IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming

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***Abstract*—This paper discusses how agriculture has become one of the prime reasons for the wastage of energy and water during food production. In order to control the use of resources in farming, we introduce a novel concept called IncentiveChain. The application idea is to distribute crypto ether as a reward to the farmers because they play key roles in keeping a check on resource usage and can benefit through these schemes economically. We provide a state-of-the-art architecture and design, which includes participation from national agricultural departments and local regional utility companies to embed various technologies and data together to make the IncentiveChain application practical. We have successfully implemented IncentiveChain to show the transfer of ether from utility company accounts to farmer accounts and the currency being collected by the farmer in a more secure way using the blockchain, removing third-party vulnerabilities.**

***Index terms*—** Smart Agriculture; Blockchain (BC); Cryptocurrency; Farm Incentive.

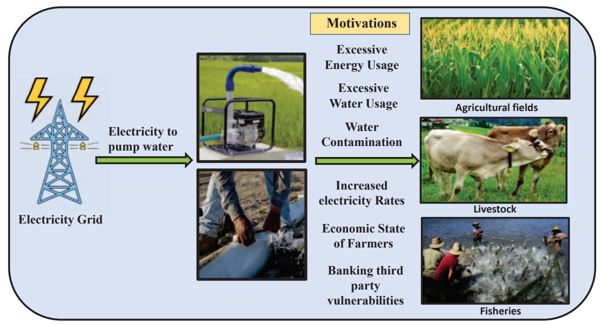

Fig. 1: Motivations for IncentiveChain application.

I. Introduction

The Earth's surface is covered with 70% water, out of which oceans cover 97%, and freshwater is only 3%. Water is important for the existence of all species on Earth. The rivers, lakes, and groundwater withdrawals are helpful for various industrial, domestic, and agricultural purposes [1]. However, water is becoming scarce due to climatic changes, nitrate contamination due to overuse of fertilizers [2], [3] in agriculture, and global warming. The agricultural domain accounts for about 70% of the world's water withdrawals, but only 10% is used effectively. With the increase in population, water wastage has further increased [4]. The worldwide fund estimate shows that 2500 trillion liters of water are used in agriculture every year, on which 1500 trillion liters go to waste [5]. Besides water, electricity plays a significant part in society and helps support economic and industrial organizations. Its role in agriculture for pumping water to the fields for growing crops and hygiene of livestock and other uses is irreplaceable [6]. Current pandemic situations worldwide [7] have increased the cost of electricity and caused a decrease in supply; hence it should be used effectively in all aspects. Some of the motivations for the current paper are provided in Fig. 1.

Farming includes different domains such as raising crops, poultry, livestock, fish/shellfish, dairy products, ornamental plants, and nursery products [8]. In all these different fields, the role of the farmer is crucial in carrying out agricultural tasks with specialized skills and required knowledge. Their correct decisions in various stages of planting, watering areas, and fertilizing to remove weeds help in marketing their produce. If farmers had a way to limit resource usage in the fields, it could be helpful in reducing the carbon footprint globally.

In the current paper, we discuss a state-of-the-art design for giving incentives to the farmers in the form of cryptocurrency for using water and electricity efficiently in their fields. Farmers are attracted to inducement schemes rapidly as they increase their income level and are more careful while using water and electricity in their field activities. The utility services installed on farms collect information regarding the number of watts and hundred cubic feet (HCF) units used for generating monthly bills. A country's agriculture department is mainly responsible for developing and executing federal laws related to farming, forestry, and food. The department can attach ether points to the amount of water and electricity units used, thus providing incentives to the farmers, once the units are equaled. In order to make these practices functional, a system is required with a robust design for incentives, responsible participation from farmers, and efforts from national and local levels. A more detailed explanation of the architecture is discussed in Section IV.

The paper is organized as follows: We elucidate on the problems and propose a state of the art solution in Section

II. In Section III we discuss previous works on efficient water and energy usage in farming and blockchain usage in smart farming. A novel architecture and algorithms for the proposed IncentiveChain system are explained in Section IV. For validating the current system we implement and give the results in Sections V and Section VI respectively. Finally, we discuss the conclusions and future directions for the current paper in Section VII.

II. Sate-of-the-Art Contributions

A. Problems discussed

- Farming as a key reason for electrical and water wastage.
- More pumping of water from underground aquifers by farmers for growing food.
- Agriculture is among the leading causes of water pollution globally.
- Rise of electricity usage in farming by the producers.

B. Proposed Ideas in the Current Paper

- Attracting farmers through money inducements for saving resources during farming.
- Increasing the economic status of the farmers by introducing financial rewards.
- Introducing security in banking transactions by distributing cryptocurrency.
- Increasing trust among participants for the data transferred.

C. State-of-the-art Solutions

- Novel architecture incentivizes farmers for efficient water and electricity usage in farming.
- State of-the-art approach for consistency, standard, and trust in communication between relevant parties using the blockchain.
- Distribution of cryptocurrency for introducing more security in bank transactions.
- Implementation of the system using a decentralized blockchain approach.

III. Related Prior Works

A. Previous Work for efficient use of water and electricity

Many smart methods and research works have been proposed for the efficient use of water and electricity in farming, and here we elaborate on some of them. [9] introduces a path design for agriculture unmanned vehicles (UAV) to decrease the usage of water and energy during the farming process through dynamic models and water stress indicators. The decisions in the model are taken using UAV image collection and are based on the crop conditions to sprinkle the water on the crops only if necessary. The implementation of the system is done using simulations to show to performance of the application.

The authors in [10] have discussed an IoT implementation in decreasing the communication gap between the smart devices and the farmers. The IoT devices make use of sensors and models to determine the water levels, motor controls and soil dampness. The application has an interface that can be controlled easily by the farmer through smart phone accessibility. To power the sensors, the application makes use of renewable energy, i.e., solar power to reduce the power consumption for pumping water to the fields.

The work in [11] demonstrates an irrigation system based on fuzzy based intelligence using a wireless sensor network to calculate the status of the water and moisture content in the soil. The performance analysis is done to show that the approach is far better than the conventional irrigation system and decreases water and electricity use in farming while increasing the crop yield. The authors in [12] discuss wireless sensor networks to measure water status, temperature, position, pressure and acceleration to increase the produce with efficient use of water and energy resources for improving agriculture precision. With the help of a large number sensors installed, a farmer can understand the condition of the crops at the micro level.

All these methodologies reduce water and energy usage in farming, but they depend solely on smart things and technologies that need to be installed in fields. The cost and maintenance of the equipment are more than the income of most of the farmers in developing countries who are responsible for most of the world's food production. The current incentive chain system can be designed as a smart application and embedded into utility company systems to estimate the amount of ether generated for the number of utility units saved. Table I gives a comparison between the earlier works to the current system. The application dispenses cryptocurrency to the producers who utilize the resources optimally and practice eco-friendly options for growing crops [13]. The mobile application can be accessed easily by the farmer to get the incentive chain services directly from the utility companies.

B. Previous Work on Blockchain for Smart Agriculture

Blockchain and distributed ledger technology have been explored in a variety of applications including smart cities, smart healthcare, and smart transportation [14], [15]. However, its usage in smart agriculture is still lacking.

The blockchain has different uses in the field of smart agriculture for ensuring trust, visibility, and provenance of the end product to consumers, securely sharing data and building applications for providing insurance to farmers. [16] implements a blockchain set in the Interplanetary file system (IPFS) for storage and security for groundwater data transmissions collected on fields. The system is built with a distributed and decentralized platform to perform double hashing on the data to increase trust and quality.

The authors in [17] give a study on how blockchain can be used in the supply chain. Drawbacks of the traditional supply chain using database systems and storage and cost limitations of the blockchain are overcome by introducing a "Database+Blockchain" structure for implementing on-chain

TABLE I: Previous works for efficient water and energy usage in farming.

Application	Technology	Incentives to Farmers	Maintainance
Lopez and Giraldo [9]	UAV	No	Very High
Vijayaraja et al. [10]	IoT and Solar	No	Very High
Jamroen et al. [11]	Wireless Sensor Network	No	Very High
Kumar et al. [12]	Sensors	No	Very High
IncentiveChain [Current-Paper]	**Blockchain**	**Yes**	**Very Low and easy to use**

and off-chain traceability information system. The ethereum blockchain encryption is performed on data for securing and sharing between relevant stakeholders present in the the supply chain.

An application for providing crop insurance for farmers is given in [18]. The paper discusses the application's initial stages in various developing countries and its use for farmers. The smart contract is designed to contain the main logic of the application, where automating the system can be helpful for easy usage and communication between different entities involved.

[19] presents an agricultural food supply chain embedded with IoT devices to get and consume the data along the application chain. The application was designed using both ethereum and sawtooth and compared to calculate the performances in terms of latency, CPU and network usage, and cost.

This current paper uses cryptocurrency and data security features of blockchain to build a robust incentive system for farmers. Table II lists various previous works that were carried out using blockchain technology in the field of smart agriculture.

TABLE II: Previous Work on Blockchain for Smart Agriculture.

Application	Domain	Technology
G-DaM [16]	Smart Agriculture	IPFS + Ethereum Smart Contract
Traceability System [17]	Smart Agriculture	Ethereum Smart Contract
Crop Insurance [18]	Smart Agriculture	Ethereum Smart Contract
Traceability in Agri-Food supply chain [19]	Smart Agriculture	Ethereum & Sawtooth

IV. Proposed State-of-the-Art Architecture and Algorithms

The section gives a novel architecture and algorithms for the current paper IncentiveChain.

A. Novel Architecture for Incentive Chain

There are multiple entities present in the proposed architecture. The modules that have key role in the design are service providers, data provider, user interface and the application layer. The service provider is responsible for designing the incentive chain product, processing the payments, and maintaining the market availability along with customer care. It also collects and manages the ethereum data, agriculture department laws and rates fixed to the utility units. As discussed in the introduction, the agriculture department plays very important role in this application design. They help in generating and executing laws related to agricultural farming and decides the number of ethereum units to a certain amount of electricity and water units. Once these units are equaled by the farmer, the cryptocurrency is deposited directly in to their accounts through this application. The user interface is mainly for helping the farmers to register to the incentive chain application through utility companies. The smart contract inside the ethereum blockchain (blockchain layer) is useful for writing the main logic of the program, over the application layer. The smart contract acts as in-charge for sending the payments to the farmer. The other actors and components that are included in the architecture are the utility company, which manages customers' utility bill data and performs payouts in a faster and transparent way. The blockchain platform automatically triggers the payments to the farmers near the utility company in case the usage of water and electricity units are matched with the agricultural department standards. The proposed state of the art architecture for incentive chain is illustrated in the Fig. 2. The blockchain network directly partners with the utility companies, data providers and service providers to make the architecture more distributed to avoid central system drawbacks. The financial payouts to the farmers are in the form of cryptocurrency in this design.

B. Blockchain cryptocurrency

A cryptocurrency is a digital asset that works mainly on the principles of cryptography for securing financial transactions that take place in an online way. Some of the examples include bitcoin, ether, litecoin, and ripple. The encryption helps evade additional layers for verifying asset transfer, avoids duplication and third parties as trust sources, and sends currency only to relevant parties [20]

C. Proposed algorithms

1) Farmer Registration: To Initialize the process, a farmer object structure (str[F_o]) is created with the attributes of unique

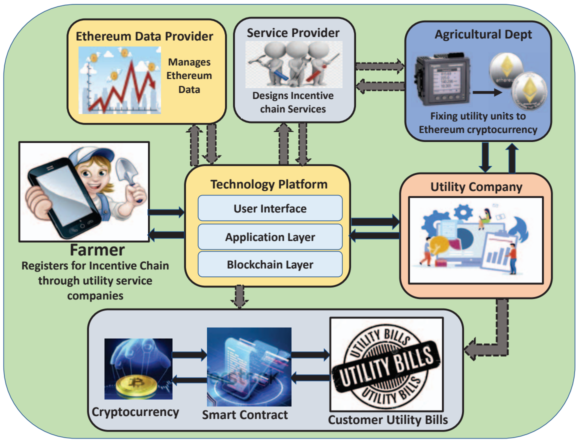

Fig. 2: State-of-the-Art IncentiveChain Architecture.

Algorithm 1 Farmer Registration

$str[F_{\text{o}}] \leftarrow (id, name, A_{\text{n}})$.
$SP_{\text{key}} \leftarrow (SP_{\text{id}}, F_{\text{id}})$.
$D_{\text{b}} \leftarrow store(SP_{\text{key}}, str[F_{\text{o}}])$.
$B_{\text{n}} \leftarrow D_{\text{b}}$

id, name, account no, contact details, history. To register the farmer client, a key (SP_{key}) is created by the service provider (SP). The key contains the id of the service provider (SP_{id}) and the id of the farmer. Both farmer object and the key object are stored in the database (D_b). Once the farmer gets registered, his details are stored on the blockchain network (B_n). Algorithm 1 shows steps to the point for recovering data.

2) Retrieving Details: After generating the key and storing it in the blockchain network (B_n), to retrieve the farmer details, the service provider searches for the desired farmer string object; if it exists, the data is retrieved, otherwise returns an error, as shown in algorithm 2.

3) Smart Contract SC): The smart contract runs through the ethereum virtual machine. It contains the main application logic for IncentiveChain. It has functions for payment objects, payment clients and access control mechanisms between the entities to enable trust of the data. The smart contract is responsible for triggering the fully automated payment processes to the farmers. It communicates between utility companies and service providers for generating ethereum and sending the payments towards farmer clients. The payment structure (str[P]) is created with the attributes of unique payment id P_{id}, name, bill amount, units saved (U_{saved}) and ether generated (Eth_g). For the payment client (str[PC]), the structure includes payment client id (PC_{id}), payment id (P_{id}), amount of ether receiving (Eth_r), acceptance indicator (Acc_I) and date of payment received ($Date_p$) attributes. After creating these two structures they are stored in the database (D_b) and then on the blockchain network (B_n), as illustrated in algorithm 3.

4) Issuing a Payment: Algorithm 4 shows the steps involved for issuing a payment to the farmer. The service provider (SP) verifies and validates before distributing

Algorithm 2 Retrieving Details

$SP_{\text{key}} \leftarrow (SP_{\text{id}}, F_{\text{id}})$.
Search(SP_{key}) in (B_n).
if exists **then**
  Retrieve desired str[F_o].
else
  Return Error.
end if
End the process.

Algorithm 3 Smart Contract

$str[P] \leftarrow (P_{\text{id}}, name, bill, U_{\text{saved}}, Eth_{\text{g}})$.
$str[PC] \leftarrow (PC_{\text{id}}, P_{\text{id}}, Eth_{\text{g}}), Acc_{\text{I}}, Date_{\text{p}}$.
$D_{\text{b}} \leftarrow store(str[P], str[PC])$.
$B_{\text{n}} \leftarrow D_{\text{b}}$
End the process.

ethereum. One all the verifications and payments are done, the status is stored in the database and then on the blockchain network.

V. IncentiveChain Implementation

Here we discuss the design flow required for developing the current IncentiveChain application as given in Fig. 3. Web 3.0 is the recent world wide web that acts as the foundational layer for getting application services and uses vast blockchain-based technologies. In this application, the web3.js package interacts with regional and ethereum nodes. For designing the front-end we use reactJS, i.e., react javascript, a metamask wallet for communicating to the back-end blockchain and collecting transaction fees, a node package manager for creating local nodes, and the truffle suite tools for developing incentive chain application. The ganache blockchain mirrors the actual functionality of the ethereum blockchain, which comes with ten free accounts, each containing a balance of 100 ether, and can act as personal accounts for different entities involved in the current application. The ganache showing the list of ten free accounts and user interface for the current application are shown in Fig. 4 and Fig. 5, respectively. The smart contract logic is written using the solidity programming language to execute terms based on a predetermined set of parameters. The complete application design with smart contracts is built on the truffle framework and connects the application entities to each of the ganache accounts through configuration. Fig. 6 shows how the front end connects to the back end blockchain with the help of the metamask wallet.

With solidity smart contract code, three functions for deployer, utility company, and farmer are defined. The data structure lists the farmer account number and ether amount and stores the data on the blockchain using a mapping functionality. Each of these functionalities are checked using tools of 'chai' and additional test scenarios for each account. The contract address is usually given when a contract is deployed to the ethereum blockchain. The address comes from the creator's

Algorithm 4 Issue a Payment

SP checks the authenticity of all the entities involved and confirms farmers eligibility for ethreum payment through SC.
SP checks if the Payment client (str[PC]) already exists in B_n .
SP calculates ethereum for no. of utility units saved through SC.
if all checks valid **then**
  Proceed Payment .
else
  Return Error.
end if
Store in D_b
$B_n \leftarrow D_b$

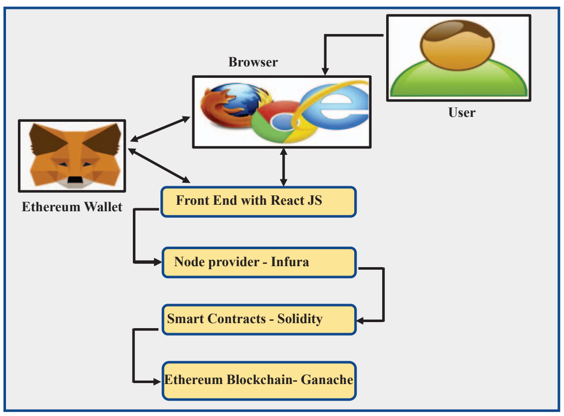

Fig. 3: Design Flow.

address and the number of transactions sent from that address. A new function called 'createEther' is created for enabling the utility company to accept the farmer account number and ether generated as arguments. Events and logs are created to trigger and log the data. Once the createEther function is done, we have written events and functions for accepting cryptocurrency. When the function inside createEther is called, the farmer submits the account number. The function is made payable, which means it will accept cryptocurrency. The structure

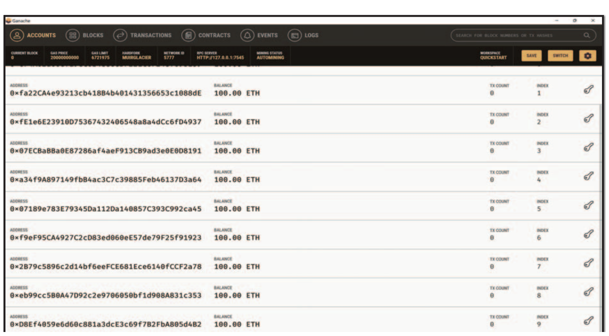

Fig. 4: Ganache ten free accounts.

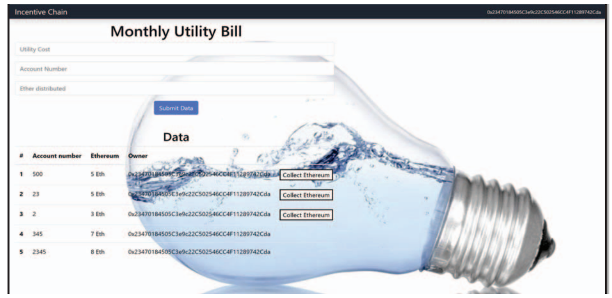

Fig. 5: User Interface.

and event are updated to payable status in order to pay the farmer. In the first step, the bill generated from the utility company is called through mapping and creating a new copy in the memory. Next comes storing the current owner to a variable and transferring the ownership to the Utility bill. In the last step, we trigger the event saying that the bill and ether have been generated successfully. The event and function 'farmercollect' is written to collect the currency. We tested the incentive chain application through truffle on the local ganache blockchain to confirm its functionality. Once the contract code executes on actual BC, we cannot revert the code, hence the testing requirement. The results for the application are discussed in the next section. The test checks if the utility company has transferred the ether, checks if the farmer has the ether currency, and checks for the failure cases.

VI. Experimental Results

The farmers, utility companies, and deployer addresses are assigned to the first three accounts in ganache through smart contract where the functions 'createEther', 'farmercollect' are defined and tested successfully. Each account has its own private key to connect to the ethereum wallet to perform the transactions (Tx). The working of the application is divided into two steps. In the first step, we connect the metamask wallet to the utility company account to enter the values for the farmer account number, the bill amount, and the number of ether the farmer gained to submit the data in the form of a list. In the second step, we connect to the farmer account to collect the ethereum from the utility company. Both steps are given in Fig. 6.

The application results are shown in Fig. 7 and Table III, where the farmer account has ethereum balance increased, and the utility company's has decreased. The application works successfully to illustrate the ether balance moving from utility company accounts to the farmer accounts and lists the data authentically. The origin and owner of the data sender account and receiver account are changed once the farmer receives the amount to avoid fraud in ether transactions.

VII. Conclusion and Future Direction

The current paper proposes a novel idea for incentivizing farmers for using water and electricity efficiently during farming. It can solve and reduce energy wastage problems faced

TABLE III: Results.

Account Holder	**Account Address**	**Starting Balance**	**Balance After Tx**
Farmer	0xe84223e28C0 5f993dc4E0480c C3c1CDFB93dA520	100 Eth	112.80 Eth
Utility Company	0x23470184505C 3e9c22C502546CC 4F11289742Cda	100 Eth	92.95 Eth
Deployer	0x367CE2BBFA 0a0a1aEc5105734 9cad678FD7Ea572	100 Eth	93.98 Eth

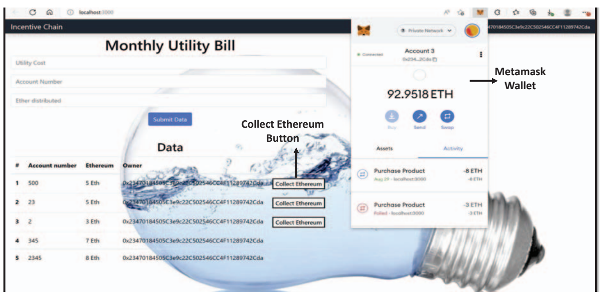

Fig. 6: Application Execution

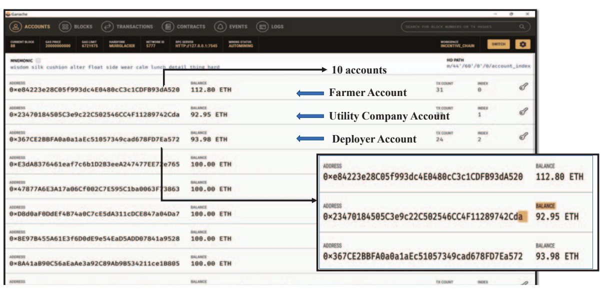

Fig. 7: Results.

during agricultural stages. This paper a proposes state-of-the-art architecture and platform for different entities and provides a new method for generating utility bills with cryptocurrency. We assume the application idea would be a success because of the inducements introduced for the farmer in energy saving process. The application is successfully implemented to move the ether cryptocurrency from utility companies to the farmer accounts from a user interface, but can be further improved by introducing automation to the system. The smart contract logic helps in access control and data security with more quality. In the future the current application can be enhanced and connected to the real time systems to see the actual performance in the true world.

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