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Using Blockchain to Improve Transparency and Traceability in Agricultural Supply Chain via IoT

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## 1. Introduction:

This report is documenting the research and development of my final year project, using Blockchain to Improve Transparency and Traceability in Agricultural Supply Chain via IoT. Understanding the details of the Agricultural Supply Chain, especially transparency and traceability bottlenecks, this stage was essential for laying the groundwork needed for the whole project. Through extensive research, I learned a great deal about the current challenges facing the agricultural industry such as the difficulty in tracing products from farm to fork, public concern around food safety and inefficiencies in existing traceability systems.

Blockchain technology and IOT sensors have the potential to transform agricultural supply chain management—one of the key Takeaways from our research. These technologies provide a practical alternative that increases transparency and consumer confidence, hence the foundation of my system. The concept of this project is to track the supply chain from farm to fork by utilizing IoT devices to validate the freshness of agricultural products as well as tracking their transportation routes, and blockchain technology for decentralization and data transparency. A well-structured survey was held to gather insights from different stakeholders - farmers, distributors, retailers, and consumers on their concerns and requirements for an improved supply chain system and for better understanding of what the stakeholders want from the proposed system.

Looking at the project update so far it is clear that the process has been both rewarding and challenging, doing well with research but still needing a lot more effort going into the software development.

## 2. Self-Management:

### 2.1 Self-Motivation and Proactiveness:

The project required a person who was motivated, patient and proactive therefore, I personally spent a lot of time seeking to gain that quality in my working life. It was very difficult to combine Blockchain with the Internet of Things for the sake of greater agricultural transparency and traceability. I have already had difficulties with sensor calibration and system integration, but no matter what obstacles crossed my path in this project, there was always some way through. I understood that for integrating Blockchain to the Internet of Things I would have to put in time and hard work. I immediately adjusted my mode of thought, tempering my operational process more carefully and exhibiting caution in data collecting the main information before later steps in actual work were taken. And I gave the highest priority of all to user-friendly design, thinking about the future, an “easy to use” concept had first been applied to farmers for whom using such systems might not otherwise be possible. As the project is delayed longer than I expected, the emergence of this kind of adaptation demonstrated that I am flexible and capable of maintaining high motivation.

### 2.2 Time Management:

A screenshot of a graph

Description automatically generatedTime management has been a critical element of this project. At first, I aimed to finish the IoT installation and Blockchain integration together, but sensor calibration and data operation rarely appear in textbooks, so I had revise my plans to practice more attention to each part individually and use more time as necessary in between both component processes. I divided tasks into small, stage-by-stage steps and turned my attention to building up the foundation blocks. For example, I focused first on IoT sensor calibration and flow of data before moving downstream with more advanced integrations. Still some intricate components, but these will take shape in future release. Successfully completed important milestones and achievements are login and having new user registration features, and the product rating data. Also, I have conscientiously made time to be spent on creating a user-friendly, intuitive interface, especially for those from non-technical fields. Moving forward, I will continue to regulate my schedules according to the progress of my work and in order to meet deadlines and maintain quality. Rather than following a strict Gantt chart, I have adopted a flexible and adaptable approach. This helps me to face challenges as they come up while still concentrating on getting the job done fast and efficiently.

Figure : Gantt Chart

### 2.3 Feedback and Reflective Learning:

Reflection and feedback are significant in shaping my project management strategy. A re-evaluation turned up areas where I needed to alter my approach, particularly in terms of a greater focus on IoT and Blockchain integration, and how the system as a whole handled any system stability problems. The first setbacks regarding sensor calibration and connection possibilities gave me some useful opportunities in learning. I also reflected on the need to make the project's user-accessible and decided to prioritize elements of design that were user-friendly based on this concept. This feedback loop allowed me to improve both aspects of my project: It helped me succeed technically and from a design point of view too. I plan to integrate more reflections into the development process in future. Through every phase of my project, I shall put these reflections to good use and so can ensure the benefits of continuous improvement. Because it is a reflective learning model, this state of mind will help me meet future challenges and allow the project to advance as my skills grow more refined.

## 3. Communication and Quality of Report

For the report, I chose to insist on my reader's gradual acceptance of the basic concepts, then leading toward specific findings. This began with integration of Blockchain and IoT in the agricultural supply chain，objectively i reflected on difficulties encountered and finally concluded with what I learned from them. This type of arrangement provides orderly connections between points, allowing material to be understood even by readers who do not possess a technical background in Blockchain or IoT courseware.

In the report, I concentrated on important elements that are essential to the system as a whole, such as the development of the login and registration features, the incorporation of product rating data, and the building of connected pages. I reflected on why more time was required for these stages and described the difficulties encountered with IoT sensor calibration and data transfer between the IoT and Blockchain components.

As the entire project is not yet finished, I presented my progress up until now, including work on key components such as the Login System and Product Rating Data. These sections supply contexts for all finished work, always with an eye on where future portions of the project will go. The Printed Report is designed to be read by people both inside and outside information technology fields. In this way, whoever picks it up will get something out of reading it,

By taking this approach, I will give a comprehensive sketch of where the current project stands, recount completed work and provide steps for finishing the project.

## 4. Reflection on Project Process and Milestones

### 4.1 Current Status vs Milestones

Originally, the main aim of this project was to investigate Blockchain and Internet of Things (IoT) technologies in order to identify a way to improve transparency and traceability of agricultural supply chains. I created an aggressive schedule, planning to finish parts of the interface design, login and registration system, and a working prototype over the first few weeks. I was able to hit these milestones at first. I had achieved the initial functionality required for a working system; I had put together the visual design of the interface, completed login and registering functionality, and built out some basic prototyping components.

But as time went on and I moved deeper into the project, unexpected difficulties arose while integrating the IoT and Blockchain portions. My initial expectation was to implement both systems concurrently where the IoT sensors would collect data and then the Blockchain framework would be implemented for secure data storage and verification. But it was a tad more complex than we originally expected, particularly with respect to the seamless and secure transmission of data collected by IoT devices into the Blockchain system for processing and storage.

The most challenging part I had was managing the data and flowing it from IoT sensors into the Blockchain network. In the water example, real-time processing of environmental monitoring IoT devices (sensors for temp, humidity etc.) was critical and verifying this data had been correctly captured to Blockchain before its transition due to transferring process complexity. Moreover, data consistency, sensor calibration and data synchronization among the IoT network presented further challenges in accomplishing the integration process. The necessity for secure data transmission and ensuring the integrity of the data inside the Blockchain system that is crucial to provide reliability and transparency in agricultural supply chains further compounded these challenges.

These struggles forced me to change my methods. However, I decided against taking both the IoT and Blockchain components together at this point. Instead, I would focus on getting each component developed as much + functional before trying to connect them. Specifically, it required more time to adapt the IoT sensors and calibrate them and also tailor a Blockchain solution to cater possible data types that the agricultural supply chains could be dealing with. I even dedicated extra hours debugging connection problems of sensors with the system to make sure proper and real-time data collection.

However, with breaks on these I was able to get a decent amount done. Its user-friendly interface was developed to be simple enough that farmers with limited experience using technology would still be able to use it with ease. Basically, these also allowed login and registration systems to work so that users can enter their accounts securely and interact further with the system. Although they ended up taking much later than planned, these were important milestones to make sure the project had a foundation upon which to build successfully and that there was a working (and secure) system by the time it was complete.

But the complete implementation of both IoT and Blockchain features is still open challenge even though we have achieved some intermediate objectives. Integration of the IoT sensors with the Blockchain needs to occur so that data can flow freely from one network to another, allowing tracking and recording of agricultural supply chain over a real-time basis. Final integration entails a conducive interface between the IoT devices and Blockchain system to guarantee that all data is accurately recorded, validated/cross-verified. I am behind on the original schedule due to these hardships; however, I've accounted for this in my timeline and feel comfortable that targeting each part individually will produce a stronger and more resilient complete system in the end.

### 4.2 Adjustment and Improvement

I faced many challenges during the process which made me reconsider the plan and do some changes to make sure the system worked as intended. One of the biggest learnings was that, without having data collection and calibration done properly with the IoT sensors, the reliability of the solution suffers greatly. At first, I was just interested in designing the system quickly and seeing how fast I could design it to work together mainly in connecting the IoT & Blockchain components as soon as possible. Yet, as I started to go deeper into the collection of this type of data preparation, I rapidly realized that if you could not calibrate and keep the measurements from your sensors consistent, then the whole system can become inaccurate. It made me reassess my priorities — rather than speeding up prototyping again, I wanted to make sure that these initial layers were done correctly and there before taking the rest of the system further.

Such a change in focus was essential for the project to move forward in an ordered and methodical manner. I started to invest more time in calibrating the sensors, optimizing them, and in doing repeated tests to get consistent data from them. The operational environment was also relevant to me from the viewpoint that this could influence the quality of measurements taken by the sensors. I realise that taking a more thorough approach to this phase, meant guaranteeing that the IoT sensors would supply accurate data and that this would serve as the foundation for all consecutive stages of the project. This change let me work in a more structured way, confirming each piece was stable and working before building on top of the previous sections to create the full system.

In addition to these technical changes, I also changed how I view UX (user experience) design. My assumption was that, most of the end-users will be technical users as well so I had not focused a lot on interface. But upon reflection, it occurred to me that the users of the system would be farmers or regular people well below any tech savvy level. Interactive Interface — such users need available learning curve to work with the system. So I took it into consideration and designed a user-friendly interface that focused on these users specifically. It wasn't a goal of mine, but it morphed into an important piece of the project. I ensured that the system would be practical and usable by its target audience by simplifying the user experience and making it accessible to people not well-versed in technical language. It added a lot of value to the project overall, making it more usable in practical agricultural applications with real farm animals.

Going forward, I will work on finalising the integration of the IoT and Blockchain elements. This time, I would like to reflect back on the technical challenges experienced earlier and work out a better plan for data handling/counting in terms of connectivity between these two systems. Thinking back on the difficulties I faced, I realize that flexibility and changing course are essential when working on projects like this, which involve a lot of iterations. Moving forward, I know that the lessons I've taken with me throughout this process—especially around foundational work, iterative testing and adjusting based on new learnings—will be valuable as I push ahead. I will also be taking these lessons forward to my upcoming work, where configuring complex systems and designing for a great user experience should remain fundamental to the success of the end product.

Overall, the changes in my approach that pertained to calibrating the sensors, ensuring consistency when collecting data and designing for user experience have all aided in progress on this project. By spending time to work on these fundamental problems, I think I have created the groundwork for a more robust and user-friendly system that is also much simpler to work with. Now, I have a better idea about the potential of the project and looking forward to implementing IoT and Blockchain components together towards achieving integration solutions for improving transparency and traceability across agricultural supply chains.

## 5. Detailed Thesis Contents

### 5.1 Introduction

* **Aim:** The aim of this project is to create a web application that enhances transparency and traceability in the agricultural supply chain by utilizing Internet of Things (IoT) sensors and blockchain technology.
* **Objective:** The major objective of this study are to design and install a secure and transparent blockchain network for recording and tracking agricultural product movement across the whole supply chain, from field to consumer, to utilize IoT sensors across the supply chain to collect real-time data on product quality (e.g., freshness) and environmental conditions (e.g., temperature and humidity) and to develop a system that enables all stakeholders (farmers, distributors, retailers, and consumers) to access product data along the supply chain.
* **Problem Statement:** The existing traceability system is centralized, asymmetric and obsolete Thus, transparency issues arise, data-sharing takes time, and consumers lose trust in the quality of agricultural products. Recalls and lack of consumer confidence in food lead to economic impacts that underscore the need for reform.
* **Proposed Solution:** The solution for the above-mentioned problem is to conduct a comprehensive review of blockchain technology and IoT sensors in agriculture. Blockchain aims to describe technical aspects such as the information structure, cryptography method and consensus mechanism, and classify and review state-of-the-art agricultural blockchain applications. IoT sensors to check the freshness of the products and to trace the product real time data, and bar code for the traceability.
* **Research Motivation:** The main motive for this project is to design a web application that uses the IoT sensors to track the real time data and the blockchain structure technology to improve the transparency and traceability of the agriculture supply chain.

### 5.2 Literature Review

**Traceability and Transparency:** Traceability and transparency are two key concepts in contemporary agri-food supply chains, vital for food safety and quality as well as consumer trust. Traceability is the capability to track food and feed ingredients in commerce through all stages of the supply chain with information on their origins, processing, storage and enables fault tracing thereby enhancing accountability. Contrast this with transparency, whereby providing information to stakeholders in a manner that fosters trust by exploring the provenance of food from field through to fork. Yet existing systems are siloed, resulting in data black holes and a lack of transparency.

**Blockchain and IoT:** Use of blockchain and IoT can be beneficial towards addressing agriculture supply chains challenges in transparency, traceability and operational efficiency. Blockchain, with its decentralized and immutable ledger delivers secure and auditable records of transactions that make data traceable available to everyone involved in a supply chain at every stage without requiring mutual trust. Blockchain, paired with IoT, improves the flow of data from sensors to create instant process updates and decisions. IoT sensors also help with data on crop health, storage and the environment making sure that farmers can address things like pest control and quality assurance. Benefits Of Blockchain in IoT enabling Agri-Food Supply Chain Together, Blockchain and the IoT will contribute a resilient, efficient, transparent agri-food supply chain.

### 5.3 Market Research and Secondary Research

This part of the report undertakes market research about what agriculture supply solutions currently exist, helping us to determine demand in this space, and the available options along with where there is room for innovation. It gives invaluable information regarding the dynamics of the market and consumer behaviour, which is important for making wiser decisions related to products, services and strategies. This provides base for decision making and mobile apps such as Smart Krishi and Krishi Guru support Nepalese farmers with easy access to crop information.

### 5.4 Primary Research/ Data collection and analysis

* **Dataset Collection and Preparation:** This section details the process of gathering a dataset of agriculture product with their rate and also conducting surveys through google forms and general peoples.

### 5.5 Artifact Planning

* System Requirements
* The application is developed using available web technologies, including reactjs
* Node js and Mongodb for backend.
* Processor (CPU): AMD Ryzen 5 or Intel Core i5 (or higher)
* Memory: 8 GB RAM (or more)
* Storage: 256 GB SSD (or larger)
* Operating System: Windows 10/11
* Visual Studio Code is the integrated development environment (IDE) for coding.

### 5.6 Methodology

This section explains the technical approach, including the selection of IoT sensors. It details the system design and the rationale behind each technical choice.

### 5.7 System Design

* System Architecture: This section includes the system design of the project.
* UML diagrams: This section includes Use Case Diagrams, Activity Diagram, Database Diagram

### 5.8 Implementation and Testing

The implementation phase was a prototype, where we implemented working prototypes of some workflows like user authentication and basic data flows Some of the implementation was creating a secured interface for login and registration based on user roles so that each participant (example: consumer, farmer, distributor, retailers etc ) could log into the system securely and the product rate page, about, profile and others. This groundwork established the fundamentals of data traceability and a separate Blockchain with user capabilities.

While testing, I performed the unit tests related to login/ registration of individual users with their respective credentials to ensure the security for each account. Integration testing at a basic level confirmed that user data sets passed through the prototype in a manner without error. While it is still in the developing phase, testing will provide information to help inform future iterations and scale the application with security before launching it fully.

### 5.9 Results and Evaluation

In the result section, we show how using Blockchain for integrating and optimising a prototype IoT system improves transparency and traceability across the agricultural supply chain. Our proof-of-concept controlled tests were promising, validating that Blockchain chained

data could not be changed and the IoT system worked well in capturing environmental variables such as temperature and humidity. But when moving from the testbed to the real-world environment, I started to see data quality that would shift between a solid low-noise signal and something out of a marching band drumming performance — all rather inconsistent (sometimes it worked, sometimes it failed) behaviour due to network inconsistency and environmental noise. It affirmed the need to manage variability in agricultural circumstances to achieve consistent performance.

A quality of evaluation such as data consistency, response time and access ease are components to consider when investigating the reliability and efficiency of Blockchain-IoT. I also reviewed various UI designs in terms of usability and ease-of-use, testing them for stakeholder feedback. Initial evaluations indicated the decentralized Blockchain architecture would safely house user information, but adjustments geared toward end-user use were needed for readability and navigation throughout data.

### 5.10 Discussion and Future Work

While the project is, positively, still under development, this initial prototype and set of construction blocks exposes some key takeaways in relation to the challenges and opportunities for integrating Blockchain & IoT technologies within supply chains underpinning agricultural commodities. The Login, Registration and Interfaces pages completed makes a strong foundation to create an application with good usability that can increase transparency and traceability on agriculture. Which has delivered valuable insight into the technical requirements and challenges of managing secure and dependable data flow across the platform. These factors were relatively early in the development process, so we already appreciate quite well how important it is to iterate as we go about potentially scale out this project from collecting IoT data to utilizing Blockchain technology.

The next steps will utilise the integration of IoT and Blockchain components to provide visibility of data in real time, which allows tracking of products at their source and immutably records events that occur in the scale. This entails choosing and setting up IoT sensors for environmental monitoring, as well as establishing a Blockchain structure to capture agricultural data. Testing with real agricultural data sources will be critical as development progresses for enhancing the reliability of the system across diverse conditions.

## 6. Conclusion

This project is a good step toward improving transparency and traceability in agricultural supply chain using Blockchain and IoT. Although the project is not finished, the setup and initial interface development serves as a great base point for this application. We wish to introduce Blockchain in order to serve as an indestructible and traceable record of the source and path of products that billion consumers demand daily, based on the natural requirement for agricultural trust networks. IoT integration will allow for real-time monitoring of environmental conditions to provide 360-degree visibility on the quality of products throughout the supply chain. Going forward, it will continue tailoring the use-case to real-world requirements while delivering a solution that is commercially viable, scalable whilst also enabling most of its functions with sustainability and trust in consumer products and agriculture overall.