# Everything You Wanted to Know about Smart Agriculture

## Expert Lecture – AICTE Training and Learning Academy Faculty Development Program (ATAL-FDP)

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Saraju P. Mohanty

University of North Texas, USA.

**Email:** saraju.mohanty@unt.edu **Website:** http://www.smohanty.org

# Outline

- Need for Smart Agriculture
- Agriculture → Smart Agriculture
- Factors affecting type of crop
- Technologies used in Smart Agriculture
- Smart Agriculture – Case Studies
- Challenges and Issues in Smart Agriculture
- Smart Agriculture Applications
- Smart Agriculture & FL
- Supply chain- Practical Implementation
- Security and Privacy Challenges in Smart Agriculture
- Research Publishing – Best Practices

# Smart Agriculture – Drivers → The Need

# Global Population Explosion

- Global population expected to be 9 billion by 2050 compared current population of 7.8 billion.
- Population → Demand for natural resources → Demand for food
- Need of the Time: Make the agriculture utilize fewer natural resources, increase yield and make the farms climate independent.

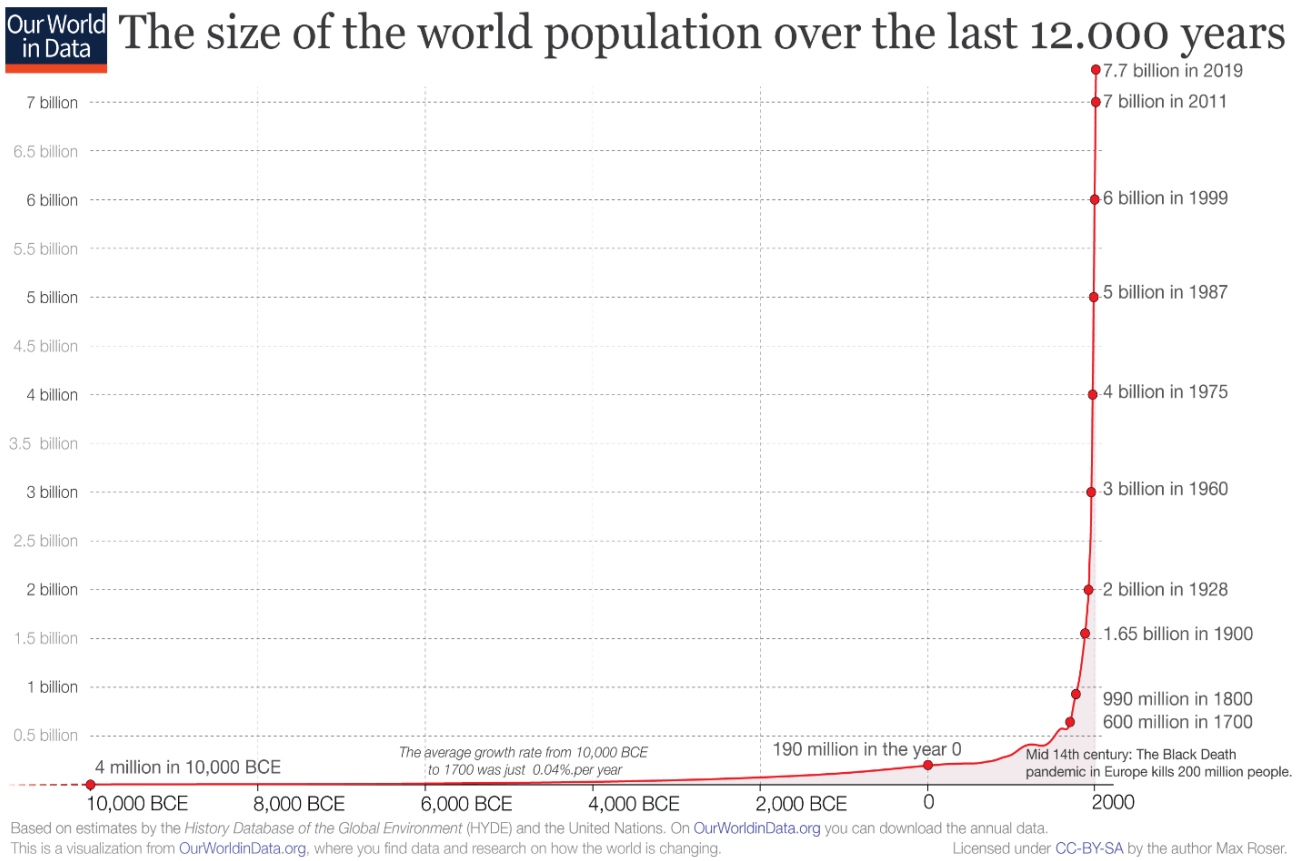


Image Source: https://ourworldindata.org/world-population-growth

# World Hunger

- According to world hunger clock, 828 million people are under nourished.
- Controlling population is one way of tackling with raise in demand of food.
- Increase the agriculture production is one more remedy which can reduce World hunger.

# Can we Have Any Crop, at Any Place?

- The factors determine the type of crop that can be farmed based on different environmental properties:
  - Climate
  - Elevation
  - Slope
  - Soil
  - Water availability
  - …
  - …

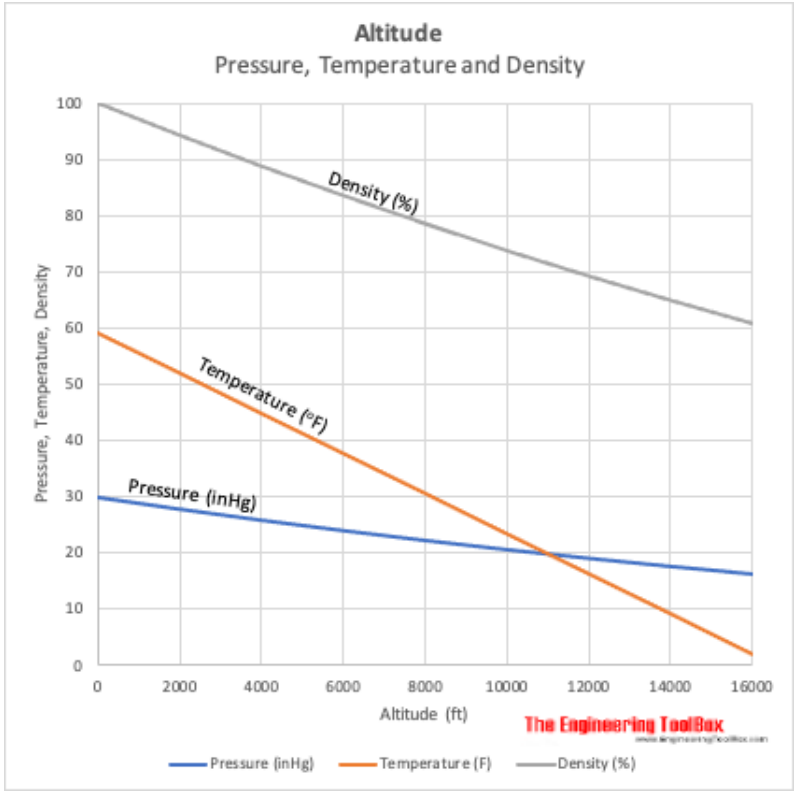
# Any Crop, Any Place: Climate

- Precipitation, sunlight, latitude, longitude
- Snow cover, water bodies $\in \boldsymbol{Climate}$;
- $\boldsymbol{Crop\ Yield} = \boldsymbol{f}(\boldsymbol{Climate})$.
- Growing Degree Days (GDD) = $\frac{\boldsymbol{Max.Temp+Min.Temp}}{\boldsymbol{2}} - \boldsymbol{Base\ Temp}$;
- $\boldsymbol{Crop\ Growth} = \boldsymbol{f}(\boldsymbol{GDD})$.
- $\boldsymbol{Types\ of\ Crops} = \boldsymbol{f}(\boldsymbol{Climate})$.

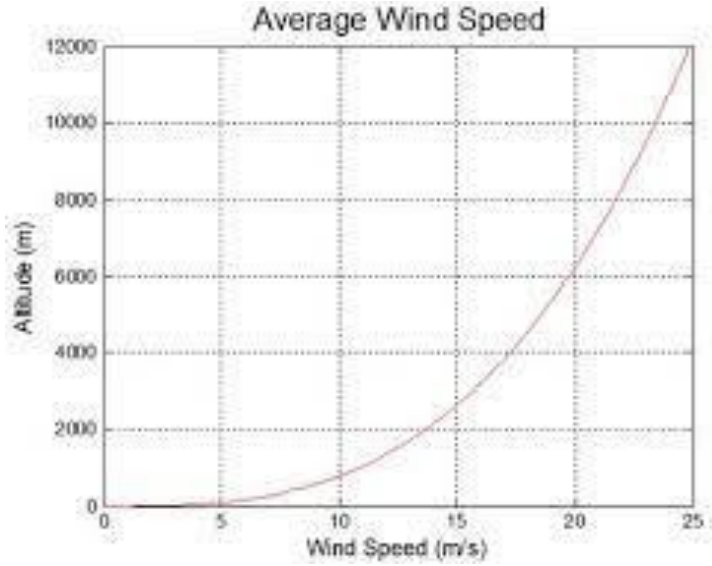
Growing Degree Days (GDD) aka Growing Degree Units (GDUs)
→ a measure of heat accumulation
→ used by farmers to predict plant and animal development rates: date that a flower will bloom, a crop will reach maturity, or an insect will emerge from dormancy

# Any Crop, Any Place: Elevation and Slope

- Affects soil formation, water drainage, and availability.
- Limits Arable land.
- 1% of crops are grown with elevation greater than 2000m (e.g., wheat, rye, oats, barley and some vegetables.)




https://www.engineeringtoolbox.com/air-altitude-temperature-d_461.html




https://www.quora.com/Does-wind-speed-increase-at-higher-altitudes-Considering-that-the-air-gets-thinner-it-would-be-assumed-that-the-wind-speed-would-reduce-as-well

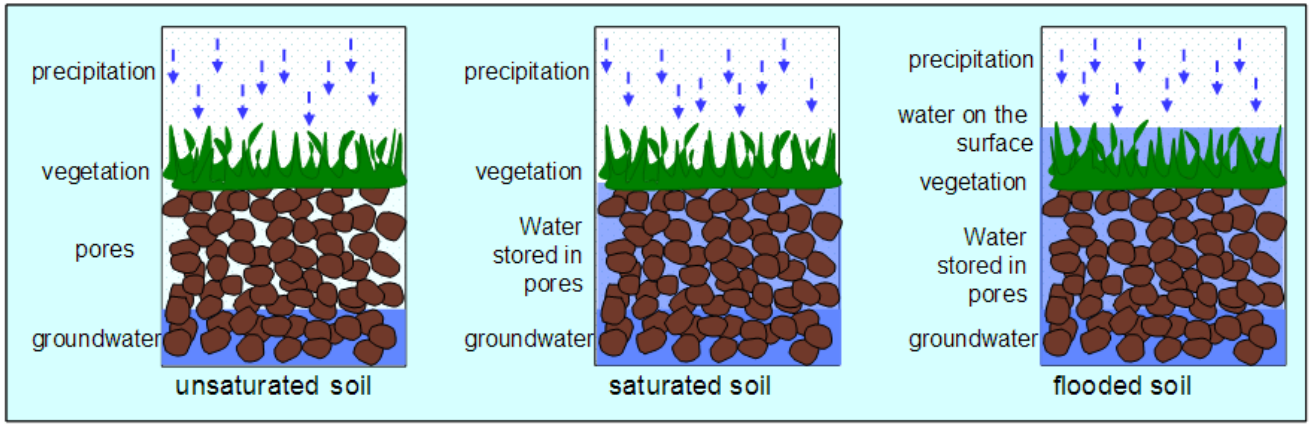
# Any Crop, Any Place: Soil

- Formed from weathering rocks (source for minerals needed); Organic-matter contents ( source of fertilizers).

- Soil properties effecting the crop:
  - Depth - Approx. 100cm of depth for growth
  - Texture – Determines water holding capacity and root aeration
  - Organic matter content – Breakdowns faster in sandy soils than fine soils
  - Fertility – Potential capacity of soil to support plant growth
  - Minerology – Soil chemical characters like pH, Salinity, Cation-Exchange Capacity (CEC).

# Any Crop, Any Place: Soil Water

- $Soil\ Water = f(Precipitation, Percolation)$
- **Percolation**: Process of a liquid slowly passing through a filter.
- **Precipitation**: Water that is falling out of the sky, e.g., rain, drizzle, snow, sleet, and hail.
- $Types\ of\ Crops, Plant\ Growth = f(Soil\ Water)$.




- Excessive soil water is also a problem during flowering, pollination and grain filling.

# Any Crop, Any Place: Vicious Negative Feedback Cycle

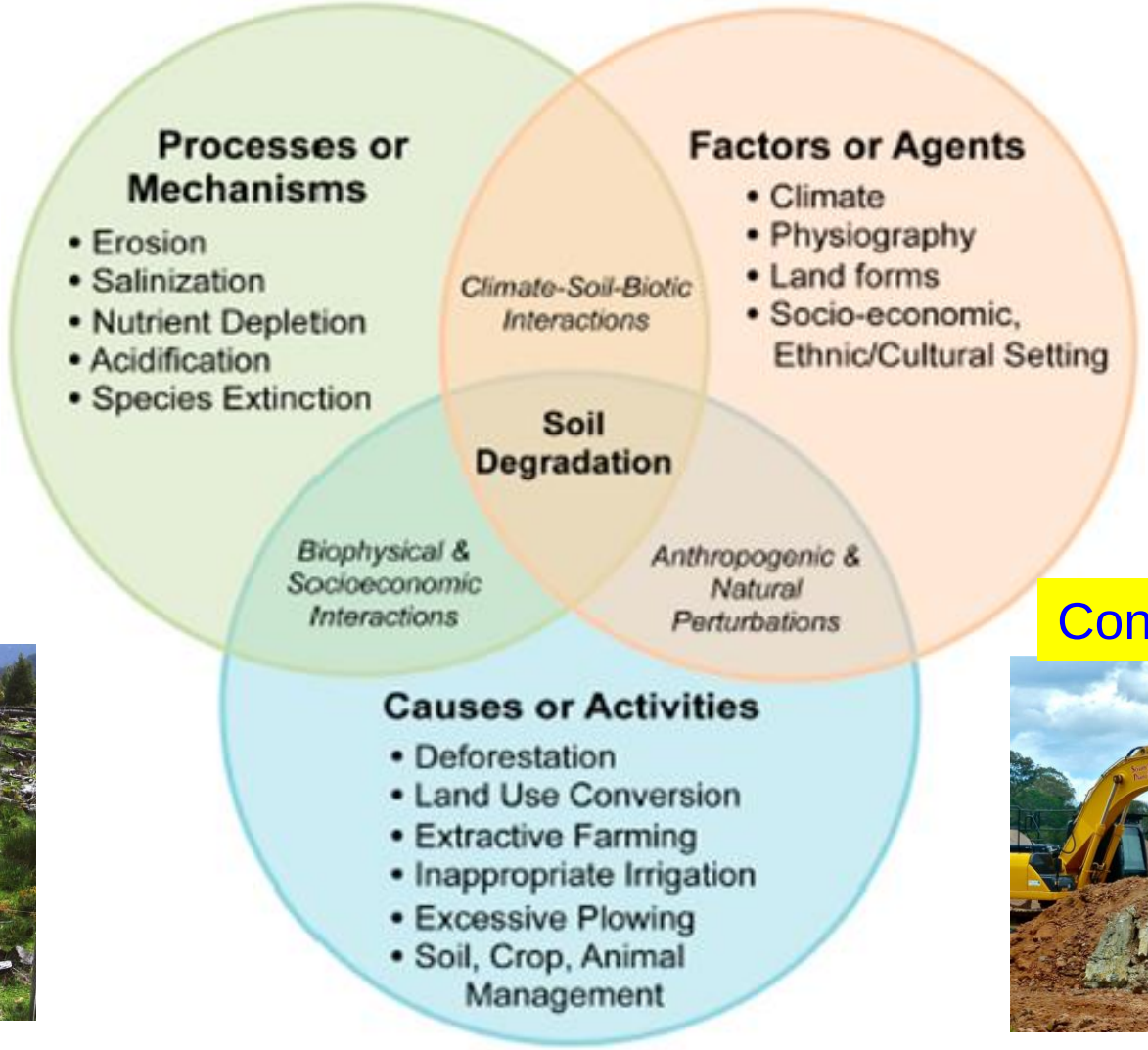
- Land usage for other needs
  - Growth is population is causing the need for residential land which is reducing the amount of arable land available for farming.
  - Growth in population → Need for residential land
  - Growth in population → Demand for farm products
  - Demand for farm products → Need for farmland (Paradoxical)

Vicious Negative Feedback Cycle:
Population Increase → Increase in Need for Residential Land → Decrease in Farm Land → Increased Demand for Farm Products

# Agricultural Land Reduction is a Global Crisis

## Salination

## Deforestation



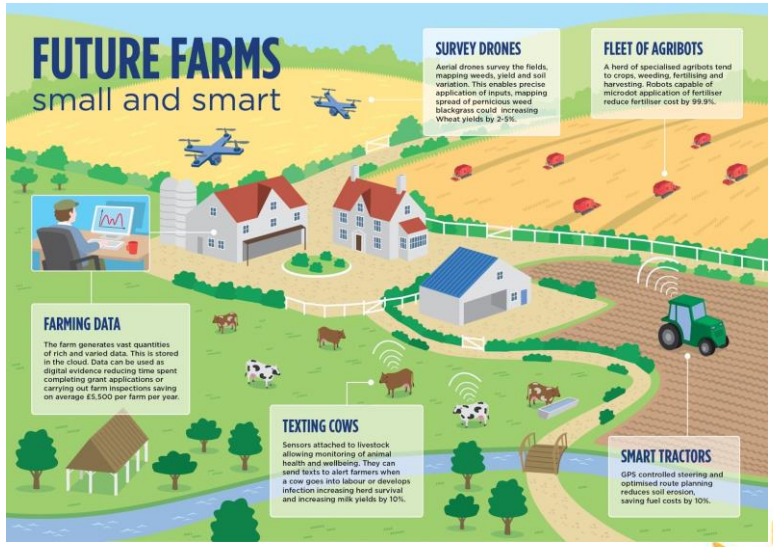

## Soil Erosion

## Construction on Farm Land


Source: https://www.ommegaonline.org/article-details/Restoration-of-Degraded-Agricultural-Land-A-Review/1928

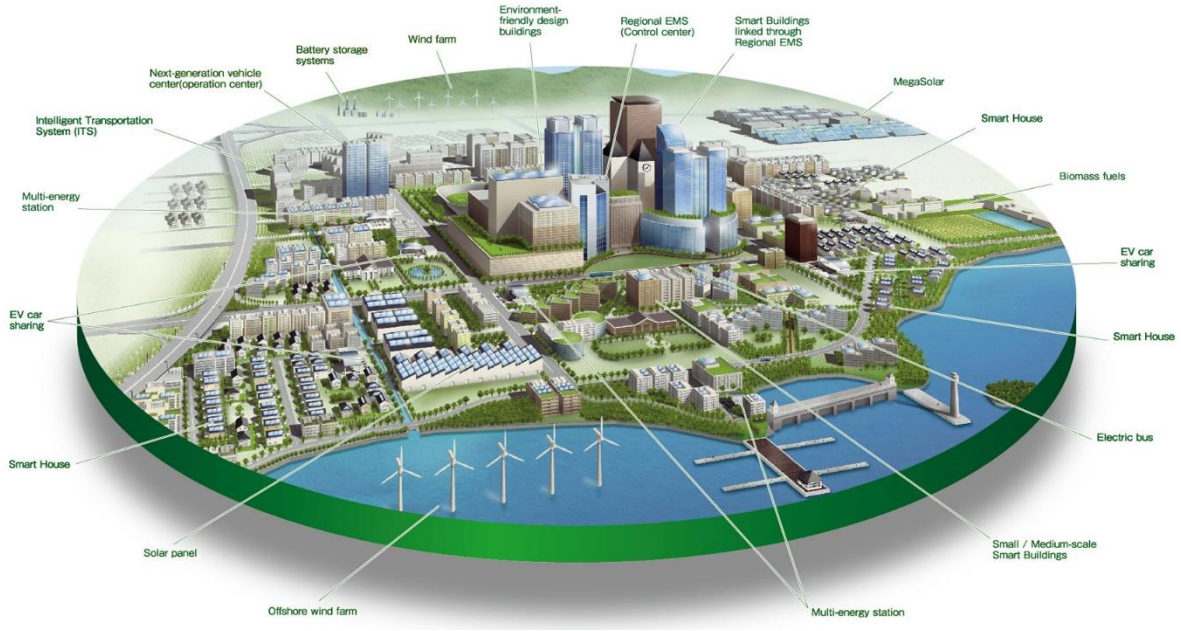
# Solution → Smart Agriculture

- Population control techniques are in place and still have not effectively solving the food scarcity.
- Need to make farms climate and environment resistant.
- Finding ways to cultivate and produce reasonable yield in non-favorable conditions.
- Reduce need of resources such as farm area.

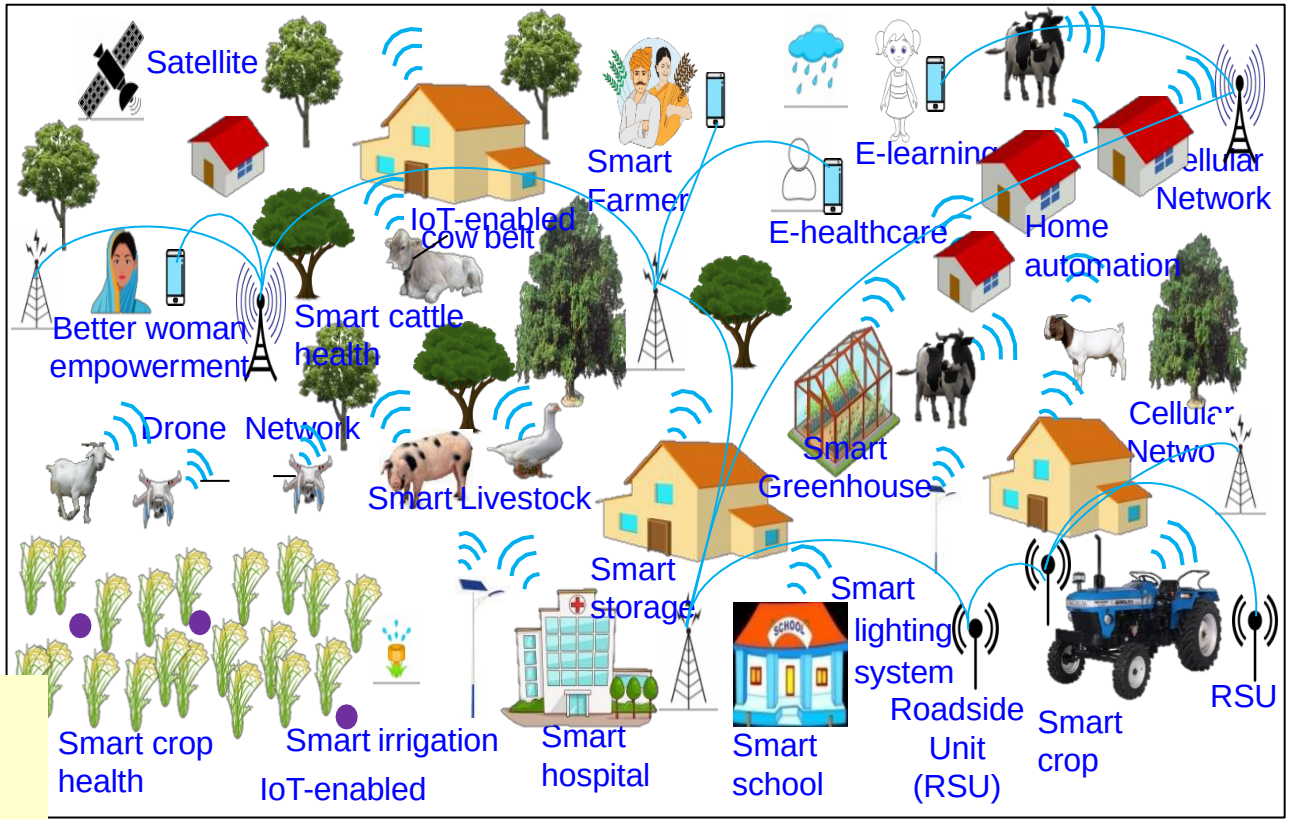



Agriculture or farming is the practice of cultivating plants and livestock.

# Crucial for → Smart Cities and Smart Villages




Source: http://edwingarcia.info/2014/04/26/principal/

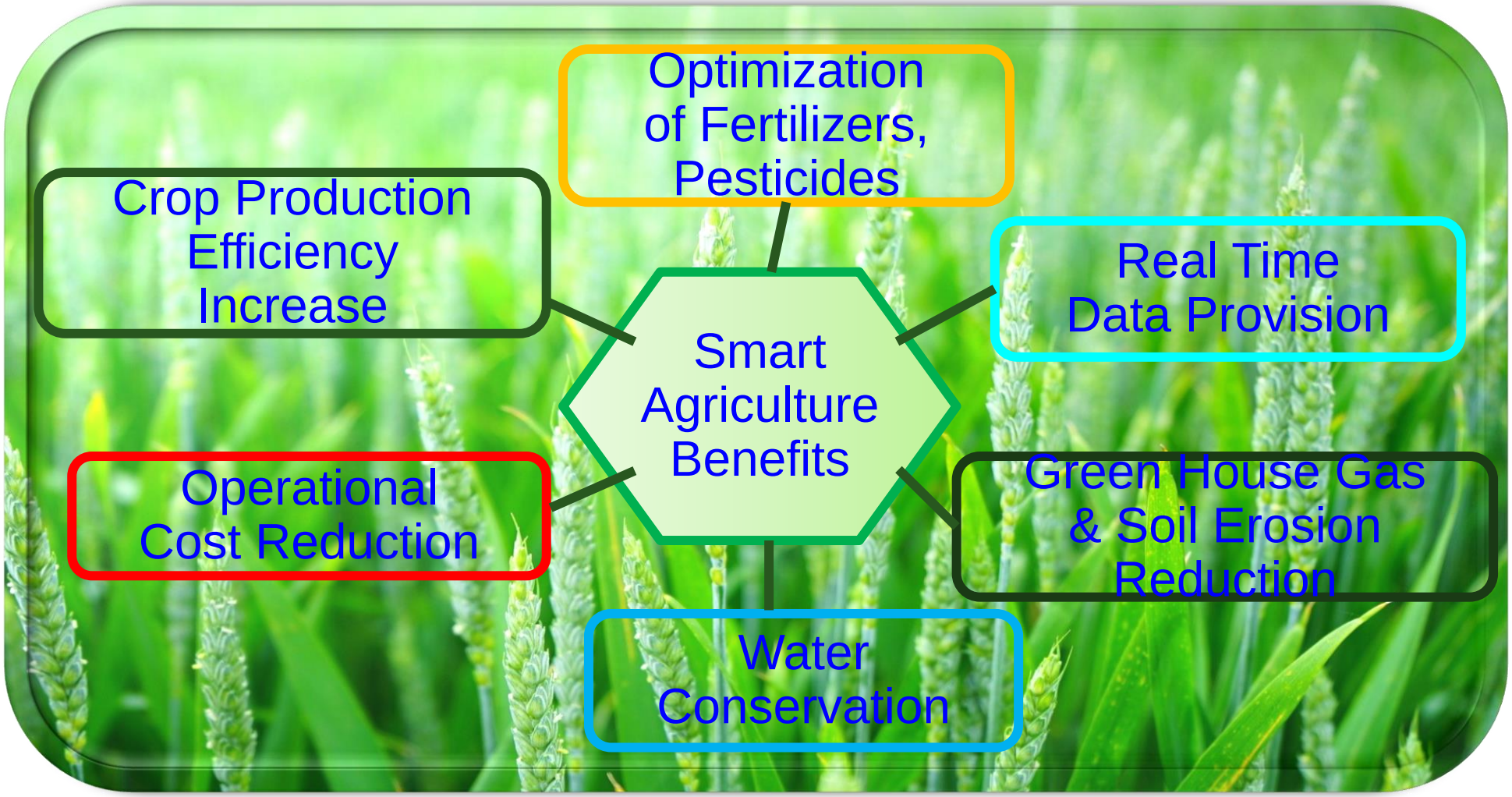



## Smart Cities
CPS Types - More
Design Cost - High
Operation Cost – High
Energy Requirement - High

## Smart Villages
CPS Types - Less
Design Cost - Low
Operation Cost – Low
Energy Requirement - Low

Source; P. Chanak and I. Banerjee, "Internet of Things-enabled Smart Villages: Recent Advances and Challenges," *IEEE Consumer Electronics Magazine*, DOI: 10.1109/MCE.2020.3013244.

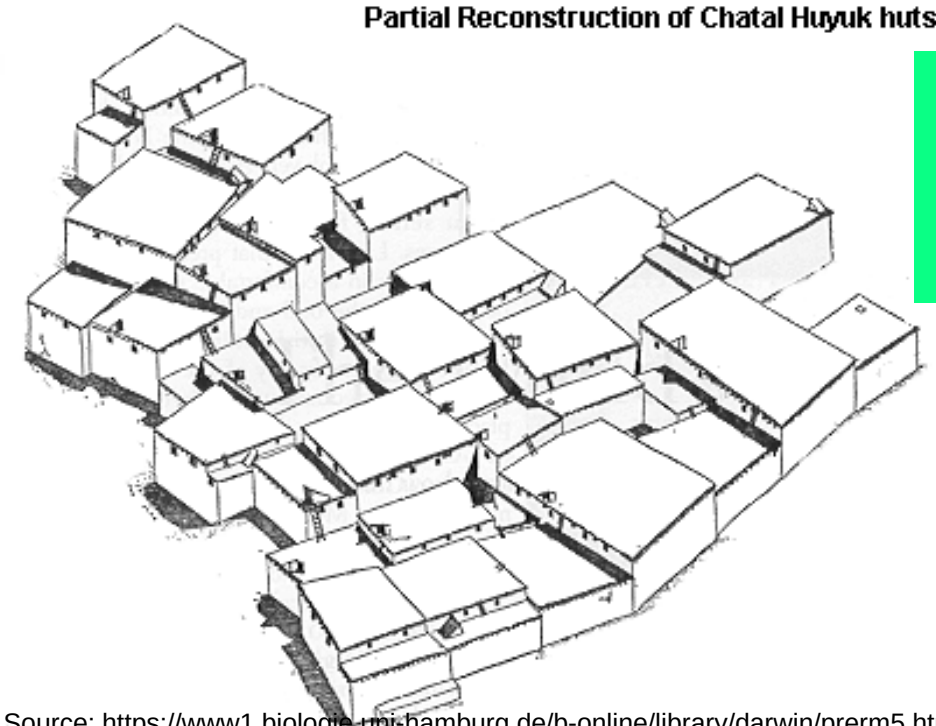
# Benefits of Smart Agriculture




Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Agriculture → Smart Agriculture: Broad Overview

# Cities and Villages - History



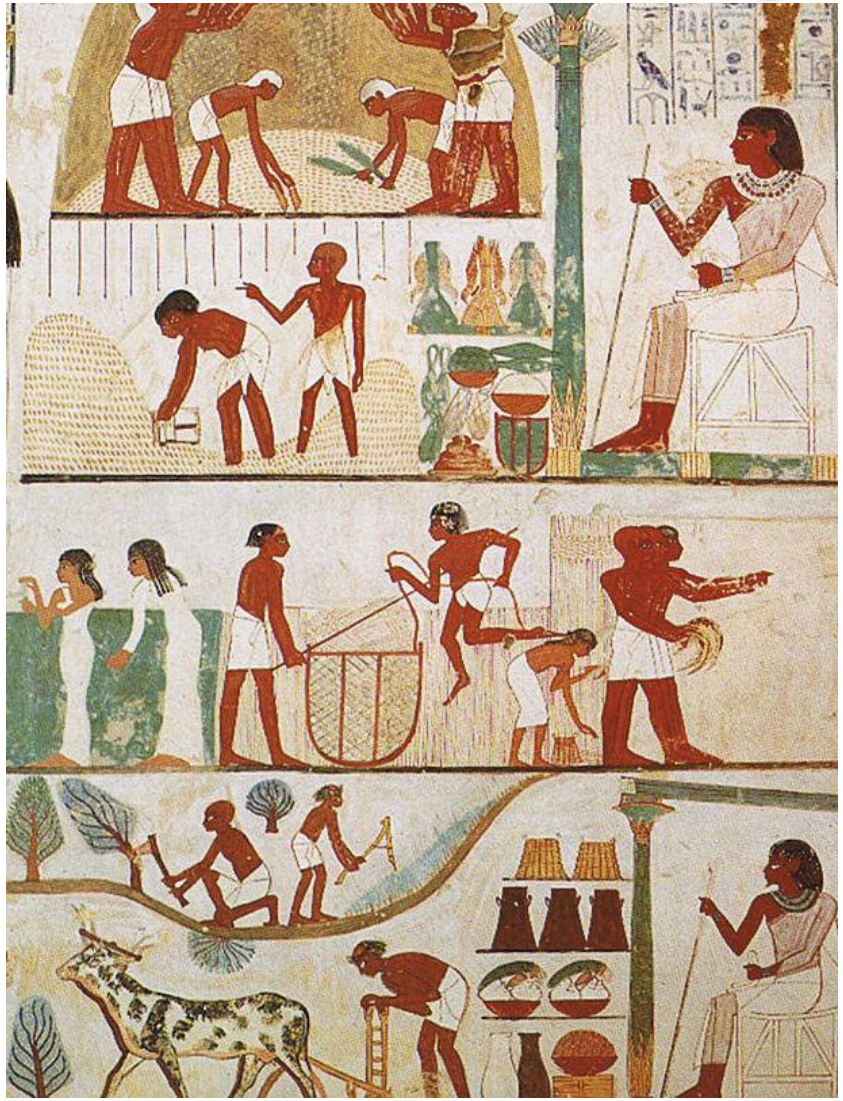

Source: https://www1.biologie.uni-hamburg.de/b-online/library/darwin/prerm5.htm
Based on a reconstruction by Orrin C. Shane III

"First true cities arose in Mesopotamia, and in the Indus and Nile valleys sometime around 3500 BCE."
-- LeGates and Stout 2016, The City Reader

- ✓ After 10,000 BC humans settled down in villages.
- ✓ Neolithic village at Chatal Huyuk in Anatolia (now Turkey) of area 13 hectors built in 7,000 BC.
- ✓ Partial reconstruction of the village gives an idea of buildings.

Indus Valley Civilization (3300 BCE to 1300 BCE)

# Agriculture History



Agriculture or farming is the practice of cultivating plants and livestock.

Agriculture played a Key Role in the growth of civilization.

Ancient Egypt
- 15th century BC (1500 BC to 1401 BC)

# Agriculture is the Key Factor of Civilization

- 10,000 BC: Farming started by Ancient Egyptian Civilization on the Nile River.
- 9,000 BC: Indus Valley civilization started wheat and barley.
- 8,000 BC: Sumerians started to live in villages near the Tigris and Euphrates rivers and made a canal system for irrigation.
- 8,000 BC: Asian rice was domesticated on the Pearl River in southern China.
- 3,000 BC: Americas farmed squash, beans, and cacao.
- 2,500 BC: Animal-drawn plough in the Indus Valley Civilization.

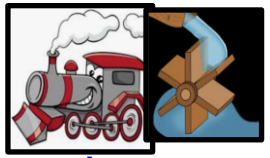
# Agricultural Evolutions & Industrial Revolutions

- Indigenous Tools
- Manual work
- Animal Power

**Agriculture 1.0**

1784

**Industry 1.0**



Steam engine and waterpower

1870

**Green Revolution**

- Tractor
- Fertilizer
- Pesticide

**Agriculture 2.0**

1950

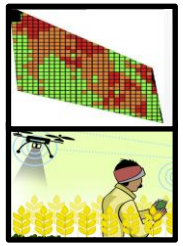
**Industry 2.0**

- Mass production
- Electrical Energy

1969

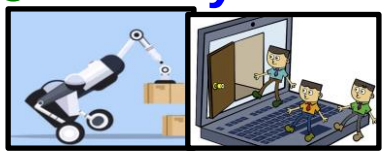
- Variable rate application
- Yield Monitoring
- Guidance System

**Agriculture 3.0**



1992

**Industry 3.0**



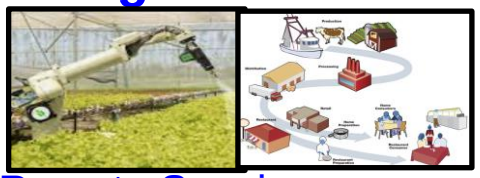
- Automation
- Information Technology

2011

**Groups for Precision Agriculture**

- Remote Sensing
- Trustworthy Supply chain
- Autonomous Farming

**Agriculture 4.0**



2017 **Industry 4.0**


- AI
- IoT
- Bigdata
- Blockchain

2030

**Industry 4.0 in Agriculture**

2050

Source: Y. Liu, X. Ma, L. Shu, G. P. Hancke and A. M. Abu-Mahfouz, "From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges," *IEEE Transactions on Industrial Informatics*, vol. 17, no. 6, pp. 4322-4334, June 2021.

# Precision Farming

- Precision Farming or Agriculture: Farming with optimization, accuracy, and customized solutions for a particular field or crop with the help of different technologies.
- A vital component of this is the use of ICT and a wide array of items such as:
  - Drones
  - GPS guidance
  - Robotics
  - Sensors
  - Soil sampling
  - Telematics

Source: https://www.dtn.com/precision-farming-vs-digital-farming-vs-smart-farming-whats-the-difference/

# Digital Farming

- Digital agriculture is about collecting and analyzing data.
- Develops actionable intelligence and generates substantial added value from data.
- Helps farmers increase production, save money, and reduce hazards.

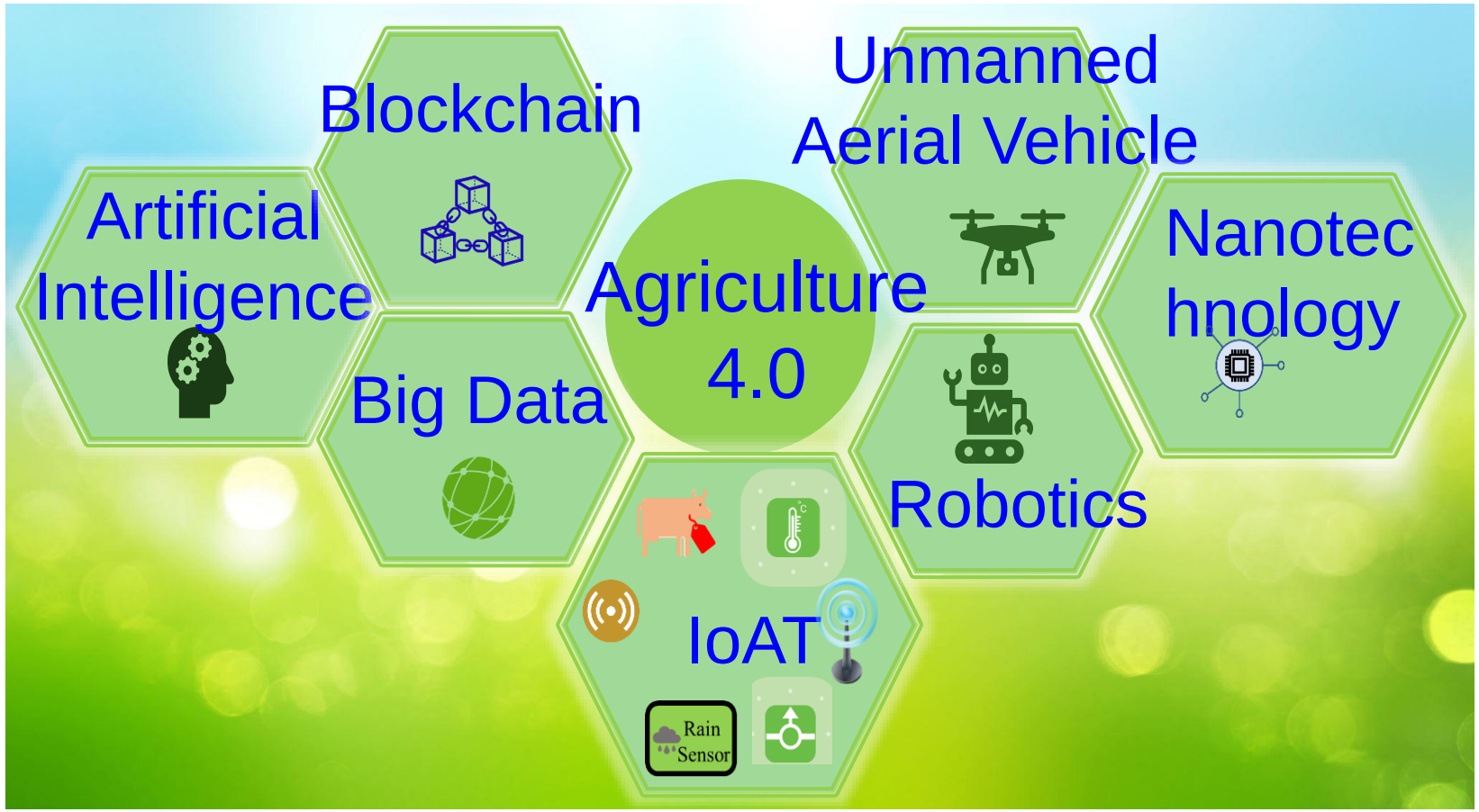
Source: https://www.dtn.com/precision-farming-vs-digital-farming-vs-smart-farming-whats-the-difference/

**“Consistent application of the methods of precision farming and smart farming, internal and external networking of the farm and use of web-based data platforms together with Big Data analyses”.**

**- DLG (German Agricultural Society)**

# Smart Agriculture (sAgriculture)

**"Smart Agriculture"** refers to the usage of technologies like Internet-of-Agro-Things (IoAT), AI, sensors, location systems, and robots on the farm to improve agricultural productivity while optimizing the human labor and land usage.

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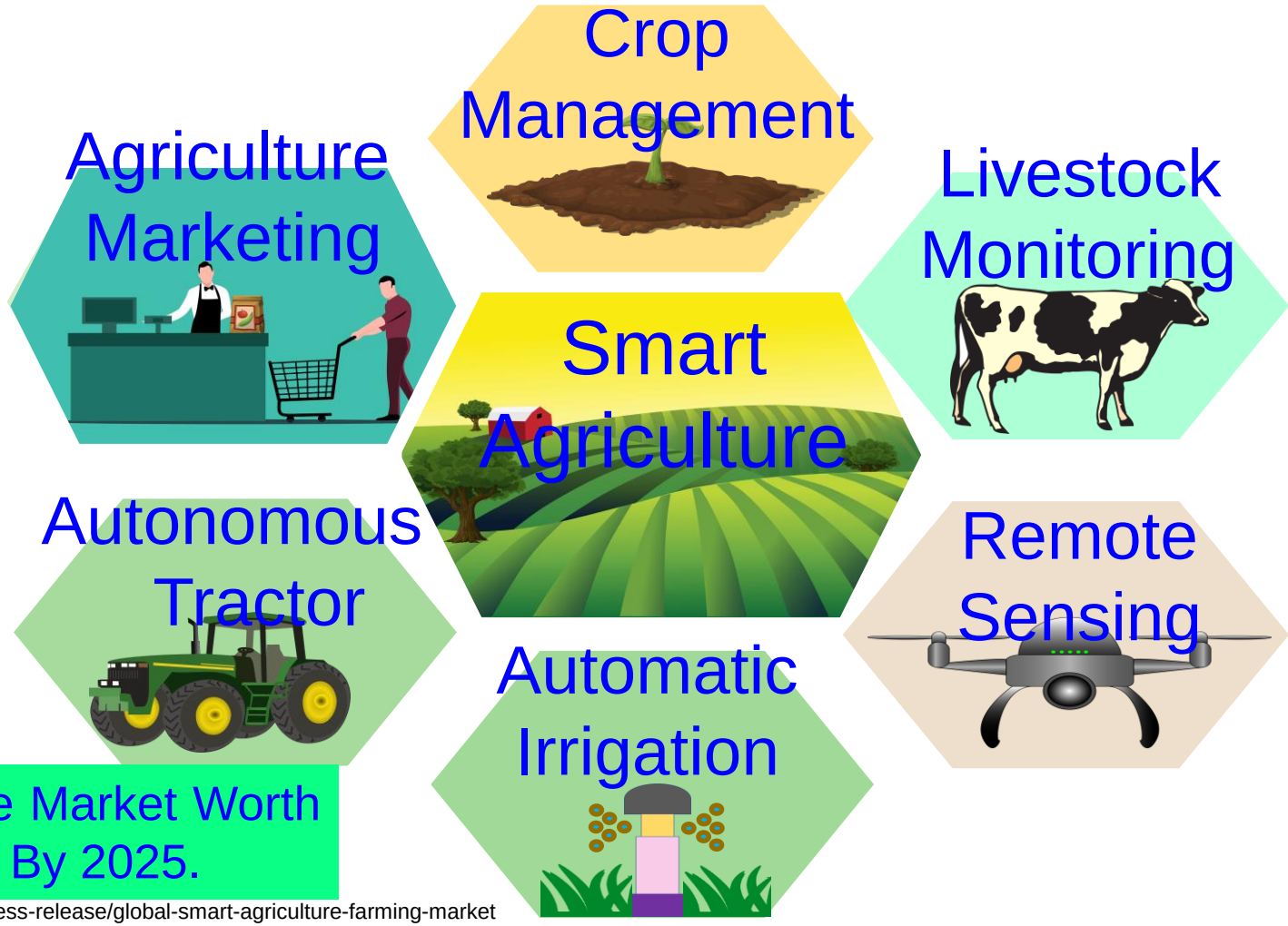
# Agriculture to Smart Agriculture

- Traditional agriculture:
  - manual labor
  - low productivity
  - Climate dependency
  - Limited by geography
- Smart Agriculture:
  - Sustainable
  - Intelligent
  - Efficient
  - Eco-friendly




Smart Agriculture Market Worth US$18.21 Billion By 2025.

Sources: http://www.grandviewresearch.com/press-release/global-smart-agriculture-farming-market

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

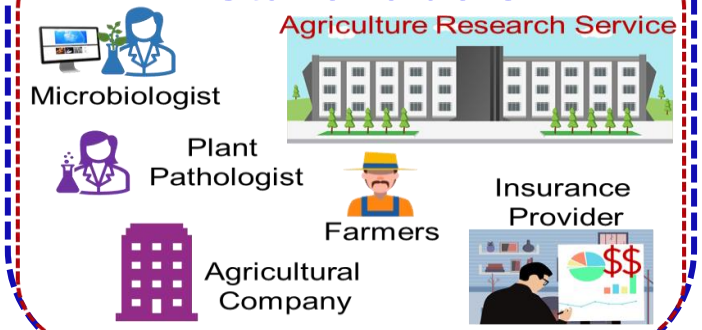
# Agriculture Cyber Physical System (A-CPS)

## Physical Systems

### Things

### Edge Computing Platform

### Stakeholders




Orchard

Smart Village

## Network Fabric

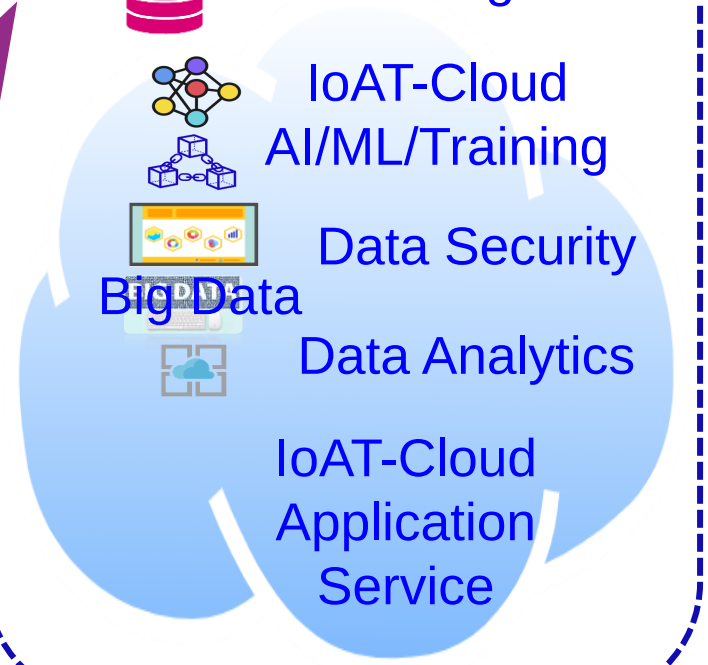

Internet-of-Agro-Things (IoAT) is the backbone of Smart Agriculture

### Edge AI/ML Training

### Local User Interface

### Remote User Interface

## Cyber Systems




Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Applications of Smart Agriculture

Crop Management

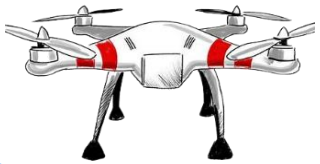
Livestock

Remote Sensing

Autonomous Tractor

Weather Monitoring

Satellite

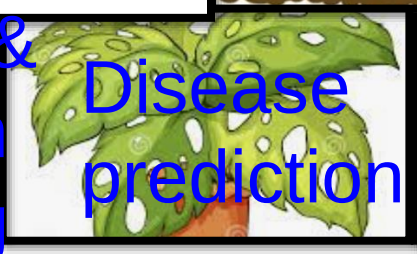


UAV

Soil Monitoring

Crop Monitoring

Disease & Location Tracking



Disease prediction

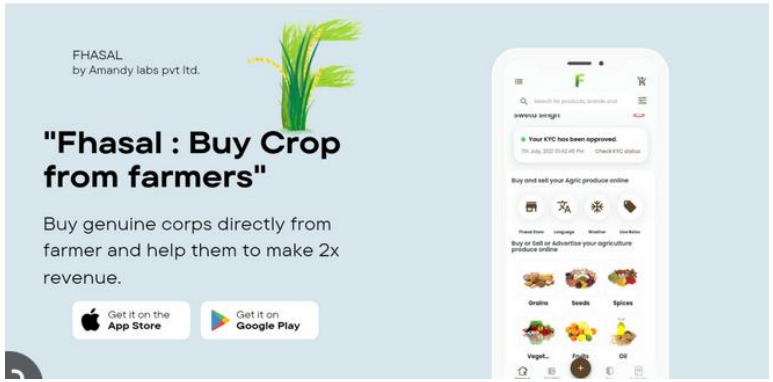
Water Monitoring

Consumers

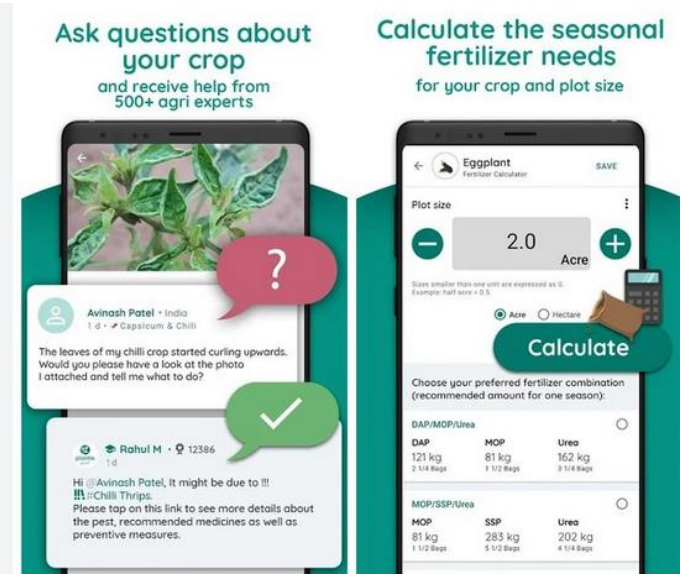
Agriculture Supply Chain

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, S. P. Mohanty, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Smart Agriculture Apps








## Soil Sampler

Farmis
Contains ads

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## BoosterAGRO

Booster Ag Tech, Inc.

4.4★ 2.54K reviews | 100K+ Downloads | Everyone

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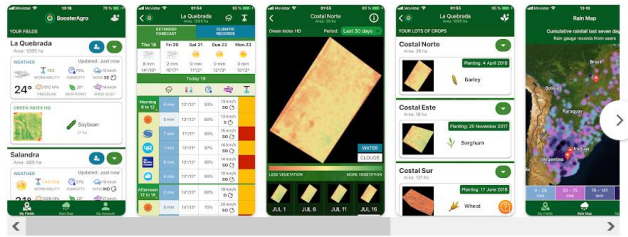

## Crop Farmers App

Bivatec Ltd
Contains ads · In-app purchases

3.9★ 237 reviews | 10K+ Downloads | Everyone

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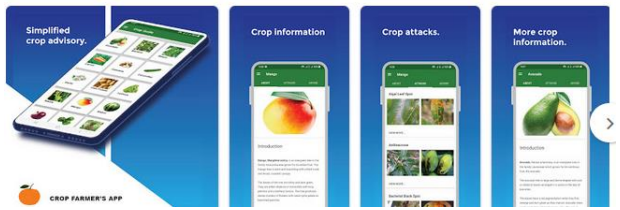
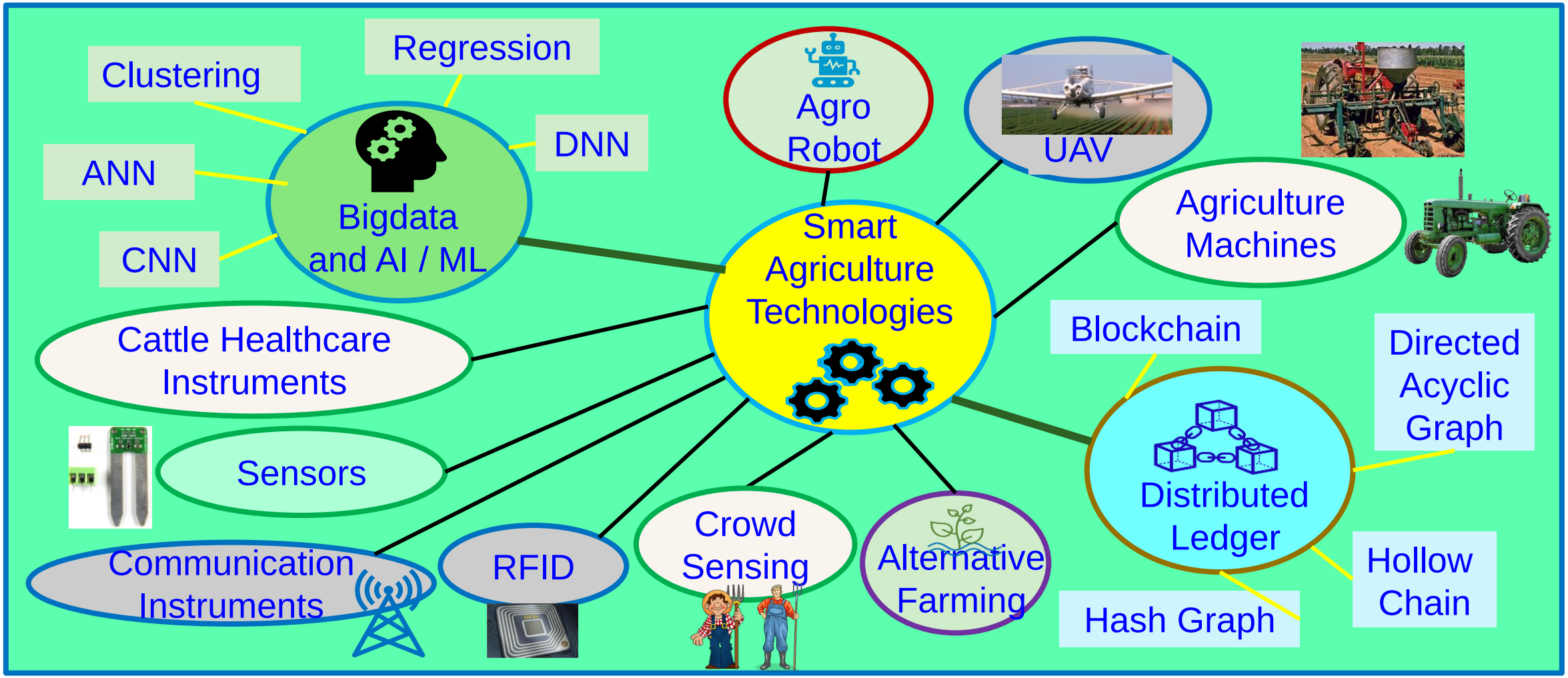


# Smart Agriculture – Technologies

# Smart Agriculture Technologies

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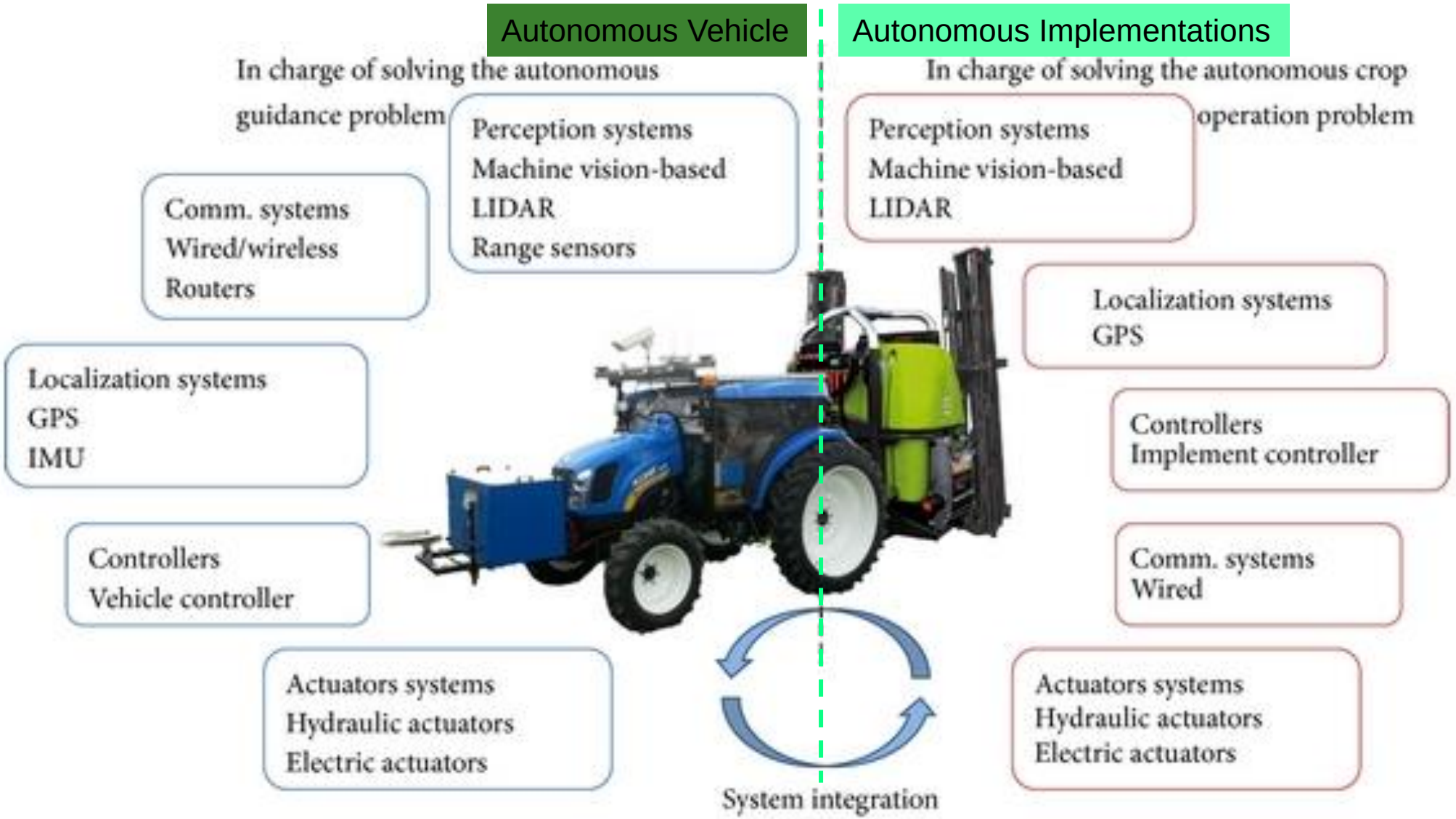
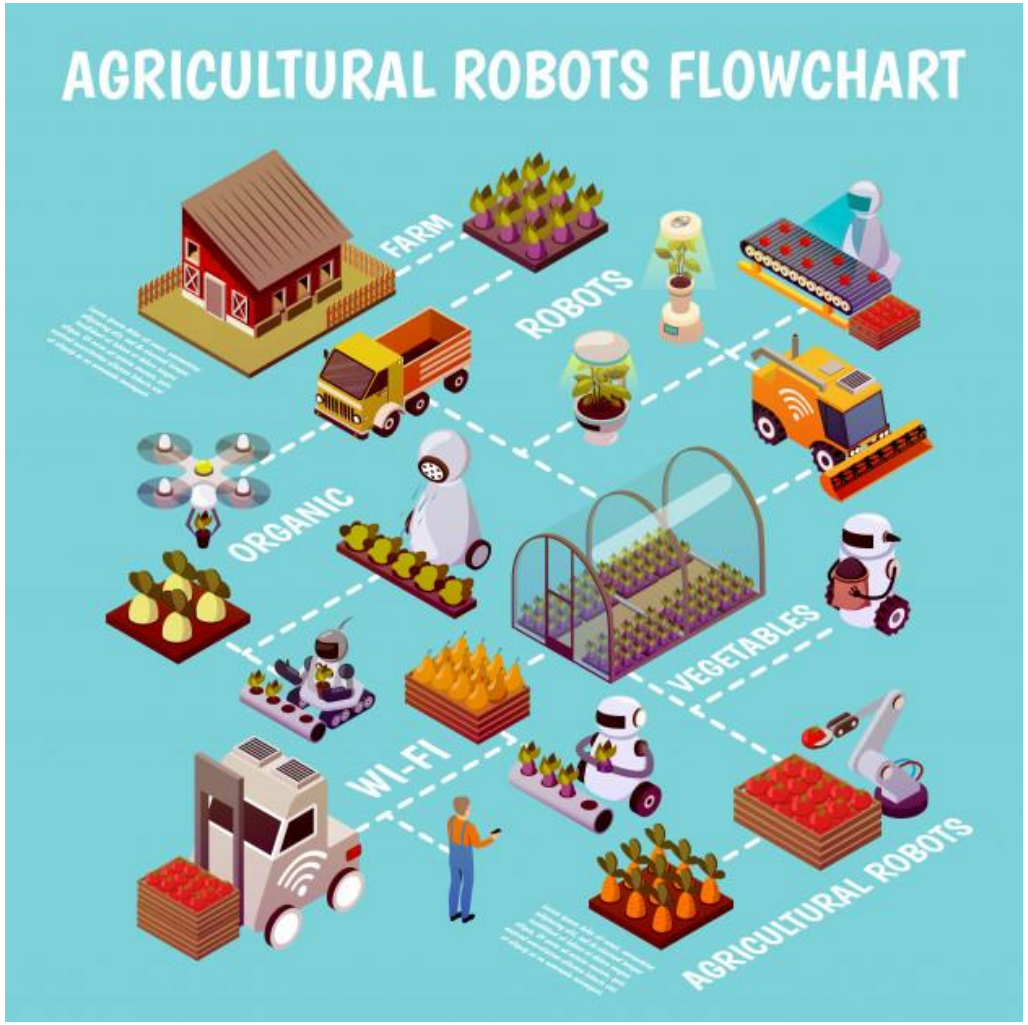
# Driverless Tractors



# Autonomous and Robotic Labor

- Due to migration of people from rural areas to urban areas, there is shortage in labor for farming.
- Use of Autonomous and Robotic labor can increase the productivity and quality of work.



# Drones or UAV for Smart Agriculture

- An automated flying tool which has pre-planned flight and controlled by remote is called a drone.
- Usage includes:
  - Imaging for identification of weeds.
  - Fertilizer and weedicide applications.
  - Weather forecasting.
- Makes use of different sensors, actuators and GPS.

# Planting and Sowing Tools

- Unlike other autonomous applications implemented in the farms, using autonomous robots for planting and sowing is successful.
- It is easy to implement and perform the operations.
- Before planting, seedbed must be prepared for creating favorable conditions.

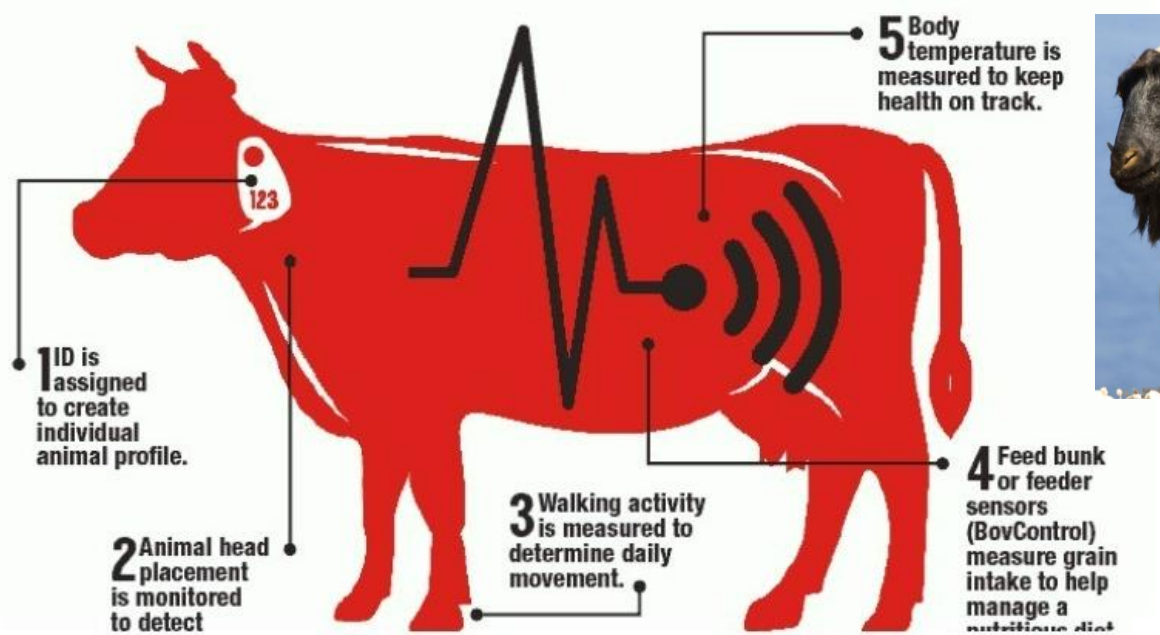
# Automatic Irrigation Systems

- Surface Drip Irrigation (SDI) is used to distribute the water evenly in the farm.
- These SDI are typically controlled manually to increase the efficiency.
- Using moisture sensors to integrate to the SDI can help in better crop yield.
- IoT sensors are integrated with SDI which can also be linked with fertigation (Irrigation water plus fertilizer).

# Livestock Monitoring System


Source: https://www.sensaphone.com/industries/livestock

# Livestock Health Monitoring Instruments

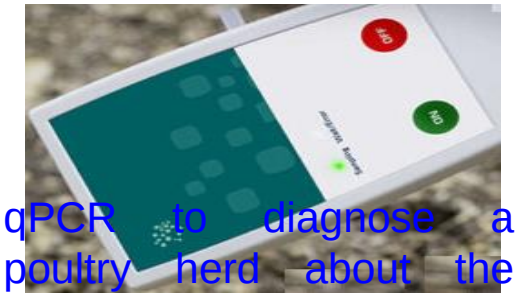



Source: B. Sharma and D. Koundal, “Cattle health monitoring system using wireless sensor network: a survey from innovation perspective”, IET Wireless Sensor System, 8: 2018, pp. 143-151, DOI: https://doi.org/10.1049/iet-wss.2017.0060


Thermometer for horses, dogs, sheep, pigs and cows

Cattle Stomach Healthcare

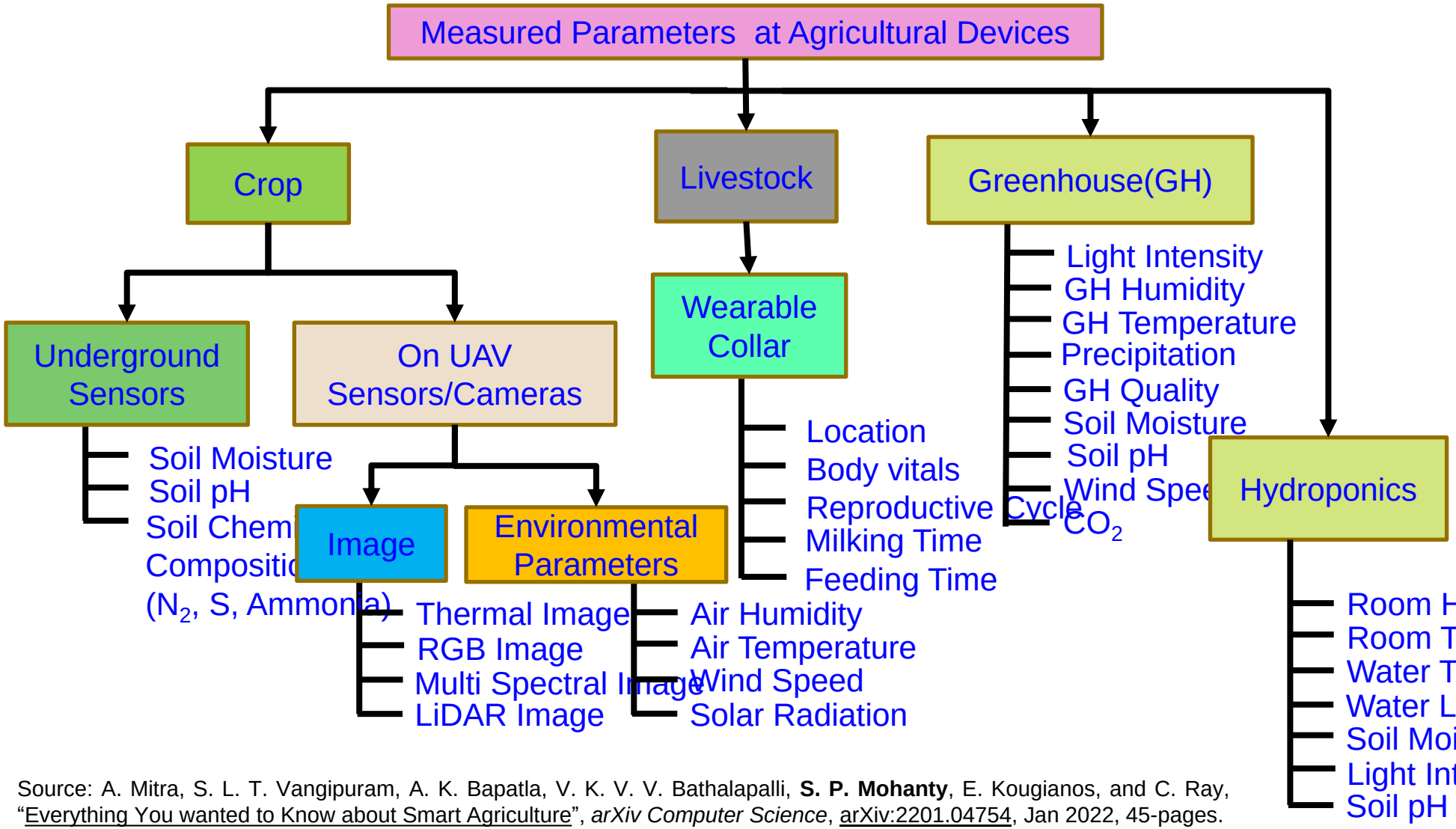

Livestock Heat Stress Monitor



qPCR to diagnose a poultry herd about the presence of bacteria and viruses from air sample


pH, and Oxidation and Reduction Potential (ORP) Sensor for Fish Farm

# Smart Agriculture - Sensors



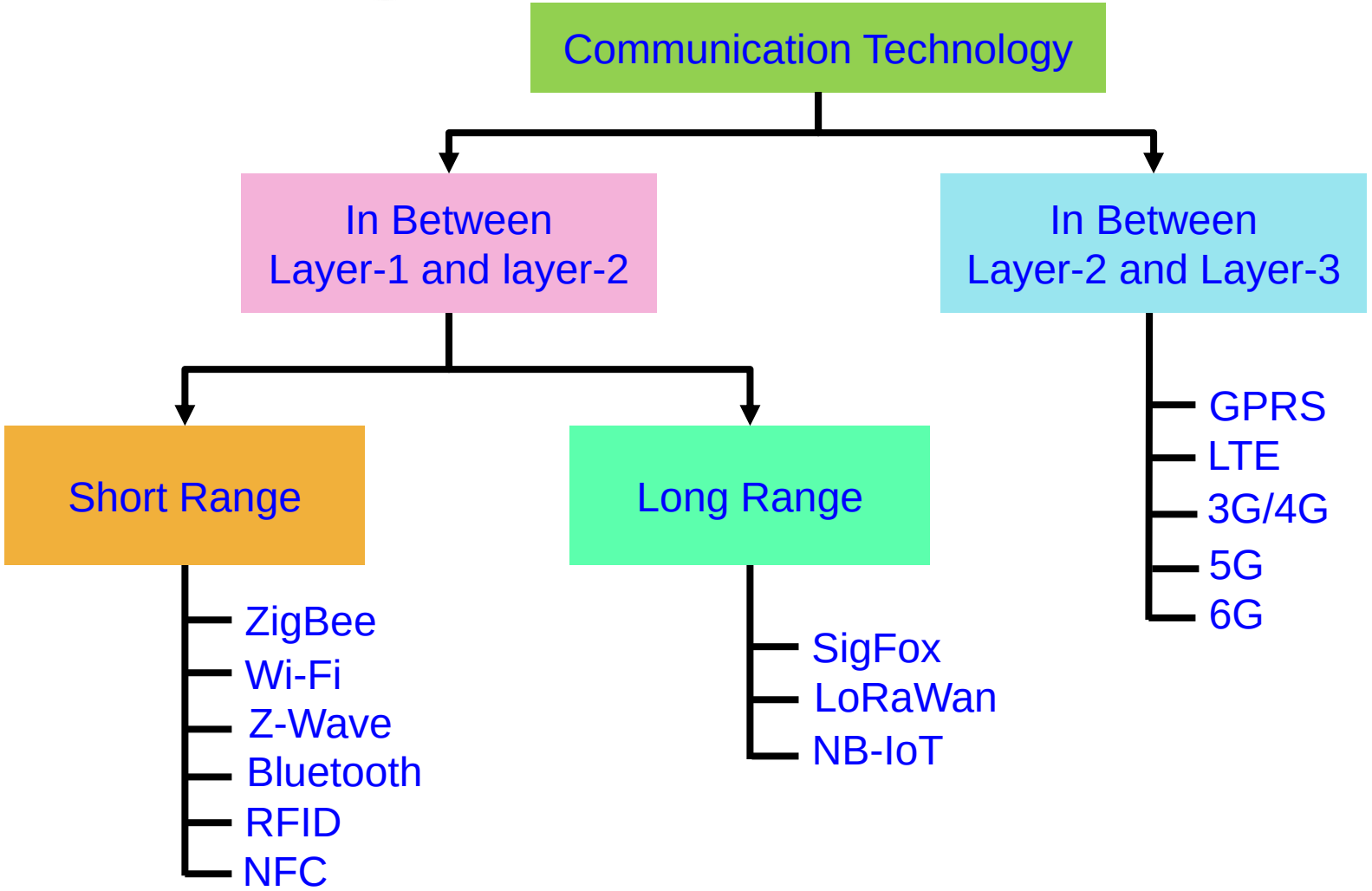


https://www.aliexpress.us/item/3256803422818261.html?gatewayAdapt=glo2usa4itemAdapt&_randl_shipto=US


https://www.rikasensor.com/smart-agriculture-for-iot-applications-air-temperature-and-humidity-sensor.html

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Smart Agriculture – Communication Technology

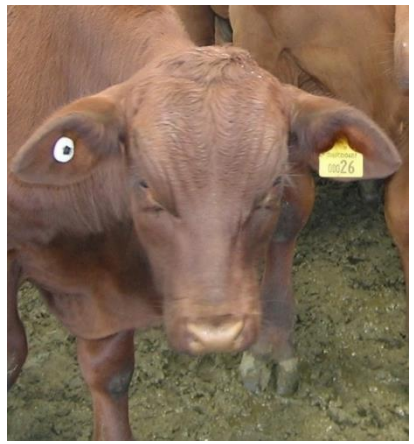



**Connectivity Layer-1 :** Near Range ZigBee, Wi-Fi, Z-Wave, Bluetooth, Radio Frequency Identification (RFID), and Near Field Communication (NFC).

**Connectivity Layer-2 :** Cellular Technologies like Ground Penetrating Radar Services (GPRS), Long-Term Evolution (LTE), 3G/4G, and 5G.

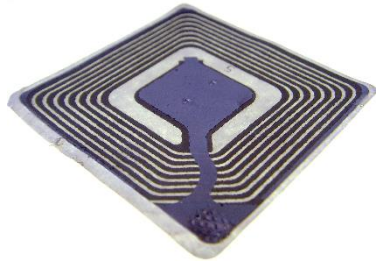
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# RFID Technology



Selected RFID Attacks

- Physical RFID Threats
  - Disabling Tags
  - Tag Modification
  - Cloning Tags
  - Reverse Engineering and Physical Exploration
- RFID Channel Threats
  - Eavesdropping
  - Snooping
  - Skimming
  - Replay Attack
  - Relay Attacks
  - Electromagnetic Interference
- System Threats
  - Counterfeiting and Spoofing Attacks
  - Tracing and Tracking
  - Password Decoding
  - Denial of Service (DoS) Attacks




Numerous Applications

Source: Khattab 2017: Springer 2017 RFID Security

# Smart Agriculture – AI/ML Technology

Crop Management

Soil Management

Smart Irrigation

Pest / Disease Control

Weed Control

Livestock Management

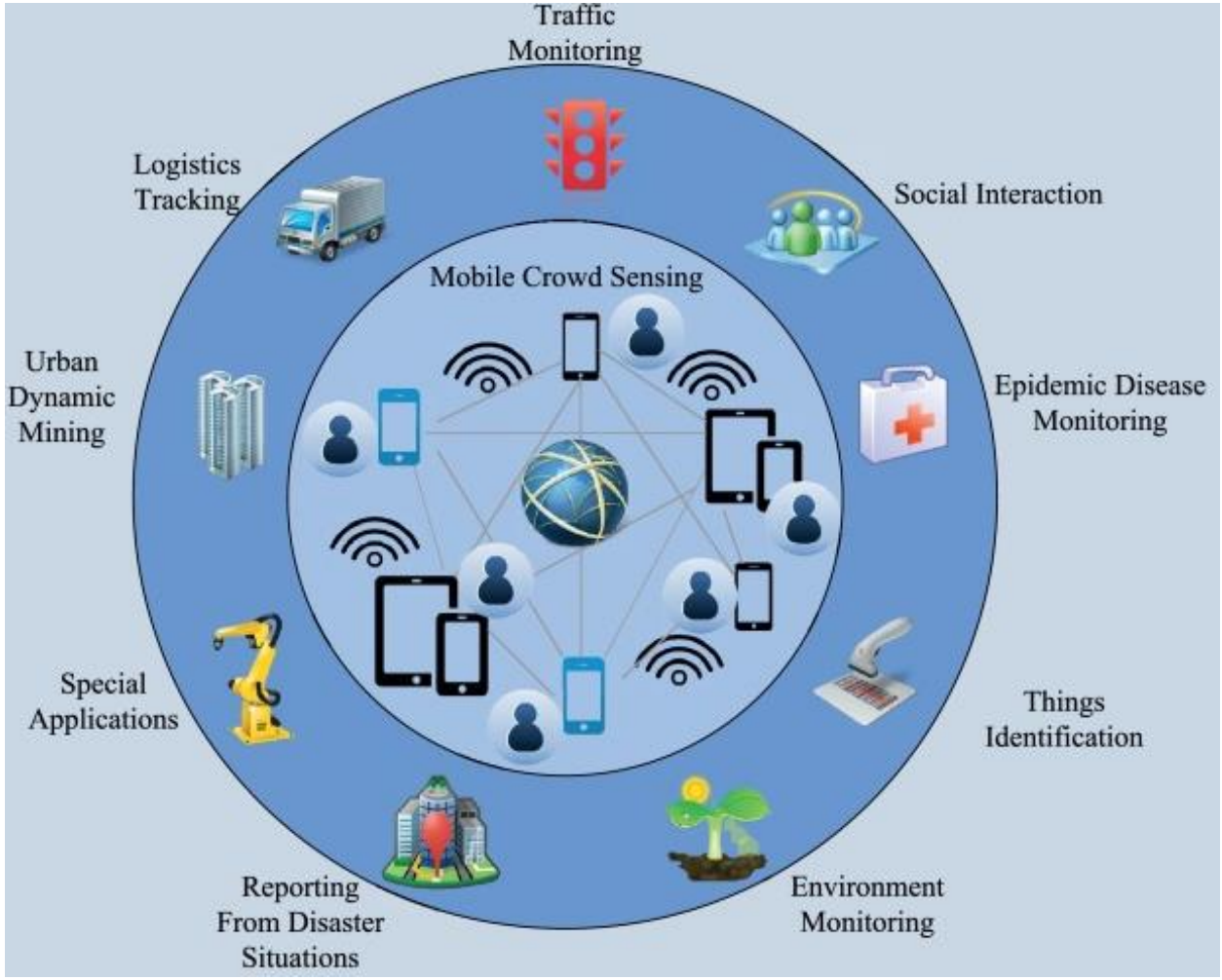
Alternative Farming

SVM ANN DNN CNN Regression Bayesian Models Decision Tree Fuzzy Logic
Clustering Instance Based Models Ensemble Learning Long Short Term Memory

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Agriculture Data – Crowd Sensing

- Data is an asset.
- Helps in communicating farm related issues with stakeholders.
- Smart phones and wearable devices are used to collect data from the farms.
- Advantages include low cost, scalable and mobility.
- Components of crowd sensing: Data processing technology, Incentive Mechanism, Crowd sensing software platform

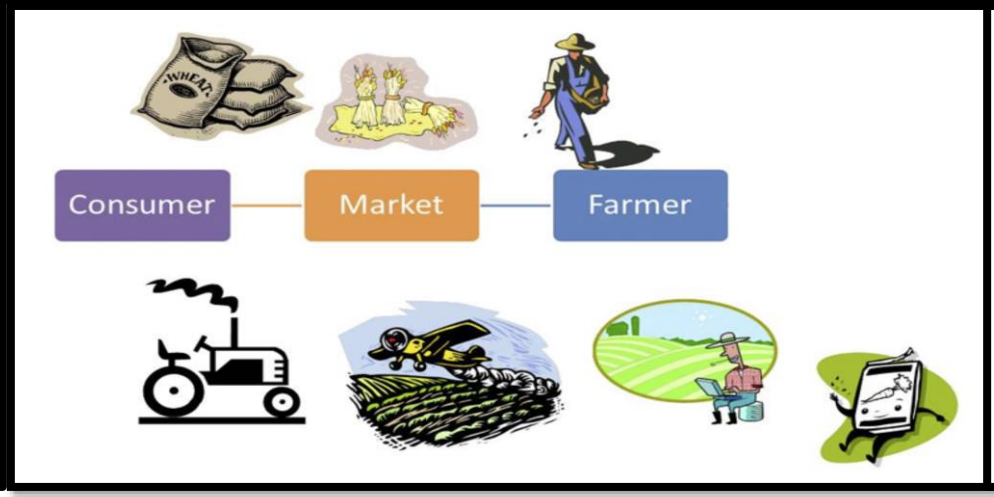


# Roles of Blockchain in A-CPS

**Visibility** **Food Safety** **Provenance** **Traceability** **Farm Supervision**





**Land Registration** **Supply Chain** **Farmer Incentives**

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# Smart Agriculture – Some Challenges

# Smart Agriculture – Challenges

Power Availability

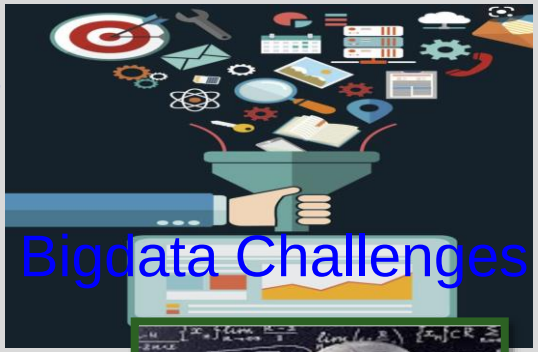
Networking and Communication

Reliability

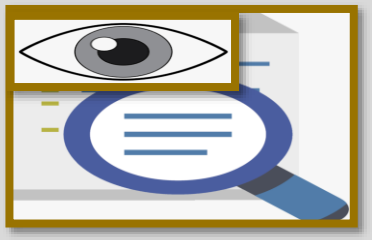
Scalability

Hardware Security


Farmer's Learning Curve



Bigdata Challenges



Data Security and Privacy

Natural Disaster

Technical Malfunction

AI Challenges

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Learning Curve for Smart Agriculture can be Long

- Smart Agriculture requires setting up of IoT architecture and sensor networks.
- Errors in such setup can lead to drastic losses in the farms.
- Farmers should be thoroughly acquainted with usage of this technology.

# Connectivity can be an Issue in Rural Areas

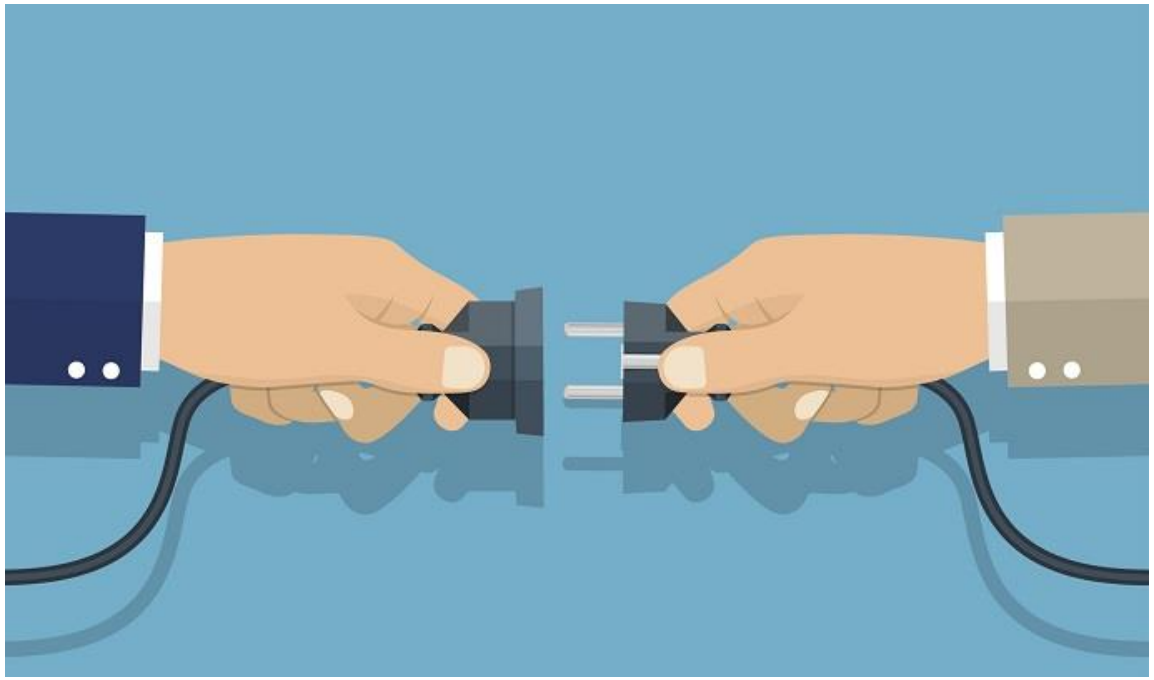
- Reliable internet connectivity is not possible in many of the remote villages in the world.
- Network performance and bandwidth requirements may not be achieved because lack of the infrastructure as in urban areas.
- Delay in real-time applications if computing is dependent on IoT-cloud.

# Energy Depletion Risks

- Smart agriculture may reduce need for resources but needs lot of data centers.
- All the infrastructure used will consume large amounts of energy which may cause energy depletion.

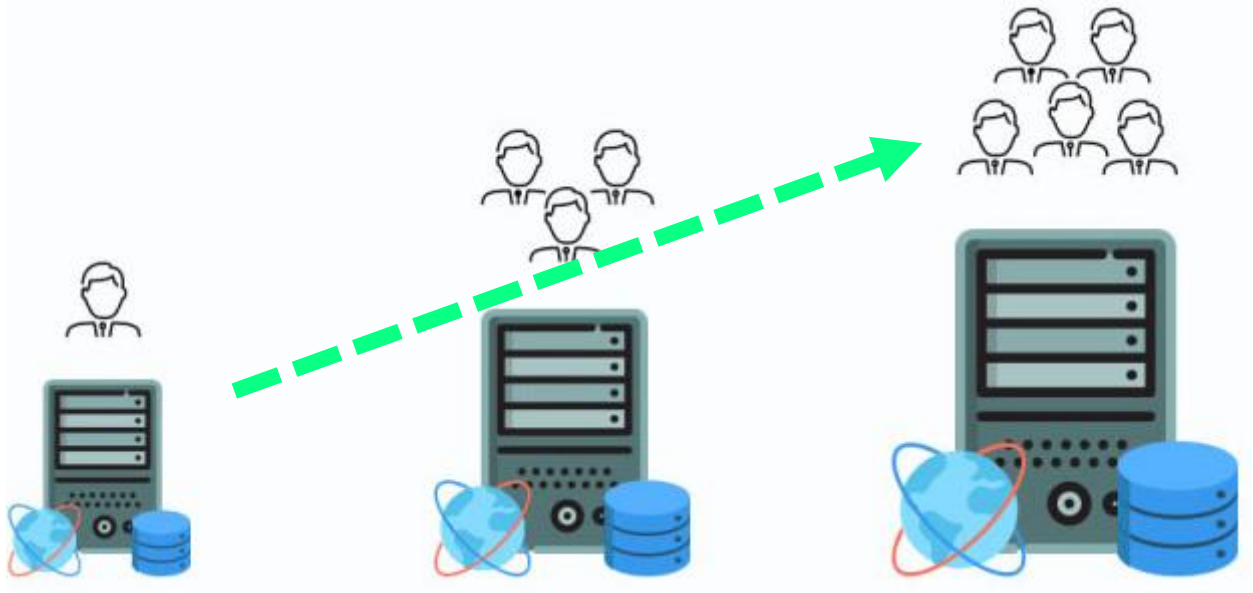
# Interoperability Can be an Issue for the Smart Agriculture Equipment

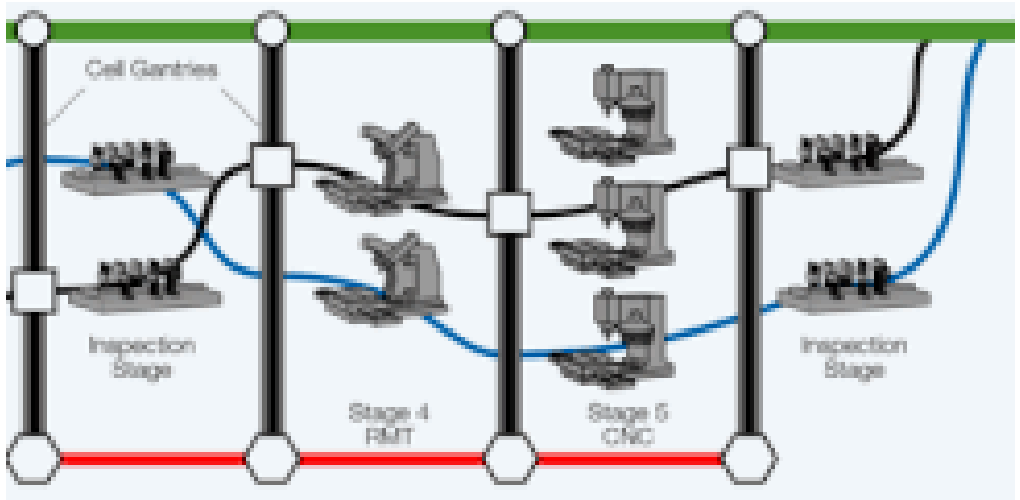
- Technologies used in Smart Agriculture are developing rapidly.
- Lack of technology standards → Interoperability issues.
- Creation of additional gateways to translate data between two systems is more common.
- Solution lies in making the standalone devices and gateways to farmer-friendly platforms.



# Lack of Scalability and Configurability

- Farms can be any size, single owner can have large farms or several small farms.
- Same technology should be capable enough to handle different variety of farmlands in dimension and nature.
- Technologies used should be self-configurable.





# Technical Failures

- Even most resilient systems will have failure due to unforeseen events.
- Such events in Smart Agriculture can incur large losses both in terms of money and quality of products.
- Food safety can be compromised because of such issues.

# Challenges of Data in IoT/CPS are Multifold



Data Curation

Data Cost

Data Storage

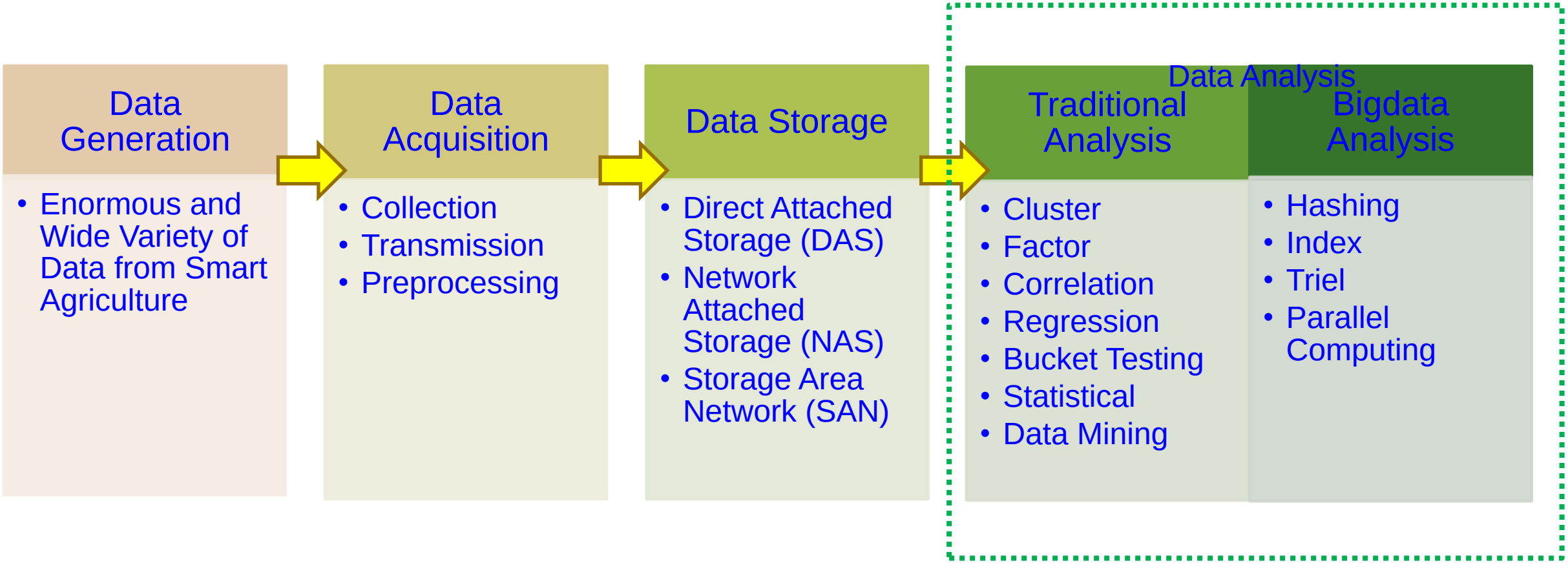
Lots of Data

Data Ownership

Data Modeling

Data Quality

# Bigdata Flow in Smart Agriculture

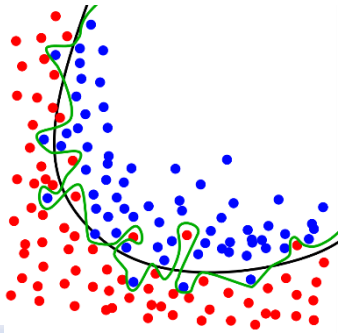


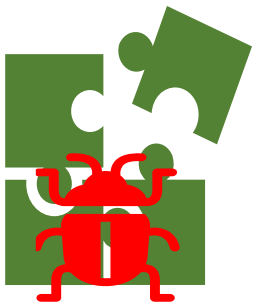

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# AI/ML Modeling Issues

Machine Learning Issues

- High Energy Requirements
- High Computational Resource Requirements
- Large Amount of Data Requirements
- Underfitting and Overfitting Issue
- Class Imbalance Issue
- Fake Data Issue
- Attack on Training Process



Source: Mohanty ISCT Keynote 2019

# Security Issues in IoAT

- Smart Farms are Hackable Farms: IoT in Agriculture can improve the efficiency in productivity and feed 8.5 billion people by 2030. But it can also become vulnerable to various cyber security threats.

  https://spectrum.ieee.org/cybersecurity-report-how-smart-farming-can-be-hacked

  https://cacm.acm.org/news/251235-cybersecurity-report-smart-farms-are-hackable-farms/fulltext

- DHS report highlights that implementation of advanced precision farming technology in livestock monitoring and crop management sectors is also bringing new cybersecurity issues along with efficiency

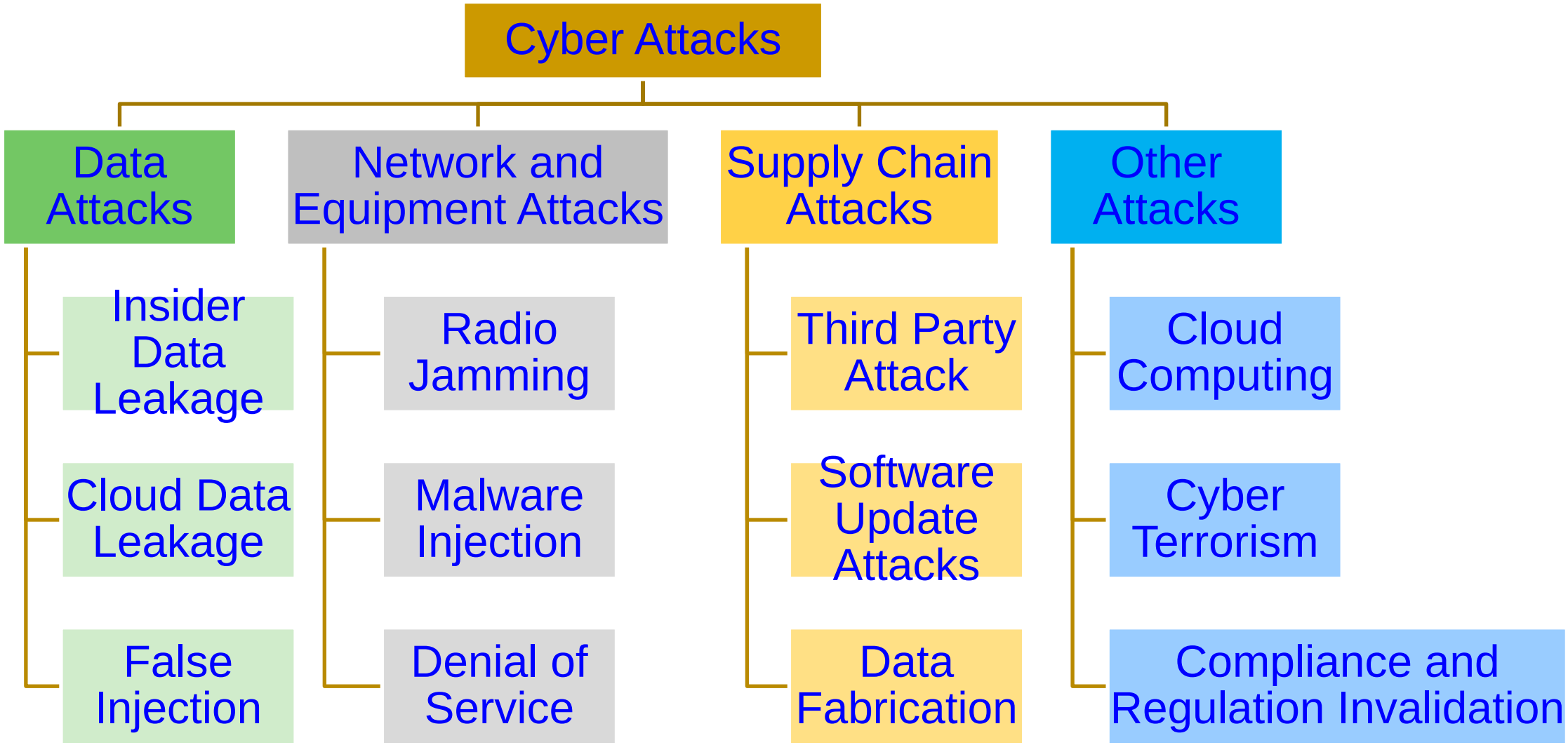
  https://www.dhs.gov/sites/default/files/publications/2018%20AEP_Threats_to_Precision_Agriculture.pdf

# Smart Agriculture - Security Challenges

- Harsh Environment
- Threats from equipment
  - High voltage pulses
  - Interference
- Unauthorized access
- Interception of node communication
- Malicious data attacks
- Control system intrusion

Source: X. Yang *et al.*, "A Survey on Smart Agriculture: Development Modes, Technologies, and Security and Privacy Challenges," *IEEE/CAA Journal of Automatica Sinica*, vol. 8, no. 2, pp. 273-302,

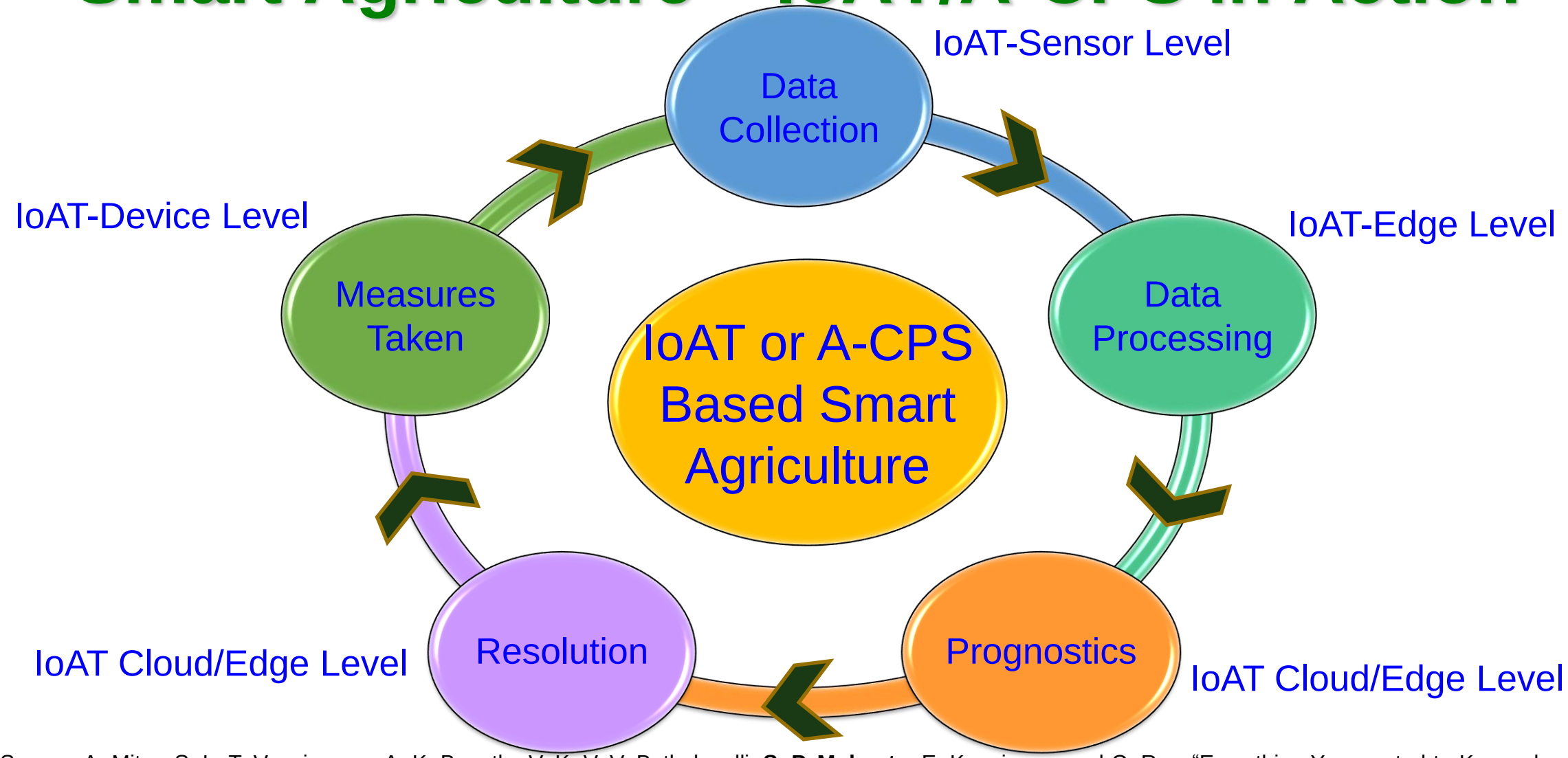
# Smart Agriculture - Security Challenges




Source: M. Gupta, M. Abdelsalam, S. Khorsandroo and S. Mittal, "Security and Privacy in Smart Farming: Challenges and Opportunities," *IEEE Access*, vol. 8, pp. 34564-34584

# Smart Agriculture Case Studies – AI/ML Solutions

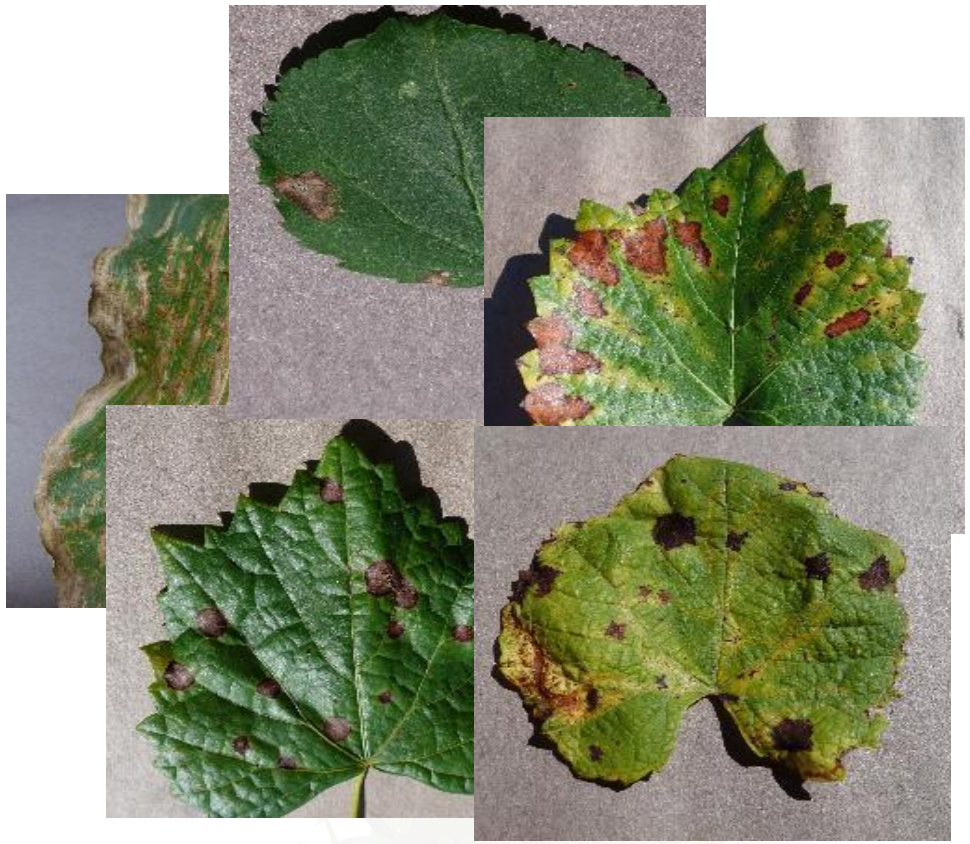
# Smart Agriculture – IoAT/A-CPS in Action




Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Crop Damage and Disease Problem

- Disease prevents the growth of plants.
  - Affect quality of the crop.
  - Reduce final yield.

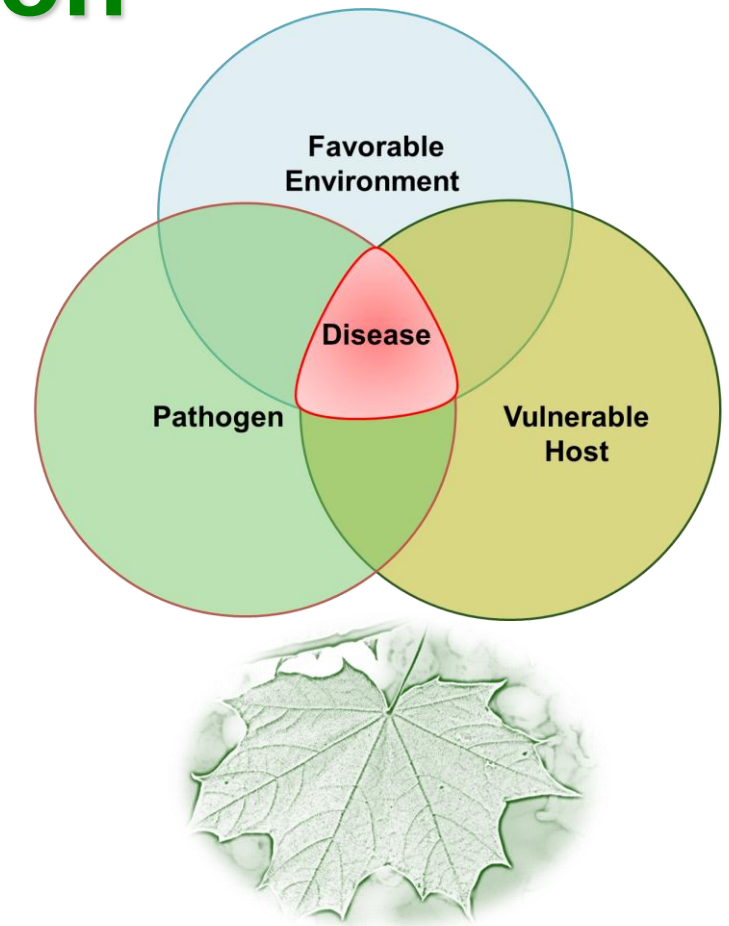


- Farmers need to –
  - Monitor the field regularly.
  - Detect disease early.
  - Identify the disease.
  - Know about the severity of the disease (many of them).
  - Determine the extent of damage (from disasters).

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Automatic Plant Disease Detection and Leaf Damage Estimation

- Plants, like all living things, are prone to diseases.
- It varies with seasons and plant types.
- External conditions or living organisms can cause diseases. Nutritional deficit, heat, flooding, and freezing are some examples of external agents that cause non-infectious or abiotic diseases.
- Plant pathogens like fungi, bacteria, viruses, and algae cause biotic diseases.
- Disease occurs when all three factors of Disease Triangle are present concurrently.

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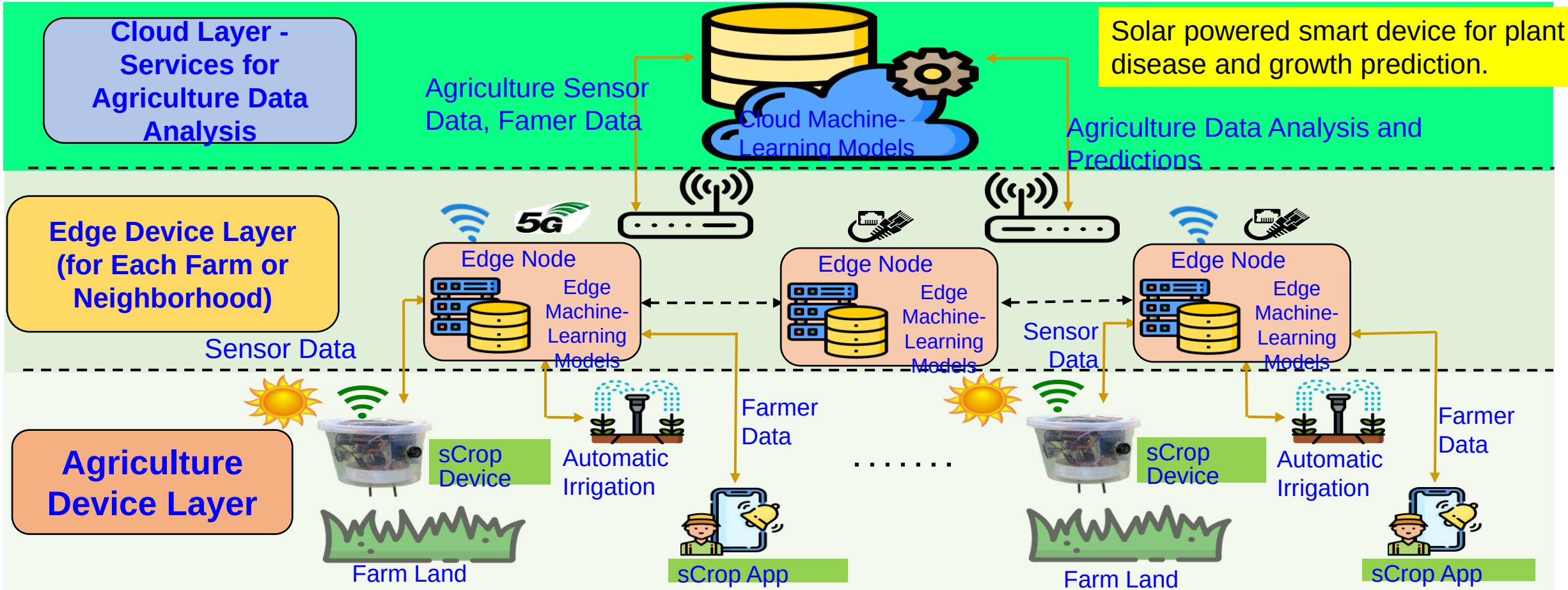
# Automatic Crop Damage Estimation: Related Prior Works

| Works | Year | Disease Type | Damage Estimation |
|---|---|---|---|
| Ji et al. | 2020 | Crop Leaf Diseases | Yes |
| Mohanty et al. | 2016 | Multi Crop Disease | No |
| Ji et al. | 2020 | Grape Leaf Diseases | No |
| Wang | 2022 | Fragrant Pear Diseases | No |
| Ozguven et al. | 2019 | Sugar Beet Leaf Spot Diseases | No |
| Pallagani et al. | 2019 | Multi Disease | No |
| Sun et al. | 2020 | Maize Leaf Blight Disease | No |
| Xavier et al. | 2019 | Ramularia Leaf Blight Cotton Disease | No |
| Saleem et al. | 2020 | Multi Crop Disease | No |
| **Current Paper** | **2022** | **Multi Crop Disease** | **Yes** |

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Our sCrop: A Device for Automatic Disease Prediction, Crop Selection, and Irrigation in IoAT




Source: V. Udutalapally, **S. P. Mohanty**, V. Pallagani, and V. Khandelwal, "sCrop: A Novel Device for Sustainable Automatic Disease Prediction, Crop Selection, and Irrigation in Internet-of-Agro-Things for Smart Agriculture", *IEEE Sensors Journal (JSEN)*, Vol. 21, No. 16, August 2021, pp. 17525--17538, DOI: https://doi.org/10.1109/JSEN.2020.3032438.

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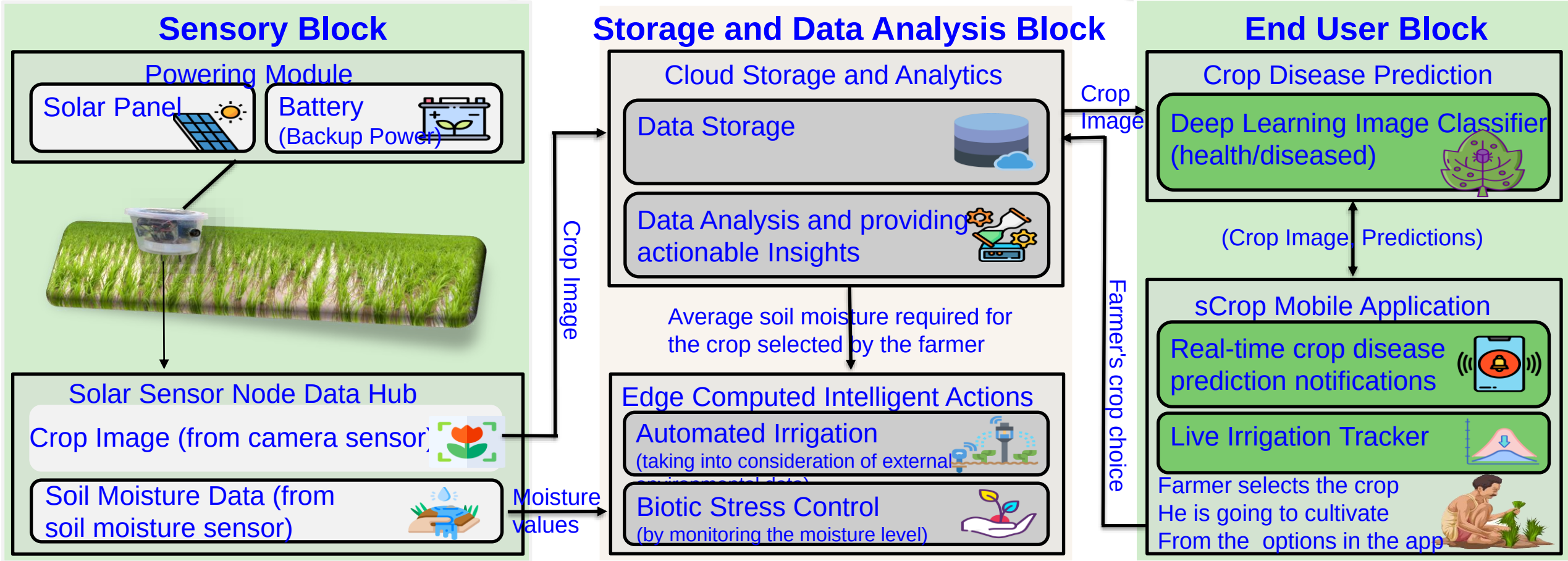


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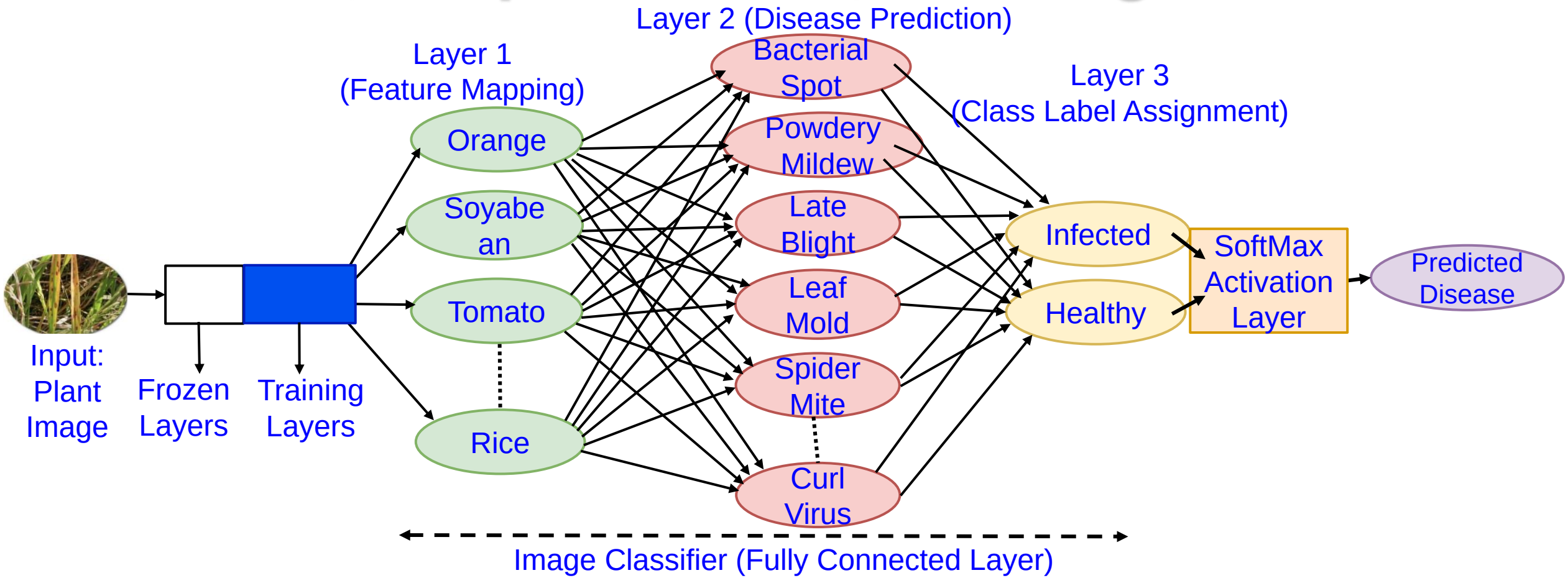


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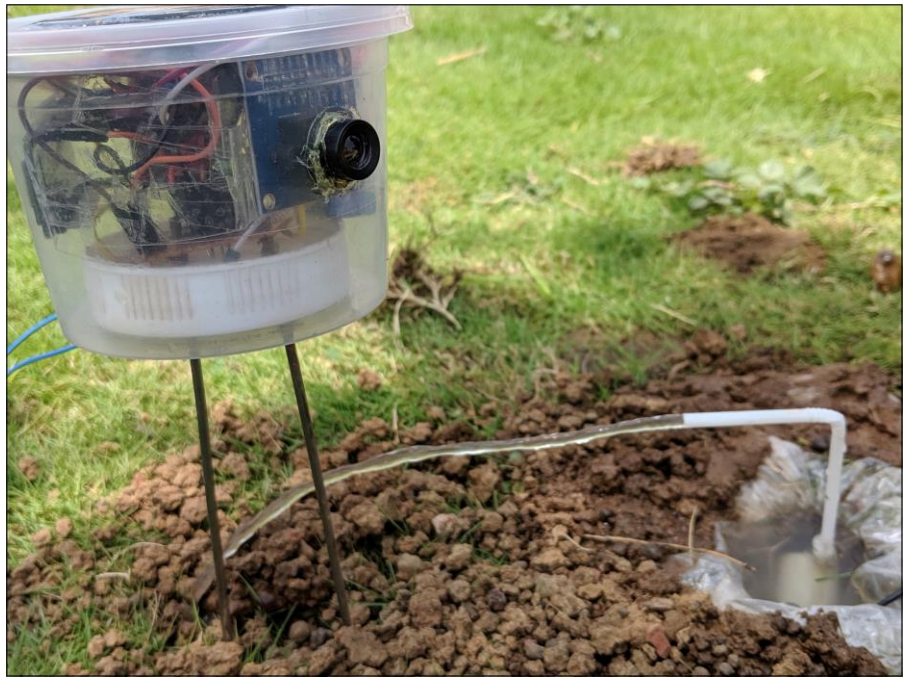
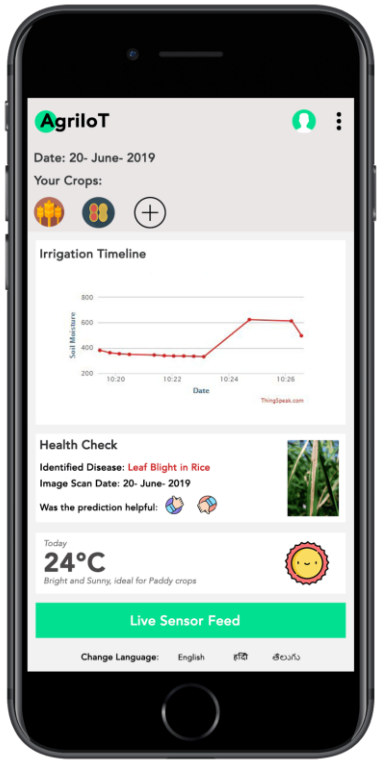


sCrop Device Prototype with Irrigation




sCrop App

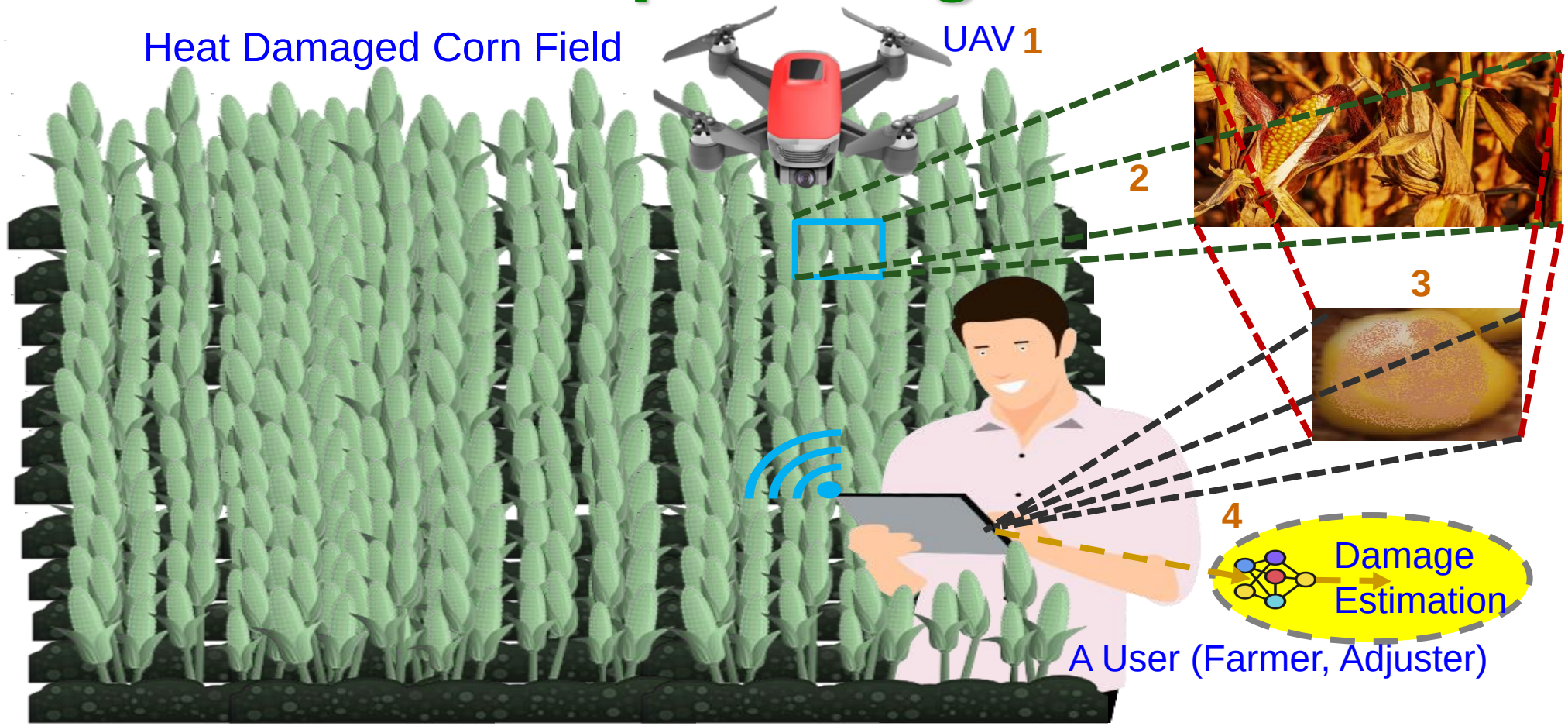
Healthy Tomato

Infected Tomato

sCrop Accuracy – 99.24%

Source: V. Udutalapally, **S. P. Mohanty**, V. Pallagani, and V. Khandelwal, "sCrop: A Novel Device for Sustainable Automatic Disease Prediction, Crop Selection, and Irrigation in Internet-of-Agro-Things for Smart Agriculture", *IEEE Sensors Journal (JSEN)*, Vol. 21, No. 16, August 2021, pp. 17525--17538, DOI: https://doi.org/10.1109/JSEN.2020.3032438.

# Our eCrop: A Framework for Automatic Crop Damage Estimation




1 → UAV takes Photo of Corn Ear

2 → Damage Area Detection of Corn Ear

3 → 50% of Damaged Area Selection

4→ Damage Type Detection for Corn Kernel and Process is Repeated for the Selected Area

A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, "eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture", *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: https://doi.org/10.1007/s42979-022-01216-8.

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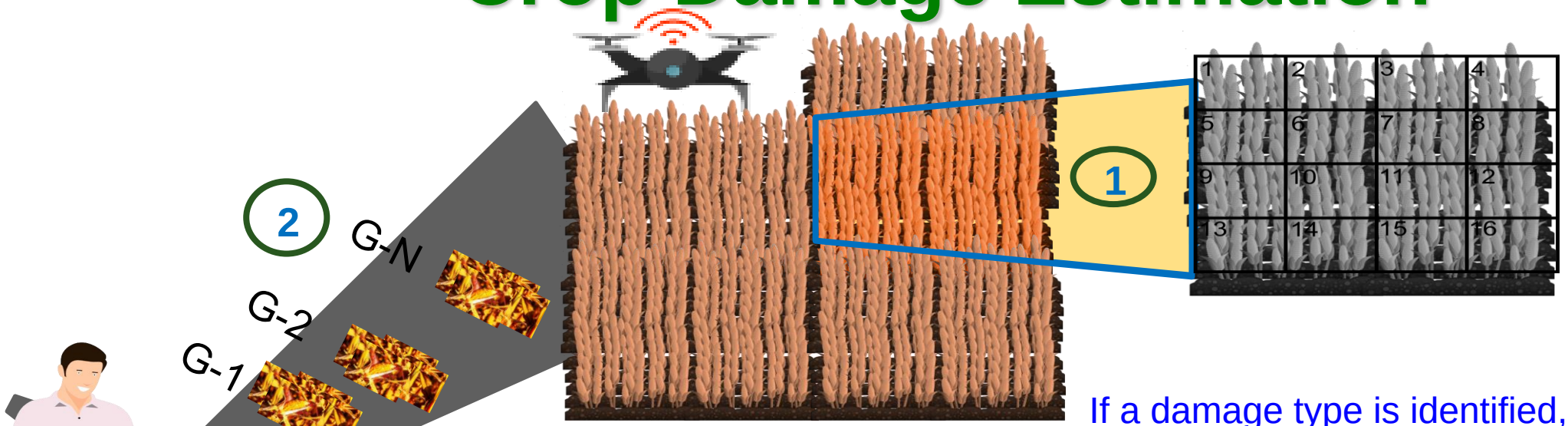
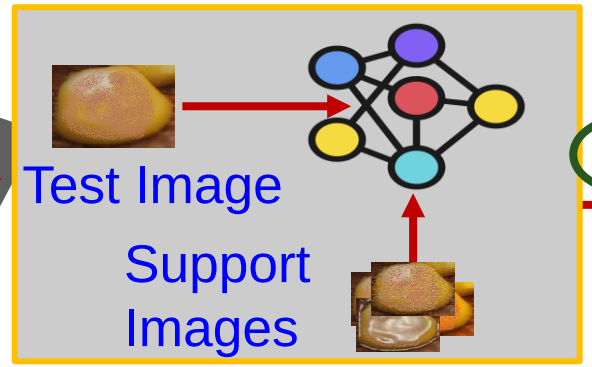



Damage Type:
- Heat
- Frost
- Diseases
- Insect Eating




If a damage type is identified, then a grid is updated with 1.

| | | | |
|---|---|---|---|
| 1 1 | 2 1 | 3 1 | 4 1 |
| 5 1 | 6 1 | 7 1 | 8 0 |
| 9 1 | 10 1 | 11 1 | 12 0 |
| 13 1 | 14 1 | 15 0 | 16 0 |

4

5

Total Claim Calculation

A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, "eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture", *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: https://doi.org/10.1007/s42979-022-01216-8.

# Our eCrop: Comparative Perspective

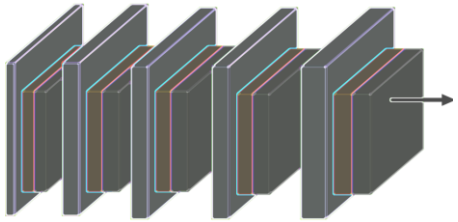
| Works | Year | Damage Type | Accuracy (%) | Real Time |
|---|---|---|---|---|
| Sosa et al. [202] | 2021 | Hail | 87.01 | No |
| Sawant et al. [195] | 2019 | Cyclone, earthquakes, hail storms, and flood | 87.23, 92.22 | No |
| Yang et al. [245] | 2019 | Cold | 82.19 | No |
| Pallagani et al. [174] | 2019 | Crop disease | 99.24 | Yes |
| Di et al. [67] | 2018 | Natural Disaster | 95.00 | No |
| Hsuan et al. [105] | 2018 | Heavy rain and typhoon | NA | No |
| Kwak et al. [133] | 2015 | Flood | 80.00 | No |
| eCrop | 2022 | Any damage type: heat, frost, diseases, and insect | **92.86** | Yes |

A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, "eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture", *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: https://doi.org/10.1007/s42979-022-01216-8.

# Our aGROdet: A Framework for Plant Disease Detection and Leaf Damage Estimation

- Detect plant diseases.
- Estimate corresponding leaf damage.

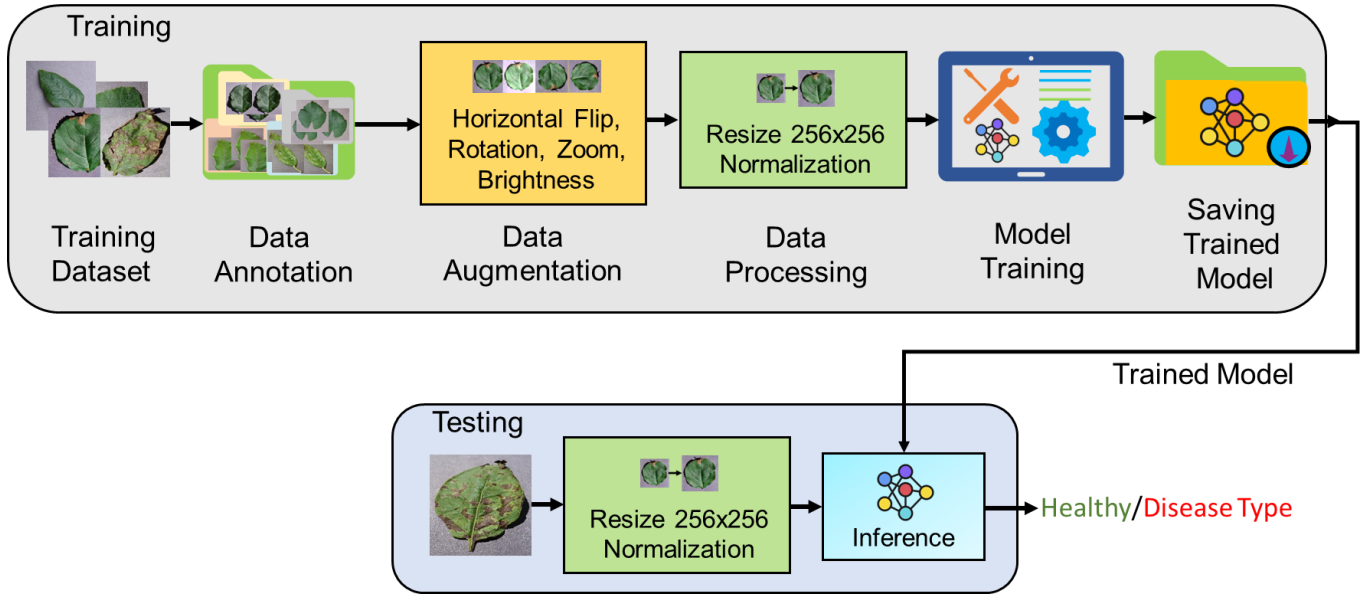
- Identification of the disease -
  - Convolutional neural network-based method.
- Estimation of the severity of leaf damage –
  - Pixel-based thresholding method.



- Regular monitoring of fields and checking conditions of the plants through aGROdet can detect the disease early.

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

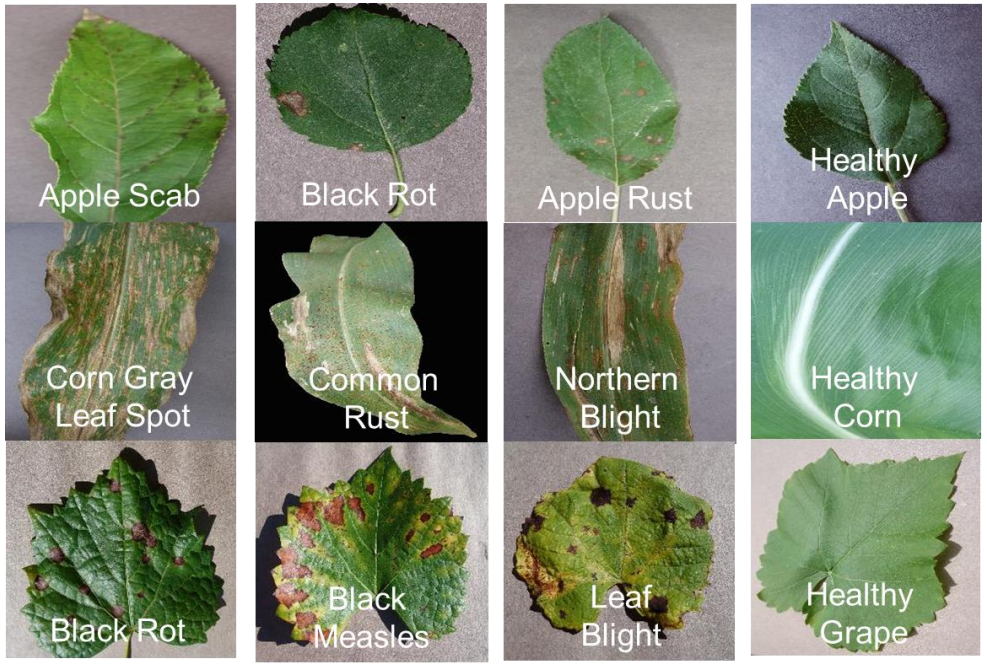
# Our aGROdet: Plant Disease Detection



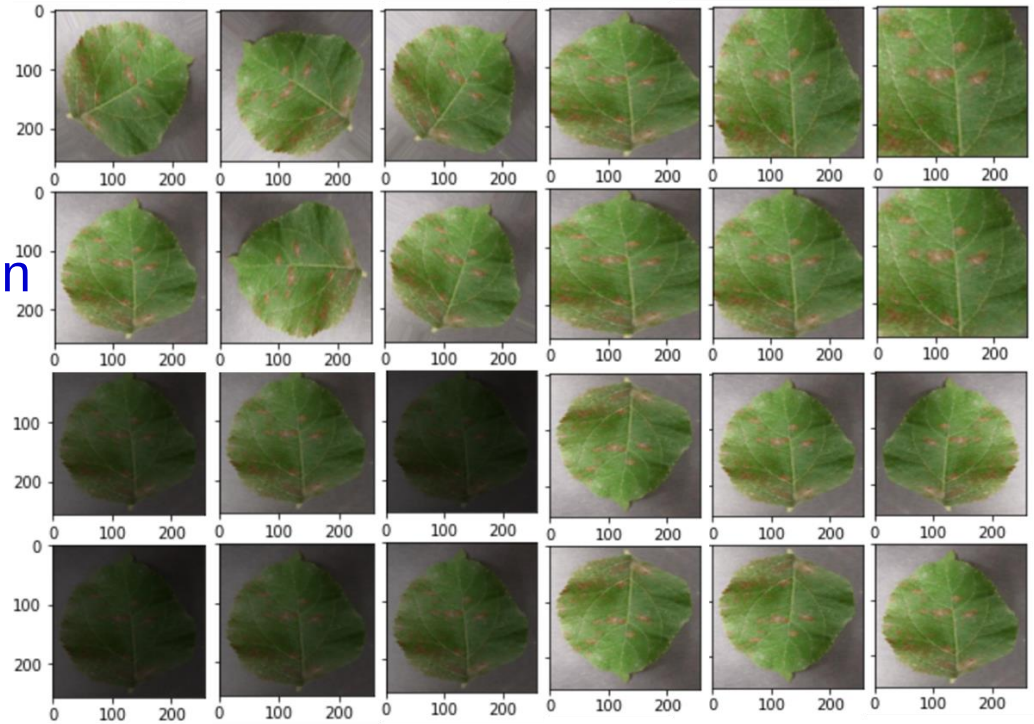

- The augmented and preprocessed data is used for training the network.
- Adam optimizer with an initial learning rate of 0.001.
- Model trained for 75 epochs.
- Model trained with and without a reduced learning rate of factor 0.1.
- Trained model is saved for future inference.
- Model evaluated using unseen 5,562 images.
- Implemented in Keras with TensorFlow back end.

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Our aGROdet: Dataset Processing



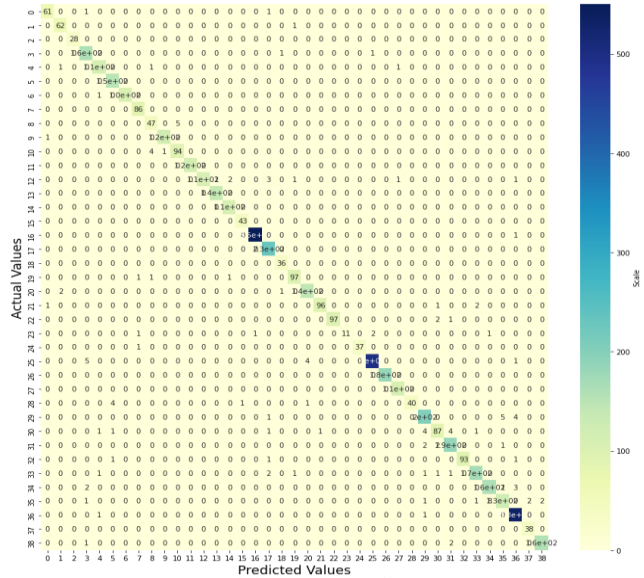

Data Augmentation



- Data augmented on the fly
- Rotation, Zoom, Brightness, Horizontal Flip.

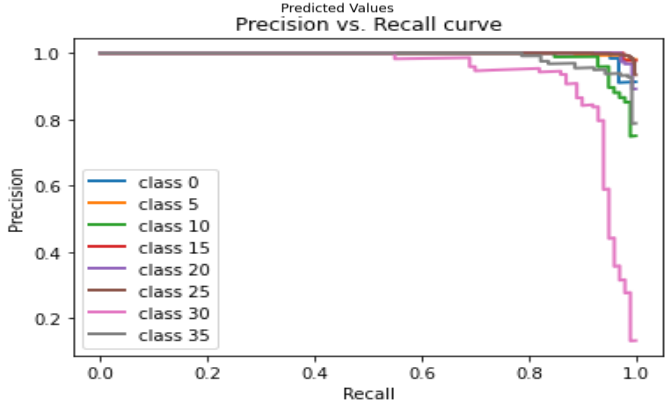
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

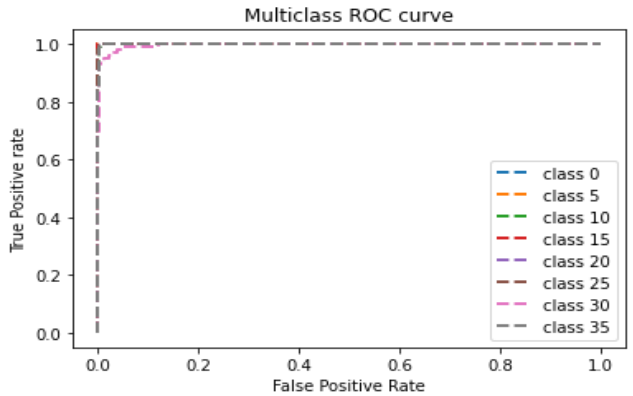
# Our aGROdet: Performance Evaluation of Disease Detection




- Results are for Training without reduced learning rate.
- Classes are denoted by numbers instead of the class names to fit into the space.

| Training Type | Data Augmentation | Accuracy (%) | | |
|---|---|---|---|---|
| | | Training | Validation | Testing |
| Without reduced learning rate | Yes | 96.34 | 96.40 | 96.10 |
| With reduced learning rate | Yes | 98.89 | 98.41 | 98.58 |



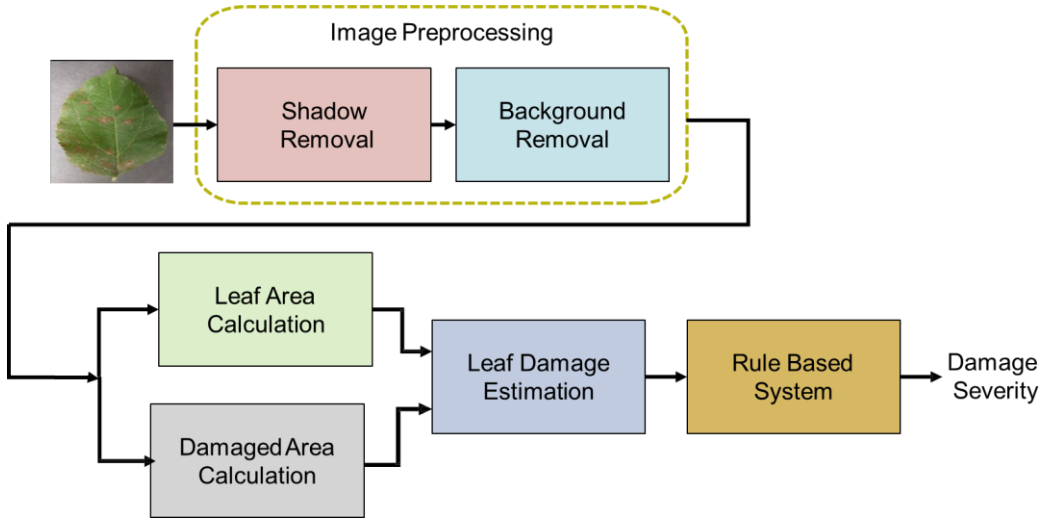



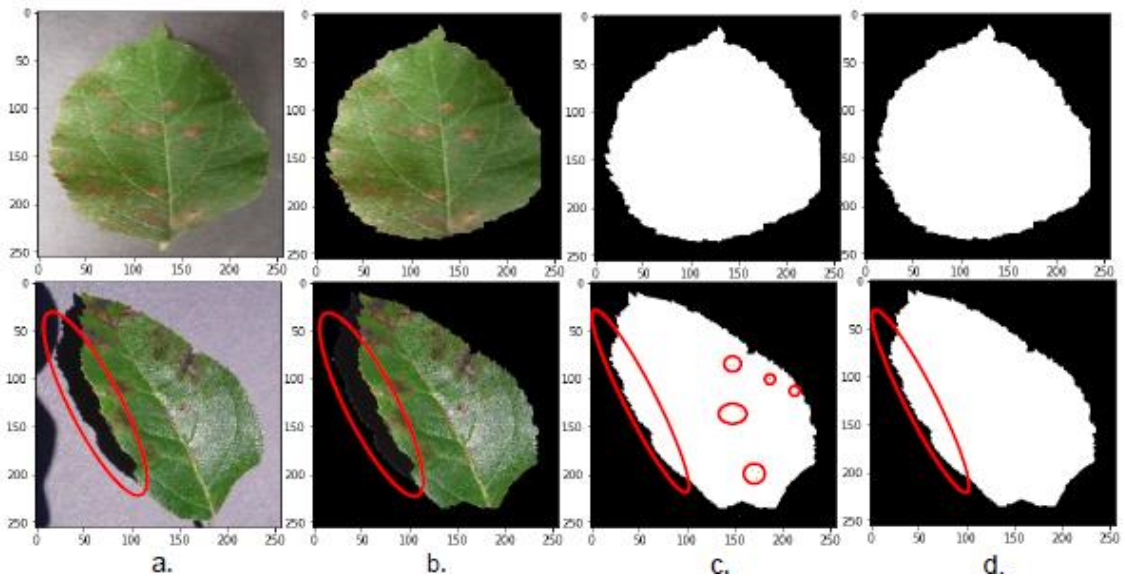

| Works | Disease Type | Accuracy (%) | Damage Estimation |
|---|---|---|---|
| Ji et al. [112] | Multi Disease | 86.70 | Yes |
| Mohanty et al. [163] | Multi Disease | 99.35 | No |
| Ji et al. [113] | Single | 98.57 | No |
| Wang [231] | Single | 96.26 | No |
| Ozguven et al. [173] | Single | 95.48 | No |
| Pallagani et al. [174] | Multi Disease | 99.24 | No |
| Current paper | Multi Disease | 98.58 | Yes |

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Our aGROdet: Leaf Damage Severity Estimation

- To estimate leaf damage severity –
  - Leaf area and damage area are calculated.
  - Ratio of these two areas gives the percentage of leaf damage.
  - Finally, a rule-based system predicts the damage severity.



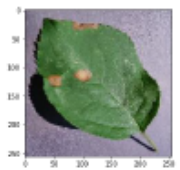
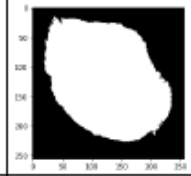
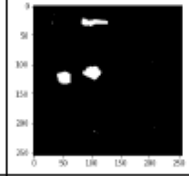
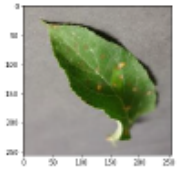
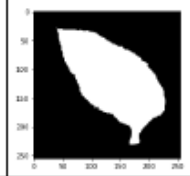
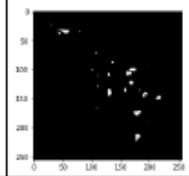
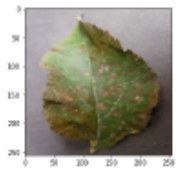
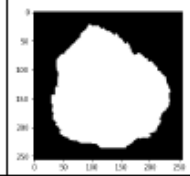
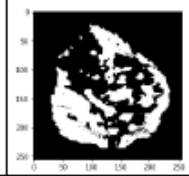
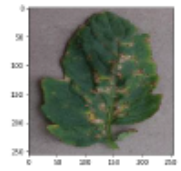
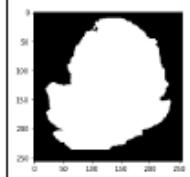
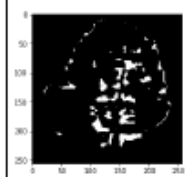
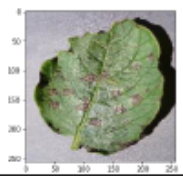
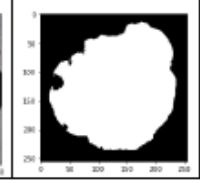
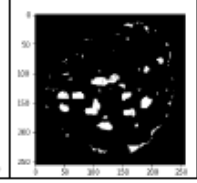




Leaf Area Detection by Creating Leaf Mask -

a. Input Image .
b. Background Segmentation by GrabCut Algorithm.
c. Mask Creation for the Leaf ; RGB->HSV; thresholding over black color; mask inverted.
d. Noise Reduction from the Mask. Red large ovals show the shadow around the foreground object and small circles highlight the shadows on the foreground object.

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Our aGROdet: Leaf Damage Estimation

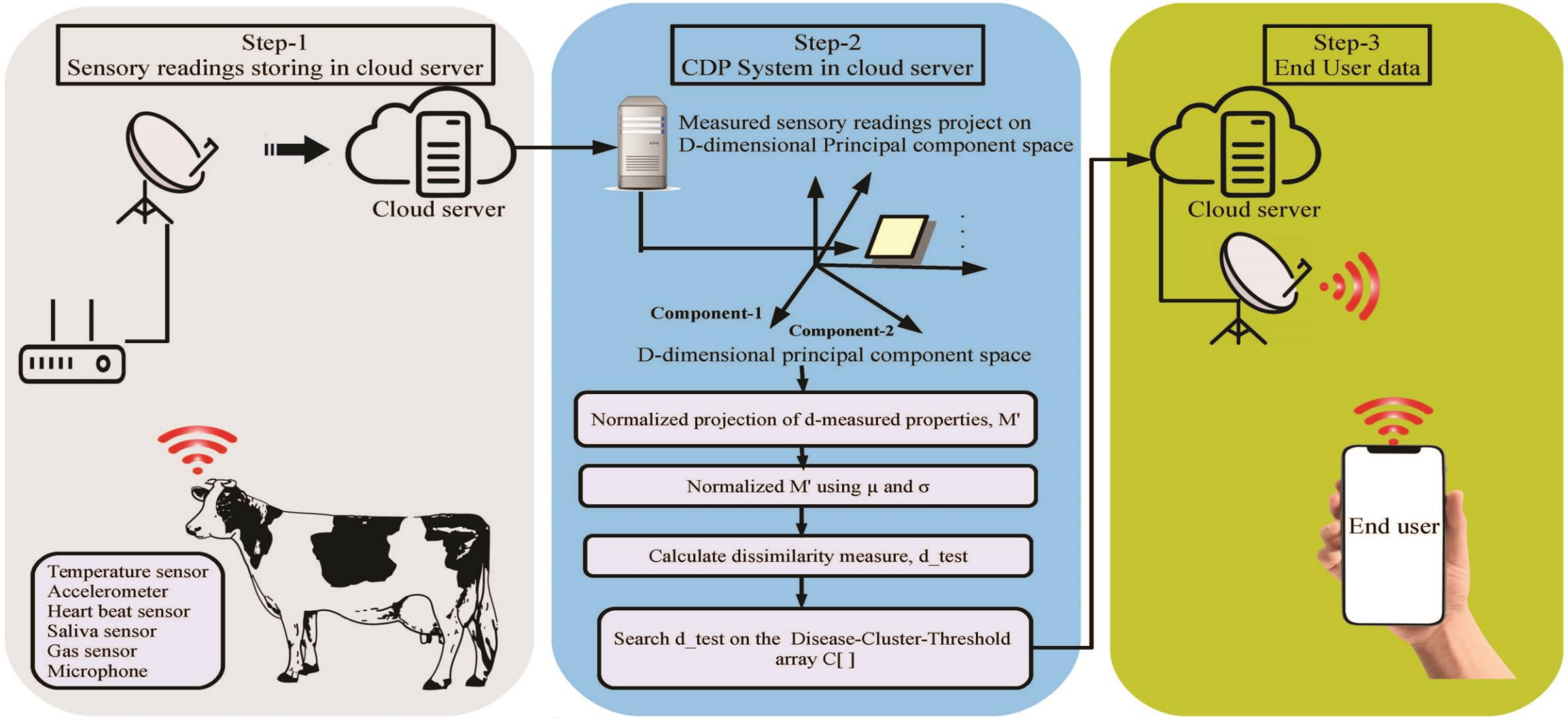
| Image | Leaf Mask | Damage Mask | Estimated Damage (%) | Damage Severity Grade |
|---|---|---|---|---|
|  |  |  | 3.95 | 1 |
|  |  |  | 2.97 | 1 |
|  |  |  | 53.49 | 5 |
|  |  |  | 10.69 | 3 |
|  |  |  | 9.49 | 2 |

- Achieved-
  - Damage estimation by aGROdet is not affected as damage masks even in the presence of shadows.
  - When there is some specular reflection in the image, aGROdet can still correctly estimates the damage of leaves.
  - No experiment for corn leaf images in the dataset as whole leaf is not visible.

- Limitations –
  - For variegated plants (e.g., Abelia, Azalia, Boxwood, Cape Jasmine, Hydrangea, and Lilac)- healthy leaves have other colors (yellow or white) damage estimation is not correct.
  - It takes yellow color as the abiotic stress.

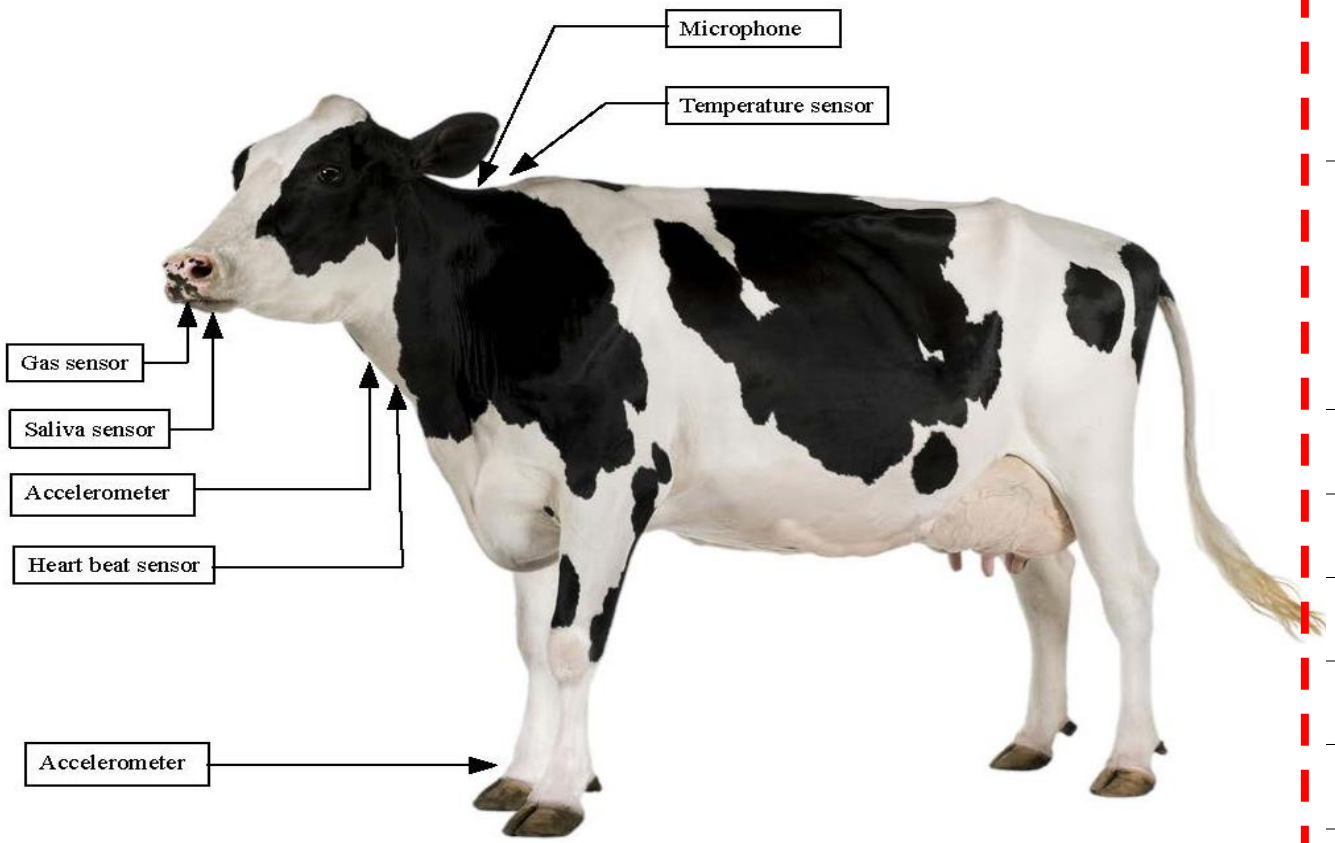
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

# Our LiveCare - IoT-Based Cattle Healthcare Framework




Source: P. S. Chatterjee, N. K. Ray, and **S. P. Mohanty**, "LiveCare: An IoT based Healthcare Framework for Livestocks in Smart Agriculture", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 67, No. 4, Nov 2021, pp. 257—265, DOI: https://doi.org/10.1109/TCE.2021.3128236.

# Our LiveCare - IoT-Based Cattle Healthcare Framework




| Sensor | Behavior | Value [9][29] | | |
|---|---|---|---|---|
| (1) Temperature Sensor | Cold | $35.5°C$ to $38.5°C$ | | |
| | Normal | $38.5°C$ to $39.5°C$ | | |
| | Low fever | $39.5°C$ to $40.5°C$ | | |
| | Middle fever | $40.5°C$ to $41.5°C$ | | |
| | High fever | Above $41.5°C$ | | |
| (2) Three-axis Accelerometer | | **X** | **Y** | **Z** |
| | Standing still | constant | – | constant |
| | Moving | variable | variable | variable |
| | Prostration | constant | constant | constant |
| | Lameness | variable | – | variable |
| | Discomfort | variable | variable | variable |
| (3) Microphone | Mooing or Coughing | yes | | |
| | | No | | |
| (4) Gas sensor | Smell of breath | yes | | |
| | | No | | |
| (5) Load sensor | Load shifting | yes (load varies on four legs) | | |
| | | No (load constant on four legs) | | |
| (6) Heartbeat sensor | Heart rate (normal for adult cow) | 48 to 84 beats per minute | | |
| | Heart rate (anxiety) | Above 84 beats per minute | | |
| (7) Electrical conductivity sensor | For healthy cow | 4 to 6 milliSiemens (ms) | | |
| | Clinically infected cow | Above 6 milliSiemens (ms) | | |
| (8) Saliva sensor | Saliva hangs from mouth | Present | | |
| | | Not present | | |

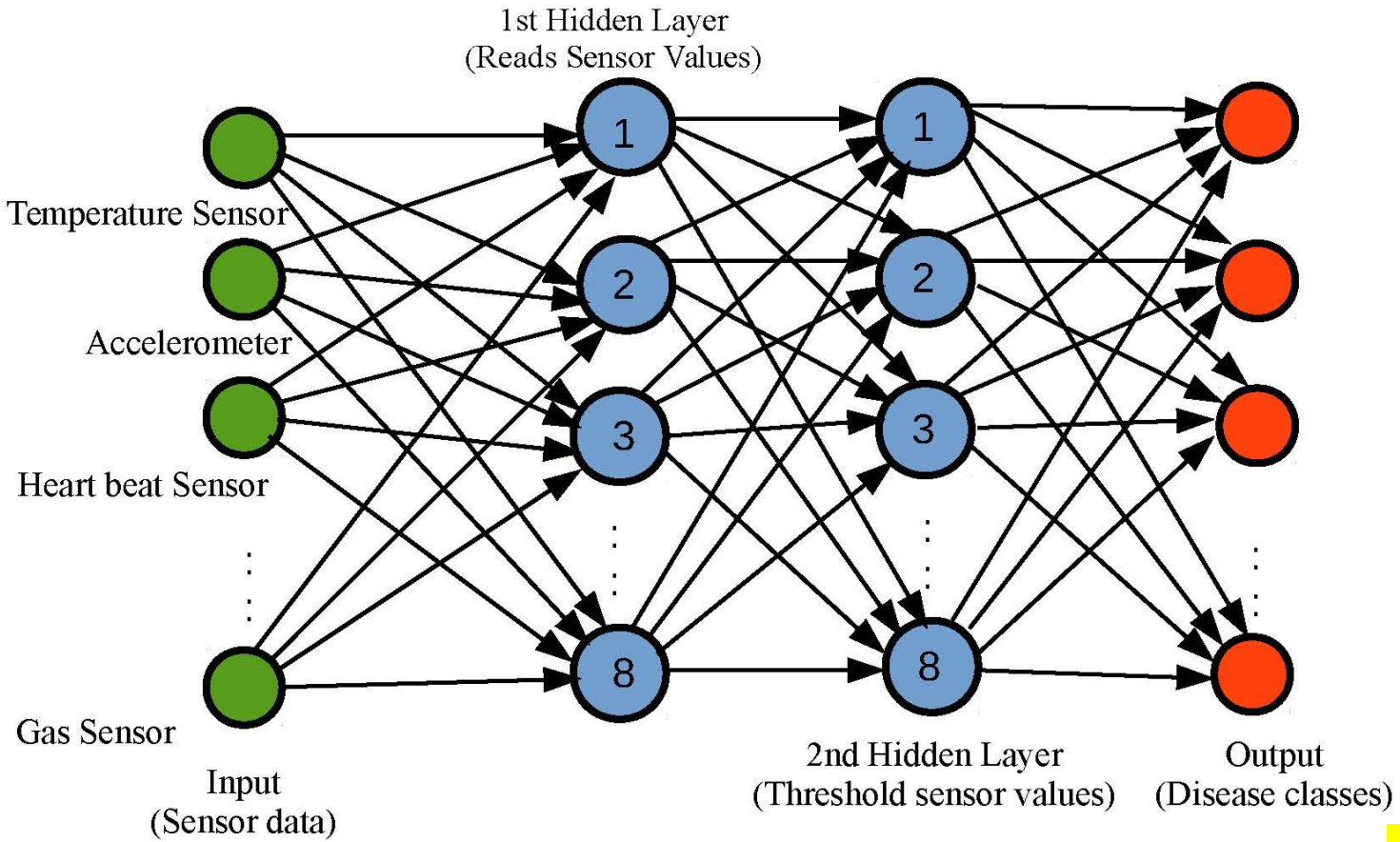
Source: P. S. Chatterjee, N. K. Ray, and **S. P. Mohanty**, "LiveCare: An IoT based Healthcare Framework for Livestocks in Smart Agriculture", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 67, No. 4, Nov 2021, pp. 257—265, DOI: https://doi.org/10.1109/TCE.2021.3128236.

# Our LiveCare - IoT-Based Cattle Healthcare Framework

| Disease [24] | Symptoms [25, 26] | Measurable behavioral changes | Sensors |
|---|---|---|---|
| (1) Fever | Discomfort | Lethargic | Accelerometer(neck) |
| | High temperature | Increase in body temperature | Temperature sensor(neck) |
| | Ache | Mooing | Microphone(neck) |
| (2) Mastitis | Prostration | Laying down less frequently | Accelerometer(neck) |
| | Activity during milking | Kicking | Accelerometer(feet) |
| | Discomfort and pain | Restlessness | Accelerometer(feet and neck), Microphone(neck) |
| | Less food intake | Less grazing | Accelerometer(feet and neck) |
| | Weight distribution | Weight shifting | Load sensors (under feet) |
| (3) Lameness | Less consumption of food | Less grazing | Accelerometer(feet and neck) |
| | Mounting | Less movement | Accelerometer(feet and neck) |
| | Hitch | Uneven load distribution on legs | Load sensor (under feet) |
| (4) Ovarian cysts | Abnormal estrous behavior | Restlessness | Accelerometer(feet and neck) |
| | Bellowing | Mooing | Microphone(neck) |
| | Body temperature | High body temperature | Temperature sensor(neck) |
| | Quality of milk | Conductivity | Electrical conductivity sensor (udder) |
| (5) Oestrus | Increased estrogen and progesterone level | Restlessness | Accelerometer(feet and neck) |
| | Less consumption of food | Less grazing | Accelerometer(feet and neck) |
| (6) Ketosis | Weight loss | Weight loss | Load sensor (under feet) |
| | Reduced appetite | Less grazing | Accelerometer(feet and neck) |
| | Smell of breath | – | Gas sensor(nose) |
| | Fever | High temperature | Temperature sensor(neck) |
| (7) Pneumonia | Rapid pulse | Rapid breathing rate | Heartbeat sensor (vein on neck) |
| | Fever | High temperature | Temperature sensor(neck) |
| | Coughing | Coughing | Microphone |
| | Loss of appetite | Less grazing | Accelerometer(feet and neck) |
| (8) Black quarter | Fever | High temperature | Temperature sensor(neck) |
| | Loss of appetite | Less grazing | Accelerometer(feet and neck) |
| | Dullness | Less activity | Accelerometer(feet and neck) |
| | Suspended rumination | less rumination | Microphone (neck), Accelerometer(neck) |
| | Rapid pulse | Rapid heart rate | Heartbeat sensor (vein on neck) |
| | Lameness | Lameness on effected leg | Accelerometer(feet and neck), Load sensor (Under feet) |
| | Prostration | Prostration | Accelerometer(feet and neck) |
| (9) Foot and mouth disease | Fever | High temperature | Temperature sensor(neck) |
| | Saliva | Saliva hangs from mouth | Saliva sensor (mouth) |
| | Lameness | Lameness | Accelerometer(feet and neck), Load sensors (under feet) |

Source: P. S. Chatterjee, N. K. Ray, and **S. P. Mohanty**, "LiveCare: An IoT based Healthcare Framework for Livestocks in Smart Agriculture", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 67, No. 4, Nov 2021, pp. 257—265, DOI: https://doi.org/10.1109/TCE.2021.3128236.

# Our LiveCare - IoT-Based Cattle Healthcare Framework




Fully-Connected Neural Network (FCNN)

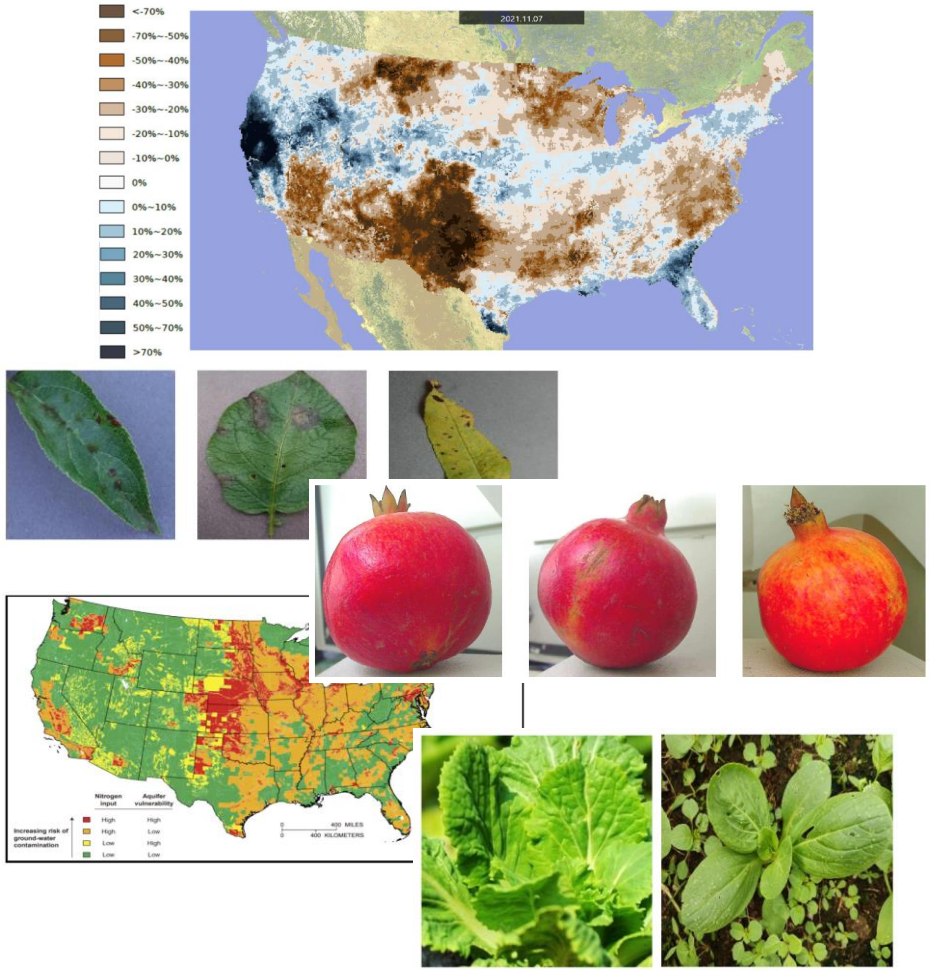
Comparison of different approaches.

| Approaches | Behavior monitoring | Disease detection | Limitations |
|---|---|---|---|
| Jha, et al. [8] | Yes | No | Reports Only about the behavioral changes due to different disease. |
| Swain [10] | Yes | No | Limited to display real time health graphs. |
| Suresh [12] | Yes | No | Limited to identify unhealthy cattle based on sensory readings. |
| Esener, et [13] | No | Yes | Identify subclinical or clinical level mastitis. |
| Haladjian, [16] | Yes | Yes | Detect lameness from the accelerometer readings. |
| Vyas, et al. [17] | Yes | Yes | Detect foot and mouth disease and mastitis |
| Lee [18] | Yes | Yes | Detect breeding cows, estrus start, peak estrus activities, and estrus finish. |
| **LiveCare (Proposed)** | Yes | 9 different diseases can be detected | |

Accuracy of our Proposed Cow-Disease Prediction (CDP) Algorithm – 100%

Source: P. S. Chatterjee, N. K. Ray, and **S. P. Mohanty**, "LiveCare: An IoT based Healthcare Framework for Livestocks in Smart Agriculture", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 67, No. 4, Nov 2021, pp. 257—265, DOI: https://doi.org/10.1109/TCE.2021.3128236.

# Smart Agriculture- Datasets for AI

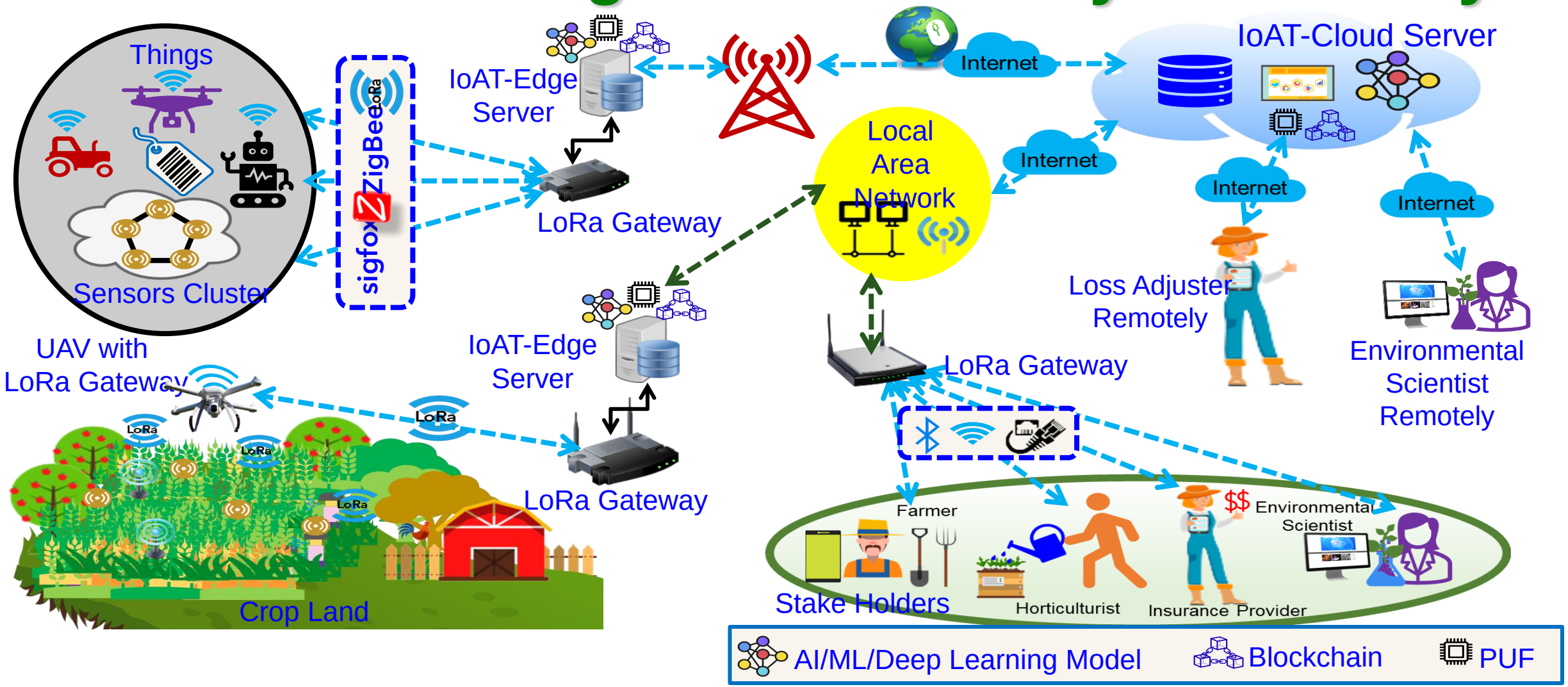



| Dataset | Source | Dataset Format | Link |
|---|---|---|---|
| Crop Yield & Production | USDA & NASS | .php | https://www.nass.usda.gov/Charts_and_Maps/ |
| Crop Condition & Soil Moisture | Crop-CASMA | .gis | https://nassgeo.csiss.gmu.edu/CropCASMA/ |
| Plant Diseases | Kaggle | .jpg | https://www.kaggle.com/saroz014/plant-diseases |
| Soil Health & Characterization | NCSS | .mdb | https://new.cloudvault.usda.gov/index.php/s/7iknp275KdTKwCA |
| Pesticide use in Agriculture | USGS | .php, .txt | https://water.usgs.gov/nawqa/pnsp/usage/maps/ |
| Water use in Agriculture | USGS | Tableau | https://labs.waterdata.usgs.gov/visualizations/water-use-15 |
| Groundwater Nitrate Contamination | USGS | .jpeg | https://prd-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/thumbnails/image/wss-nitrogen-map-us-risk-areas.jpg |
| Disaster Analysis | USDA & NASS | .png, .pdf | https://www.nass.usda.gov/Research_and_Science/Disaster-Analysis/ |

[Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.]

# Smart Agriculture Case Studies - Cybersecurity Solutions

# A-CPS with Integrated AI and Cybersecurity

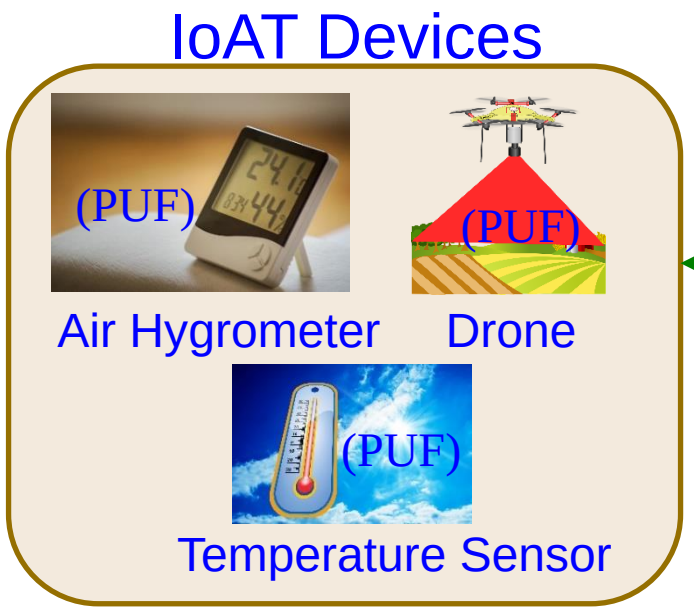



Source: A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, "eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture", *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: https://doi.org/10.1007/s42979-022-01216-8.

# Smart Agriculture Cybersecurity - Solutions

- Developing IoAT-Edge and IoAT-cloud centric network model
- Integrate A-CPS with Security-by-Design (SbD) and Privacy-by-Design (PbD) measures right at the design phase.
- Using Intrusion detection systems
- PUF based energy-efficient solutions for integrated security
- Blockchain based solutions for data and device integrity
- Physical countermeasures
  - Machine learning based countermeasures
- Constant security analysis

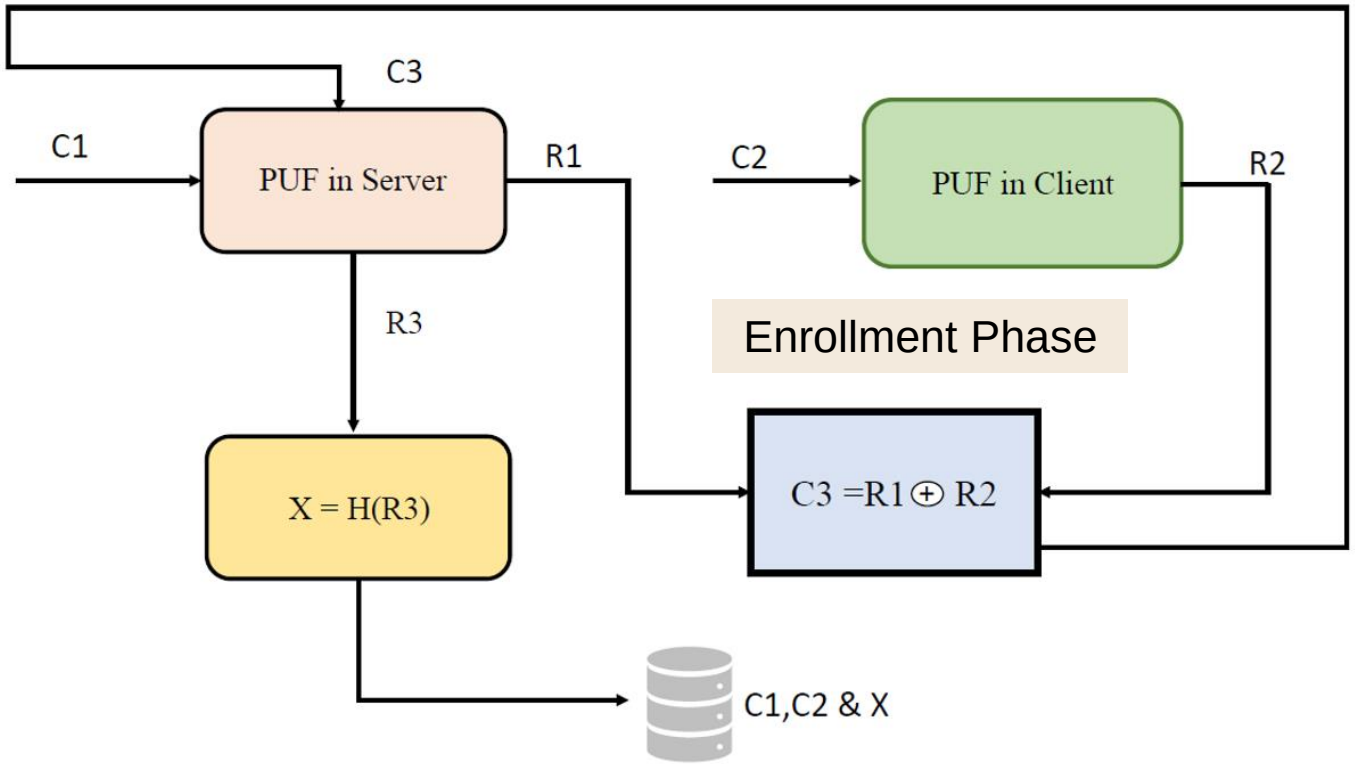
# Our Security-by-Design Approach for Robust IoAT




Edge Server authenticates the devices using the PUF key of each electronic device which is the fingerprint for that device

Source: V. K. V. V. Bathalapalli, S. P. Mohanty, E. Kougianos, V. P. Yanambaka, B. K. Baniya and B. Rout, "A PUF-based Approach for Sustainable Cybersecurity in Smart Agriculture," in *Proc. 19th OITS International Conference on Information Technology (OCIT)*, 2021, pp. 375-380, doi: 10.1109/OCIT53463.2021.00080.

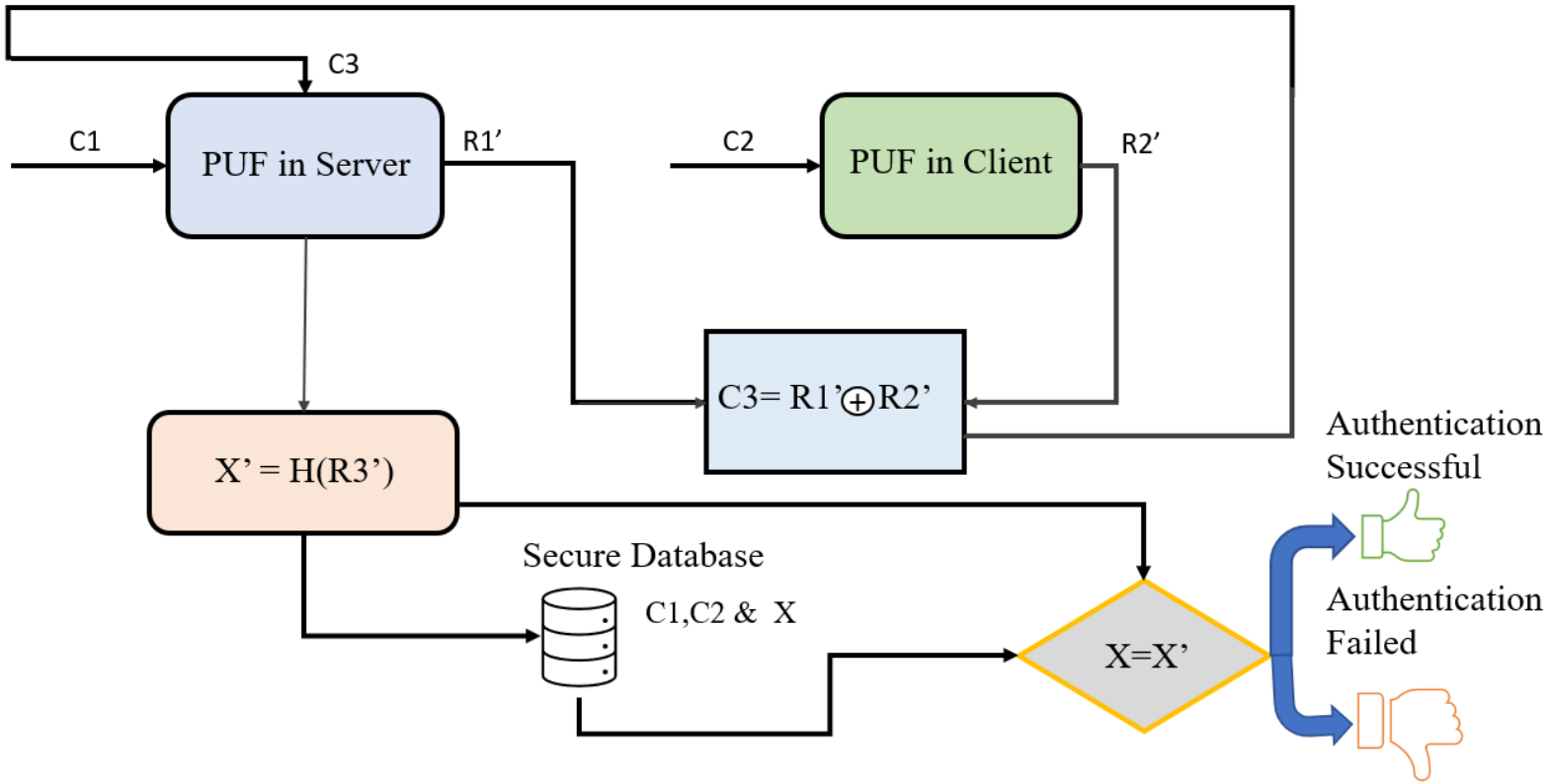
# Enrollment Phase of the Proposed Security Protocol




C1 => R1
C2 => R2
C3 = R1 XOR R2
C3 => R3
X = H(R3)
X, C1,C2 are stored in Database

Source: V. K. V. V. Bathalapalli, S. P. Mohanty, E. Kougianos, V. P. Yanambaka, B. K. Baniya and B. Rout, "A PUF-based Approach for Sustainable Cybersecurity in Smart Agriculture," in *Proc. 19th OITS International Conference on Information Technology (OCIT)*, 2021, pp. 375-380, doi: 10.1109/OCIT53463.2021.00080.

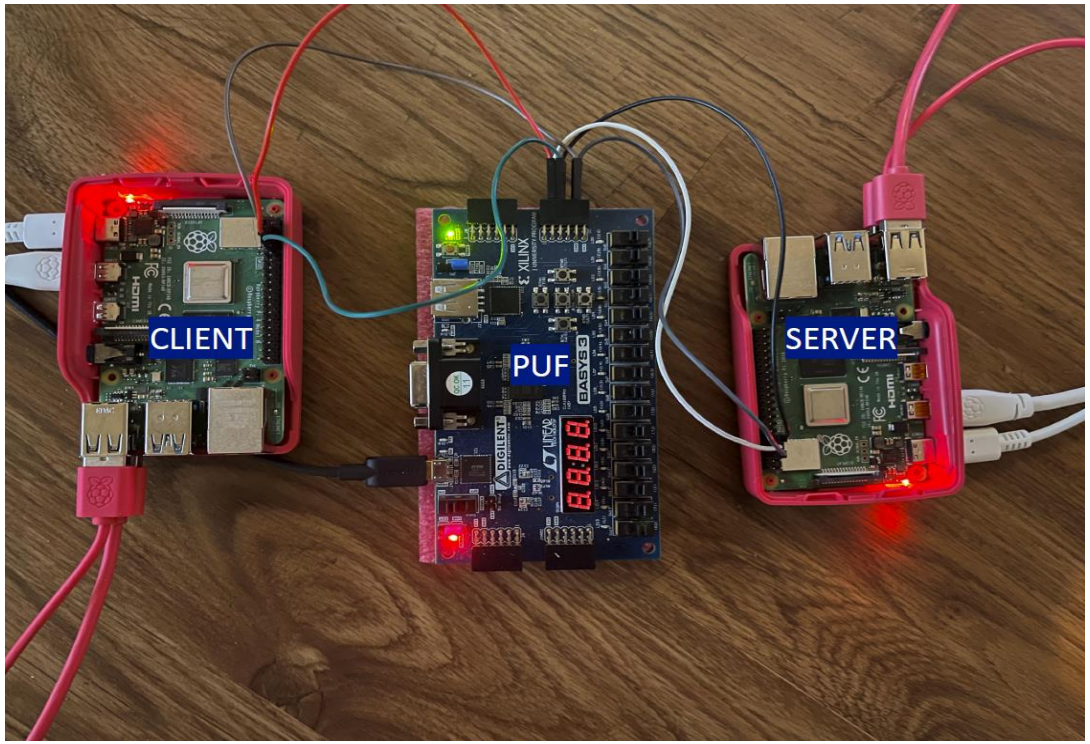
# Authentication Phase of the Proposed Security Protocol




Only C1 and C2 are retrieved and given as inputs to the PUF module. The final Hash value X is compared with the stored hash value X to authenticate the device

Source: V. K. V. V. Bathalapalli, S. P. Mohanty, E. Kougianos, V. P. Yanambaka, B. K. Baniya and B. Rout, "A PUF-based Approach for Sustainable Cybersecurity in Smart Agriculture," in *Proc. 19th OITS International Conference on Information Technology (OCIT)*, 2021, pp. 375-380, doi: 10.1109/OCIT53463.2021.00080.

# Prototype of the Proposed Security Scheme




| Parameter | Value |
|---|---|
| Hamming Distance | 48% |
| Randomness | 41.07% |
| Time Taken to Authenticate the Device in Seconds | 0.16 to 2.93 Seconds |
| FPGA | Basys 3, Artix-7 |

Source: V. K. V. V. Bathalapalli, S. P. Mohanty, E. Kougianos, V. P. Yanambaka, B. K. Baniya and B. Rout, "A PUF-based Approach for Sustainable Cybersecurity in Smart Agriculture," in *Proc. 19th OITS International Conference on Information Technology (OCIT)*, 2021, pp. 375-380, doi: 10.1109/OCIT53463.2021.00080.

# Our G-DaM: Introduction-Ground Water Data

Water Contamination

Availability of Water

Wireless Sensors/
Satellites

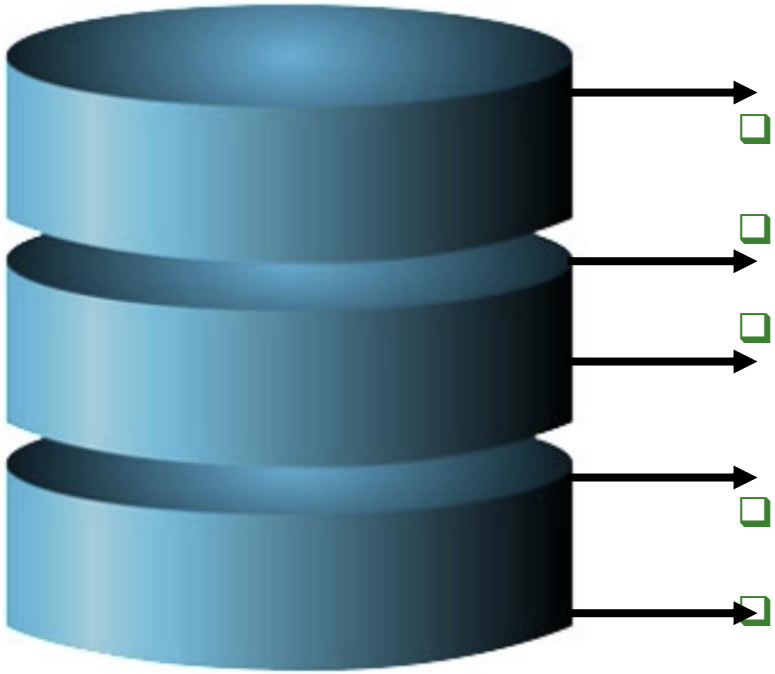
Groundwater
Data

Data Research

- Groundwater is 1.69 % of total water on earth.
- Source of sustenance.
- Data collected from diverse sources.
- Helps in Increasing Food Production
- Checking Water Availability
- Predicting Water supplies.
- Analysis of Contaminant Water .

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

# Our G-DaM: Motivation



Ground Water Data

- Incorrect Data leads to Inaccurate Models.
- Poor Deductions.
- Authenticity of the Data sent from Web.
- Tampered and Modified Quality by Hackers.
- Uncertain Data Integrity.
- High Risk in Centralized and Cloud Systems.
- Additional Blockchain storage Limitations

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

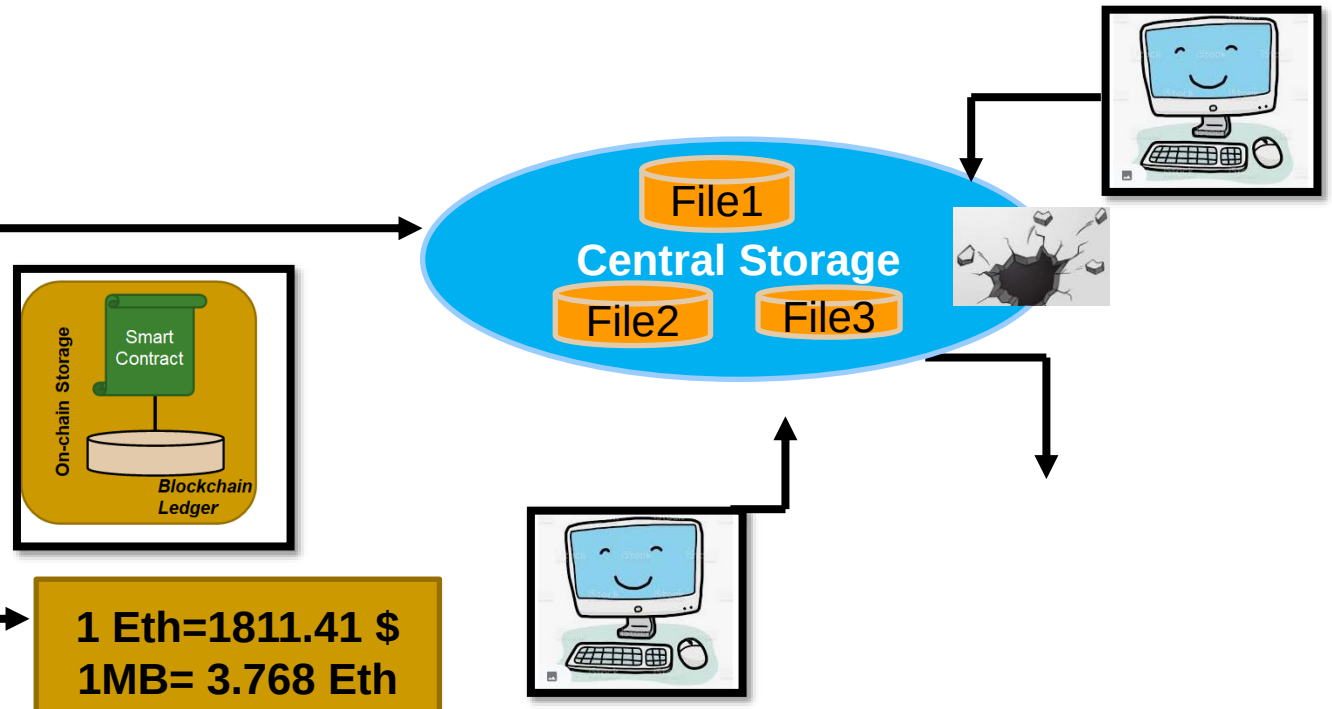
# Our G-DaM: Related Research

| Application | Domain | Data Storage | Security Level | Cost | Computation |
|---|---|---|---|---|---|
| Nguyen et al.[4] | Supply-chain Data | Decentralized- On-Chain | High-SH | High | High |
| Umamaheshwari et al.[5] | Crop Farming Data | Decentralized- On-Chain | High-SH | High | High |
| Pincheira et al. [6] | Water Usage Data | Decentralized- On-Chain | High-SH | High | High |
| Turganbaev et al. [7] | Groundwater Data | Centralized | Low | High | High |
| Yi et al. [8] | Groundwater Data | Centralized | Low | High | High |
| Zhu et al. [9] | Groundwater Data | Centralized | Low | High | High |
| Iwanaga et al. [10] | Groundwater Data | Centralized | Low | High | High |
| **G-DaM [Current-Paper]** | Groundwater Data | Decentralized- On-Chain | High-DH | Low | Low |

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

# Issues in Existing works

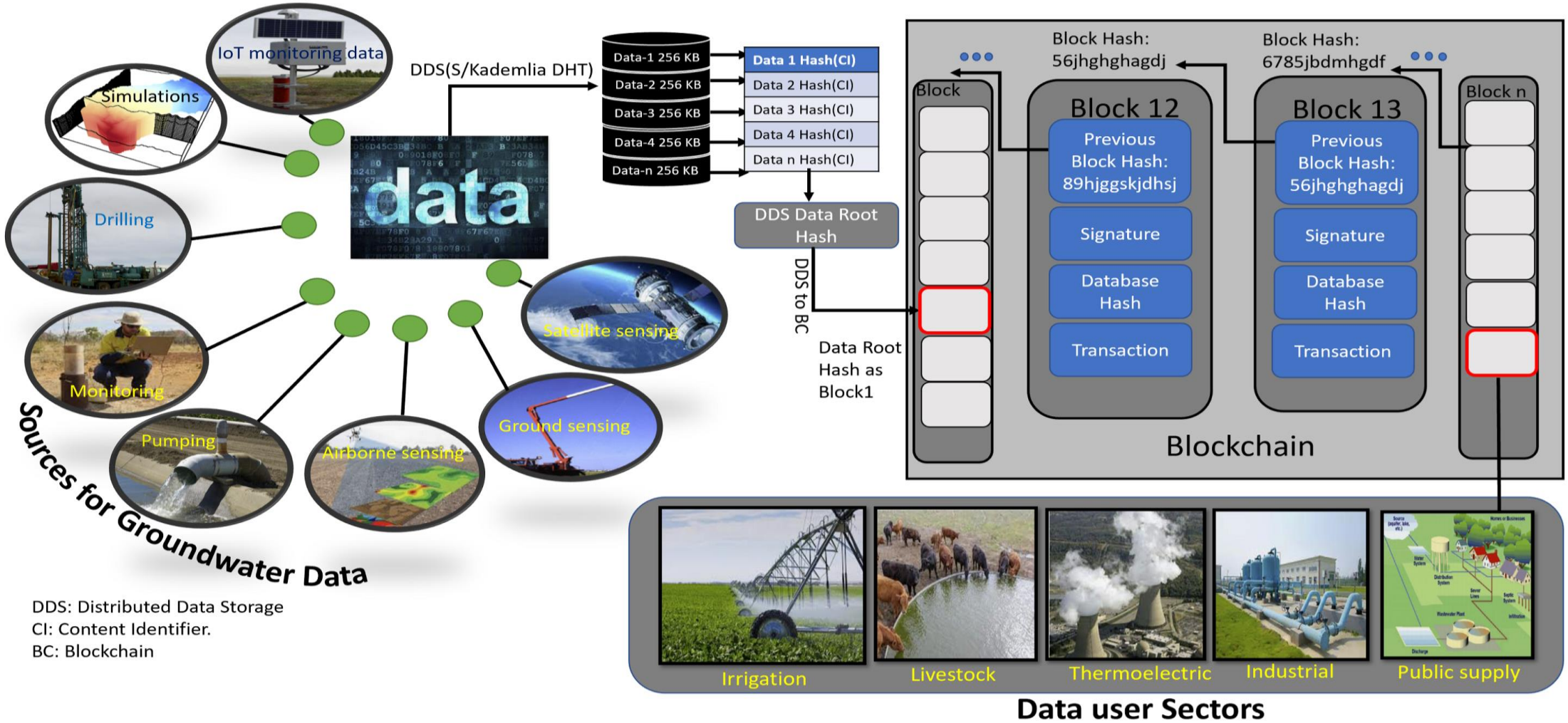
- Centralized Data storage.
- Decentralized –On-Chain Storage
  - High Transaction Fees
  - High Block validating Time(Mining Time)




- Single point failure
- High Energy Consumption
- Bandwidth Bottlenecks

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

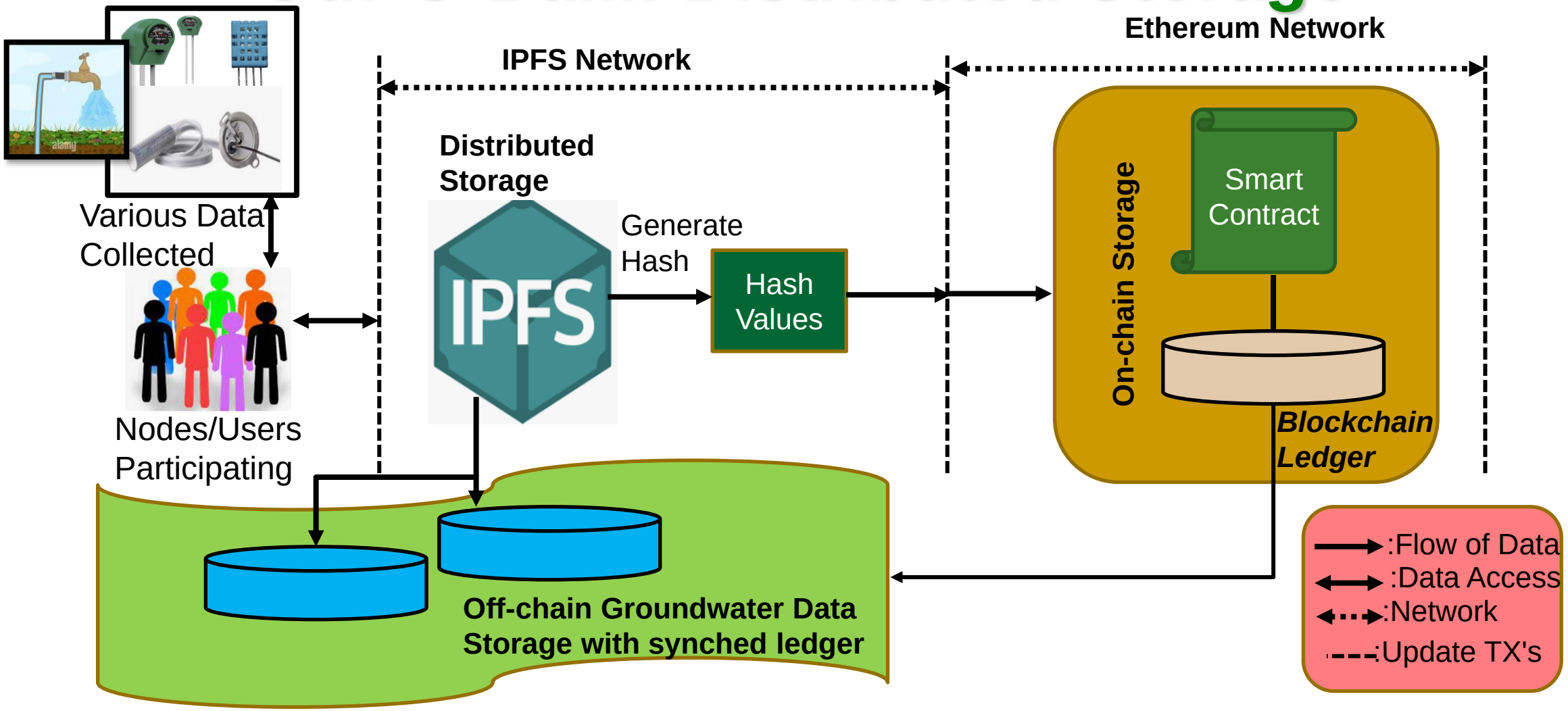
# Our G-DaM: Proposed Architecture




DDS: Distributed Data Storage
CI: Content Identifier.
BC: Blockchain

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

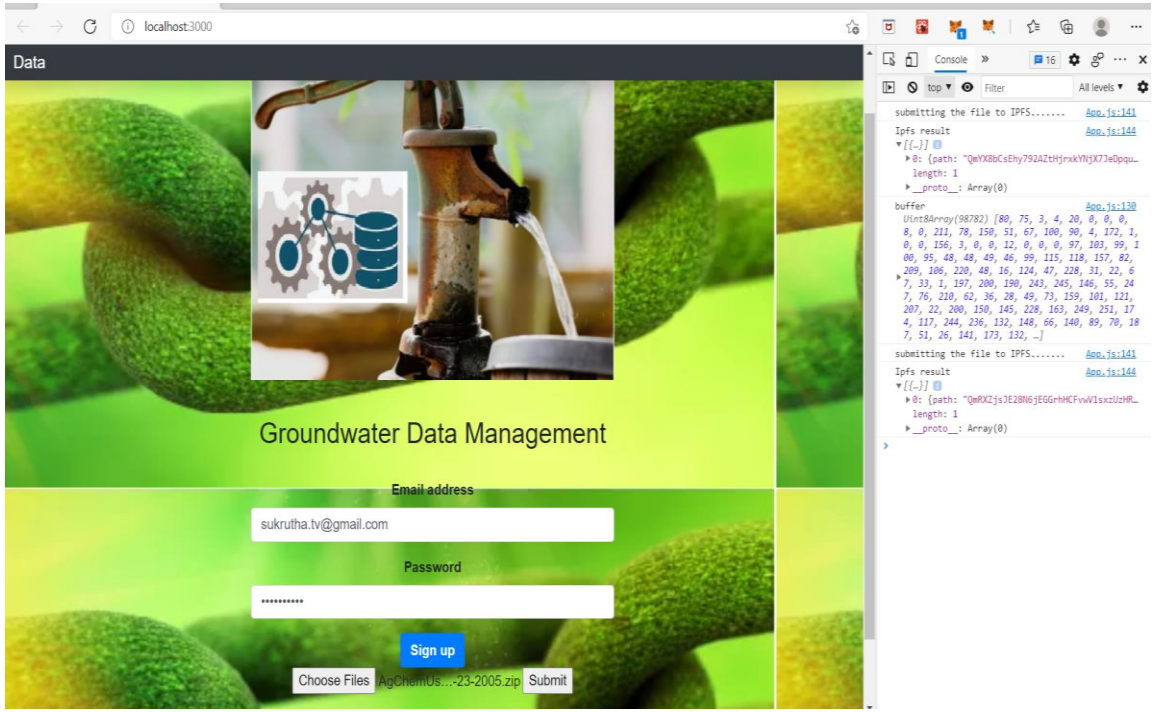
# Our G-DaM: Distributed Storage




Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

# Our G-DaM: Functional Verification

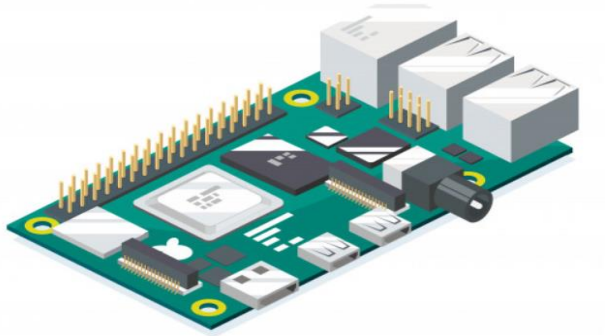
- Groundwater Data is redirected towards IPFS residing in End Systems.
- IPFS Generates Hash of the Groundwater Data.
- The IPFS Hash is stored on Blockchain as a Transaction.
- Blockchain generates Transaction Hash.




G-DaM User Interface

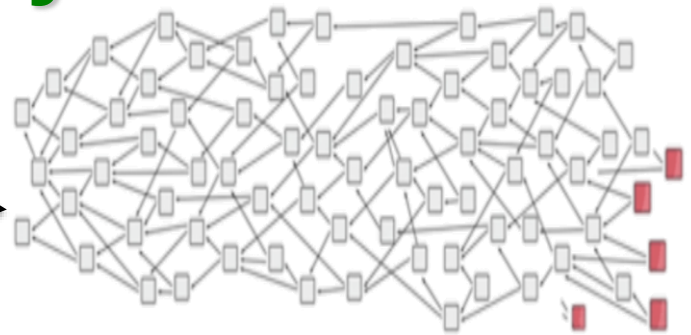
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

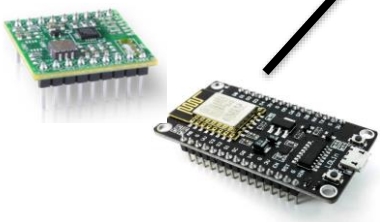
# Our sFarm: A Distributed Ledger based Remote Crop Monitoring System



Raspberry Pi 4
Model B

Transaction generation





DHT11 and Node MCU

Dielectric Soil moisture sensor and Node MCU

Monitoring Dashboard

Farmers

pH Sensor and Node MCU

Source: A. K. Bapatla, **S. P. Mohanty**, and E. Kougianos, "sFarm: A Distributed Ledger based Remote Crop Monitoring System for Smart Farming", in *Proceedings of the 4th IFIP International Internet of Things Conference (IFIP-IoT)*, 2021, pp. 13—31, DOI: https://doi.org/10.1007/978-3-030-96466-5_2

# 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

# 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.

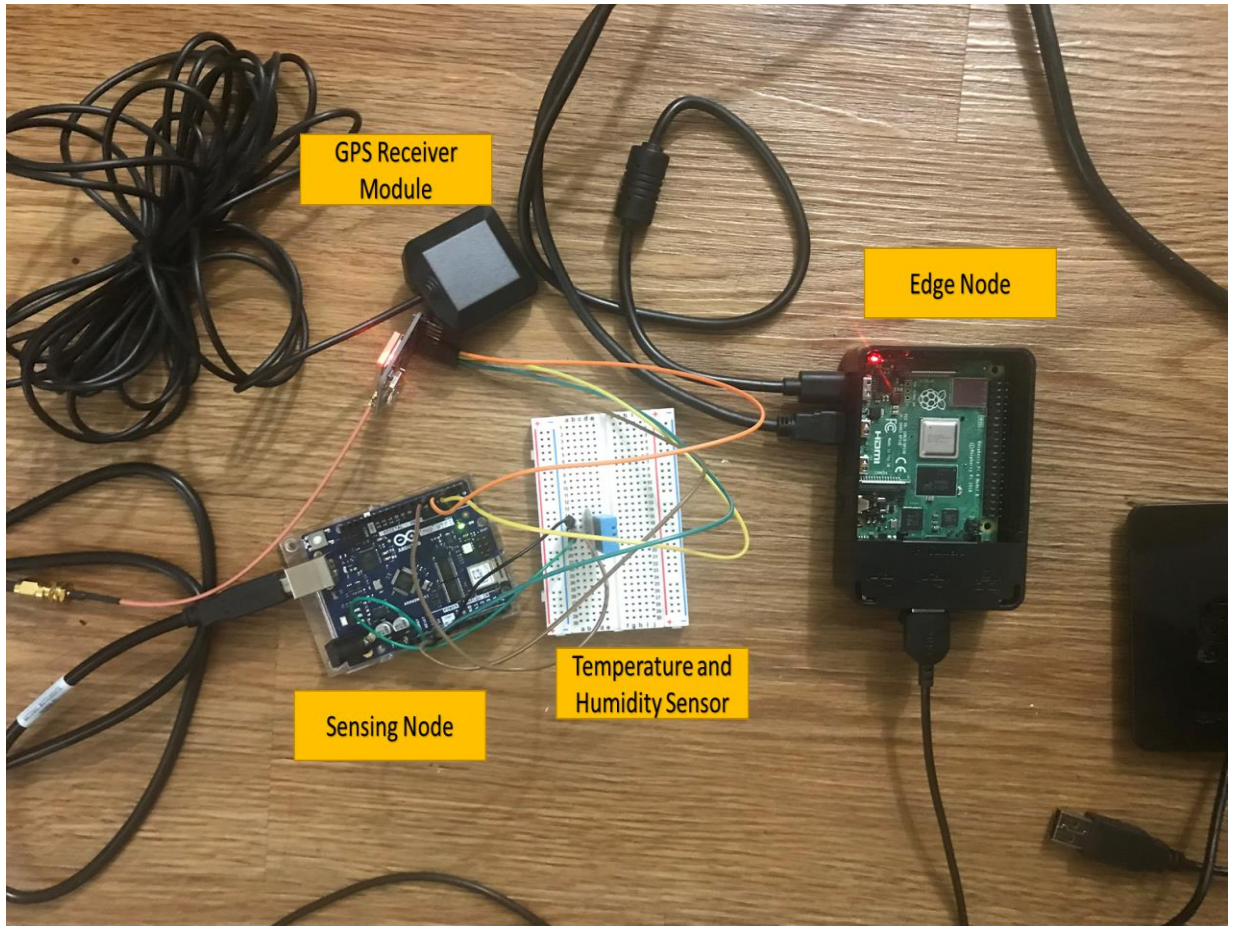
# Our sFarm: Solution

- Tangle is a data structure behind the IOTA which is a Directed Acyclic Graph (DAG).
- Directed Acyclic Graphs (DAG) are the data structures which grow in one direction and doesn't have cyclic structures within.
- Tangle is maintained and updated at all the nodes in the network.
- Any new transaction is published will be attached to the Tangle tips.
- Will be single source of truth.

# 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. |
| Transaction time | Increases with increase in network traffic | Decreases with increase in network traffic. |
| Scalability | Predetermined block sizes and block generation times may 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. |

# Our sFarm: Implementation




COM12

```
 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
```

Source: A. K. Bapatla, **S. P. Mohanty**, and E. Kougianos, "sFarm: A Distributed Ledger based Remote Crop Monitoring System for Smart Farming", in *Proceedings of the 4th IFIP International Internet of Things Conference (IFIP-IoT)*, 2021, pp. 13—31, DOI: https://doi.org/10.1007/978-3-030-96466-5_2

# Our 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 |

Source: A. K. Bapatla, **S. P. Mohanty**, and E. Kougianos, "sFarm: A Distributed Ledger based Remote Crop Monitoring System for Smart Farming", in *Proceedings of the 4th IFIP International Internet of Things Conference (IFIP-IoT)*, 2021, pp. 13—31, DOI: https://doi.org/10.1007/978-3-030-96466-5_2

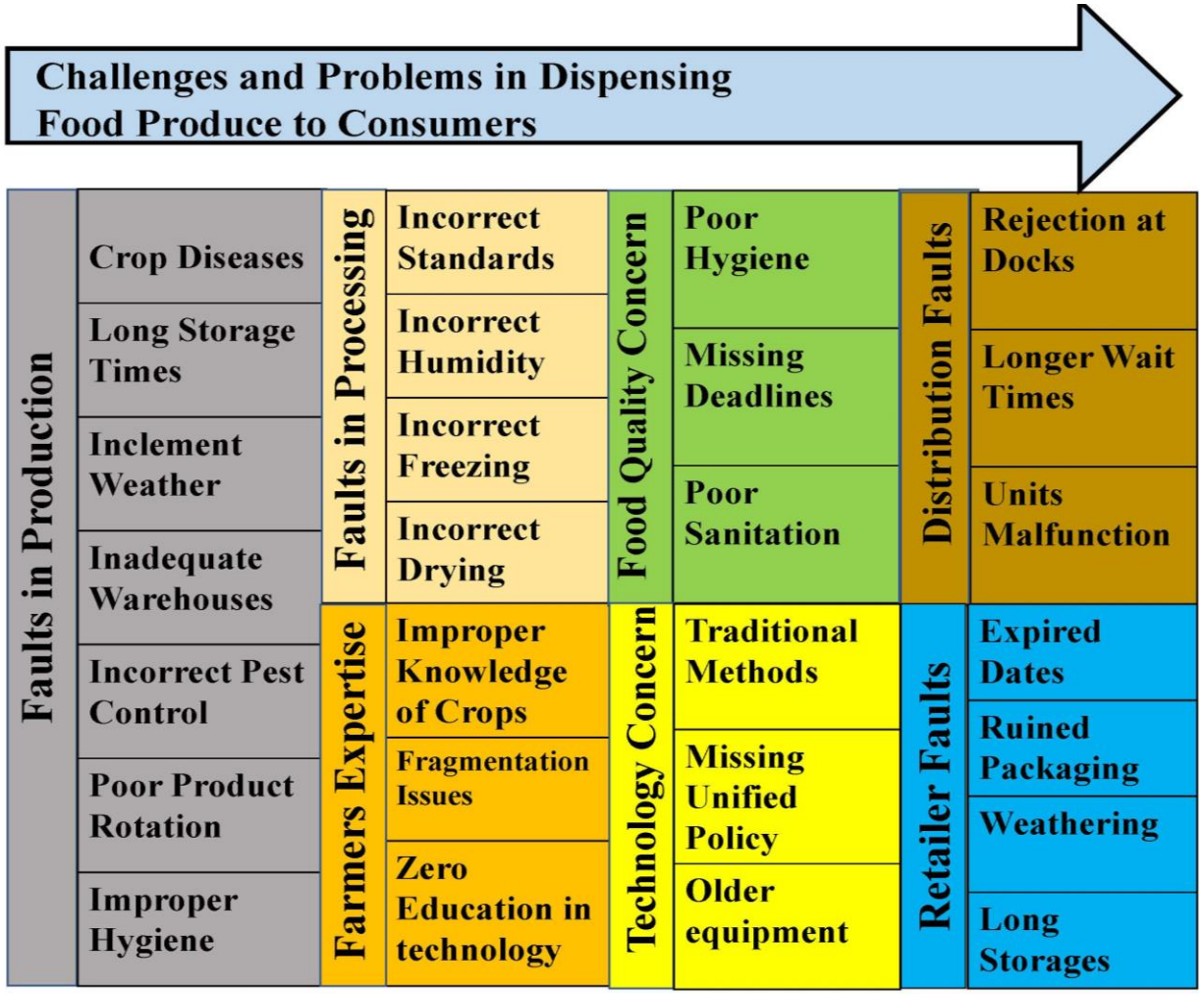
# Food Safety and Quality

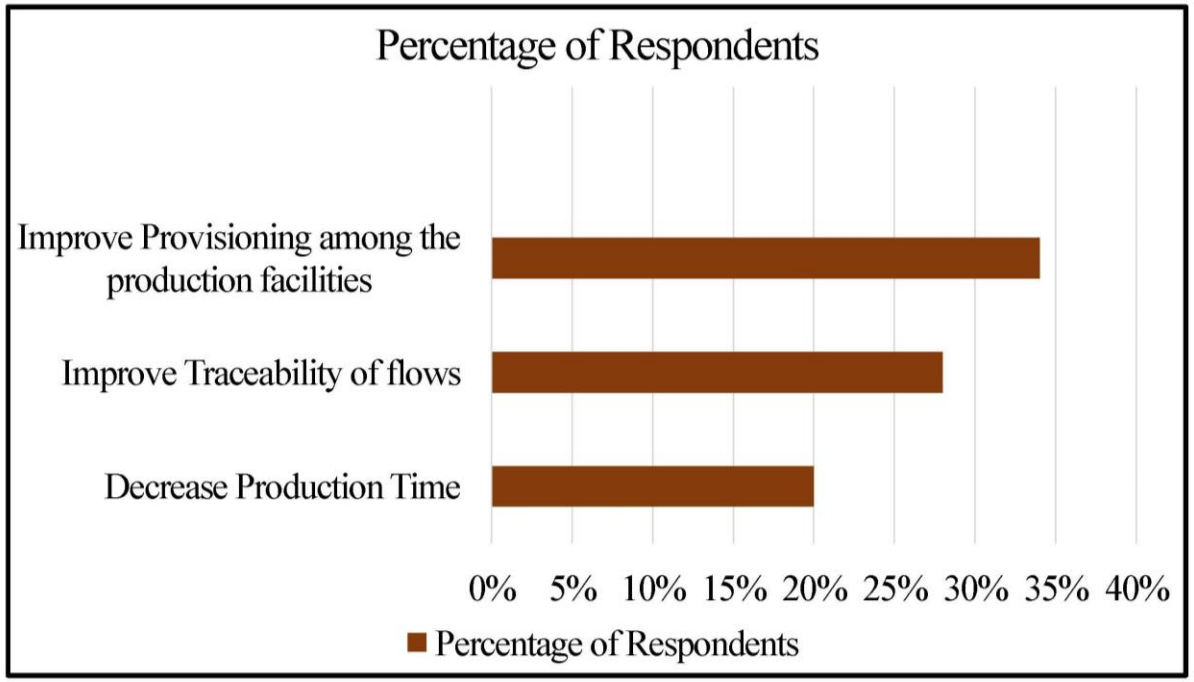
# LinkedIn Video That Got My Attention

https://www.linkedin.com/posts/omar-al-bardan_nutraceuticals-nutraceutical-nutrition-activity-6999846535878348800-WvJn?utm_source=li_share&utm_content=feedcontent&utm_medium=g_dt_web&utm_campaign=copy

Source: Omar Al Bardan_LinkedIn_2022_Common Counterfeit Foods and How to Identify Them

# Challenges of Agricultural Production Distribution

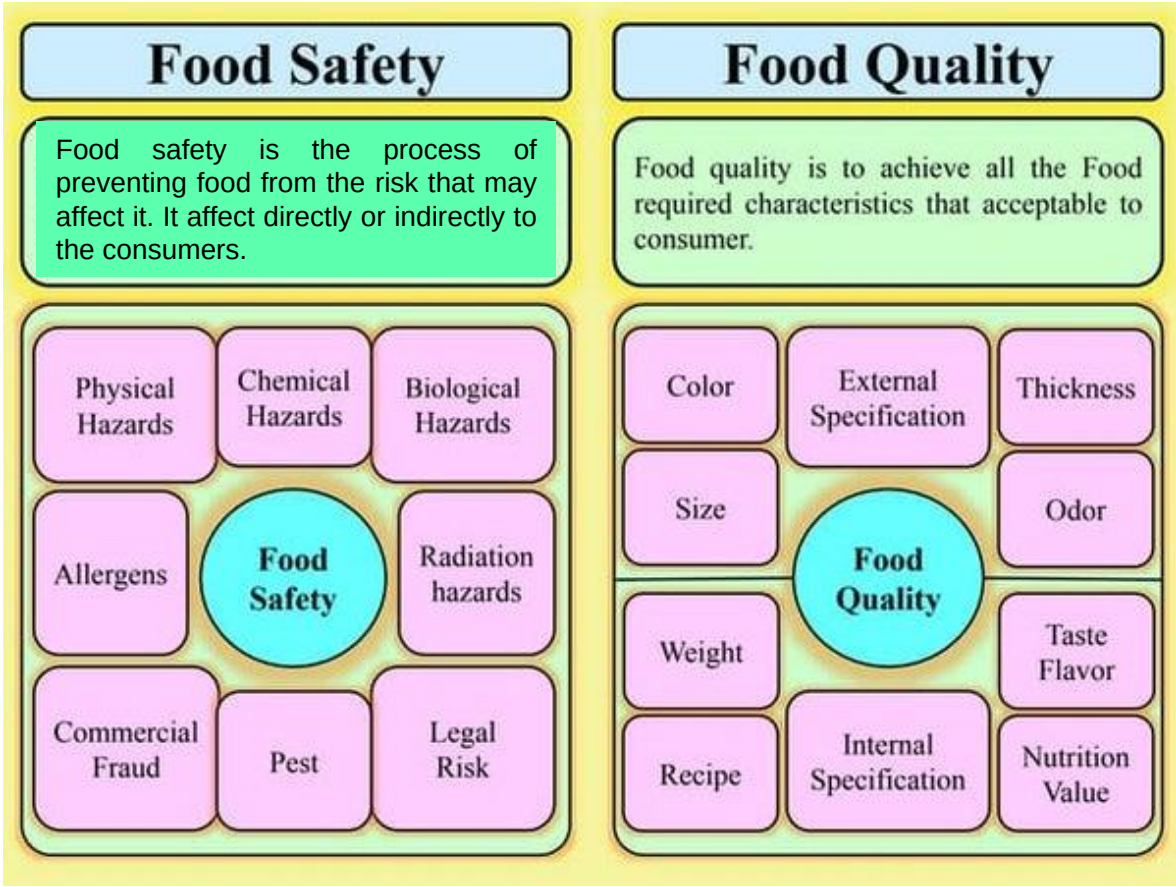



Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# Food Safety Vs Food Quality


Source: https://inewtrition.com/ensuring-food-safety-quality/

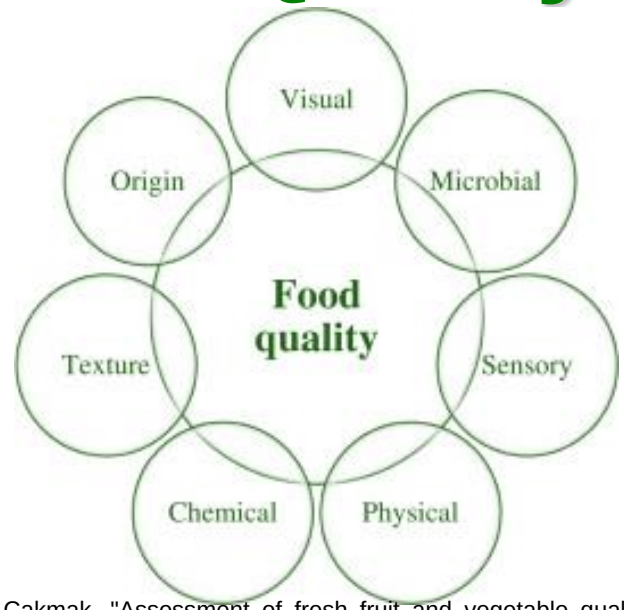



Source: https://www.slideshare.net/ijazulhaqrana/food-safety-vs-food-quality

# Fruit and Vegetable Safety and Quality?

Source: https://www.openpr.com/news/2062098/food-safety-testing-market-swot-analysis-by-key-players


Source: https://aimcontrolgroup.com/en/fruit-inspection-and-vegetable-quality-control.html




Source: H.Cakmak, "Assessment of fresh fruit and vegetable quality with non-destructive methods", Food Quality and Shelf Life, Editor - C. M. Galanakis, Academic Press, 2019, ISBN: 978-0-12-817190-5, pp. 303-331.

Am I really eating
what I think I am eating?

Source: https://aimcontrolgroup.com/en/fruit-inspection-and-vegetable-quality-control.html

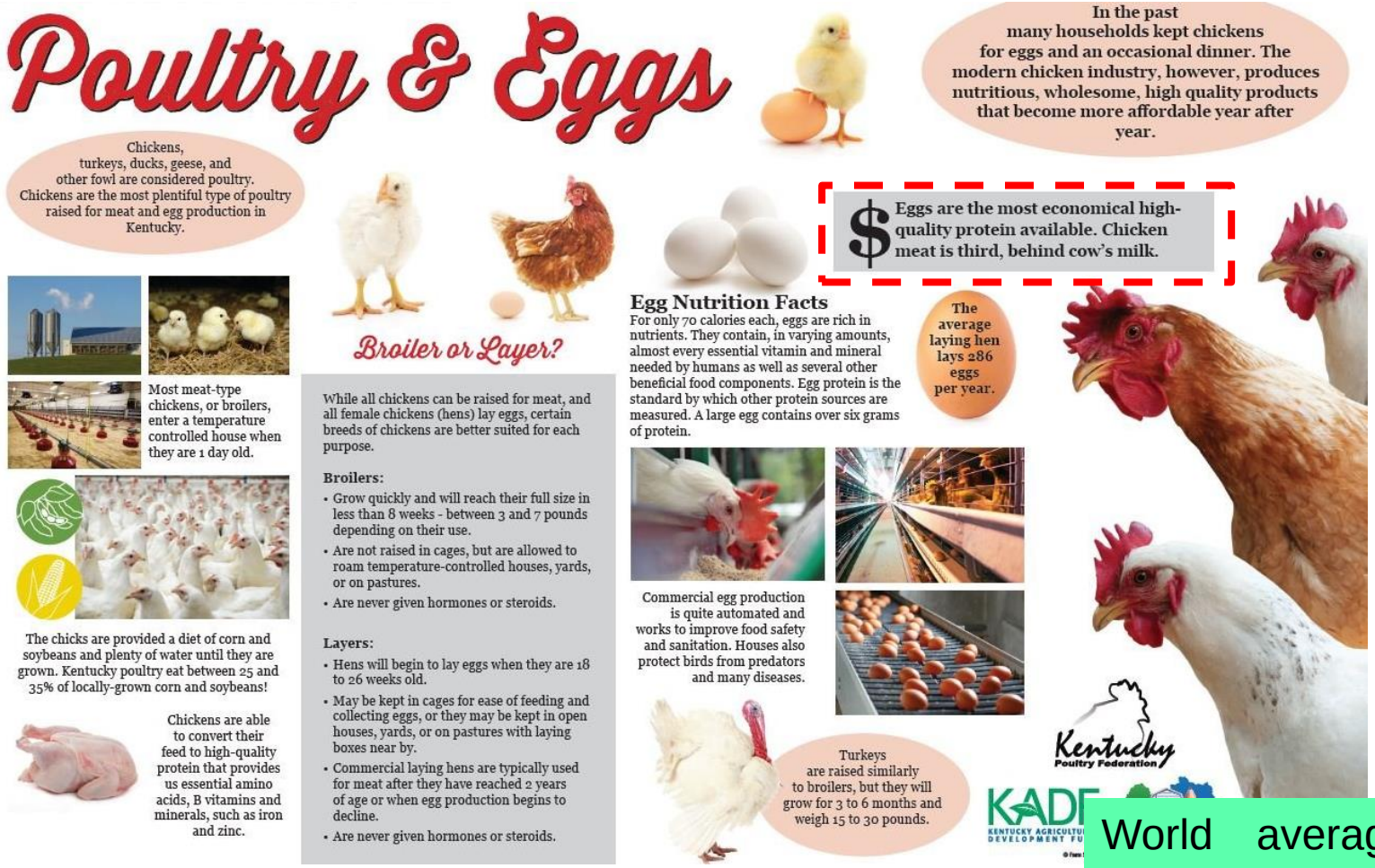
# Fish Safety and Quality?


Source: https://www.sciencedirect.com/science/article/pii/B9780128242964000074

Source: https://kiribatifishltd.com/quality-assurance/

Am I eating a fish that is safe for my body?

# Poultry Safety and Quality?




Source: https://www.teachkyag.org/lessons/learn-about-poultry-and-eggs

Source: https://hgic.clemson.edu/factsheet/safe-handling-of-poultry/

Is this Egg safe to use?

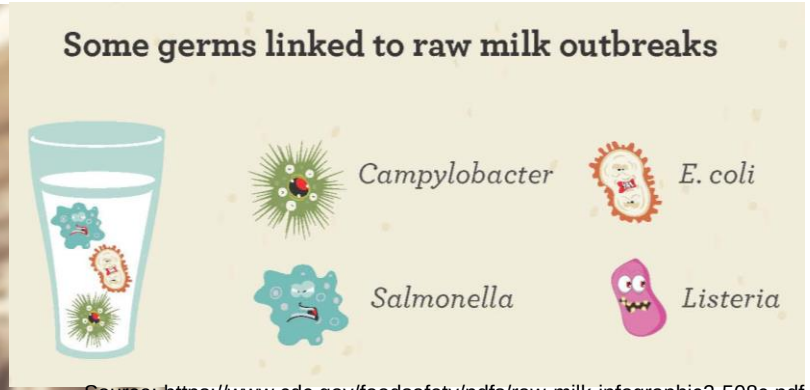
Source: https://www.meatpoultry.com/articles/22221-poultry-processing-tech-quality-controls

Is this Chicken Meat safe to eat?

World average consumption per person per year: 161 eggs (2018 data)

# Milk Safety and Quality?

Source: https://www.foodnavigator-asia.com/Article/2019/11/04/Myth-busted-FSSAI-claims-local-milk-to-be-largely-safe-despite-widespread-quality-fears




Source: https://www.cdc.gov/foodsafety/pdfs/raw-milk-infographic2-508c.pdf

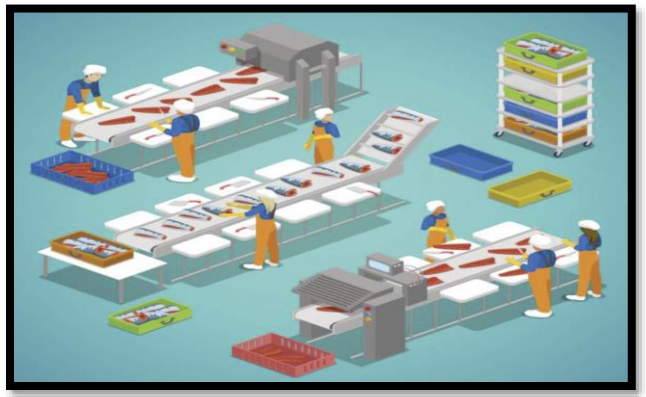
\+ Spoilage in the supply chain

How Safe is the Milk that I am Drinking?


Source: A. Poghossian, H. Geissler, and M. J. Schöning, "Rapid methods and sensors for milk quality monitoring and spoilage detection", *Biosensors and Bioelectronics*, Volume 140, 2019.

# Stages in Agricultural Product Distribution

Storage



Packing and Processing

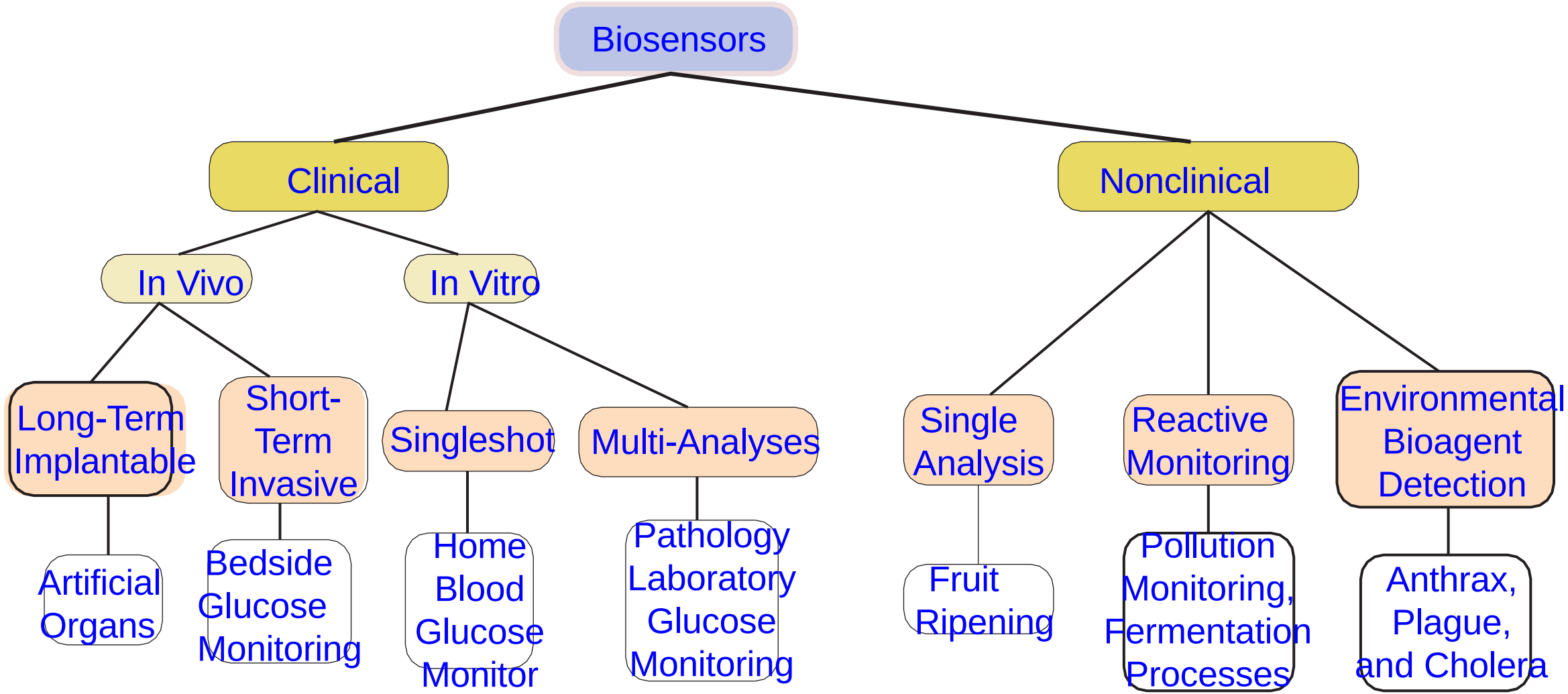
How to ensure safety and quality of food through legitimate supply chain?

Transportation


Produce

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# Time to Go Back to the Basics of Biosensors




Source: **S. P. Mohanty** and E. Kougianos, "Biosensors: A Tutorial Review", *IEEE Potentials*, Vol. 25, No. 2, March/April 2006, pp. 35-40.

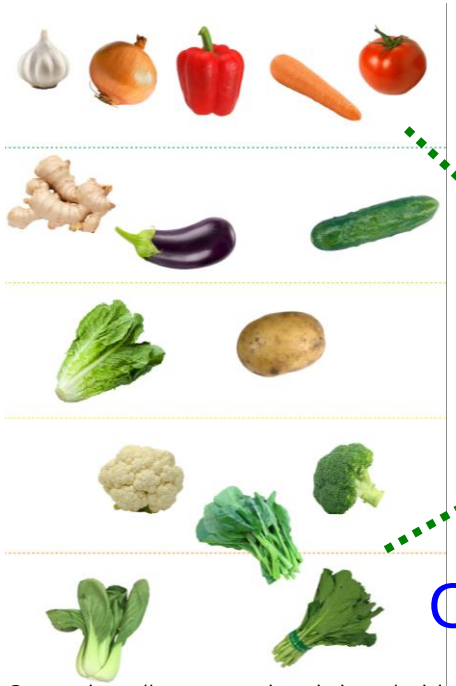
# Food Safety and Security

- Changes in:
  - Climate-smart farming
  - Eco-friendly farming
- Improved:
  - Larger growth
  - Economic stability of farmers

# Food Labelling

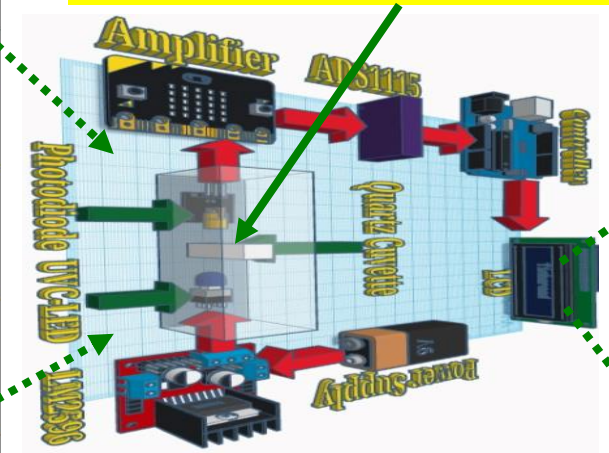
- Changes in:
  - Bar code usage
  - 2D visual tags
  - Efficient warehouse management
  - Tag base identification technologies
- Improved:
  - Well organized fields
  - Time saving

# Our Food-Care: A Device for Detection of Fertilizer Contamination in Fruits and Vegetables



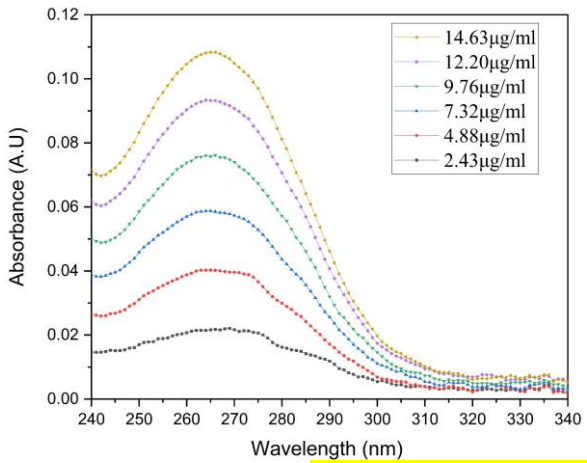
Source: https://www.smartshanghai.com/articles/wellbeing/are-your-fruits-veggies-safe-nitrate-testing-

Quartz cuvettes of length 10mm for sample solution.




Contamination Level
- Acceptable
- Moderate
- Severe
- Dangerous

Peak absorbance spectrum of 265nm at different nitrate concentrations.




Our Food-Care Device

Fruit and Vegetables - Nitride Contaminated?

Need for Device which is:
- ✓ Portable
- ✓ Works with dry or wet samples
- ✓ User safe
- ✓ Accurate
- ✓ IoT-Enable

Source: G. Saxena, C. Sahu, A. Joshi, and **S. P. Mohanty**, "Food-Care: An Optoelectronic Device for Detection of Fertilizer Contamination in Fruits and Vegetables in Smart Agriculture Framework", in *Proc. of IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted as demo.

# Imbalance Diet is a Global Issue

- Imbalanced diet can be either more or fewer of certain nutrients than the body needs.
- In 2017, 11 million deaths and 255 million disability-adjusted life-years (DALYs) were attributable to dietary risk factors.
- Eating wrong type of food is potential cause of a dietary imbalance:

Source: https://obesity-diet.nutritionalconference.com/events-list/imbalanced-diet-effects-and-causes
https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext

# Imbalance Diet – Impact on Human Body

Obesity

Inflammatory Disease

Reproductive Disease

Impact on Immune System

Kidney Disease

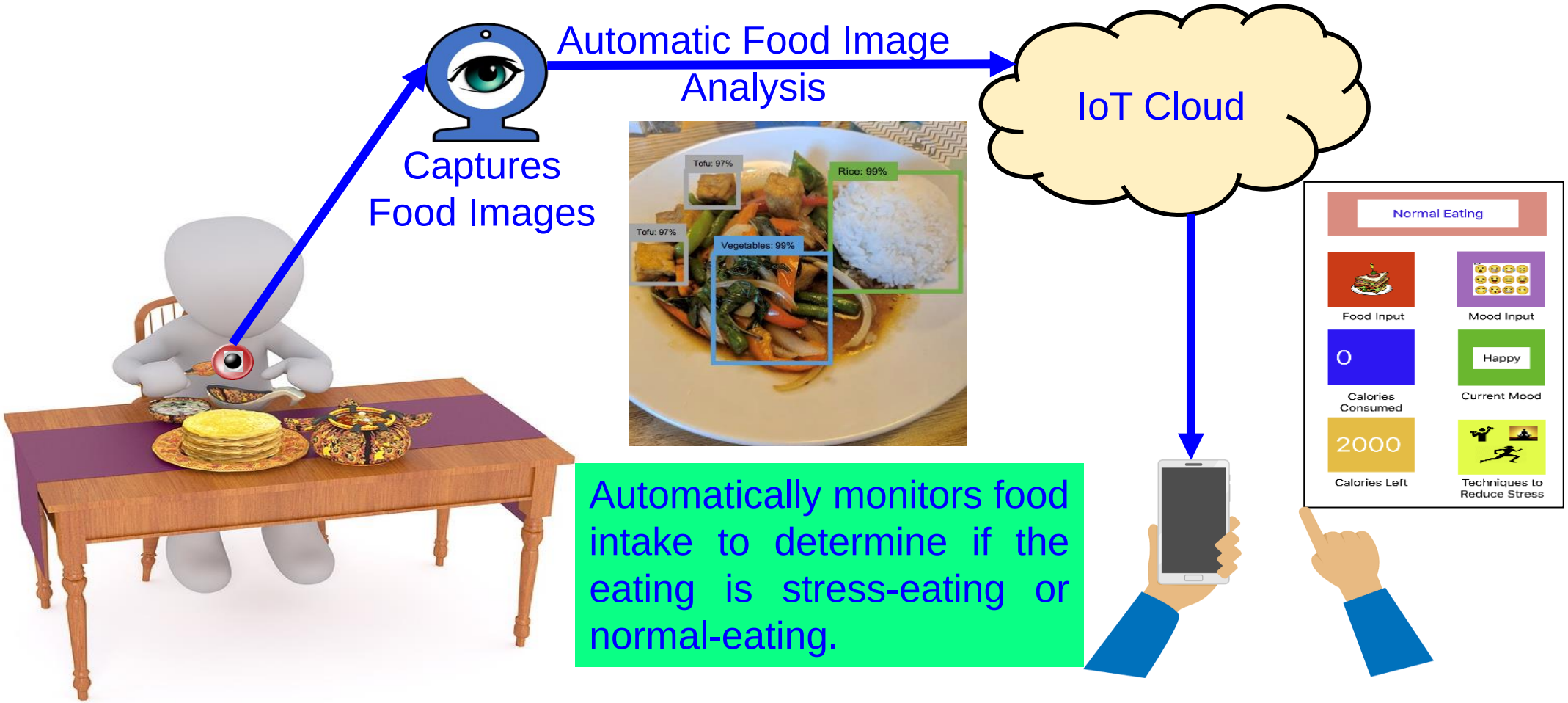
Insulin Secretion

Hypertension

Cardiac Disease

Source: A. Mitra, S. Goel, **S. P. Mohanty**, E. Kougianos, and L. Rachakonda, "iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare", in *Proceedings of the IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted.

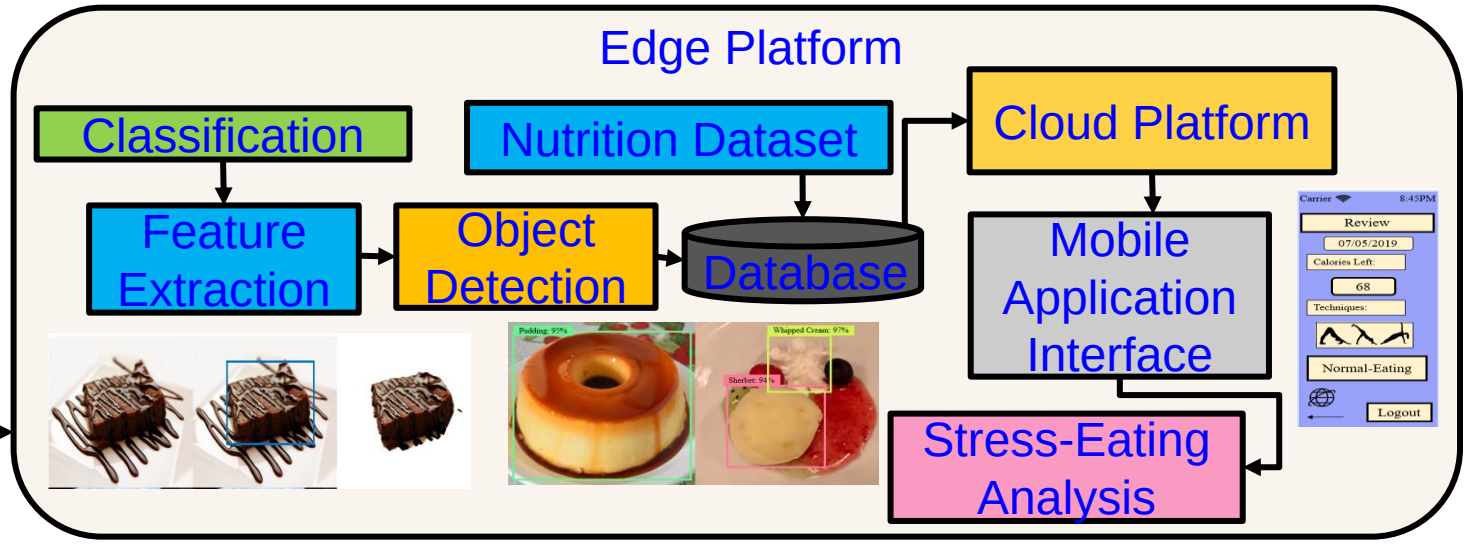
# Automatic Diet Monitoring & Control - Our Vision




Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, “iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT”, *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

# Smart Healthcare – Diet Monitoring - iLog

Reference Image




iLog- Fully Automated Detection System with 98% accuracy.

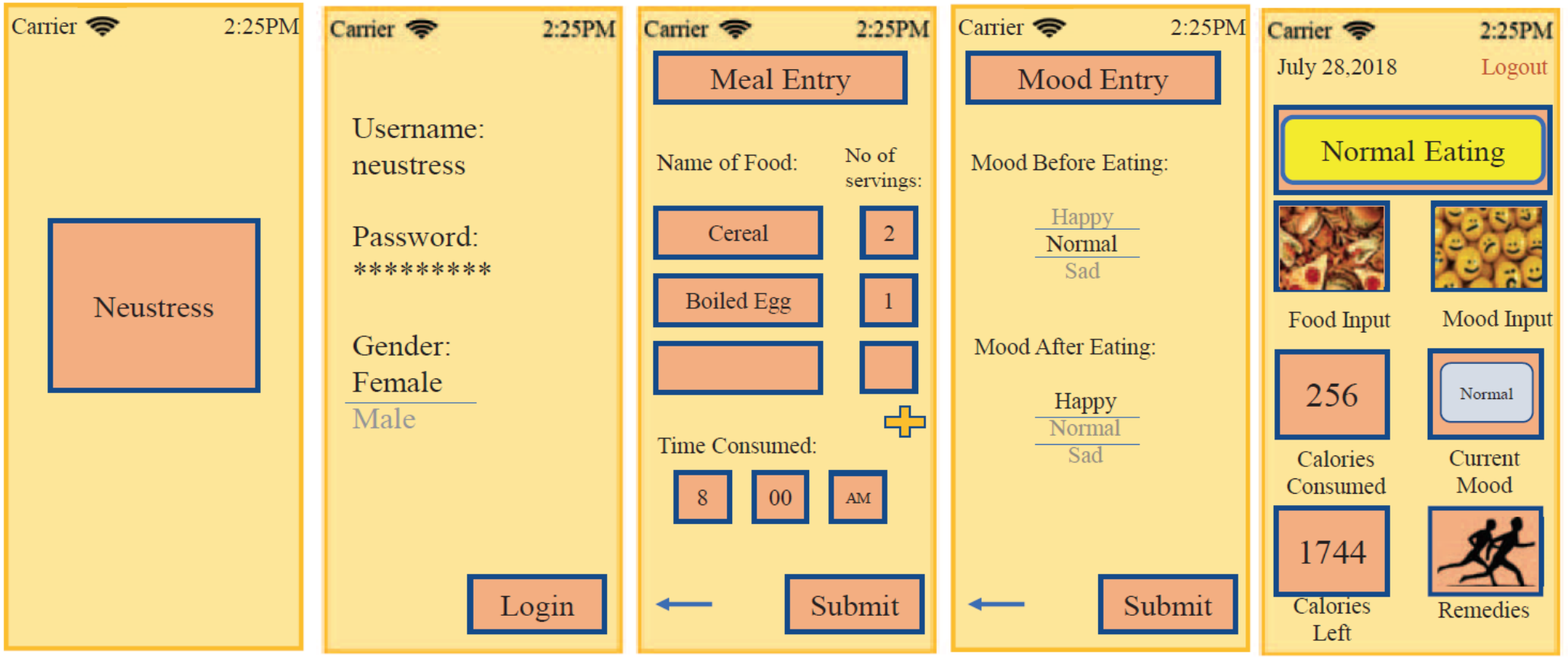
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, “iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT”, *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

# Smart Healthcare – iLog


The data collected is sent to the Firebase Database in which the calorie count is generated by using a dataset with calories and sugars count of individual items from data.gov.

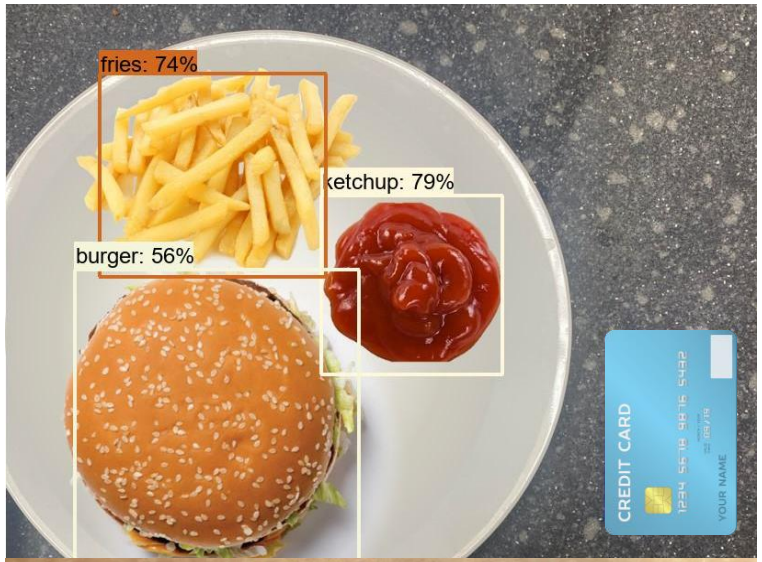
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, “iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT”, *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

# Smart Healthcare – iLog

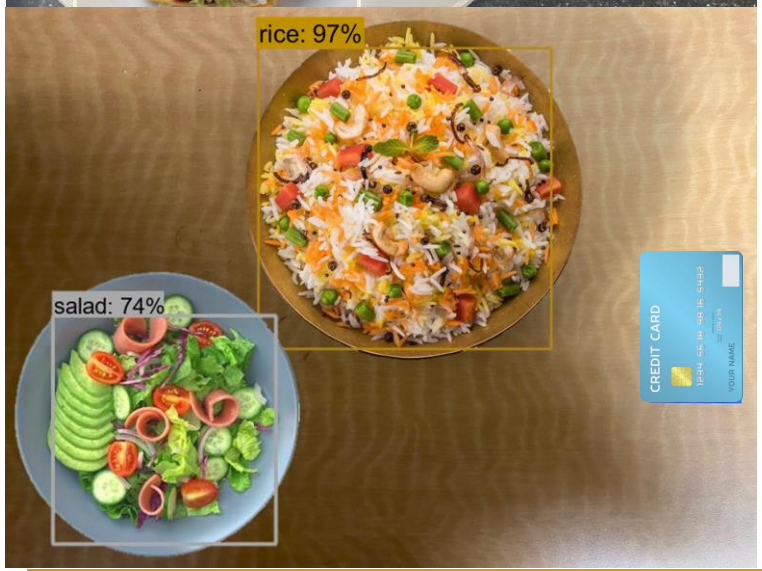



Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

# Smart Healthcare - Diet Monitoring - iLog 2.0




| Food Item | Saturated Fat (g) | Sugar (g) | Sodium (mg) | Protein (g) | Carbohydrates (g) |
|---|---|---|---|---|---|
| Fries | 6.44 | 1.56 | 244 | 4.03 | 34.84 |
| Burger | 6.87 | 4.67 | 481 | 17.29 | 48.14 |
| Ketchup | 0 | 3.2 | 136 | 0.2 | 4.13 |
| Total | 13.31 | 9.43 | 861 | 21.52 | 87.11 |

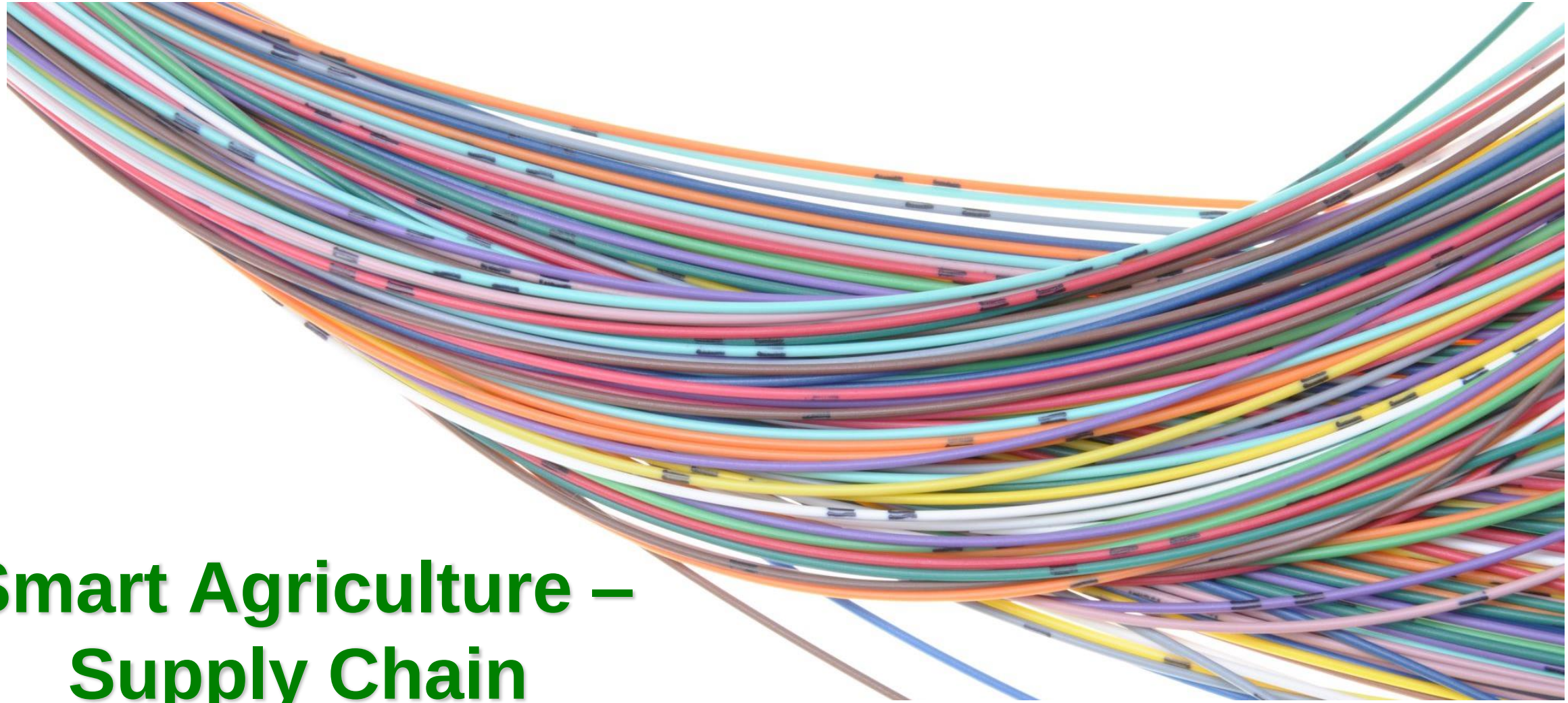



| Food Item | Saturated Fat (g) | Sugar (g) | Sodium (mg) | Protein (g) | Carbohydrates (g) |
|---|---|---|---|---|---|
| Rice | 0.3 | 0.3 | 6 | 12.9 | 135 |
| Salad | 0.8 | 3.9 | 264 | 1.1 | 7 |
| Total | 1.1 | 4.2 | 270 | 14 | 142 |

Source: A. Mitra, S. Goel, **S. P. Mohanty**, E. Kougianos, and L. Rachakonda, “iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare”, in *Proceedings of the IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted.

# Agriculture e-marketing

- Below are some of the applications during this trend:
  - Web portals
  - Facilitating consumer and retailer interaction
  - Online availability
  - Improved social approach
  - E-store
- Due to this trend:
  - It improved economic condition
  - Communication gaps are eliminated
  - Marketing of surplus goods



# Smart Agriculture – Supply Chain

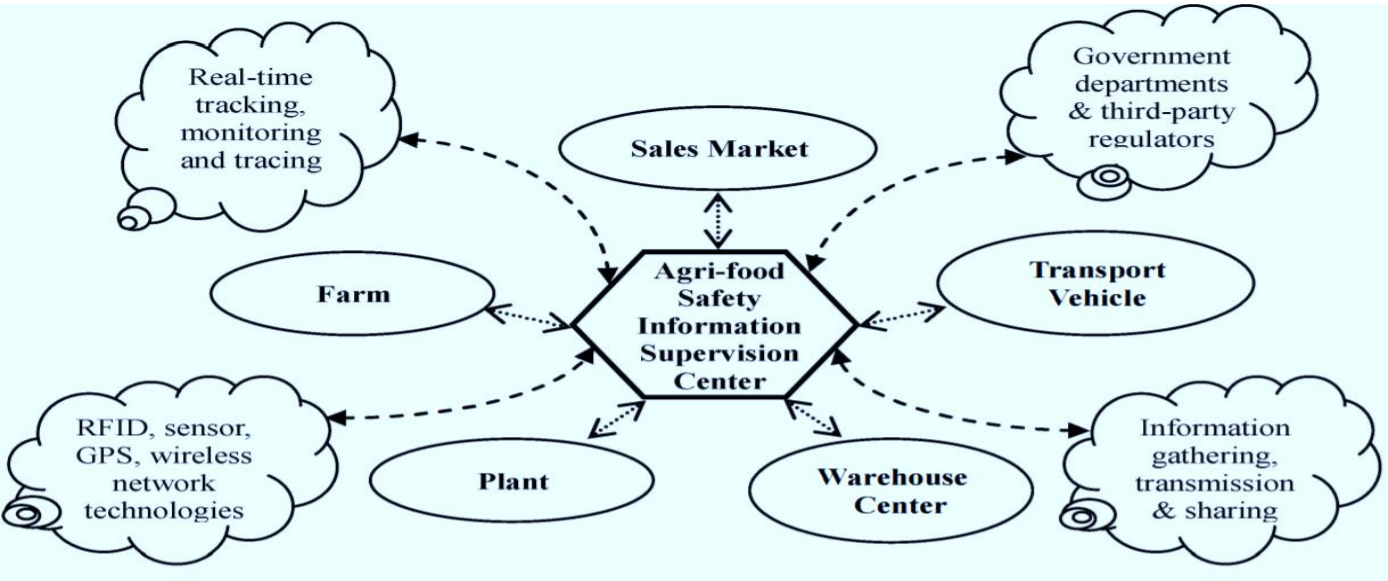
# Transparent Supply Chain

- Scenario involving a transaction between retailer with source of goods making a transaction with customer and a bank involved in lending working capital to retailer.
- Types of entries in this scenario:
  - Information flow (Order details or payment confirmations)
  - Inventory flow (Actual goods transfer between retailer and customer)
  - Financial flow (Monetary transactions)
- ERP (Enterprise Resource Planning) systems cannot connect all these flow effectively and may result in execution errors which go untraceable and in turn affect the decision-making and conflict resolving.

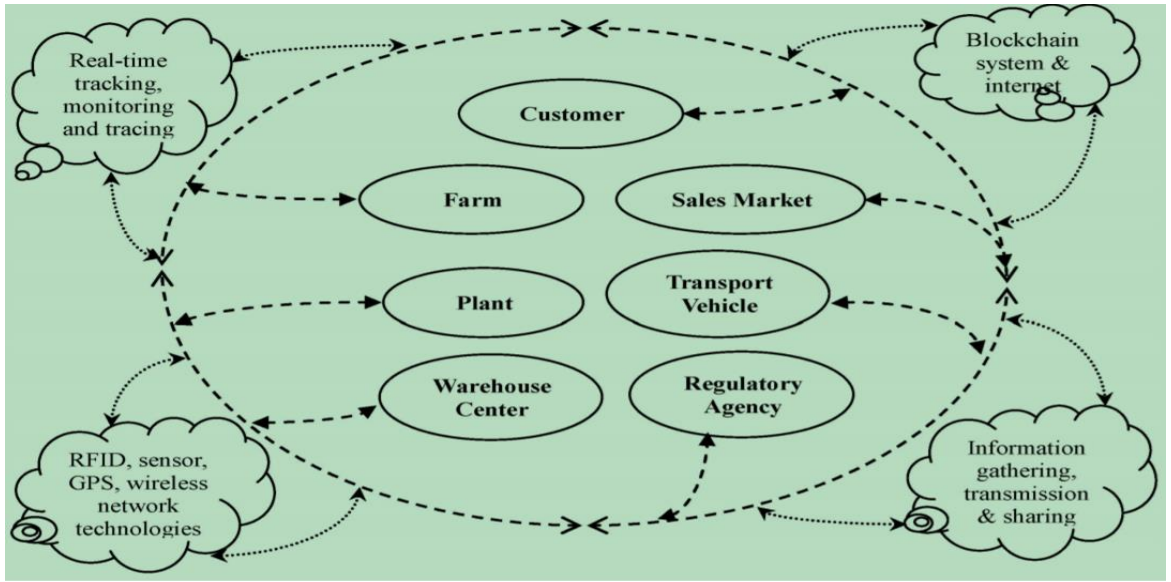
# Transparent Supply Chain

- Adding to this, supply chain activities are too complex to capture.
  - Orders may split into multiple shipments or multiple orders combined to single shipment.
- Using Blockchain enables:
  - Faster delivery of products
  - Cost-efficient delivery
  - Enhances product traceability
  - Improves co-ordination between the entities in supply chain
  - Aiding access to finance

# Food Traceability Using Efficient Supply Chain



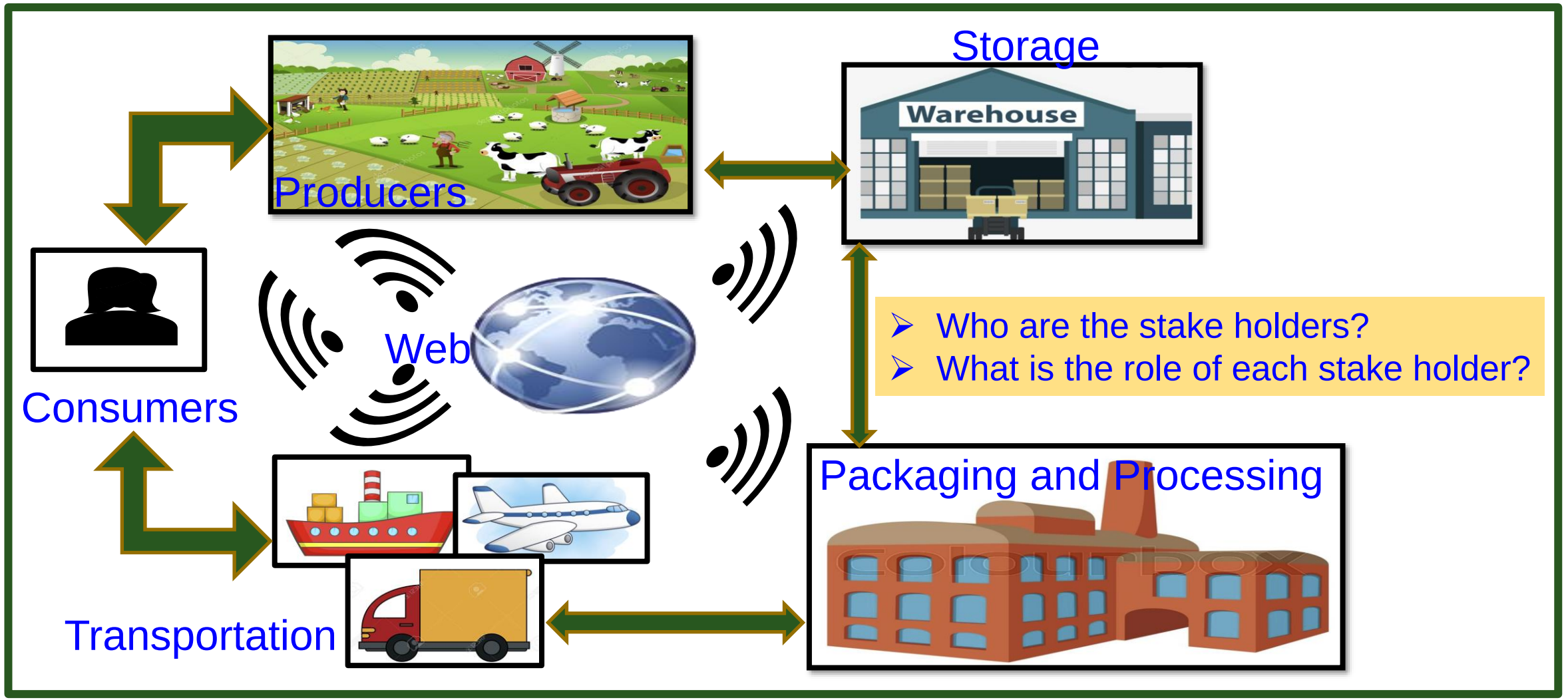

Centralized System




Blockchain based Decentralized System

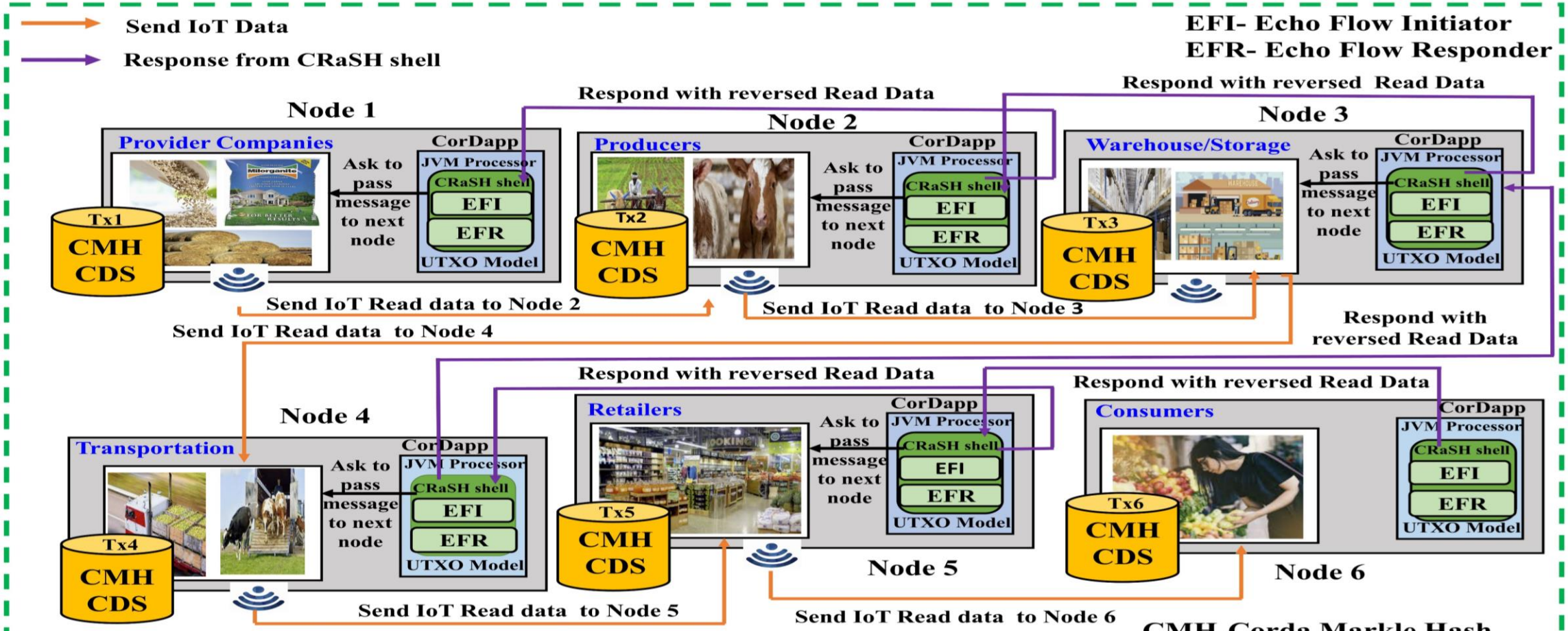
Source: Feng Tian, "An agri-food supply chain traceability system for China based on RFID & blockchain technology," in *Proc. 13th International Conference on Service Systems and Service Management (ICSSSM)*, 2016, pp. 1-6, doi: 10.1109/ICSSSM.2016.7538424.

# Agriculture Supply Chain



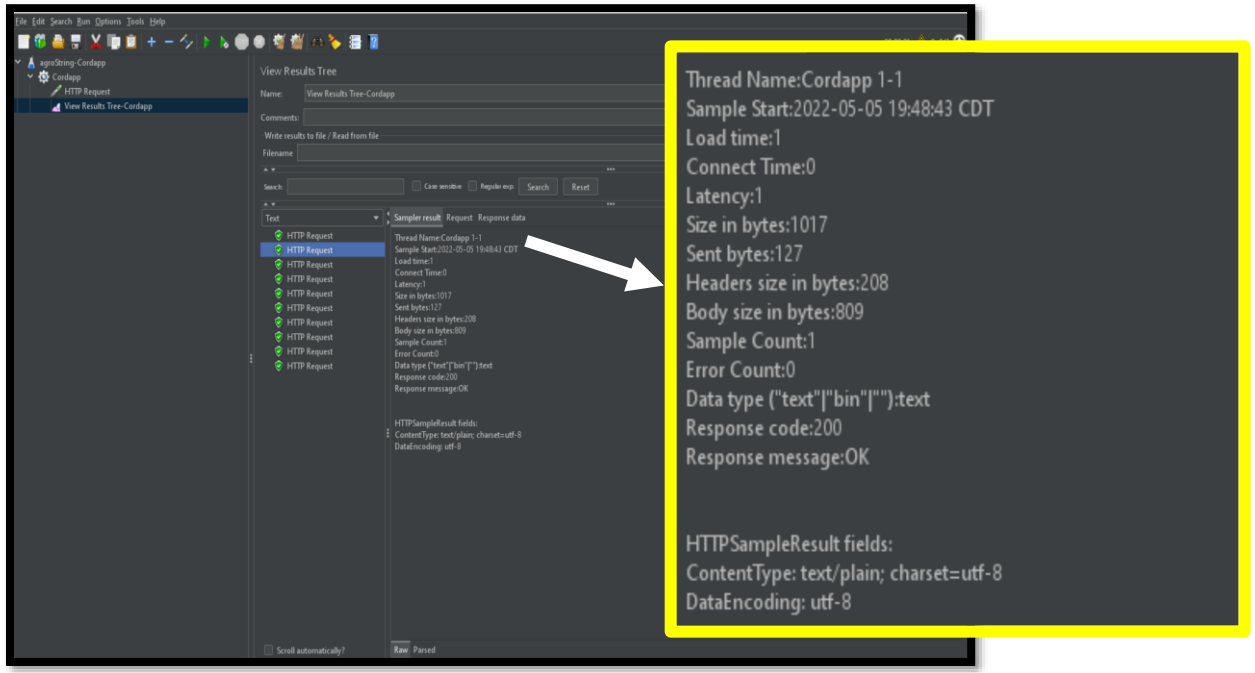

Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Our agroString: Visibility and Provenance in Agriculture through a Private Blockchain

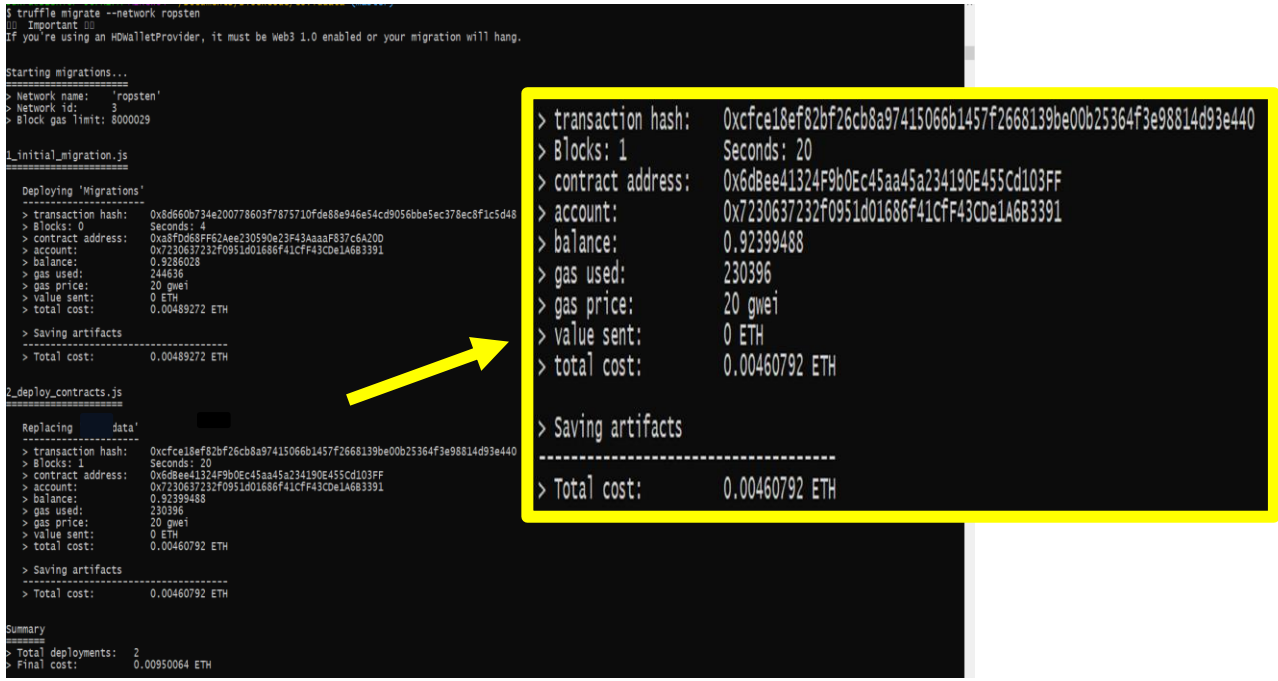



Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# Our agroString: Visibility and Provenance in Agriculture through a Private Blockchain




Test for Private Blockchain




Test for Public Blockchain

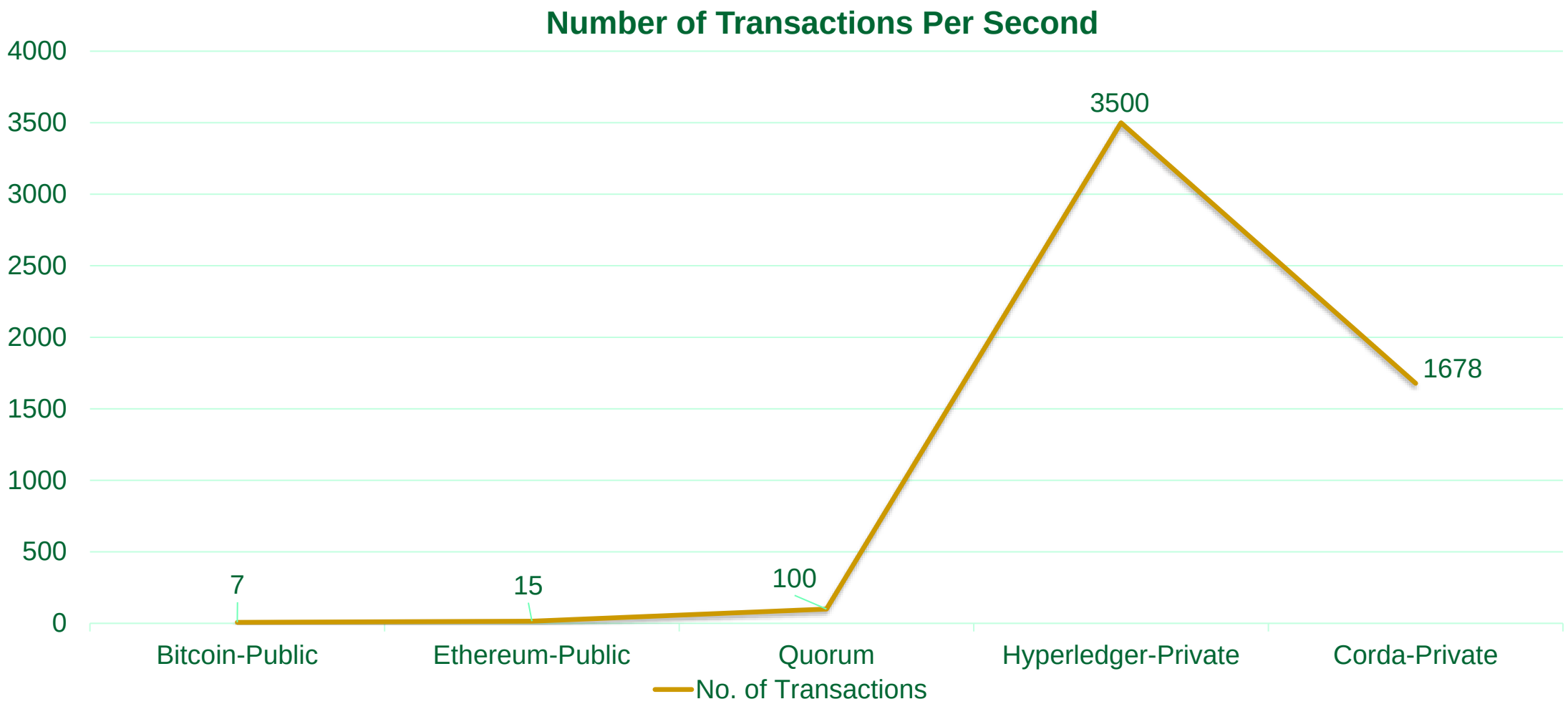
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# Our agroString: Comparative Perspectives

| Application | Blockchain | Latency | Off-chain Storage | Transaction Cost | Financial Application |
|---|---|---|---|---|---|
| Fish Supplychain [16] | RFID | Not used | High | Centralized | Low |
| agro food Supplychain [17] | RFID | Ethereum | High | Decentralized | High |
| Cow Tracking [18] | IoT | Not Used | High | Centralized | Low |
| Traceability System [21] | Hyperledger | 0.5 s | Used-Database | Hyperledger-No Cost | No |
| **agroString [Current-Paper]** | **Corda** | **1ms** | **Not Used** | **No Cost** | **Yes** |
| 1 KB = 0.032 Eth[40] 1MB= 32.768 1Eth= 1944.84 [38] | | | | | |

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# Our agroString: Comparative Perspectives




Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

# AgriBlockIoT - Blockchain-based Traceability in Agri-Food Supply Chain Management

- Actors involved in the supply chain process:
  - Provider
  - Producer
  - Processor
  - Distributor
  - Retailer
  - Consumer


Image Source: M. P. Caro, M. S. Ali, M. Vecchio and R. Giaffreda, "Blockchain-based traceability in Agri-Food supply chain management: A practical implementation," in *Proc. IoT Vertical and Topical Summit on Agriculture - Tuscany (IoT Tuscany)*, 2018, pp. 1-4, doi: 10.1109/IOT-TUSCANY.2018.8373021.

# AgriBlockIoT - Transactions to be stored

- Raw material purchasing – sale of purchases
- Planting – How many seeds and farm parameters
- Growing – Regular farm status by using sensors
- Farming- pesticides, fertilizers usage statistics etc.
- Harvesting – Information about the produce from farms.
- Delivery to processor – Transfer of product from farm to processor
- Processing
- Delivery to Retailers
- Retailing
- Consuming

Image Source: M. P. Caro, M. S. Ali, M. Vecchio and R. Giaffreda, "Blockchain-based traceability in Agri-Food supply chain management: A practical implementation," in *Proc. IoT Vertical and Topical Summit on Agriculture - Tuscany (IoT Tuscany)*, 2018, pp. 1-4, doi: 10.1109/IOT-TUSCANY.2018.8373021.

# Blockchain Inspired RFID-Based Information Architecture for Food Supply Chain

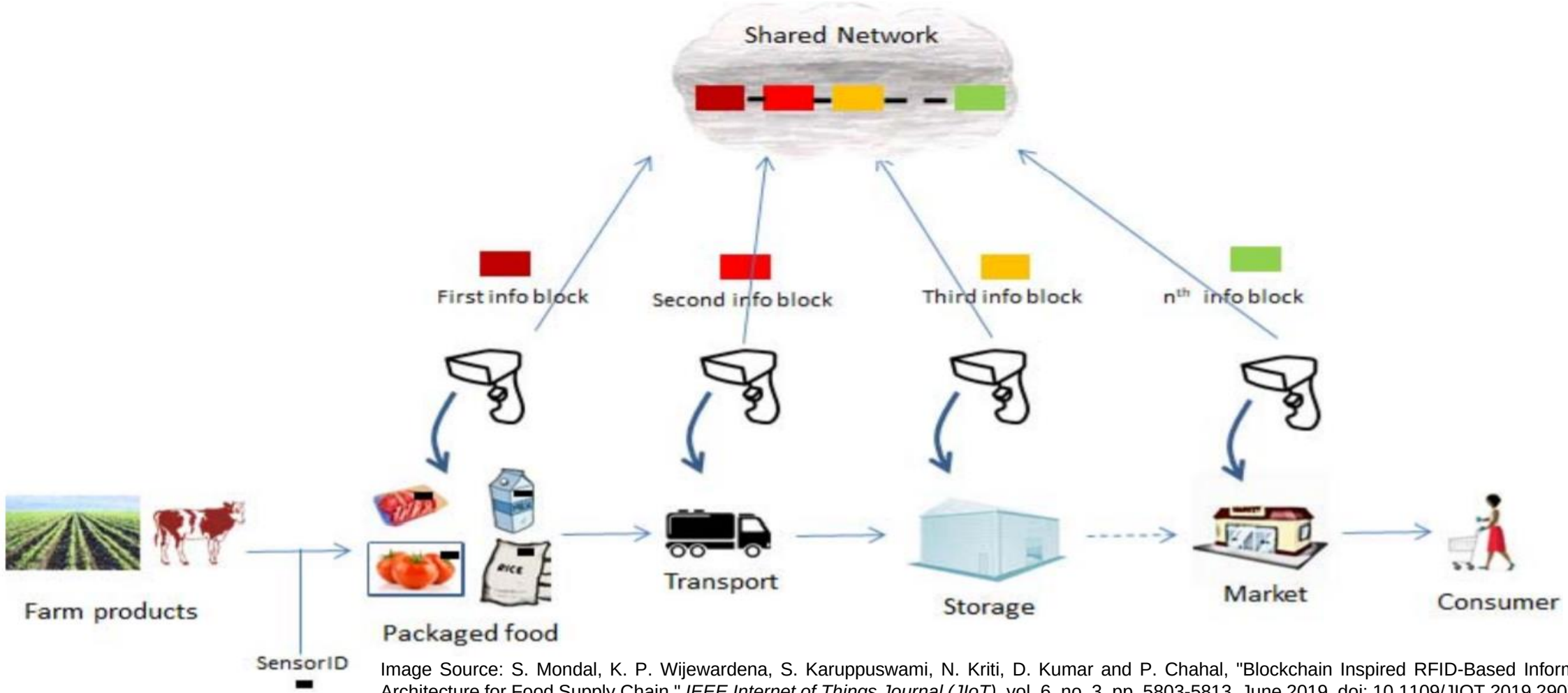



Image Source: S. Mondal, K. P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar and P. Chahal, "Blockchain Inspired RFID-Based Information Architecture for Food Supply Chain," *IEEE Internet of Things Journal (JIoT)*, vol. 6, no. 3, pp. 5803-5813, June 2019, doi: 10.1109/JIOT.2019.2907658.

# Blockchain Inspired RFID-Based Information Architecture

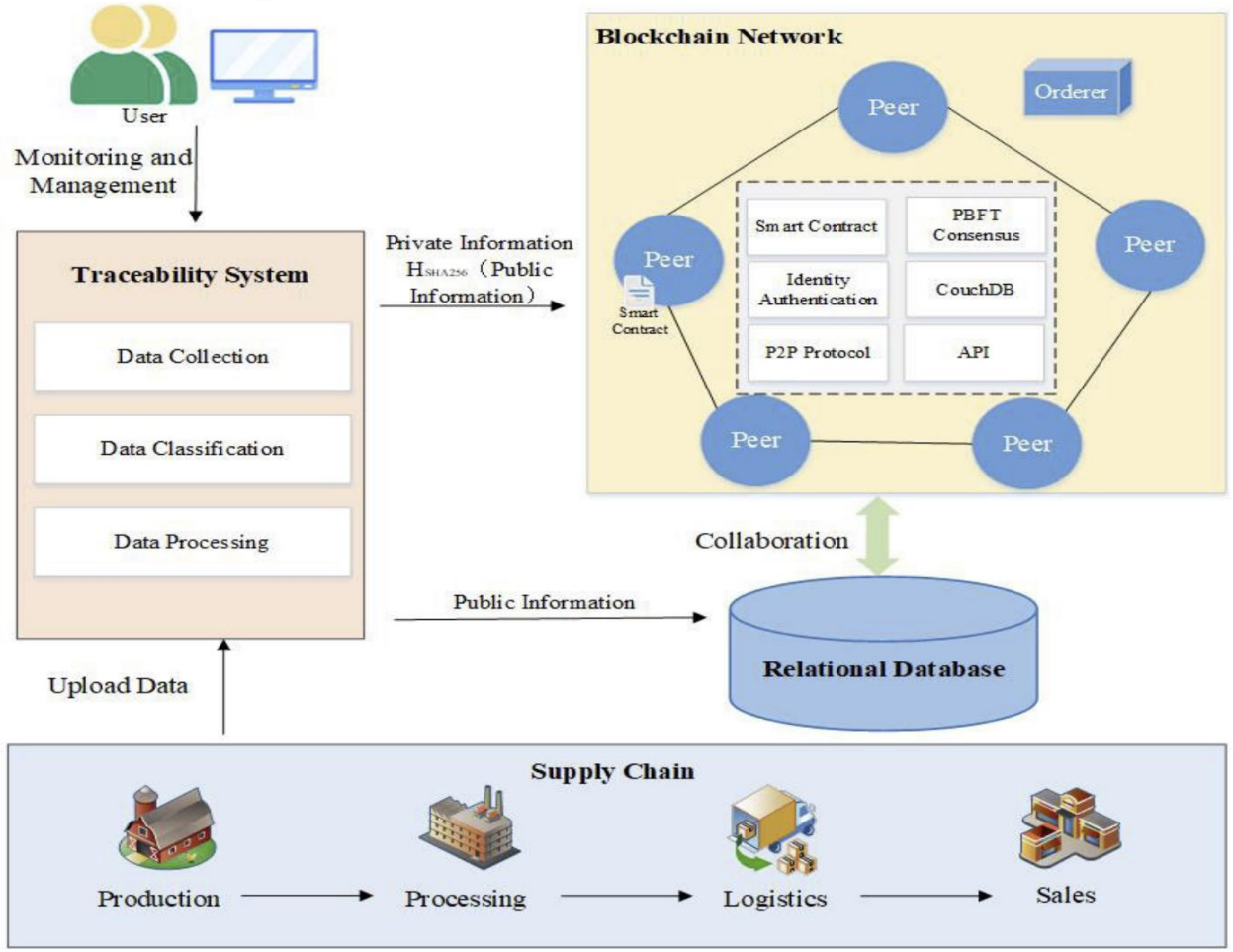
- Proof-of-Object (PoO):
  - PoW in conventional Blockchains is resource thirsty.
  - Possession of the object is proven using cryptographically to make transaction valid to be added to block.
- Dual Addressing:
  - Cyber Addressing – A public address in the blockchain memory
  - RFID Addressing – A physical address specific to food package and should be linked to Cyber address in such a way that Cyber address can be derived from physical address, but inverse operation is computationally expensive.

Image Source: S. Mondal, K. P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar and P. Chahal, "Blockchain Inspired RFID-Based Information Architecture for Food Supply Chain," *IEEE Internet of Things Journal (JIoT)*, vol. 6, no. 3, pp. 5803-5813, June 2019, doi: 10.1109/JIOT.2019.2907658.

# A Trusted Blockchain-Based Traceability System for Fruit and Vegetable Agricultural Products

**On-chain and Off-chain Data Storage Technology:**

| Key | ID |
|---|---|
| Value | {<br>"Type": "Info",<br>"ID": "36",<br>"PrivateData":"e515789cae824dad1699f74687a87bf158ceb04b89fdc8b01f7609d6c49ca66adbcf8a4b9bd2c34aea64c3",<br>"InfoHash":"429ab56c73040aaf65247e44279d073abb13110654aa99798d5835931065b98e"<br>} |

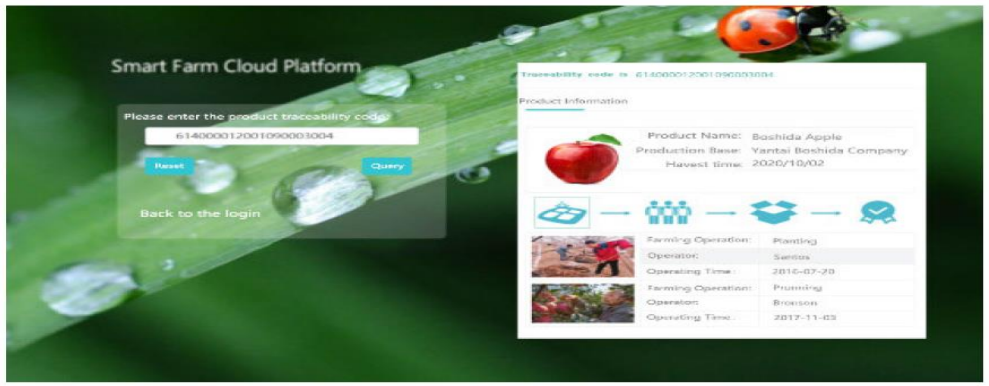



Source: X. Yang, M. Li, H. Yu, M. Wang, D. Xu and C. Sun, "A Trusted Blockchain-Based Traceability System for Fruit and Vegetable Agricultural Products," *IEEE Access*, vol. 9, 2021, pp. 36282-36293.

# A Trusted Blockchain-Based Traceability System for Fruit and Vegetable Agricultural Products

**Application of Traceability of System**


(a) The tag of apple.




(b) Query results of traceability code input on the web.

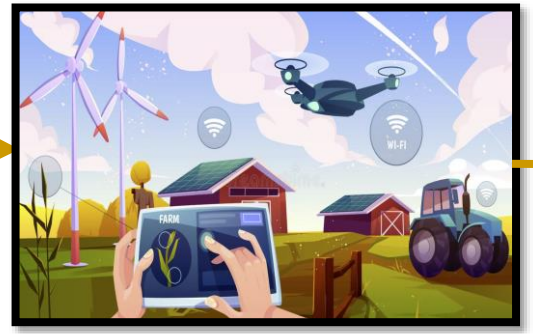

(c) Mobile phone scan query results.

Source: X. Yang, M. Li, H. Yu, M. Wang, D. Xu and C. Sun, "A Trusted Blockchain-Based Traceability System for Fruit and Vegetable Agricultural Products," *IEEE Access*, vol. 9, 2021, pp. 36282-36293.

# Is there a Reward for Doing Great Job in Farming?

# Impact of Agriculture Finance on Farm Yield

Value Chain Financing



- Use of New Technology
- Improved access to banking services
- Adopting new technology easily

- Increased crop production
- Income is Increased

Agricultural Finance

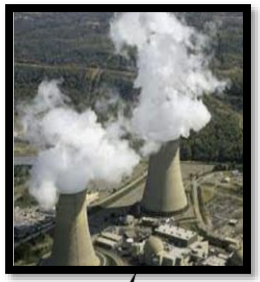
Direct Financing

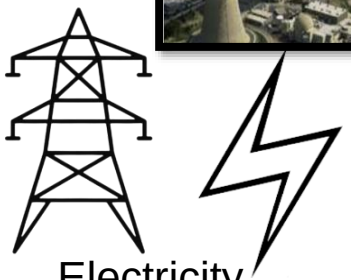
- Use of Traditional Tools
- Separation from the financial Services
- Isolation from financing

- Decreased crop production
- Low Yield
- Reduced Income

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

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





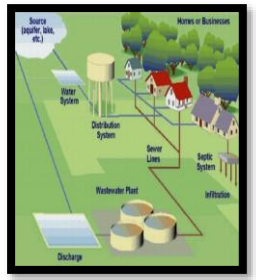
Electricity

Water

Wastage reasons

Climate Change

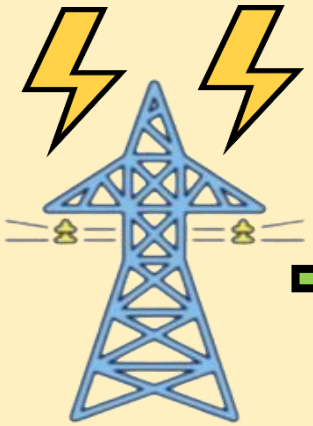

Overpopulation

- Water & energy use in different domains.
- Present Scenario: Electricity & water wastage
- Farming as main source for water and energy wastage.
- Recognizing farmers as main entity in farming.

Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

# Our IncentiveChain: Motivation



Electricity Grid

Electricity to pump water

**Motivations**

Excessive Energy Usage

Excessive Water Usage

Water Contamination

Increased electricity Rates

Economic State of Farmers

Banking third party vulnerabilities

Agricultural fields

Livestock

Fisheries

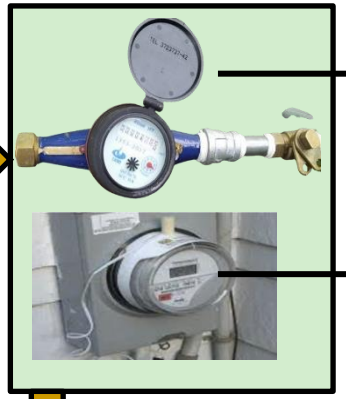
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

# Our IncentiveChain: The Idea

Farming fields

Farmer

Using water & electricity on farms



Water meter

Electricity meter

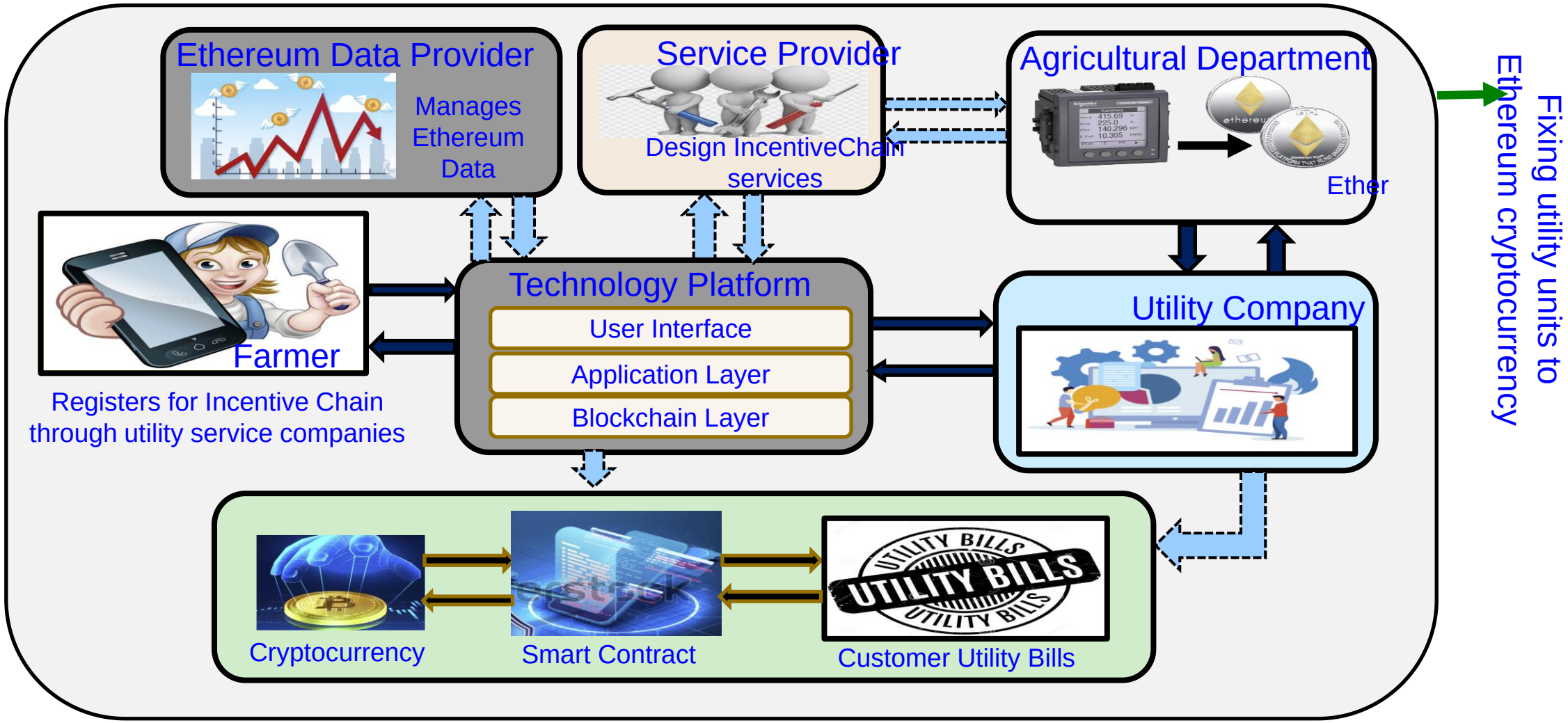
No of Units saved during farming


Converting saved units to ether cryptocurrency

Providing ether rewards to farmers for saving resources

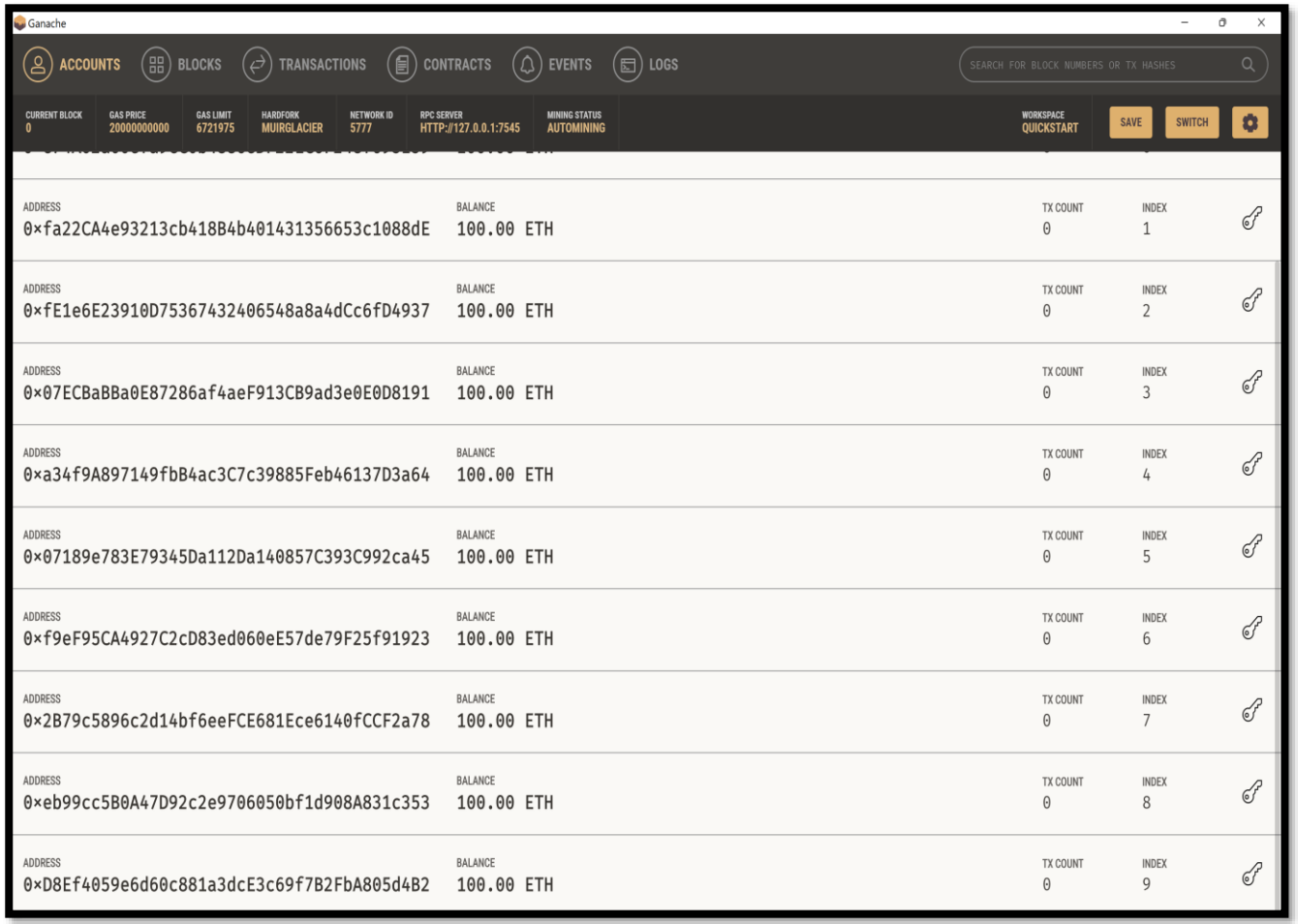
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

# Our IncentiveChain: Architecture




Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

# Our IncentiveChain: Ganache Public Blockchain

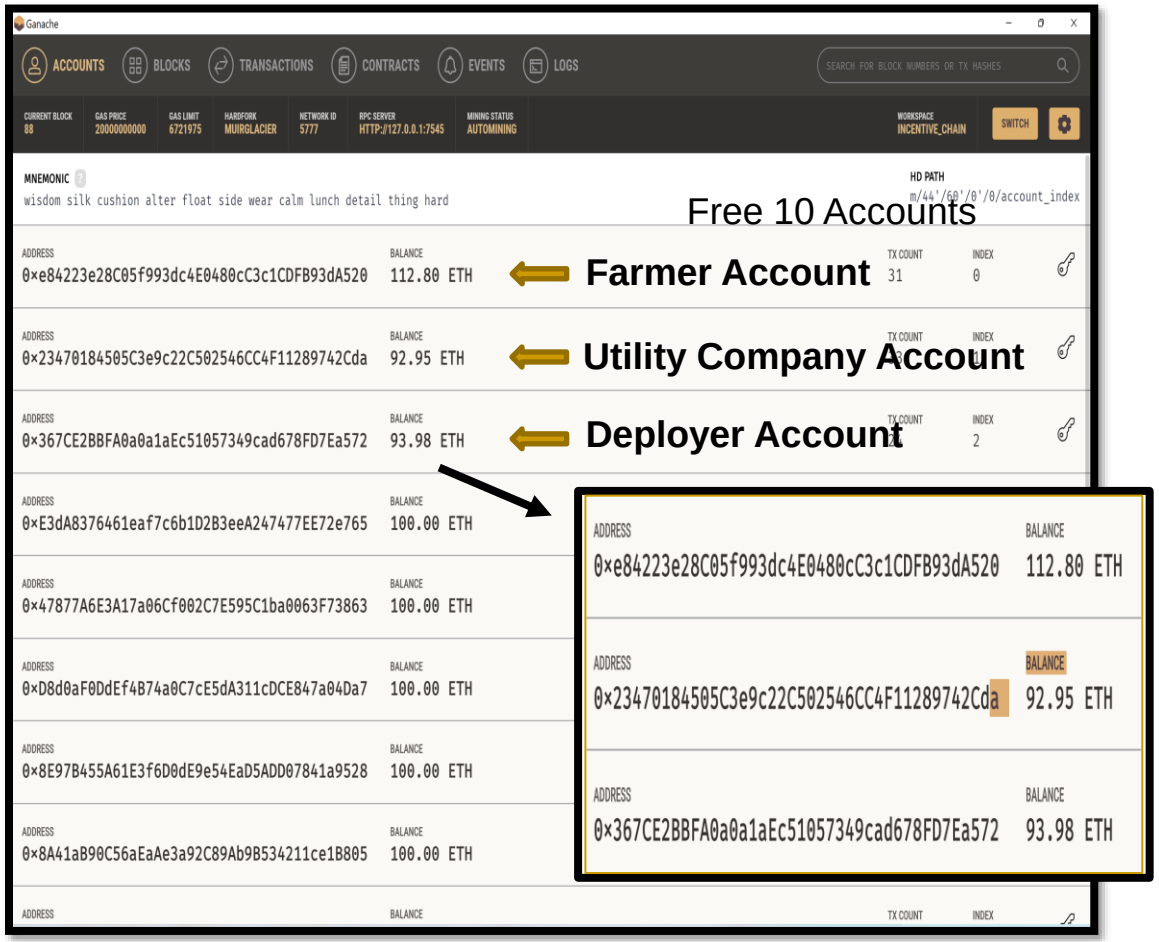



- Ganache mirrors actual blockchain.
- Provides 10 free Accounts with each 100Eth.
- In IncentiveChain we create three accounts:
  - Farmer
  - Utility Company
  - Deployer

Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

# Our IncentiveChain: Experiment Results

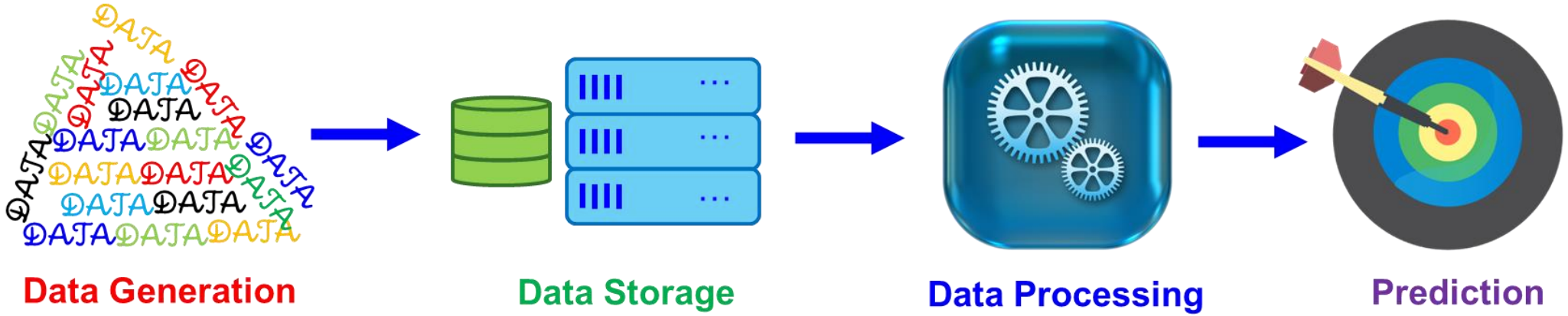
| Account Holder | Account Address | Before Tx | Balance after Tx |
|---|---|---|---|
| Farmer | 0xe84223e28C05f 993dc4E0480cC3c 1CDFB93dA520 | 100 Eth | 112.80 Eth |
| Utility Company | 0x23470184505C 3e9c22C502546C C 4F11289742Cda | 100 Eth | 92.95 Eth |
| Deployer | 0x367CE2BBFA0a 0a1aEc51057349c ad678FD7Ea572 | 100 Eth | 93.98 Eth |

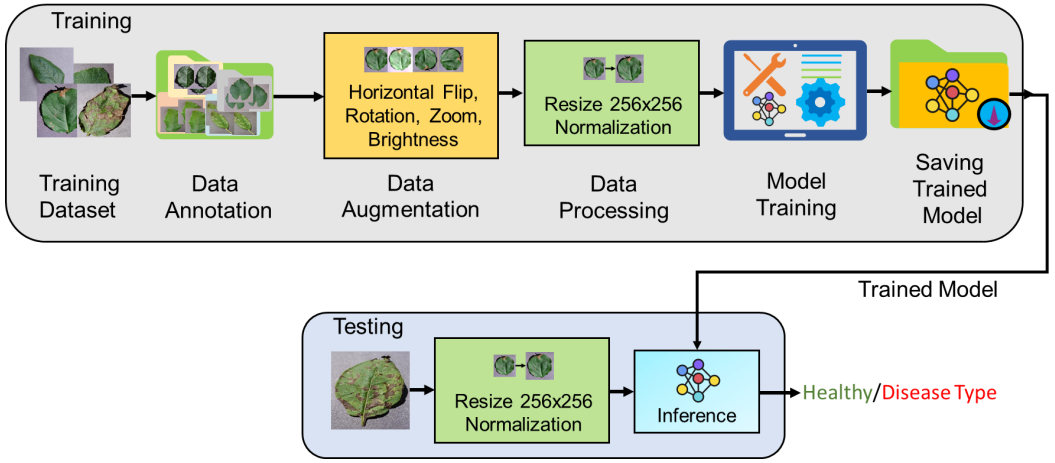



Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

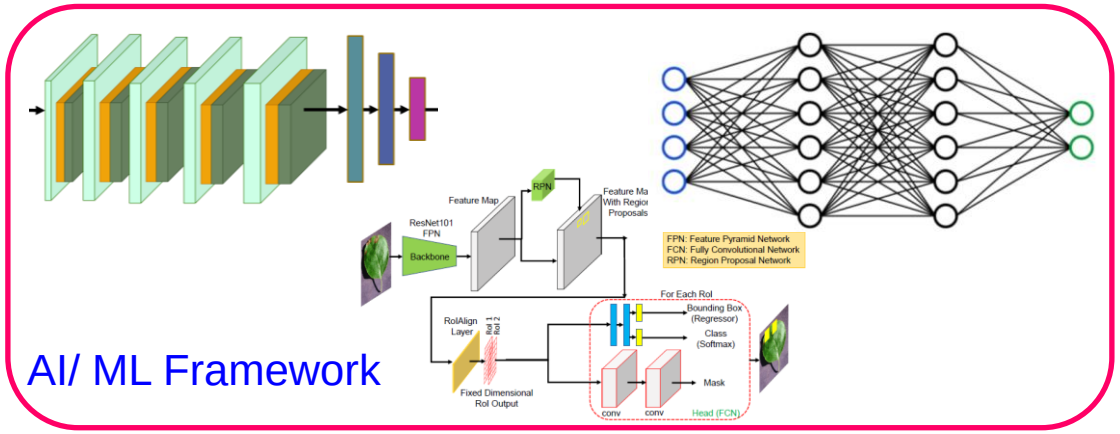
# Smart Agriculture and Federated Learning

# Smart Agriculture – AI/ML Workflow

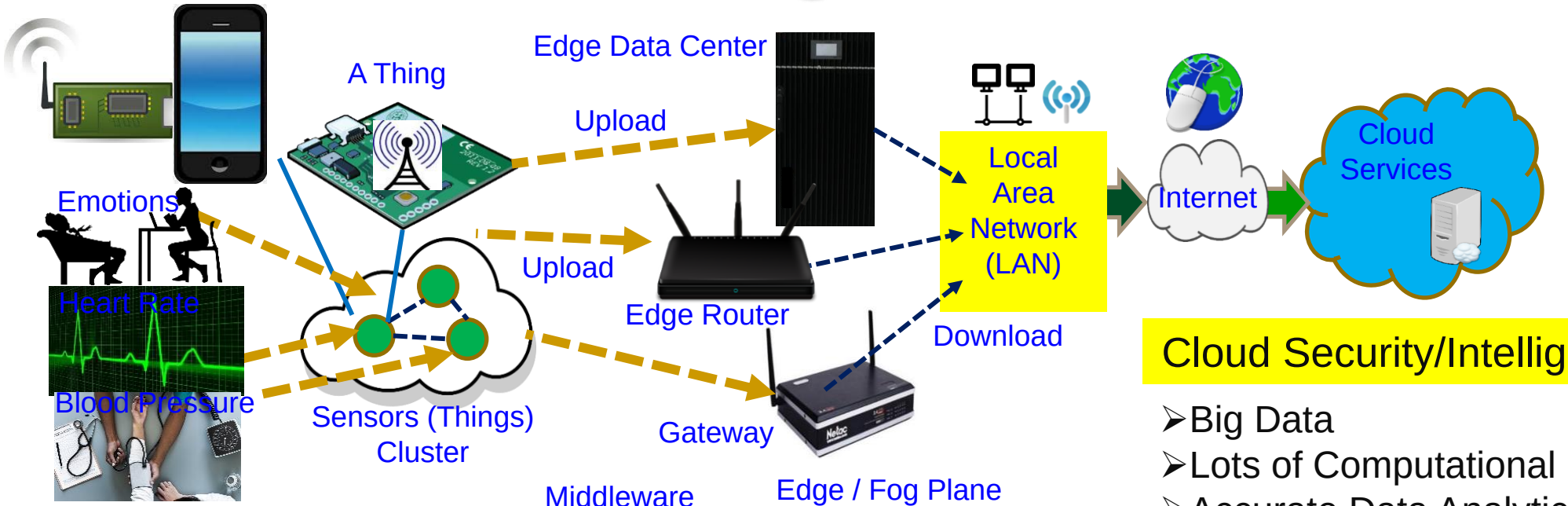



[Source: Alakananda Mitra, "Machine Learning Methods for Data Quality Aspects in Edge Computing Platforms," PhD Dissertation, UNT, 2022.]



# CPS – IoT-Edge Vs IoT-Cloud




## End Security/Intelligence

- Minimal Data
- Minimal Computational Resource
- Least Accurate Data Analytics
- Very Rapid Response

## Edge Security/Intelligence

- Less Data
- Less Computational Resource
- Less Accurate Data Analytics
- Rapid Response

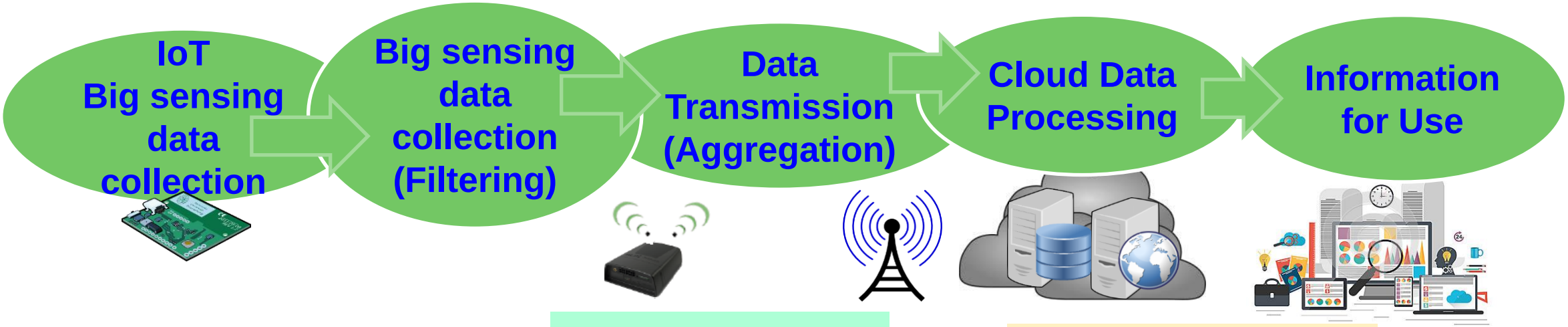
## Cloud Security/Intelligence

- Big Data
- Lots of Computational Resource
- Accurate Data Analytics
- Latency in Network
- Energy overhead in Communications

TinyML at End and/or Edge is key for smart villages.

Heavy-Duty ML is more suitable for smart cities

# Secure Data Curation a Solution for Fake Data?




Edge Training:
- ➢ Data Signature
- ➢ Model Signature

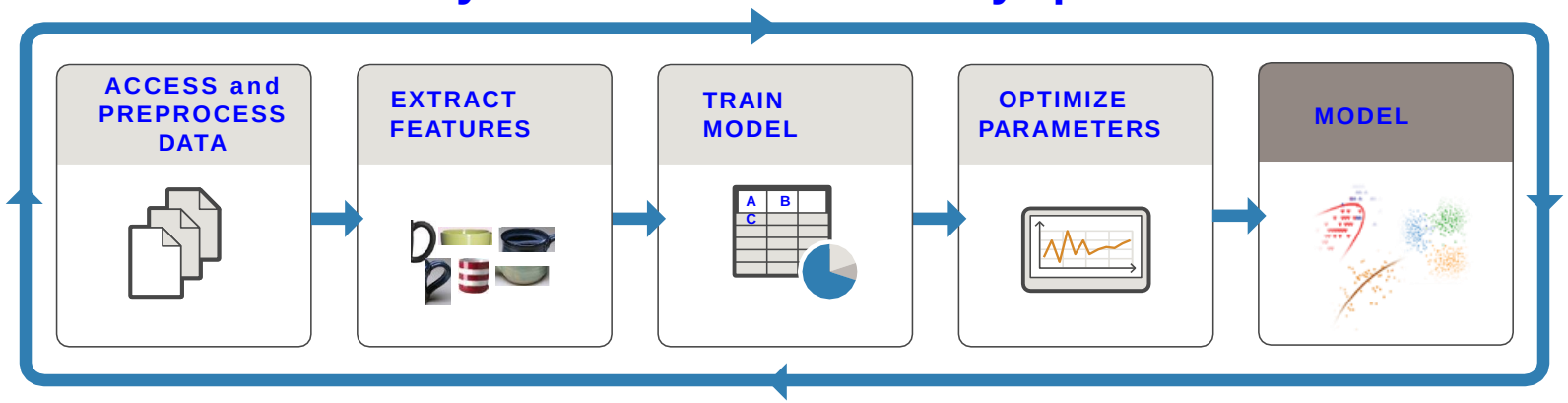
Cloud Training:
- ❖ Data Signature
- ❖ Model Signature

Fake Data Defense:
- Stop (Shield)
- Detect

Source: C. Yang, D. Puthal, S. P. Mohanty, and E. Kougianos, "Big-Sensing-Data Curation for the Cloud is Coming", *IEEE Consumer Electronics Magazine (CEM)*, Volume 6, Issue 4, October 2017, pp. 48--56.

# TinyML - Key for Smart Cities and Smart Villages

**TRAIN: Iterate until you achieve satisfactory performance.**

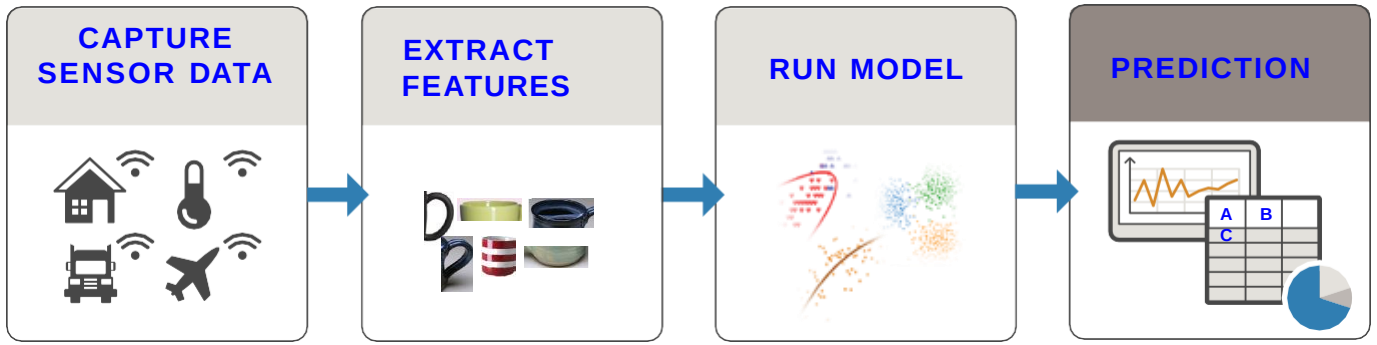



Needs Significant:

- Computational Resource
- Computation Energy

Solution: Reduce Training Time and/or Computational Resource

**PREDICT: Integrate trained models into applications.**



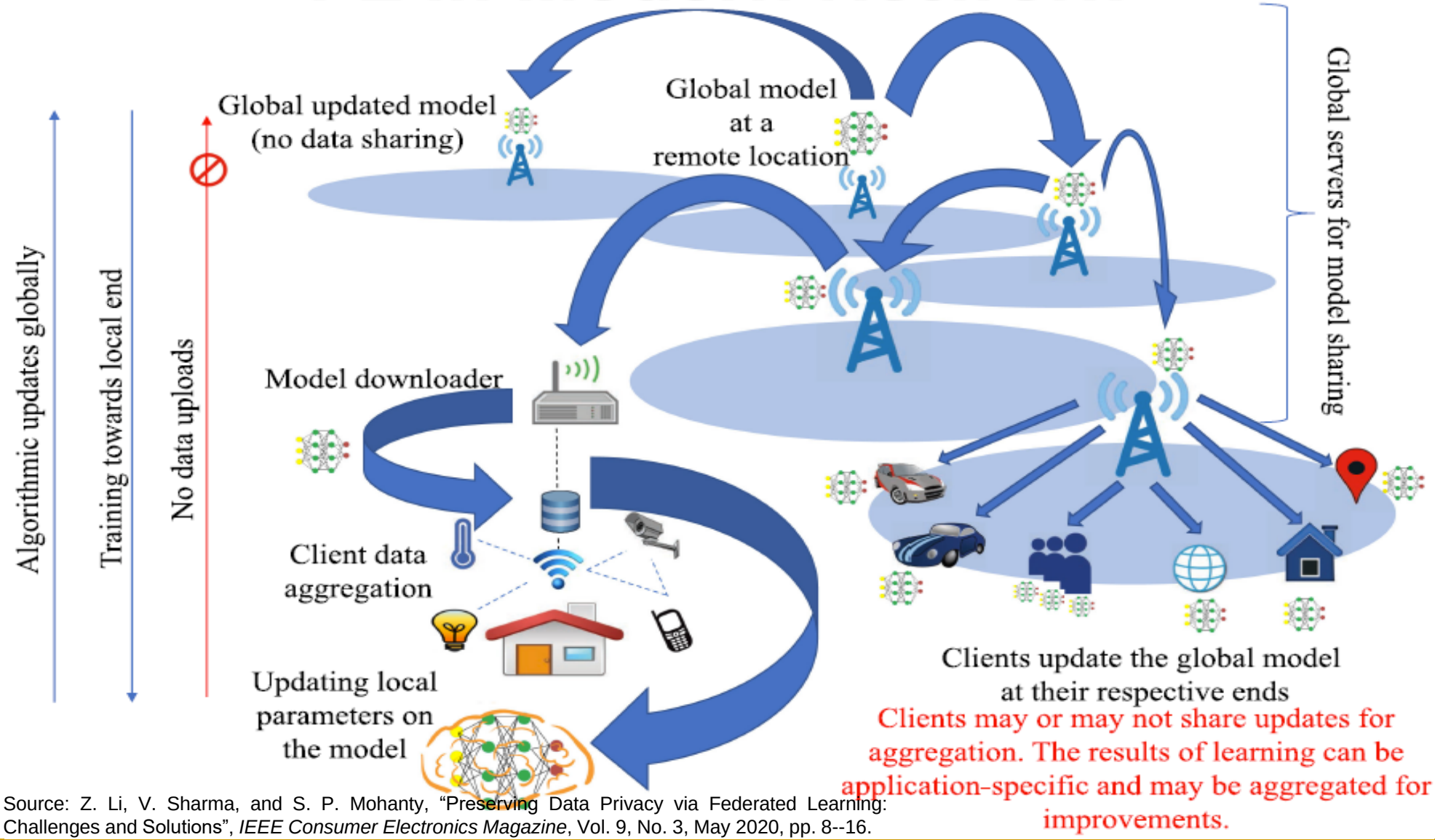

Needs:

- Computational Resource
- Computation Energy

Solution: TinyML

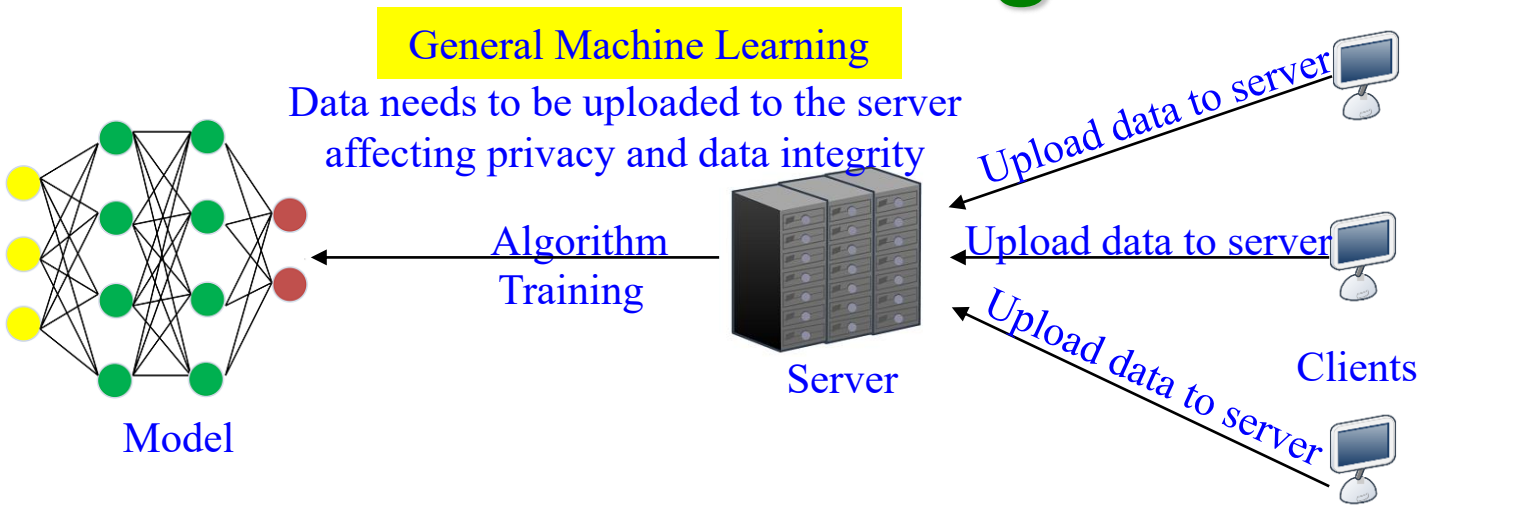
Source: https://www.mathworks.com/campaigns/offers/mastering-machine-learning-with-matlab.html

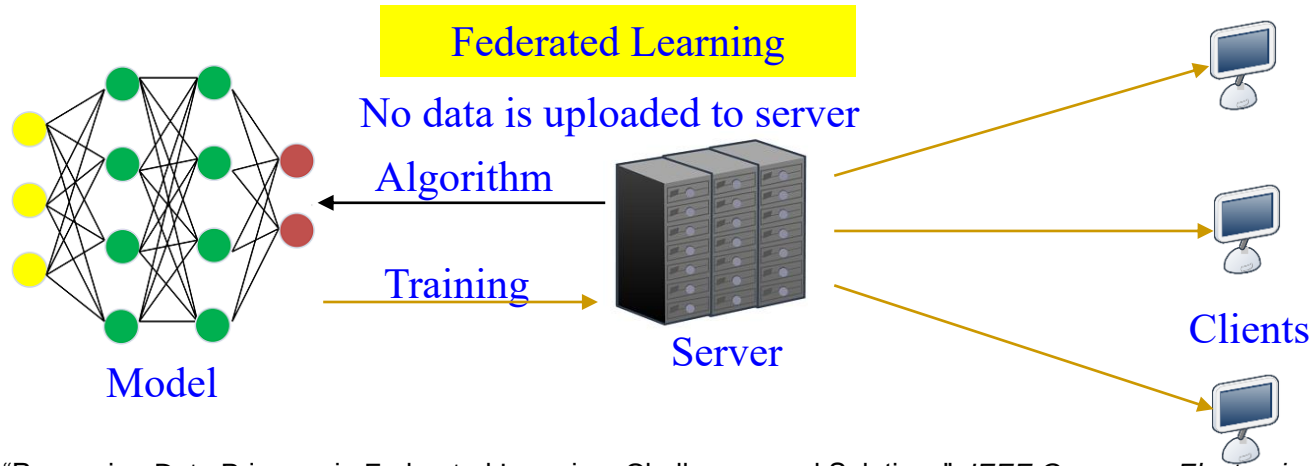
# FL In Modern Network




Source: Z. Li, V. Sharma, and S. P. Mohanty, "Preserving Data Privacy via Federated Learning: Challenges and Solutions", *IEEE Consumer Electronics Magazine*, Vol. 9, No. 3, May 2020, pp. 8--16.

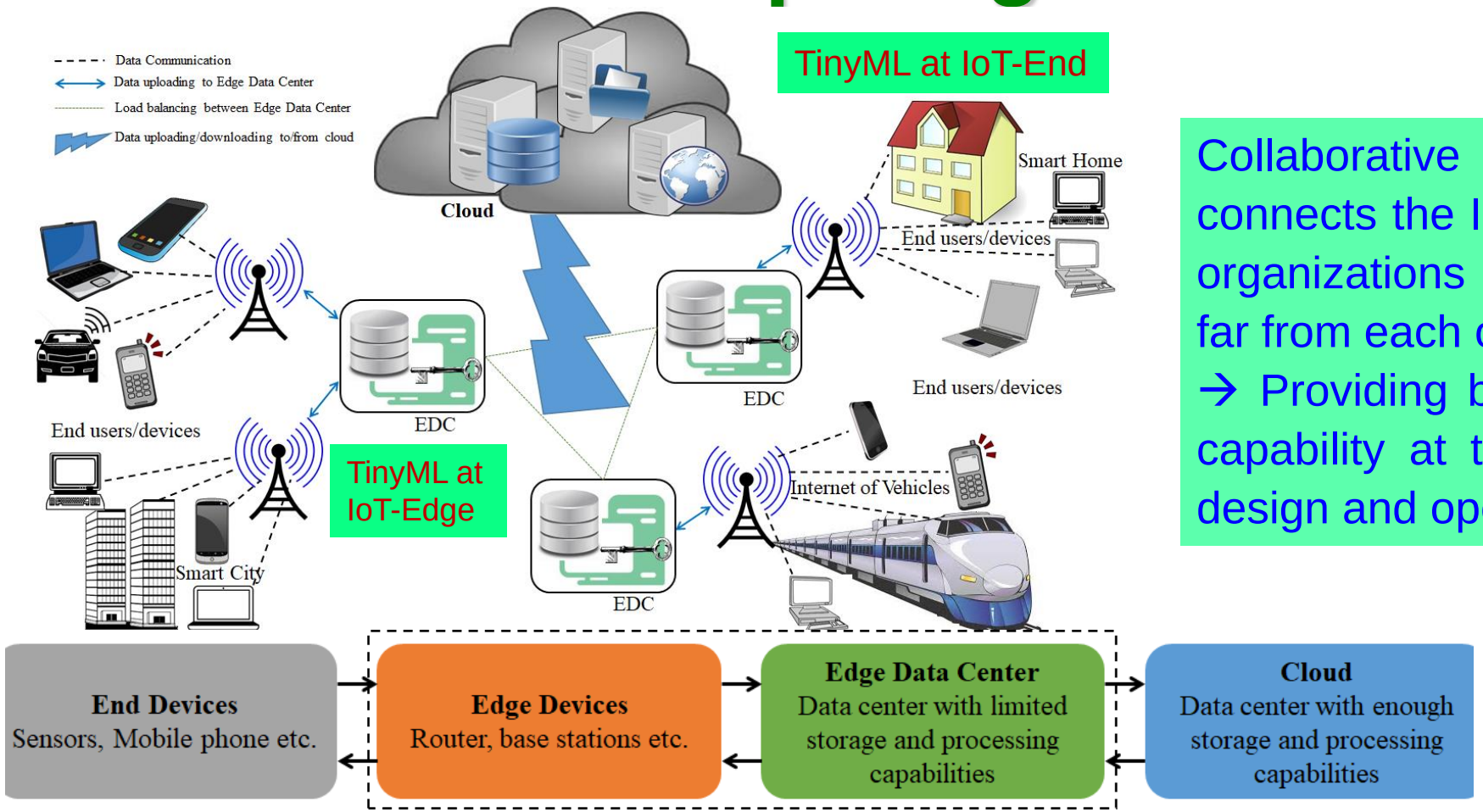
# Distributed Machine Learning to Reduce Training Time




Source: Z. Li, V. Sharma, and S. P. Mohanty, "Preserving Data Privacy via Federated Learning: Challenges and Solutions", *IEEE Consumer Electronics Magazine*, Vol. 9, No. 3, May 2020, pp. 8--16.

# Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages

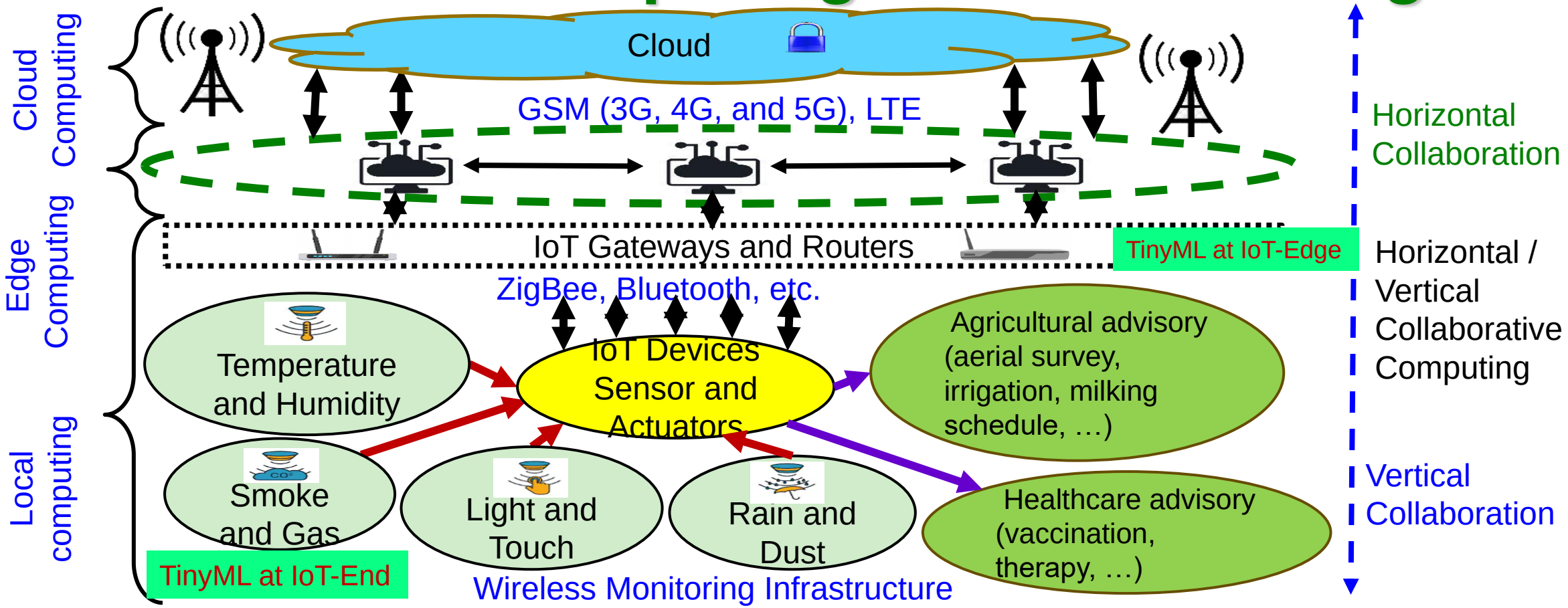



Collaborative edge computing connects the IoT-edges of multiple organizations that can be near or far from each other

→ Providing bigger computational capability at the edge with lower design and operation cost.

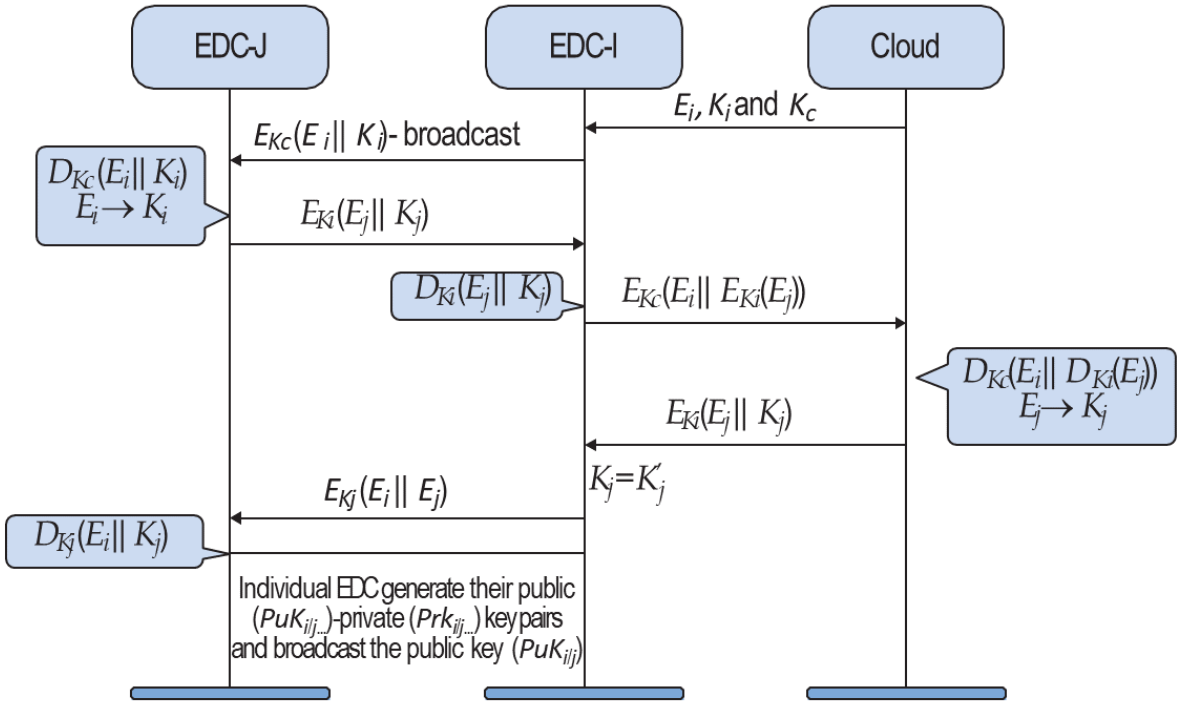
Source: D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya, "Secure and Sustainable Load Balancing of Edge Data Centers in Fog Computing", *IEEE Communications Mag*, Vol. 56, No 5, May 2018, pp. 60--65.

# Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages




Source: D. Puthal, S. P. Mohanty, S. Wilson and U. Choppali, "Collaborative Edge Computing for Smart Villages", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 10, No. 03, May 2021, pp. 68-71.

# Our Proposed Secure Edge Datacenter




Secure edge datacenter –
- Balances load among the EDCs
- Authenticates EDCs

**Algorithm 1: Load Balancing Technique**

1. If (EDC-I is overloaded)
2. EDC-I broadcast ($E_i$, $L_i$)
3. EDC-J (neighbor EDC) verifies:
4. If ($E_i$ is in database) & ($p \leq 0.6 \& L_i << (n-m)$)
5. Response $E_{Kpu_i}(E_j || K_j || p)$
6. EDC-I perform $D_{Kpr_i}(E_j || K_j || p)$
7. $k'_j \leftarrow E_j$
8. If ($k'_j = k_j$)
9. EDC-I select EDC-J for load balancing.

Response time of the destination EDC has reduced by 20-30% using the proposed allocation approach.

Source: D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya, "Secure and Sustainable Load Balancing of Edge Data Centers in Fog Computing", *IEEE Communications Magazine*, Volume 56, Issue 5, May 2018, pp. 60--65.

# Research Publishing – Best Practices

# Publishing Venue – Where to Publish?

- Magazine, Transactions, Letters, or Conference Proceedings?
- Depends on the content of a manuscript.
- First fix a venue → Write? OR First Write → venue?
- Magazine Article – Broad scope
- Journal/Transactions Papers – Focused scope and concrete results
- Letters Papers – Focused scope and brief results
- Conference Proceedings Papers – Focused scope and quick dissemination to receive direct feedback from peers

# Publishing Venue – Magazine?

- Articles should be broadly scoped.
- Technical articles may be suitable, but these should be of general interest to an engineering audience and of broader scope than archival technical papers or conference proceedings papers.
- Articles related to the background story behind engineering standards or practical experiences in product specification and design of mainstream systems.
- Tutorials on related technologies or techniques are also strongly encouraged.

# Publishing Venue – Journal/Transactions?

- Journal/Transactions are archival venues, just not intended for quick dissemination of research.
- Articles should have both depth and breadth.
- The work should have strong novelty. It must advance the state-of-the-art the to be published.
- The work should stand for decades without being outdated.
- The experimental results need to be rigorous.
- Manuscript need to survive multiple iterations of review process.
- Long Review Cycles. So authors should pay attention to every minor details. It may get one more round of revision just for a minor issue.

# Publishing Venue – Conference Proceedings?

- Conference Publishing may be for quick dissemination.
- Conference Presentations facilitates direct interaction with peers.
- Conference attendance may help researchers in their career advancement.
- Conference reviews can help to improve the work further which may then eventually become a journal publishing.
- Work-in-Progress (WIP) and Research-Session-Demo (RDS) are alternative modes of dissemination to get feedback on ongoing research from the peers.

# Conference → Journal OR Journal → Conference?

- Conference publishing first → corresponding journal

  OR

  Journal publishing first → corresponding conference
- To my experience: I see that most of the researchers follow the first option and few researchers follow the second option.
- In either case one shouldn't have the same text and figures.
  - These are two distinct publications for the authors.
  - After acceptance both the journal paper and conference paper appear in digital library, a similarity software will flag the similarity.

# Shall I Target Journal/Transactions Submission Directly Without a Conference Paper of the Work?

- Short Answer: No
- Reviews received from the Initial Conference Version of the work can strengthen the work to become a journal paper eventually.
- Reviewers of the journal manuscript can have better impression if they find that it is already based on a quality conference paper.
- Journal have longer review cycle which may not correctly timestamp the idea published in the journal paper. Imagine rejection of the journal manuscript after 6-8 months of review cycle, loosing the time.

# Conference → Journal: How to Do it?

- Publisher need anywhere between 30%-70% additional materials over the conference version for a journal article.
- Final judgement is typically up to the Editor-in-Chief (EiC) of specific journal/transactions.
- Key aspects of extending a conference paper to a journal article: additional novel contributions, thorough literature analysis, more experimental results, additional figures, and additional Tables.
- Complete rewriting of the text and redrawing of any figures used is a good idea to avoid similarity issues and the copyright aspects as in many cases the publishers conference proceedings and the journal/transactions may not the same.
- Remember to cite the conference paper on the current journal paper; may be even write in the acknowledgement.

# Journal → Conference: How to Do it?

- It is not common to present a journal published paper as a a conference paper.
- Things are changing – Too many conference looking for audience
- Short conference paper as possible option
- Research Demo Session (RDS) papers is another option
- Complete rewriting of the text and redrawing of any figures used is a good idea to avoid similarity issues and the copyright aspects as in many cases the publishers of conference proceedings and the journal/transactions may be different.
- Remember to cite the journal paper on the current conference paper; may be even write in the acknowledgement.

# Is it Important to Suggest Reviewers Names when Submitting a Journal/Transactions Manuscript?

- Short Answer: Yes
- Associate Editors are typically overloaded, they may pick few of the reviewers from your suggested list.
- The manuscript may be handled by an AE who is working on a closely, but no exactly on the area of the manuscript, so may take time to find sufficient reviewers.
- You never know your preferred reviewer may see your work favorably!

# How Important is Open-Access Publishing?

- Thoughts on the current state of academic publishing
  - Journal papers are important OR Conference papers
  - Open Access is better OR traditional closed access
- Thoughts on Open-Access:
  - Arxiv (https://arxiv.org/), TechRxiv (https://www.techrxiv.org/)
  - Data Regulation – Quality Data is key
- One aspect of academic publishing that is very important/significant these days
  - Open Access and Research Reproducibility

# Journal Review Process Takes Long Time, Should I Only Publish in Conference?

- Short Answer – No
- Journals are archival purposes and publish thoroughly reviewed works. So quality of work can improve if reviews are good.
- Option to time stamp the idea, before submitting to Journal:
  - Make a conference paper
  - Put it in open access depository like arXiv, TechRxiv, etc.

# Journal Review Process Takes Long Time, Should I Submit to Multiple Venues for Faster Publishing?

- Short Answer: No
- Submitting same manuscript to multiple journals/transactions at a time is not allowed.
- Submitting same manuscript to a journals/transactions and a conference at a time is not allowed.
- Danger of being rejected without review from multiple venues.

# I Can Publish in Journals, Why Should I Bother for Conferences?

- Short Answer – Yes
- Networking with Global Peers
- Direct Interaction with Peers → Boost Researcher's Confidence
- Meet people who can help in job search
- Meet people who can your reference for job search
- Meet people who can be reviewer of your next papers
- Meet people who can be external examiner of thesis/dissertation (if applicable)

# Does the Look and Formatting of the Manuscript Matter during Submission?

- Short Answer: Yes
- Note: First Impression Lasts Long
- Reviewer maynot be interested to read details if the manuscript doesn't look professional and clear.
- Look and legibility are important to attract attention.
- Danger of the manuscript being returned without review.

# How important is author ordering in a publication?

- Short Answer: No definite answer
- In some disciplines the faculty mentor is typically the last author.
- In some cases, the primary contributor is the first author and other is made based on level of contributions to the work.

# How Important is Social Media for Researchers?

- Short Answer: Not Much
- How important is social media for researchers? Should Ph.D. students invest time in building profiles & networks social media?
  - Neutral – Publicity + Typical Negativity of social media (Privacy issues)
- How challenging do you feel it is for new Ph.D. researchers to get published? Any advice/tips?
  - Reasonable challenging for new researchers, Conference → Journals

# Why Should I Spend Time as a Reviewer?

- Short Answer - Yes
- Early Learning: Researchers who are engaged in cutting-edge research can't find learning materials from the text books. By the time a research findings appear in text book, they are outdated. A researcher can stay up to date and learn from other researcher if he/she reviews their manuscripts.
- Learning Quality expected in a specific journal/conference. Accordingly, one can use that experience to improve own manuscripts before submissions.
- Service to the profession and community.

# What are the Best Practices of Publishing?

- Short Answer: No definite answer
- Differs in one area of research to another area of research, from disciplines to another, and from publisher to another publisher. Some rule of thumb:
  - Publish one idea in one venue
  - Do best job for all text including references
  - Give credit to existing literature
  - Read articles/papers from a target venue before preparing own manuscript
  - Pay attention to each minor or major aspects; too many small → rejection
  - Learn to handle rejection

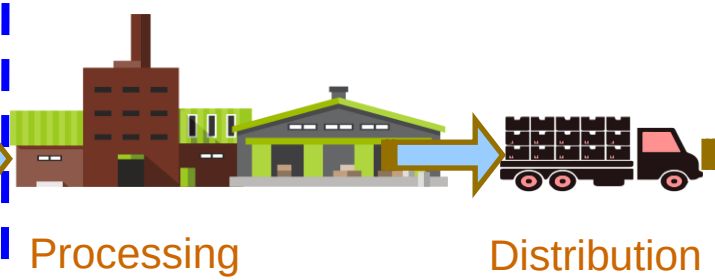
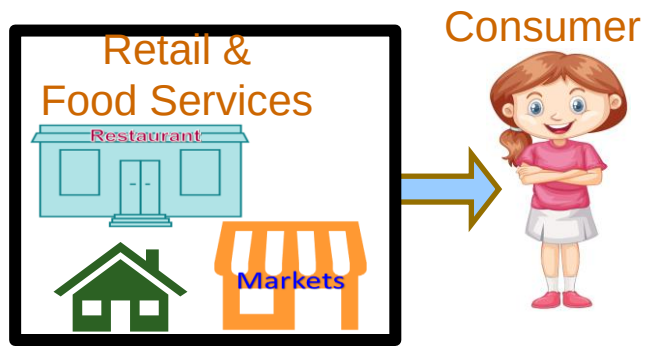
# A Big Qeuestion – Where to Publish?

- As an author after I have always asked myself:
  - First Option: My article is an excellent scholarly product because it got published what my peers think as a selective or top venue.

    OR
  - Second Option: My article is an excellent scholarly product because it is read and/or cited my peers and it makes the venue great wherever it is published.
- Most of the researchers have a tendency to choose the first option from the above.
- However, I strongly believe that if an article has real strength then it should be second option.

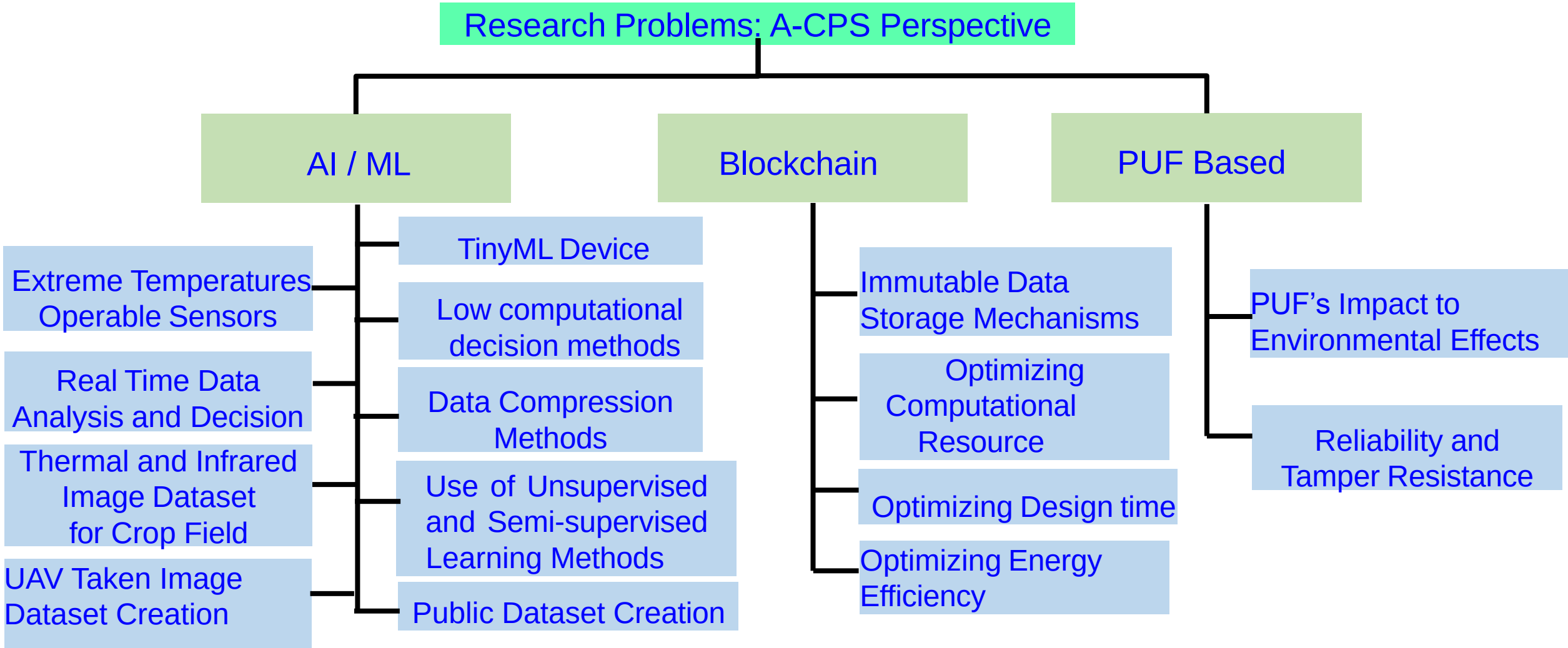
# Conclusions and Future Research

# Smart Agriculture - Multifold Research Possibility

| Levels | Field Level | Processing & Distribution Level | Consumer Level |
|---|---|---|---|
| |   |   |   |
| **Affecting Factors** | Drought, Flood, Frost, Disease, Hail, Wildfire, Storm, Humidity, Soil Nutrients, pH of Water | Extreme Temperature, Humidity Variation, Wildfire, Flood, Insect & Pests | Extreme Temperature, Humidity Variation, Wildfire, Flood, Seasonality |
| **Effects** | Crop Damage, Crop Loss, Crop Growth Reduction, Crop Yield Reduction, and Finally Financial Loss of the Farmers. | Supply Chain disruption | Shortage of Food, Food Price Increase, Inflation |
| **Research Areas** | Crop damage Estimation, Yield Estimation, Insurance Processing Automation, Growth Estimation | Supply Chain Management | Food Safety, Consumer Behavior, Nutrition |
| **Technologies** | AI/ML/Deep Learning, Block Chain, PUF, Robotics, IoT, UAV | AI/ML, Block Chain, Advanced Analytics, 3D Printing, IoT, Robotics | AI/ML, Analytics, Data Collection, Statistics, Mathematics, Sociology |

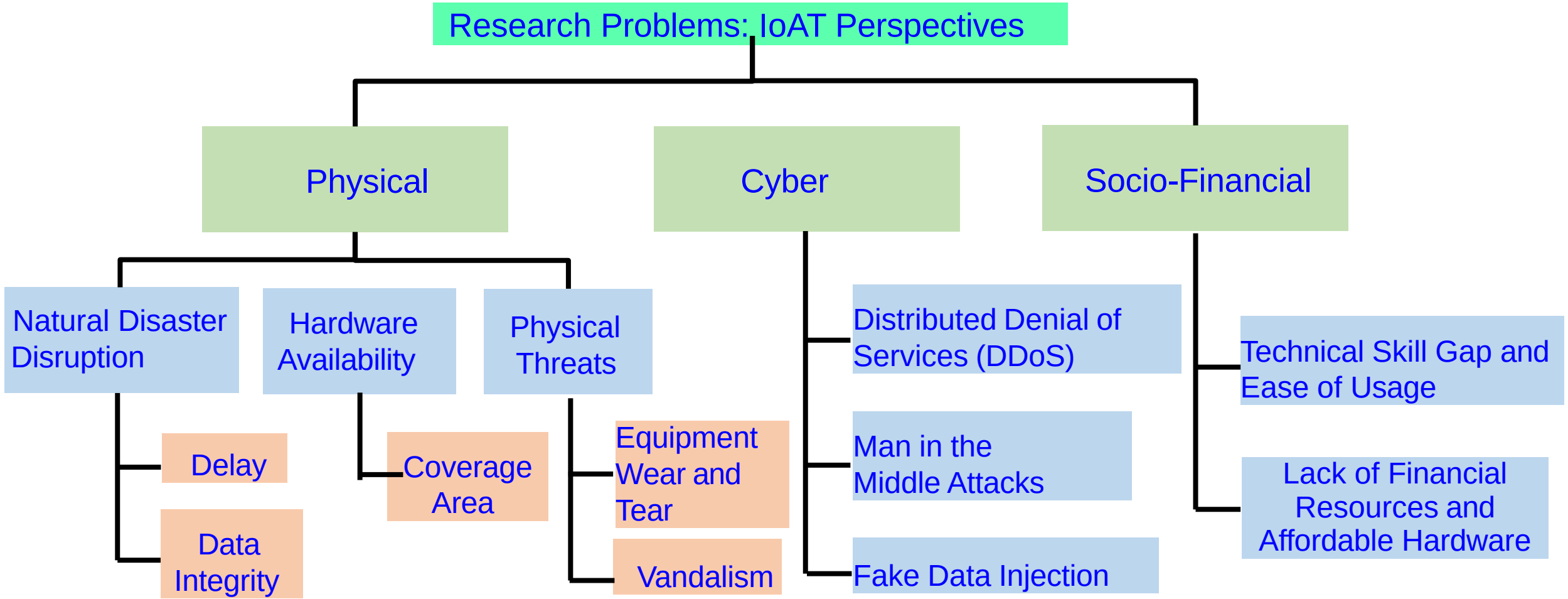
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Smart Agriculture - Research Problems




Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# Smart Agriculture - Research Problems

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# Conclusion

- Smart Agriculture is a very needed advancement for sustainability of humans in coming years.
- Technologies in Smart Agriculture are improving, and new technologies are being introduced everyday.
- Smart agriculture research is very challenging as involves diverse form of life (plant, animal …) and stake holder (farmer, engineers, distributor, insurance …).
- Having A-CPS with limited network connectivity and power supply is challenging.
- Educating farmers is the main challenge.
- Not many years far from realizing dream of hunger free society.

# Future Research

- Research in educating farmers with technology usage.
- Efficient energy consumption techniques as millions of IoT devices will involve.
- Blockchain in transparent chains for increasing consumer awareness and safety.
- Efficient sensors and actuator technologies.
- Big data analytics and AI methods.
- Communication and Connectivity Technologies
- Secure and privacy compliance approaches.