT extended to various use cases in precision agriculture, where data-driven and tech-savvy approaches are employed to optimize farming practices [42]. Here are some notable use cases:

Supply-Chain-Traceability: In order to track the origin within the journey of agricultural products from farm to consumer. This ensures transparency in the context can enable the user in quality, protection, and validating verification for the purchase of food.

IoT Data Management:- Internet-of-Things (IoT) sensors with devices are utilised for precision agriculture to monitor soil conditions, weather, crop health, and more. Blockchain can securely record and manage the data generated by these devices, ensuring its integrity and enabling data sharing among stakeholders.

Smart Contracts for Agreements: Smart contracts on a blockchain can automate agreements and transactions between farmers, suppliers, and buyers. For example, contracts can be set up to trigger automatic orders for supplies when specific conditions are met, such as low fertilizer levels or unfavourable weather forecasts [43] [44].

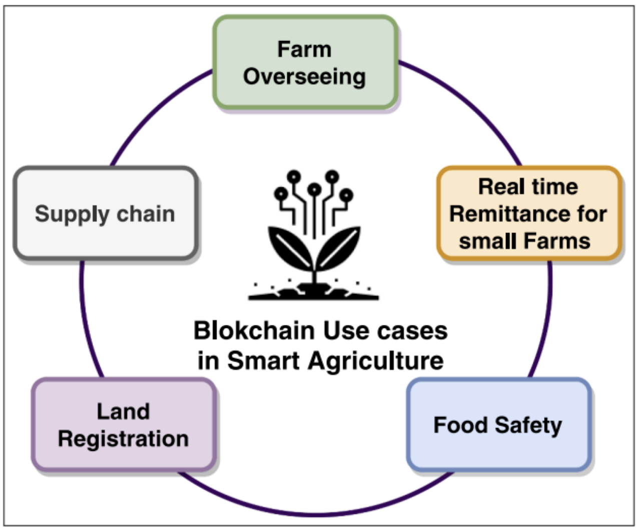

Figure 7. Use cases of blockchain in precision agriculture

- Crop and Livestock Monitoring: Blockchain can store data from sensors and drones used to monitor crop conditions, livestock health, and environmental factors. This data can be shared securely with relevant parties, such as farmers, agronomists, and government agencies.

- Weather Forecasting and Disaster Management: Weather data recorded on a blockchain can be utilized for more accurate and timely weather forecasts, aiding in proactive decision-making for farmers. It can also support disaster management and response in case of natural calamities.
- Soil Health and Nutrient Management: Blockchain can maintain records of soil test results and nutrient management plans, helping farmers optimize fertilization and irrigation practices while reducing environmental impacts.
- Certifications and Compliance: Blockchain can ensure the secure storage of certifications related to organic farming, fair trade, or sustainability practices. This is crucial for demonstrating adherence to regulations and standards.
- Data Sharing and Collaboration: Blockchain can present a protected manifesto for distribution of agricultural research, data, within the best practices among farmers, researchers, and agricultural organizations, fostering collaboration and knowledge sharing.
- Agricultural Finance: Blockchain can streamline and secure agricultural financing, enabling farmers to access capital for investments in precision farming technologies and practices.
- Food Safety and Quality Assurance: Through blockchain, food products can be tracked from the farm to the table, allowing for rapid classification besides contaminated recall or unsafe food harvests, enhancing standards under food safety.
- Market Access and Fair Pricing: Blockchain-based platforms can connect farmers directly with consumers and buyers, eliminating intermediaries and ensuring fair pricing, which is especially relevant for small-scale and local farmers.
- Carbon Credit Trading: In precision agriculture, blockchain can facilitate the tracking and trading of carbon credits, as sustainable farming practices can lead to reduced carbon emissions and increased carbon sequestration.

These use cases demonstrate how BT can contribute to the productivity, transparency, as well as sustainability of precision agriculture, benefiting farmers, consumers, and the environment. As precision agriculture continues to evolve prominent responsibility for optimizing farming practices [45]. Furthermore, processes within the agricultural sector to enhance transparency, traceability, and efficiency. The primary products and processes used in agricultural blockchain applications include Fresh Produce: Fresh fruits and vegetables are often tracked using blockchain to provide produce, ensuring food safety and quality. Meat and Poultry: Blockchain is used to trace the source of meat and poultry products, enabling consumers to verify the conditions in which the animals were raised and the safety of the final products. Dairy Products: Blockchain is employed to verify the source of dairy products like milk and cheese, ensuring that they meet quality and safety standards. Seafood: The seafood industry uses blockchain to track the journey of fish and other seafood products from the ocean to the dinner table, helping to combat illegal fishing and ensure product authenticity. Grains and Cereals: Blockchain is used to trace grains and cereals from the farm to the product, providing transparency about the farming practices and quality. Coffee and Tea: High-value crops like coffee and tea are often tracked using blockchain to demonstrate their origin, quality, and adherence to sustainability standards. Honey: The honey industry uses blockchain to verify the source of honey products and to ensure that they are pure and free from adulteration. Wine and Spirits: Blockchain can trace the production and distribution of wine and spirits, allowing consumers to verify the authenticity of the product. Cotton and Textiles: The textile industry employs blockchain to trace the source of cotton and other materials used in clothing and textiles, demonstrating sustainability and ethical sourcing. Nuts and Seeds: Products like almonds, peanuts, and seeds are tracked through blockchain to ensure safety and quality. Herbs and Spices: Blockchain is used to verify the source and quality of herbs and spices, which are often sourced globally [46]. Organic Products: Organic agriculture relies on blockchain to certify the authenticity of organic products and the adherence to organic farming standards. Fertilizers and Chemicals: Blockchain is used in the tracking of agricultural inputs like fertilizers and chemicals to ensure their proper use and adherence to regulations. Livestock

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and Aquaculture: Blockchain helps monitor the health and conditions of livestock and aquaculture products to ensure animal welfare and product quality. Supply Chain and Logistics: Beyond specific products, blockchain is employed to enhance supply chain and logistics management, providing transparency and efficiency in the movement of agricultural products. These are just some of the primary products and processes within the agricultural sector where blockchain technology is applied to benefit the users that are widely recognized.

4. Data variants stored in the blockchain for agricultural applications:

In agricultural applications of blockchain, various types of data are stored on the blockchain to augment clearness, traceability, and productivity throughout the supply chain. The specific data stored may include [47]:

Provenance Data: Evidence approximately the source of agricultural products, including details about the farm or producer, planting dates, and harvesting methods.

Geospatial Data: Geographic coordinates or location data, which can help pinpoint the exact location where crops are grown, or animals are raised.

Crop and Livestock Data: Data on crop health, livestock well-being, and growth conditions, often collected through IoT devices and sensors.

Supply Chain Information: Data correlated to the movement of products within the system entering transportation, storage, and handling conditions.

Quality Metrics: Data regarding the quality of agricultural products, which may include measurements such as moisture content, temperature, and freshness indicators.

Environmental Conditions: Information about environmental factors that can affect product quality, such as humidity, temperature, and weather conditions during transportation and storage.

Certifications and Compliance: Records of certifications related to organic farming, fair trade practices, and adherence to industry or regulatory standards.

Transaction and Payment Data: Data communicated to financial transactions under this can be payment records to farmers and suppliers.

Pesticide and Chemical Use: Data on the use of pesticides, herbicides, and chemicals on crops, helping ensure compliance with safety and regulatory standards.

Food Safety Records: Information related to food safety testing, inspections, and quality control measures to guarantee that food products meet safety standards.

Packaging and Labeling Data: Details about packaging materials, labeling, and barcodes used for tracking products and ensuring authenticity.

Sustainability Metrics: Information about sustainable farming practices, such as carbon footprint reduction, water management, and ethical sourcing.

Market Data: Data related to market trends, prices, and demand for agricultural products, which can influence supply chain decisions.

Harvest and Yield Data: Records of crop yields and harvest volumes, which are essential for crop planning and inventory management.

Logistical Data: Information on logistics and transportation, including shipping routes, delivery times, and handling practices.

Weather and Climate Data: Historical and real-time weather and climate data, which can affect crop growth and quality.

Smart Contract Data: The terms and conditions of smart contracts that automate transactions and agreements within the supply chain.

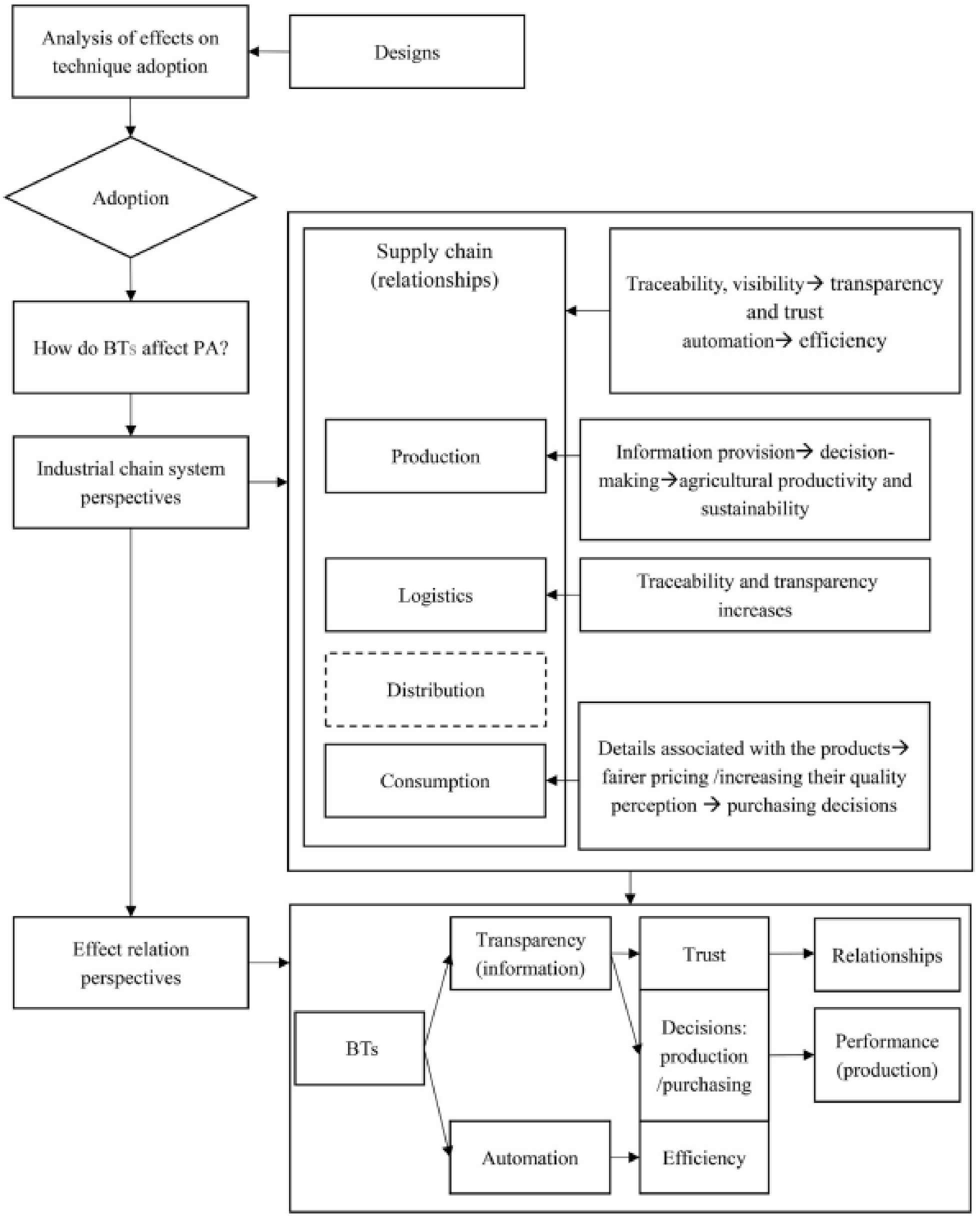

Figure 8. Summarizing the role of blockchain in agriculture

Figure 8 demonstrated gives the clear understanding of BT role under field of agricultural sector. Ensuring this utilisation which can subject to the greater efficacy with the knowledge gained towards BT points are securely and immutably recorded, making it possible to trace the journey of agricultural-products in authentication to the quality and protection. Therefore, such combination of these data types promotes significant obviousness with trust within the agricultural supply chain. Blockchain's core roles revolve around enhancing security, trust, and transparency in a wide range of applications across industries [48]. Its potential continues to expand as it drives innovation and transformative solutions in the digital age.

5. Recent Advancements:

5.1 Integration of blockchain with IoT

The amalgamation of blockchain with the Internet of Things (IoT) extends enormous impending to transform countless manufacturing. This combination of technologies enhances data security, transparency, and trust in IoT applications [49]. Foremost features of BT with IoT,

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Data-Integrity and Security: BT guarantees the integrity with IoT data security. IoT devices collect vast amounts of data, and blockchain's cryptographic features protect this data from tampering, ensuring its trustworthiness.

Decentralized Network: Both blockchain and IoT operate on decentralized networks. This decentralization passes the central authority requirement, enhancing more resilience within IoT networks and ensuring continuous data flow.

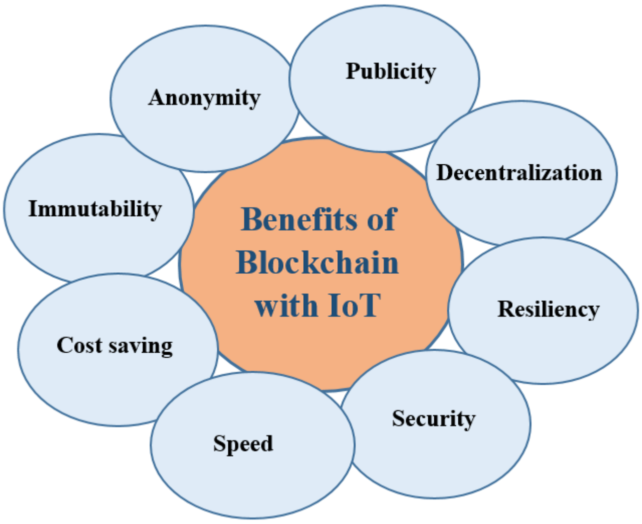

Figure 9. Advantageous actions in integrating IoT with blockchain

Smart Contracts: BT allows for smart contracts implementation, agreements into self-executing that automate processes based on predefined conditions. In IoT, smart contracts can trigger actions or payments when specific conditions are met, enhancing automation and efficiency.

Immutable Records: IoT devices can record data on a blockchain in a tamper-proof manner. This is particularly useful in applications like supply chain traceability, where the history of products can be stored into safer system of BT.

Secure Identity and Authentication: Blockchain provides a framework for secure device identity and verification, shrinking the consequence of unofficial approach with IoT devices or networks.

Ownership and Control: Blockchain can establish clear ownership of data in correlation with IoT-devices. Users have control over their data, granting or revoking access as needed.

Data Monetization: IoT statistics can be strongly revealed coupled with moulded through BT-based platforms, allowing users to gain value from their data while maintaining control over it.

Interoperability: Blockchain can serve as a common platform for IoT devices from different manufacturers, facilitating interoperability and communication between devices from various ecosystems.

Supply Chain and Logistics: Blockchain enhances transparency in supply chains by recording the journey of products from their source. IoT sensors can continuously monitor and feed data to the blockchain, providing real-time visibility into the supply chain.

Energy Management: In energy grids, blockchain and IoT utilised for consumed energy optimization which can facilitate those trades for devices connected in reach to the peer-to-peer networks.

Healthcare: In healthcare, IoT coupled with blockchain improvise the safety and privacy of patient data, streamline medical record management, and support telemedicine applications.

Smart Cities: IoT sensors and devices in smart cities can benefit from blockchain's data security and transparent decision-making processes. This can lead to more efficient public services and infrastructure management.

Environmental Monitoring: IoT sensors for environmental monitoring can securely record data on blockchain, aiding in the tracking of environmental changes, pollution levels, and wildlife conservation efforts.

Agriculture: In precision agriculture, IoT devices can monitor crops and livestock, and blockchain ensures data integrity chain of traceability.

Transportation and Autonomous Vehicles: IoT-enabled vehicles and autonomous vehicles can securely interact with traffic management systems and other vehicles through blockchain, enhancing safety and efficiency.

Therefore, these opportunities help to improve data security, trust, and automation in various domains. As these technologies continue to evolve, their combined potential is expected to grow, impacting industries in novel and transformative ways.

5.2 Challenges

Integrating blockchain technology with IoT networks offers substantial advantages, but it also presents a series of complex challenges. These challenges encompass issues such as scalability for functioning into the greater information that initiates with IoT device generation, concerns regarding data privacy and security, and the need for interoperability between various IoT devices that use different protocols [50]. Furthermore, latency, energy efficiency, and compliance with data protection regulations are critical considerations. The integration can also involve high costs and complexity, potentially hindering smaller-scale IoT deployments. Oracles, which provide external data to blockchains, can introduce vulnerabilities. Additionally, standardization is crucial to prevent fragmentation and ensure compatibility. Lastly, the adoption of these technologies and educational efforts to enhance awareness among stakeholders are cardinal for harnessing the detailed prospective of blockchain and IoT integration [51] [52]. As both blockchain and IoT technologies continue to evolve, ongoing collaboration and innovation are expected to address these challenges and make the integration more accessible and effective.

6. Conclusion:

In conclusion, blockchain technology holds immense promise in revolutionizing precision agriculture. Its applications, from ensuring traceability in the supply chain to optimizing farming practices, are poised to bring about significant advancements in the agricultural sector. This review paper has dealt with various contexts under the benefits and challenges in current trend with the BT. Through blockchain, the industry can achieve greater transparency, data integrity, and trust, allowing buyers for developing the selected alternatives concerning the cuisine in its consume. While challenges exist, including issues of scalability, data privacy, and interoperability, ongoing developments in blockchain and the growing awareness of its potential are driving solutions to these challenges. As technology continues to evolve, precision agriculture, guided by blockchain, has the potential to enhance food safety, environmental sustainability, and efficiency in the production and allocation of products in agriculture. BT is not only a disruptive force but a transformative one in the realm of precision agriculture, and its integration with another sophisticated machineries, such as IoT and AI, will shape the future of farming practices and food production. With the industry's ongoing adoption of blockchain technology, it stands to gain the advantages of this innovative approach, promoting a more sustainable and transparent agricultural ecosystem.

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