# Block Farm: Blockchain-Based Platform for the Agriculture Supply Chain


**Udai Bhan Trivedi, Manoj Srivastava, and Manish Kumar**

## 1 Introduction

Blockchain is a peer-to-peer decentralized ledger that collects a growing number of transaction records from a hierarchically growing blockchain and uses cryptographic technology to secure each block to ensure transaction data integrity [1]. New blocks are added to the global blockchain only after the decentralized consensus system is completed. More specifically, a block stores a hash (the value of an entire block that can be considered a cryptographic image) and a hash value (the previous block that acts as a cryptographic relationship to the previous block in the blockchain). The network uses a secure blockchain and (III) a decentralized consensus method that monitors the acquisition of new blocks in a blockchain learning protocol to ensure the consistency of data records in each copy of the blockchain stored on each node. As a result, the blockchain ensures that transaction records cannot be modified or altered once a transaction record is added to a block and the block is successfully created and canceled on the blockchain. Blockchain also ensures the integrity of the data in each block of the chain, and the blocks created on the blockchain cannot be altered in any way. Blockchain acts as a secure, distributed ledger that records all transactions between two participants in an efficient, reliable, and verifiable manner in an open network system [2].

A block is added to the issuing node's blockchain containing the transaction. A block consists of a block header and data. The block header contains metadata about the block. Block data consists of a list of verified and legitimate transactions sent to

U. B. Trivedi (✉)
Pranveer Singh Institute of Technology, Kanpur, Uttar Pradesh, India
e-mail: udaibhantrivedi@gmail.com

M. Srivastava
Dr. Gaur Hari Singhania Institute of Management and Research, Kanpur, Uttar Pradesh, India

M. Kumar
Galgotias College of Engineering and Technology (GCET), Greater Noida, Uttar Pradesh, India



B. K. Roy et al. (eds.), *Cryptology and Network Security with Machine Learning*,
Algorithms for Intelligent Systems, https://doi.org/10.1007/978-981-99-2229-1_26

**Table 1** Component of block in blockchain

| |
|---|
| • Block header |
| (a) Block number: Indicate the version number of the block |
| (b) Hash of the previous block: Use SHA 256 (Algorithm) |
| (c) Hash of current block: Use SHA 256 (Algorithm) |
| (d) Timestamp: indicates when the block was created |
| (e) Difficulty target to adjust the difficulty of mining |
| (f) Nonce |
| • Block data |
| (a) Consist of all transactions and other data that may be present |

the blockchain network. By cryptographically signing a transaction, the issuer of the digital asset verifies the correctness, legality, and validity of the transaction form. Ensure that the party presenting the digital asset for a transaction has access to the private key used to sign the existing digital asset. Each transaction in a published block is verified by additional full nodes to ensure correctness and validity. If the transaction is not valid, the lock is rejected. The following data fields are used by many blockchain implementations [3] (Table 1).

## *1.1 Chain of Blocks*

Blocks are the building blocks of the blockchain. The header from the preceding block's hash digest is included in each block. A new hash would be generated if a block that had already been published had been modified. As a consequence, since they incorporate the hash of the previous block, each successive block will have a unique hash. This makes it easier to spot corrupted data and reject it [4] (Fig. 1).

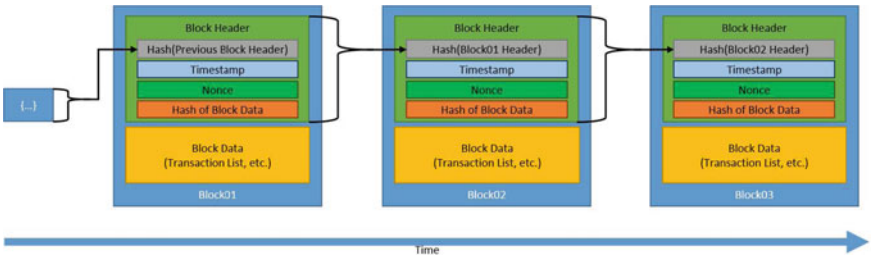


**Fig. 1** Generic chain of blocks

### *1.2 Hash Chained Storage*

The two main building blocks for building a blockchain using hash chain storage are the Hash index and the Merkel tree.

A hash pointer is a cryptographic hash of data that directs the user to where the data are stored. You can use a hash pointer to check if the data have changed. Hash tokens are used to combine blocks of data into a blockchain structure. Each block specifies a hash pointer to that block, specifying the address where the information from the previous block is stored. Users can publicly verify data hashes to prove that stored data have not been altered. If an attacker tries to change the data in each block of the entire chain to hide the damage, the attacker would have to change the hash of each previous block, which is almost impossible [5].

### *1.3 Digital Signature*

A digital signature verifies data using cryptographic techniques. Also, it is a way to ensure that the data have not been changed. The digital signature system consists of three main parts. The first element of the key generation algorithm is the generation of two keys: one to sign messages and preserve their confidentiality. This key is called the private key. The other is available to the public. This key is called the public key, used to verify that the message was signed with the private key. The signature algorithm is the second important factor. Sender sign incoming messages using the provided private key. The validation algorithm is the third important element. It accepts three inputs: signature, message, and public key then uses a public key that verifies the signature of a message and returns a Boolean result [6].

### *1.4 Elliptic Curve Digital Signature Algorithm (ECDSA)*

One of the most advanced public key encryption systems is Elliptic Curve Digital. Signature Algorithm (ECDSA). Elliptic curve encryption keys are smaller than intermediate keys obtained using digital signature technology. Elliptic curve cryptography is a type of public key encryption based on the algebraic arrangement of an elliptic curve in a bounded field. Elliptic curve cryptography is often used to create fake numbers, digital signatures, and other similar data. An electronic digital signature is an authentication mechanism that uses a pair of public keys and a digital certificate as a signature to verify the identity of a recipient or sender of information [7].

### *1.5 Nonce*

A random number that is used only once is called a cryptographic nonce. The data can be parsed into different values of the encrypted nonce generating multiple hash digests each time.

$$\text{Digest} = \text{hash (data} + \text{nonce)}$$

There are ways to get different summary results by changing the unknown values while keeping the same data. The consensus model POW uses this method [5].

### *1.6 Consensus Protocol*

The techniques through which all users within a distributed ledger concur on the accuracy of the underlying data are known as consensus protocols. The fact that all parties acknowledge a single "real" version of the data makes a distributed ledger one of its major features. An event known as a fork happens when current Blockchain participants choose to incorporate data in a way that is incompatible with established protocols.

The ledger splits as a result of forks, resulting in the formation of two groups, each of which validates its version of the ledger. Participants must stick to the same fork of the ledger to continue interacting with one another. As Block Farm is based on Ethereum PoS (Proof of Stake) consensus protocol has been used in the proposed system [8] (Table 2).

## 2 Literature Review

The various have been reviewed and considered to get an idea about the main stakeholders and their role in the traditional model. The various process where trust is the main deficit area. Try to find out the module where transparency and tracking are required. The literature review enabled us to understand Blockchain applications in agriculture, blockchain-based agricultural modeling, and the benefits and obstacles of blockchain deployment in the agricultural supply chain (Table 3).

**Table 2** Consensus protocol

| Consensus protocol | Overview |
|---|---|
| Proof of work | Validate new blocks of data using calculations. Participants in this plan must group transactions into a single block, apply a hash function along with some additional information, and then join the plan |
| Proof of stake | To participate in the verification process, validators (special nodes) must deposit collateral and cast votes on legitimate blocks. In contrast to Proof of Work, which focuses on proving the user has a significant amount of processing power, Proof of Stake is based on proving that users have invested in tokens of value in the network |
| Ripple protocol | The server confirms new transactions by combining open transactions into a "candidate list." Then all participants vote on which legitimate transactions should be recorded in the ledger<br>The final state of the closed ledger will include all transactions that have received at least 80% of "yes" votes |
| Proof of elapsed time | As part of the Intel Ledger Concept, Intel used the processor's capability to provide the hardware with a cryptographically signed timestamp to create a validation lottery. The transaction that will enter the next block in the chain is determined by the transaction in the chain with the next timestamp. Compared to proof-of-work, this consensus mechanism consumes much less energy, so it is more suitable for IoT devices |

## 3 Platforms for the Agriculture Supply Chain: Block Farm

Block Farm will help supply chain and market players by reducing inefficiencies. A dynamic and smooth software solution from Block Farm serves conventional, well-established agricultural supply networks. Block Farm will promote farmers and the companies that assist them to connect with customers to expand and strengthen their supply chains by enabling one-to-one global trade. Block Farm seeks to have a good influence on both societies at large and the world's agricultural industry. Block Farm will offer a cutting-edge digital strategy and the necessary industry expertise to give farmers and the vital companies that support them more value. Block Farm can meet the demands of the sector as more farmers switch from bulk handling to residential storage. Farmers may sell their goods directly to local or foreign customers from their home storage systems by utilizing blockchain technology in a secure, low-risk setting [13] (Table 4).

**Table 3** Literature review

| Number | Year | Key findings of the paper specified in reference number |
|---|---|---|
| 1 | 2021 | Srivastava, R, etc. discussed emergent concerns for further blockchain research that have been found, with a focus on supply chain and agriculture management |
| 2 | 2021 | Yadav, V.S, etc. in his study identified and modeled the key drivers of long-term food security in India using a multi-criteria decision-making (MCDM) strategy |
| 3 | 2021 | Valoppi, F, etc. presented a description of cellular agriculture and other alternative methods of food production |
| 4 | 2021 | Zhu, L., etc. built a blockchain-based big data sharing solution after carefully analyzing the advantages of blockchain-based large data sharing |
| 5 | 2021 | Alkahtani, M., etc. in his research paper incorporated the blockchain impact into agricultural supply chain management using web design elements |
| 6 | 2021 | Liu, W., etc. presented the report which examines the body of research on blockchain technology and ICTs in agriculture from 2011 to 2020 |
| 7 | 2021 | Tan, H.Y., etc. examined rural green credit utilizing a hierarchical blockchain model |
| 8 | 2021 | Yang, X., etc. presented popular methods for developing smart agriculture that covered: precision agriculture, convenience agriculture, and disciplined agriculture |
| 9 | 2021 | Rijanto, A.in his paper looked at how businesses finance themselves and how blockchain is used in agriculture |
| 10 | 2021 | VanWassenaer, L., etc. used a reference framework to identify key requirements for fresh agrifood use cases and better comprehend various blockchain applications |
| 11 | 2021 | Awan, S.H., etc. proposed a hybrid smart model that incorporates both Internet of Things (IoT) and blockchain capabilities, with a novel approach for transforming conventional agriculture into smart agriculture |
| 12 | 2021 | Vangala, A., etc. define the key needs for smart agriculture have been defined, and generic blockchain-based security architecture has been proposed |
| 13 | 2020 | Kamble, S.S., etc. This study identifies drivers for the implementation of blockchain technology in agricultural supply chains to increase the traceability |
| 14 | 2020 | Chen, Y.Y., etc. investigated agriculture's democratization, autocratization, centralization, and decentralization in terms of their ramifications and logical connections with other institutional and technological concepts |
| 15 | 2020 | Sharma, R., etc. research has shown the particular importance of how some machine learning application is used in agricultural supply chains (ASC) and accelerate ASC stability and performance |
| 16 | 2020 | Osmanoglu, M., etc. in their study recommended a blockchain-based approach to enhance agricultural product yield estimates |
| 17 | 2020 | Zhang, X.H., etc. in his study explored the opportunities and challenges of ensuring agricultural data quality through edge computing with other blockchain-based technologies |
| 18 | 2020 | Yadav, V.S, etc. Obstacles to the blockchain were identified, and an integrated model of those barriers' interrelationships and the strength of their relationships was introduced with a special focus on the Indian agriculture supply chain's adaption |

(continued)

**Table 3** (continued)

| Number | Year | Key findings of the paper specified in reference number |
|---|---|---|
| 19 | 2020 | The Paper by Ferrag, M.A., etc. discussed the privacy issues and security challenges of IoT-based agriculture and outlined several risks affecting the sector, such as privacy attacks, authentication, confidentiality, availability, and integrity aspects |
| 20 | 2020 | Iqbal, R., etc. discussed the effectiveness of precision agriculture by utilizing blockchain and IoT systems in safe agricultural applications, such as tracking animal attacks, primarily through a Repelling and Notifying System |
| 21 | 2020 | Xiong, H., etc. presented an overview of blockchain applications in the food supply chain, agricultural insurance, smart agriculture, and agricultural transactions, including a discussion of data security issues in small farms |

**Table 4** Stakeholders of block farm

| | |
|---|---|
| 1. Farmers | 2. Manufactures requiring agricultural products (dairies, flour mills, breweries, etc.) |
| 3. Farmer representatives (brokers) | 4. Smaller farming cooperatives |
| 5. Trucking and logistics companies | 6. Suppliers of agricultural inputs (chemicals, fertilizers, etc.) |
| 7. Logistics brokers | 8. Importers and exporters of bulk commodities |
| 9. Buyers of agricultural products | 10. Customers and end users |

## *3.1 Operational Efficiency*

### 3.1.1 Tracking and Automation (Supply Chain)

Combining user-friendly mobile applications for agricultural operations and transportation with powerful online business management, Block Farm provides an end-to-end view of the agricultural supply chain. Block Farm provides data to farmers, brokers, and logistics companies to automate the farm-to-consumer transportation process. Data are collected at each stage of the SCM and each shipment is time-stamped upon receipt and delivery. Real-time updates are sent to all parties after each transaction is completed. Block Farm will improve productivity and visibility, simplifies inventory, automates inventory orders, and removes tedious paperwork from the system (Fig. 2; Table 5).

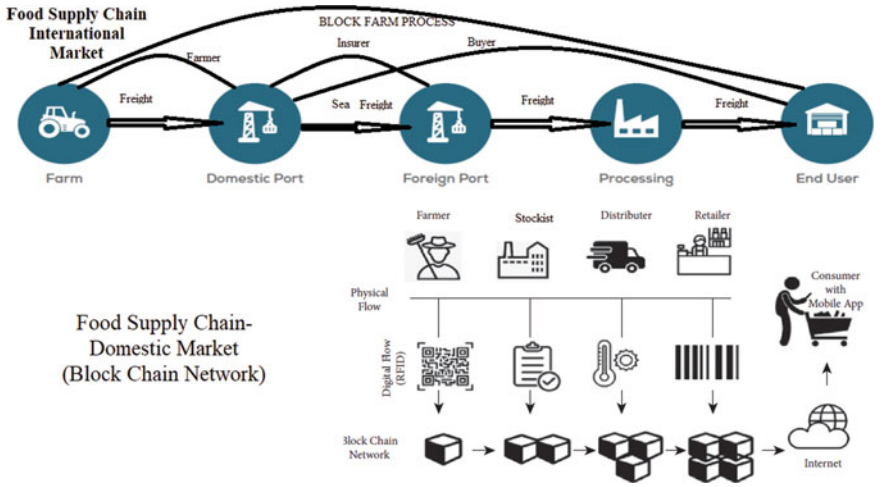


**Fig. 2** Blockchain-based (Block Farm) process of the agriculture supply chain

**Table 5** Advantages of block farm

| FARM-domestic port/stockist | Domestic port-processing/ distributor | Processing/retailer-end-user/ customer |
|---|---|---|
| One computer program | Supply-chain management | Complete stock tracing |
| Exclusive origin stock | Decreased dependence on banks | Evidence of origin |
| An increase in stock visibility | De-risked business deals | More precise product recalls |
| Decreased capital costs | There are no currency concerns | Certainty of supply |
| Less handling | Exact insurance rates | |
| Reduced storage costs | Fewer manual documents | |
| E-commerce cash boards | Decreased administrative costs | |
| Under the control of the farmer | | |

### 3.1.2 Information and Data Transparency

Users will have more options with Block Farm to make a fact-based decision based on Market information and data. By viewing inventory, consumers can see exactly how many items they have, where they are going, when they will arrive and how much they cost. Users can be sure that improving profits is important at every level of the supply chain.

Buyers and end users will benefit from increased data quality and completeness as they can monitor and track the entire supply chain using a single system across all industries [8].

### 3.1.3 Smart Contract

Block Farm will offer simple contract options for farmers, brokers, buyers, and logistics companies. Block Farm will provide the largest automated software for creating products and shipping contracts. The blockchain system allows buyers, sellers, and goods to communicate in a blockchain system, ensuring the security of both sides of the transaction. Using blockchain technology, Block Farm will create the first global marketplace for authentic agricultural products [9, 10].

### 3.1.4 Record Keeping/Proof of Origin

By creating an immutable blockchain record of the journey from paddock to plate, proof of origin can be provided as goods move through the supply chain. At each level, the major supply chain actors are listed along with the supply chain nodes that each of these organizations owns and controls (e.g., fields, silos, vehicles, and delivery locations). Additionally, Block Farm tracks key product information including weights, species, grades, specifications, and inputs. Blockchain enables a fully transparent and traceable supply chain, giving all consumers a clear view of the goods, they buy [11].

## *3.2 Financial Benefits*

### 3.2.1 Reducing the Cost of Capital

Block Farm users will pay FARMCOIN to create a contract to buy and sell agricultural products. Any subsequent changes to the business contract to add new data to the public blockchain will be charged as a FARMCOIN transaction fee. FARMCOIN payment is required to complete the transaction of goods between seller and buyer if the contract is suspended, closed, or suspended. On settlement day, both seller and buyer can trade using FARMCOIN tokens to reduce complexity and risk. This is especially important for international commodity contracts because it eliminates many burdensome transaction fees, including many foreign exchange contracts, bank guarantees, and letters of credit. Blockchain allows sellers and buyers around the world to use a single currency, eliminating the hassle and dependence on financial intermediaries.

Block Farm aims to make credit more affordable and accessible to farmers by providing greater visibility into farm inventory and reducing lender risk. With Block Farm, banks may view the farmer's current "position" and history of custody, both of which are recorded and certified by the blockchain. In addition, investors consider any guarantee of payments made by the farmer (future sales supported by an acceptable contract). Financial institutions can use Block Farm's data to reduce the risk of their financing by gaining access to previously unobtainable information about the farmers' real circumstances [14, 15].

### 3.2.2 Improving Cash Flow

Most small and medium-sized businesses fail due to poor cash flow, and agricultural supply companies are no different. Participants in the agricultural SCM suffer from low liquidity in their daily operations. Companies try to reconcile accounts receivable and accounts payable to maintain a stable and predictable cash flow. Unfortunately, as agricultural products move through the supply chain, the number of delinquent loans increases. Blockchain allows companies to raise capital and improve liquidity for supply chain participants using future contracts with existing customers [10, 12].

### 3.2.3 Insurance

Authorized insurance companies will have unprecedented access to farm inventory, storage, and transportation through Block Farm. In addition, new Internet of Things (IoT) solutions for heavy agricultural equipment and storage offer more opportunities to optimize the data stored in the Block Farm. With access to up-to-date, accurate, and irreversible data, insurance companies can more effectively assess claims, provide customized solutions for customers, pay claims, manage risk, detect suspicious activity, and improve fraud assessment. On the other hand, farmers, consumers, and logistics companies will have access to a wider range of insurance solutions with more accurate and affordable risk premiums [13].

### 3.2.4 Peer-To-Peer Lending

A farm of any size can connect to Block Farm in a secure (P2P) lending environment that allows companies with excess cash to provide short-term loans to those who need access to short-term financing. With Block Farm's platform, like-minded farmers can get better credit offers than conventional overdraft loans and reduce the cost of agricultural financial products.

## 4 FARMCOIN Tokens

FARMCOIN coins will use by Block Farm on the Ethereum public blockchain. The FARMCOIN token becomes a trading instrument token to pay for access to the Block Farm system through a payment gateway. Block Farm generates FARMCOIN tokens that will be profitably sold on the open market as revenue. In addition, a portion of FARMCOIN token sales will be transferred to Block Farm to expand the commodity pool. The price of the Block Farm system (such as fees and rewards) will be determined using the value of fiat currency to reduce volatility in crypto markets. However, users are charged with FARMCOIN tokens.

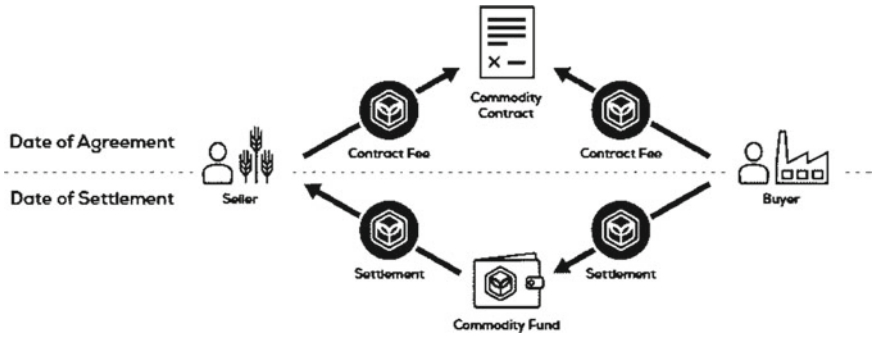


**Fig. 3** Commodity contract between seller and buyer

### *4.1 Commodity Contract*

Block Farm users will pay FARMCOIN to create a contract to buy and sell agricultural products. Any subsequent changes to the business contract to add new data to the public blockchain will be charged as a FARMCOIN transaction fee. FARMCOIN payment is required to complete the transaction of goods between seller and buyer if the contract is suspended, closed, or suspended. On settlement day, both seller and buyer can trade using FARMCOIN tokens to reduce complexity and risk. This is especially important for international commodity contracts because it eliminates many burdensome transaction fees, including many letters of credit, bank guarantees, and foreign exchange contracts. FARMCOIN will allow sellers and buyers around the world to use a single currency, which will eliminate the hassle and dependence on financial intermediaries (Fig. 3).

## 5 Technological Architecture of Block Farm

In the Block Farm Model of Blockchain, the application layer consists of various modules which can access directly through Public Block Farm Layer or indirectly through the Private Block Farm Layer [8] (Fig. 4).

### *5.1 Public Block Farm Layer*

Block Farm uses the Ethereum blockchain (main contract, public blockchain data record, FARMCOIN token trading, and network rights) to create smart FARMCOIN tokens that can be traded on third-party token exchanges. Commodity smart contracts, inventory smart contracts, raw data sources, and FARMCOIN transactions are all available through the public blockchain layer. The public Ethereum blockchain and

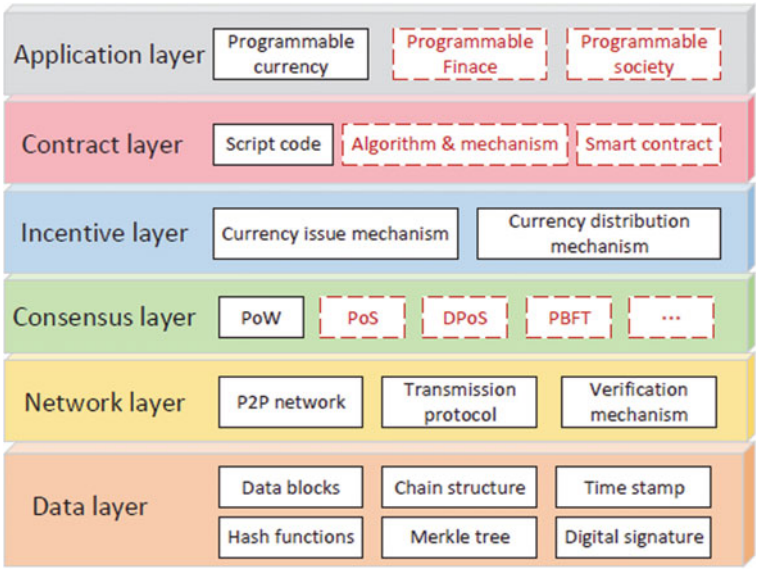


**Fig. 4** Blockchain architecture [8]

third-party exchanges operate independently of Block Farm, providing secure and decentralized smart contracts and FARMCOIN tokens.

## *5.2 Private Block Farm Layer*

Because agriculture and supply chain transactions occur frequently and in large numbers, a private blockchain layer can be used to better manage data volumes and reduce transaction costs and delays associated with public blockchains. The private layer of the Ethereum blockchain (main network) communicates with the public blockchain. Block Farm's private blockchain will be used to store private data on commodity contracts, shipping contracts, supply chains, warehouse management, agriculture, and more. Block Farm uses this technique to achieve an optimal match to the underlying application, expected traffic, and load.

## *5.3 Payment Platform*

Block Farm payment platform accepts direct payments for access to applications. Payment is accepted in the form of FARMCOIN tokens and fiat money (credit card) through payment gateways. As many consumers in Block Farm's target market are

unfamiliar with blockchain technology and tokens, credit card payments will be allowed as a temporary solution, reducing barriers to adoption. Credit card payments can be used to purchase FARMCOIN tokens on public exchanges, which are then processed in the same way as live FARMCOIN payments. As Block Farm's private blockchain evolves, the credit card payment gateway will be removed and FARMCOIN tokens will become the exclusive payment method for accessing the system (Fig. 5; Tables 6 and 7).

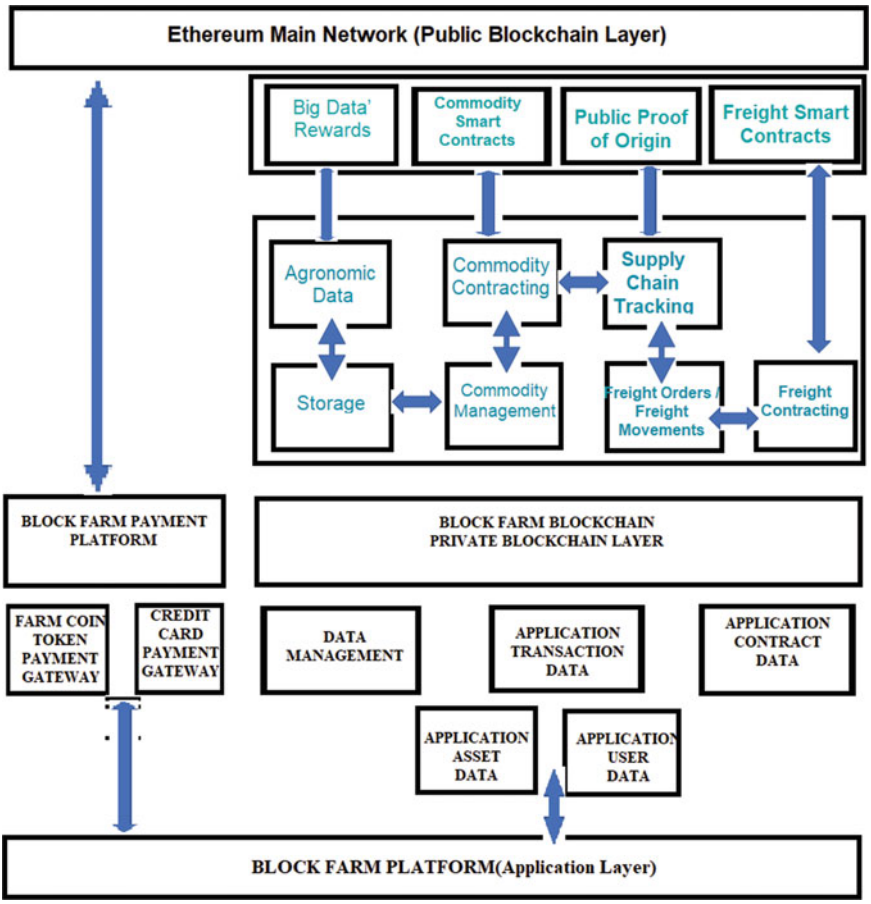


**Fig. 5** Suggestive architecture of block farm (Application Layer)

**Table 6** Proposed modules in application layers/users of block farm and platform

| Module in application layer | | Users | Platforms |
|---|---|---|---|
| Commodity contracts | Freight tendering | Growers (Farmers) | Web browser (PC/Mac) |
| Freight orders | Insurances | Brokers | Android (Mobile) |
| Freight movements | Online marketplace | Logistics | iOS (Mobile) |
| Stock management | Invoicing | Buyers | |
| Reporting | Production estimates | Receival sites | |
| Admin/Config | Cash boards | | |

**Table 7** Module of application layer and its functionality

| Module name | Functionality |
|---|---|
| Block Farm marketplace | Block Farm receives a commission when Resource Resellers join using the marketplace in exchange for making the link. FARMCOIN tokens are used to pay market commissions |
| Freight contract | Similarly, to freight contracts, freight orders and movement contracts will be created and managed where the parties in the supply chain pay in FARMCOIN to send the data to the public blockchain. Contracts for the supply of goods can be concluded between the seller or buyer of goods and an intermediary or supplier of goods. FARMCOIN will also receive compensation for the award of specific transport contracts to subcontractors for transport orders managed by a transport intermediary |
| Freight tender | Merchants in need of transportation services can register their needs using Block Farm's freight bidding module. This feature promotes competitive pricing by enabling potential suppliers to offer the best prices to win the contract. FARMCOIN tokens are used to pay Block Farm commissions for connecting vendors and logistics providers |
| Supply chain tracking | Each point of the transaction must be recorded in the supply chain to track the product and provide a complete record of the journey from paddock to plate. Parental authority and ownership may change multiple times between farms and end consumers as products move from one member of the supply chain to another. Each stage of loading, noise, or change of owner is paid by the user and paid in FARMCOIN |
| Commodity management | Goods are frequently inspected as they are assembled and moved through the supply chain to confirm that they meet the specified quality, grade, and weight. Product data are entered into the blockchain at each checkpoint to create an end-to-end record and provide a complete view. In addition, as goods move through the supply chain, any treatment or use of gas is tracked. The cost of collecting product data is charged in FARMCOIN tokens |

(continued)

**Table 7** (continued)

| Module name | Functionality |
|---|---|
| Share-farming contracts | Collective contracts provide an opportunity for farmers to work together and increase the profitability of their farms. Cooperative farming contracts give landowners and farmers the opportunity to grow their businesses by bringing together farmers who want to grow. Collaborative farm contracts are promoted by Block Farm, which also stores this data on Block Farm's private blockchain. Agricultural contract structure, conversion, and termination fees are valued in FARMCOIN tokens |
| FARMCOIN as a reward token | Agronomic and agriculture data are collected on field activities and conditions during the growing season. These details include soil analysis, production forecast, fertilizer and nutrient content, chemicals, pesticides, and more. This data has a variety of uses, as it not only helps identify trends and patterns in agricultural "big data" but also influences consumer purchasing decisions. Agricultural data are collected and published on Block Farm's private blockchain to ensure full transparency of each product. Block Farm plans to reward users who process data with FARMCOIN tokens generated directly from data revenue to encourage additional contributions |

## 6 Conclusion

All the players in the agricultural supply chain, including farmers, transport businesses, intermediaries, traders, buyers, and consumers will be able to do so fast and risk-free transactions with the Block Farm platform. Block Farm connects stakeholders of the agricultural supply chain as a global platform, promoting transparency and traceability from the paddock to the fork. Agricultural supply chain internal and external complementary platforms can be customized by the Block Farm ecosystem, which is secure, scalable, and open. Customers can use Block Farm as: stand-alone solution or add-on to current software. A FARMCOIN token works as digital money that facilitates communication between supply chain participants and the Block Farm platform. FARMCOIN will evolve as multifunctional utility coin that trades on exchanges and serves as the "fuel" of the Block Farm system. This paper tries to outline the conceptual model of the agriculture supply chain system for the local and international market and help all stakeholders in their business processes.

## References

1. Narayanan A, Bonneau J, Felten E, Miller A, Goldfeder S (2016) Bitcoin and cryptocurrency technologies: a comprehensive introduction
2. Zheng Z, Xie S, Dai H-N, Chen X, Wang H (2017) An overview of blockchain technology: architecture, consensus, and future trends, June. https://doi.org/10.1109/BigDataCongress.2017.85
3. Nakamoto S (2009) Bitcoin: a peer-to-peer electronic cash system. In: Cryptography mailing list, March. https://metzdowd.com

4. UK Government Office for Science (2016) Distributed ledger technology: beyond blockchain
5. Trivedi UB, Sharma S (2023) Digitally signed document chain (DSDC) blockchain. In: Singh PK, Wierzchoń ST, Tanwar S, Rodrigues JJPC, Ganzha M (eds) Proceedings of third international conference on computing, communications, and cyber-security. Lecture Notes in Networks and Systems, vol 421. Springer, Singapore
6. Srivastava R, Zhang JZ, Eachempati P (2021) Blockchain technology and its applications in agriculture and supply chain management: a retrospective overview and analysis. Enterp Inf Syst 94
7. Steem: An incentivized, blockchain-based, public content platform (2017)
8. Zhang R, Xue R, Liu L (2019) Security and privacy on blockchain. ACM Comput Surv (CSUR)
9. Mavilia R, Pisani R (2021) Blockchain for agricultural sector: the case of South Africa. Afr J Sci Technol Innov Dev
10. Liu ZL, Wei H, Wang DB (2021) Functional agricultural monitoring data storage based on sustainable block chain technology. J Clean Prod
11. Friha O, Ferrag MA, Shu L, Maglaras L, Wang XC (2021) Internet of Things for the future of smart agriculture: a comprehensive survey of emerging technologies. IEEE-CAA J Autom Sin
12. Torky M, Hassanein AE (2020) Integrating blockchain and the internet of things in precision agriculture: analysis, opportunities, and challenges. Comput Electron Agric
13. Salah K, Nizamuddin N, Jayaraman R, Omar M (2019) Blockchain-based soybean traceability in agricultural supply chain. IEEE Access
14. Kamilaris A, Fonts A, Prenafeta-Boldu FX (2019) The rise of blockchain technology in agriculture and food supply chains. Trends Food Sci Technol
15. Lin YP, Petway JR, Anthony J, Mukhtar H, Liao SW, Chou CF, Ho YF (2017) Blockchain: the evolutionary next step for ICT E-Agriculture. Environments