sFarm: A Distributed Ledger based Remote Crop Monitoring System for Smart Farming

Anand Kumar Bapatla[1], Saraju P.Mohanty[2], Elias Kougianos[3]

University of North Texas, Denton, TX 76203, USA.[1,2,3]

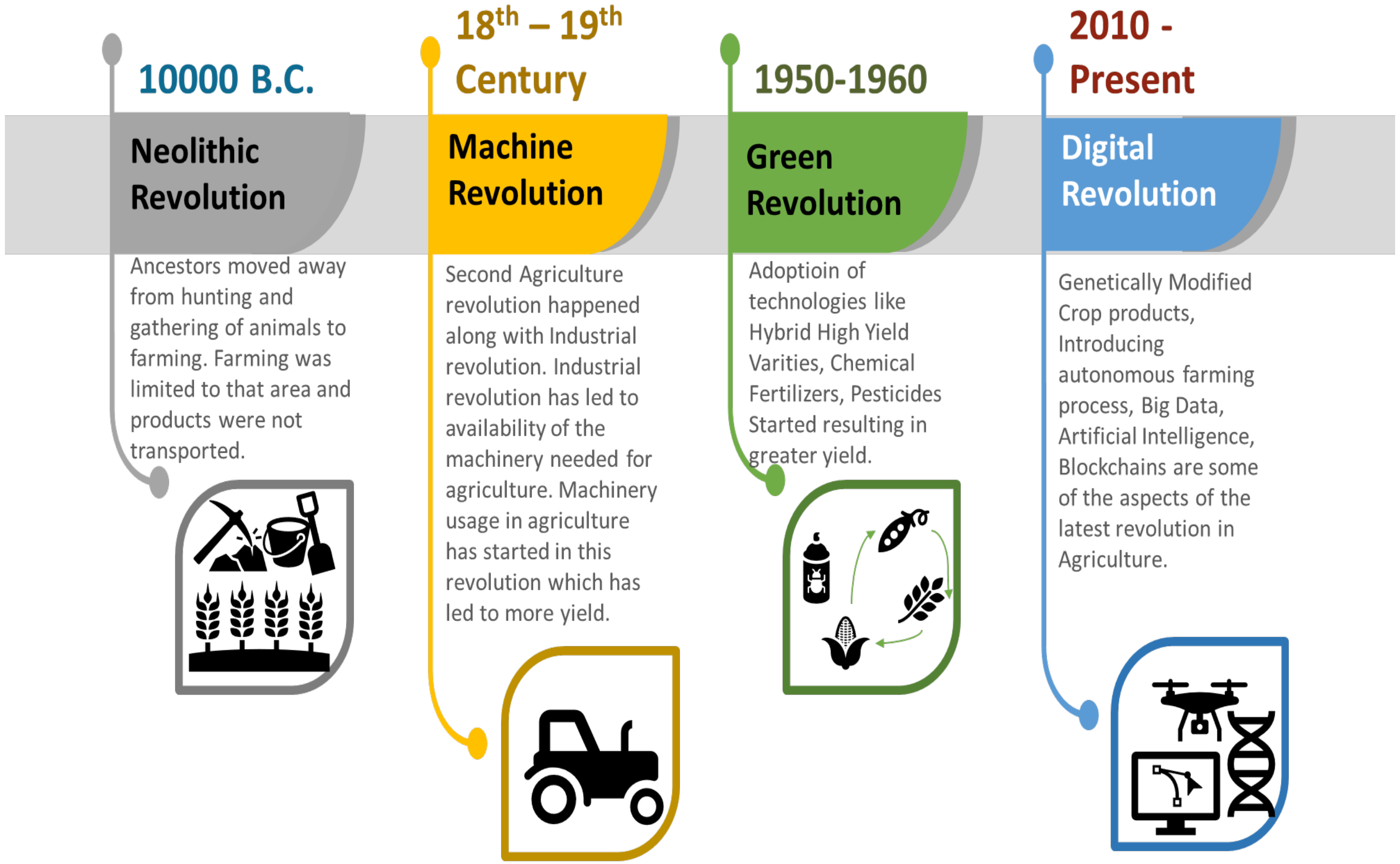
Email: AnandKumarBapatla@my.unt.edu[1], Saraju.Mohanty@unt.edu[2] and Elias.Kougianos@unt.edu[3]

Outline of the Talk

- Introduction
- Problems with Centralized Architecture
- Novel Solutions Proposed in sFarm
- Related Research
- Architectural Overview of sFarm
- Implementation and Results
- sFarm as Community Data Sharing Application
- Scalability of sFarm
- Conclusion and Future Research

Introduction

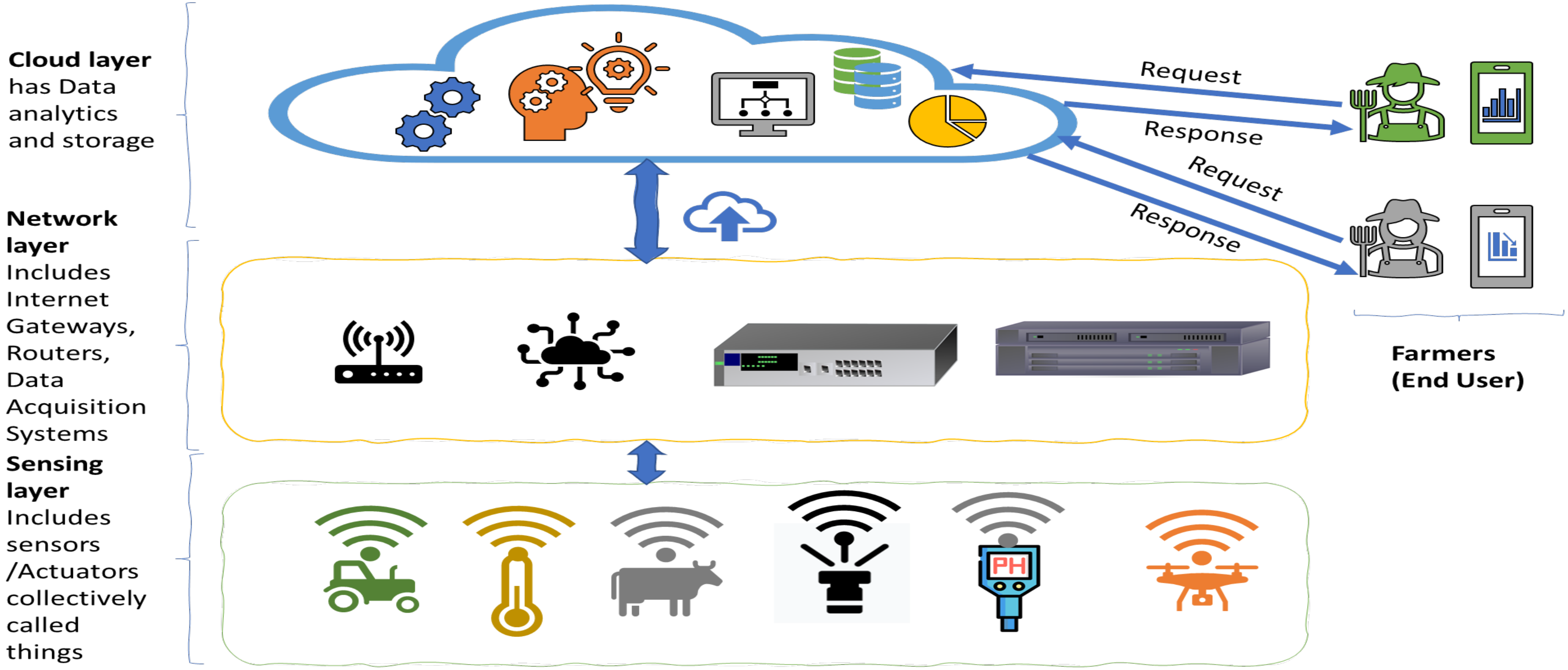
- Agriculture is a way of life more than an occupation.
- Driving factors for agriculture revolutions
  - Global population explosion and increase in food product demand.
  - Limited natural resources.
  - Climatic Conditions.
  - Urbanization and limited manual labor.



Introduction

- Solutions?
  - Smart agriculture is a new agricultural trend which integrates different latest technologies to assist farming by providing real-time decision-making capability along with intelligent control and minimal usage of resources, while making the yield high and predictable.
- Technologies in Agriculture 4.0
  - Internet of Agro Things (IoAT)
  - Big data
  - Artificial Intelligence (AI)
  - Distributed Ledger Technologies (DLT)
- Crop Monitoring System

Layered Architecture for Crop Monitoring

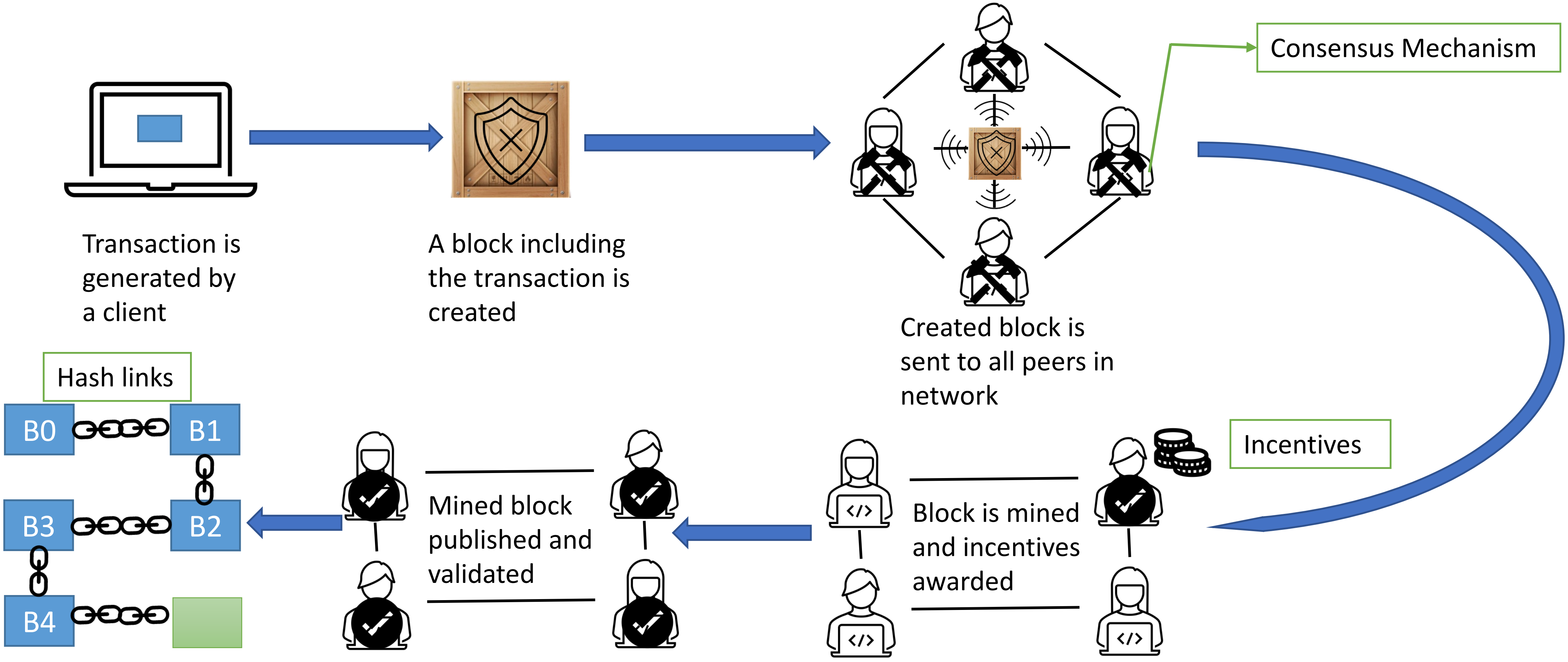


Problems with Centralized Architecture

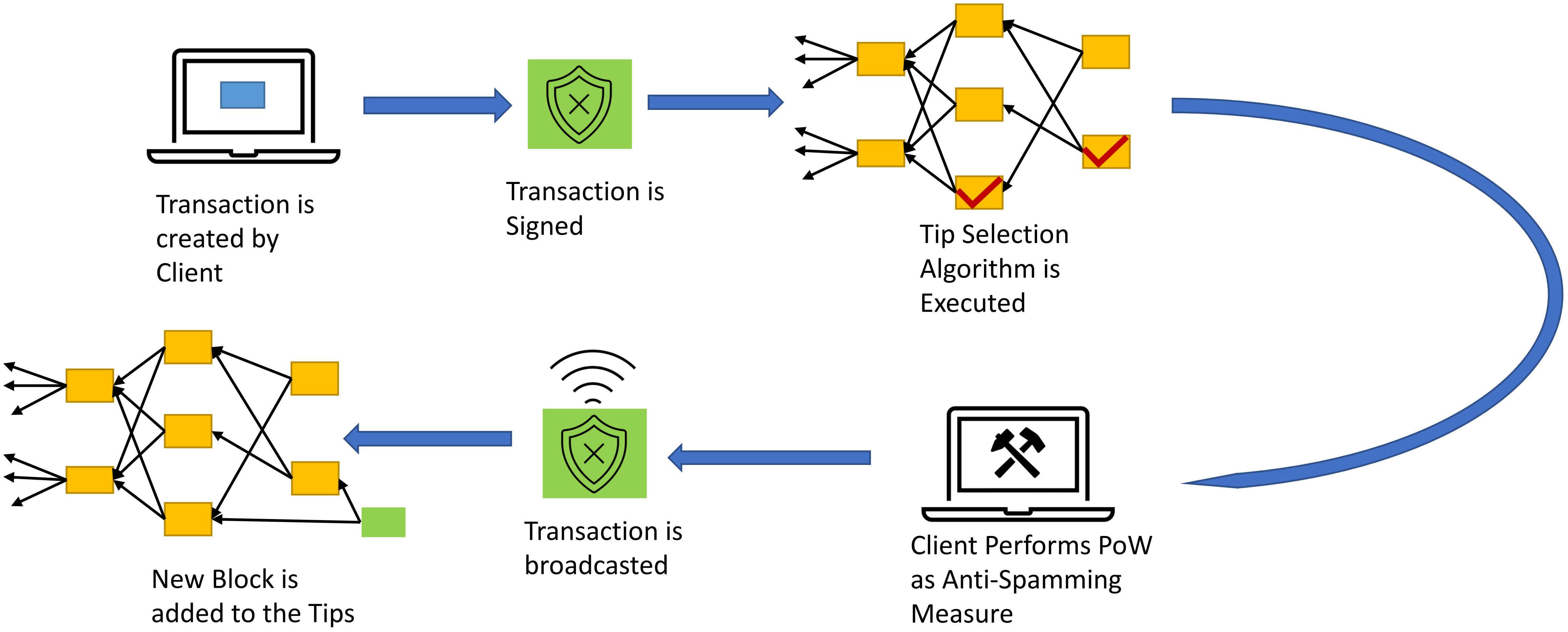
- Single Point of Failure.
- Centralized authorities controlling and monetizing the shared data.
- Data security and privacy issues.
- False data injection.
- Network congestion bottleneck.
- Distributed Denial-of-Service attacks.
- Cost of infrastructure usage and maintenance is usually high.

Solution? Decentralized networks

Blockchain Transaction Process



Tangle DL Transaction Process



Novel Solutions Proposed in sFarm

- Decentralized data sharing platform with real time data sharing.
- Providing a secure crop monitoring system to eliminate different security threats.
- Avoiding data tampering by providing a single source of truth using a distributed ledger.
- Continuous monitoring of different farm parameters and reporting.
- Cost-efficient infrastructure for building and maintaining.

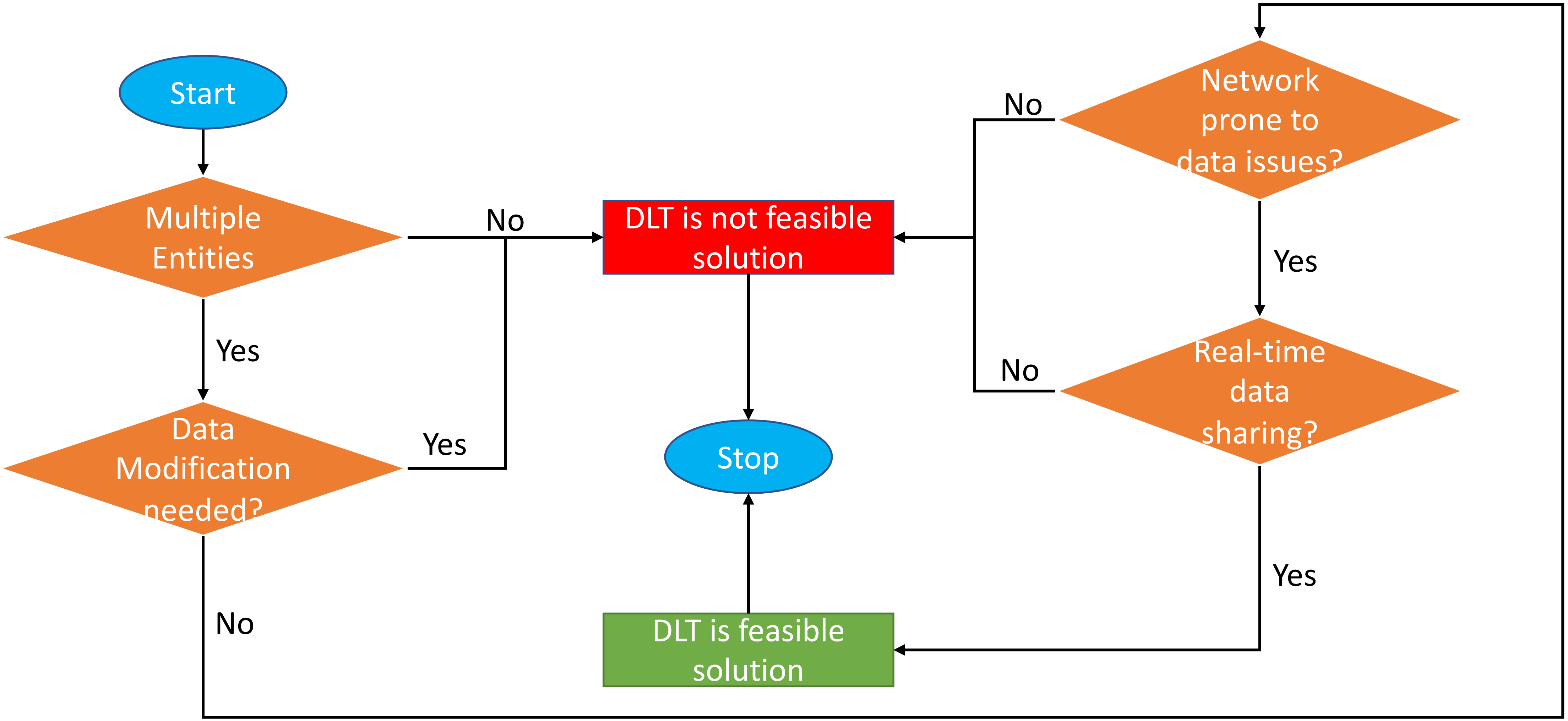
Blockchain vs IOTA Tangle

Feature	Blockchain	IOTA Tangle
Structure	Special type of DAG where each block is connected to previous block using hash pointer.	Data blocks flow in one direction and each block is connected to two other blocks using hash pointers.
Security	Provides high security by using complex consensus	Provides less security compared to blockchain and is apt solution for not much critical applications needing scalability.
Decentralization	Decentralized and no need for coordinator node.	Less decentralization as there is a coordinator node.
Cost of transaction	Certain transaction fee will be levied for each transaction, and it may increase based on the traffic congestion.	There are no miners in Tangle making it fee-less for sending transactions.

Blockchain vs IOTA Tangle

Feature	Blockchain	IOTA Tangle
Transaction time	Increases with increase in network traffic	Decreases with increase in network traffic.
Scalability	Predetermined block sizes and block generation times will make the transactions to stall and limit the scalability.	Each transaction node performs PoW for two tip nodes in tangle for its transaction to be attached, hence making tangle highly scalable with large number of participants.
Applications	Designed specifically for digital asset control and ownership.	Designed for IoT Applications to reach the scalability and provide security.

Is Distributed Ledger Feasible Solution?



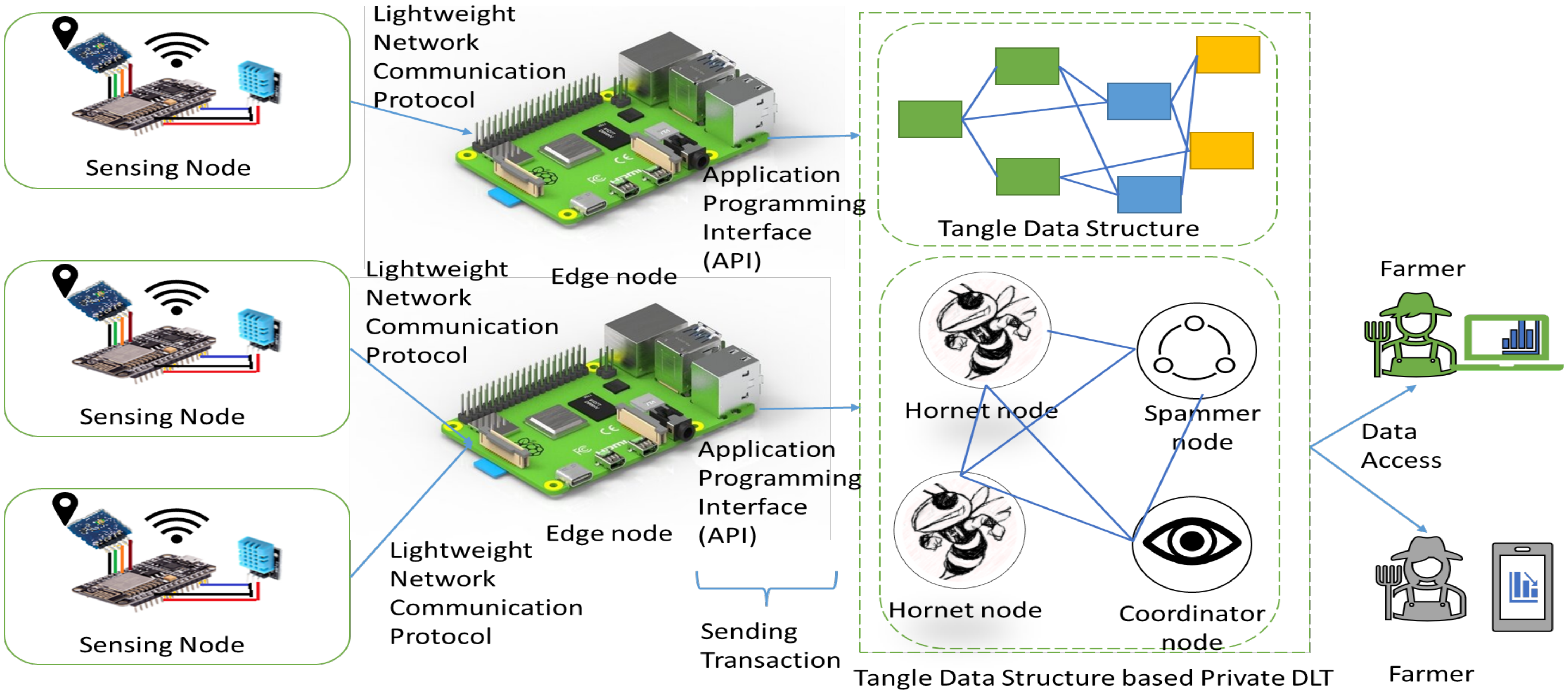
Related Research

Related Research	Contributions	Drawbacks
Lamtzidis et al.	Data Marketplace application using DLT and IoT technologies was designed and analyzed.	Public DLT is used which causes data privacy issues.
Elham et al.	Proposed a poultry farm monitoring system using public IOTA DLT and accessed using MAM data protocol.	Public DLT is used which causes data privacy issues. Scalability and Reliability of proposed system is not analyzed.
Rahman et al.	Proposed a secure data sharing model for smart agriculture. Proposed model was implemented in EOS environment and analyzed.	EOS works on Proof-of-Stake (PoS), more useful in financial application where dishonest nodes are penalized on the stake.
Huh et al.	Potential use of Ethereum smart contracts in IoT environment is analyzed.	Smart Contracts were implemented on Ethereum Platform which has very less throughput.

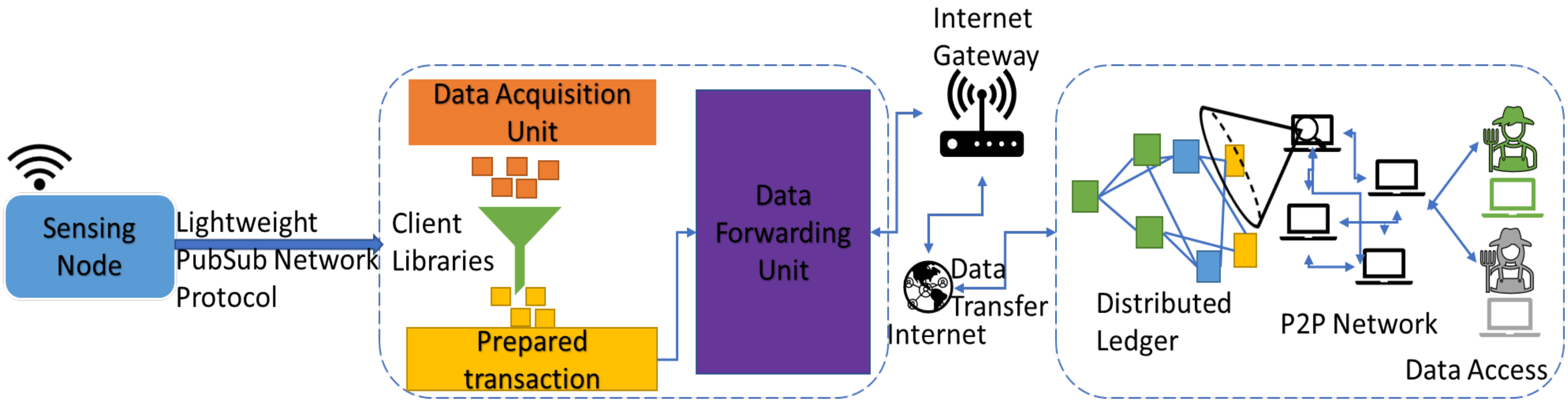
Related Prior Works

Related Research	Contributions	Drawbacks
Puthal et al.	A light weight IoT-friendly consensus mechanism called Proof-of-Authentication (PoAh) is proposed replacing the resource consuming PoW and improved the transaction confirmation times.	Full fledge client libraries are not available yet for easy integration of proposed consensus mechanism.
Malik et al.	These authors have proposed a blockchain based solution for supply chain in smart agriculture. They made use of Access Control Lists (ACL) and Smart contracts to build a three-layered architecture.	Supply Chain Application
Madumidha et al.	Authors had discussed about different entities participating in the supply chain of agricultural products and use-case analysis was done for using RFID and IoT systems.	Supply Chain Application

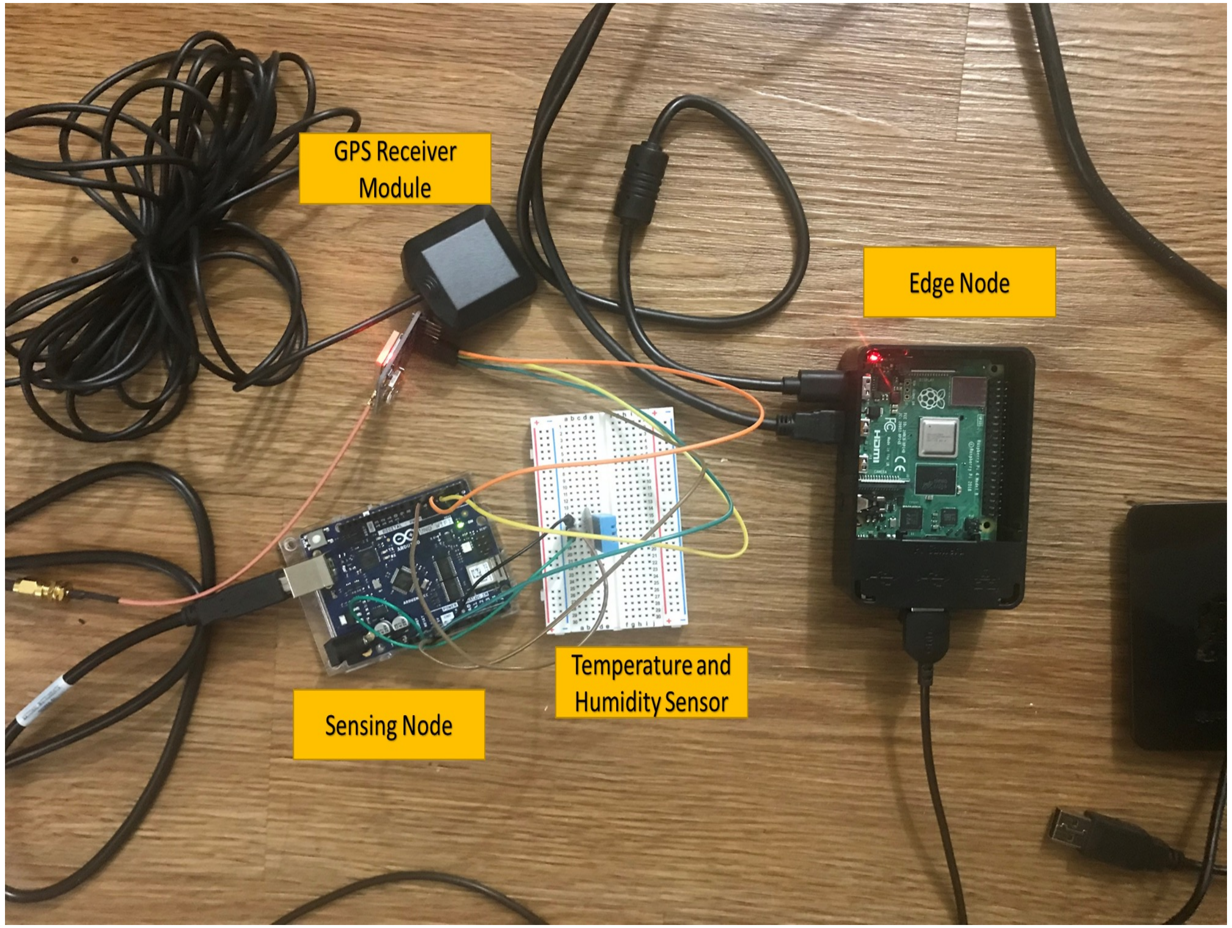
Architectural Overview of sFarm



Block Diagram of sFarm



Implementation: sFarm Node



COM12

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 Humidity: 49.00%  Temperature: 21.70°C 71.06Location: 3312.7810N, 9709.4609W
Location (in degrees, works with Google Maps): 33.2130, -97.1577
Speed (knots): 0.02
Angle: 23.56
Altitude: 211.80
Satellites: 9

 Humidity: 49.00%  Temperature: 21.70°C 71.06Location: 3312.7812N, 97095.4609W
Location (in degrees, works with Google Maps): 33.2130, -112.5976
Speed (knots): 0.03
Angle: 20.55
Altitude: 211.80
Satellites: 9

 Humidity: 49.00%  Temperature: 21.70°C 71.06Location: 3312.7812N, 9709.4609W
Location (in degrees, works with Google Maps): 33.2130, -97.1577
Speed (knots): 0.03
Angle: 50.07
Altitude: 211.80
Satellites: 9
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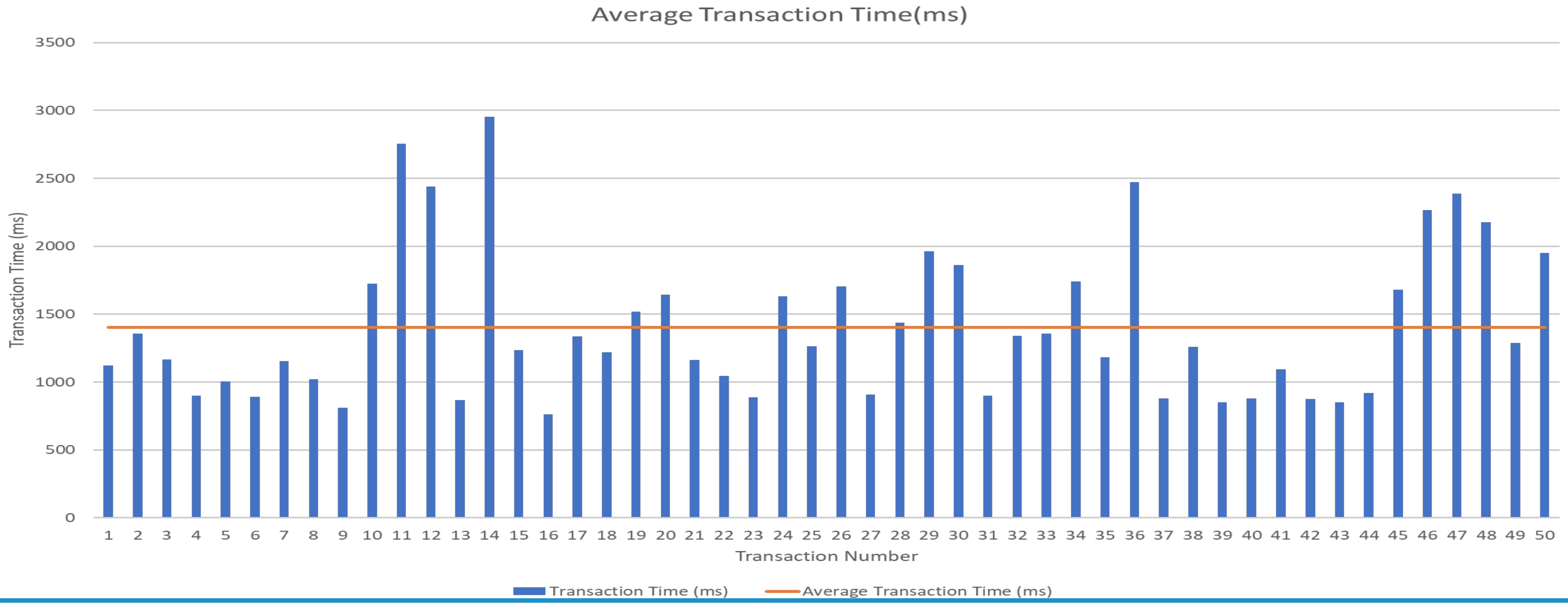
Average Transaction Time

- An edge node with a quad-core ARM A72 CPU with 4 GB RAM is considered and 50 test runs are performed.



sFarm as Community Data Sharing Platform

Dataset	Size of Dataset (in KB)	Number of Records	Average Transaction Time (in sec)	Estimated Upload Times (in hr)
Crop Recommendation Dataset	146.52	2200	1.01	0.31
Corn Yield	2781	23475	2.29	14.96
Crop Production Dataset	14958	246091	1.24	85.04

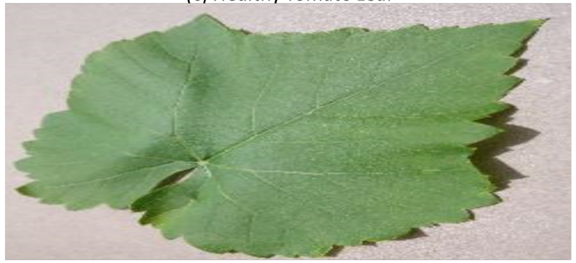
sFarm as Community Data Sharing Platform

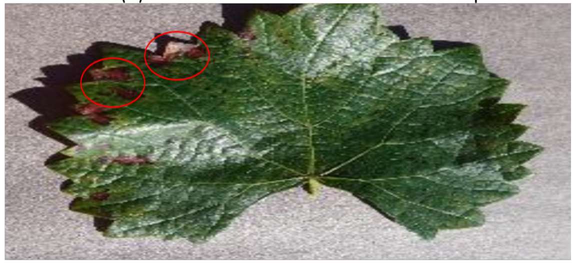

(a) Healthy Apple Leaf


(b) Black Rot Infected Apple Leaf


(c) Healthy Tomato Leaf


(d) Tomato Leaf Infected with Bacterial Spots


(e) Healthy Grape Leaf


(f) Grape Leaf infected with Black Measles


(a) Pomegranate with Superior G1 Q1 Quality


(b) Pomegranate with G2 Q1 Quality


(c) Pomegranate with G3 Q1 Quality


(d) Pomegranate with G3 Q4 Quality

Image Source: Bhattarai, S.: New plant diseases dataset (2019), https://www.kaggle.com/vipoooool/new-plant-diseases-dataset

Image Source: R, A.K.: Pomegranate fruit dataset (2020), https://www.kaggle.com/kumararun37/pomegranate-fruit-dataset

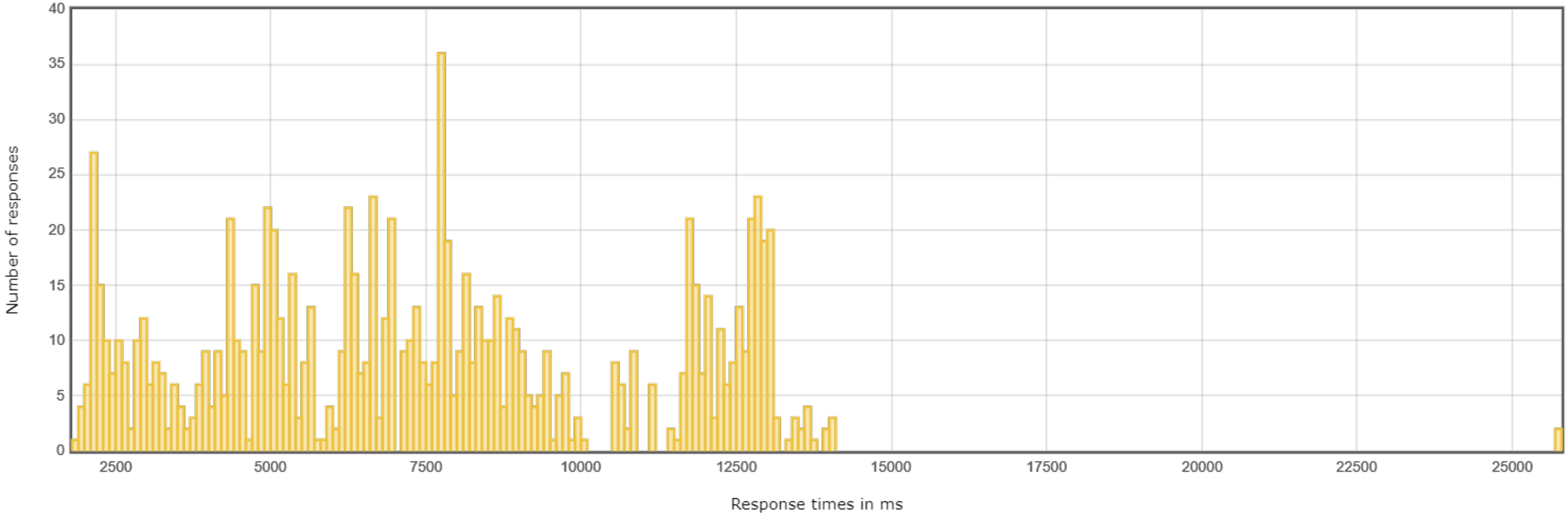
Validation

- Data Privacy and Security
  - By implementing Private DL, Adversaries are avoided to join the network. Transactions outside the network is filtered.
- DDoS
  - Each client node must perform PoW for tips before sending transaction which will prevent spamming the network.
- Power Consumption
  - 4 units of electricity per 1000 sensing nodes running continuously for a day.

Load Testing Results of sFarm

Parameter	Value
Number of Samples Data Transactions sent	1000
Load Duration	1 Minute
Failed Transactions	10
Percentage of Error	1%
Average Response Time(ms)	7566.76
Minimum Response Time(ms)	1883
Maximum Response Time(ms)	25760
Median Response Time(ms)	7314.00
Throughput (Transactions/Second)	38.03

Response Time Distribution of sFarm



Comparative Analysis

Feature	Lamtzidis et al.	Current Paper
DLT Platform	IOTA	IOTA
Type of DLT	Public	Private
PoW	Local	Local
Transaction Time (in Sec)	60	1.8
Throughput (Tx/Sec)	5	38.03

Conclusions

- Distribute Ledger based Crop Monitoring System Proposed in sFarm has average transaction time of 7.5 Sec and 1% error rate.
- Proposed system is proved to be scalable with throughput 38.03 Tx/sec and low power consumption 4 units of electricity for 1000 sensing nodes per day.
- Scalability is analyzed by performing load test analysis on one node and results has shown promising usage of proposed application.
- Data Security and Privacy threats are avoided by using Private DLT.

Future Research

- Full level prototype to be deployed in real-time environment.
- Providing convenient Graphical User Interface (GUI) options for ease of use.
- Including AI/ML techniques to alert farmer based on monitoring field parameters.

Thank you!