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Dynamic Information Sharing in Vehicular Social Network for Agricultural Supply Chain

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***Abstract*—A Social Network of Vehicles or a Vehicular Social Network (VSN) is the modern adaptation of the Internet of Vehicles (IoV). In VSN, the vehicles in the network socialize with each other by disseminating information of common interests such as traffic information, weather conditions, road situations, toll gates, vacant car parking slots and media, etc. This new venture calls for developments in the areas of secure information storage and transmission among the entities of the VSN. VSNs make use of social behaviors and mobility of nodes to develop novel recommendation systems and route planning. Thus, VSNs can be utilized in most day-to-day applications that comprise a transportation system. Existing VSN frameworks are slow in learning regarding labelling of nodes and are susceptible to data loss and manipulation. This work proposes to develop a VSN of moving vehicles for an agricultural supply chain system with dynamic information dissemination capabilities. Further, communities are to be created for the stakeholders to facilitate communication amongst them and the security of the information shared is ensured using blockchain.**

***Index Terms*— Vehicular Social Network, Agriculture, Supply Chain, Information Sharing, Community Detection.**

I. Introduction

The population of the country is rapidly expanding which constantly creates the need for more resources and facilities among which food is a major component. The increase in population has raised the pressure on the farmers of our country as they have to meet elevating requirements of food and crop. Despite this surge in the need for food, the amenities available for the procurement and distribution of agricultural products remains meek and of poor quality. This domain does not see much improvement in terms of infrastructure thereby hindering the personal growth of workers of the agricultural sector. Due to the unavailability of a system that is in favor of the farmers, they are prevented from taking charge of the distribution process and are heavily dependent on money-hungry middle men for the supply chain who reap all the profits. Vehicular Social Networks have found extensive usage in several domains for the purpose of sharing and communication information among the several participants. This concept can be utilized in constructing a system for communication within an agricultural supply chain. However, the VSN is limited to enabling communication within static nodes and provides no security of the information being shared.
Agricultural supply chains in use are biased towards the benefit of the business men and leave no profits for the farmers. This is unjust towards the farmers. VSNs have been developed before for the purpose of defence but have yet to be extended to the domain of agriculture. Previous works in VSN achieve a model for information

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dissemination along with the integration of concepts of blockchain. However, the framework is slow, is computationally expensive, and the techniques used for data sharing have limited capabilities.

The algorithm used to form communities is slow as it involves several computations. The proposed system reduces the time complexity of the algorithm by minimizing the number of computations. Further, in vehicular social networks, existing systems neglect the effect that mobility and imprecision in data about position may have on information sharing. The above shortcomings are considered when developing the proposed VSN for an agricultural supply chain.

The proposed system is a vehicular social network in which the entities share information among themselves to act as an optimized distribution system. The VSN also possess the ability to detect communities amongst the stakeholders in an agricultural supply chain environment. Blockchain technologies are used for maintaining security of data and enabling smart contracts while dynamic information sharing is achieved by using an alliance formation technique.

II. RELATED WORKS

Roghani et. al. formulated a novel algorithm for forming communities within a network in [1]. The algorithm, LBLD: Local Balanced Label Diffusion, made use of the adjacency list of the nodes to assign labels. The nodes were assessed for similarity with their adjacent nodes based on which their importance was evaluated. The most important nodes were chosen as cores from which the communities were formed. The algorithm was evaluated on several existing datasets and the results were compared with existing algorithms such as CNN, Louvain, and Leiden methods. The LBLD algorithm performed equally well as the existing algorithms and, in certain cases, out-performs them.

Su et. al. developed a framework for a Lightweight Vehicular Blockchain-Enabled Secure Data Sharing Network (LVBS) in [2]. A collaborative network between ground and aerial vehicles, aided by blockchain, was developed. Data sharing was enabled by employing a two-tier reinforcement learning based incentive algorithm. Tracing and logging of the data shared was done using a credit-based consensus algorithm. The LVBS enhanced security and ensured high quality of the data shared. However the algorithm is limited to a single agent system. The blockchain technology also showed improper behaviors. The improper behavior in blockchain can be handled by using a misbehavior detection method based on deep learning.

Autonomous Vehicles (AVs) with communication capabilities provide a platform for both convenient transportation as well as social communication. Thus, AVs must offer a means to exchange information in a timely fashion. Li et. al. made use of the social relations between the AVs and the Age of Information (AoI) to enable information dissemination in real-time within a Vehicular Social Network (VSN) in [3]. The importance of the vehicular social relations and wireless communication of information dissemination were analyzed using the average Peak Network AoI (PNAoI) which was minimized using a parametric optimization scheme. The impact of the mobility of the AVs or scenarios where the position of the AV is unknown or imprecisely known were beyond the scope of this paper. In the proposed model, the relative position of the AVs can be computed from the relative time of a handshake.

Netizens have access to several online social network (OSN) services that enable them to communicate and share information with other internet users. However, these OSNs do not provide protection of user's privacy at all times. Hu et. al. developed a Group-Based Access Control (oGBAC) framework to ensure that privacy of users was maintained during information dissemination in OSNs in [4]. The flow of information among the groups was monitored with the help of information flow rules that were derived from the relation of the attributes. The framework's accuracy was low when deployed in real-world applications and untrusted nodes remained unhandled. The proposed system can handle these untrusted nodes by identifying them by assessing their relevance to the network.

Real-world networks are heterogeneous and dynamic in nature which makes it hard to reason about their structure. Peng et. al. introduced an approach for modelling dynamic information networks using minimal memory resources and computational time in [5]. Multiple nodes with similar semantics were represented using a shared vector unlike the traditional method of representing each node by a unique vector. Information was traded among these reduced vectors with the help of Recursive Neural Network (RsNN) to analyze the semantics of the nodes in a cuboidal space. This model showed a decrease in memory footprint as well as in processing time. The algorithm generated considerable error due to data loss when the number of nodes was small.

Traditional node classification systems in a Heterogeneous Information Network (HIN) make use of the relative importance of links. They do not consider the importance of the types of the links to the class labels of the nodes. Han et. al. suggested a Tensor-based Markov Chain (T-Mark) approach which can simultaneously predict labels of unlabeled nodes as well as compute the relative importance of the types of links in [6]. The HINs were represented using three-dimensional tensors which are solved using an iterative algorithm built based on Markov Chains. This algorithm showed enhanced accuracy in classification of unlabeled nodes as well as generating link rankings based on their type. However, this algorithm produced low accuracy when dealing with large scale networks that have sparse connections between nodes. The proposed work can resolve this by applying a more efficient algorithm that combines the various available links regardless of their type.

Traditional traceability systems face problems regarding data security, lack of transparency and centralization of management. Yang et. al. developed a traceability system based on blockchain technology that uses a dual-storage structure combining database and blockchain for tracing information both on-chain and off-chain in [7]. This produced an efficient supply chain and querying system. A reputation-based smart contract was developed to allow nodes to publish data into the blockchain. However, actual businesses require multi-chains that are beyond the scope of this paper. The proposed system can explore the capabilities of cross-chain technology between multiple chains to make the framework suitable for real-life implementation.

Agricultural food supply chain systems have several flaws. Wang et. al. developed a framework based on smart contracts to trace the workflow of and implement traceability in agricultural food supply chains in [8]. This improved the integrity of the transaction records as well as the security. Further, farmers were able to store information regarding their season's harvest in the form of smart contracts which helped achieve decentralization as well as traceability of products. However, the framework did not ensure the reliability of the transactions. In the proposed model, the reliability of the transactions can be handled by the blockchain mechanism.

Anupriya et. al. employed several existing machine learning algorithms that are popularly used for image processing to detect the freshness of bananas in [9]. A dataset comprising of bananas at various stages of ripeness were pre-assigned with labels based on their freshness. Prediction models such as CNN, VGG-16, and DenseNet were employed to assess the freshness of a banana based on an image input and the VGG-16 model produced the best results with an accuracy of 98%. However, this model was built based on a pre-labelled dataset. The outcome and the model depends on the accuracy with which the images are labelled which is subjective based on the user. Thus, it is required to have a definite standard for defining the freshness of a fruit. An approach that does not rely on a labelled dataset and considers a different factor for classification is proposed.

The different stakeholders of the agricultural supply chain represent the different nodes of the VSN. The connections between them are established in a dynamic environment with the help of alliance formation strategies. Wu et. al. discussed a strategy for alliance formation in dynamic environments is in [10]. The work suggested utilizing four different factors to establish alliance for a node: probability of the node being newly introduced to the network, probability of involving its previous collaborator, size of the alliance, and the time for which the node is not part of any alliance. Involving the new nodes ensured extensive connectivity between the nodes and sharing of information shows high performance. However, repeated alliance formation with old collaborators was an issue that diminished the extent to which the new nodes were included. The proposed work should ensure that all new collaborators should be accounted for while forming alliances.

III. Proposed Architecture and System Design

The proposed system develops a vehicular social network consisting of several nodes each with their own responsibilities. The network architecture consists of several collection centers where the quality of the products is assessed and the quantity is weighed. The products are then transported to a distribution center where the type of end consumer is determined based on the quality and quantity assessments. Image processing techniques are used to analyze the quality of produce.

At the distribution center, once the end consumer is decided, the vehicle to be used for the transportation is determined based on the product and its quantity. Following this, the center requests for the required type of vehicle in order to transfer the products to the consumer. The information regarding the product is communicated between the consumer and farmer via information sharing. Dynamic information sharing is used to efficiently allocate vehicles for delivery based on proximity and availability.

In order to share information optimally, the nearest and best-suited node of the network must be chosen. This is implemented by detecting communities among the nodes of the network. By this, a node shares information to the nearest and best node. Further, to ensure that the data being shared is secure, blockchain concepts are used. The entire system is developed to handle the dynamically changing information.

A. DISVSN Architecture

The system architecture consists of a VSN of various stakeholders in an agricultural supply chain and the sharing of information between them [2]. The architecture can be divided into the following modules: quality assessment of agricultural commodities, determination of the end consumer, vehicle-type determination for transportation, detection of communities between the various stakeholders, secure information sharing using blockchain, and dynamic information sharing in VSN.

Quality assessment is done at the collection centers while decision making regarding the end users is done at the distribution center. Quality assessment is done to evaluate the lifetime of the commodity and assign it a grade based on freshness [9]. This quality grade, along with the quantity, is used to determine the end consumer to whom the products will be delivered. Further, the type of vehicle to use for transportation is determined based on the quantity of the produce as well as its perishability. This is done at the distribution center.

Detection of communities among the nodes of the VSN is essential for optimal information dissemination. Community detection is done to aggregate the nodes into groups. Each community consists of one distribution center, several collection centers, vehicles and customers. Each of the stakeholders share information to another stakeholder (node) within its community as required. The information shared between the nodes varies according to the type of the node. Formation of communities ensure that distribution centers approach vehicles and consumers that are nearest to them in order to save time and resources [1]. Further, collection centers can handover their goods to a central distribution center. The same applies to the farmers who handover their produce to collection centers.

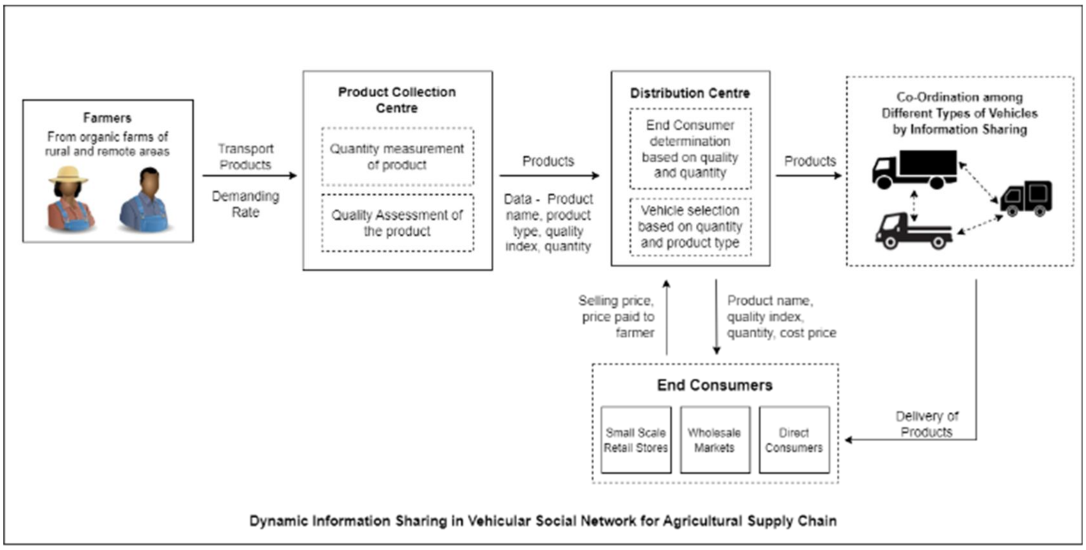

Figure 1. DISVSN Architecture

Information is shared between the stakeholders of the agricultural using blockchain technology. This ensures the data is transmitted safely and also allows for secure transactions. Dynamic information sharing is required so that distribution centers can communicate with the nearest vehicle and collaborate on deliveries. This is based on the proximity of the vehicles to the centers which is continuously changing as they move. An alliance formation strategy is used to achieve this [10]. The overall system architecture that implements DISVSN for an agricultural supply chain is shown in Fig. 1. The figure highlights the various stakeholders present in the system which are the farmers, end consumers, vehicles, collection centers, and distribution centers. It also describes the information that is shared between them.

IV. EXPERIMENTAL ANALYSIS

A. Quality Assessment

Quality assessment is done to evaluate the lifetime of the commodity and assign it a grade based on freshness. The quality assessment module made use of two algorithms to compare results and choose the best one. The first method used was based on the VGG-16 algorithm [9]. The second method, which was a novel algorithm, was based on the percentage coverage of dark spots on the produce. The images of produce were converted to corresponding grayscale images. The darks spots and patches were isolated with the help of a color threshold. The percentage of area of dark spots on the produce was used to assign a quality grade to the product.

B. Community Detection

Community detection is required to group the different nodes into communities based on their proximity to each other. This was done by using the geolocation of the nodes. The algorithm is based on diffusion of labels starting from the nodes that have a degree more than one and establishing a community based on two similarity scores, one based on adjacent nodes and the other based on the geo-location of the node. Importance of the nodes were calculated and the labelling process starts from the most important node.

The communities were detected with the help of the adjacency list of each of the nodes of the VSN. The algorithm to achieve this is outlined in [1]. The algorithm works by identifying the nodes of the VSN that have a degree more than one. The similarity of these nodes with each of their adjacent nodes was computed. This results in two similarity scores. One is based on adjacency, as described in [1], and the other one is based on their geo-location. The second similarity score was introduced to consider the impact that proximity of the nodes has on community formation. These two scores were combined to compute the node importance score for each of the nodes with degree more than 1.

Each node's label was initialized to zero and a label counter is defined to keep track of the labels being assigned. The nodes with highest importance had their labels assigned first using the similarity score with respect to their adjacent nodes. After this, specific nodes were chosen to act as community centers. For the proposed system, the nodes corresponding to distribution centers were chosen to be the centers. The labels of the nodes neighboring these centers were assigned using diffusion. This was done based on a community importance score that is computed using node importance and degree of the nodes. Finally, the label of the nodes with degree one are diffused. The quality of the communities that were formed was evaluated with the help of a modularity score.

C. Information Sharing using Blockchain

The information collected at various stages of the communication process was stored and transferred using blockchain. The data collected and stored depended on the stakeholder that is involved. The information was shared between the various nodes of the VSN based on the community they belong to [2]. The community labels that were assigned as a result of community detection were stored in the system. At each of the nodes that represent the different stakeholders of the agricultural supply chain, relevant data was collected. The corresponding smart contracts were created and stored on the blockchain [8]. Information was shared to nodes of the same community after performing verification of community labels. Notification to the stakeholders were done by message transmission using cellular communication.

D. Dynamic Information Sharing in VSN

Information sharing between the stakeholders is carried out with the help of blockchain as well as the communities detected earlier. However, the vehicles are constantly in motion and the sharing of information between them is dictated by an alliance formation strategy [10]. Formation of alliances between the various nodes was achieved with the help of geo-location and community labels. The distribution centers of each community were identified and the geo-location of the various vehicles was found. For each vehicle, the nearest distribution center was found based on distance. Orders of the distribution center that were to be delivered to the same consumer that the vehicle was travelling to are notified via messages.

V. Performance and Results

The proposed system is built using Python libraries used for image processing, machine learning models, and community detection. The opencv-python library and networkx library were used. Blockchain was implemented using Ganache software.

A. Quality Assessment

The quality assessment module is aimed at identifying the freshness of the item and assigning it a quality grade. This is later used to determine the end consumer. Two approaches are used. The VGG-16 algorithm was used on a dataset containing images of bananas at various stages of ripeness [9]. The data was partitioned into several subsets based on the quality grade they are labelled with. On building the prediction model using VGG-16 on this dataset, evaluation on the test set resulted in an accuracy of 54.17%.

The second approach determines the quality grade based on the percentage of area of the item that is covered by dark spots. Based on the percentage of area covered by dark spots, the quality grade was assigned. Evaluation was done by comparing with the test set whose images have pre-labelled quality grades. This method produced an accuracy of 81.25%.

B. Community Detection

The performance of the community detection algorithm that partitions nodes based on their similarity, adjacency, geo-location, and type of node is evaluated using the modularity measure. Fig. 2. represents the various nodes of the VSN before community detection while Fig. 3. represents the nodes after community formation.

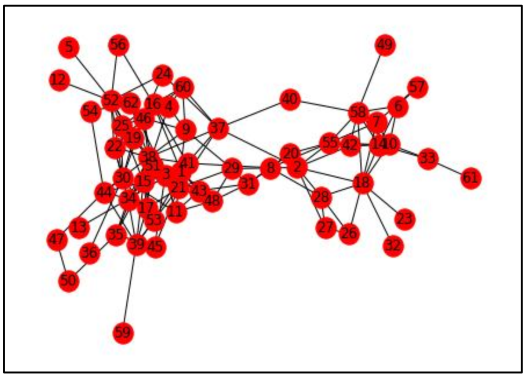

Figure 2. VSN nodes before community detection

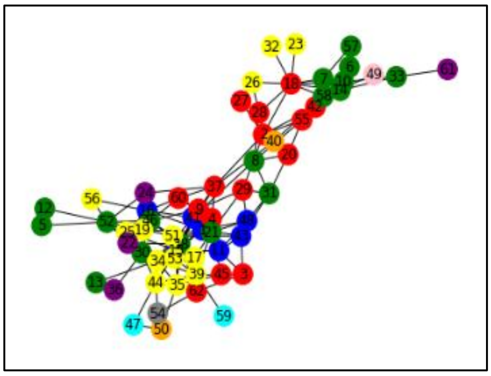

Figure 3. VSN nodes after community detection

The modularity score of the novel community detection algorithm based on similarity and geo-location used on the dataset was 0.3805. Traditional community detection algorithms produce a modularity of 0.378 on the same dataset. This difference is highlighted in Table I.

TABLE I. MODULARITY SCORES OF DIFFERENT COMMUNITY DETECTION ALGORITHMS

Community Detection Algorithm	Modularity Score
LSMD	0.378
LBLD	0.378
Proposed Novel Algorithm	0.3805

C. Information Sharing using Blockchain

The first step involved is consolidating the information of the community labels for the nodes in the VSN of the agricultural supply chain. After this, the information of the product and the farmer was collected at the product collection center. Further, the quality grade of the product was assessed using the developed algorithm. This information was written as two separate smart contracts, one for product details and the other for farmer's details. Once the information from the collection center was written to the blockchain, the distribution center accessed this information to determine the end consumer as well as the type of vehicle required. Perishable nature of the product was also considered for this. The information was consolidated into a smart contract.
After the distribution center published its information to the blockchain, the designated end consumer accessed the information and reverted the amount they pay for the product based on the details. The data is stored in a smart contract that represents the transaction. The distribution center retrieved this information to notify the concerned farmer regarding the sale.

D. Dynamic Information Sharing in VSN

The result of the module that dynamically shares information between the vehicles and the distribution centres of the VSN of the agricultural supply chain using blockchain is discussed in this section. Fig. 4. shows the geographical plot of the different centres of the VSN.
The geolocation of the vehicles in the VSN, which varies with time, was consolidated and the distribution centre nearest to them was found. The nearest distribution centre for two vehicles of the dataset have been isolated and represent graphically in Fig. 5. along with the time-series movement of the vehicles.
After the nearest distribution center was determined for each vehicle of the VSN, the details associated with it were stored. Once the information was conveyed to the relevant distribution centers of the VSN, they accessed

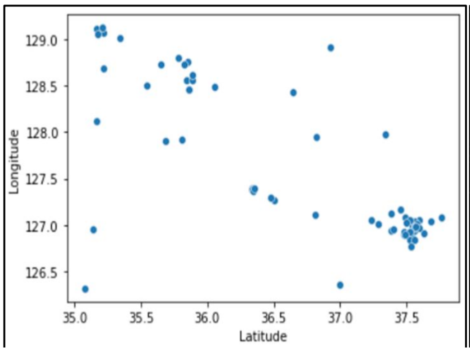

Figure 4. Geographical plot of centers of VSN

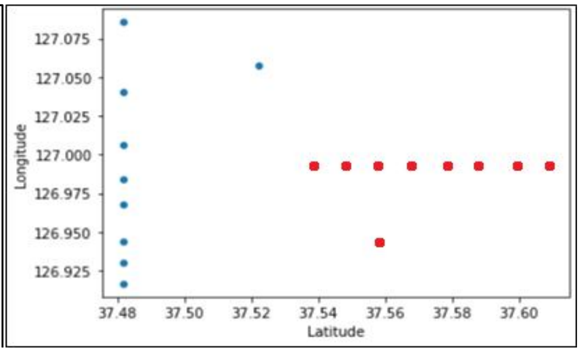

Figure 5. Geographical plot of isolated distribution centers

the details of their respective orders from the corresponding blocks of the blockchain. They retrieved information regarding the end consumer, quantity, and perishable nature of the good. If the distribution center had a delivery pending to the end consumer the vehicle was travelling to, it notified the driver if they are present within a certain radius. The vehicle could then take a detour to accommodate this request.

F. Blockchain

The proposed DISVSN system for an agricultural supply chain implements sharing of information using a blockchain to ensure security of the information that is shared between the various stakeholders. The system supports transmission of information between the static as well as the dynamic components of the VSN. Each of these nodes contribute different volumes of data to the traffic. This is computationally expensive as the blockchain program performs encryption and decryption on the data during storage and retrieval operations respectively. All operations on the blockchain are carried out at the expense of a currency. Large volumes of data would result in high expenditures. Fig. 6. outlines the expenditure during a 30 sec frame of the operation of the DISVSN system.

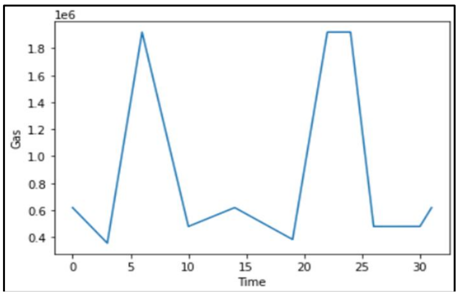

Figure 6. Blockchain expenditure during information sharing

The graph in Fig. 6. shows the variation of the currency used by the blockchain, called ‘Gas’, over time. The Gas is in the order of 1e6 indicating the complexity of the computations that are performed while utilizing the blockchain. The huge variation in the graph shows that certain communications between nodes involve higher transfer of data and more complex operations

VI. CONCLUSION

The system developed has quality assessment capabilities for collection centres to assess the quality of the product the farmers bring to them. The model helps label the item with a quality grade. Along with this, the quantity of the item is provided, using which the distribution centres decide the suitable end consumer. Using the quantity of the product as well as its perishability, the type of vehicle required for transport is determined. Further, communities of nodes centred on distribution centres are detected. This helps each of the stakeholders choose the best node/stakeholder they can share information to. Using these functionalities, information sharing between the nodes in the VSN of the agricultural supply chain is achieved. The information is stored as smart contracts on a blockchain. Separate smart contracts are defined for the information shared from each of the nodes of the VSN.

Further, dynamic sharing of information has been integrated by allowing vehicles to publish their details regarding geolocation and end consumer by which distribution centres can notify vehicles passing by them to carry their orders too if they share the same destination. The developed system ensures transparency regarding profits to the farmers and they are notified about their earnings via an SMS.

At present, the system notifies farmers about their sale using a text based SMS. An enhanced approach based on voice messaging can be determined to enable ease of understanding for the farmers. Further, a more secure method of transaction of funds requires research. The blockchain ensures security of the information however it is expensive and resource intensive. Methods to optimize the use of the blockchain are imperative. The developed DISVSN system can be developed into an application with an easy-to-use interface that would help farmers and the various stakeholders enhance the agricultural sector.

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