SMART PLANT DISORDER IDENTIFICATION SYSTEM USING COMPUTER VISION TECHNOLOGY

Bilal Imran Sariffodeen

IT17354516

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Department of Computer Systems Engineering

Sri Lanka Institute of Information Technology

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DECLARATION

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ABSTRACT

Agriculture is a knowledge-intensive industry. Yet, for most farming communities, there is a lack of scientific knowledge of fundamental agricultural practices. As a developing country which traditionally has been dependent on agriculture, most Sri Lankan farmers rely on heuristic practices. This approach is primarily employed for fertilizer administration. According to the Food Agriculture Organization (FAO), 'unnecessary use of fertilizer' by Sri Lankan farmers leads to critical soil pollution, degrading cultivable land and corresponding contamination has an inadvertent effect on crop and consumer health. A common perspective among farmers is: 'applying more fertilizer leads to a better yield', which is a misconception encouraged by Fertilizer Vendors for profitability and accepted by most traditional farmers. The low penetrability of expert knowledge to the grassroots level has been a complication in increasing relevant awareness. Since farmers are often dependent on Vendors for Fertilizer purchasing, they are also reliant on them with regards to decision making and expertise; generating a vendor-centric purchasing ecosystem for fertilizer. In such a critical context, this research component was aimed at providing a solution for the information asymmetry and knowledge gap existent with respect to the adequate administering of fertilizer. The proposed solution was a decentralized, distributed system integrating experts and farmers to enhance informed decision-making capacity of farmers. The necessity to interlink experts in agriculture to the impoverished and knowledge-redundant farming communities was of critical importance. Hence, this platform would employ a blockchain-based approach and would be community-driven, with relevant stakeholders being enabled to communicate effectively. The vendor-role has been marginalized, with him being able to cater to the farmers only based on requirement. The approach made via a permissioned blockchain network was envisioned with the objective of empowering the farming community with scientifically backed inputs of knowledge, condoning the proposed e-Agriculture strategy for Sri Lanka.

Keywords - Agriculture, Blockchain, Fertilizer, Information asymmetry, e-Agriculture Strategy

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LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
SDG	Sustainable Development Goals
MDG	Millennium Development Goals
ICT	Information Communication Technology
RAS	Rural Advisory Systems
TFP	Total Factor Productivity
4IR	Fourth Industrial Revolution
SDK	Software Development Kit

1. INTRODUCTION

Sri Lanka is an island nation with 66,000 sq km of land area with prehistoric settlements dating back to 125,000 years. The accurately documented history of Sri Lanka is at around 3000 years, of which agriculture is the prominent livelihood [16]. In recent years, predominantly during the latter stages of, and after the Civil War; Sri Lanka has shown one of the highest GDP growth rates per capita in South Asia, rising from US$859 in 2000 to US$3,256 in 2013 [18]. Sri Lanka has also attained the most Milennial Development Goals (MDG) amongst South Asian countries, with a GDP growth which has been pro-poor, with the consumption of the bottom 40% being at 3.3% in comparison to the 2.8% of the other 60%. Agriculture is the foremost contributor to poverty reduction, with a 5.7% increase in Agriculture related wages [16]. With the evolving technological landscape in Sri Lanka and the devolving interest in scientifically-backed agricultural practices, the need for a technology-oriented and driven communicability solution to promote availability of information and precision agriculture is evident.

1.1 Background

The Agriculture sector contributes up-to 6.9% of the national GDP and 26.1% of Sri Lankans are directly employed in the agriculture sector. 31.8% of the total Sri Lankan workforce is involved in an agriculture-related trade [1]. According to the World Bank [13], agriculture is a major contributor of poverty reduction and welfare in Sri Lanka with over 1.65 million smallholder farmers operating in less than 2 hectares of cultivable land. Although agriculture is not as prominent as it was, it is a major driving force of the country's economy. In a local context, several key factors have been identified as contributors to the stunted growth of agriculture-related industries in Sri Lanka [13]:

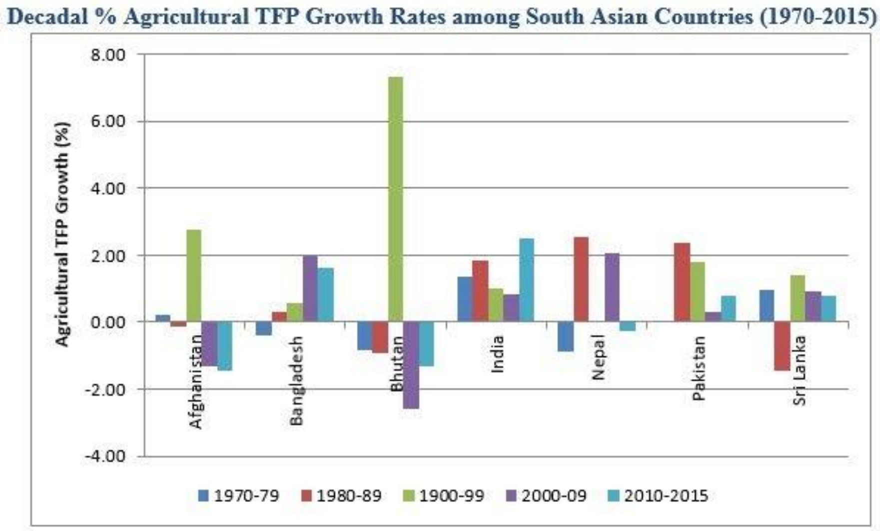
- Weaknesses in agricultural strategies and policy implementation.
- Public sector regulatory interventions are considerably heavy in commodity markets.

- Service delivery is weak in rural areas.
- The destructive impact of 3-decade long civil war and the 2004 Tsunami disaster.

While such policy and governance-related complexes do raise concern, the lack of literacy and awareness among farmers is also a major drawback for the agricultural sector [3]. In the Indian Subcontinent, most farmers remain illiterate and impoverished. They operate in isolation, with little or no bargaining capacity and lack high-quality agricultural practices that could improve their productivity.

The adverse effect of a lack of awareness amongst the farming community in Sri Lanka is very evident. A common misconception among farmers, specifically in more rural areas, is that the usage of fertilizer has a proportionate effect on yield, i.e. the higher fertilizer quantity used; the better yield [5]. While this is a widely accepted misconception, the more evident actuality is that excessive or inappropriate usage of fertilizer has led to a drastic circumstance where 50% of agricultural land is in a degraded condition in Sri Lanka. One other scenario is: certain nutrient deficiencies show similar properties. As such, farmers are inclined to confuse the deficiency and administer inappropriate fertilizer, having a significant effect on the yield and overall, wellbeing of the crop [5]. Such practices are not regulated by scientific supervision nor verified by agricultural experts, emphasizing a knowledge gap that needs to be addressed with imminent effect.

After the ‘4th Industrial Revolution’ (4IR) [14], the accessibility of farmers to technological solutions has enhanced, evolving from low impact Information Communication Technologies to technological solutions offering productive, competitive, and sustainable outcomes. In Sri Lanka, the need for such technological innovations is only becoming more evident. The yield of agriculture products in Sri Lanka have stagnated at unsatisfactory levels, even when considering the factor of it being a developing country [14]. Considering the Total Factor Productivity (TFP) growth in the South Asian region [15], Sri Lanka is performing very poorly and the TFP growth of the country is also witnessing a steady decline. The following comparison between other South Asian countries would provide more clarity with regards to this predicament:



Source: The International Food Policy Research Institute. (2018). Dataset. Retrieved from *http://dx.doi.org/10.7910/DVN/IDOCML*

Figure 1.1: Agricultural TFP Growth Rate: South Asia [14]

Currently, the quality and safety of food is given special attention and the inferior quality of most Sri Lankan agricultural products is a considerable challenge. A major contributing factor for this is inefficient use of inputs, which encompasses subsidised fertilizer overuse [14]. As referred to earlier, such practices not only have an effect on food quality but also contribute to depletion of agricultural land [5]. With the technologically adept youth gradually losing interest in pursuing agriculture as a way of life and with heuristical practices adversely affecting yield and the environment, a technologically sustainable 'Smart Farming' approach is best suited. As such, the e-agricultural strategy of Sri Lanka [16] offers the following deliverables:

- Food crop self-sufficiency, saving foreign exchange on imports of these food items
- Enhance abundance of safe food by promoting eco-friendly practices and curtailing agro chemicals and pesticides in food crop production
- Ensure food security via appropriate buffer stock management
- Introducing agro-ecological regional food crop cultivation programs
- Increase the productivity of crop production via technological innovations

- Establish proper coordination among all agricultural stakeholders in the local food production process and connect all schools, civil organizations and general public to the program
- Provide quality inputs for production and establish proper marketing mechanism for their products
- Ensure building a healthy nation.

The practice of eco-friendly agro-chemical administration was identified as a key objective and an efficient solution can be offered by means of an effective technological innovation. The potential of this solution to extend to providing an efficient and verified marketing mechanism for agro-fertilizer, which is a key constituent in agricultural inputs, would encompass a crucial deliverable of the e-agriculture strategy as well. As identifiable by following Figure 2, Data Analytics and Storage backed by an adequate approach such as Image Processing and Machine Learning could encourage precision agriculture and also make available actionable knowledge. Accordingly, in compliance to FAO strategies [16], the real time availability of data across the right medium, streamlining through the right entities, could be immensely beneficial for all those involved in farming practices in Sri Lanka. As such, the proposed component explores a potential innovation to streamline the flow of information, promote real time availability of data for adequate purposes and promote precision agriculture with actionable knowledge.

Figure 1.2 ICTs and e-Agriculture [16]

In the current age of information, farming communities would stand to benefit by real time information. The validity of information available at the disposal of a farmer is empowered by this information being sustainable and tailored specific to their location and circumstances. In a knowledge intensive industry such as agriculture, with a varying landscape, having information that is immune to change of circumstance is salient [16]. Fertilizer administration is one of the most mismanaged segments of agriculture [14] and is one such practice which requires tailor made information. Evidently, print and library-based information are redundant to the user as they are mostly out-dated and do not provide clarity and depth with regards to most issues faced by farmers [19]. Empowering farmers with accurate information does not only converge to the industry but also has a societal impact. Furthermore, such a lack of information has inclined the 'millennials' to withdraw from farming practices, at times even if it has been a livelihood pursued for generations. This has attracted people from rural areas to urban centers in search of more streamlined employment [19].

The ensuing sections would clarify identified research gaps existing in adapting such an approach, the research problems addressed, objectives and the methodology constructed, based on a comprehensive literature survey in the section to follow.

1.2 Literature Survey

In the Sri Lankan economic backdrop, it is evident by the preceding section that agriculture is of vital importance. With the contribution agriculture related industries make toward empowering the segment of the less benefited population [16], it is paramount that more feasible and penetrable solutions should be offered for the issues faced by farming communities. Mismanagement of fertilizer is one such area of concern as nearly 50% of cultivable land is in degraded condition due to inappropriate administration of fertilizers [5]. While this is an issue that should be addressed immediately, the corresponding concern with regards to availability of actionable information to the farming communities is also significant [19]. This literature survey would take a multi-pronged approach as it would analyze the current status quo of input management in agriculture i.e. fertilizer practices, the lack of information penetrability to the farming communities, and a comparison of current approaches made to mitigate this issue and also an overview of how blockchain technology has been employed in agriculture and in real time knowledge sharing.

According to the FAO-ITU E-Agriculture Strategy Guide for Asia-Pacific region [16], improving the capability of farmers to access knowledge-banks, and institutions via Information and Communication Technologies (ICT) improves their productivity and profitability. Availability of right information, at the right time, in the right format, and through the right medium, influences and affects the livelihoods of many stakeholders involved in agriculture through enhanced decision-making capabilities. Furthermore, recommendations made by e-Agriculture strategy guide encourages awareness-raising, effective engagement of key stakeholders and action to resolve issues of ICT access, especially in rural areas [16]. Such a notion is proposed to improve the sustainability of agricultural practices and encourage better yield from cultivations. The lack of awareness among farmers often leads to poor judgement and decision making [3] as, in most cases, decisions would be taken relying on word of mouth or outdated practices. Soil is a silent ally for food production [5], and is similar to a living organism. Soil conditions are susceptible to change and hence, there is no 'proven or verified' approach to treating soil via inputs such as fertilizer. If the soil condition is a deflecting factor, the approach made toward management of soil content should be flexible. Since the soil condition can have an inadvertent effect on human health and also on food safety, the Sri Lankan government, just as of most nations, have realized the importance of sustainable soil management practices [16]. Furthermore, according to the FAO of the United Nations, sustainable use of fertilizer is a key factor in such an approach. It has identified unnecessary usage of fertilizer as the key contributor of degrading soil conditions in cultivable land. Accordingly, the adverse effect on the environment due to unsustainable soil management is evident [20]. As such, a point of concern is how certain fertilizer has been used inappropriately, mostly prompted by misidentification of nutrient deficiencies in plants. This has created an unhealthy surplus of certain nutrients, tilting the delicate balance of soil composition which has a long-term effect on most living organisms [20]. While this is a point of concern which has been discussed extensively, most farmers, especially in rural areas of developing countries, abide by traditional approaches and heuristic practices. Rural advisory services [RAS] are crucial to identifying and putting the need of farmers to context, ensuring sustainable farming, food security and poverty reduction [22]. Extending the capability of knowledge sharing and empowering relevant institutions is a key factor of MDGs and as a nation in the forefront of the region with respect to these goals [16], an extension outreach to the Sri Lankan farming community with regards to making information available is crucial. While Information Communications Technology based solutions have been proposed to enhance better decision making, most approaches of this sort have been institutionalized or marginalized with only a segment of farmers gaining sufficient access [21]. Any approach that has been made for a universal solution which could fix the gap existing in information flow has had low penetrability in Sri Lanka. The adaptation of a new e-Agriculture strategy [14] could change this dynamic, yet, a noticeable solution is yet to be proposed. As stated by IBM [2], although government subsidies and other relevant institutions provide the farming communities with relief, most farmers remain impoverished. Factors ranging from inconsistent weather conditions to fluctuating market prices could have an impact on their profitability. In such a climate, there exists an increasing requirement for a reliable, convenient and sustainable solution to address various challenges. A major concern, primarily for small-scale farmers, is the overhead cost of involving labourers or individuals for certain tasks which cannot be managed by the farmer alone. Such tasks mostly entail matters which can be resolved by an ICT based solution IBM states that [2], e-Agriculture solutions would ideally lower overhead costs while improving productivity. This concept has been proven by Grameen initiatives carried out by entrepreneurs in rural India; where demographic details were collected from rural farmers and suggestions were made based on analysis of a software developed by Intel for the Grameen initiative [2]. Accordingly, it is perceptible that a Knowledge Sharing mechanism could yield positive outcomes if implemented in a sensible manner. Such a mechanism should have a streamlined approach in sharing information real time. Inadequately planned long-term fertilization regimes and management practices often have a negative impact on soil chemical and microbial properties [3], resulting in soil pollution and toxicity. This is mostly impacted by the lack of awareness on accurate fertilization regimes. Agronomically-oriented research has been conducted on enhancing soil management practices and fertilization efficiency [8]. Yet, it is suggested that when moving from experimental, controlled environments to field conditions; issues with regards to acquired data reliability, determining correlations between variables, and practical applicability of technical recommendations add uncertainty to any approach.

According to Fujisaka [9], very few researches and implementations have been conducted to try and derive information relevant to strategies and practices followed by farmers. Most studies have not been focused on tackling an identified problem. Instead, they take a broader outlook to their approach, making recommendations for the overall upliftment of agricultural practices. As discussed above, such an approach would be inappropriate as aspects of agriculture such as input management and financial interactions require sphere-specific feedback/information if there is any. It could be further contended that ambiguities in such previous studies is one prevalent factor as to why farmers prefer to follow a heuristic approach. If a purpose-driven approach is to be made, the following breakdown would be an appropriate inception:

Table 1.1: Purpose of deriving agriculture related information

	Purpose
1	Comparing crop management in various environments and pedo-climatic conditions
2	supporting authorities and extension services with useful information to aid their decision-making when defining agro-environmental regulations and territorial development strategies,
3	to relate the most common fertilization management techniques with indicators of environmental quality

Sighting illiteracy as a contributing factor for lack of information access [10], it is also noted that the unstructured nature of rural farmland and agriculture also contributes to uneven distribution of information. Governing bodies for agriculture, specifically in developing countries where farming is a major contributor to the GDP, have significant setbacks in structuring rural agriculture in a feasible manner. As such, according to William M. Rivera [11], knowledge-driven frameworks exist for agricultural purposes which are mostly institution based and do not consist of readily available information systems for farmers to rely on. Such institution-based frameworks cater for the requirement of specific communities under obligation to these institutes, and do not offer a universal solution. Furthermore, such frameworks have only been made accessible to a fraction of the community. This fraction does not represent the general farming community and their requirements by any proportion. It is also recommended that such frameworks should be adapted into ‘Agriculture innovation systems’ and ‘Agricultural Knowledge and Information Systems’, adapting technological advancements for the benefit of the agriculture community and that these systems should be inculcated into a growingly technologically aware farming community [14] by the mediation of government entities as well as regulatory and governing bodies.

Just as management of inputs, traceability is also an important factor contributing to food security [23]. The ability to trace where your food came from, ideally to the initial source, is keenly pursued by most in the tech-savvy age. Furthermore, Demestichas et al. [23] elaborates the criticality of traceability in a business perspective, prompting commercial organizations and researchers to pursue approaches to streamline such a process, i.e. focusing on efficient supply chain management systems. In a current context, most systems rely on a centralized, and stand-alone information management [24]. Relying on a centralized point of contact for any aspect of industry from procurement to input and traceability is a risk. As such, a decentralized approach is best advised [23] [24]. As such, a trend of adapting blockchain based solutions as a decentralized and more trusted alternative is evident. There are several key indicators relevant to a context of agriculture, as to why blockchain can be adapted for the preferred decentralized approach for systems [24]:

Table 1.2 Indicators for adaptation of a blockchain approach

Minimize Opportunistic Behavior	Trust is a crucial factor during transactions and interactions between several stakeholders. Blockchain has a distributed ledger-based system which creates a trust-free setup for coordination between entities in a system. There will be streamlined records of all transactions, lifting the pressure of trust on human interaction. Vindications would be made based on an automated ledger system. Such a lift of human error would lead to minimal opportunistic behavior as the blockchain is a decisive factor in how transaction flow occurs.

Evolution of trust-based theories in supply chain and Information Management systems	There are several governance structure types including market, modular, relational, captive, and hierarchy which organize transactions (preferably in a supply chain). In a blockchain, instead of ‘who’ governs transactions, rules and policies based on these structure types, a matter of ‘what’ is considered. Smart contracts can be devised constructively to replicate trust-based theories with an integrated and automated workflow.
Enhancing overall governance structure characteristics	Blockchain is an Information Technology and hence is influenced by the perspective of Information Process Theory (IPT) which focuses on a link between environmental uncertainty, information processing and adaptation. Collaboration and Information sharing is critical for the success of any information management system and Blockchain provides a solution encapsulating plausible challenges and providing the tools to overcome them. Furthermore, the analytical capability possessed by blockchain would also increase system transparency, making such systems easier to adapt for Information Management System frameworks and governance.
Enhance Operational Relationships	Blockchain presents a transparent, distributed and auditable interface and platform for interaction of stakeholders in a system. These characteristics would improve operational and working relationships as workflow would be more organized and backlogs would be visible for anyone with the requirement to do so.
Sustainability	A blockchain based system would support a sustainable approach for sharing and organizing information and would also promote social sustainability as it would lift any existing unfair bias and also promote transparency of transactions.

Blockchain can be further enhanced to adapt a real time information management and sharing system which would be discussed in the research gap section. Through the comprehensive survey and approach made to literature, it is evident that there exists an academia-driven backdrop and socio-economic background which would benefit from and also support a blockchain based procurement system for commercial fertilizers. This approach could also be considered to be a proof-of-concept for a coordinated information management and sharing system using a permissioned (hybrid) blockchain platform.

1.3 Research Gap

During the background research and literature survey it was evident that there are several contributions made toward improving accessibility of actionable information to farmers. These approaches have been made utilizing ICTs and are primarily centric on Information Management systems. Yet, it has been proven difficult to reach out to impoverished farmers specifically of developing countries [2], and they mostly rely on heuristic agricultural and fertilizing practices relying on word-of-mouth and trial-and-error. Most such practices lack a scientific basis. The centralized nature of these Information Systems and the resulting limited scope can be contributors toward the evident lack of penetrability. Developing countries such as Sri Lanka have decisively backed an approach toward e-agriculture [14] since utilizing ICT for the purpose of 'smart farming' is a sustainable approach. However, while theoretically feasible, a practical implementation of such nature remains a considerable challenge. Regardless, a country with a high literacy level such as Sri Lanka should ideally benefit from such an approach. RAS enabling food security and sustainable farming services [22] tallying with decisive, accurate and timely information retrieval could be a major contributing factor towards enhanced and farming practices and yield in Sri Lanka. Deviation from the centralized approach and adaptation of a decentralized system [23] could be the driving force of any relevant success. The following sections explore the gap in research and relevant literature when approaching such a solution.

Although fertilizer is available in a free, open market most farmers are tempted by vendors to buy inadequate and low-quality fertilizer at uneven prices [4] with most farmers unaware of the best available product to use at relevant instances. The contributor to this practice is the lack of availability of information for the average farmer with regards to fertilizer procurement or administration. Fujisaka et. al [9] recommends that the reason for this shortcoming could be the broader outlook researchers and academics take toward agriculture in an information-driven perspective. Research conducted on fertilizer management and application have not reached far beyond controlled development stages [8] and have not been deployed in ground-level circumstances for ensuring food security. Fertilizer administration is a segment of farming which requires specific information. Farmers require specific information on 'when, how and what' to administer in the case of requiring fertilizer for their crops. If this information is not readily available or easily accessible for the common farmer, as constituents of a trust-driven industry [24], they would be quick to rely on the intermediary vendor for instructions as well. Such a trust-driven ecosystem for fertilizer procurement has long been established but is not advisable as this lack of social sustainability has a direct effect on the degradation of soil conditions in Sri Lanka. At present nearly 18% of the overall landmass in Sri Lanka has been depleted due to the adverse effects of unsustainable agricultural practices [13].

Blockchain can be utilized to uplift economic and social performance in the agriculture industry. This can be achieved due to the distributed nature of a blockchain and the transparency encouraged by it. Yet, a majority of blockchain related research has been centric to traceability and economic performance. S. Saberi et. al clarifies interactive information management to be a feature of social performance [24]. The justification of doing so is: any approach made toward a distributed information system linking farmers with relevant professionals is culturally contextual with a broad subjectivity. Furthermore, any blockchain based platform would holistically act as a conduit for interaction between several groups of stakeholders. It could be argued that this matter has social sensitivity [24] as better fertilizer administration would have a pragmatic effect on the environment and would also eventually bestow toward enhancing profitability and livelihood of the farming community, contributing to attaining Millennium Development Goals (MDG) setup by the United Nations [16].

Hence, as evident; no research has been conducted in adapting a knowledge-driven system in a universal context, to streamline fertilizer procurement by assisting the farmer to make the most well-informed decision. Therefore, this research is being conducted to introduce a solution for the beneficiaries i.e. the farmers, to be used in real-time field conditions. As related previously, fertilizer administration is a knowledge intensive and knowledge specific domain which has to weigh in a social context as well. As such, this component is intended on constructing a decentralized system for streamlined and informed fertilizer procurement for farmers, resolving any pre-existent complications through an ICT-driven approach.

1.4 Research Problem

Enabling farmers to access knowledge banks and institutions via ICT is proven to improve their productivity and profitability [7]. ICTs have proven across multiple industries to possess the potential to provide accurate feedback and help streamline proceedings. The farming communities in developing countries (Sri Lanka in the context of the research) are impoverished and mostly disadvantaged by a lack of literacy and education [16]. Accordingly, agriculture is an industry where ICT has not penetrated up-to grassroot levels [2], with any innovations being made having a controlled scope and struggling to adapt to field conditions due to feasibility and impracticality issues. Generally, farmers show a lack of interest in pursuing scientific approaches toward concurrent issues [9] and rely on human factors, traditional practices, instinct and a general consensus to solve issues which ideally require a practical and knowledge-driven approach. With the focus on the research, it has been possible to breakdown the research problem identified for this component to several questions:

• How feasible and acceptable would a technological solution integrating farmers, field experts and vendors be?

- What would be the factors to be considered when constructing a system interlinking these ley stakeholders?

• How is it possible for the proposed system to lift the asymmetry of information between the farmer and vendor?

- What information should be provided by the expert stakeholder in-order-to help farmer make most well-informed decision

• How can information be transmitted securely between farmers and experts while also maintaining transparency of transactions involving vendors?

- What methodology would provide a decentralized, secure and transparent platform for this purpose?

1.5 Objectives

1.5.1 Main Objective

The main objective of the proposed system is to streamline procurement of fertilizer. The approach to be made is using a permissioned ledger blockchain [6] to benefit the farming community and lift bias of the procurement eco-system away from the vendors. This objective can be broken down into having a multi-pronged context. When catering for the main objective the proposed system would also be fulfilling a key aspect of social performance [24] in agriculture by lifting the trust-based ecosystem. Such a trust-based ecosystem would mean that farmers often rely on 'word of mouth' of vendors to cater for their fertilizing requirements. This creates an unfair and unchecked bias toward the vendor. A blockchain implementation which would lift this bias and create a trust-free environment for procurement, supported by verification and accurate information provided by agro-experts.

1.5.2 Specific Objectives

- Initiate enhancement of information accessibility of farmers (Specifically those in rural and impoverished areas) engaging in a unique RAS system for the impoverished and illiterate farming community of Sri Lanka.
- Utilize the knowledge of agro-experts for real time feedback and assistance to farmers, encouraging well-informed decision making which would enhance yield and overall profitability of the farmers.
- Encourage better fertilizer management practices amongst farmers, aimed minimizing environmental pollution and soil degradation caused by fertilizer mismanagement.
- Encourage sustainable and safe farming, complying to the MDG set by the United Nations.

2. METHODOLOGY

2.1 Requirement Analysis for system constructed

Fertilizer Mismanagement is one of the most critical issues faced by farmers due to several key contributing reasons [14]. Fertilizing can be considered to be a knowledge intensive activity and while most farmers lack scientific knowledge in this domain, they often depend on unreliable and unverified sources for instructions as well. One such primary source is the ‘middleman’: the vendor who is responsible for the sale of agro-products of which fertilizer is a primary component. Most information provided to farmers by such entities are profit-oriented and are focused on building their customer-base rather than the upliftment of the farming community. It is evident that the identified issue has a social context as well [24].

Rural Advisory Services (RAS) contribute to upliftment of rural communities [22]. Nearly 32% of the labor force in Sri Lanka is involved in agriculture related trade [1] of which a majority are based in outstation regions which should ideally be impacted by RAS. While sustainable farming is a primary concern of international organizations such as FAO [16], RAS or any other prevalent mechanisms have failed to streamline the process of information procurement in a farmer’s perspective, which would provide accurate information at a universal scale.

Based on the observations made during the literature survey and analysis of the research gap, several primary takeaways can be identified as requirements for the system:

- A system should be in place where information could be distributed evenly, when required.
- The distributed information should be verified with relevant expertise and should ideally have a scientific background.
- The provision of information should have a streamlined flow from initiation to end point.
- The system should maintain the capability to provide real-time information based on the requirement of the farmer.

2.2 A blockchain based system

Blockchain networks are fundamentally based on peer-to-peer communication. There is an agreed consensus process built on smart contracts by which all nodes of the network must comply [23]. The validity of transactions is verified by this consensus process. This agreed automated consensus process is a key factor in implementing blockchain solutions for most interaction-driven systems. An interaction-driven network is typically trust-based [24] where approaches such as human-verification or manually maintained/third-party ledgers would hold any transaction accountable. This brings forth several complications in a compliance context as there is considerable margin for error or deference. A blockchain network uses a ledger based mechanism with the consensus providing a trust-free alternative which can be relied upon to function seamlessly and in a streamlined manner.

The following workflow would further clarify by this workflow:

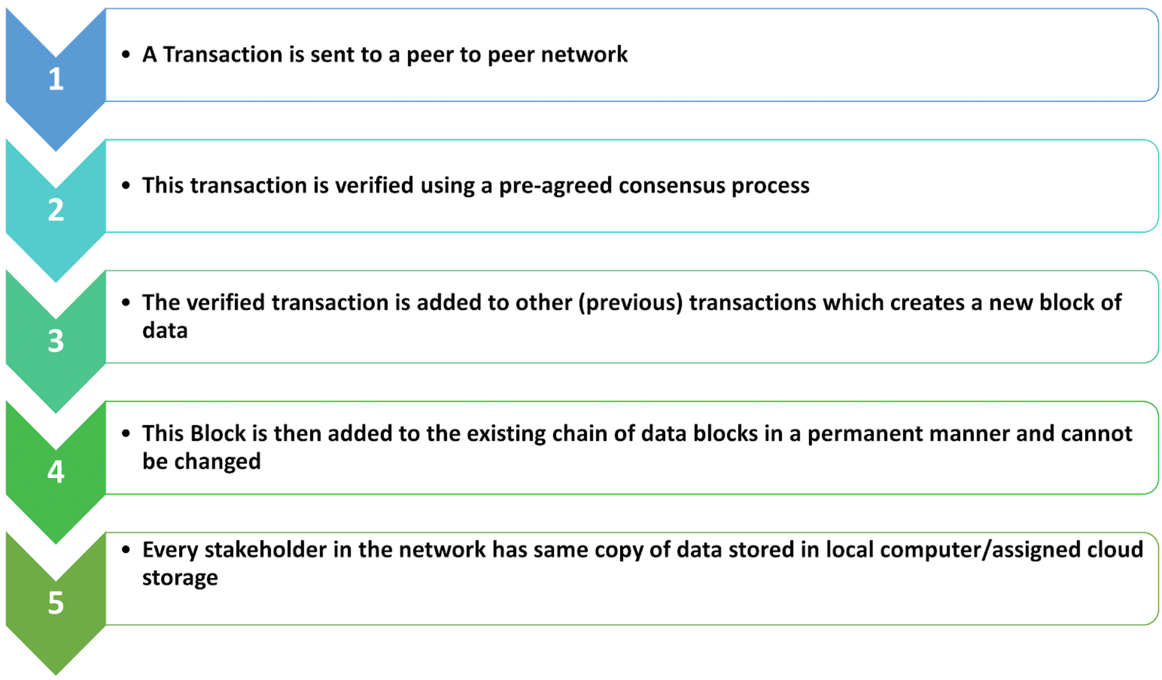


Figure 2.1: Workflow of Blockchain

As evident by observing the workflow, a blockchain based platform would greatly enhance trust, transparency and security in a transaction process. This could be sighted as the ideal solution for a system where interactions occur between several stakeholders and trust is a matter that should be taken to serious consideration.

There are three main approaches to Blockchain technology based on data handling and who can join the network. This can be clarified by the following table:

Table 2.1: Data handling of Blockchain variants

Public Blockchain Network	Anyone can participate in this network E.g. Bitcoin
Private Blockchain Network	A Centralized database on networks ideally for banks etc.
Consortium Blockchain Network	Ideal for software and systems handling data of multiple stakeholders with distributed network topology

By the preceding section, it is evident that a blockchain solution is ideal for the relevant research component, based on the identified problems and requirements that should be catered for. Of the three approaches available, a consortium blockchain is best suited for the solution. A re-visit to the requirements would clarify that whichever network is constructed, it should:

- Provide a secure gateway for communication between identified stakeholders
- Initiate confidential communication between farmer and expert
- Marginalize impact of vendors on the ecosystem.

As such, the logic for proposing a consortium blockchain is because it is private and permissioned. It can be used on multiple enterprises while permitting only those with permission to interact with the network for any transaction or make any changes for the blockchain ledger which has been agreed upon by all stakeholders. Accordingly, such a network can provide for requirements of the proposed system, utilizing the key features a consortium blockchain possesses.

Hyperledger Fabric

According to the official documentation [6], Hyperledger Fabric is “an open source enterprise-grade permissioned distributed ledger technology (DLT) platform” established under the Linux foundation. This is a modular blockchain framework which uses *plug-and-play* components as a foundation for developing blockchain-based products, solutions and applications. There are numerous ‘big-name’ companies globally which are trying to get their name associated with Hyperledger Fabric. For many organizations, Hyperledger Fabric has been an innovation which pushes ‘Enterprise Resource Planning’ systems to the next level by enhancing data integrity and further assuring trust between stakeholders.

2.3 Why Hyperledger Fabric

In Hyperledger Fabric [6], the system can be deployed on several nodes which ensures the integrity of data. The relevant data will not be lost. In a scenario in which one node crashes the system will still be up and running through the other nodes which we have created for our blockchain based system software.

Another key takeaway as to why Hyperledger Fabric is best suited for this system is: in a multiple enterprise ecosystem as the proposed system, we can assign different nodes to different enterprises and also restrict access to some or all of our data from other enterprises in the system and only give access to them on request. This would be an essential factor when establishing the proposed system as it would marginalize the impact a vendor would have, provide other stakeholders ability to monitor his transactions and would also provide a secure channel for the farmer to communicate with the expert and receive timely, relevant information for his fertilization practices.

Scalability of a blockchain is an issue discussed in-detail when they are considered to be integrated into enterprise systems. This is another issue which was identified with relevance to any network to be constructed for this particular scenario as there would be numerous stakeholders who would be categorized into the three main segments: farmers, vendors and experts. Hyperledger Fabric offers an architecture which resolves this issue by deploying different nodes in different servers. Accordingly, in the context of this scenario, the three nodes belonging to the segments of farmers, experts and vendors would be in three different servers. This offers the network a considerable and comfortable *'breathing space'* in terms of the scalability and number of peers who would be joining the respective nodes.

While the ability to assign nodes to different organizations is essential to lifting the bias toward the vendor in the fertilizer procurement ecosystem, a key feature in Fabric permits any other stakeholder to monitor and audit any transaction carried out by the vendor node. In Hyperledger Fabric, if some participant performs some action it is saved in the transaction log which gives us a complete view of any transmitted data from beginning to current state, with the keys of the person performing the transaction. As such, any malicious data forgery can easily be tracked-down to the relevant participant responsible for it. Hyperledger Fabric enables restriction of access to certain participants and permits more authority to others. Any entity performing transactions must have the identity keys for performing transactions. An identity key is somewhat similar to an access card. It provides permission for a particular participant of the network with sufficient access to fulfill his responsibilities. In an Information Security perspective, this is somewhat similar to an access control mechanism. These keys are given when a particular participant is added to the network.

When a System is divided into multiple enterprises, a lack of trust originates. In Hyperledger fabric we create an element of trust between enterprises by creating a common business logic agreed by all the enterprises. Any delegated enterprise can also restrict some of its data to others only for its personal use. Also, certain enterprises with elevated control and access can monitor the transactions of other entities. If it is the requirement of the user to trade with a stakeholder which has not been verified or is at a considerable distance, the user would not ideally know whether this entity is trustworthy or not. However, with Hyperledger Fabric, you can track the transaction history from the platform and use smart contracts to automate the payment as necessary, if necessary. As such, it's a 'win-win' situation for any stakeholder involved.

The basic functionality of Hyperledger Fabric can be elaborated as follows:

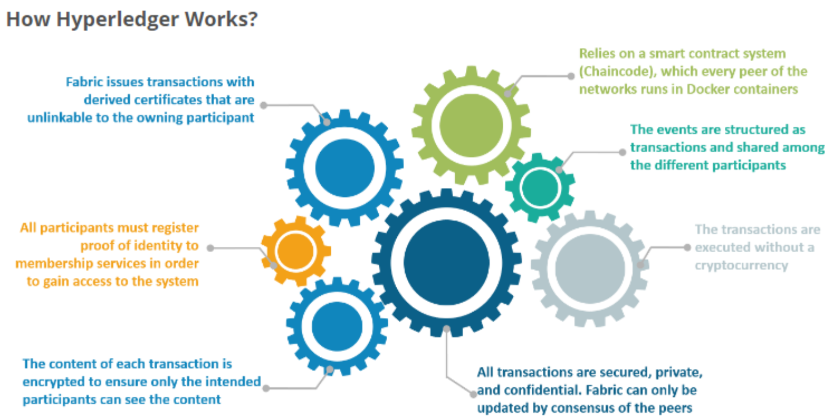


Figure 2.2: Hyperledger

2.4 Constituents of Hyperledger Fabric

The main components of the Hyperledger Fabric Network [6] are as follows:

- Peers: Peers are a fundamental element of the network because they host ledgers and smart contracts
- Ordering Service: It handles the transactional flow between peers and in the network.
- Certificate Authority: It issues identity to all the participants of the network so that no malicious actor accesses the network.
- Chaincode: The business logic of the network the structure in which data will be stored in ledger is defined in chaincode.
- Fabric Node Sdk: It's basically the API which connects web apps with the chaincodes.

Technologies taken use of when implementing a Hyperledger Fabric Network are:

- GoLang and Javascript to compose the chaincode
- Docker Containers to bring-up the peers, orderer and Certificate authority service
- Node SDK API for interacting with Hyperledger Networks

Workflow of Hyperledger Fabric:

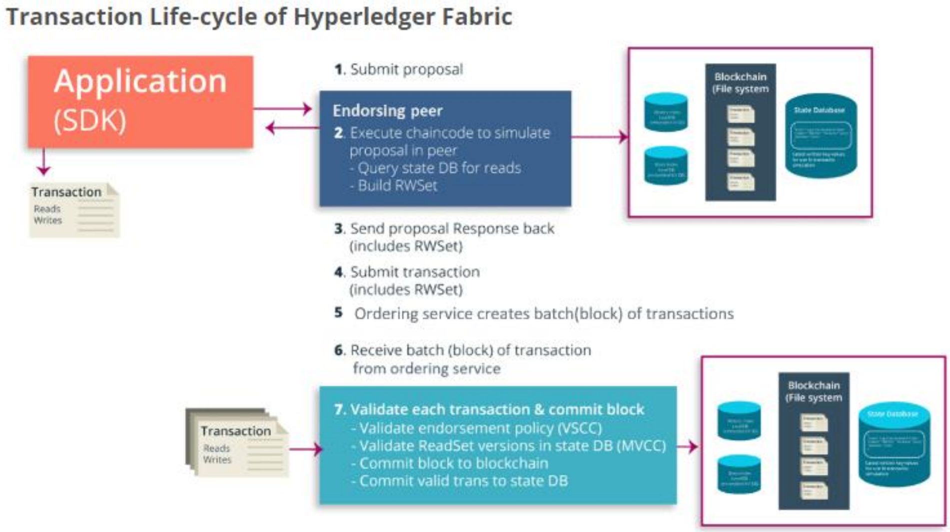


Figure 2.3: Transaction Lifecycle of Hyperledger Fabric [25]

Blockchain component for Nutrient Disorder Identification System

A blockchain-based approach would make any system much faster, simpler, and fraud-resistant, drastically reducing administrative and processing costs. A welcome effect of a transparent, fast, and efficient claim-handling process would be enhanced customer experience. Thus, in a business perspective, blockchain technology could ultimately have a direct bearing on customer satisfaction while cutting down costs and improving profitability. In the context of fertilizer procurement, the fast and efficient handling of information transmission would enable better real time decision making for the farmer, directly having a positive impact on the yield and also profitability. One other contributing factor is, once the farmer gets accustomed to the efficiency of this automated system, he would detach from obtaining heuristic instructions based on human contribution, instead choosing to rely on an automated and scientifically backed system.

We can create a three-peer network for this system one for the farmer, one for experts and one for the vendor. Farmers will send the image and condition of their crops to experts in-order-to obtain expert advice. After getting a response from an expert they can post a product request for vendors. Experts can view Farmers request and view the crop condition and post a response. They can also rate the product of the vendor. This rating system would be an indicator as to the level of recommendation of a vendor, further improving chances farmers possess toward making the best-informed decision. The system Overview Diagram for the System can be demonstrated as follows:

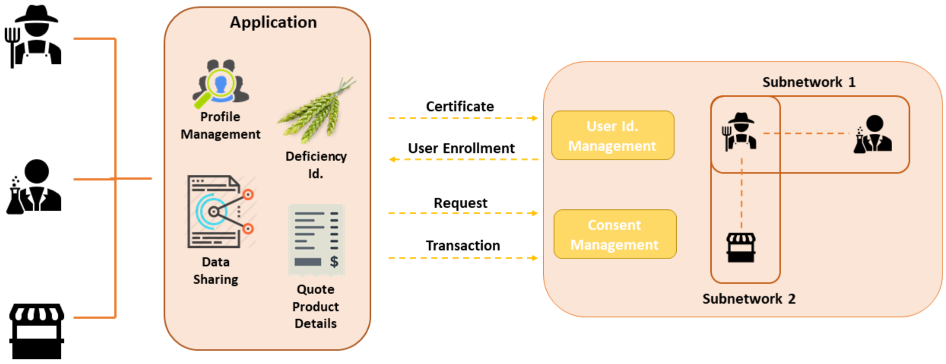


Figure 2.4: System Overview Diagram of proposed solution

2.5 System Architecture and Technical Overview of System

The System Architecture explains the high-level, overall structure of the system which would clearly indicate that the system meets the requirements and abides by the objectives set out for this research component:

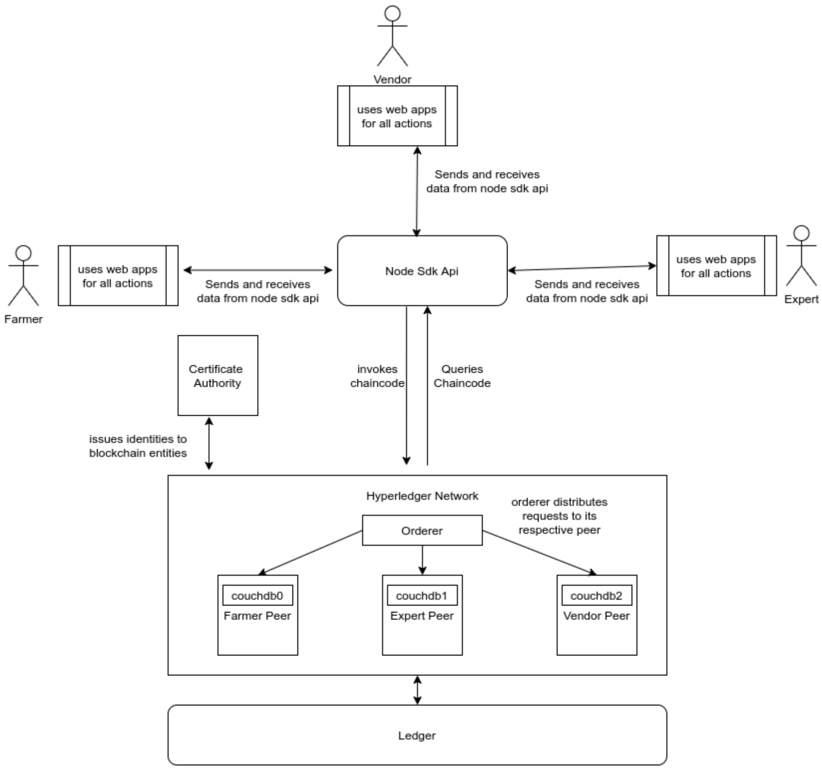


Figure 2.5: System Architecture Diagram of proposed solution

2.6 Implementation of the relevant Fabric network

Creating a Three Peer Network

Hyperledger provides its binaries which can be used for building native systems based on Hyperledger fabric.

In order to create a three-peer network using hyperledger binaries a docker file should be created and executed to raise the blockchain network.

The orderer service in a Hyperledger Fabric network is responsible for transaction ordering and endorsement of the Chaincode execution. The certificate authority is what provides and defines the accessibility each peer has in a network. Three main peers have been identified for the system as: farmer, vendor and expert. The following snippets are a demonstration of how to define an orderer service, certificate authority and a peer:

```yaml
version: '2'

volumes:
  orderer.example.com:
  peer0.org1.example.com:
  peer1.org1.example.com:
  peer2.org1.example.com:

networks:
  byfn:

services:

  ca.example.com:
    image: hyperledger/fabric-ca
    environment:
      - FABRIC_CA_HOME=/etc/hyperledger/fabric-ca-server
      - FABRIC_CA_SERVER_CA_NAME=ca.example.com
      - FABRIC_CA_SERVER_CA_CERTFILE=/etc/hyperledger/fabric-ca-server-config/ca.org1.example.com-cert.pem
      - FABRIC_CA_SERVER_TLS_KEYFILE=/etc/hyperledger/fabric-ca-server-config/CA1_PRIVATE_KEY
    ports:
      - "7054:7054"
    command: sh -c 'fabric-ca-server start --ca.certfile /etc/hyperledger/fabric-ca-server-config/ca.org1.example.com-cert.
    volumes:
      - ./crypto-config/peerOrganizations/org1.example.com/ca/:/etc/hyperledger/fabric-ca-server-config
    container_name: ca.example.com
    networks:
      - byfn

  orderer.example.com:
    extends:
      file:   base/docker-compose-base.yaml
      service: orderer.example.com
    container_name: orderer.example.com
```

Figure 2.6 Definition of Orderer, Certificate Authority and Peer

```
peer0.org1.example.com:
  container_name: peer0.org1.example.com
  image: hyperledger/fabric-peer:$IMAGE_TAG
  environment:
    #Generic peer variables
    - CORE_VM_ENDPOINT=unix:///host/var/run/docker.sock
    # the following setting starts chaincode containers on the same
    # bridge network as the peers
    # https://docs.docker.com/compose/networking/
    - CORE_VM_DOCKER_HOSTCONFIG_NETWORKMODE=${COMPOSE_PROJECT_NAME}_test
    - FABRIC_LOGGING_SPEC=INFO
    #- FABRIC_LOGGING_SPEC=DEBUG
    - CORE_PEER_TLS_ENABLED=true
    - CORE_PEER_PROFILE_ENABLED=true
    - CORE_PEER_TLS_CERT_FILE=/etc/hyperledger/fabric/tls/server.crt
    - CORE_PEER_TLS_KEY_FILE=/etc/hyperledger/fabric/tls/server.key
    - CORE_PEER_TLS_ROOTCERT_FILE=/etc/hyperledger/fabric/tls/ca.crt
    # Peer specific variabes
    - CORE_PEER_ID=peer0.org1.example.com
    - CORE_PEER_ADDRESS=peer0.org1.example.com:7051
    - CORE_PEER_LISTENADDRESS=0.0.0.0:7051
    - CORE_PEER_CHAINCODEADDRESS=peer0.org1.example.com:7052
    - CORE_PEER_CHAINCODELISTENADDRESS=0.0.0.0:7052
    - CORE_PEER_GOSSIP_BOOTSTRAP=peer0.org1.example.com:7051
    - CORE_PEER_GOSSIP_EXTERNALENDPOINT=peer0.org1.example.com:7051
    - CORE_PEER_LOCALMSPID=Org1MSP
  volumes:
      - /var/run/:/host/var/run/
      - ../organizations/peerOrganizations/org1.example.com/peers/peer0.org1.example.com/msp:/etc/hyperledger/fabric/msp
      - ../organizations/peerOrganizations/org1.example.com/peers/peer0.org1.example.com/tls:/etc/hyperledger/fabric/tls
      - peer0.org1.example.com:/var/hyperledger/production
  working_dir: /opt/gopath/src/github.com/hyperledger/fabric/peer
  command: peer node start
```

Figure 2.7 Definition of Orderer, Certificate Authority and Peer

Once the above configurations are done, it is necessary to define how the ledger will behave and what the building blocks and components of the blockchain will be. The following snippet is in reference to this proceeding:

```
Profiles:

    OneOrgsOrdererGenesis:
        <<: *ChannelDefaults
        Orderer:
            <<: *OrdererDefaults
            Organizations:
                - *OrdererOrg
            Capabilities:
                <<: *OrdererCapabilities
        Consortiums:
            SampleConsortium:
                Organizations:
                    - *Org1
    OneOrgsChannel:
        Consortium: SampleConsortium
        <<: *ChannelDefaults
        Application:
            <<: *ApplicationDefaults
            Organizations:
                - *Org1
            Capabilities:
                <<: *ApplicationCapabilities
```

Figure 2.8 Definition of Ledger

Once the docker has been set up after defining orderer, Certificate Authority and peer, it is necessary to configure the ledger specific for the requirements of our network.

The ledger is based on a key concept in Hyperledger Fabric. The ledger consists of the current state of proceedings in the platform as journals of transactions. A real-world instance to define a ledger would be a scenario where we check our bank account balance. Apart from knowing the current status, we can also check on the transactions that have been done for the account to evolve to that particular point. This being a key concept of Fabric, is also a primary component which would enable to fulfill the objectives set out for the blockchain component constructed. The coding snippet for the ledger is as follows:

```yaml
- &Org1
    # DefaultOrg defines the organization which is used in the sampleconfig
    # of the fabric.git development environment
    Name: Org1MSP

    # ID to load the MSP definition as
    ID: Org1MSP

    MSPDir: crypto-config/peerOrganizations/org1.example.com/msp

    # Policies defines the set of policies at this level of the config tree
    # For organization policies, their canonical path is usually
    #   /Channel/<Application|Orderer>/<OrgName>/<PolicyName>
    Policies:
        Readers:
            Type: Signature
            Rule: "OR('Org1MSP.admin', 'Org1MSP.peer', 'Org1MSP.client')"
        Writers:
            Type: Signature
            Rule: "OR('Org1MSP.admin', 'Org1MSP.client')"
        Admins:
            Type: Signature
            Rule: "OR('Org1MSP.admin')"

    # leave this flag set to true.
    AnchorPeers:
        # AnchorPeers defines the location of peers which can be used
        # for cross org gossip communication.  Note, this value is only
        # encoded in the genesis block in the Application section context
        - Host: peer0.org1.example.com
          Port: 7051
```

Figure 2.9 Definition of Ledger

These files are run together with fabric binaries by creating a bash script file which will use the fabric binary tools and create certificates for all the components of the Hyperledger network. This snippet is demonstrated below:

```bash
function createOrgs() {

  if [ -d "organizations/peerOrganizations" ]; then
    rm -Rf organizations/peerOrganizations && rm -Rf organizations/ordererOrganizations
  fi

  # Create crypto material using cryptogen
  if [ "$CRYPTO" == "cryptogen" ]; then
    which cryptogen
    if [ "$?" -ne 0 ]; then
      echo "cryptogen tool not found. exiting"
      exit 1
    fi
    echo
    echo "##########################################################"
    echo "##### Generate certificates using cryptogen tool #########"
    echo "##########################################################"
    echo

    echo "##########################################################"
    echo "############ Create Org1 Identities ######################"
    echo "##########################################################"

    set -x
    cryptogen generate --config=./organizations/cryptogen/crypto-config-org1.yaml --output="organizations"
    res=$?
    set +x
    if [ $res -ne 0 ]; then
      echo $'\e[1;32m'"Failed to generate certificates..."$'\e[0m'
      exit 1
    fi
```

Figure 2.10 Bash Script for Certificate Creation

Once this script file is executed the three-peer blockchain network would be running. Afterwards, it's necessary for the Chaincode to be written.

Chaincode

The Chaincode would be written in ‘Golang’. Importing the Fabric binaries is the first step in implementing the Chaincode:

```go
package main

import (
    "bytes"
    "encoding/json"
    "fmt"

    //"strings"

    "github.com/hyperledger/fabric/core/chaincode/shim"
    "github.com/hyperledger/fabric/protos/peer"
)
```

Figure 2.11 Import Fabric Binaries

It will be able to communicate with the blockchain network using these imports. The ‘shim api’ is responsible for communication of Chaincode with API and a separate import should be done for the communication of peers.

Afterwards, it is necessary to define a database structure for the system. It is necessary to define how and what will be stored here. As an instance, at first a user amongst the three stakeholders (Farmer, Expert, Vendor) would be stored. The code snippet below describes the sample fields of the ‘vendor’ peer. Fundamentally, this is a definition of the blockchain database structure:

```
type Vendor struct {
    ObjectType string `json:"Type"`
    Vendor_ID  string `json:"vendor_ID"`
    Username   string `json:"username"`
    Password   string `json:"password"`
```

Figure 2.12 Blockchain Database structure

The structure below is for product related data: when a farmer requests a product or when a vendor hands out quotations or just posts a product, and also when an expert gives a review related to the product, all the relevant data is stored in this struct:

```
type Product struct {
    ObjectType string `json:"Type"`
    Product_ID string `json:"product_ID"`
    Name       string `json:"name"`
    Amount     string `json:"amount"`
    Price      string `json:"price"`
    Farmer_ID  string `json:"farmer_ID"`
    Vendor_ID  string `json:"vendor_ID"`
    Expert_ID  string `json:"expert_ID"`
    Status     string `json:"status"`
```

Figure 2.13 Blockchain Database Structure

The next structure, ‘session’; is the part where the farmer transfers information about the identified deficiency to the expert. All related information of this process is stored in the below struct of chaincode

```
type Session struct {
    ObjectType      string `json:"Type"`
    Session_ID      string `json:"session_ID"`
    Disorder_ID     string `json:"disorder_ID"`
    Findings_ID     string `json:"findings_ID"`
    Uploaded_date   string `json:"uploaded_date"`
    Image           string `json:"image"`
    Disorder_degree string `json:"disorder_degree"`
    Leaf_count      string `json:"leaf_count"`
    Farmer_ID       string `json:"farmer_ID"`
    Expert_ID       string `json:"expert_ID"`
    Status          string `json:"status"`
```

Figure 2.14 Blockchain Database Structure

The Chaincode function for posting a product can be defined as follows:

```
product_ID := args[0]
name := args[1]
amount := args[2]
price := args[3]
farmer_ID := args[4]
vendor_ID := args[5]
expert_ID := args[6]
status := args[7]

// ======Check if product Already exists

productAsBytes, err := stub.GetState(product_ID)
if err != nil {
    return shim.Error("Transaction Failed with Error: " + err.Error())
} else if productAsBytes != nil {
    return shim.Error("The Inserted product ID already Exists: " + product_ID)
}

// ===== Create product Object and Marshal to JSON

objectType := "product"
product := &Product{objectType, product_ID, name, amount, price, farmer_ID, vendor_ID, expert_ID, status}
productJSONasBytes, err := json.Marshal(product)

if err != nil {
    return shim.Error(err.Error())
}

// ======= Save product to State

err = stub.PutState(product_ID, productJSONasBytes)
if err != nil {
    return shim.Error(err.Error())
}
```

Figure 2.15 Post function in Chaincode

This defines how a product with the relevant attributes is to be posted on request or when the vendor is willing to do so.

Similarly, there is also a get method to get any data stored in the ledger. The code implementation for the get method is as follows:

```
func (t *SmartContract) queryProduct(stub shim.ChaincodeStubInterface, args []string) peer.Response {

    if len(args) < 1 {
        return shim.Error("Incorrect number of arguments. Expecting 1")
    }

    status := args[0]

    queryString := fmt.Sprintf("{\"selector\":{\"Type\":\"product\",\"status\":\"%s\"}}", status)

    queryResults, err := getQueryResultForQueryString(stub, queryString)
    if err != nil {
        return shim.Error(err.Error())
    }

    return shim.Success(queryResults)
}
```

Figure 2.16 Get Function in Chaincode

All the get post functions are similar, calling out their respective struct. They are marshalled into JSON structures and then stored in blockchain. Afterwards, the invoke function in which all the get and post methods are defined. When an API communicates with the Chaincode, its request will be received by invoke method and then this method sends it to its respective function. The invoke function is as follows:

```
func (t *SmartContract) Invoke(stub shim.ChaincodeStubInterface) peer.Response {

    // Retrieve the requested Smart Contract function and arguments
    function, args := stub.GetFunctionAndParameters()
    fmt.Println("Chaincode Invoke Is Running " + function)

    if function == "addExpert" {
        return t.addExpert(stub, args)
    }
    if function == "queryExpert" {
        return t.queryExpert(stub, args)
    }
    if function == "addFarmer" {
        return t.addFarmer(stub, args)
    }
    if function == "queryFarmer" {
        return t.queryFarmer(stub, args)
    }
    if function == "queryFarmerbyID" {
        return t.queryFarmerbyID(stub, args)
    }
    if function == "addVendor" {
        return t.addVendor(stub, args)
    }
    if function == "queryVendor" {
        return t.queryVendor(stub, args)
    }
    if function == "queryVendorbyID" {
        return t.queryVendorbyID(stub, args)
    }
```

Figure 2.17 Invoke function

<u>Deployment</u>

The Chaincode needs to be deployed on the blockchain network in order for it to run the methods for posting and getting data from the ledger. CLI operations need to be executed to deploy the chaincode file on the network.

In the directory where the blockchain network files are stored we need to execute the following command on CLI to make our chaincode work:

$ docker exec cli peer chaincode install -n agri -l golang -p path to chaincode file/agri -v 0.1

This will install the chaincode on the peers ready for usage. By this stage the blockchain network backend is running and functional. As per now, all we need is an API to send data to the blockchain.

2.6.1 Node SDK API

For the API, first a user must be enrolled so it can send and receive data from blockchain. For the purpose of demonstration, let us consider the vendor node:

```
        trustedRoots: [],
        verify: false
    };
    // be sure to change the http to https when the CA is running TLS enabled
    fabric_ca_client = new Fabric_CA_Client('http://localhost:7054', null , '', crypto_suite);

    // first check to see if the admin is already enrolled
    return fabric_client.getUserContext('admin', true);
}).then((user_from_store) => {
    if (user_from_store && user_from_store.isEnrolled()) {
        console.log('Successfully loaded admin from persistence');
        admin_user = user_from_store;
    } else {
        throw new Error('Failed to get admin.... run enrollAdmin.js');
    }

    // at this point we should have the admin user
    // first need to register the user with the CA server
    return fabric_ca_client.register({enrollmentID: 'vendor1', affiliation: 'org1.department1',role: 'client' ,  attrs: [{ na
}).then((secret) => {
    // next we need to enroll the user with CA server
    console.log('Successfully registered vendor1 - secret:'+ secret);

    return fabric_ca_client.enroll({enrollmentID: 'vendor1', enrollmentSecret: secret , attr_reqs: [{ name: "role" , optiona
}).then((enrollment) => {
  console.log('Successfully enrolled member user "vendor1" ');
  return fabric_client.createUser(
     {username: 'vendor1',
     mspid: 'Org1MSP',
     cryptoContent: { privateKeyPEM: enrollment.key.toBytes(), signedCertPEM: enrollment.certificate }
     });
}).then((user) => {
     member_user = user;
```

Figure 2.18 User Enrollment NodeJS

The path of the Certificate Authority Server has been provided, so it can get its identity certificates. Afterwards, it is necessary to set the path for exporting from the path of the peers and orderers on which the request has to be sent:

```
module.exports = {

  invokeCreate: async function (request) {

    try {

      var fabric_client = new Fabric_Client();

      // setup the fabric network
      var channel = fabric_client.newChannel('mychannel');
      var peer = fabric_client.newPeer('grpc://localhost:9051');
      channel.addPeer(peer);
      var order = fabric_client.newOrderer('grpc://localhost:7050')
      channel.addOrderer(order);

      // load the base network profile and eventHub
      let event_hub = channel.newChannelEventHub(peer);
```

Figure 2.19 Export path

Once these configurations are made, it is necessary to create an API endpoint for the network which will be running on a port on which data can be sent and retrieved using this API to blockchain:

```
app.post('/api/addFarmer', async function (req, res) {

  var request = {
    chaincodeId: 'agri',
    fcn: 'addFarmer',
    args: [

      req.body.farmer_ID,
      req.body.username,
      req.body.password

    ]
  };
console.log(req.body);
  let response = await invoke.invokeCreate(request);
  if (response) {
    if(response.status == 200)
    res.status(response.status).send({ message: "The Expert with ID: "+req.body.farmer_ID+ " is
    else
    res.status(response.status).send({ message: response.message});
  }
});
```

Figure 2.19 API endpoint of Network

Below code snippet is a jQuery for the HTML page sending data to node SDK API:

```
$(document).on('click', '#submit', function (evt) {
    evt.preventDefault();
        var username = document.getElementById('username').value;
        var password = document.getElementById('Password').value;
        var ts = Math.floor(new Date() / 1000)

        $.ajax({
            type: "GET",
            url: 'http://localhost:8000/api/queryFarmer?username='+username+'&password='+password+'',
          cache: false,
         complete: function (data, status) {
           if (status === 'error' || !data.responseText || data.responseJSON == '') {
             alert(data.responseText+"LOGIN FAILED");
           }
           else {
             var farmer_ID = data.responseJSON[0].Key;
             window.location.href = "farmer_home.html?farmer_ID="+farmer_ID+"";

           }
         }
       });



});


 </script>
 <script>if (window.module) module = window.module;</script>
```

Figure 2.20 jQuery for HTML page

The Hyperledger Fabric network can be run on multiple peers by deploying both peers on different peers to ensure data integrity etc.

3. RESULTS & DISCUSSION

3.1 Results

The result of the component constructed is a decentralized system for fertilizer procurement where ledgers will be maintained with each stakeholder. Efficient usage of this system would promote sustainable farming practices, enhance yield and magnify profitability.

3.2 Research Findings

The key issue identified when conducting the research was the lack of information with regards to sustainable and 'smart' farming communities in regions of the country away from major town centers. It is noteworthy that, during field visits conducted to agricultural research institutes, a lack of ready-made and accessible information was a major issue faced by the entire agriculture community in Sri Lanka. While researchers have the tools and the means to conduct efficient and meaningful research with regards to issues in crops and crop management, they lack an efficient mechanism to distribute this information.

Furthermore, while modern implementations are being adapted into the pipeline of agricultural research and development, most of the data and techniques used resonate a 'generation gap' as they have not been upgraded to the more modern approaches. As such, while information is available, it cannot be anticipated that any outcome would be as efficient as ones of an ICT based approach. Conclusively, while the governing and regulation bodies of Sri Lanka endorse a policy of 'smart farming' based on e-agriculture, such an approach is far-off from being integrated into the average farming and agriculture ecosystem. Any such mechanism is prevalent only in controlled field conditions.

While there is a tendency in modern generations to be more inclined toward technology, utilizing such resources for productive purposes is not very evident. Furthermore, the very exposure to the domain of technology has prompted the younger generations of predominantly agricultural backgrounds to pursue aspirations away from agriculture. One other factor contributing to this is the low profitability of farming. Yet, if sustainable farming is given sufficient attention and the approach toward farming is prompted to taking a more science and fact backed approach, farming practices would be streamlined and would generate better profitability. ICT is the gateway to sustaining a fast diminishing agriculture trade.

The factor of higher profitability to intermediaries is a demotivating factor for farmers and is also an unfair bias based on the effort generated. Lifting this norm should be approached by segregating the trust-driven and centralized information management system which is often centric around the heuristic knowledge of intermediaries. The lack of knowledge of farmers could be identified as a contributing factor to this unfair bias. Lifting any such bias could be contributed to by helping farmers make better informed and knowledge driven decisions.

3.3 Discussion

The requirement for sustainable agriculture practices, utilizing natural and artificial means of maintaining soil nutrition [9] is only evident. Initially, economically infeasible approaches [5] [7] were made, which are mostly exorbitant for the farming communities in developing regions such as Sub-Saharan Africa [6] and Sri Lanka [15]. This has also made such communities dependent on a 'middle-man' to cater for fertilizing needs which creates a bias and autocracy in such proceedings, eventually leading to these 'middle- men' capturing a margin of profit [4] due to the bias in the availability of information. Therefore, with the advancement of technology, agronomically-oriented technological research emerged as a contender for enhancing soil management practices and fertilization efficiency via effective interactions and communication [14]. The solution that has been structured utilizes technology to mitigate these identified issues and empower sustainable agricultural practices

In Sri Lanka, most farmers remain illiterate and impoverished. They operate in isolation, with little or no bargaining capacity and lack insight into high-quality agricultural practices that could improve their productivity, mostly depending on heuristic approaches [16]. A gap exists between the recommended dose and actual use of fertilizer. This is attributed to farmers most often being manipulated by vendors to use low-quality or inadequate fertilizer products at uneven prices [4]. M. Rivera et. al.

[21] emphasizes how existing agriculture-driven information systems are institution-based and lack universal availability. Given this context, a solution has been proposed utilizing a permissioned and private blockchain platform (Hyperledger Fabric). The permissioned nature of the system disables the bias toward vendors as relevant information could be shared privately between farmers and experts involved. Such a universally available system interlinking key stakeholders in fertilizer procurement in a fair manner would enable better decision-making capabilities amongst farming communities.

4. CONCLUSION

The proposed component is to construct a decentralized, community-driven informative system for farmers to make best-informed decision regarding fertilizer procurement. Studies have shown how farmers most often rely on heuristic practices for fertilizer administration. It is further discussed that information availability for rural farming communities in developing countries such as Sri Lanka is at a very primitive stage. The component is proposed sighting such shortcomings in a critical component of agriculture such as fertilizer, and modern technological advancements which ideally make farmers more exposed to ICT. The system is primarily constructed for shifting the information asymmetry which is disadvantageous for farmers and enhancing information availability. A community driven system consisting of farmers, experts and vendors would enhance interactive and informed decision-making capability of farmers. A permissioned blockchain has been recommended for preserving confidentiality of data transmitted between expert and farmer, as well as to maintain transparency in all transactions made by the vendor. Such a system would be feasible for a developing country such as Sri Lanka since internet and relevant technologies are steadily reaching out to grassroot levels of the island. Another primary contribution factor for the acceptance of proposed component as an ideal solution is the dependence of Sri Lankan economy on the Agriculture industry as well as the close association of the industry with the Sri Lankan society. Overall, the proposed component would be a steppingstone in enhancing information availability for farmers and cultivators.

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