

# Everything You Wanted to Know about Smart Agriculture

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

Silicon Institute of Technology, Bhubaneswar, India, 03 Jan 2023

Saraju P. Mohanty

University of North Texas, USA.

Email: [saraju.mohanty@unt.edu](mailto:saraju.mohanty@unt.edu) Website: <http://www.smohanty.org>

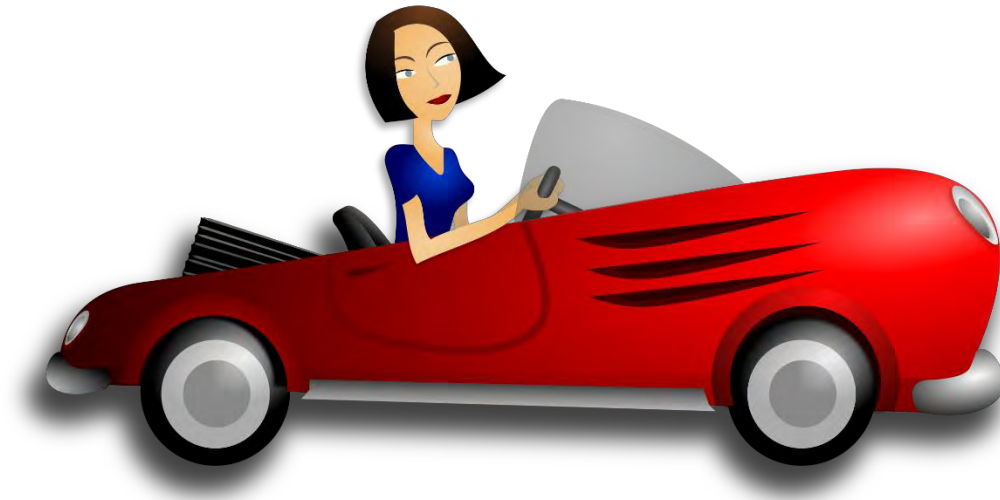


# Outline

- 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

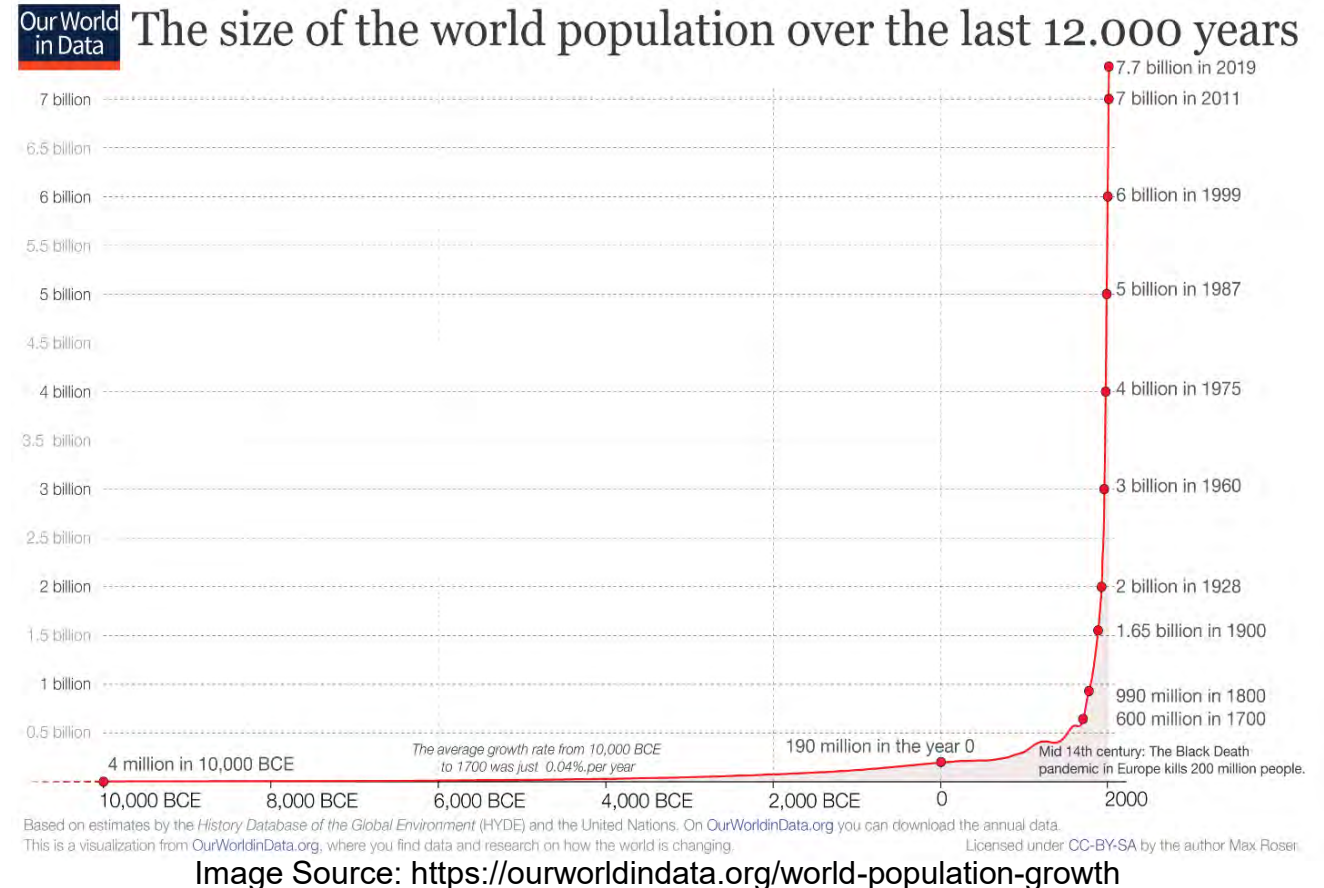
---

# 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.





# 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  $\in$  *Climate*;
- *Crop Yield* =  $f(\text{Climate})$ .
- Growing Degree Days (GDD) =  
$$\frac{\text{Max. Temp} + \text{Min. Temp}}{2} - \text{Base Temp};$$
- *Crop Growth* =  $f(\text{GDD})$ .
- *Types of Crops* =  $f(\text{Climate})$ .



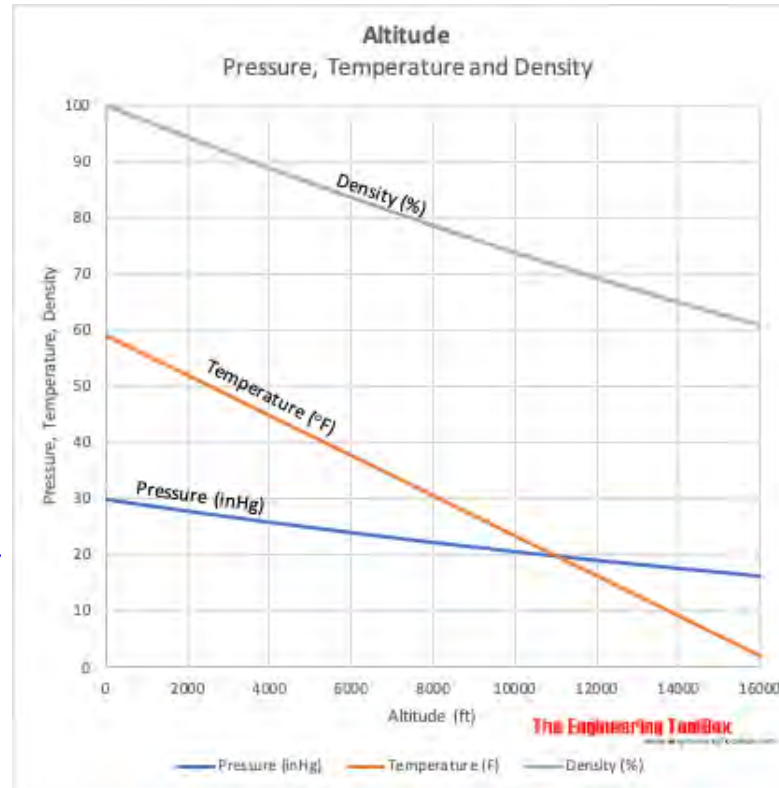
Growing Degree Days (GDD) aka Growing Degree Units (GDUs)

→ a measure of heat accumulation

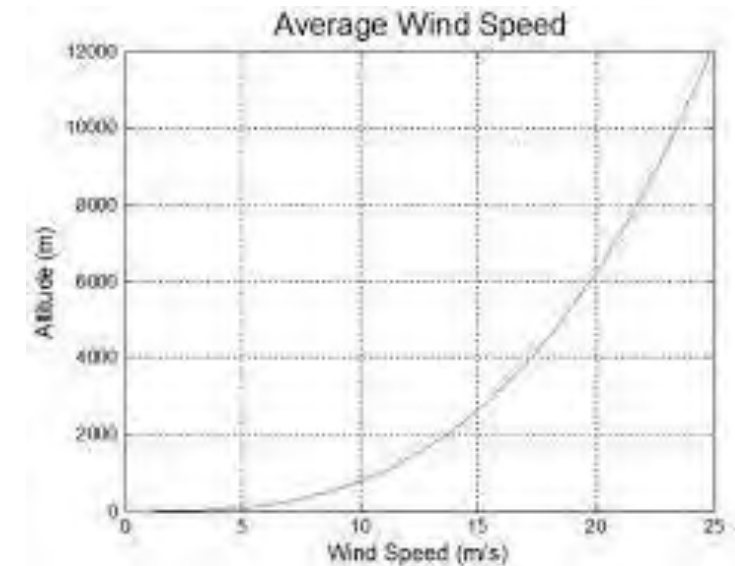
→ used by farmers to predict plant and animal development rates: date that a flower will bloom, a crop will reach maturity, or an insect will emerge from dormancy

# 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.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

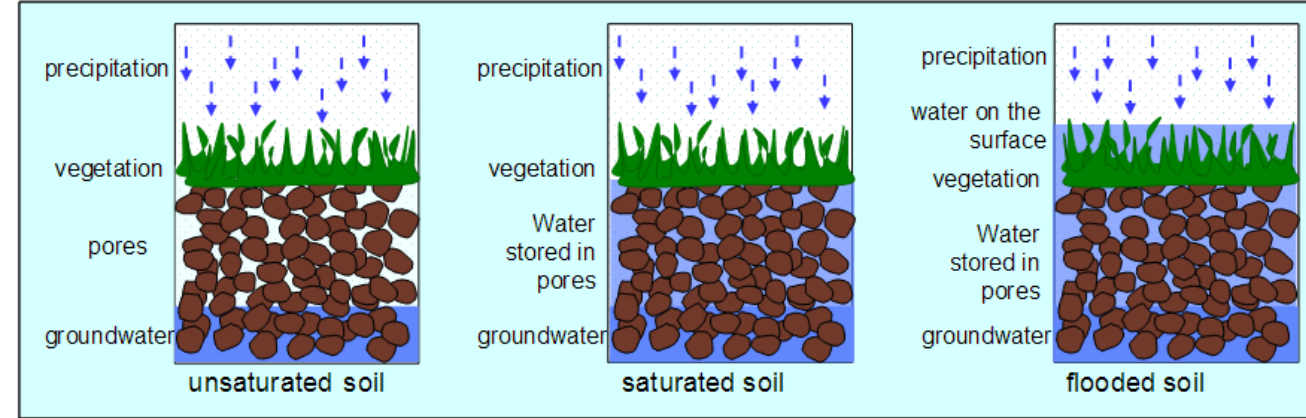
- ❑ Formed from weathering rocks (source for minerals needed); Organic-matter contents (source of fertilizers).
- Soil properties effecting the crop:
  - ❑ **Depth** - Approx. 100cm of depth for growth
  - ❑ **Texture** – Determines water holding capacity and root aeration
  - ❑ Organic matter content – 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 =  $f(\text{Precipitation, Percolation})$*
- ❑ **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 =  $f(\text{Soil Water})$ .**



- ❑ 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 in 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



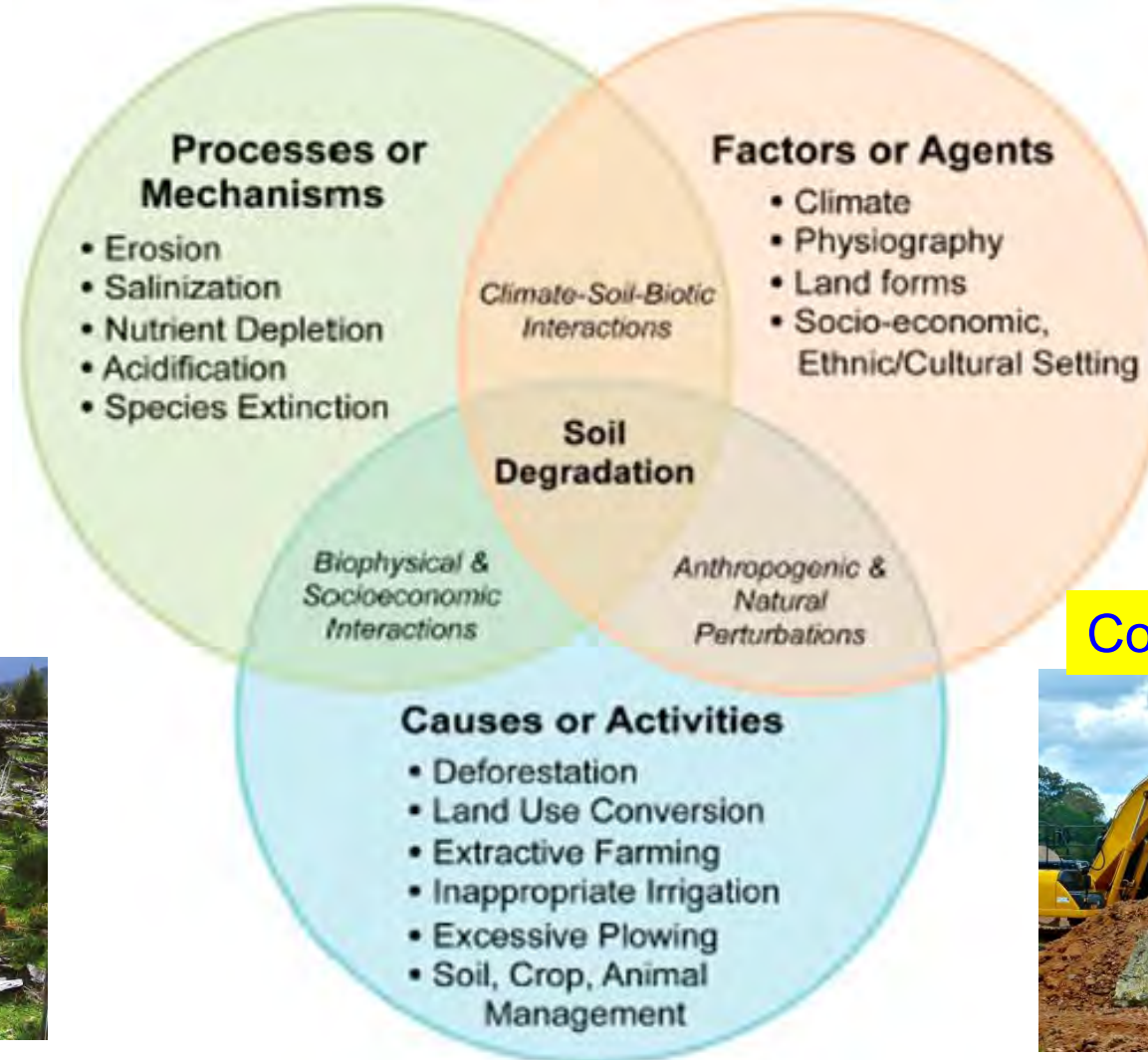
Soil Erosion



Deforestation



Construction on Farm Land

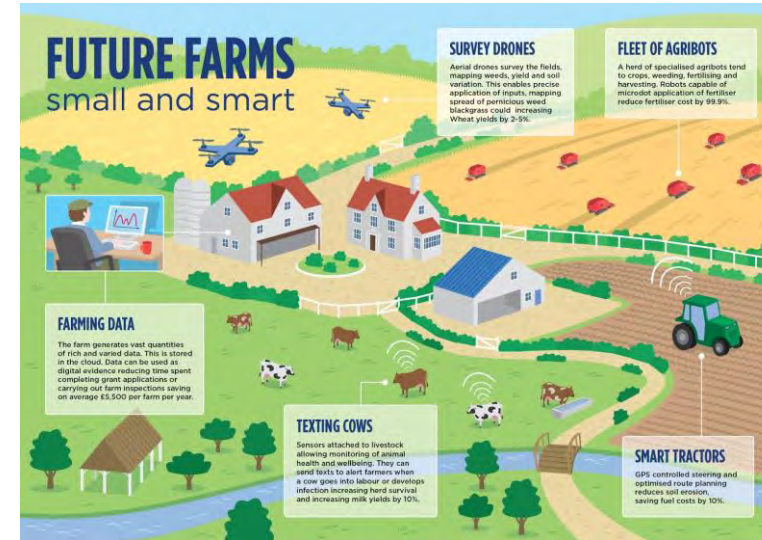


Source: <https://www.ommegaonline.org/article-details/Restoration-of-Degraded-Agricultural-Land-A-Review/1928>



# 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.



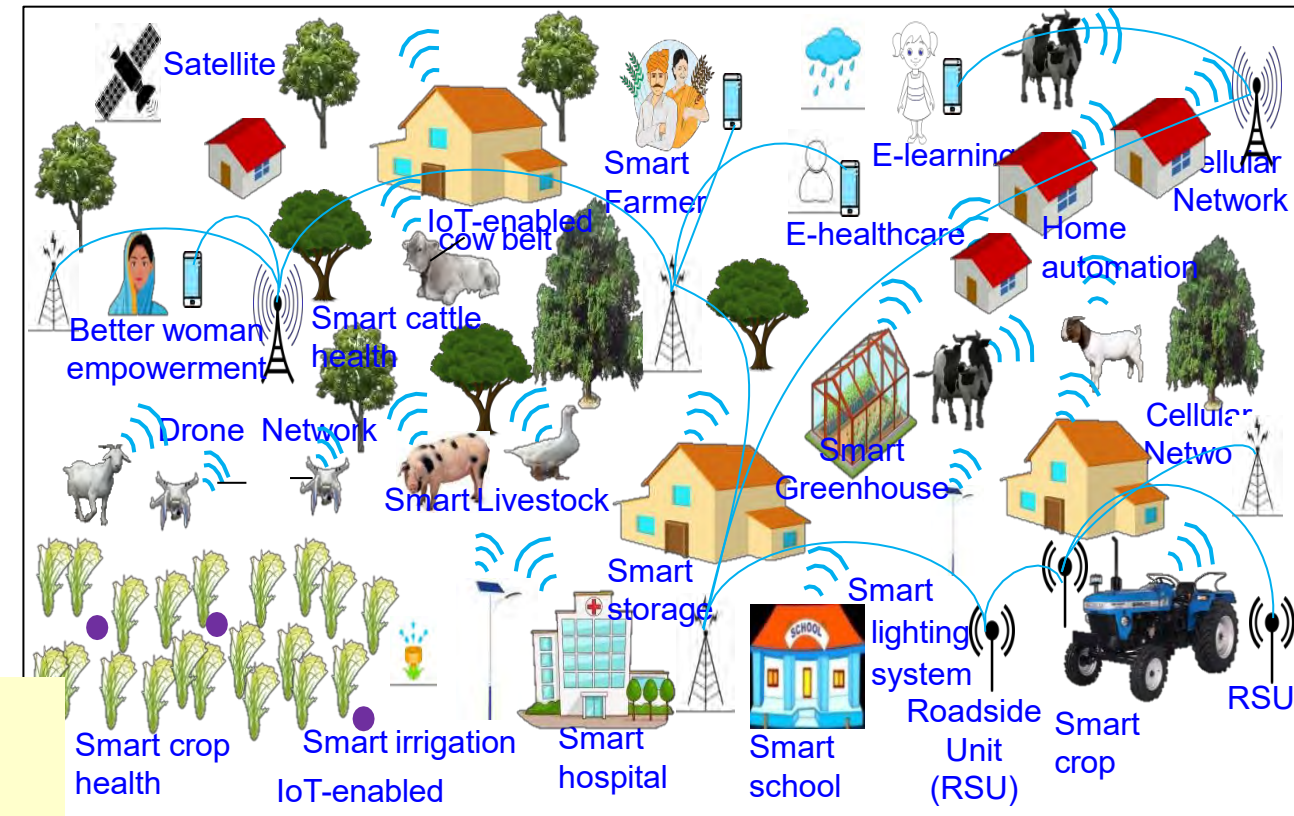
Agriculture or farming is the practice of cultivating plants and livestock.



# Crucial for → Smart Cities and Smart Villages



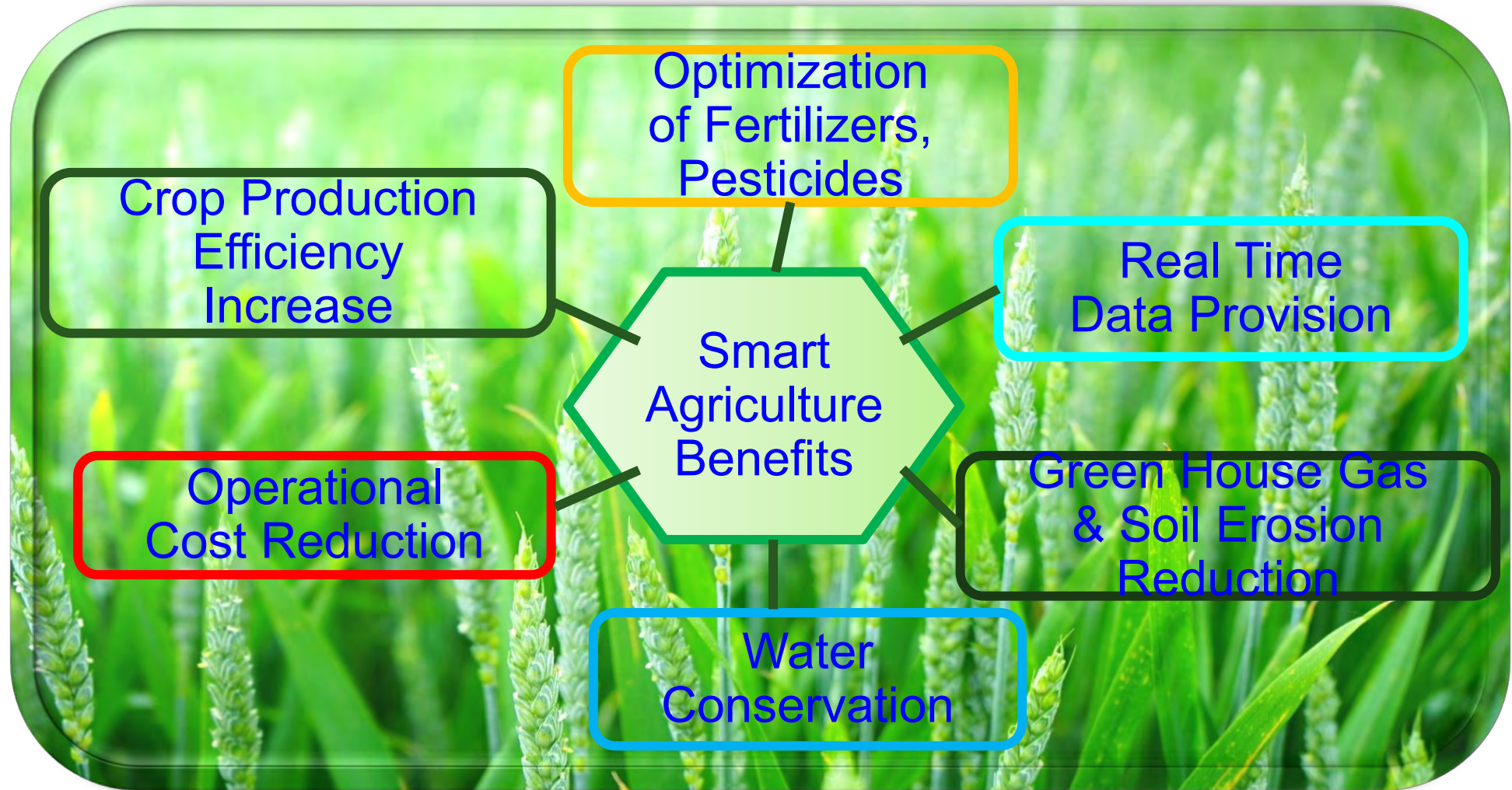
Source: <http://edwingarcia.info/2014/04/26/principal/>



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](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.

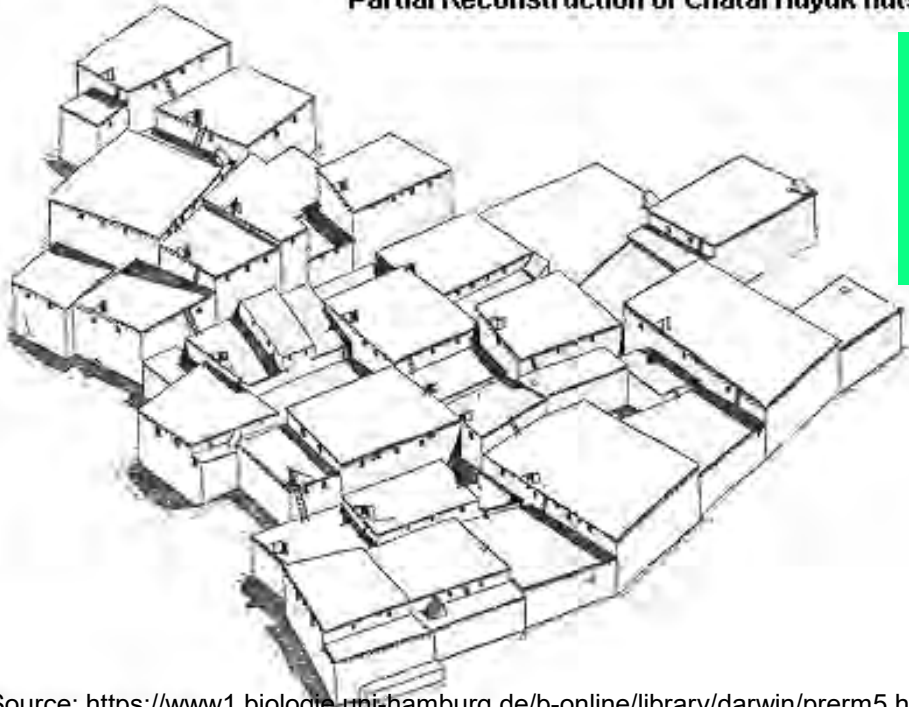
# Agriculture → Smart Agriculture: Broad Overview





# Cities and Villages - History

Partial Reconstruction of Chatal Huyuk huts



Source: <https://www1.biologie.uni-hamburg.de/b-online/library/darwin/prem5.htm>  
Based on a reconstruction by Orrin C. Shane III

- ✓ 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.

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



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.

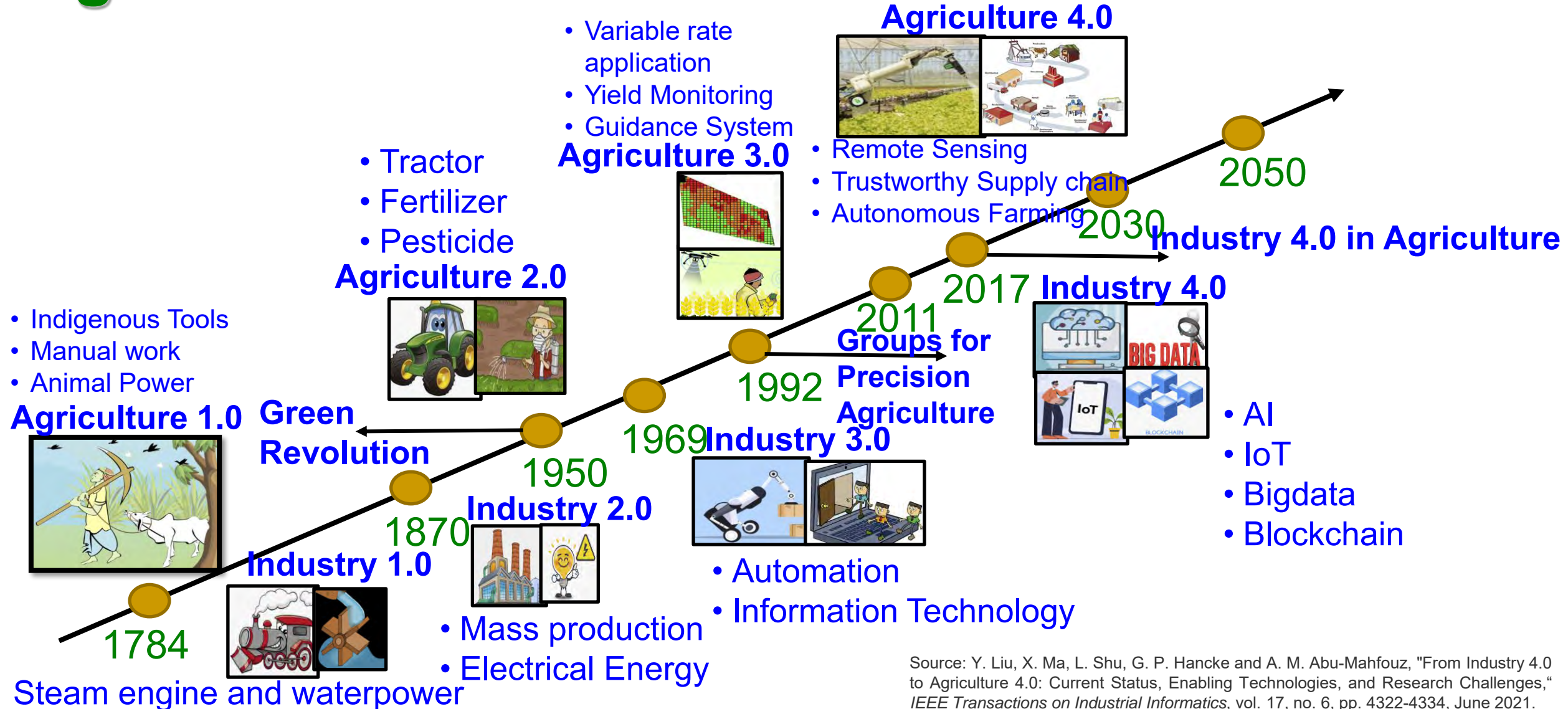
Ancient Egypt  
- 15th century BC (1500 BC to 1401 BC)

# 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



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/>

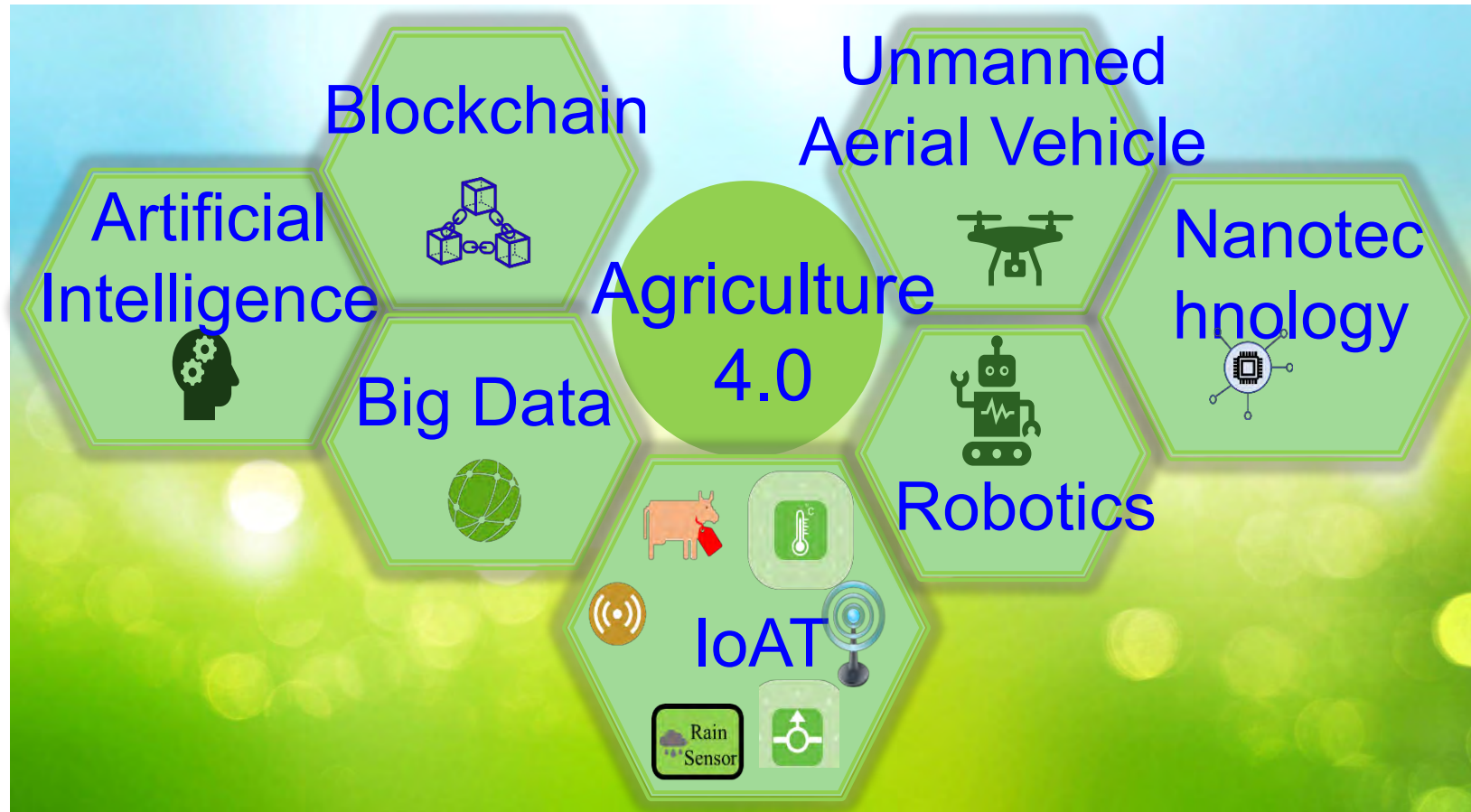
“Consistent application of the methods of precision farming and smart farming, internal and external networking of the farm and use of web-based data platforms together with Big Data analyses”.

- 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.



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](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.

# Agriculture to Smart Agriculture

## ■ Traditional agriculture:

- ❑ manual labor
- ❑ low productivity
- ❑ Climate dependency
- ❑ Limited by geography

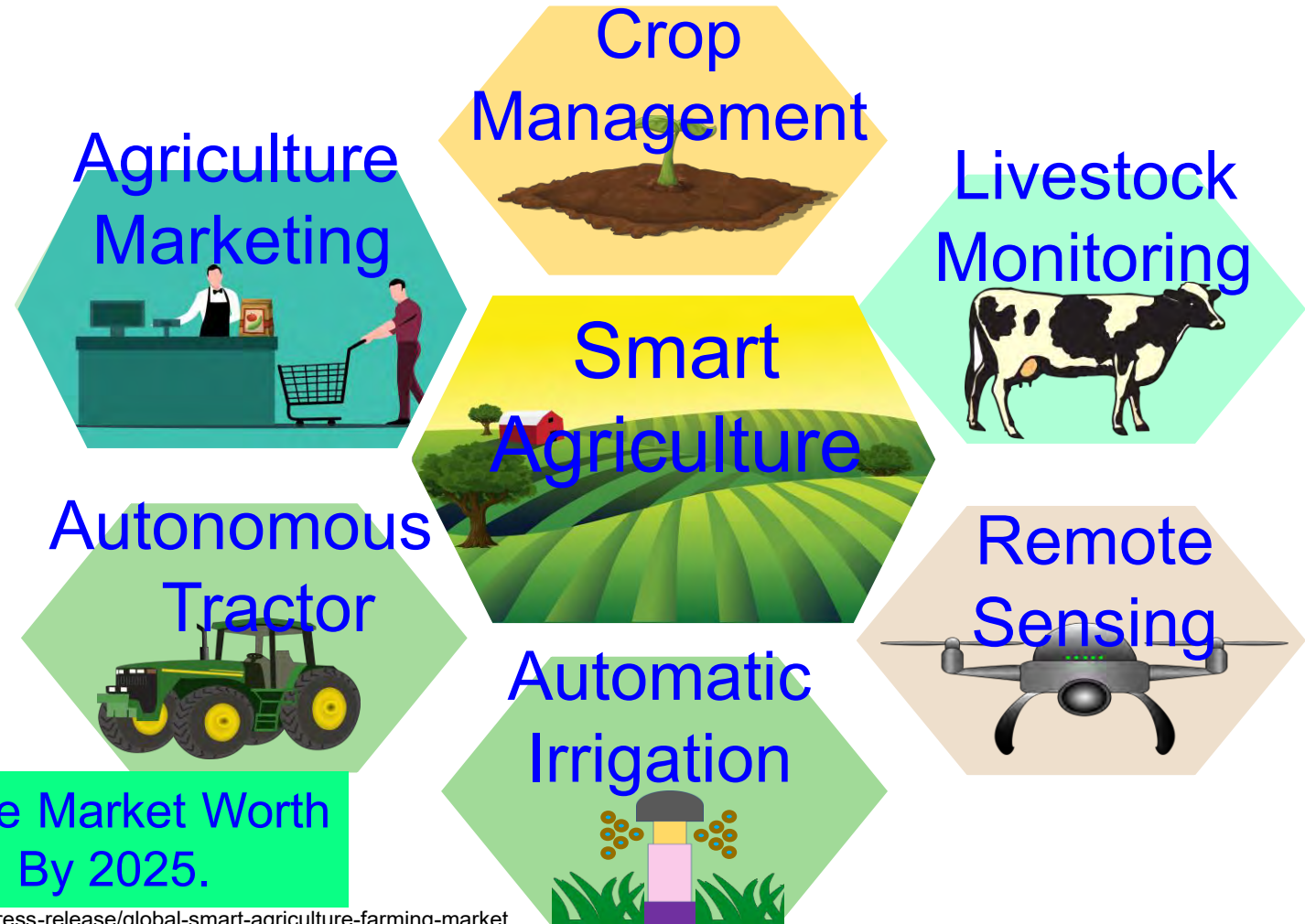
## ■ Smart Agriculture:

- ❑ Sustainable
- ❑ Intelligent
- ❑ Efficient
- ❑ Eco-friendly

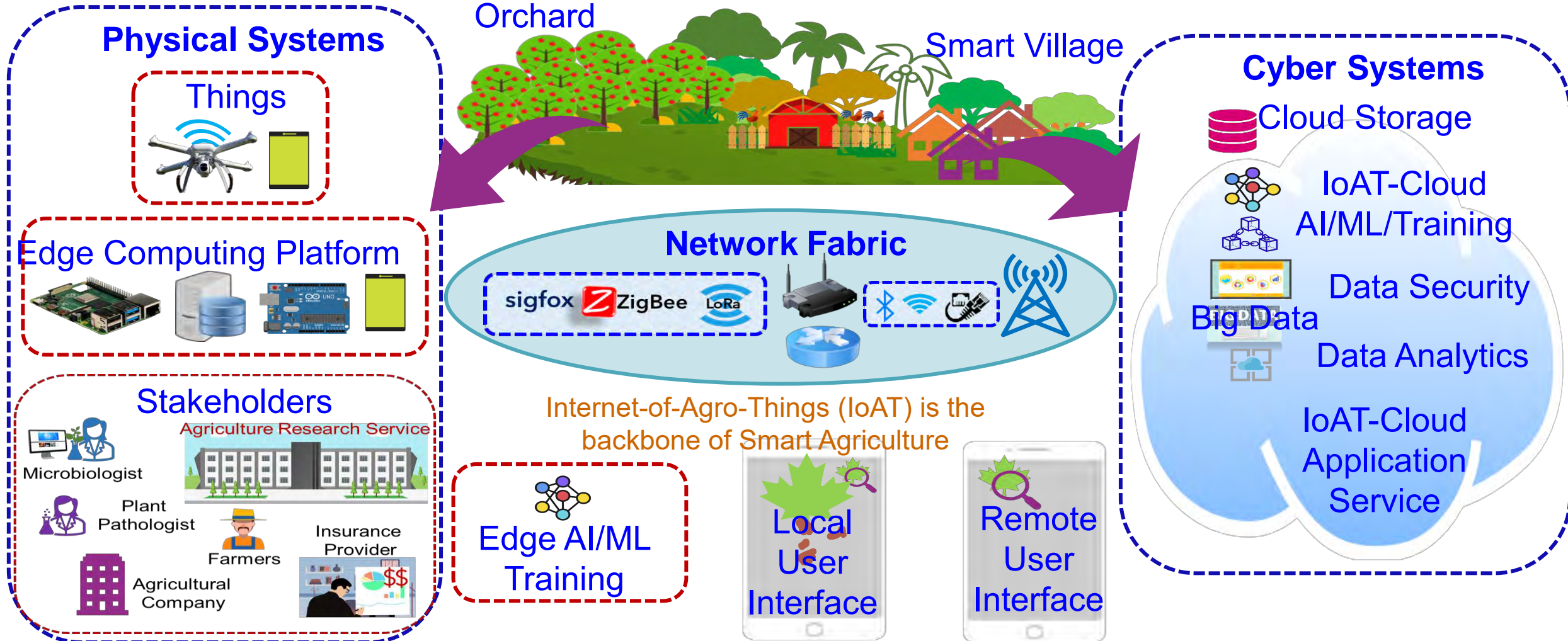
Smart Agriculture Market Worth  
US\$18.21 Billion By 2025.

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](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.



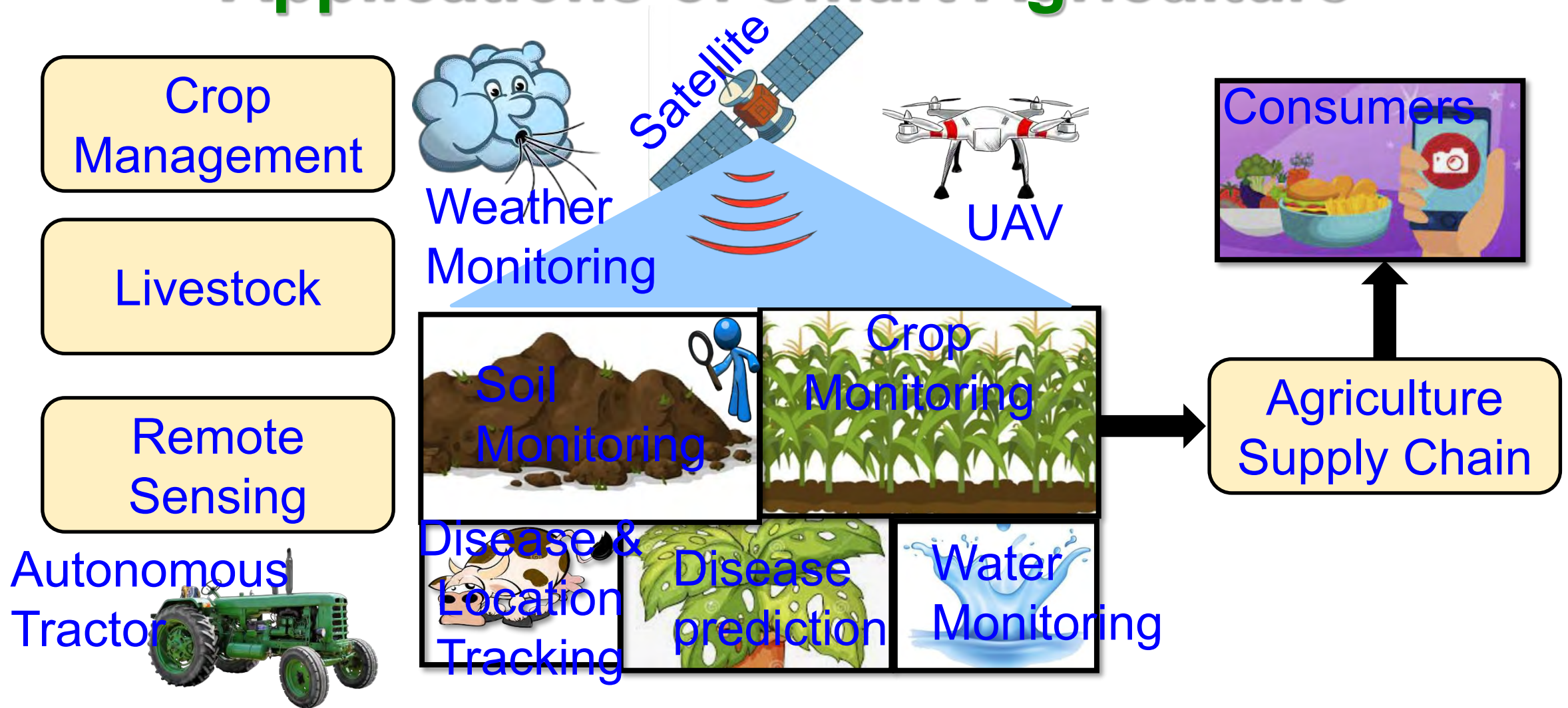
# Agriculture Cyber Physical System (A-CPS)



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](https://doi.org/10.1007/978-3-031-18872-5_1).

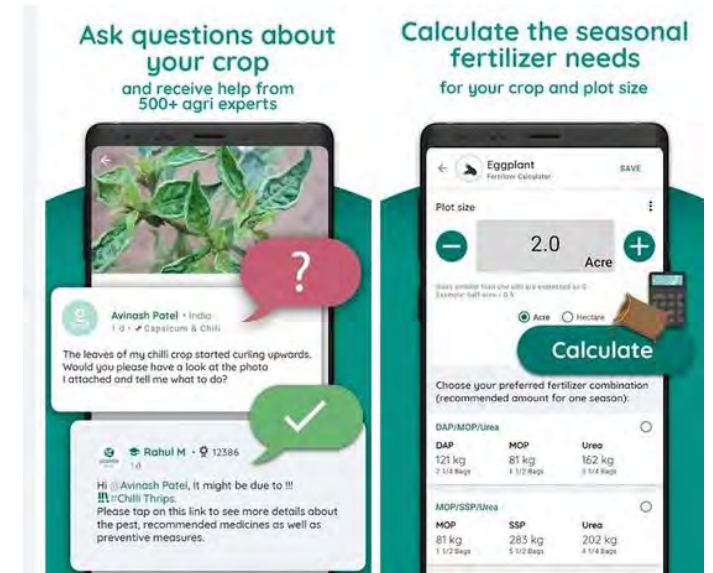
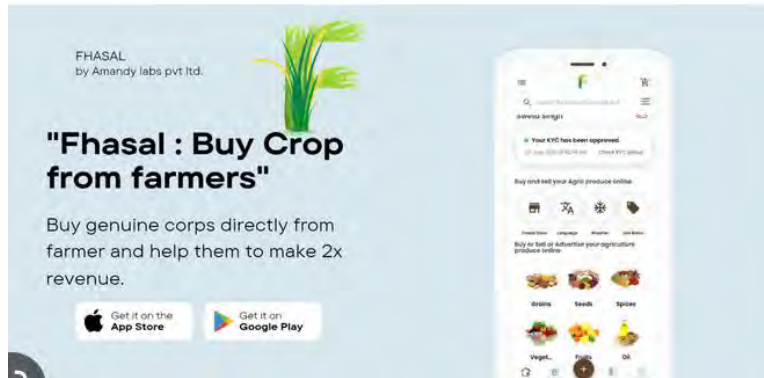


# Applications of Smart Agriculture



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.

# Smart Agriculture Apps



## Soil Sampler

Farmis

Contains ads

4.3★  
1.03K reviews

100K+  
Downloads

Everyone

## BoosterAGRO

Booster Ag Tech, Inc.

4.4★  
2.54K reviews

100K+  
Downloads

Everyone

Install Add to wishlist

You don't have any devices You can share this with your family Learn more about Family Library



## Crop Farmers App

Bivatec Ltd

Contains ads In-app purchases

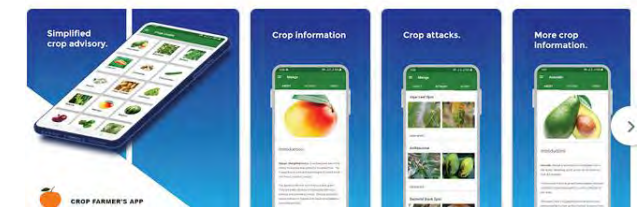
3.9★  
227 reviews

10K+  
Downloads

Everyone

Install Add to wishlist

You don't have any devices You can share this with your family Learn more about Family Library

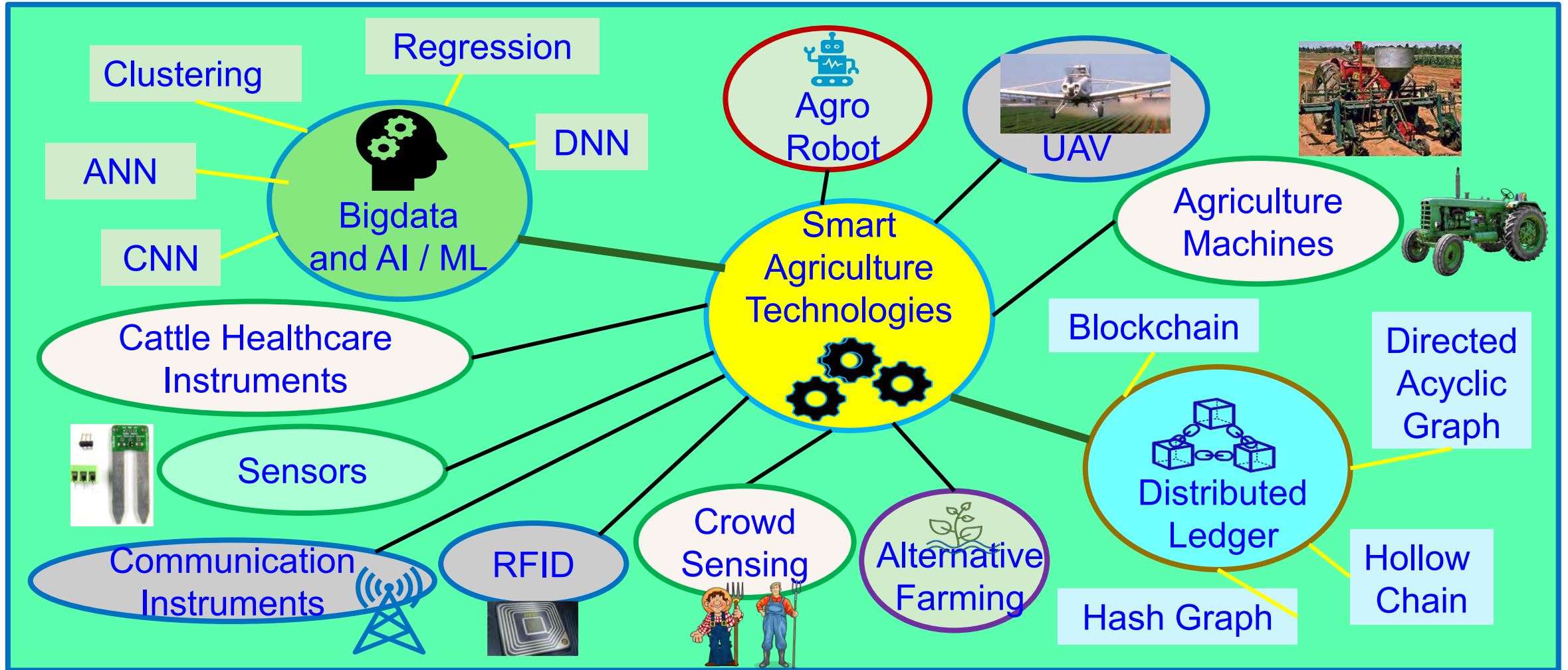


---

# Smart Agriculture – Technologies

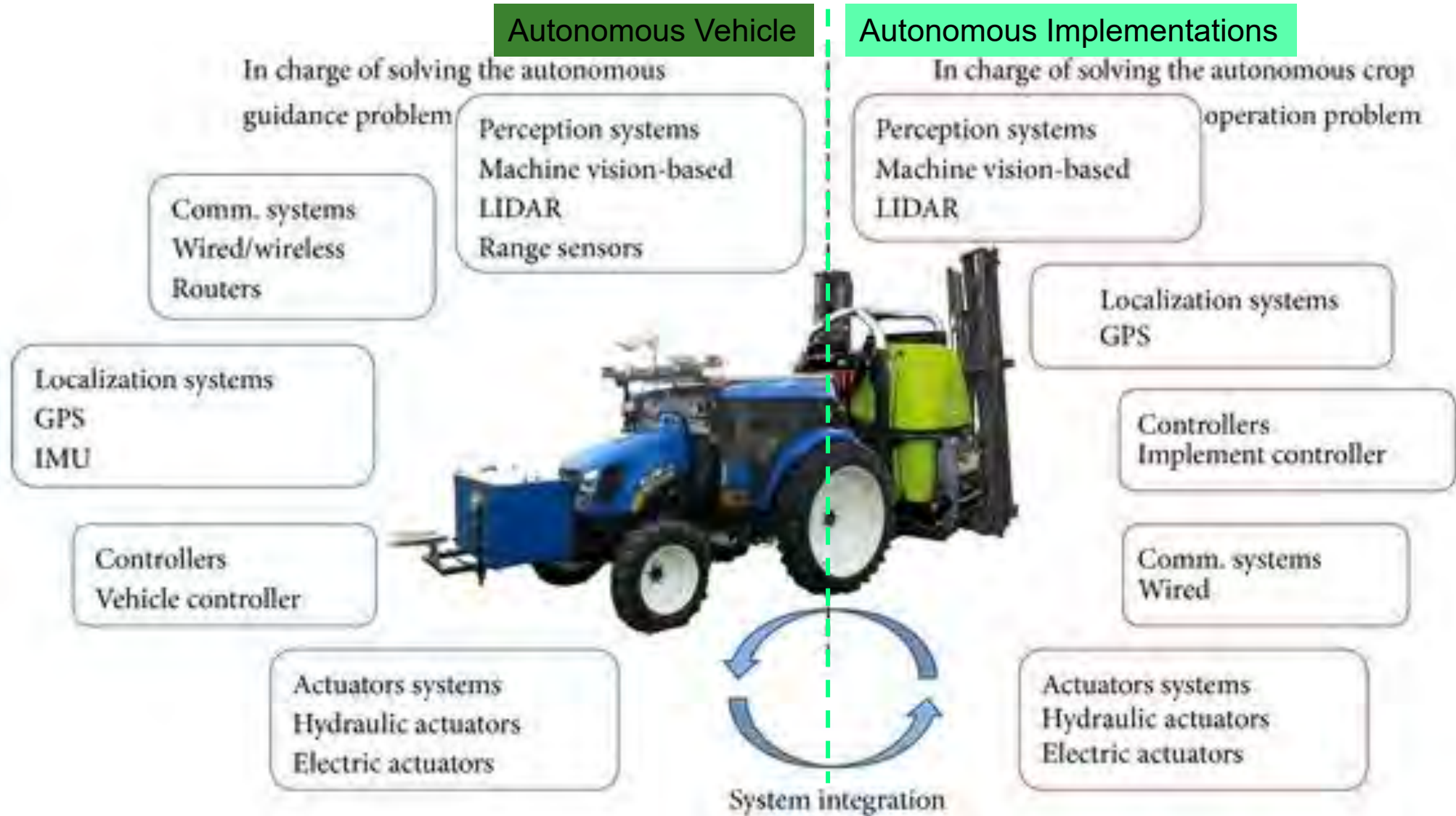


# Smart Agriculture Technologies



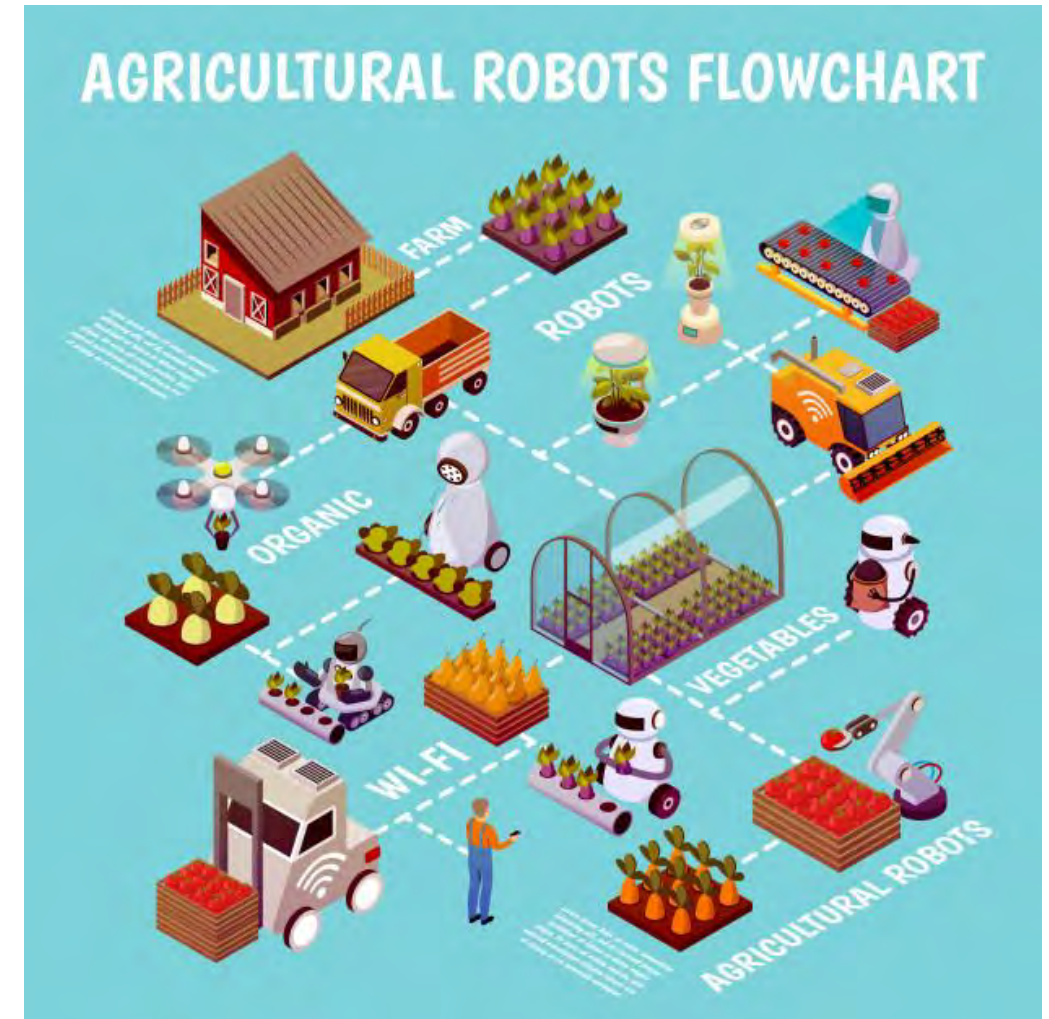
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

# 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).





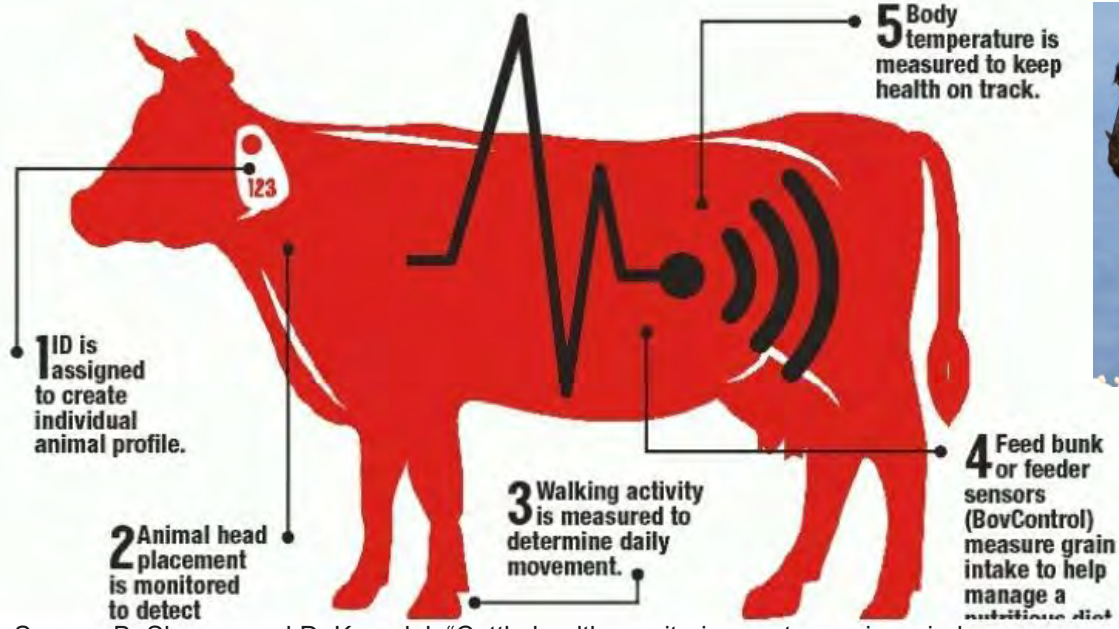
# Livestock Monitoring System



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>



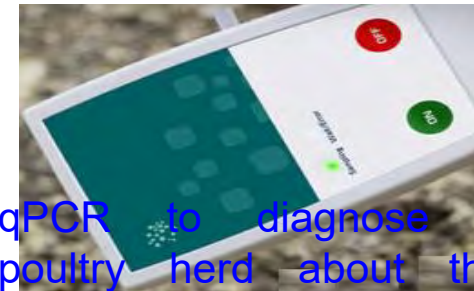
Thermometer for horses, dogs, sheep, pigs and cows



Cattle Stomach Healthcare



Livestock Heat Stress Monitor



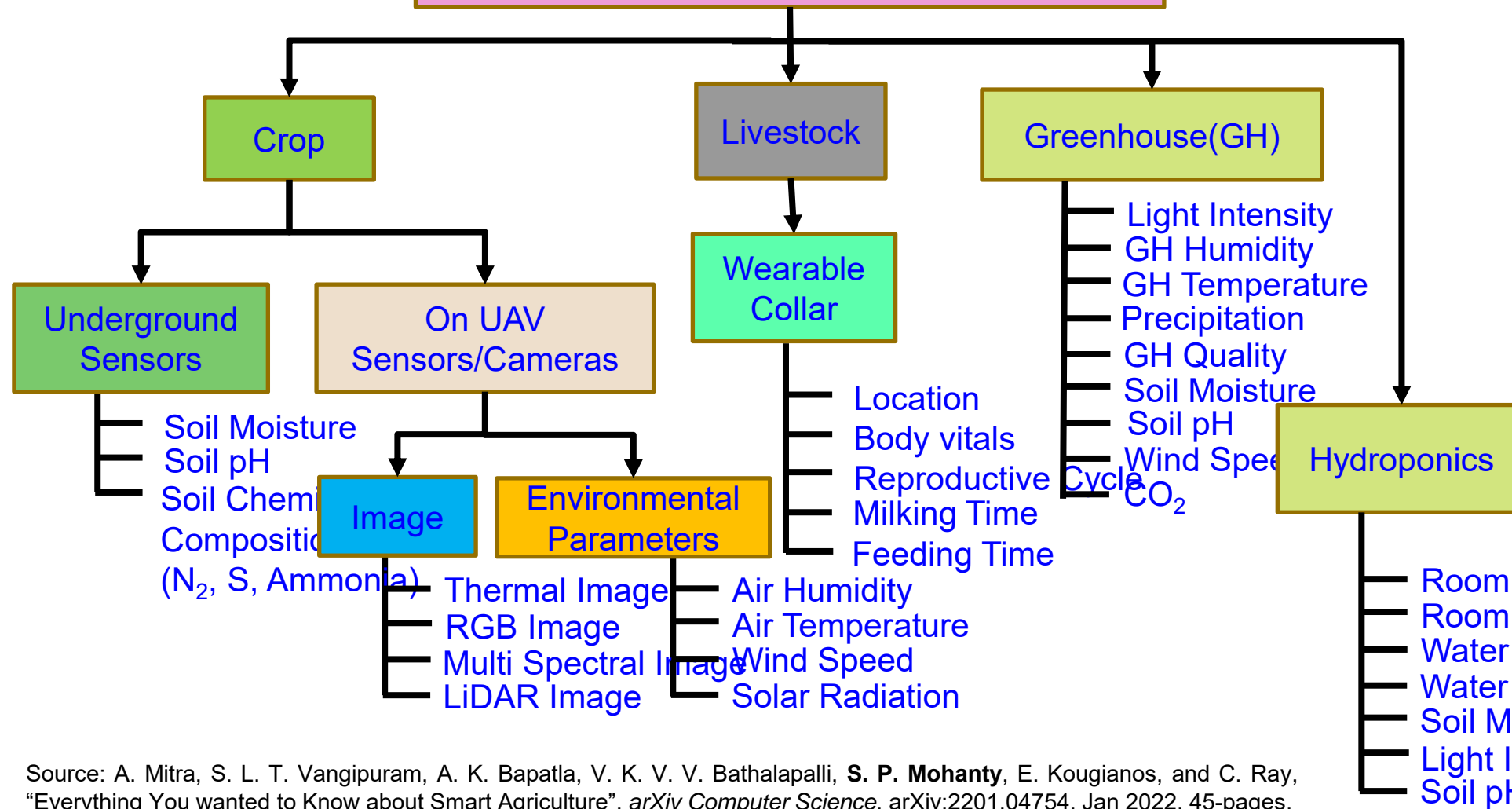
qPCR to diagnose a poultry herd about the presence of bacteria and viruses from air sample



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

# Smart Agriculture - Sensors

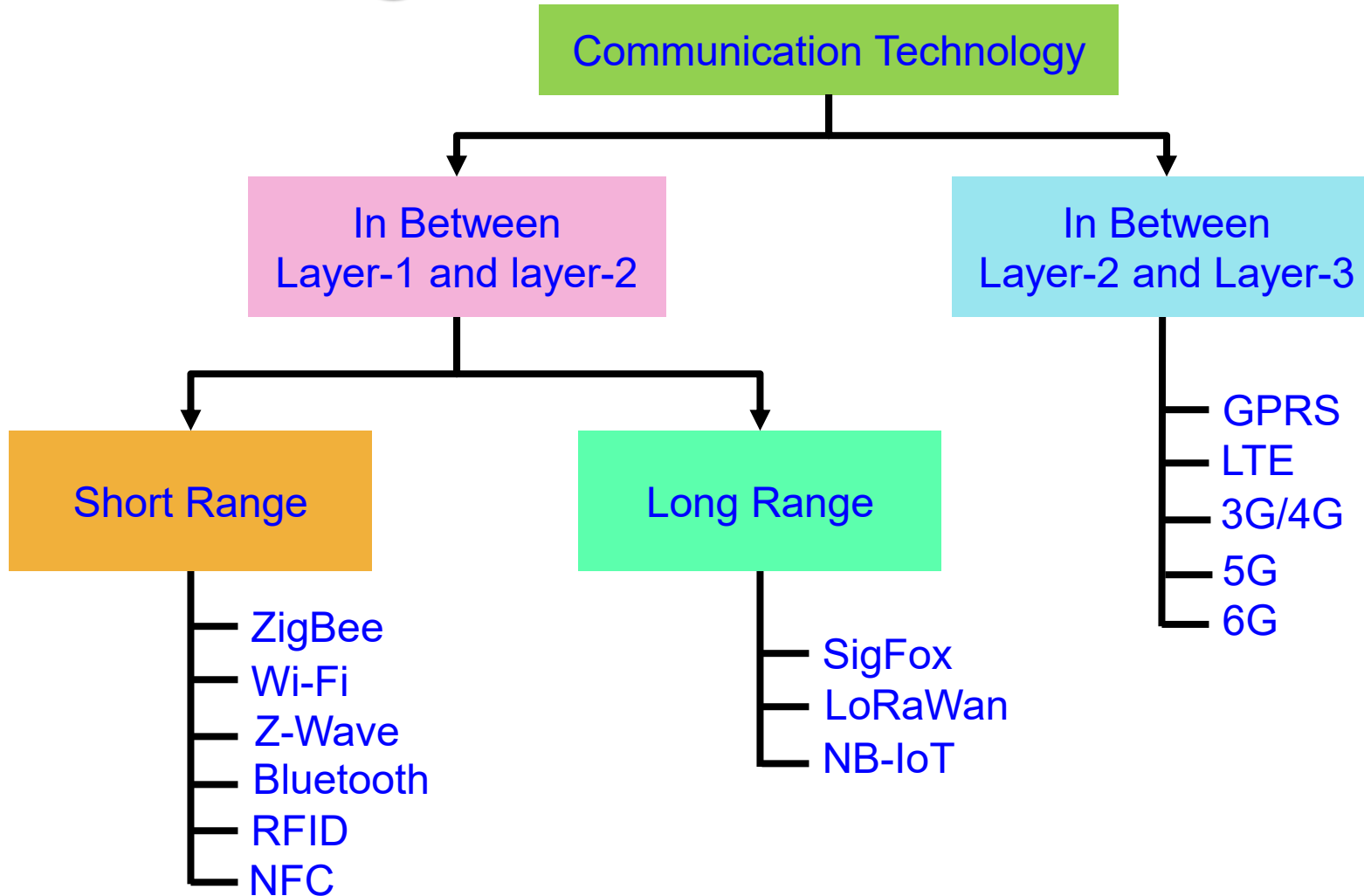
## Measured Parameters at Agricultural Devices



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](https://arxiv.org/abs/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](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.

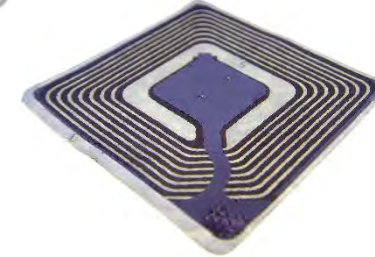
# RFID Technology



Selected  
RFID  
Attacks



Numerous Applications



Source: Khattab 2017; Springer 2017 RFID Security

# Smart Agriculture – AI/ML Technology

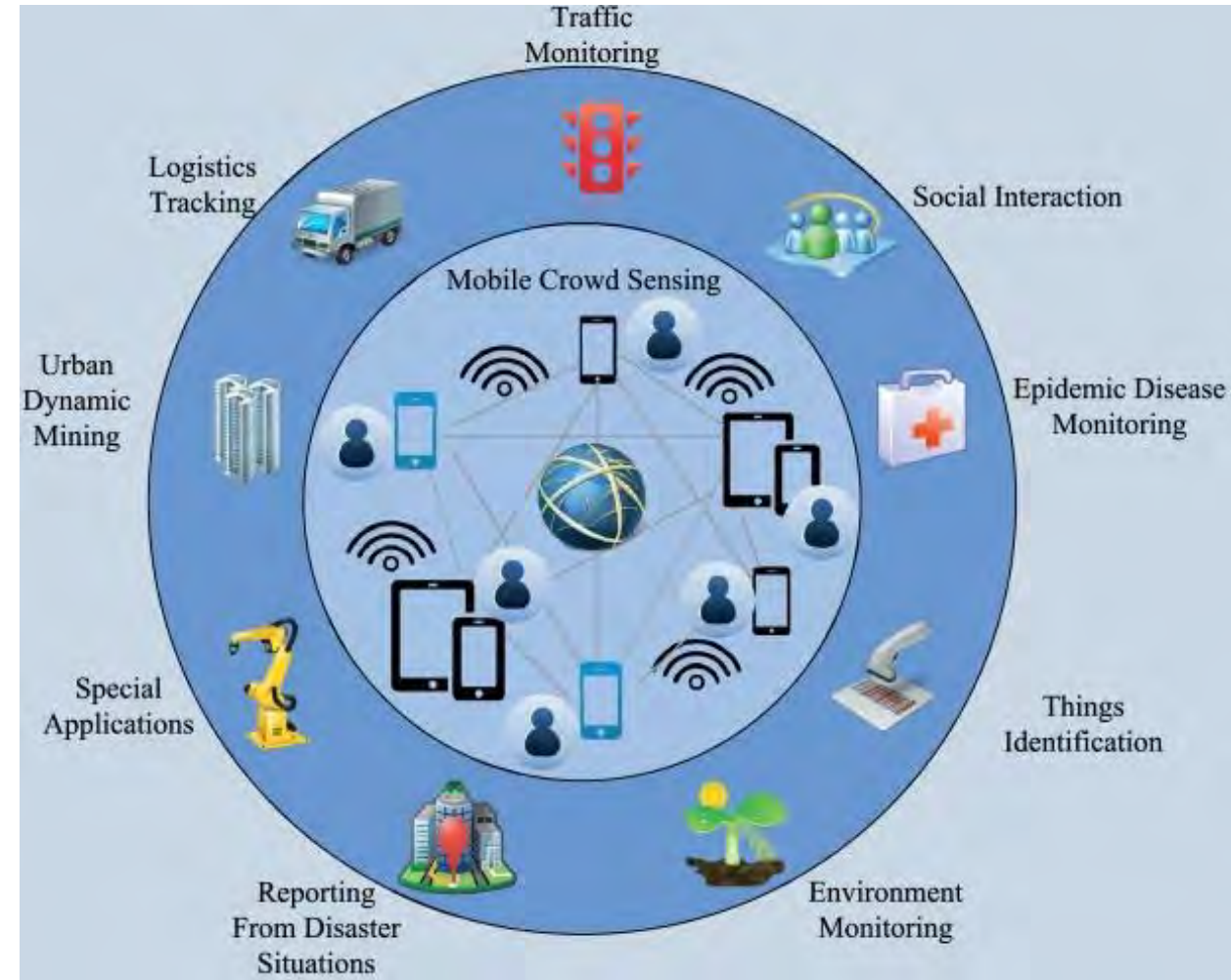


Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, “Everything You wanted to Know about Smart Agriculture”, *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.



# 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



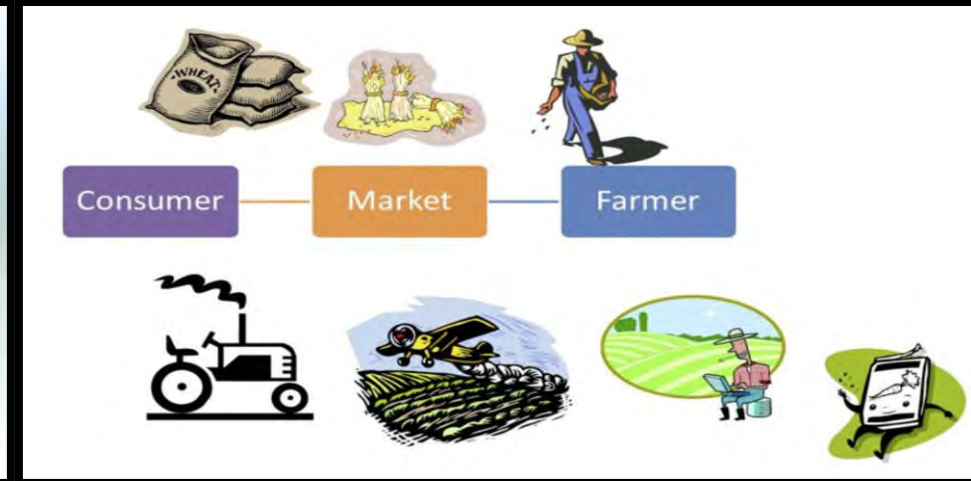
Traceability



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

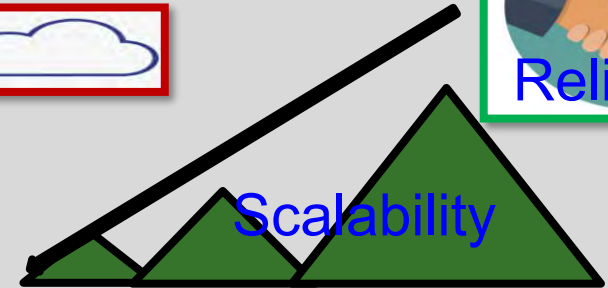
Networking and Communication



Power Availability



Reliability



Scalability



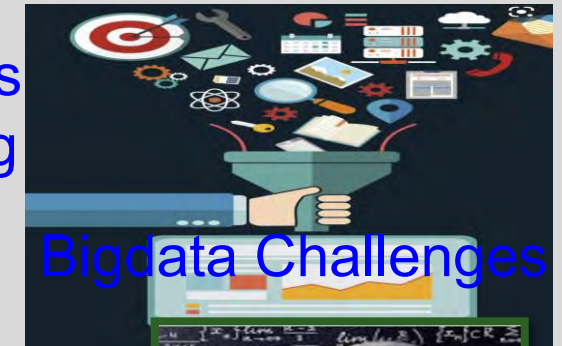
Hardware Security



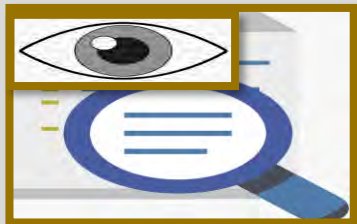
Challenges



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](https://arxiv.org/abs/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.





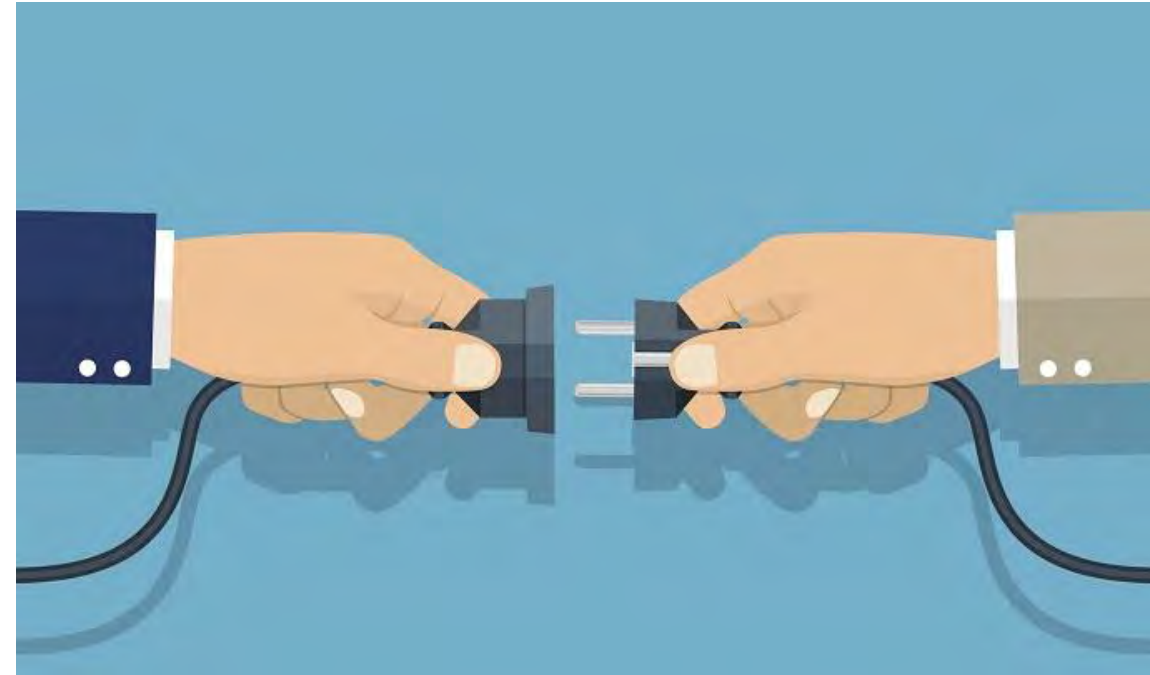
# Energy Depletion Risks

- 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.



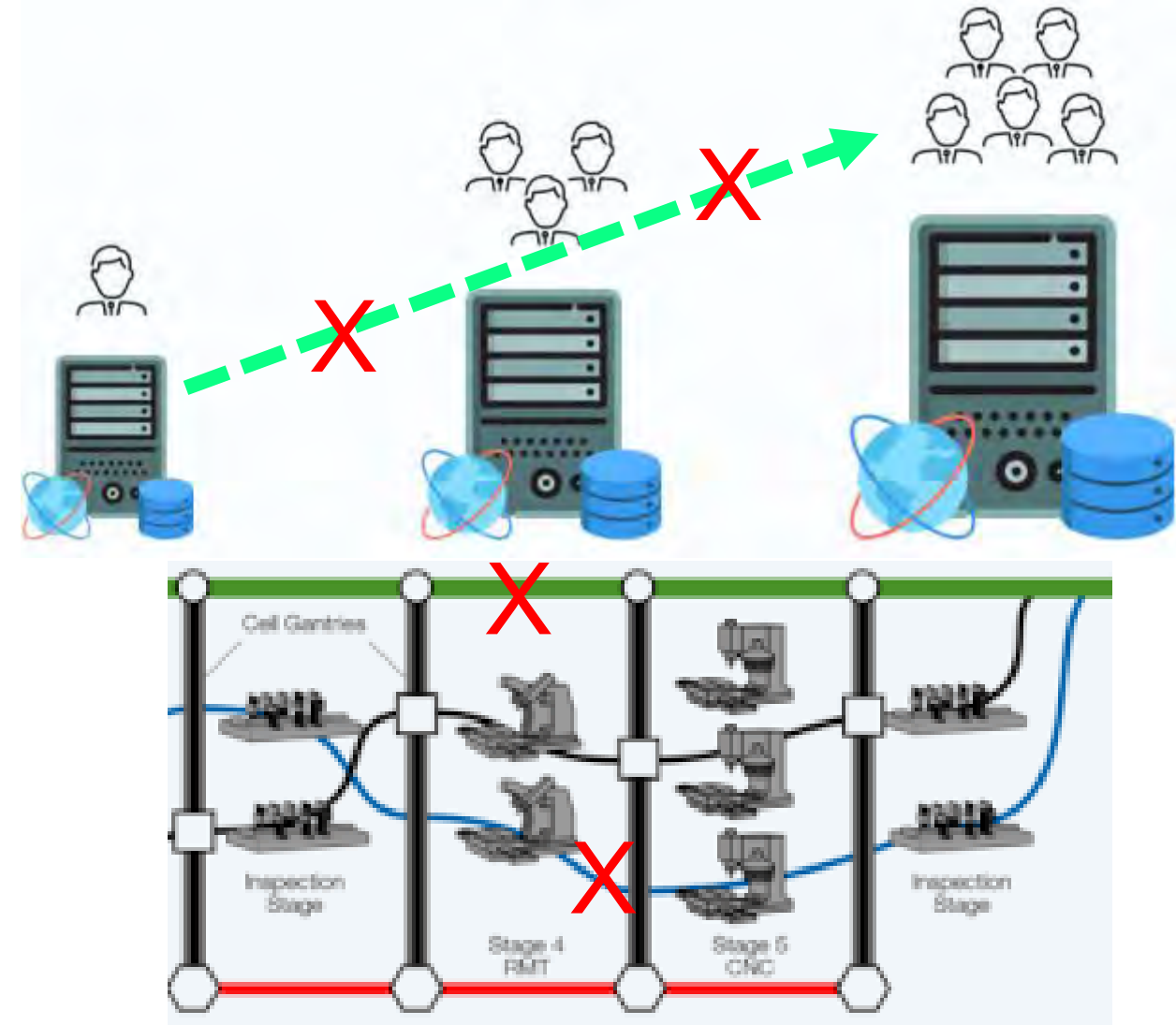
# Interoperability Can be an Issue for the Smart Agriculture Equipment

- 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

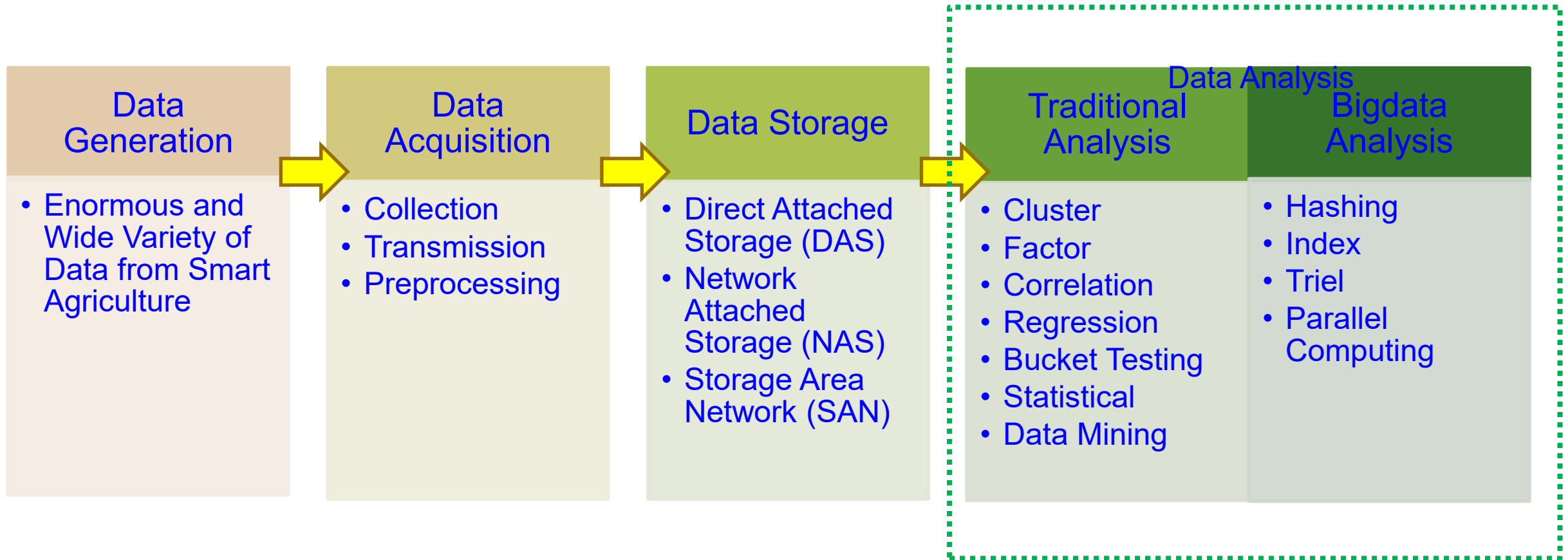
- Even most resilient systems will have failure due to unforeseen events.
- Such events in Smart Agriculture can incur large losses both in terms of money and quality of products.
- Food safety can be compromised because of such issues.



# Challenges of Data in IoT/CPS are Multifold



# 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](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.



# AI/ML Modeling Issues



## Machine Learning Issues

High Energy Requirements

High Computational Resource Requirements

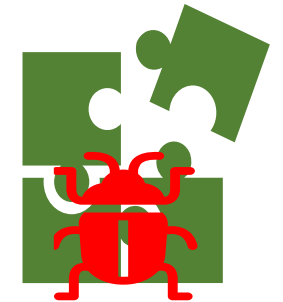
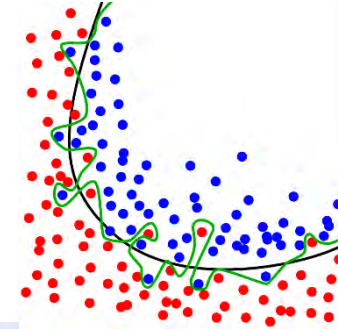
Large Amount of Data Requirements

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

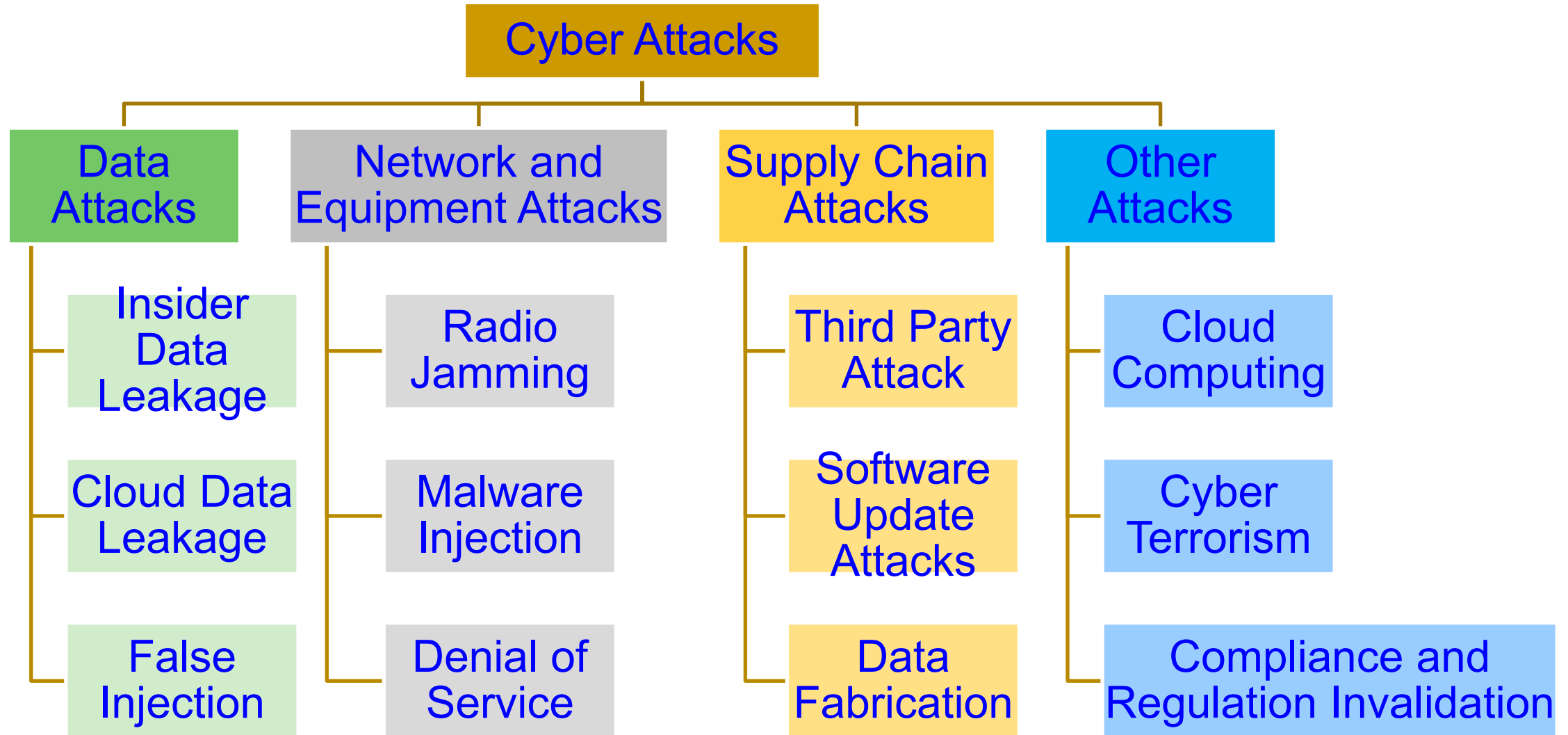
# Smart Agriculture - Security Challenges

- 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

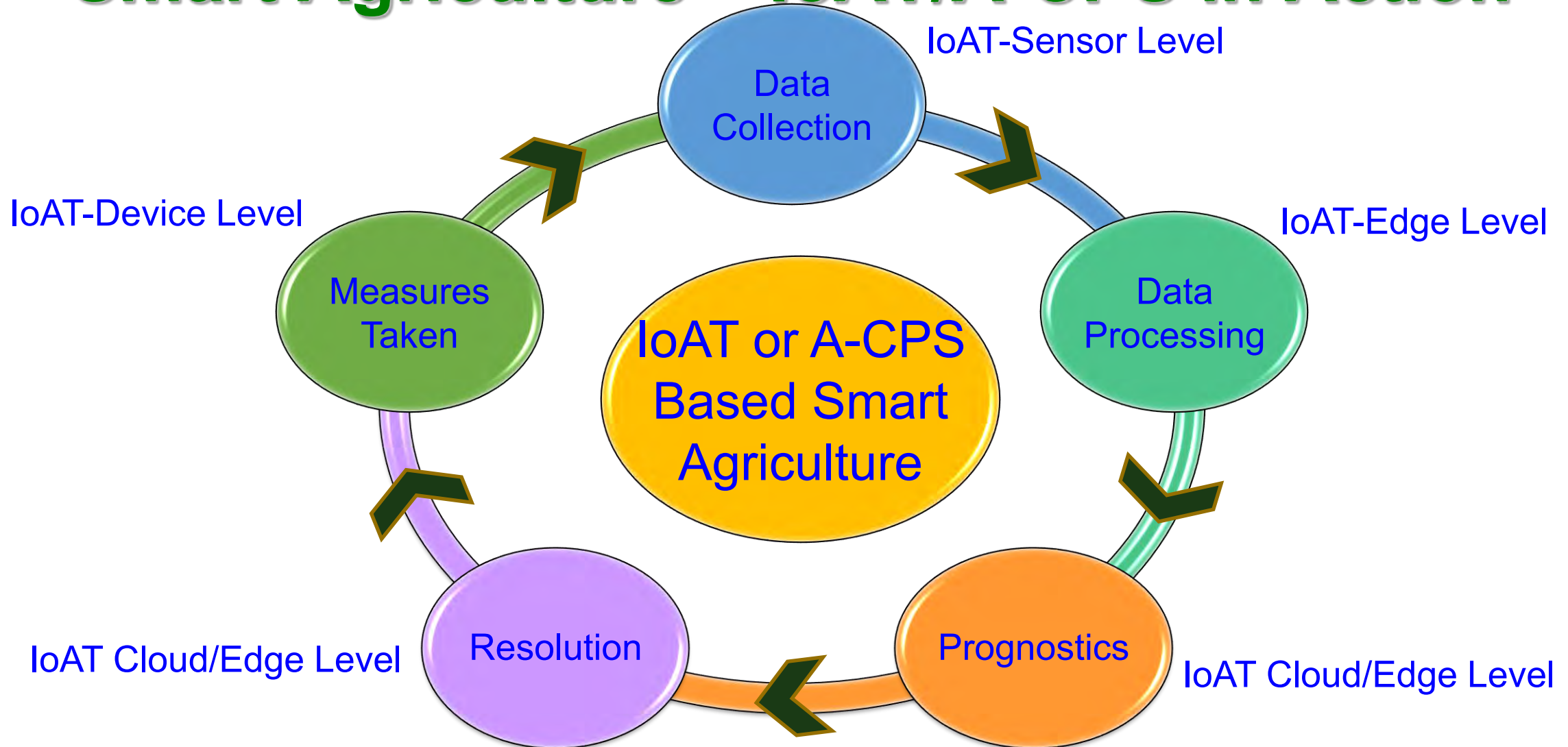


Source: M. Gupta, M. Abdelsalam, S. Khorsandroo and S. Mittal, "Security and Privacy in Smart Farming: Challenges and Opportunities," *IEEE Access*, vol. 8, pp. 34564-34584

---

# 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](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.



# Crop Damage and Disease Problem

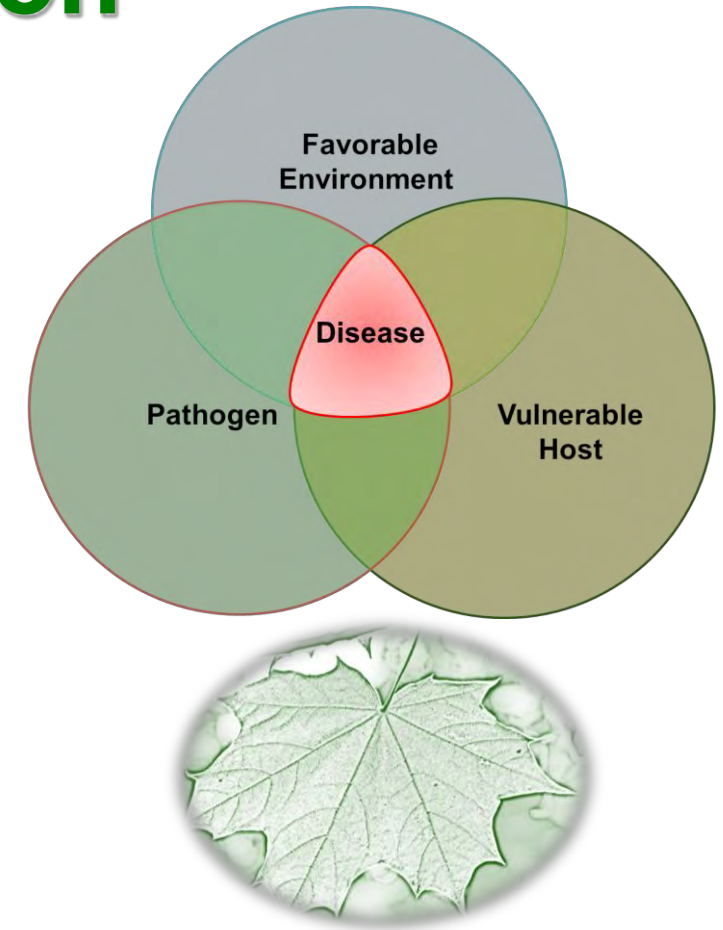
- Disease prevents the growth of plants.
  - ❑ Affect quality of the crop.
  - ❑ Reduce final yield.
- Farmers need to –
  - ❑ Monitor the field regularly.
  - ❑ Detect disease early.
  - ❑ Identify the disease.
  - ❑ Know about the severity of the disease (many of them).
  - ❑ Determine the extent of 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](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.



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](https://doi.org/10.1007/978-3-031-18872-5_1).

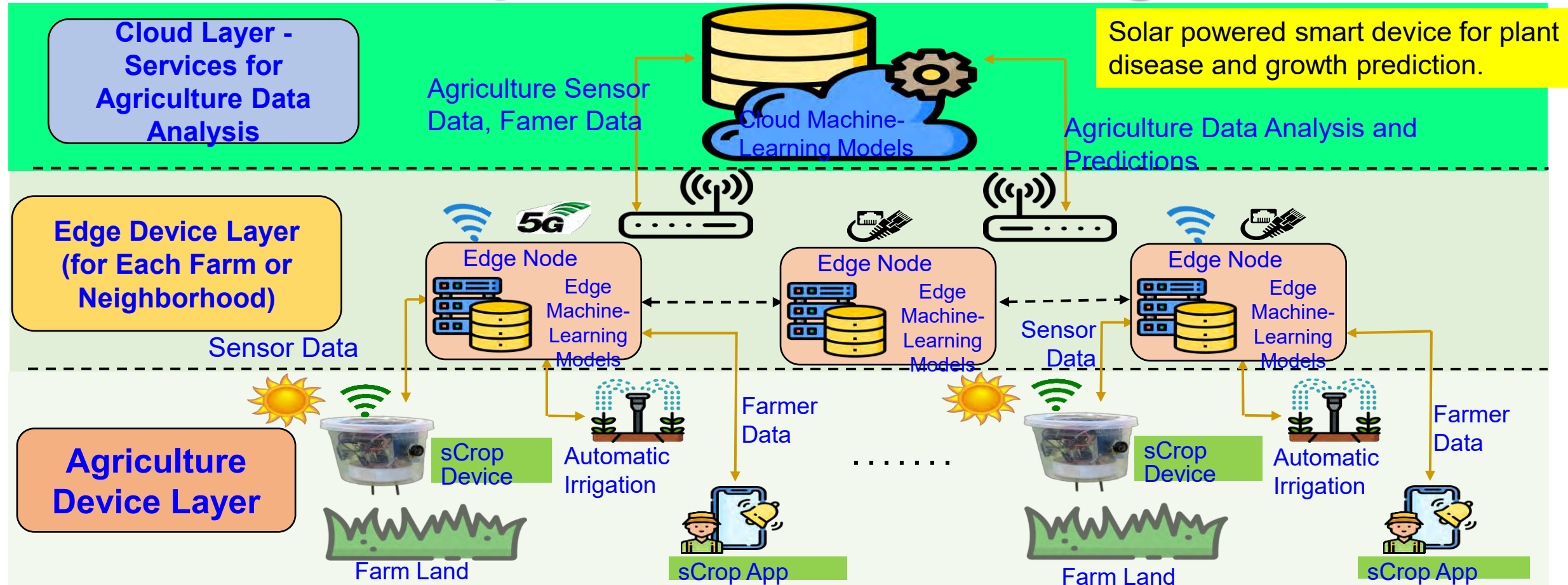
# Automatic Crop Damage Estimation: Related Prior Works

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
<b>Current Paper</b>	<b>2022</b>	<b>Multi Crop Disease</b>	<b>Yes</b>

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](https://doi.org/10.1007/978-3-031-18872-5_1).

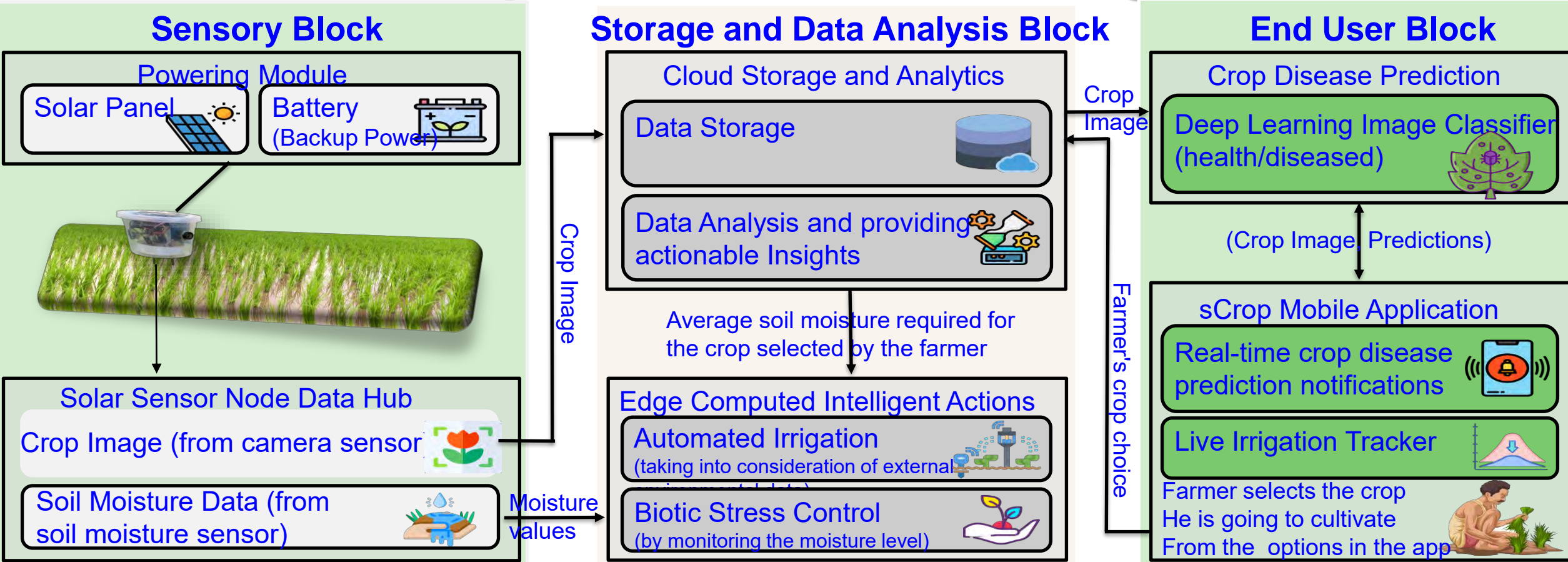


# Our sCrop: A Device for Automatic Disease Prediction, Crop Selection, and Irrigation in IoAT



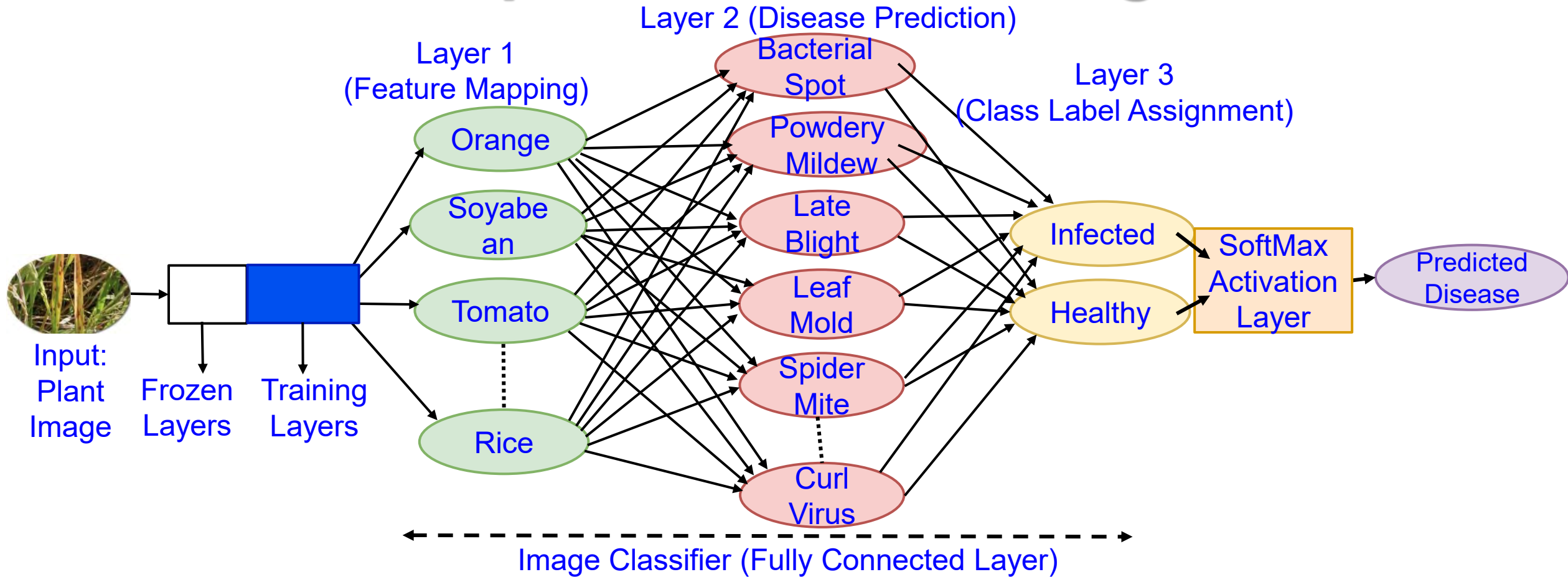
Source: V. Udutalapally, **S. P. Mohanty**, V. Pallagani, and V. Khandelwal, "sCrop: A Novel Device for Sustainable Automatic Disease Prediction, Crop Selection, and Irrigation in Internet-of-Agro-Things for Smart Agriculture", *IEEE Sensors Journal (JSEN)*, Vol. 21, No. 16, August 2021, pp. 17525--17538,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

# 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>.

# 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>.



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



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

Heat Damaged Corn Field



UAV 1

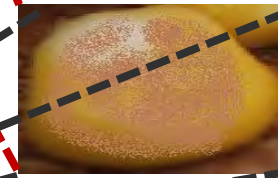
2



1 → UAV takes Photo of Corn Ear

2 → Damage Area Detection of Corn Ear

3



3 → 50% of Damaged Area Selection

4

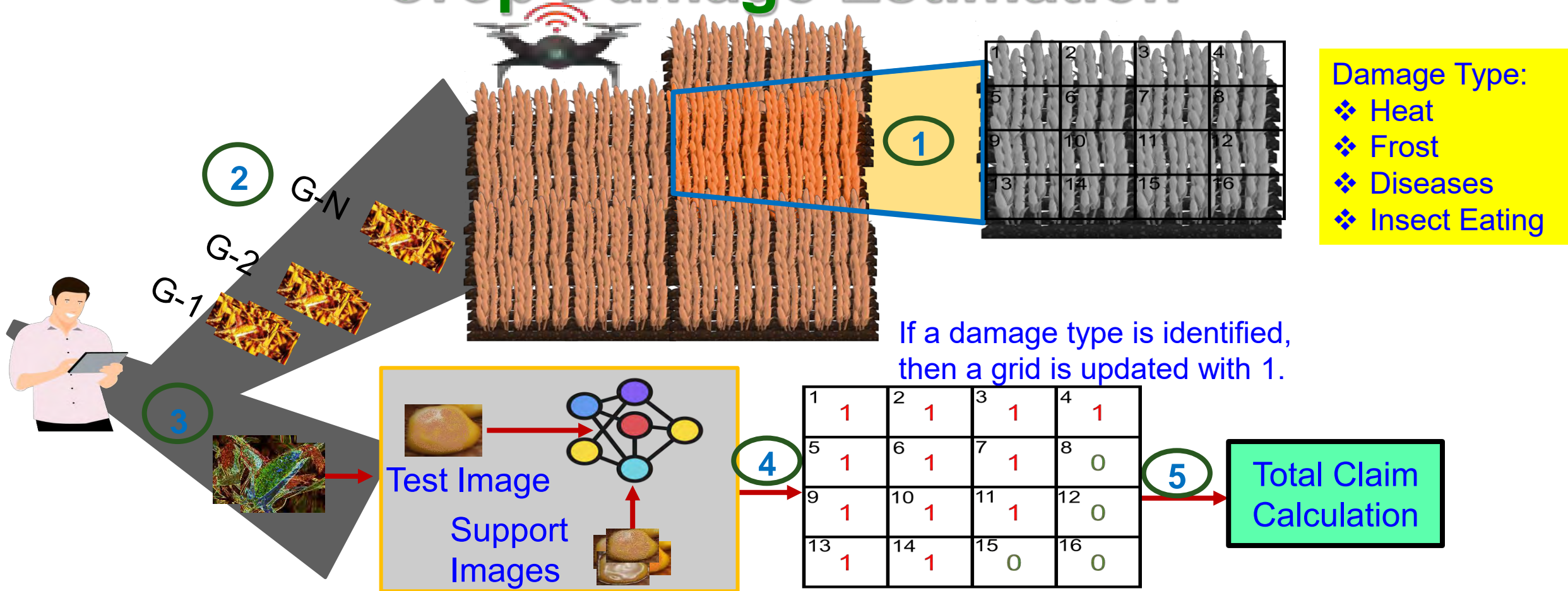


4 → Damage Type Detection for Corn Kernel and Process is Repeated for the Selected Area

A User (Farmer, Adjuster)

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: A Framework for Automatic Crop Damage Estimation



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>.



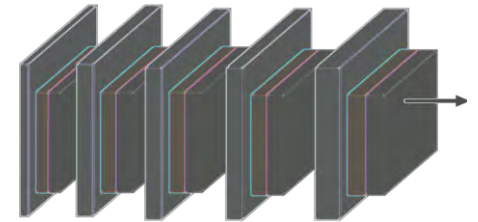
# Our eCrop: Comparative Perspective

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>.

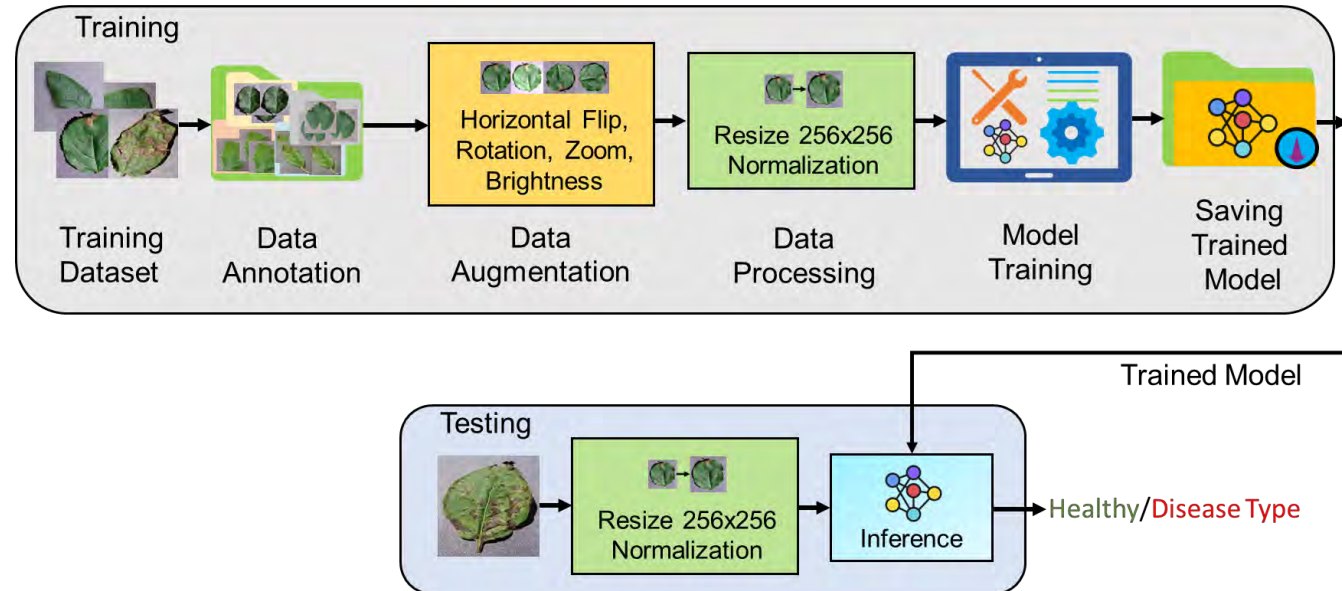
# Our aGROdet: A Framework for Plant Disease Detection and Leaf Damage Estimation

- 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](https://doi.org/10.1007/978-3-031-18872-5_1).

# Our aGROdet: Plant Disease Detection

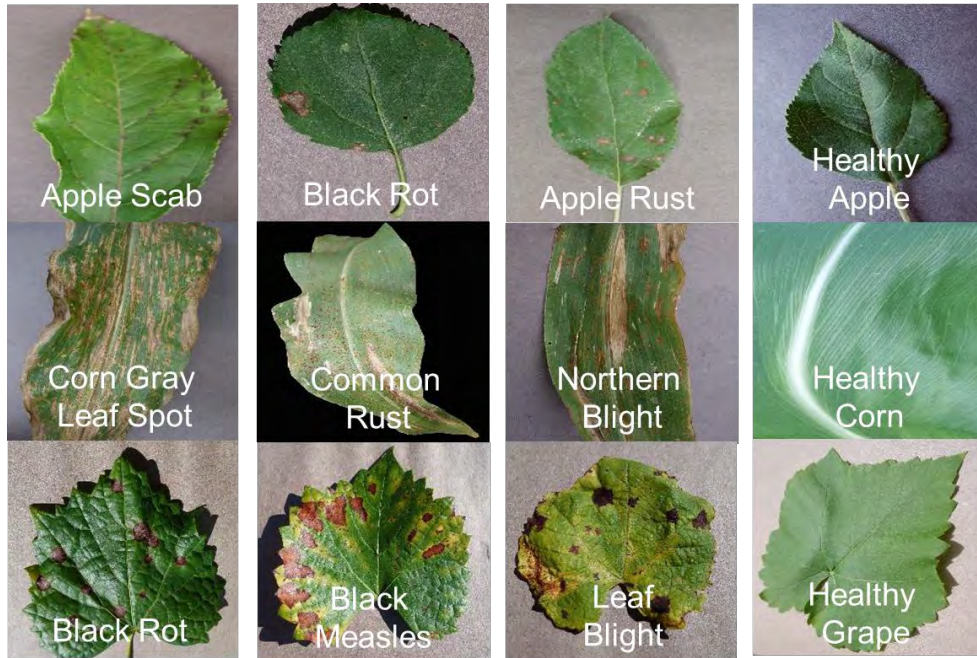


- The augmented and preprocessed data is used for training the network.
- Adam optimizer with an initial learning rate of 0.001.
- Model trained for 75 epochs.
- Model trained with and without a reduced learning rate of factor 0.1.
- Trained model is saved for future inference.
- Model evaluated using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

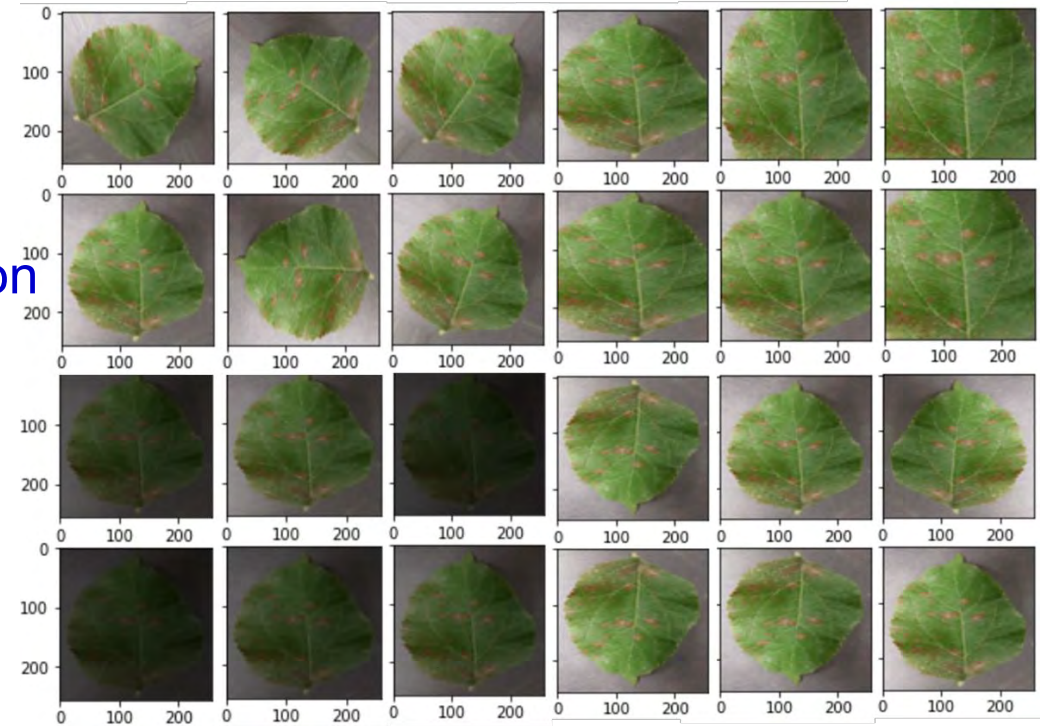
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, “aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: [https://doi.org/10.1007/978-3-031-18872-5\\_1](https://doi.org/10.1007/978-3-031-18872-5_1).



# Our aGROdet: Dataset Processing



Data  
Augmentation



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

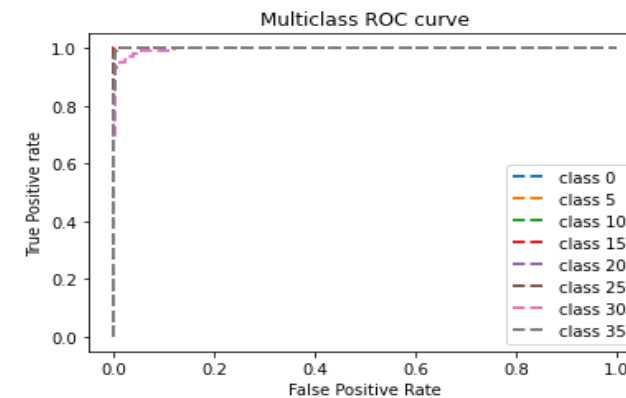
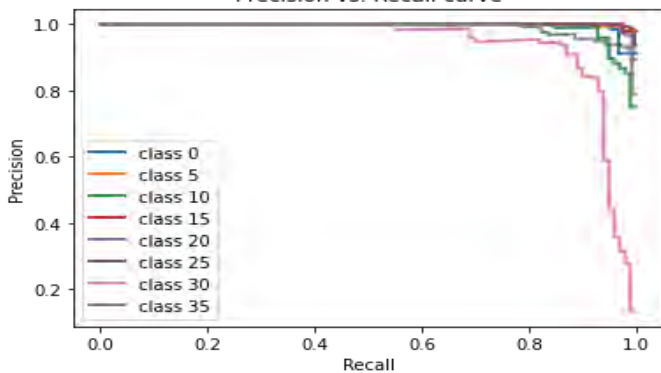
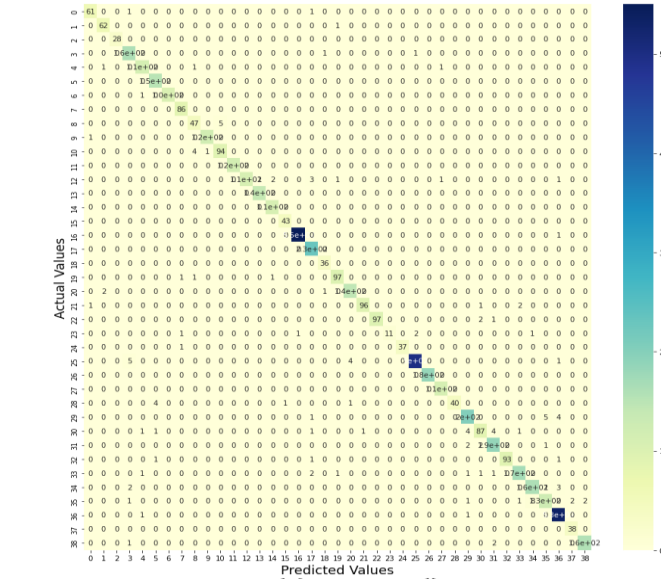
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, “aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: [https://doi.org/10.1007/978-3-031-18872-5\\_1](https://doi.org/10.1007/978-3-031-18872-5_1).

# 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
<b>Current paper</b>	<b>Multi Disease</b>	<b>98.58</b>	<b>Yes</b>

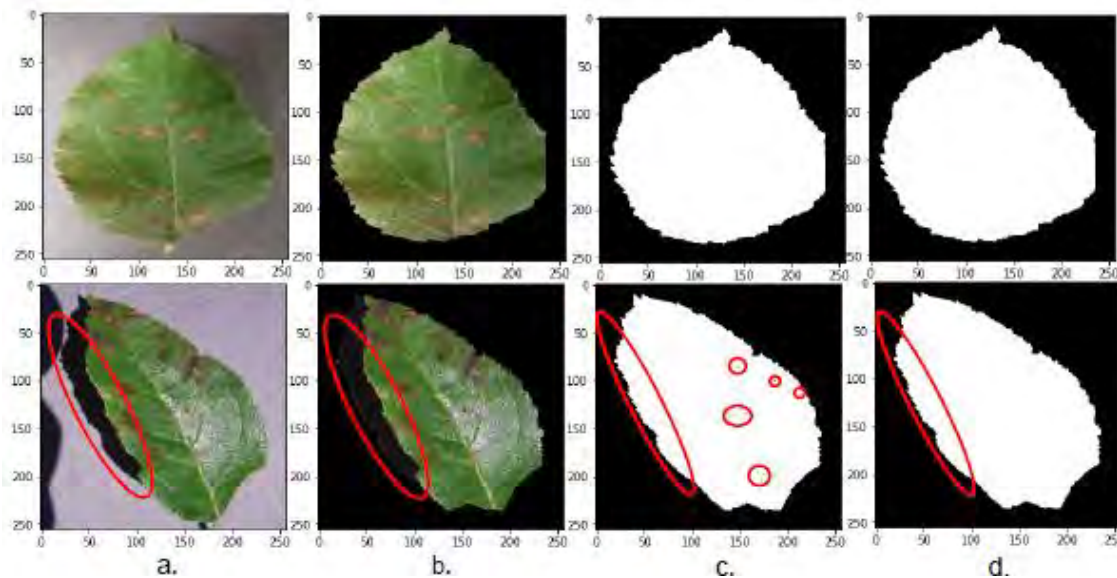
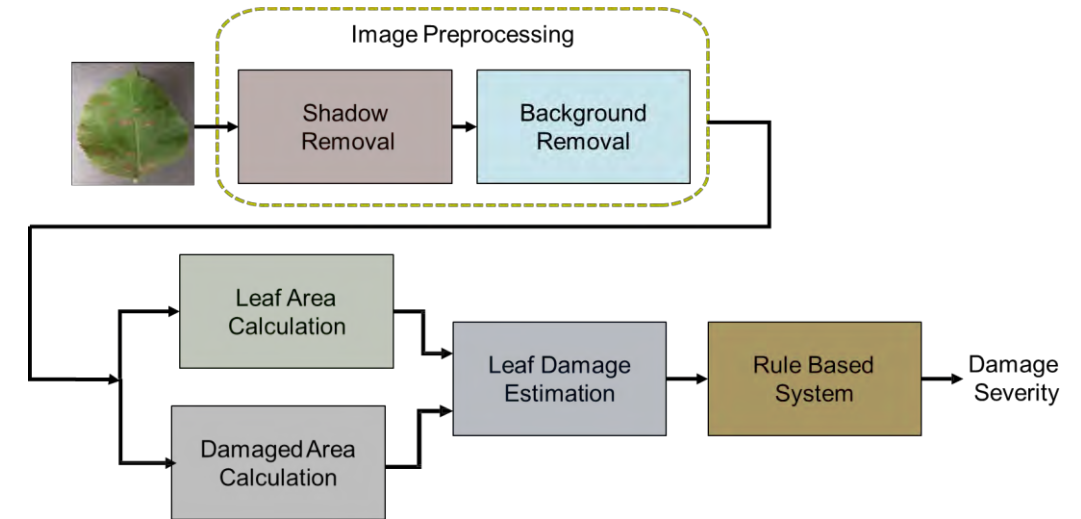


Source: A. Mitra, S. P. Mohanty, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: [https://doi.org/10.1007/978-3-031-18872-5\\_1](https://doi.org/10.1007/978-3-031-18872-5_1).



# 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.





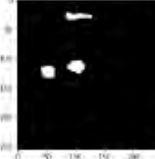


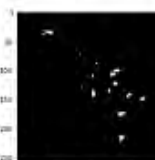


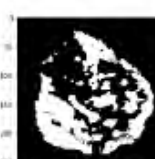





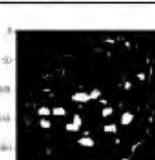
## Leaf Area Detection by Creating Leaf Mask -

- Input Image .
- Background Segmentation by GrabCut Algorithm.
- Mask Creation for the Leaf ; RGB->HSV; thresholding over black color; mask inverted.
- 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](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-

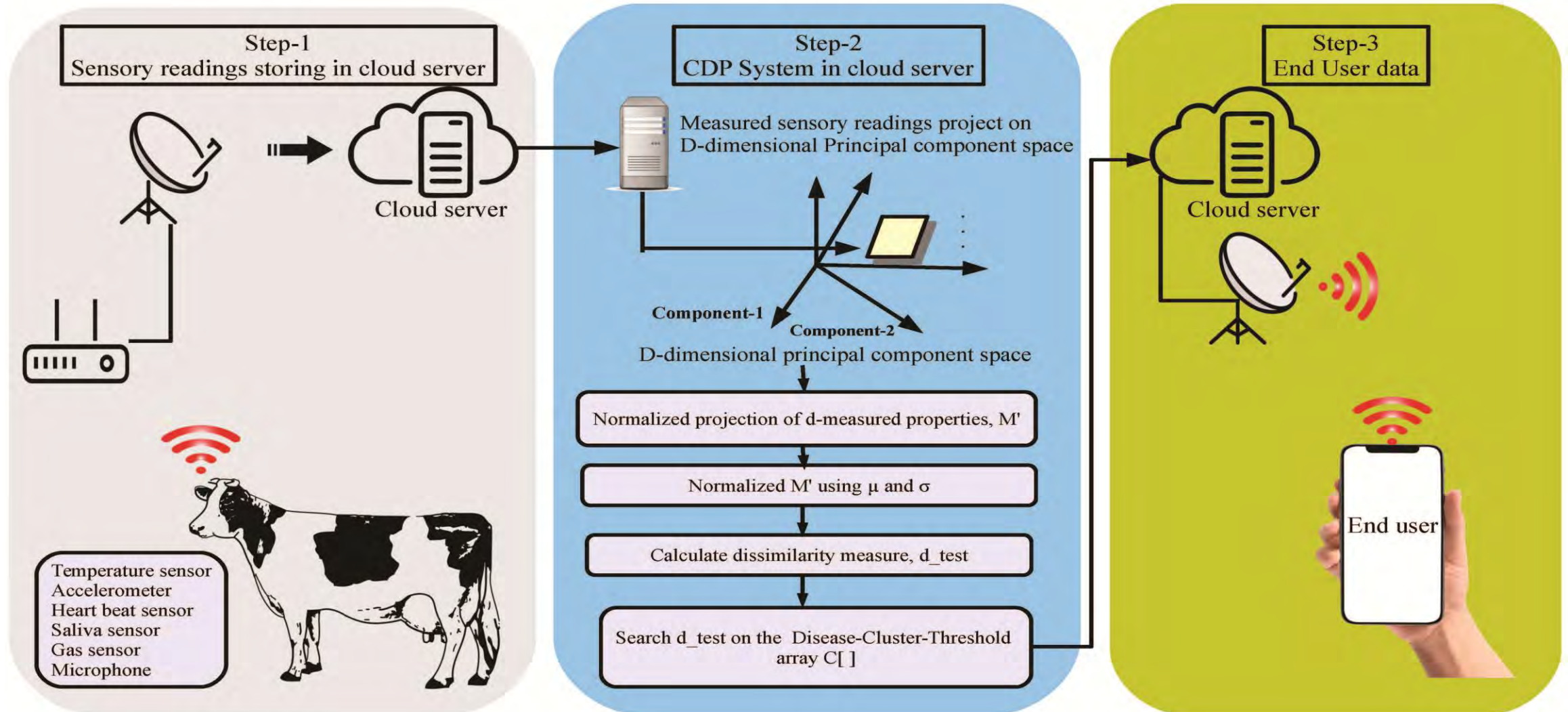
- Damage estimation by aGROdet is not affected as damage masks even in the presence of shadows.
- When there is some specular reflection in the image, aGROdet can still correctly estimates the damage of leaves.
- No experiment for corn leaf images in the dataset as whole leaf is not visible.

## ■ 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](https://doi.org/10.1007/978-3-031-18872-5_1).

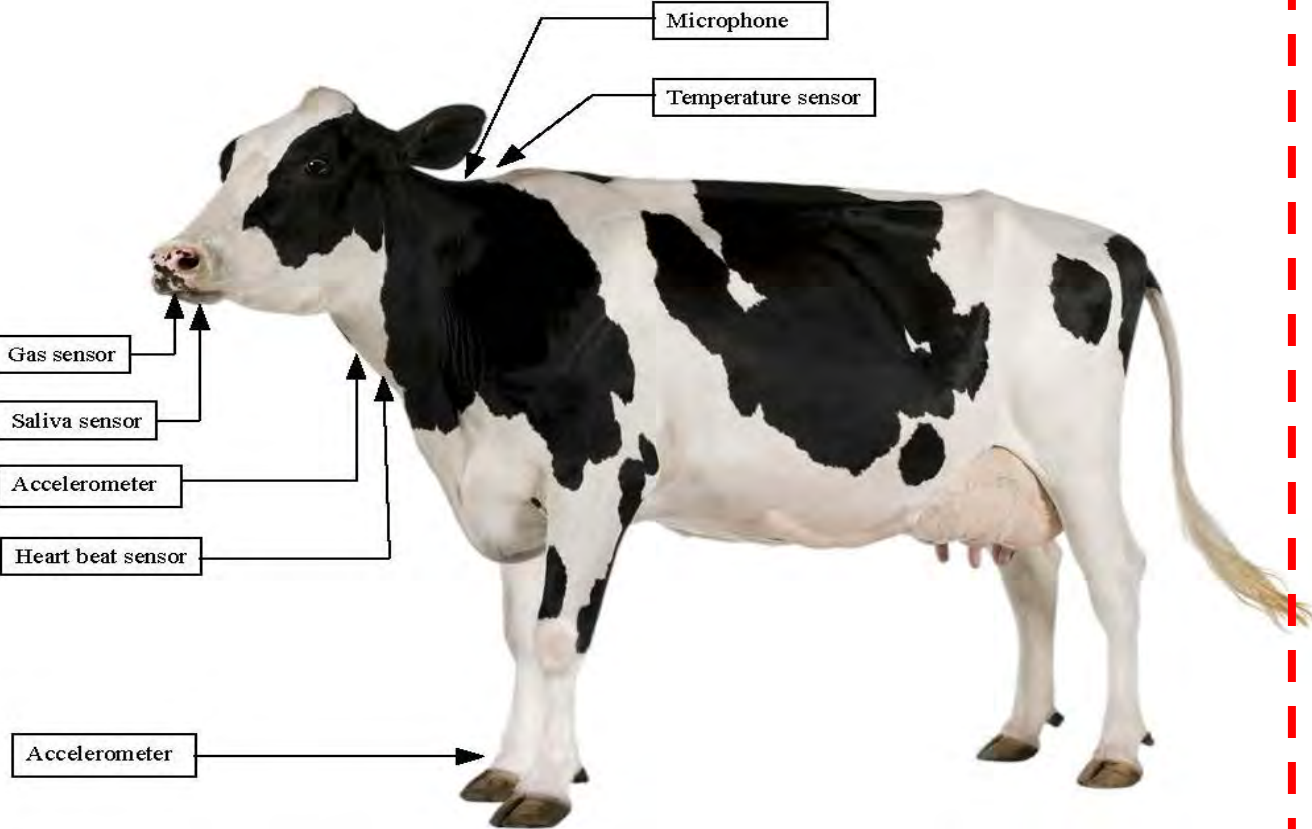
# Our LiveCare - IoT-Based Cattle Healthcare Framework



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
(3) Microphone	Discomfort	variable	variable	variable
(4) Gas sensor	Mooing or Coughing	yes		
		No		
(5) Load sensor	Smell of breath	yes		
		No		
(6) Heartbeat sensor	Load shifting	yes (load varies on four legs)		
		No (load constant on four legs)		
(7) Electrical conductivity sensor	Heart rate (normal for adult cow)	48 to 84 beats per minute		
	Heart rate (anxiety)	Above 84 beats per minute		
(8) Saliva sensor	For healthy cow	4 to 6 milliSiemens (ms)		
	Clinically infected cow	Above 6 milliSiemens (ms)		
(9) 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>.

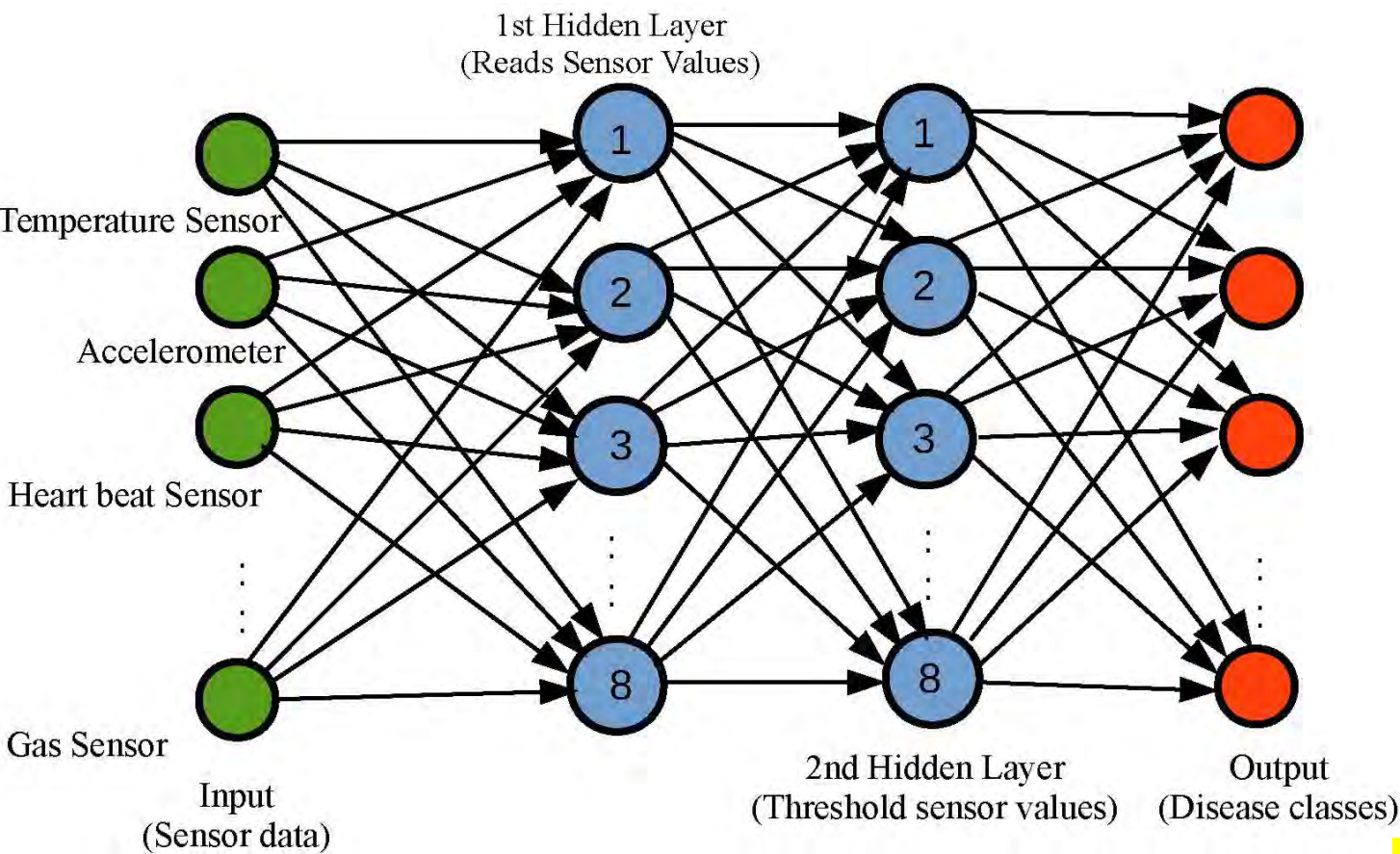


# Our LiveCare - IoT-Based Cattle Healthcare Framework

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)
(9) Foot and mouth disease	Prostration	Prostration	Accelerometer(feet and neck)
	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.
<b>LiveCare (Proposed)</b>	Yes	9 different diseases can be detected	

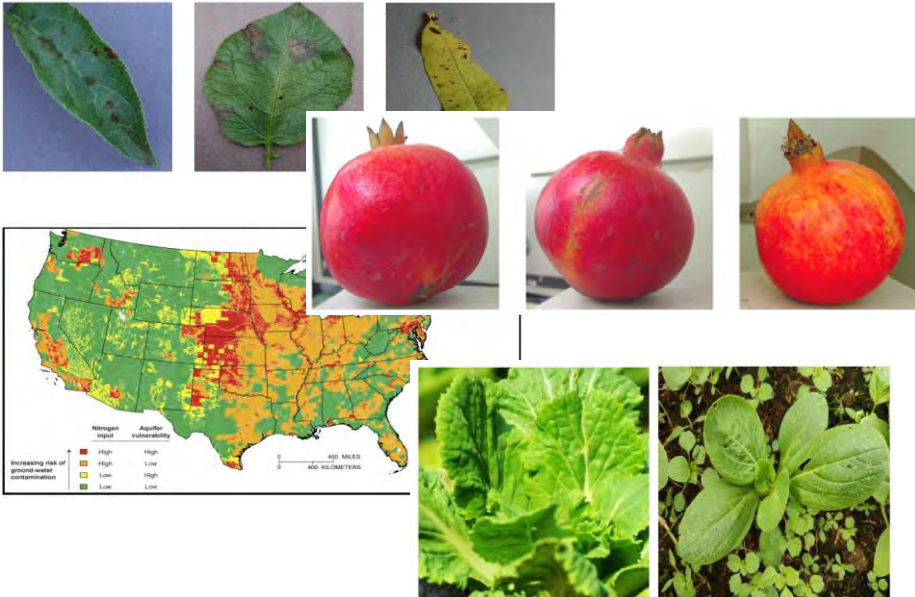
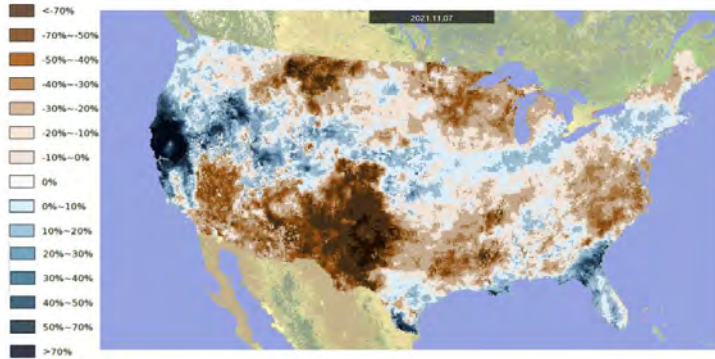
Accuracy of our Proposed Cow-Disease Prediction (CDP) Algorithm – 100%

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

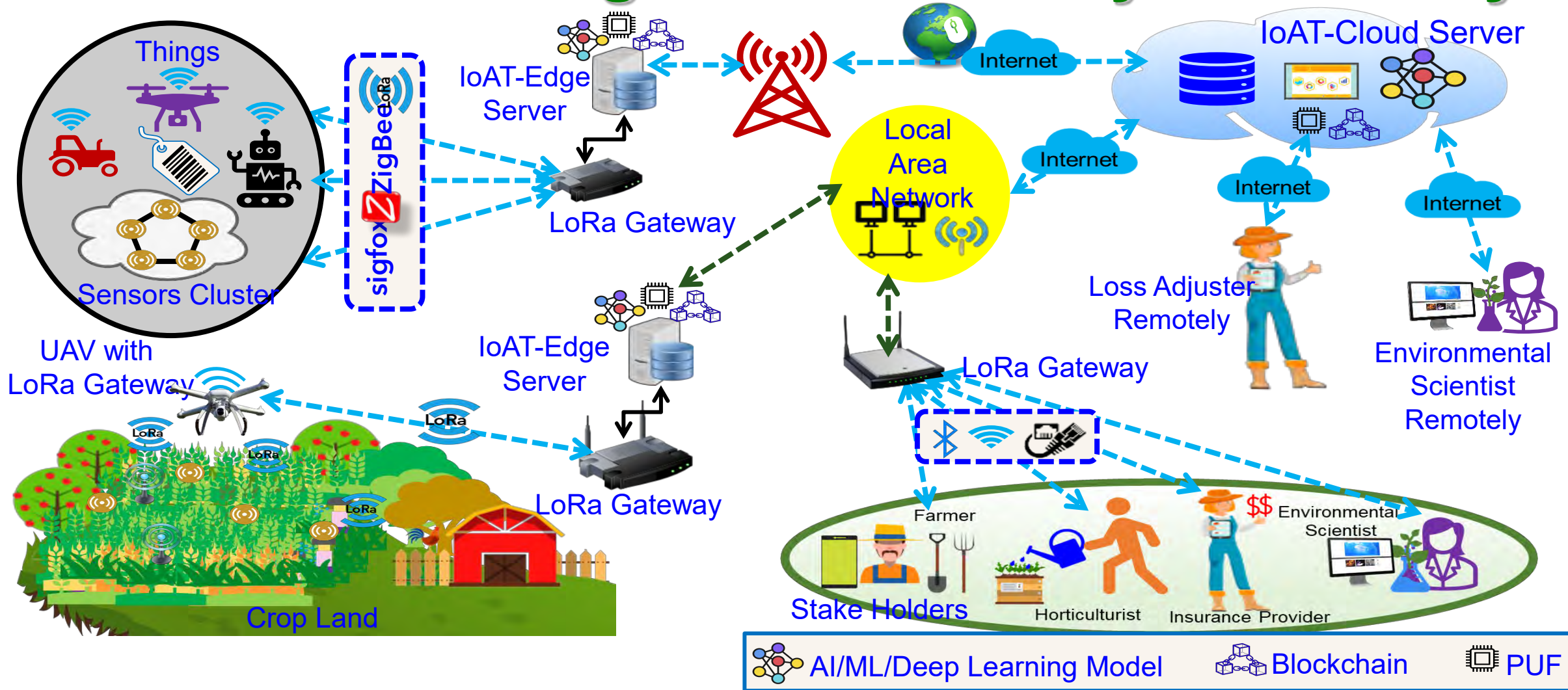
[Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, “Everything You wanted to Know about Smart Agriculture”, *arXiv Computer Science*, [arXiv:2201.04754](https://arxiv.org/abs/2201.04754), Jan 2022, 45-pages.]



---

# Smart Agriculture Case Studies - Cybersecurity Solutions

# A-CPS with Integrated AI and Cybersecurity



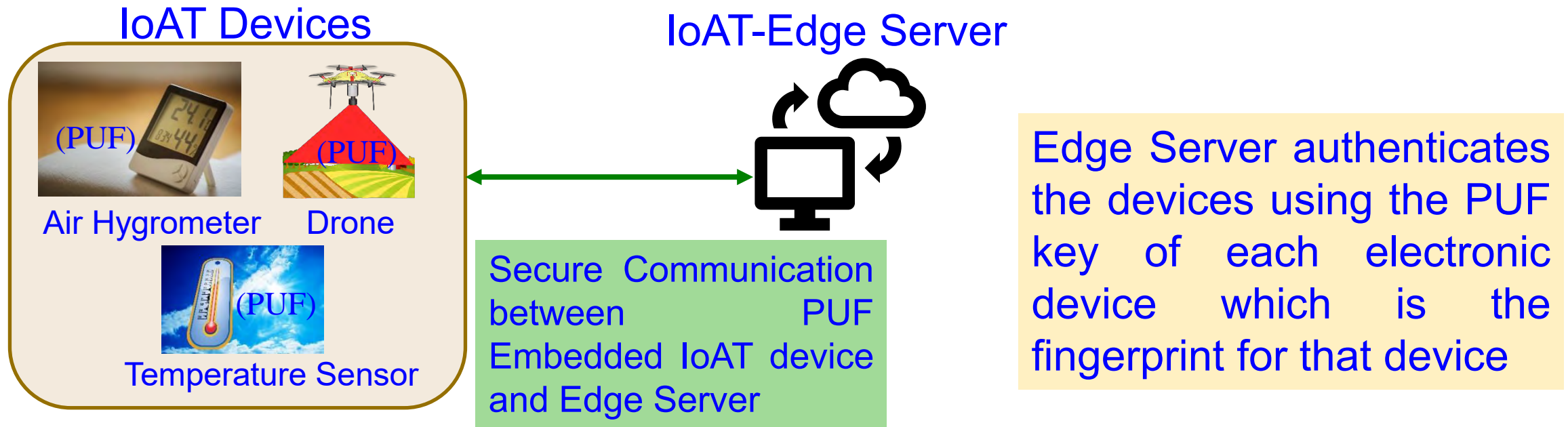
Source: A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, “eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture”, *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: <https://doi.org/10.1007/s42979-022-01216-8>.

# 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

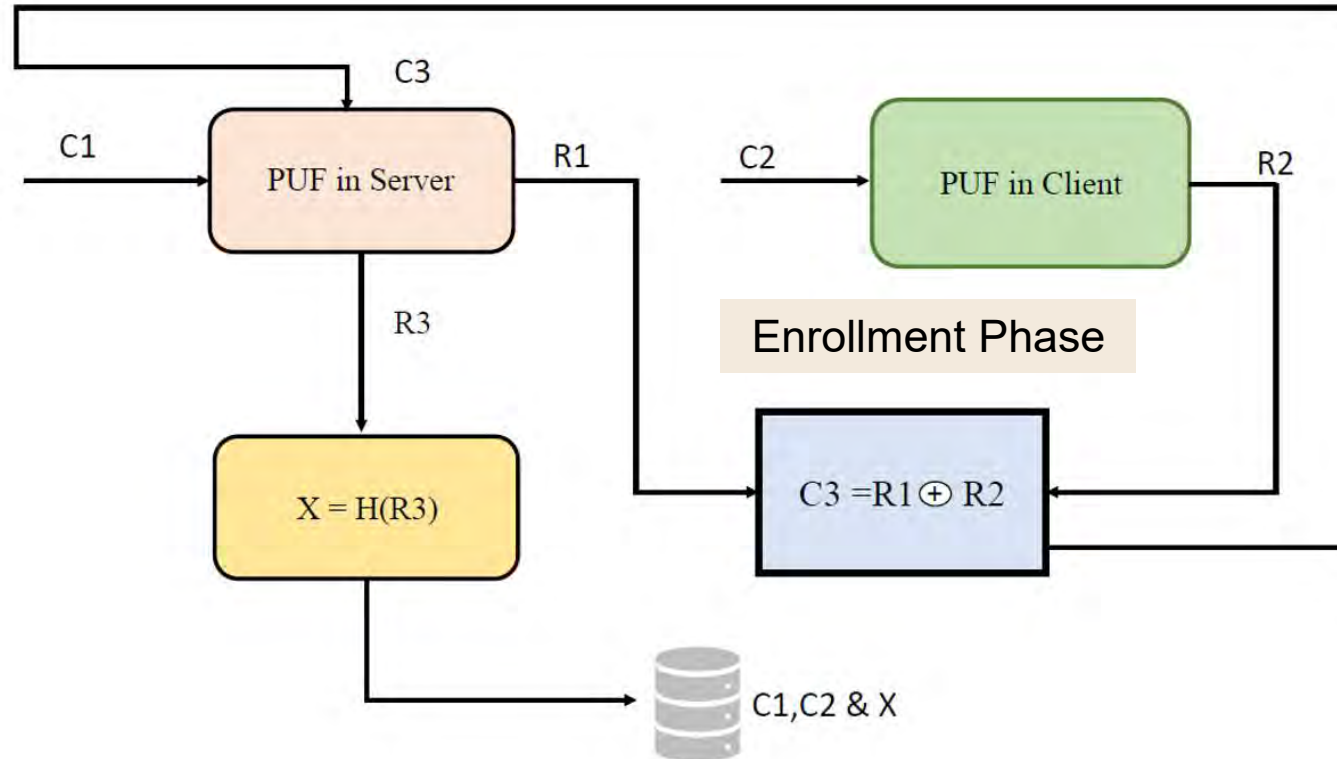


# Our Security-by-Design Approach for Robust IoAT



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.

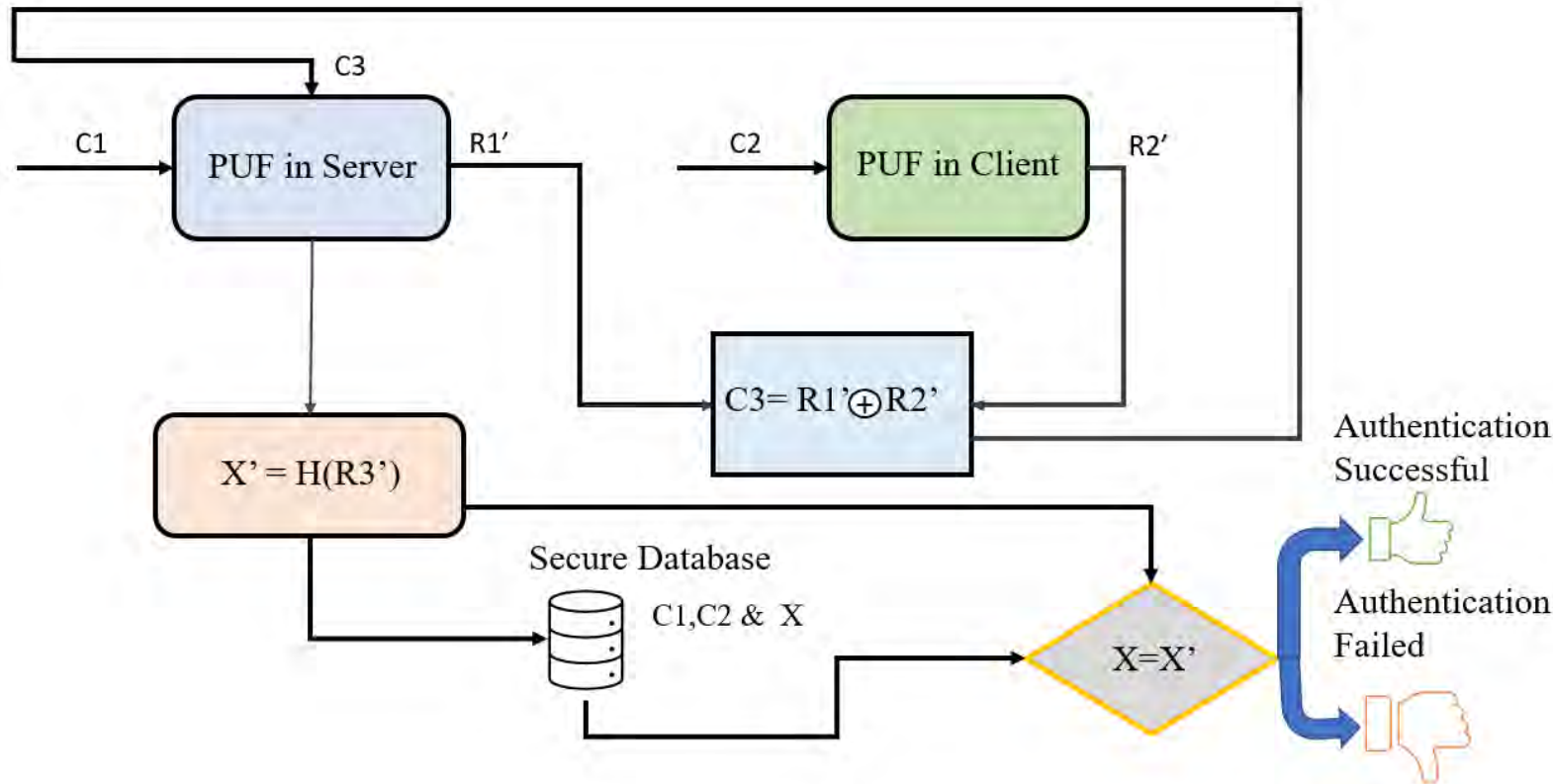
# Enrollment Phase of the Proposed Security Protocol



$C1 \Rightarrow R1$   
 $C2 \Rightarrow R2$   
 $C3 = R1 \text{ XOR } R2$   
 $C3 \Rightarrow R3$   
 $X = H(R3)$   
 $X, C1, C2$  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

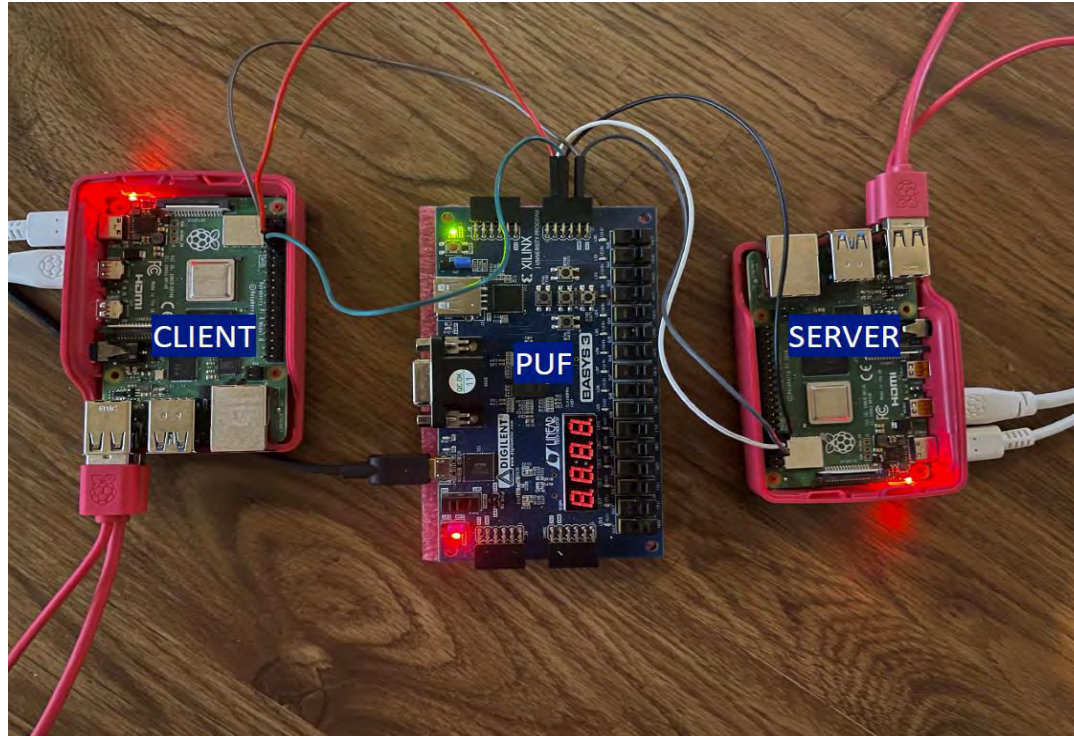


Only C1 and C2 are retrieved and given as inputs to the PUF module. The final Hash value X is compared with the stored hash value X to authenticate the device

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.



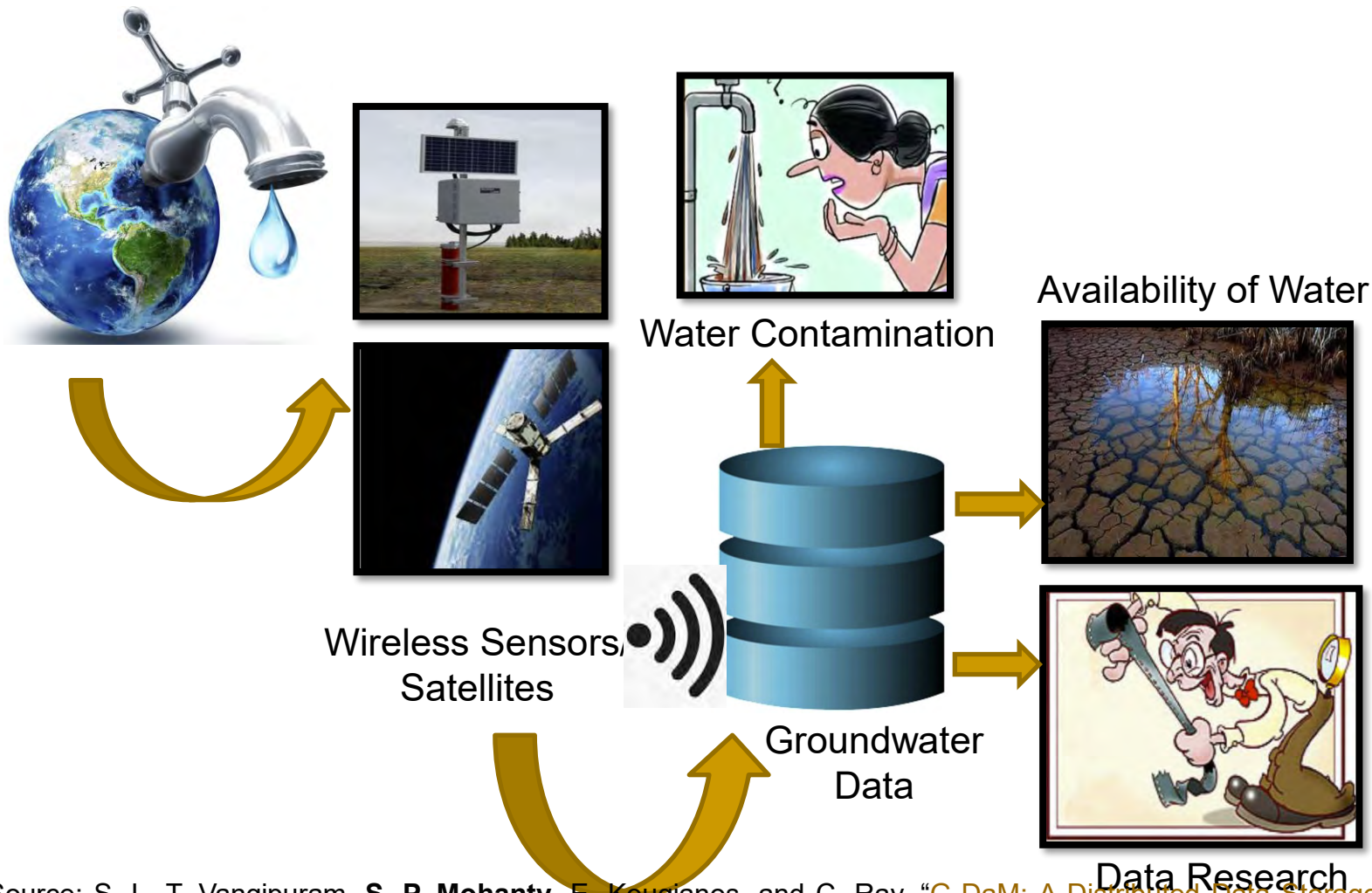
# Prototype of the Proposed Security Scheme



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.

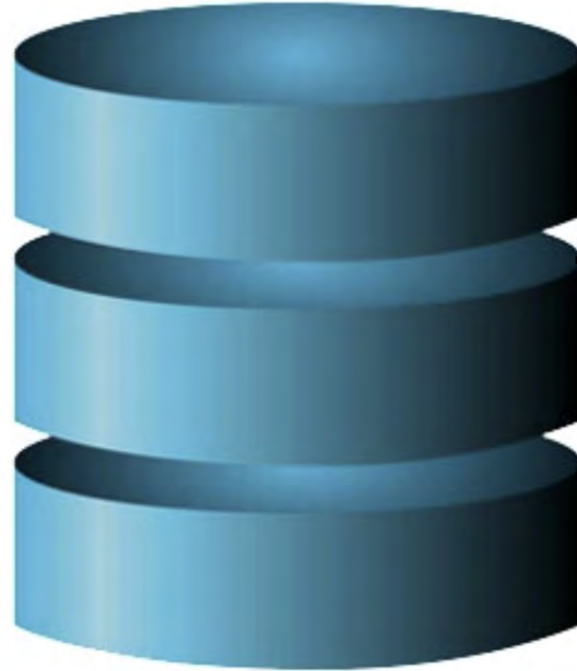
# Our G-DaM: Introduction-Ground Water Data



- ❑ 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. Kouglanos, 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>.



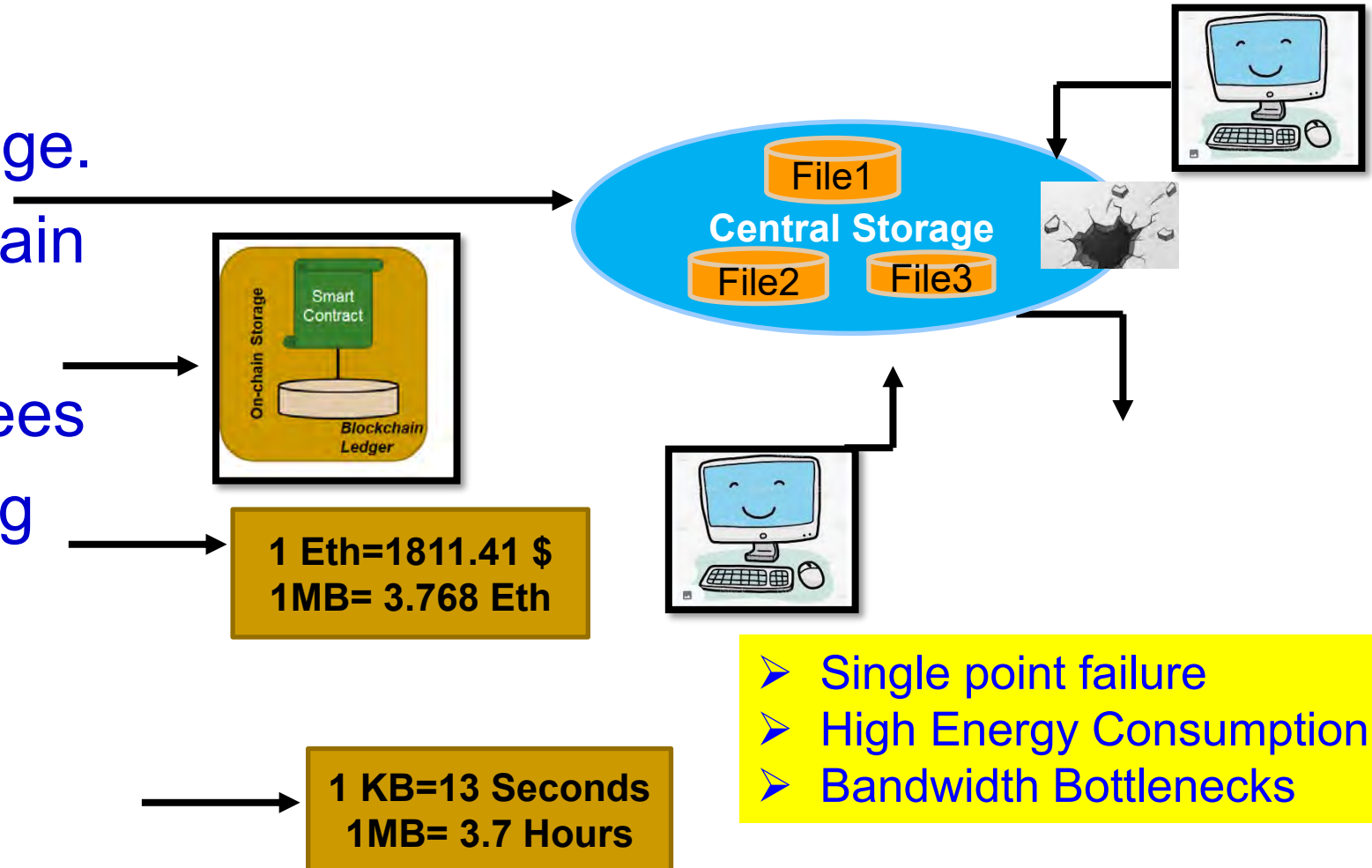
# Our G-DaM: Related Research

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
<b>G-DaM [Current-Paper]</b>	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>.

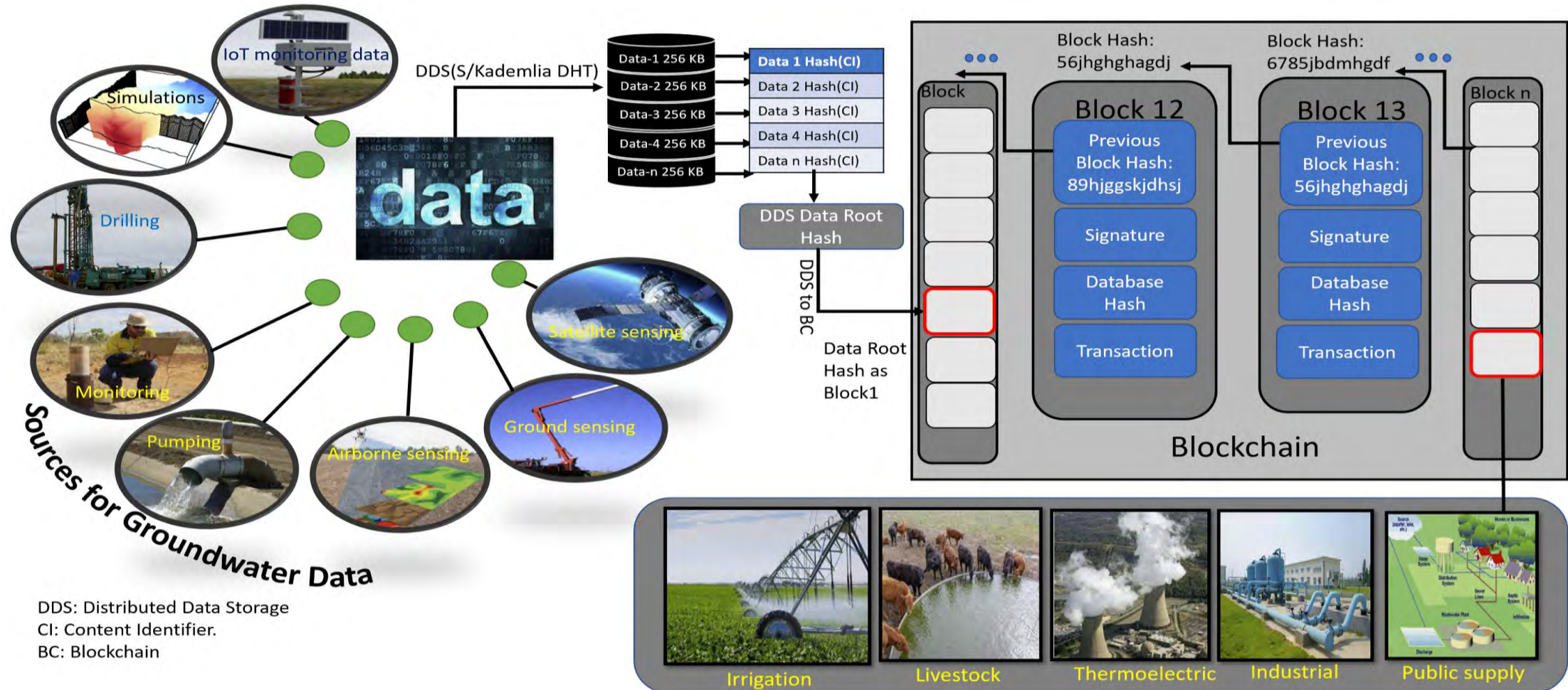
# Issues in Existing works

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



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

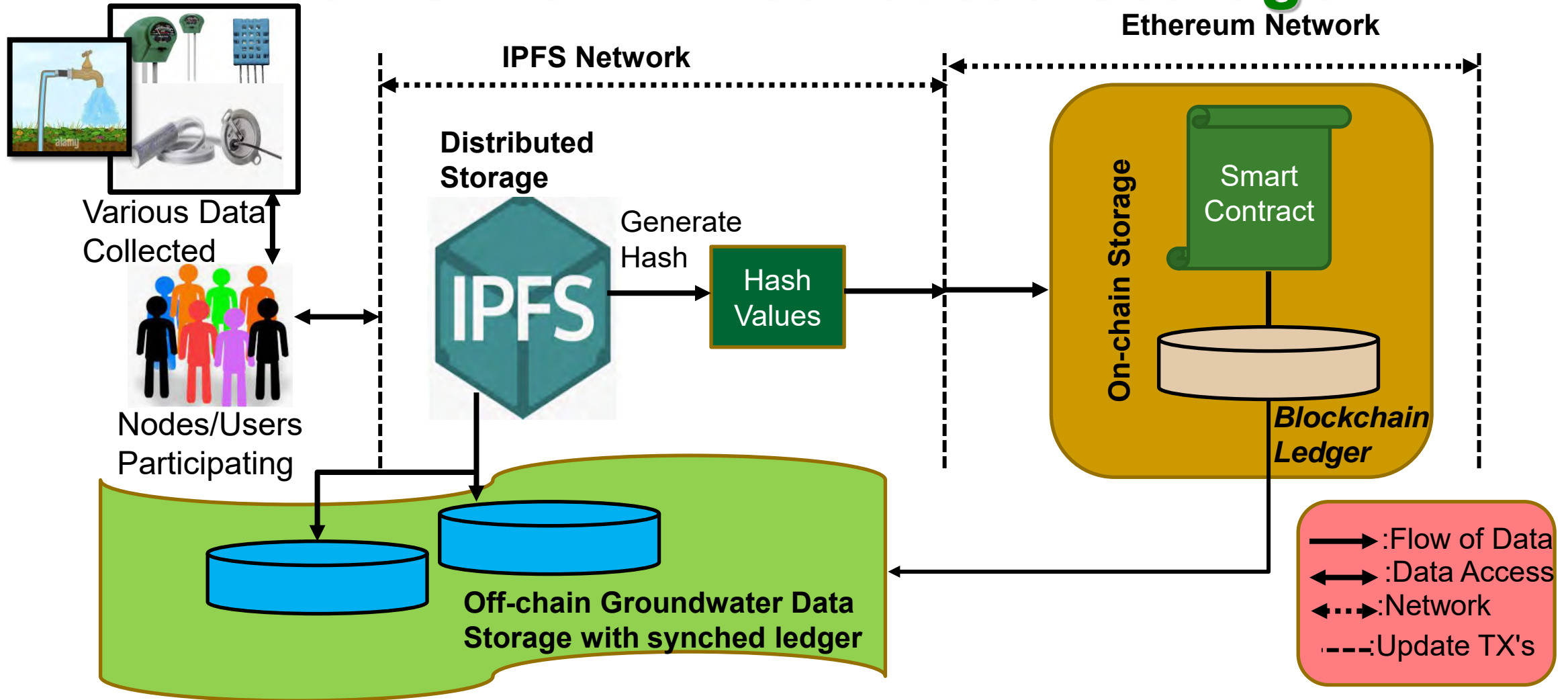


DDS: Distributed Data Storage  
CI: Content Identifier.  
BC: Blockchain

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>.



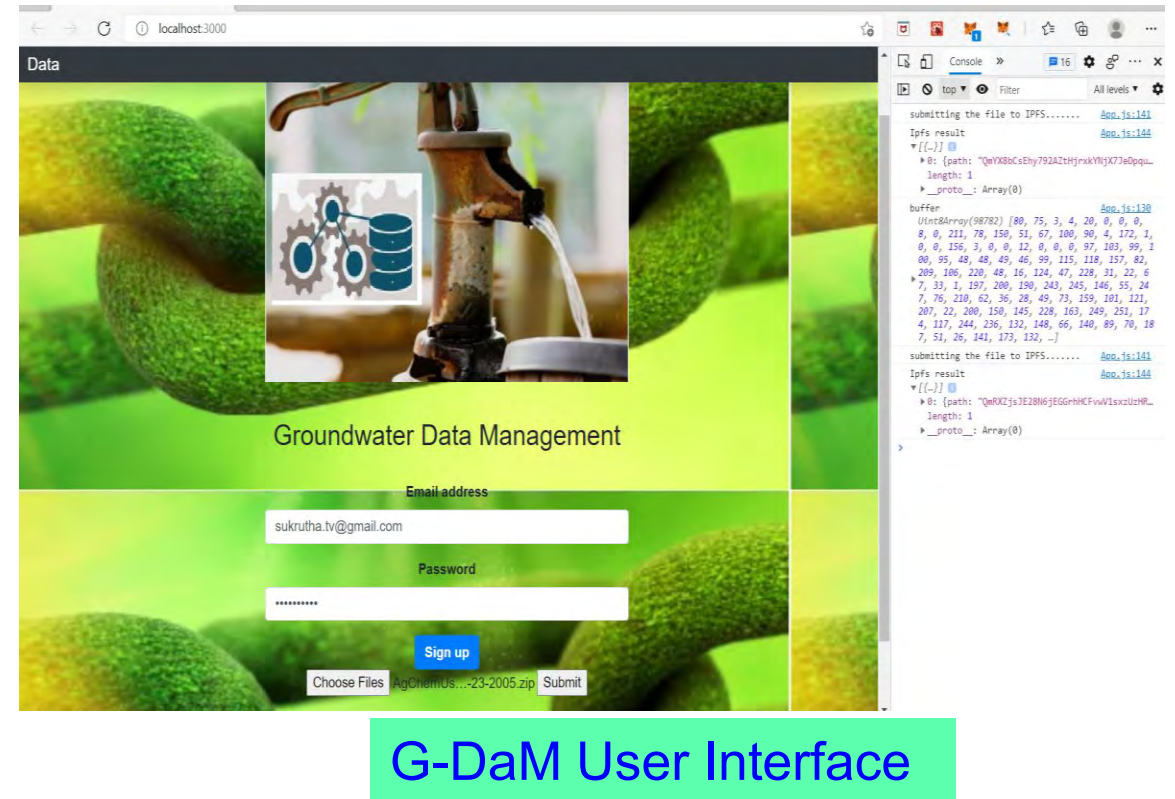
# Our G-DaM: Distributed Storage



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>.

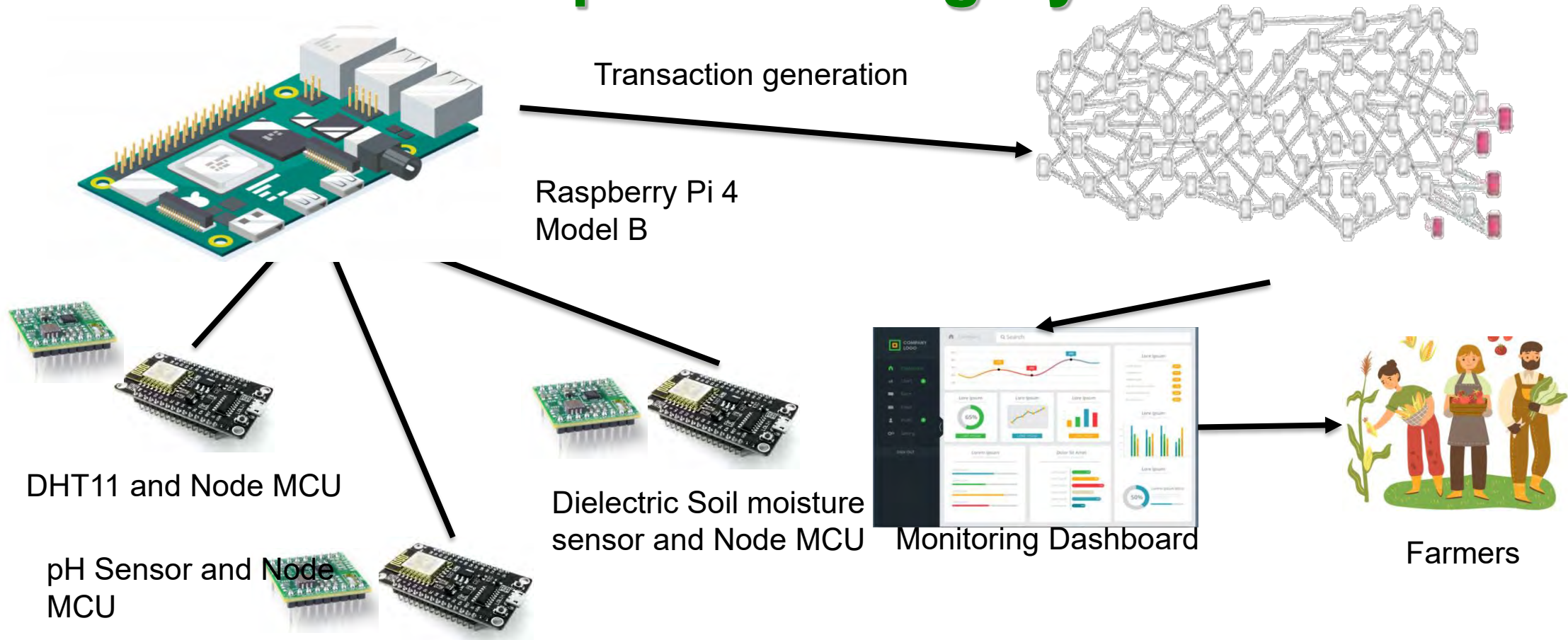
# Our G-DaM: Functional Verification

- 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.



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](https://doi.org/10.3390/s22228725)", *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



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](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

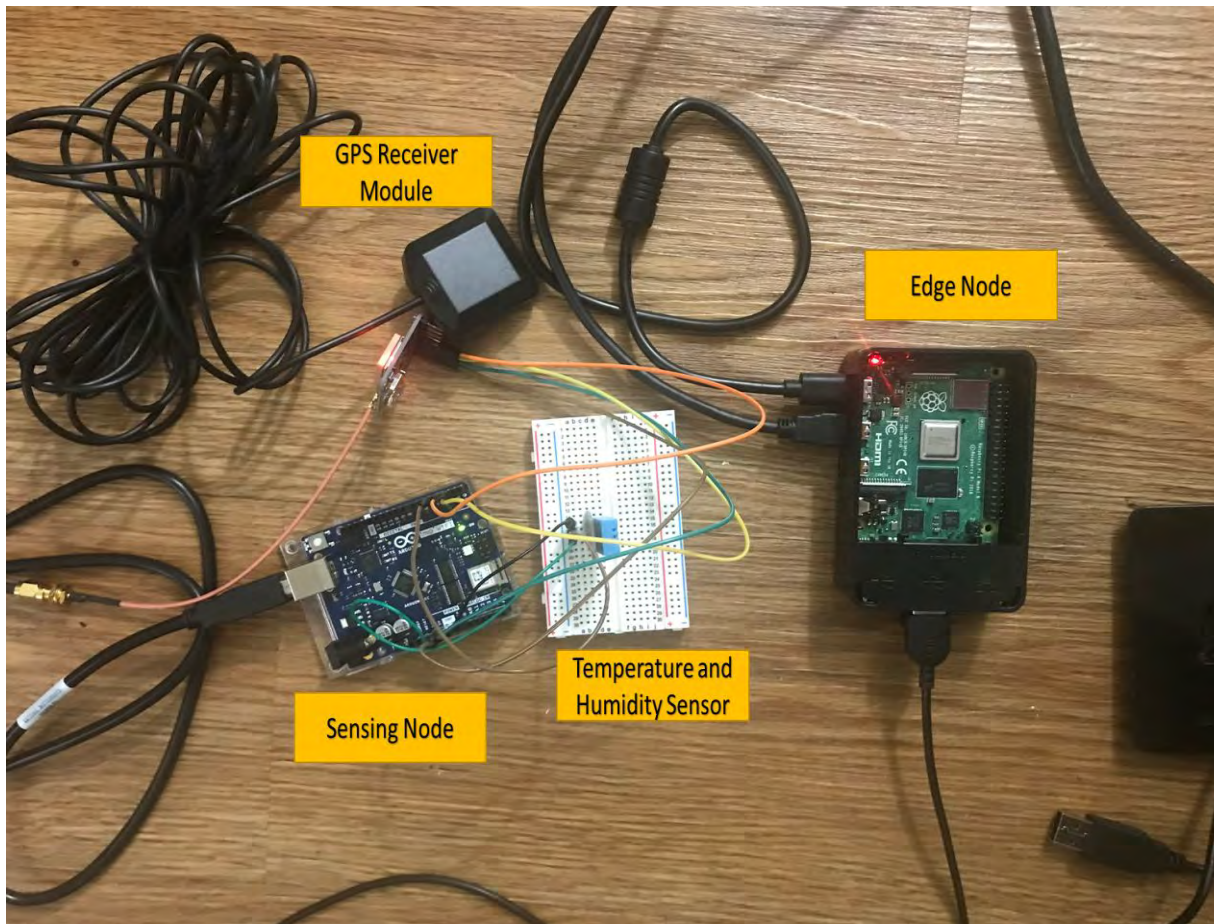
- Tangle is a data structure behind the IOTA which is a Directed Acyclic Graph (DAG).
- Directed Acyclic Graphs (DAG) are the data structures which grow in one direction and doesn't have cyclic structures within.
- Tangle is maintained and updated at all the nodes in the network.
- Any new transaction 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](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](https://doi.org/10.1007/978-3-030-96466-5_2)", 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](https://doi.org/10.1007/978-3-030-96466-5_2)



---

# Food Safety and Quality

# LinkedIn Video That Got My Attention



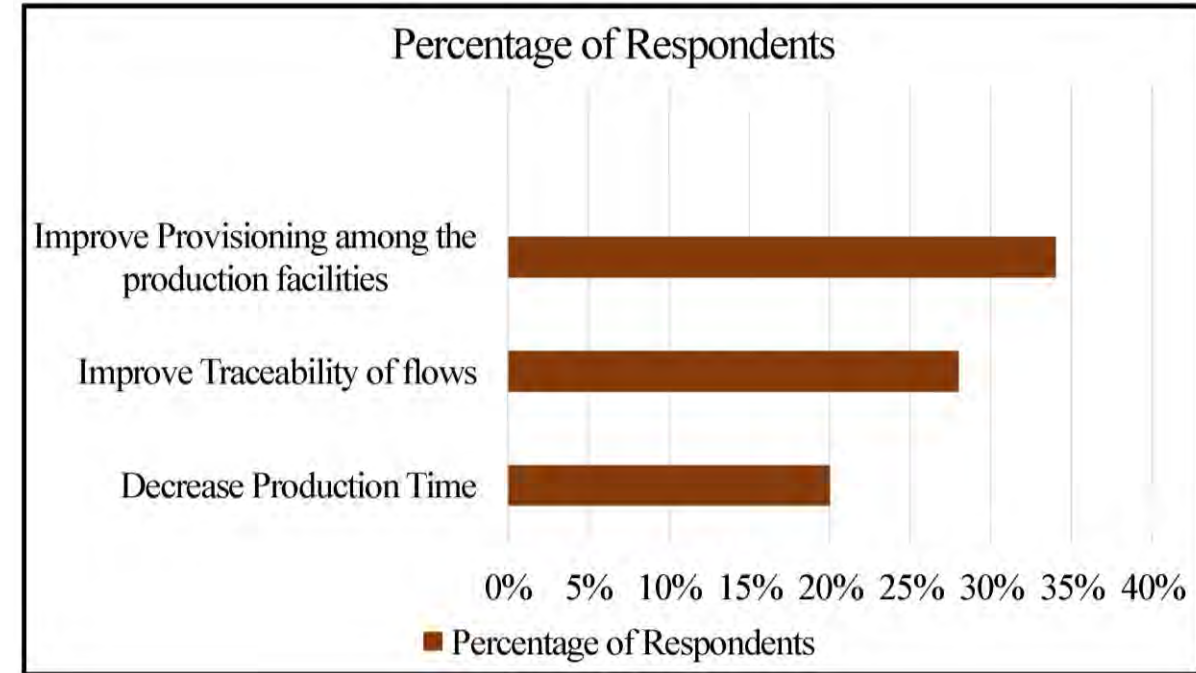
[https://www.linkedin.com/posts/omar-al-bardan\\_nutraceuticals-nutraceutical-nutrition-activity-6999846535878348800-WvJn?utm\\_source=li\\_share&utm\\_content=feedcontent&utm\\_medium=g\\_dt\\_web&utm\\_campaign=copy](https://www.linkedin.com/posts/omar-al-bardan_nutraceuticals-nutraceutical-nutrition-activity-6999846535878348800-WvJn?utm_source=li_share&utm_content=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

Challenges and Problems in Dispensing  
Food Produce to Consumers

Faults in Production	Crop Diseases	Faults in Processing	Incorrect Standards	Food Quality Concern	Poor Hygiene	Distribution Faults	Rejection at Docks
	Long Storage Times		Incorrect Humidity		Missing Deadlines		Longer Wait Times
	Inclement Weather		Incorrect Freezing		Poor Sanitation		Units Malfunction
	Inadequate Warehouses		Incorrect Drying				
	Incorrect Pest Control	Farmers Expertise	Improper Knowledge of Crops	Technology Concern	Traditional Methods	Retailer Faults	Expired Dates
	Poor Product Rotation		Fragmentation Issues		Missing Unified Policy		Ruined Packaging
	Improper Hygiene		Zero Education in technology		Older equipment		Weathering
							Long Storages



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](https://doi.org/10.3390/s22218227)", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: <https://doi.org/10.3390/s22218227>.



# Food Safety Vs Food Quality

How can we stay vigilant when developing and manufacturing products in this new world ?

iNewtrition  
FOOD SCIENCE SERVICES



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

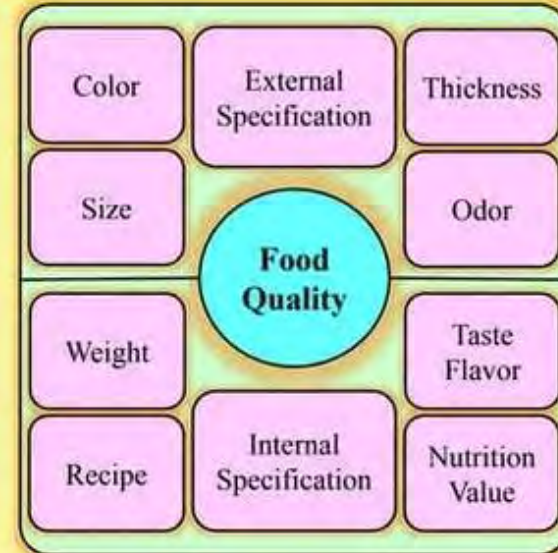
## Food Safety

Food safety is the process of preventing food from the risk that may affect it. It affect directly or indirectly to the consumers.



## Food Quality

Food quality is to achieve all the Food required characteristics that acceptable to consumer.



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>

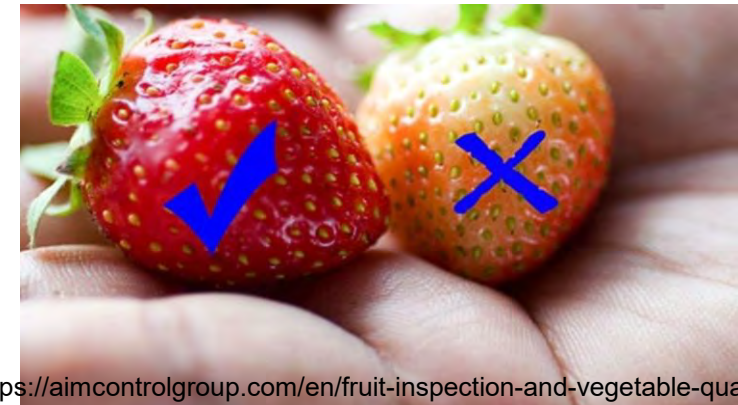


Source: <https://aimcontrolgroup.com/en/fruit-inspection-and-vegetable-quality-control.html>

Am I really eating  
what I think I am eating?



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.



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>



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





# Poultry Safety and Quality?

## Poultry & Eggs

Chickens, turkeys, ducks, geese, and other fowl are considered poultry. Chickens are the most plentiful type of poultry raised for meat and egg production in Kentucky.



Most meat-type chickens, or broilers, enter a temperature controlled house when they are 1 day old.



The chicks are provided a diet of corn and soybeans and plenty of water until they are grown. Kentucky poultry eat between 25 and 35% of locally-grown corn and soybeans!

Chickens are able to convert their feed to high-quality protein that provides us essential amino acids, B vitamins and minerals, such as iron and zinc.



*Broiler or Layer?*

While all chickens can be raised for meat, and all female chickens (hens) lay eggs, certain breeds of chickens are better suited for each purpose.

### Broilers:

- Grow quickly and will reach their full size in less than 8 weeks - between 3 and 7 pounds depending on their use.
- Are not raised in cages, but are allowed to roam temperature-controlled houses, yards, or on pastures.
- Are never given hormones or steroids.

### Layers:

- Hens will begin to lay eggs when they are 18 to 26 weeks old.
- May be kept in cages for ease of feeding and collecting eggs, or they may be kept in open houses, yards, or on pastures with laying boxes near by.
- Commercial laying hens are typically used for meat after they have reached 2 years of age or when egg production begins to decline.
- Are never given hormones or steroids.



### Egg Nutrition Facts

For only 70 calories each, eggs are rich in nutrients. They contain, in varying amounts, almost every essential vitamin and mineral needed by humans as well as several other beneficial food components. Egg protein is the standard by which other protein sources are measured. A large egg contains over six grams of protein.

The average laying hen lays 286 eggs per year.



Commercial egg production is quite automated and works to improve food safety and sanitation. Houses also protect birds from predators and many diseases.



Turkeys are raised similarly to broilers, but they will grow for 3 to 6 months and weigh 15 to 30 pounds.

In the past many households kept chickens for eggs and an occasional dinner. The modern chicken industry, however, produces nutritious, wholesome, high quality products that become more affordable year after year.

**\$** Eggs are the most economical high-quality protein available. Chicken meat is third, behind cow's milk.



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>

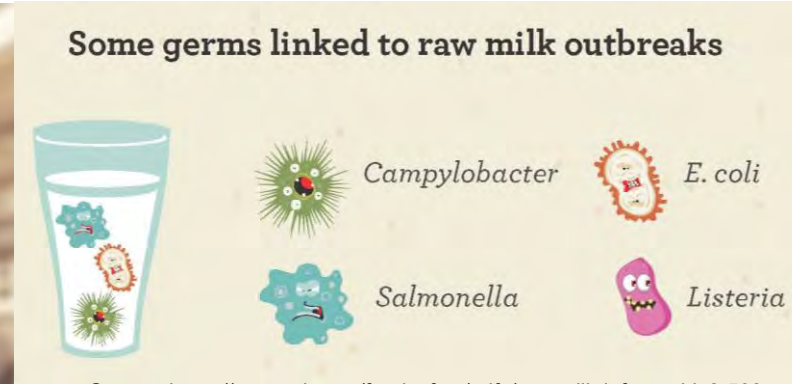
World average consumption per person per year: 161 eggs (2018 data)

Is this Chicken Meat safe to eat?

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



# Milk Safety and Quality?



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

How Safe is the Milk that I am Drinking?



Spoilage in the supply chain



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

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

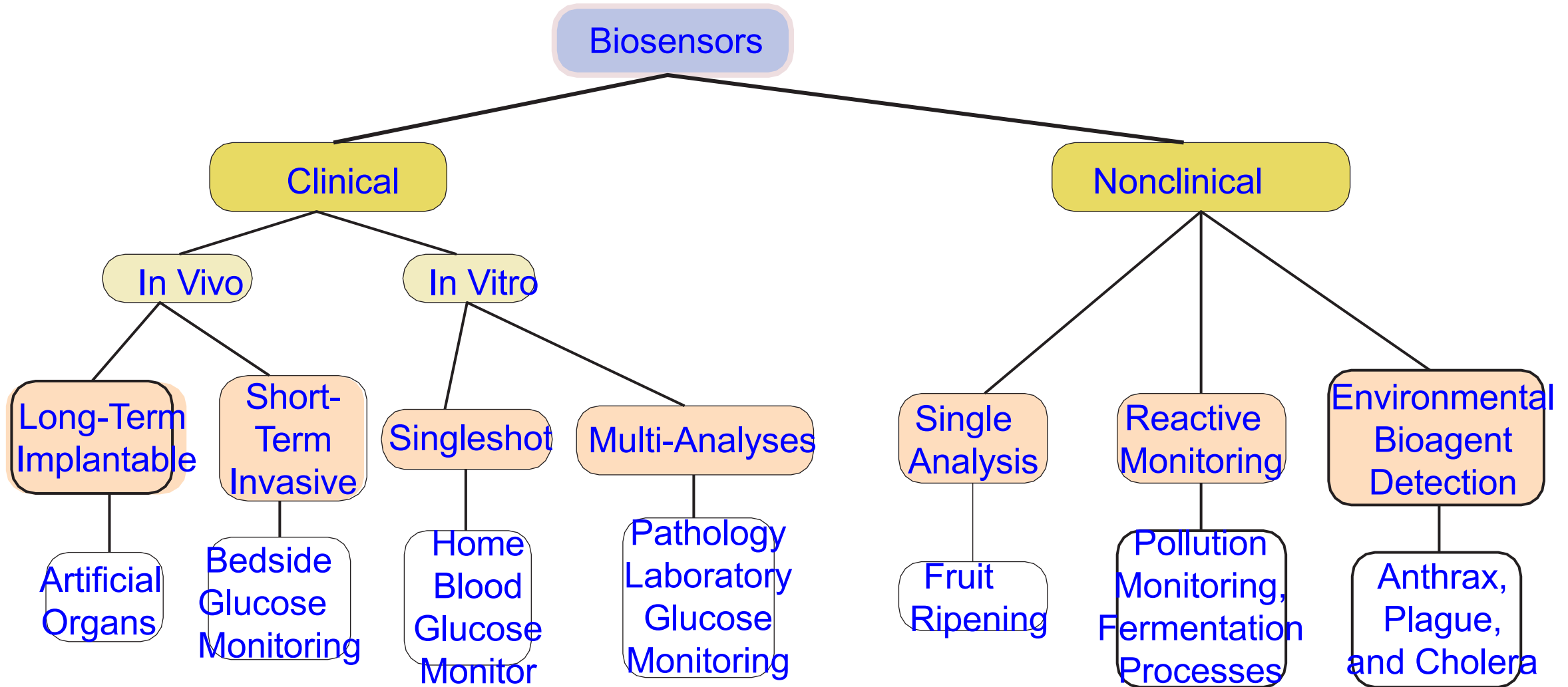
# Stages in Agricultural Product Distribution



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](https://doi.org/10.3390/s22218227)", *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

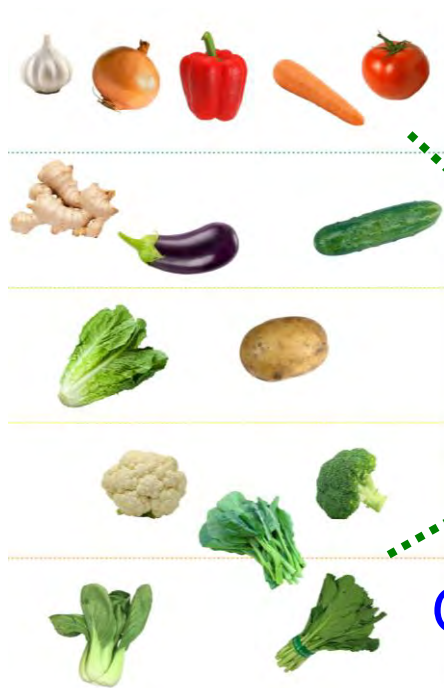
- Changes in:
  - ❑ Climate-smart farming
  - ❑ Eco-friendly farming
- Improved:
  - ❑ Larger growth
  - ❑ Economic stability of farmers

# Food Labelling

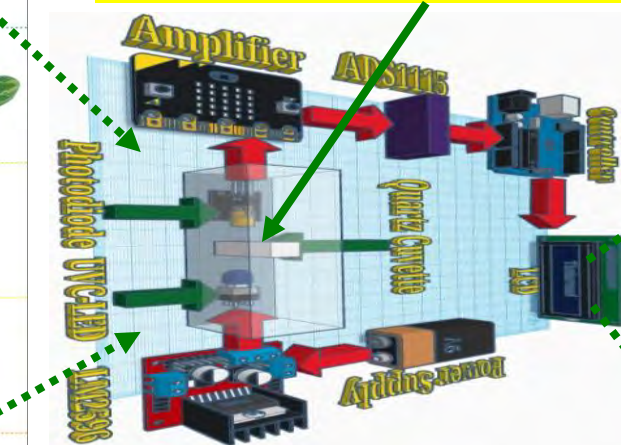
- Changes in:
  - ❑ Bar code usage
  - ❑ 2D visual tags
  - ❑ Efficient warehouse management
  - ❑ Tag base identification technologies
- Improved:
  - ❑ Well organized fields
  - ❑ Time saving



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



Quartz cuvettes of length 10mm for sample solution.

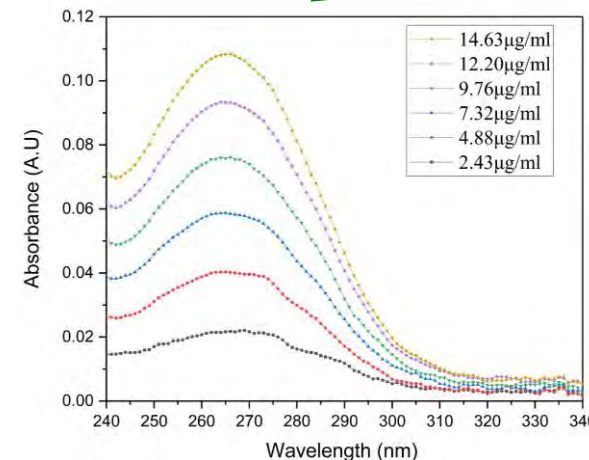


Our Food-Care Device

Contamination Level

- Acceptable
- Moderate
- Severe
- Dangerous

Peak absorbance spectrum of 265nm at different nitrate concentrations.



Need for Device which is:

- ✓ Portable
- ✓ Works with dry or wet samples
- ✓ User safe
- ✓ Accurate
- ✓ IoT-Enable

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

Fruit and Vegetables - Nitride Contaminated?

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](https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext)

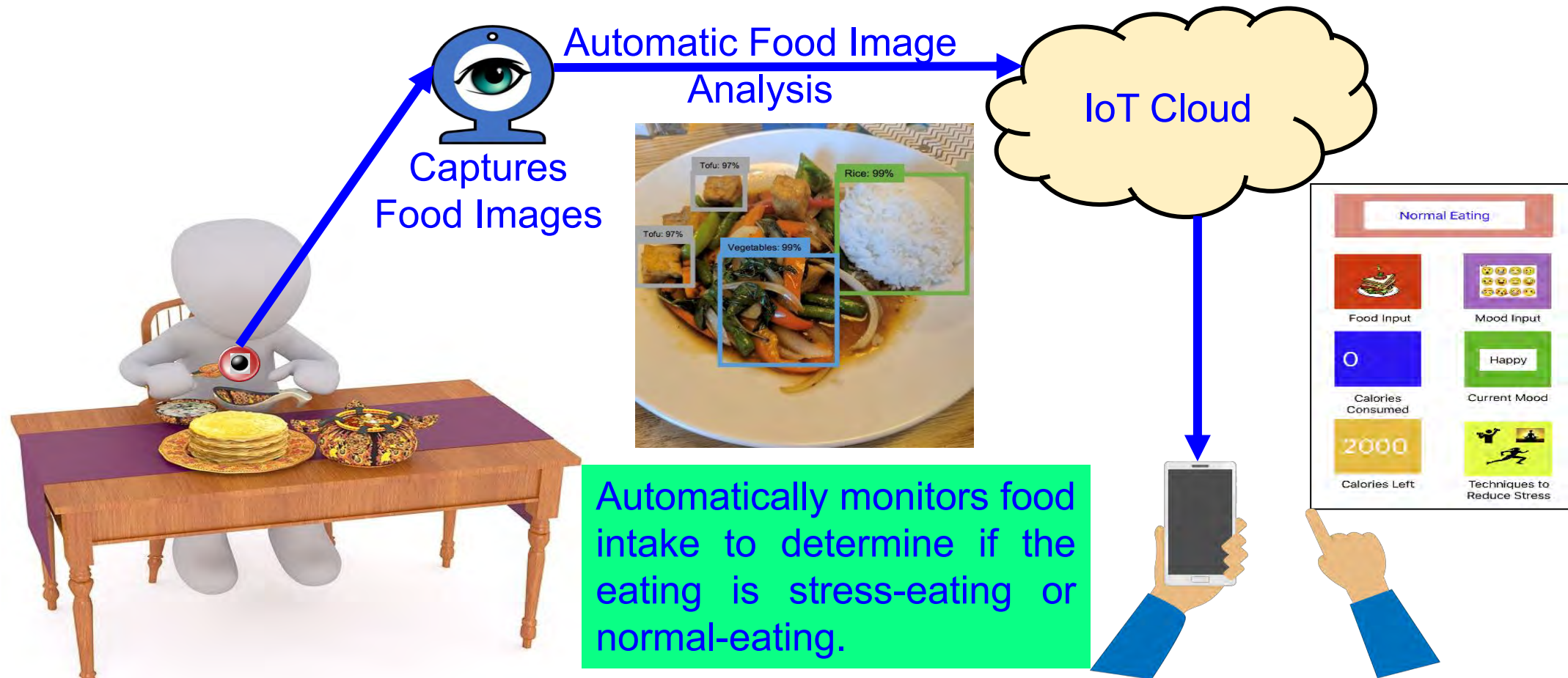
# Imbalance Diet – Impact on Human Body



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.

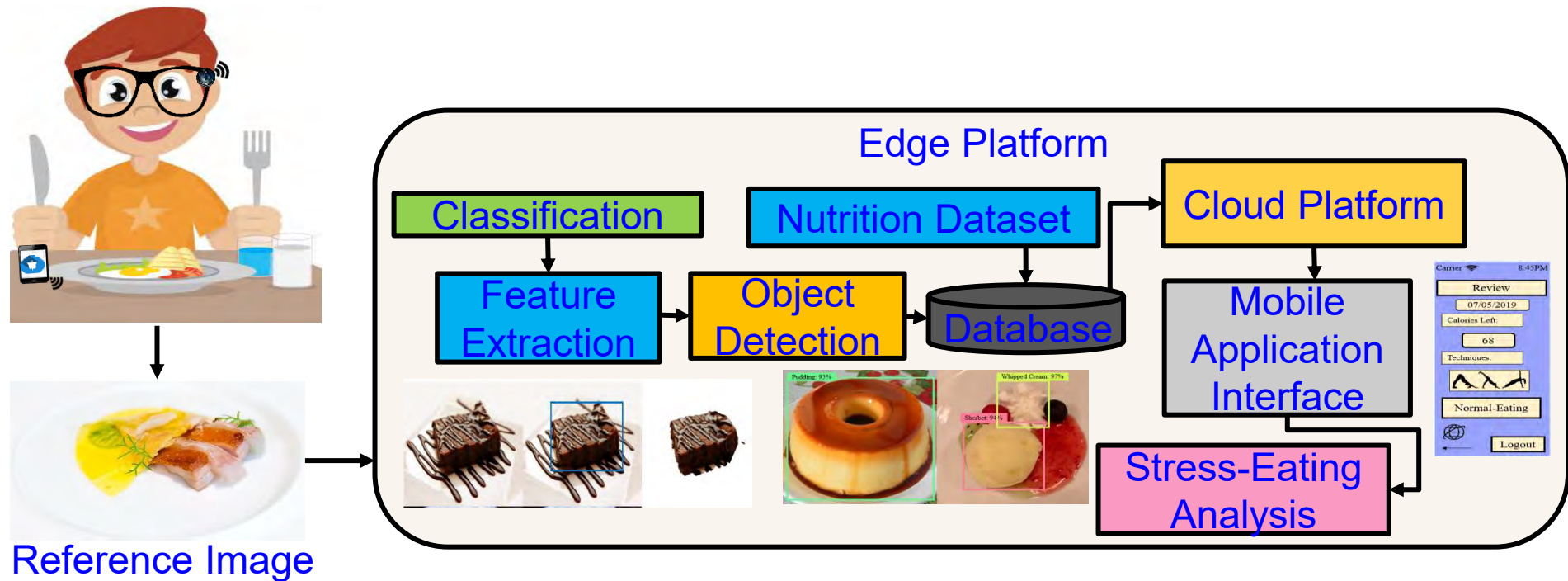


# Automatic Diet Monitoring & Control - Our Vision



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



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.



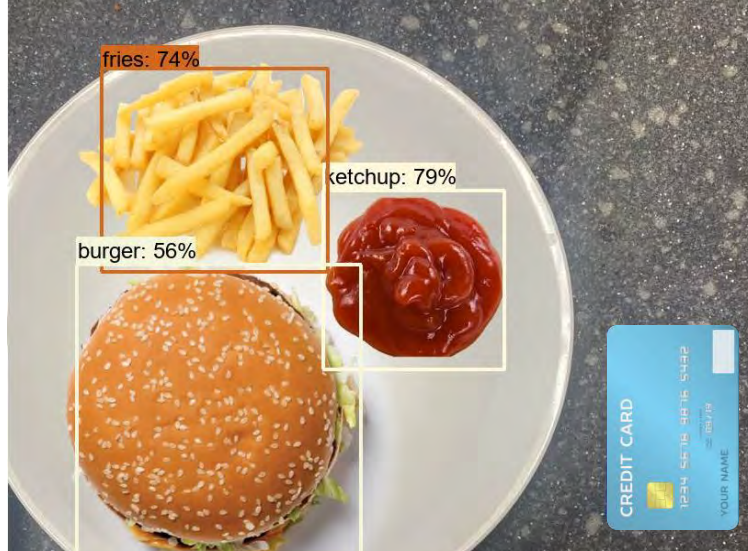
## Smart Healthcare – iLog

The figure displays five sequential screenshots of a mobile application interface, illustrating the user flow for logging in, entering meal and mood data, and viewing food and mood input details.

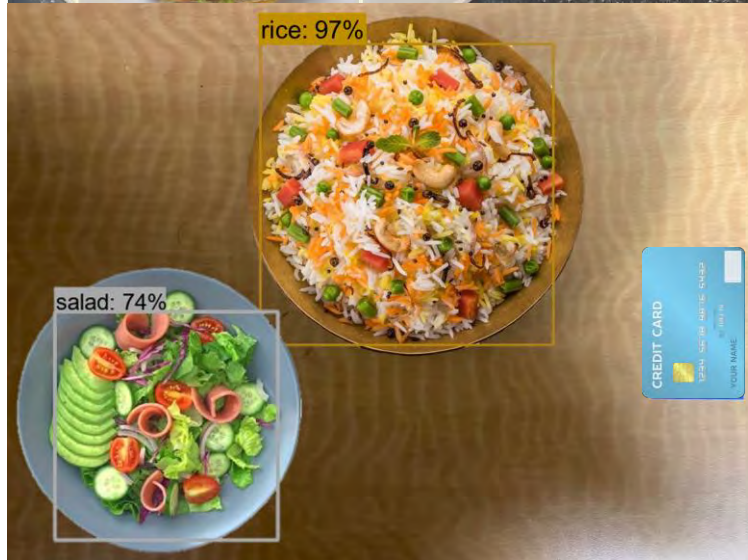
- Screen 1 (Login):** Shows a login screen with a large orange box labeled "Neustress".
- Screen 2 (Login Form):** Displays the login form with fields for Username (neustress), Password (\*\*\*\*\*), and Gender (Female/Male). A "Login" button is at the bottom.
- Screen 3 (Meal Entry):** Shows the "Meal Entry" screen with fields for Name of Food (Cereal, Boiled Egg), No of servings (2, 1), Time Consumed (8:00 AM), and a "Submit" button.
- Screen 4 (Mood Entry):** Shows the "Mood Entry" screen with fields for Mood Before Eating (Happy/Normal/Sad) and Mood After Eating (Happy/Normal/Sad). A "Submit" button is at the bottom.
- Screen 5 (Food and Mood Summary):** Shows the "Food Input" and "Mood Input" screens. The "Food Input" screen displays "256" Calories Consumed and "1744" Calories Left. The "Mood Input" screen displays "Normal" Current Mood and "Remedies" (represented by a running figure icon).

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

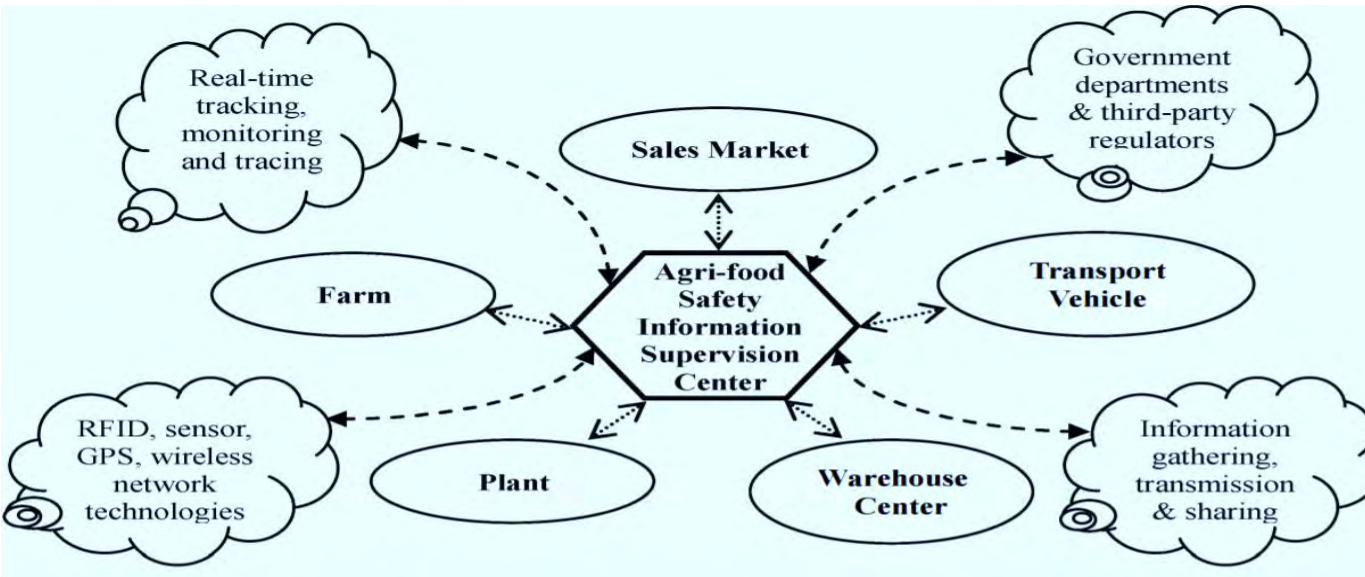
- Scenario involving a transaction between retailer with source of goods making a transaction with customer and a bank involved in lending working capital to retailer.
- Types of entries in this scenario:
  - ❑ Information flow (Order details or payment confirmations)
  - ❑ Inventory flow (Actual goods 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

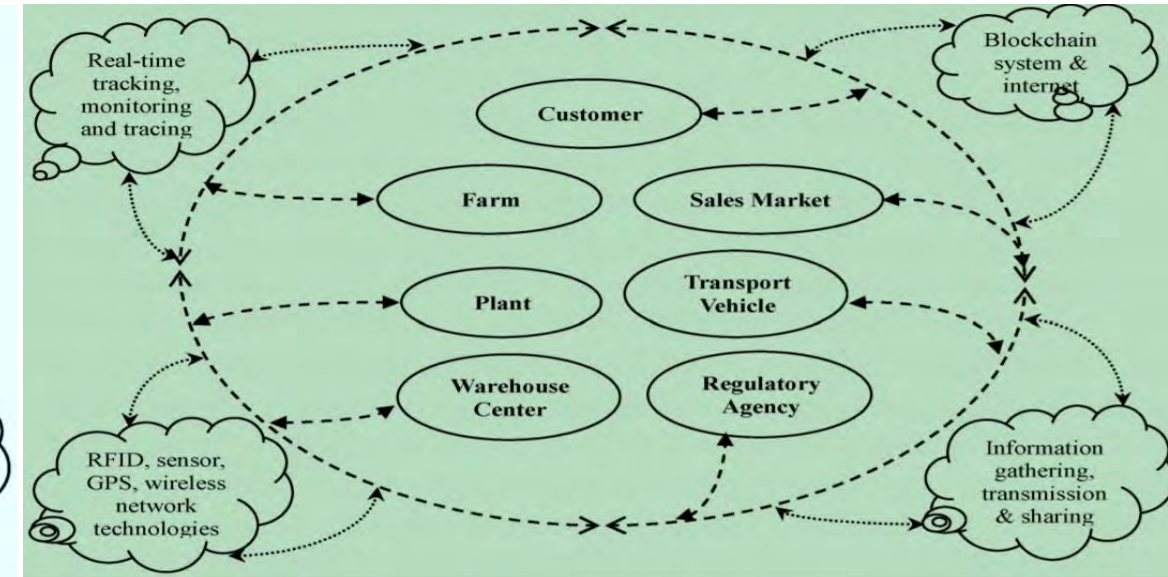
- Adding to this, supply chain activities are too complex to capture.
  - Orders may split into multiple shipments or multiple orders combined to single shipment.
- Using Blockchain enables:
  - Faster delivery of products
  - Cost-efficient delivery
  - Enhances product traceability
  - Improves co-ordination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



# Food Traceability Using Efficient Supply Chain



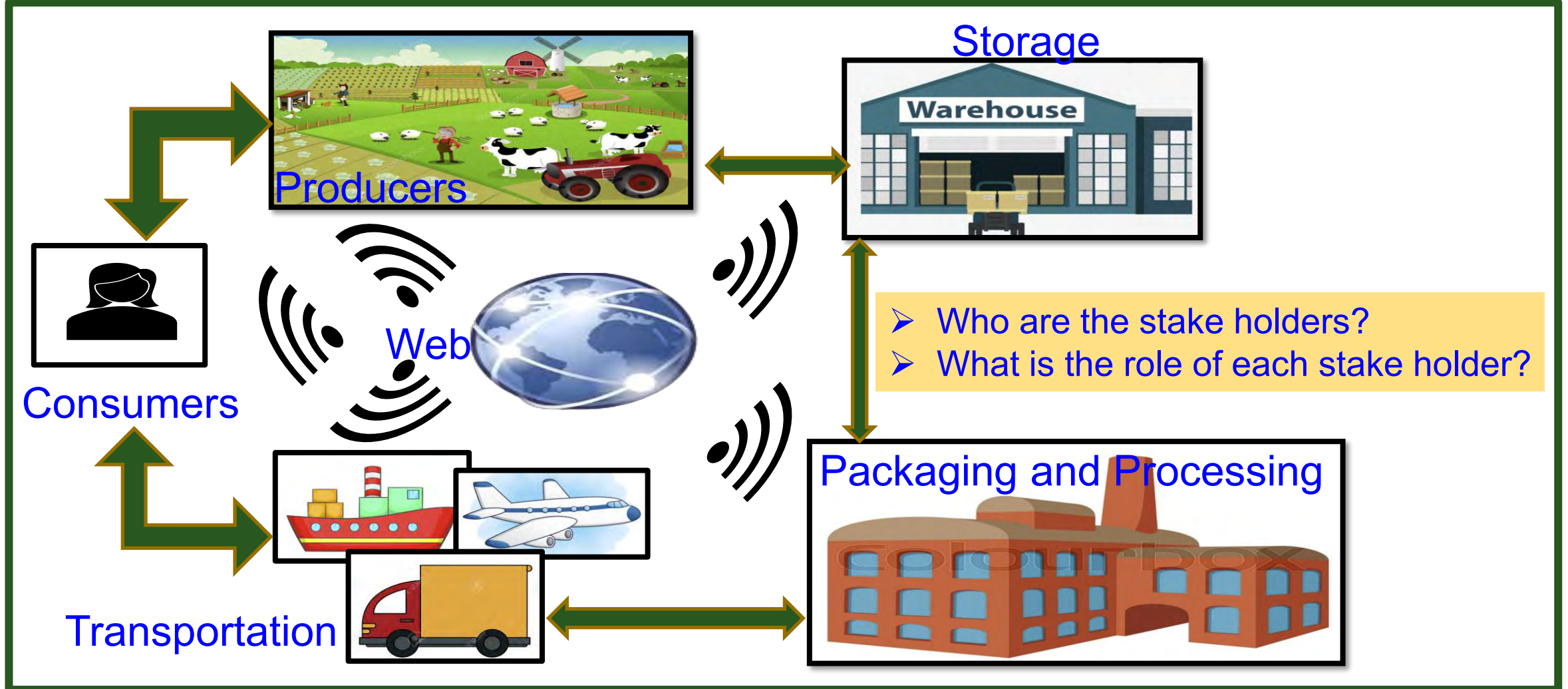
Centralized System



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.

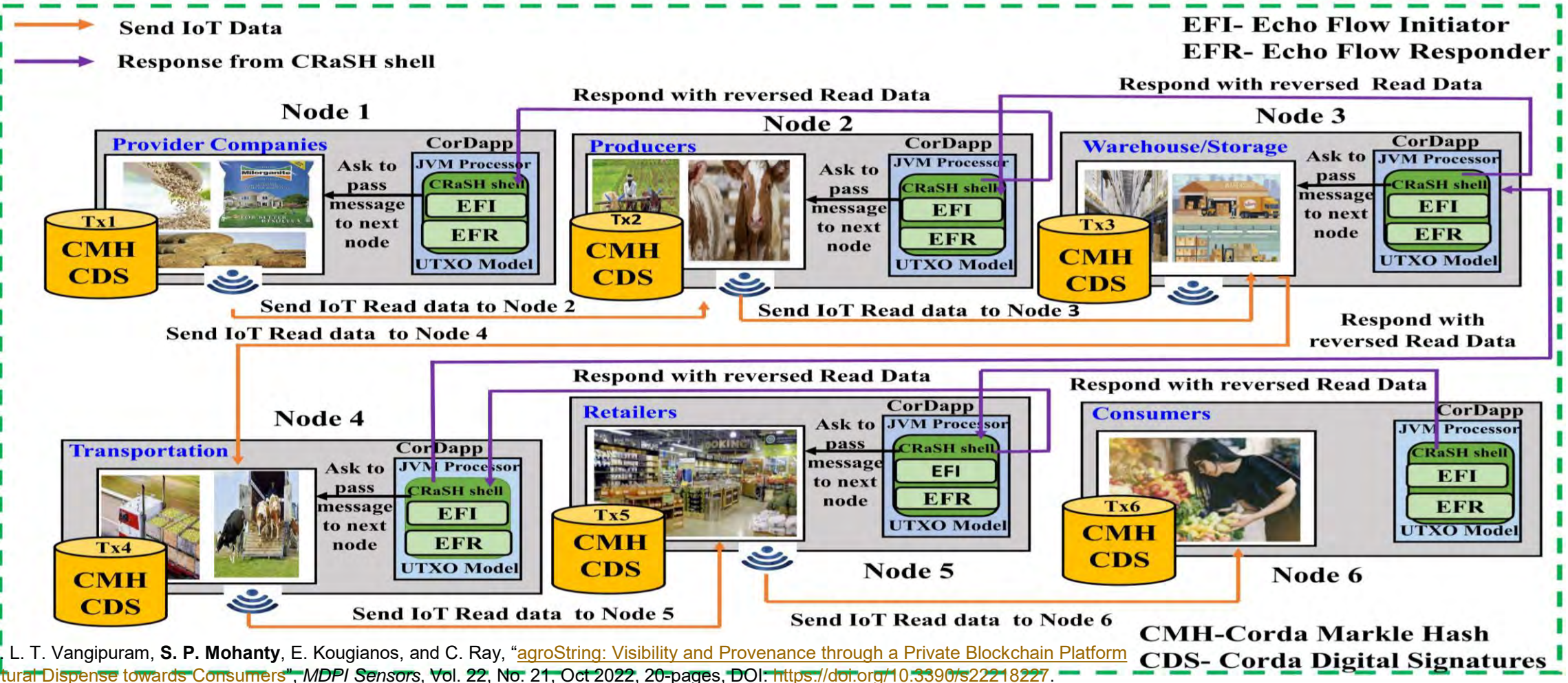
# Agriculture Supply Chain



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.

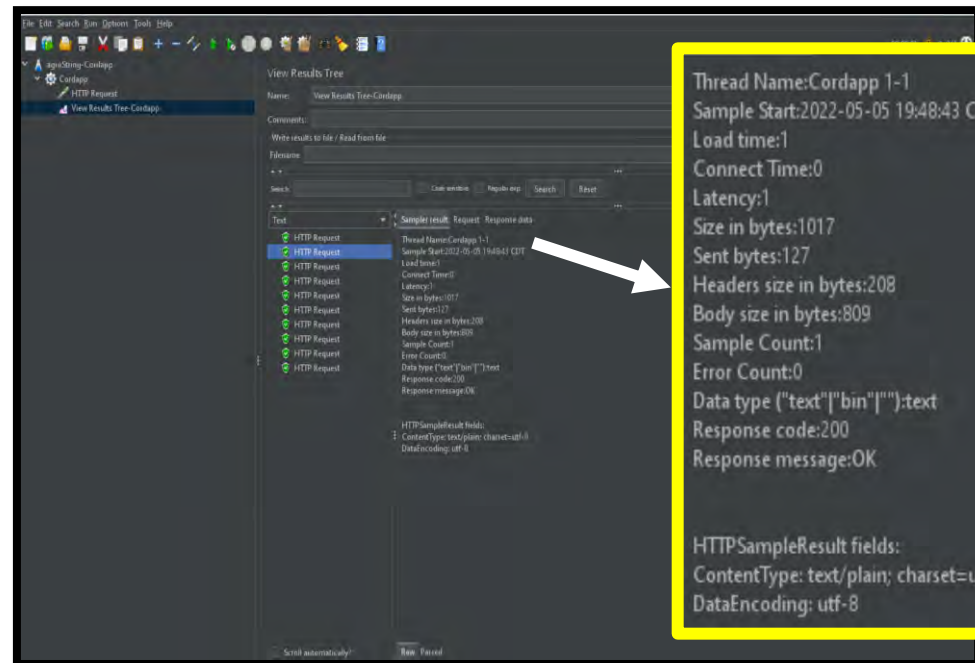


# Our agroString: Visibility and Provenance in Agriculture through a Private Blockchain

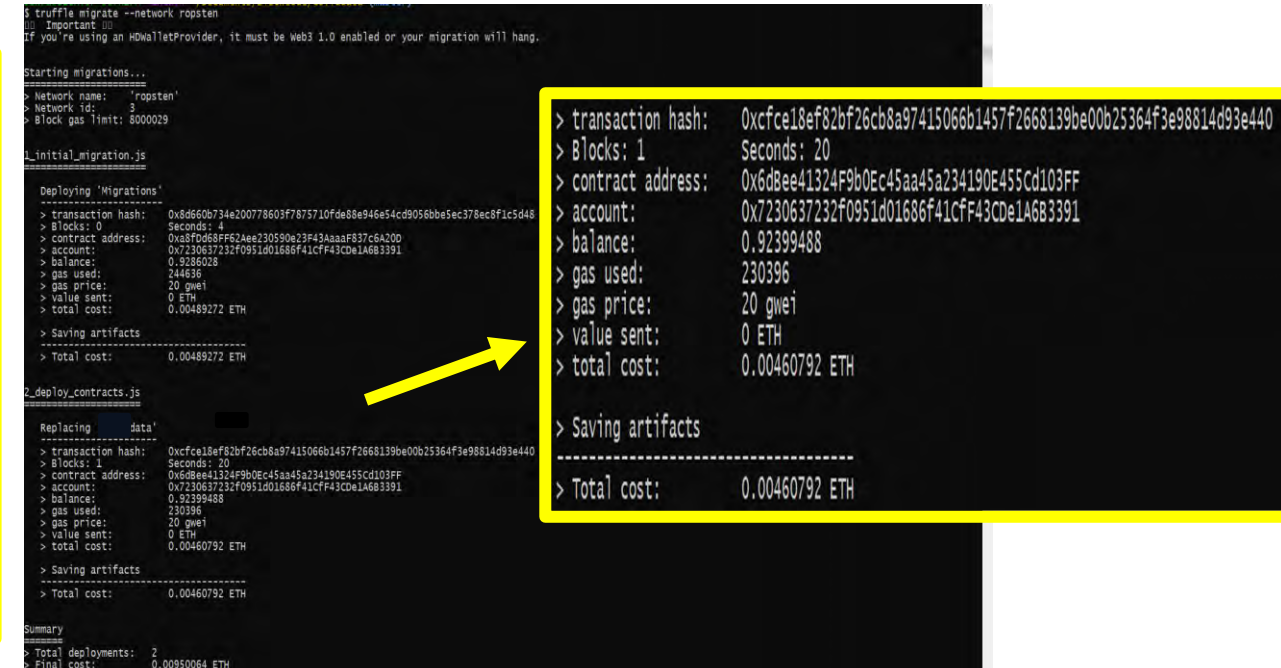




# Our agroString: Visibility and Provenance in Agriculture through a Private Blockchain



Test for Private Blockchain



Test for Public Blockchain

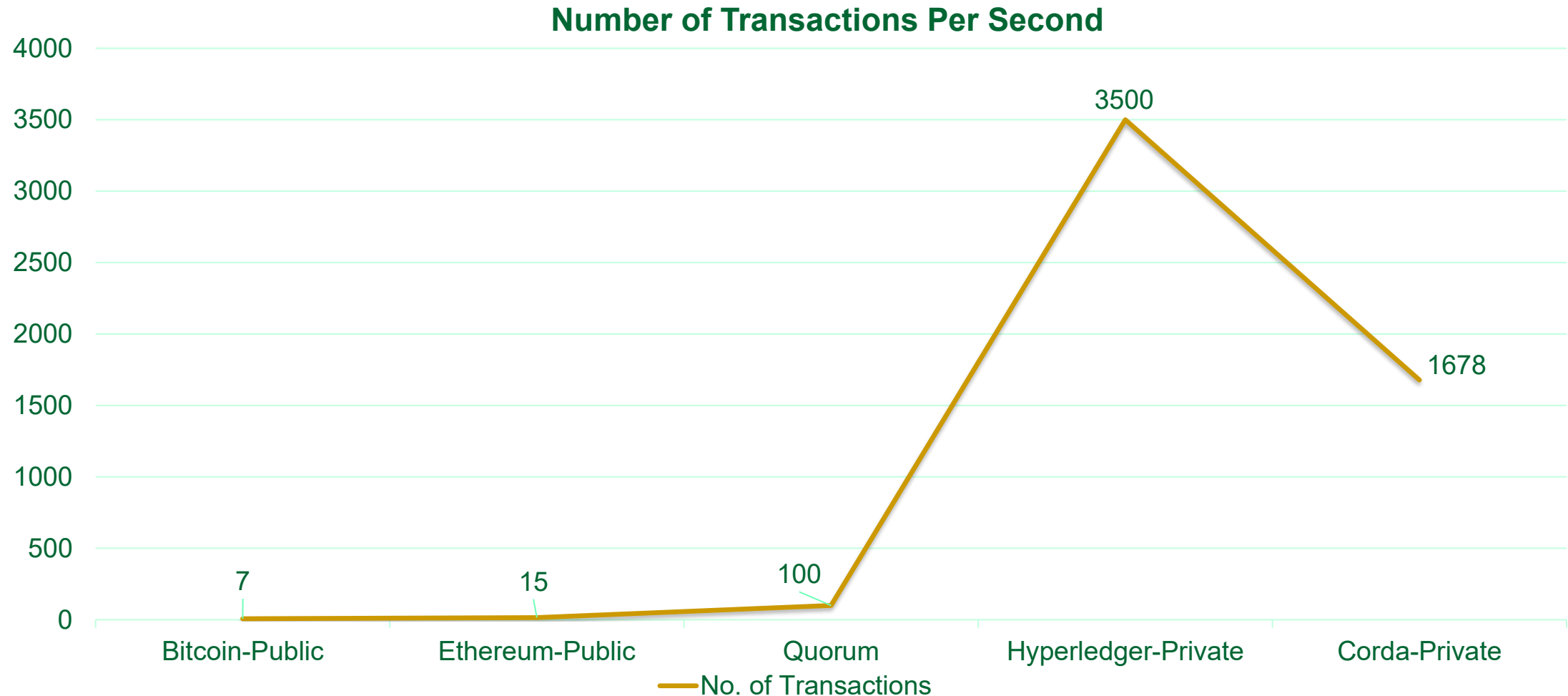
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "[agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers](https://doi.org/10.3390/s22218227)", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: <https://doi.org/10.3390/s22218227>.

# 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
<b>agroString [Current-Paper]</b>	<b>Corda</b>	<b>1ms</b>	<b>Not Used</b>	<b>No Cost</b>	<b>Yes</b>
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](https://doi.org/10.3390/s22218227)”, *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](https://doi.org/10.3390/s22218227)”, *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

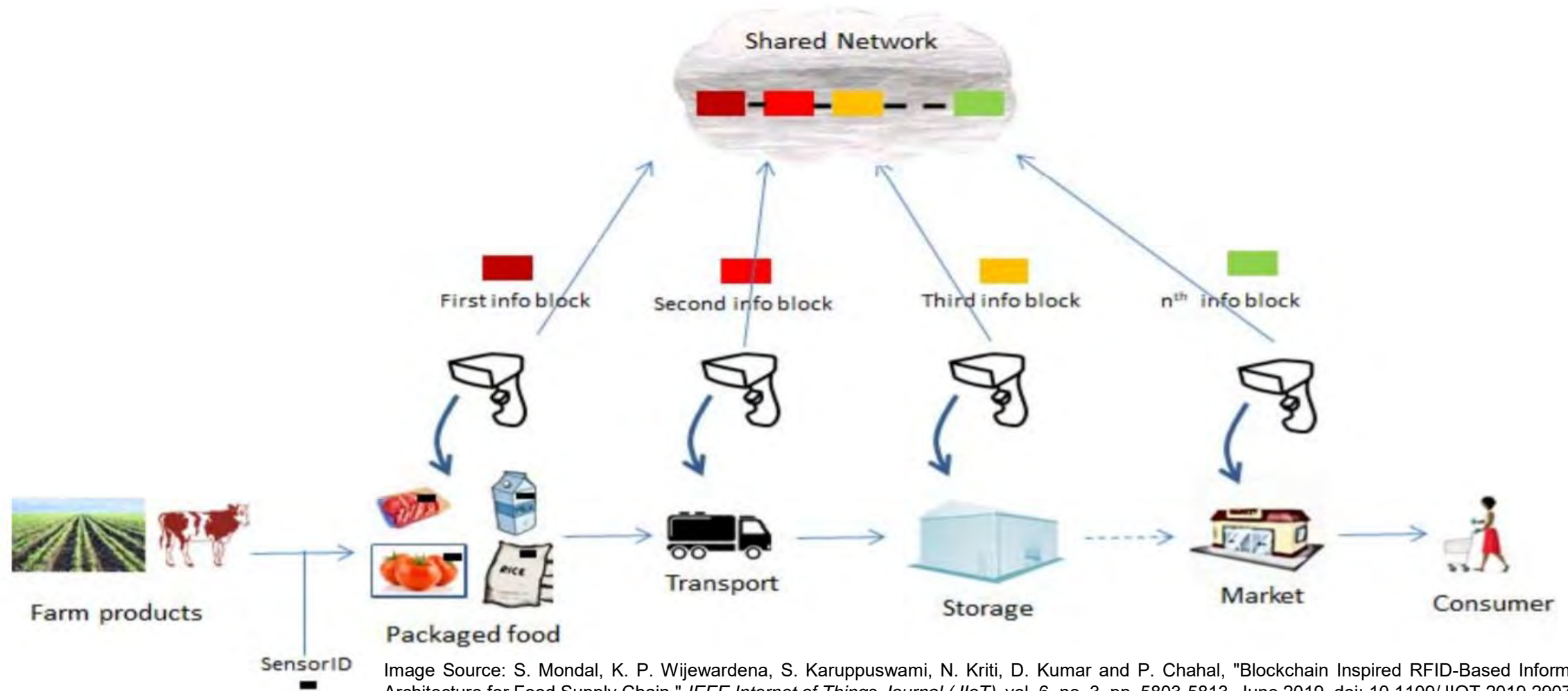


Image Source: S. Mondal, K. P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar and P. Chahal, "Blockchain Inspired RFID-Based Information Architecture for Food Supply Chain," *IEEE Internet of Things Journal (JIoT)*, vol. 6, no. 3, pp. 5803-5813, June 2019, doi: 10.1109/JIoT.2019.2907658.



# Blockchain Inspired RFID-Based Information Architecture

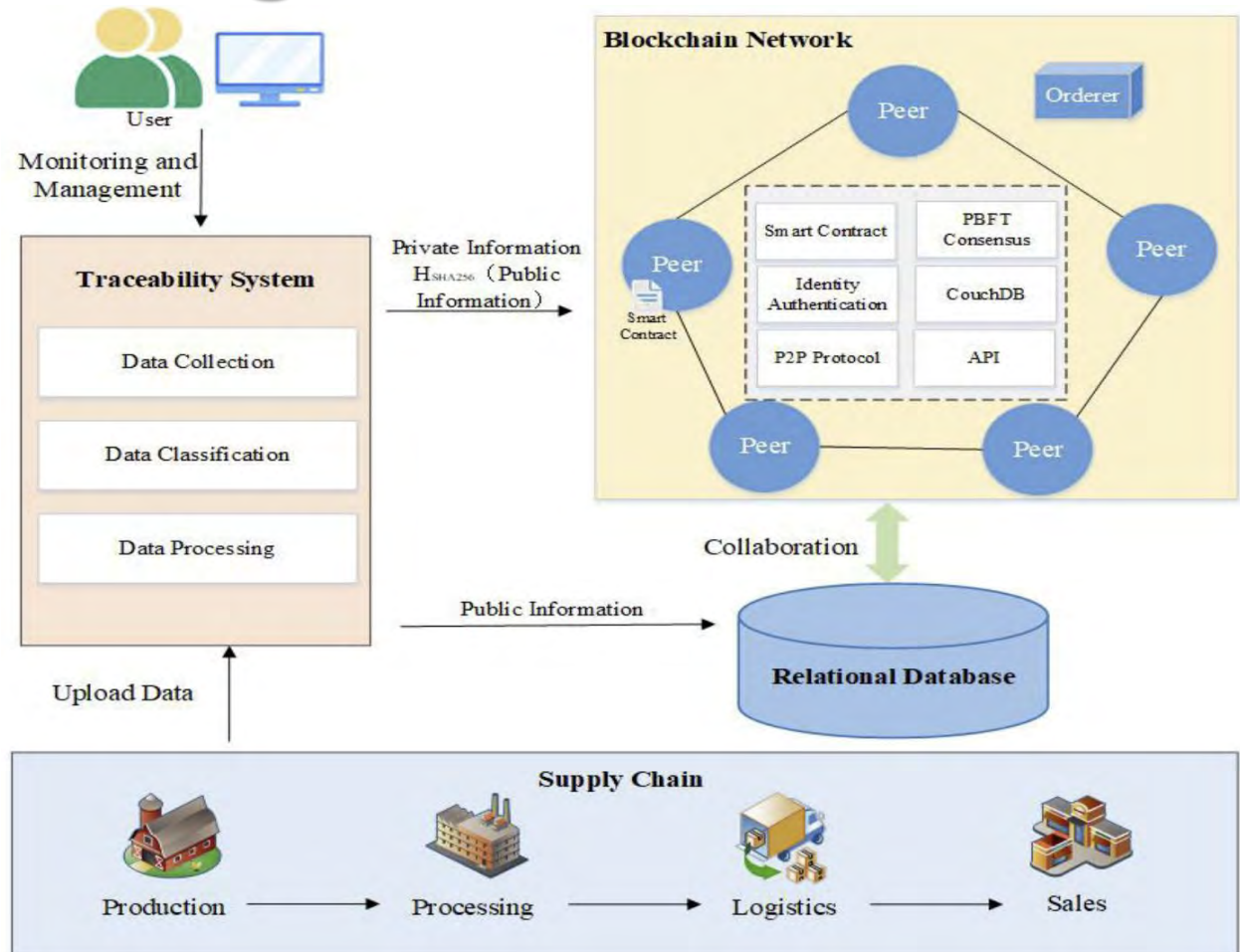
- Proof-of-Object (PoO):
  - ❑ PoW in conventional Blockchains is resource thirsty.
  - ❑ Possession of the object is proven using cryptographically to make transaction valid to be added to block.
- Dual Addressing:
  - ❑ Cyber Addressing – A public address in the blockchain memory
  - ❑ RFID Addressing – 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	<pre>{   "Type": "Info",   "ID": "36",   "PrivateData": "e515789cae824dad1699f74687a87bf158c eb04b89fdc8b01f7609d6c49ca66adbcf8a4b9bd2c34aea6 4c3",   "InfoHash": "429ab56c73040aaf65247e44279d073abb131 10654aa99798d5835931065b98e" }</pre>



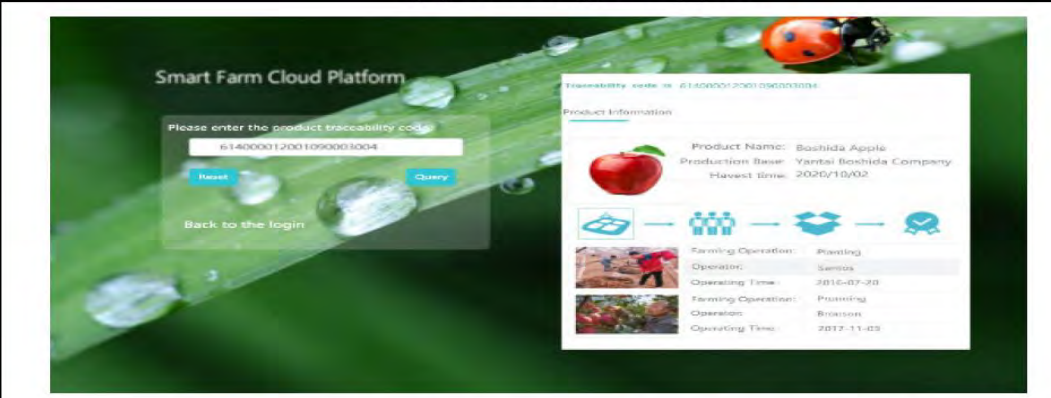
Source: X. Yang, M. Li, H. Yu, M. Wang, D. Xu and C. Sun, "A Trusted Blockchain-Based Traceability System for Fruit and Vegetable Agricultural Products," *IEEE Access*, vol. 9, 2021, pp. 36282-36293.

# 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.



---

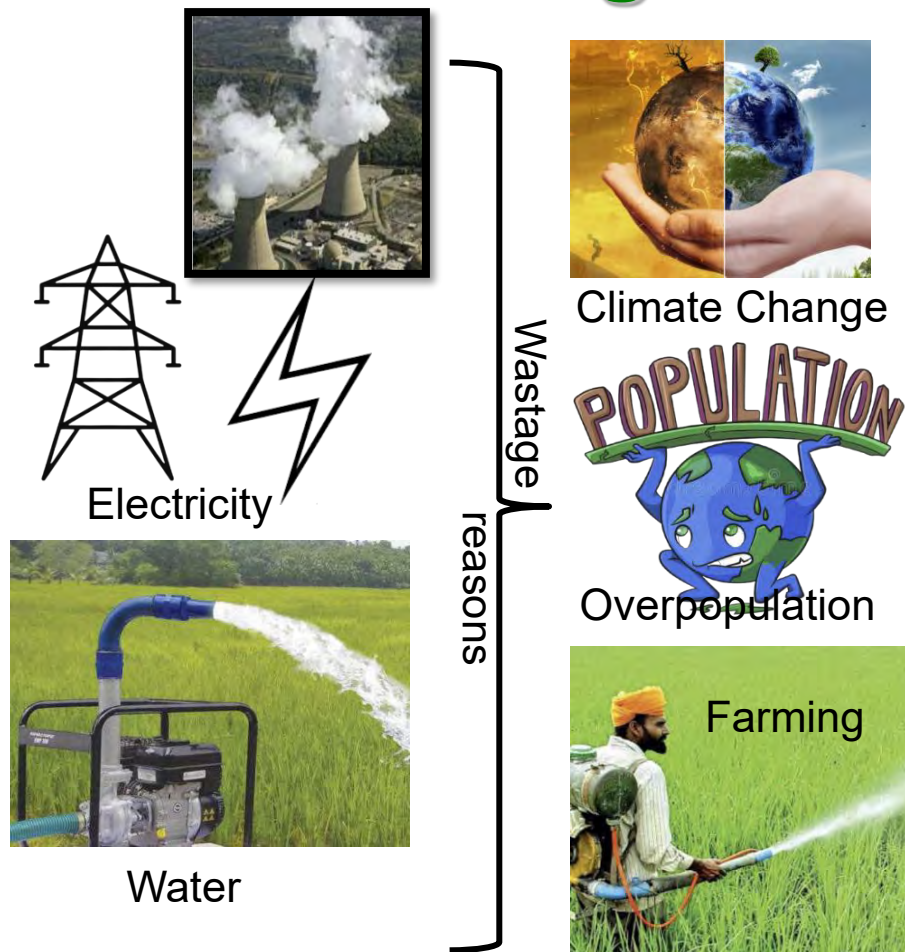
# Is there a Reward for Doing Great Job in Farming?

# Impact of Agriculture Finance on Farm Yield



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

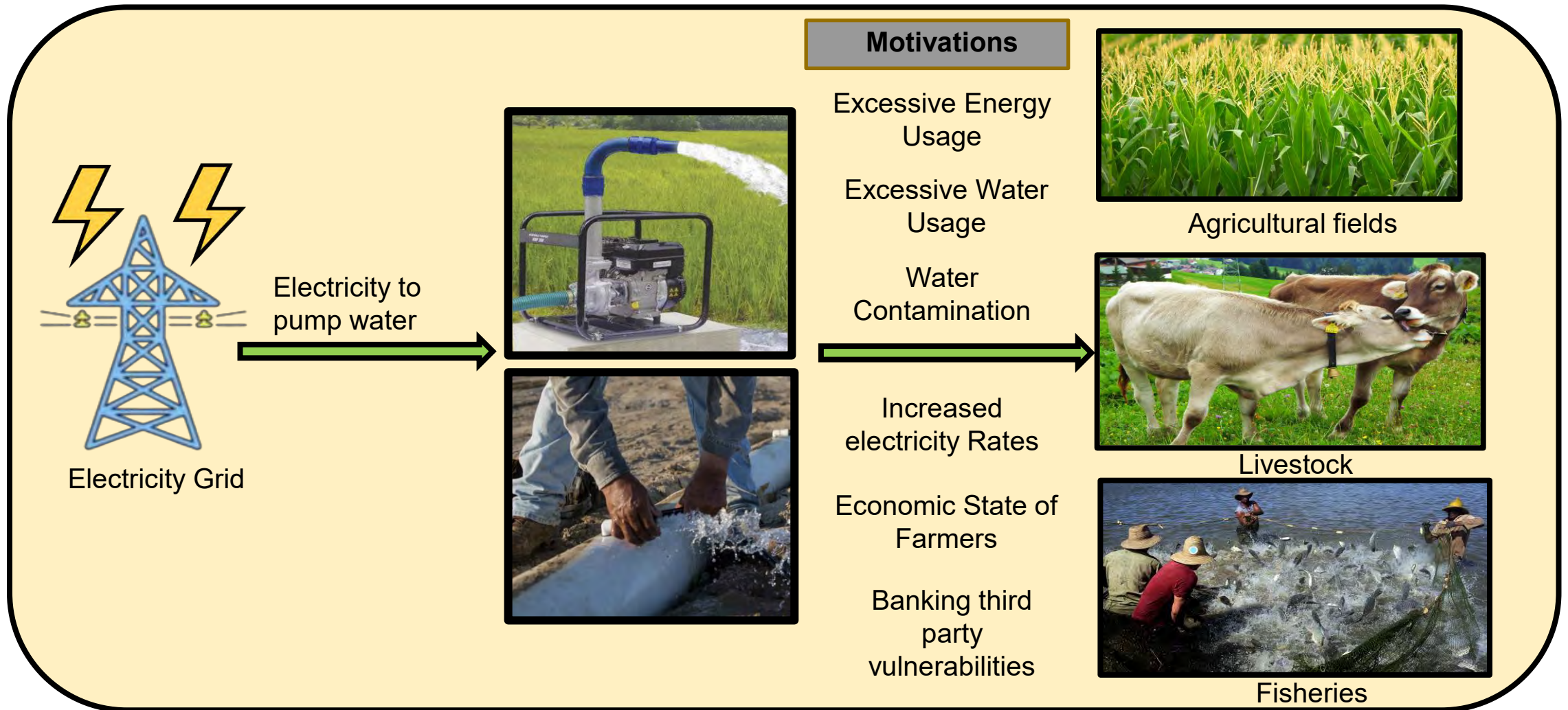


- Water & energy use in different domains.
- Present Scenario: Electricity & water wastage
- Farming as main source for water and energy wastage.
- Recognizing farmers as main entity in farming.

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.

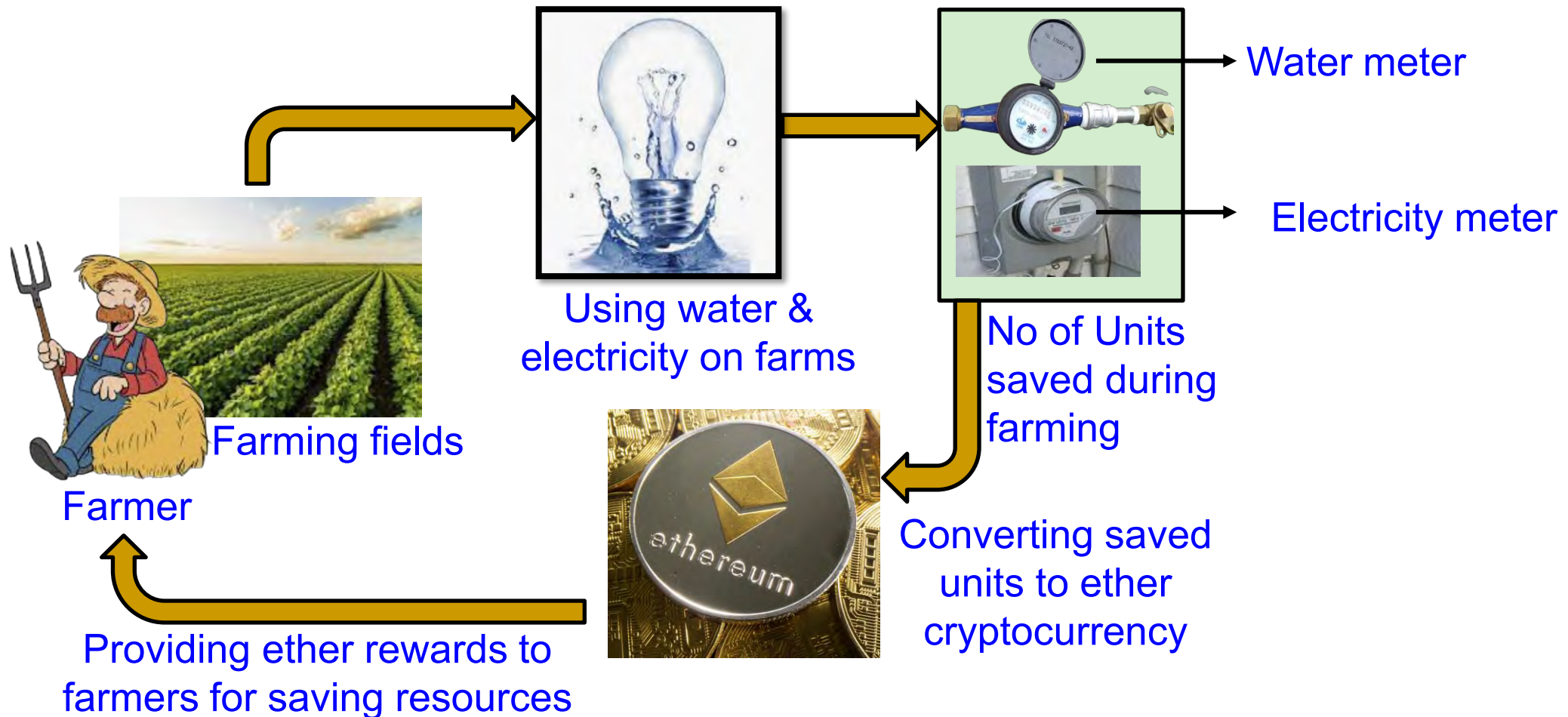


# Our IncentiveChain: Motivation



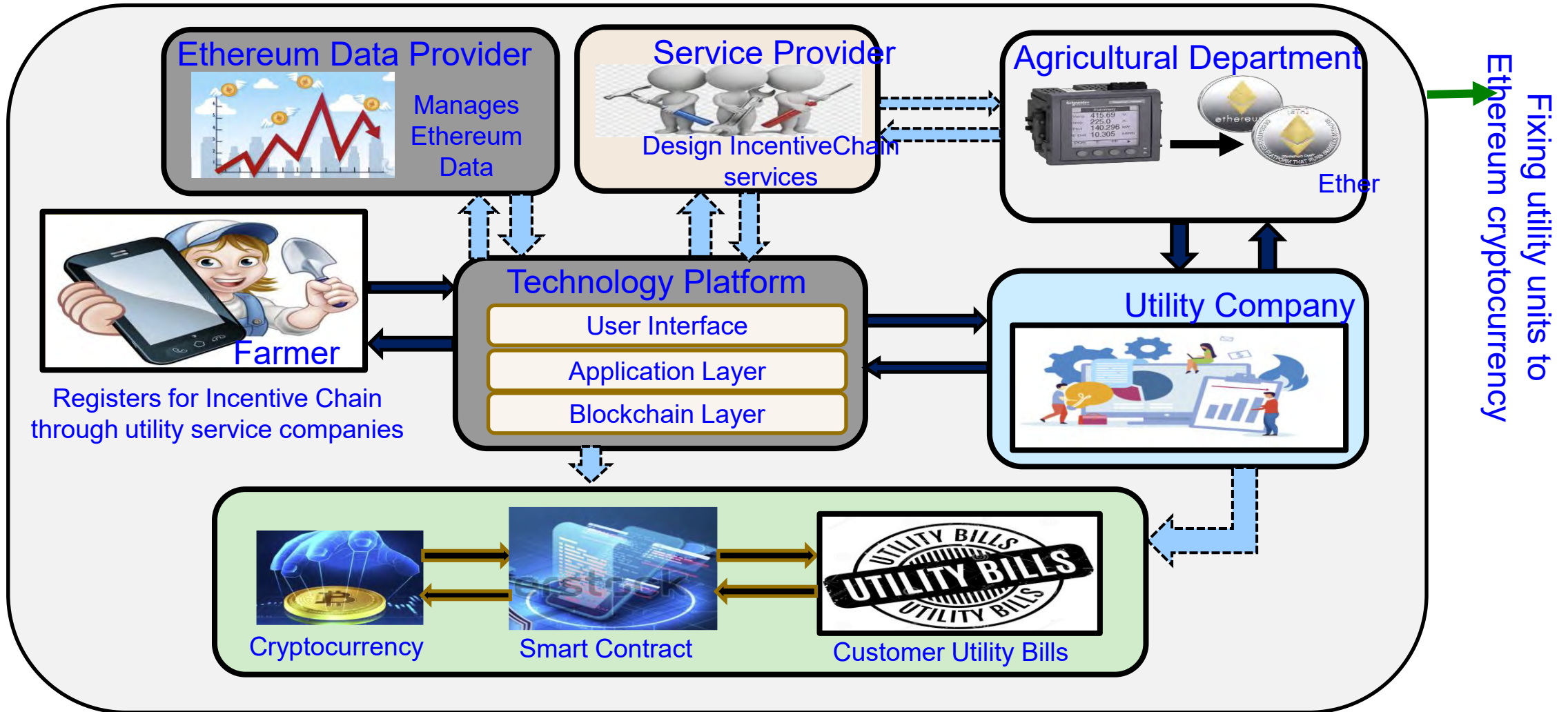
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

# Our IncentiveChain: The Idea



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.

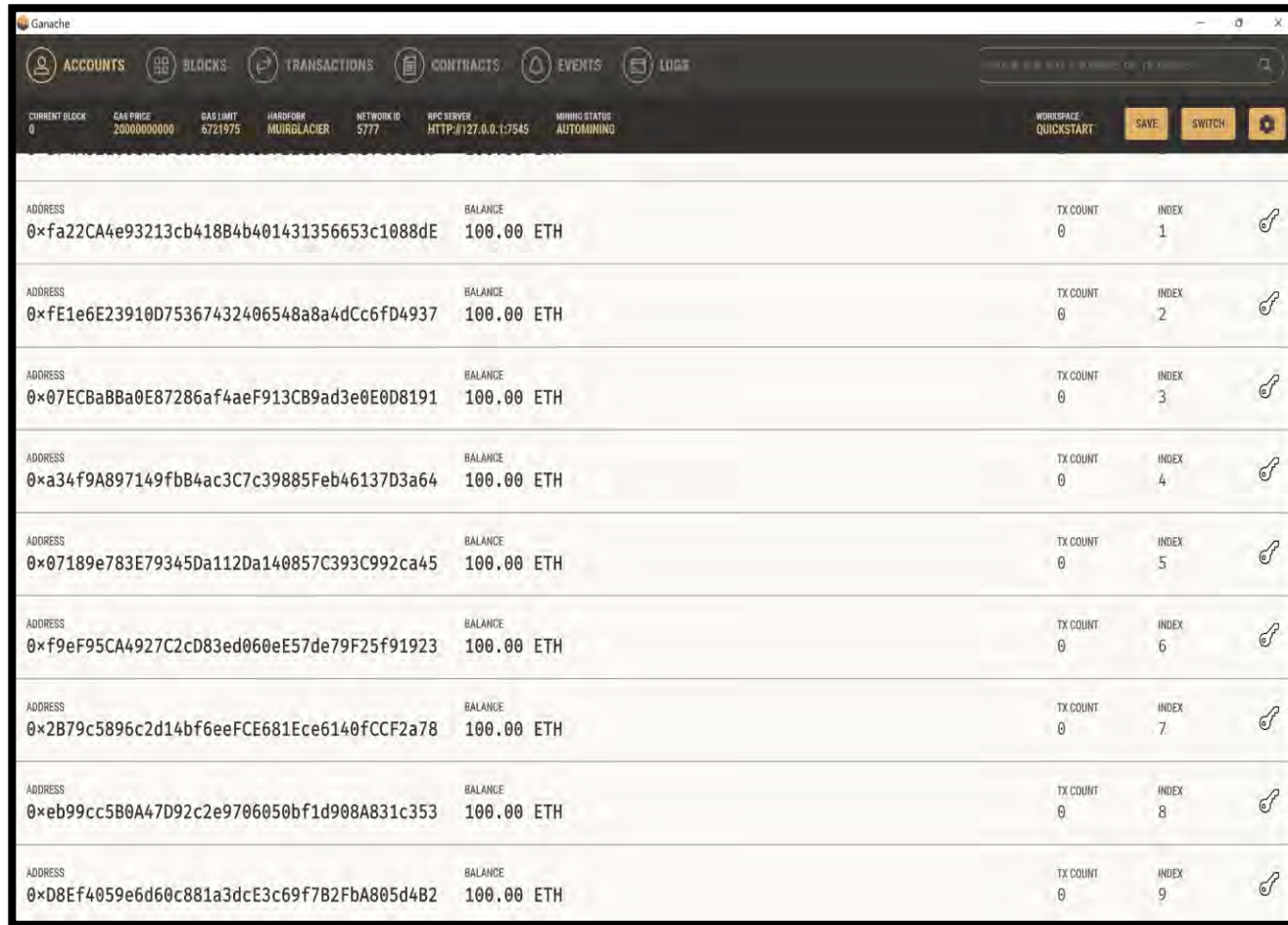
# Our IncentiveChain: Architecture



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



The screenshot shows the Ganache desktop application interface. At the top, there are tabs for ACCOUNTS, BLOCKS, TRANSACTIONS, CONTRACTS, EVENTS, and LOGS. Below the tabs, there is a status bar showing various metrics like CURRENT BLOCK, GAS PRICE, GAS LIMIT, HARDWARE, NETWORK ID, RPC SERVER, and MINING STATUS. The main area displays a list of 10 accounts, each with an ADDRESS, BALANCE, TX COUNT, and INDEX. All accounts have a balance of 100.00 ETH and a TX COUNT of 0.

ADDRESS	BALANCE	TX COUNT	INDEX
0xfa22CA4e93213cb418B4b401431356653c1088dE	100.00 ETH	0	1
0xfE1e6E23910D75367432406548a8a4dCc6fD4937	100.00 ETH	0	2
0x07ECBaBBa0E87286af4aeF913CB9ad3e0E0D8191	100.00 ETH	0	3
0xa34f9A897149fbB4ac3C7c39885Feb46137D3a64	100.00 ETH	0	4
0x07189e783E79345Da112Da140857C393C992ca45	100.00 ETH	0	5
0xf9eF95CA4927C2cD83ed060eE57de79F25f91923	100.00 ETH	0	6
0x2B79c5896c2d14bf6eeFCE681Ece6140fCCF2a78	100.00 ETH	0	7
0xeb99cc5B0A47D92c2e9706050bf1d908A831c353	100.00 ETH	0	8
0xD8Ef4059e6d60c881a3dcE3c69f7B2FbA805d4B2	100.00 ETH	0	9

- 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	0xe84223e28C05f993dc4E0480cC3c1CDFB93dA520	100 Eth	112.80 Eth
Utility Company	0x23470184505C3e9c22C502546C C 4F11289742Cda	100 Eth	92.95 Eth
Deployer	0x367CE2BBFA0a0a1aEc51057349cad678FD7Ea572	100 Eth	93.98 Eth

Free 10 Accounts

ADDRESS	BALANCE	TX COUNT	INDEX
0xe84223e28C05f993dc4E0480cC3c1CDFB93dA520	112.80 ETH	31	0
0x23470184505C3e9c22C502546CC4F11289742Cda	92.95 ETH		
0x367CE2BBFA0a0a1aEc51057349cad678FD7Ea572	93.98 ETH	2	

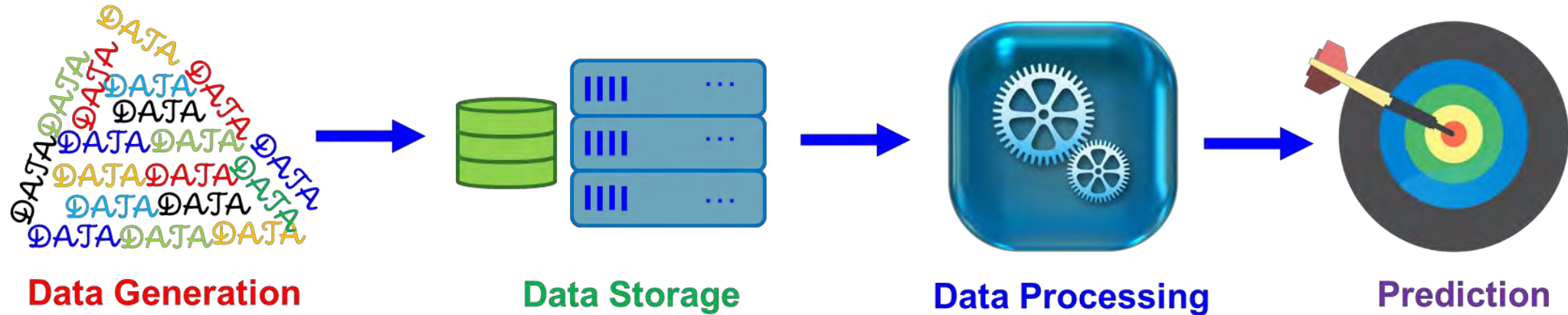
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

---

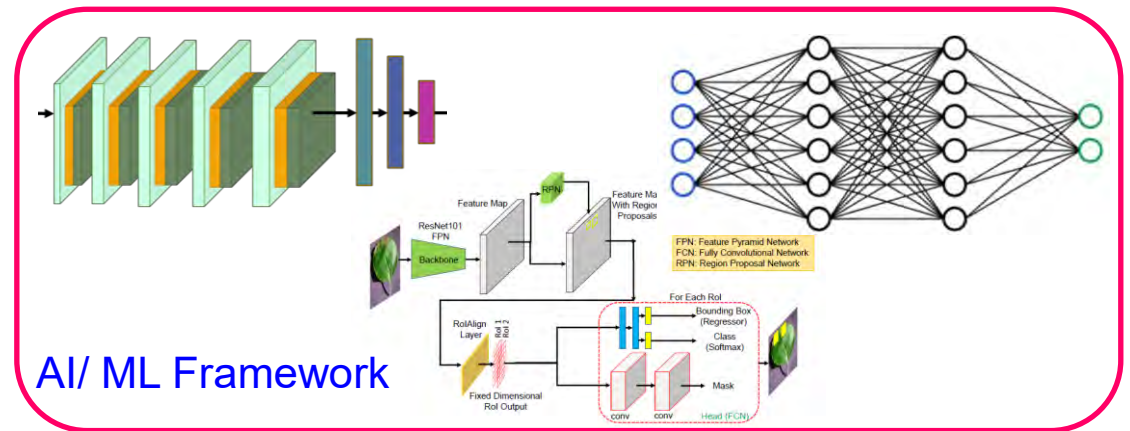
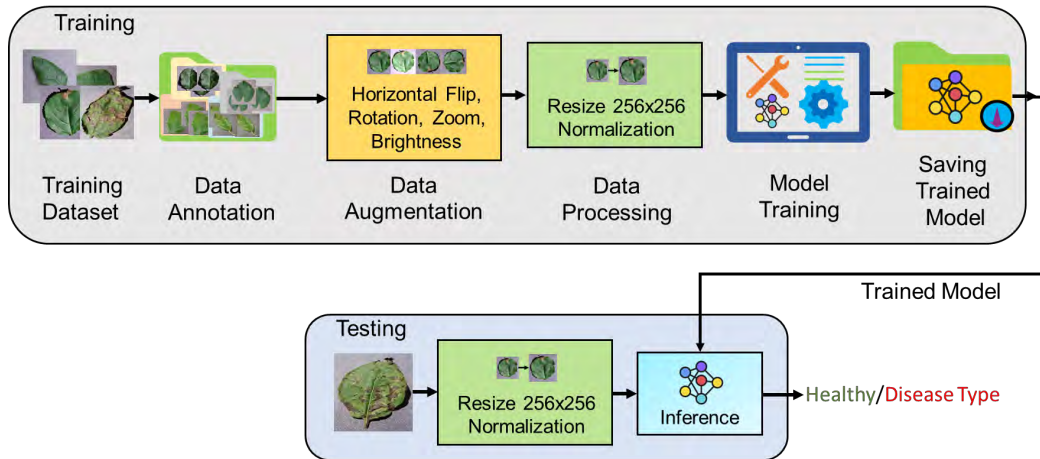
# Smart Agriculture and Federated Learning



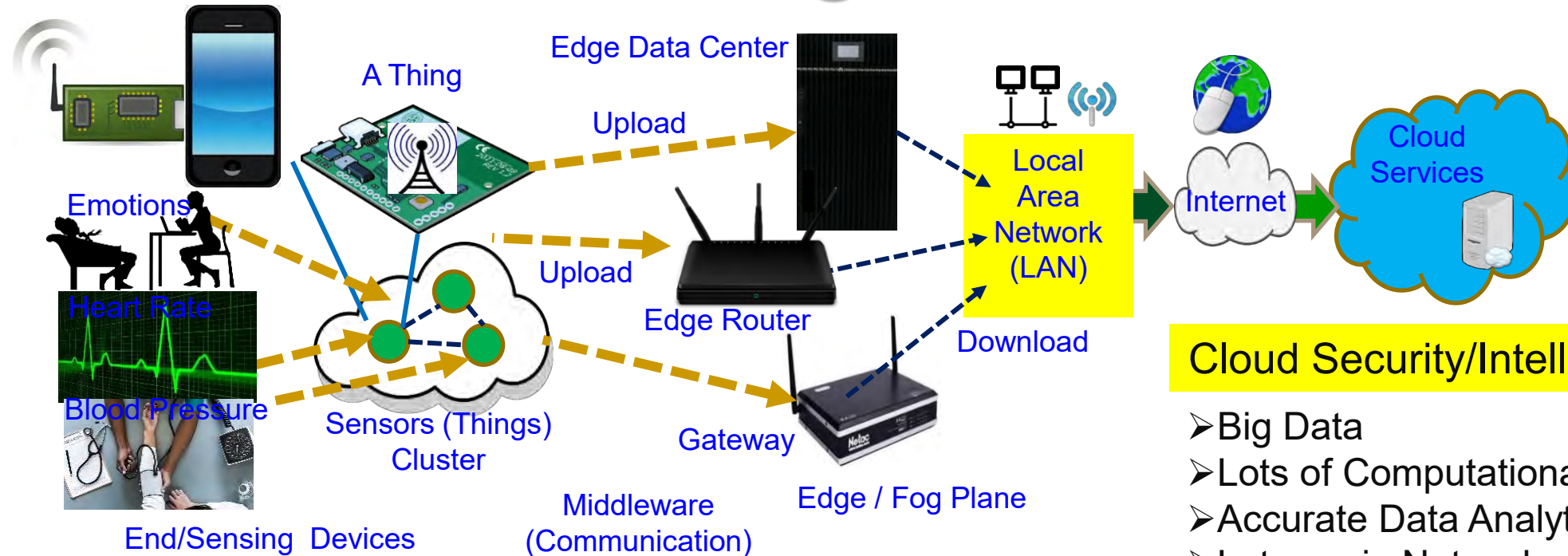
# Smart Agriculture – AI/ML Workflow



[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

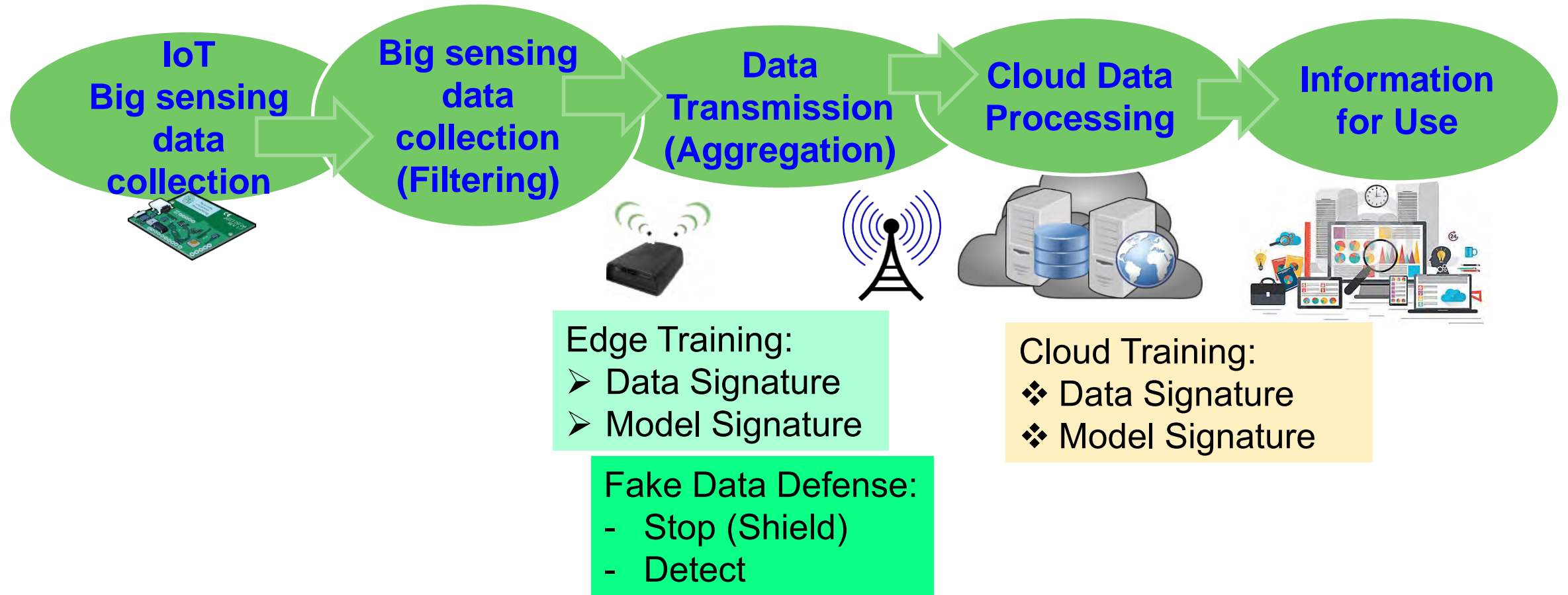
## Cloud Security/Intelligence

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

Heavy-Duty ML is more suitable for smart cities

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

# Secure Data Curation a Solution for Fake Data?

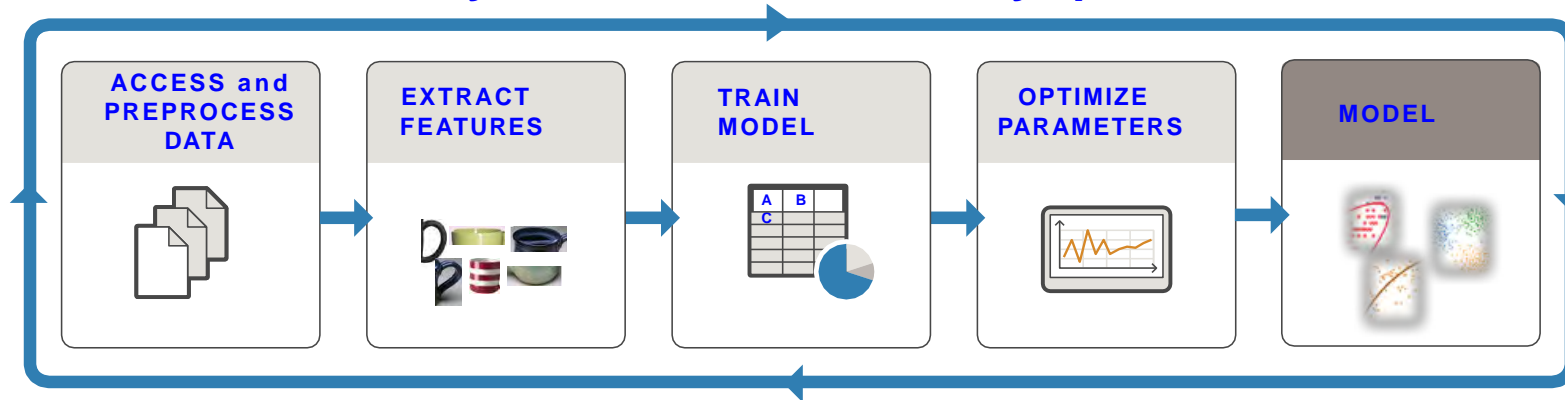


Source: C. Yang, D. Puthal, S. P. Mohanty, and E. Kougianos, "Big-Sensing-Data Curation for the Cloud is Coming", *IEEE Consumer Electronics Magazine (CEM)*, Volume 6, Issue 4, October 2017, pp. 48--56.



# TinyML - Key for Smart Cities and Smart Villages

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

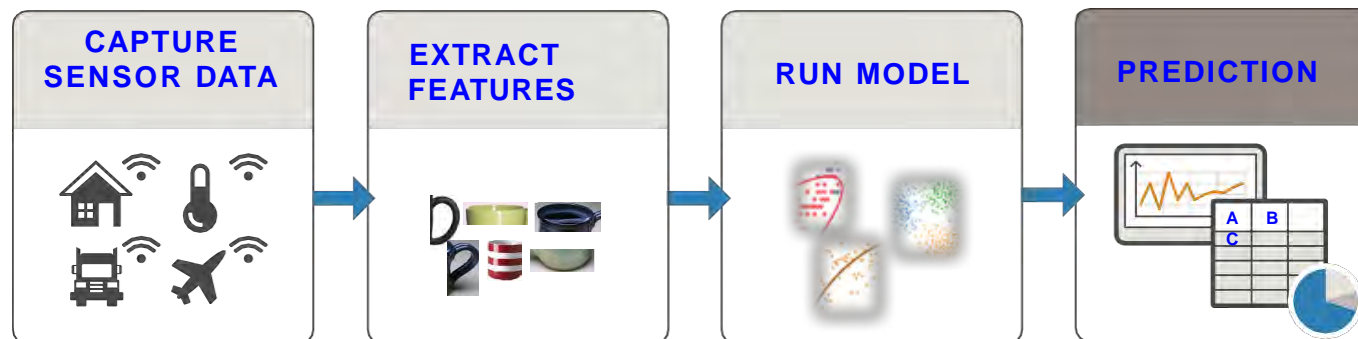


Needs Significant:

- Computational Resource
- Computation Energy

Solution: Reduce Training Time and/or Computational Resource

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



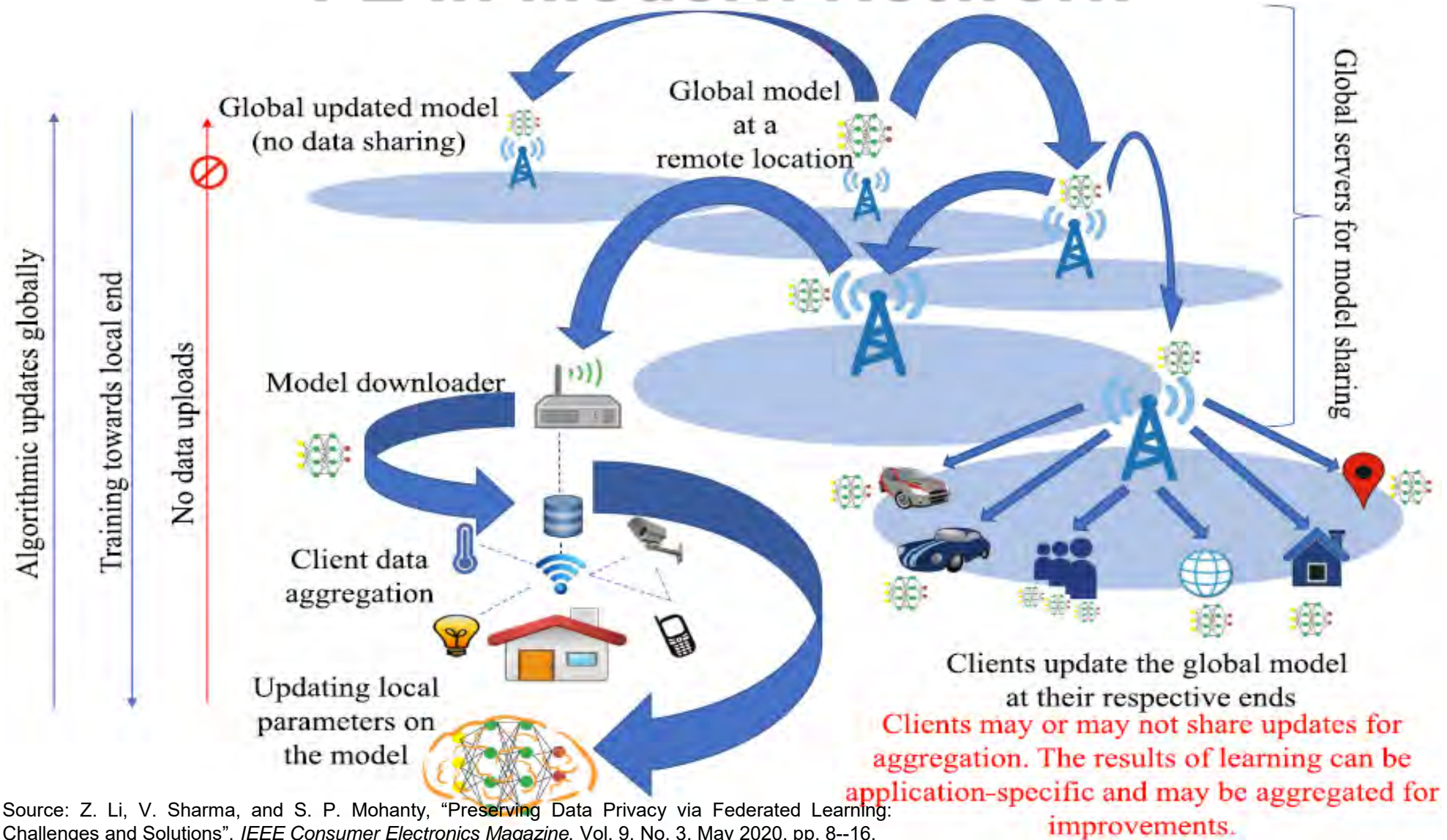
Needs:

- Computational Resource
- Computation Energy

Solution: TinyML

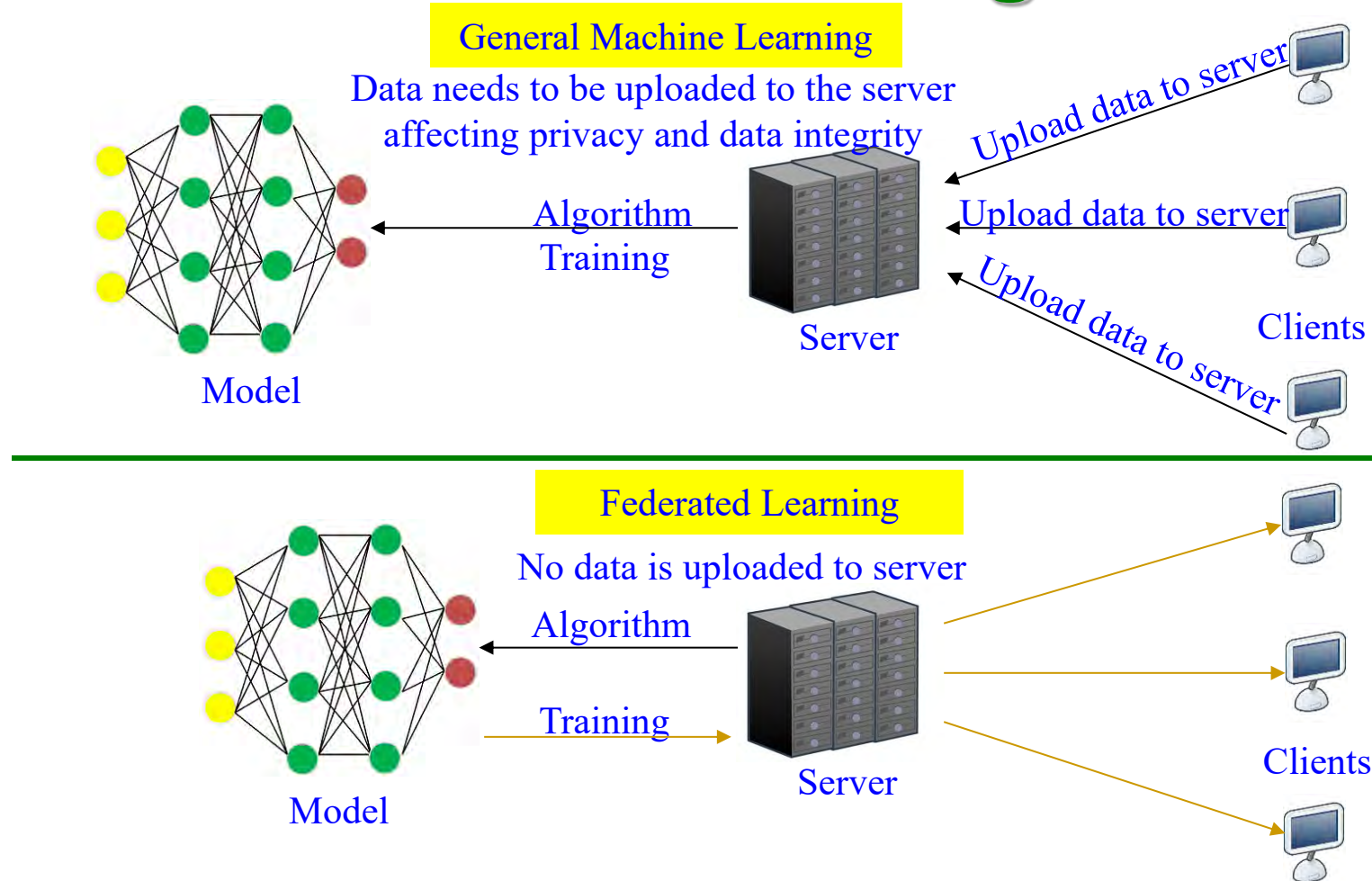
Source: <https://www.mathworks.com/campaigns/offers/mastering-machine-learning-with-matlab.html>

# 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.

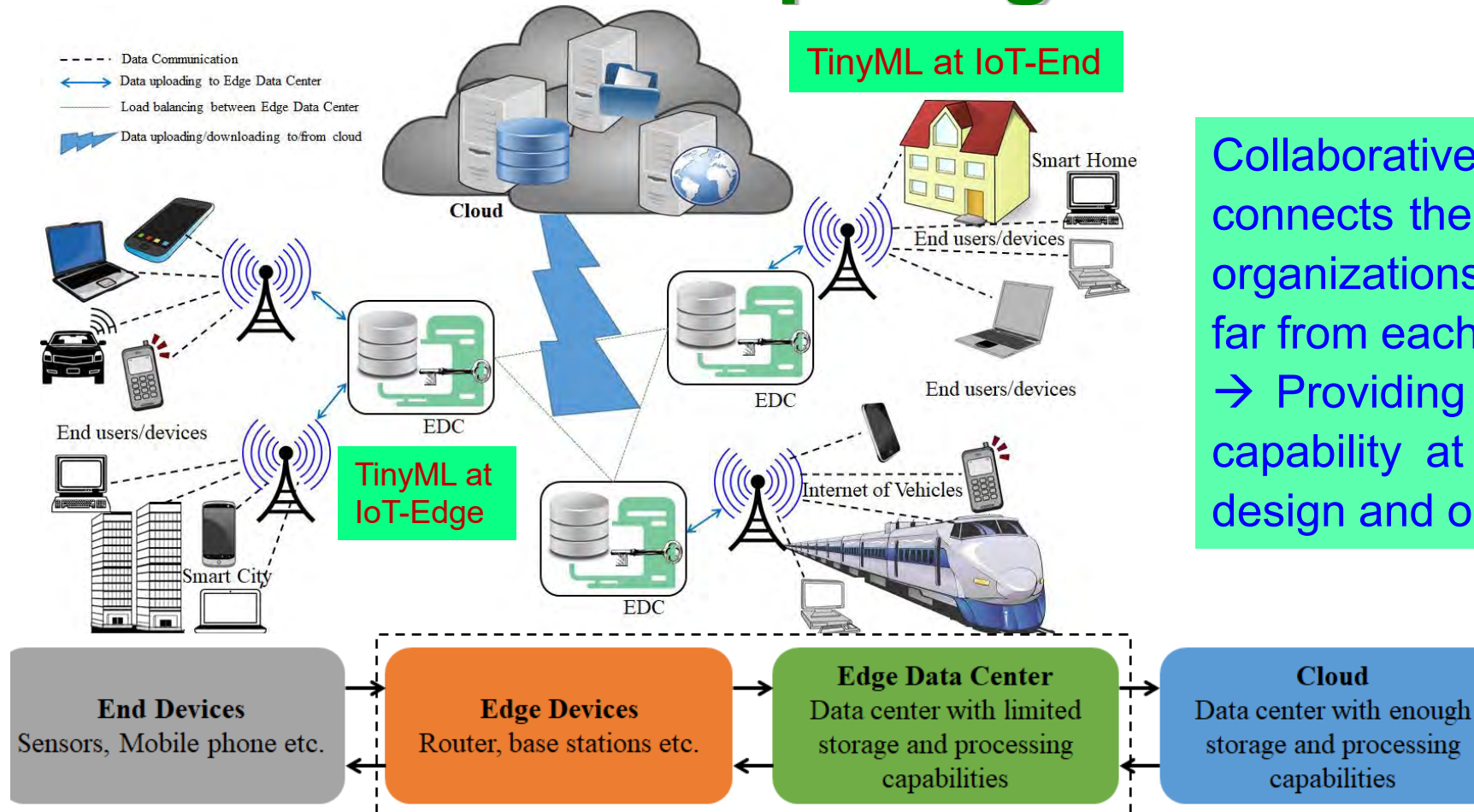
# Distributed Machine Learning to Reduce Training Time



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.



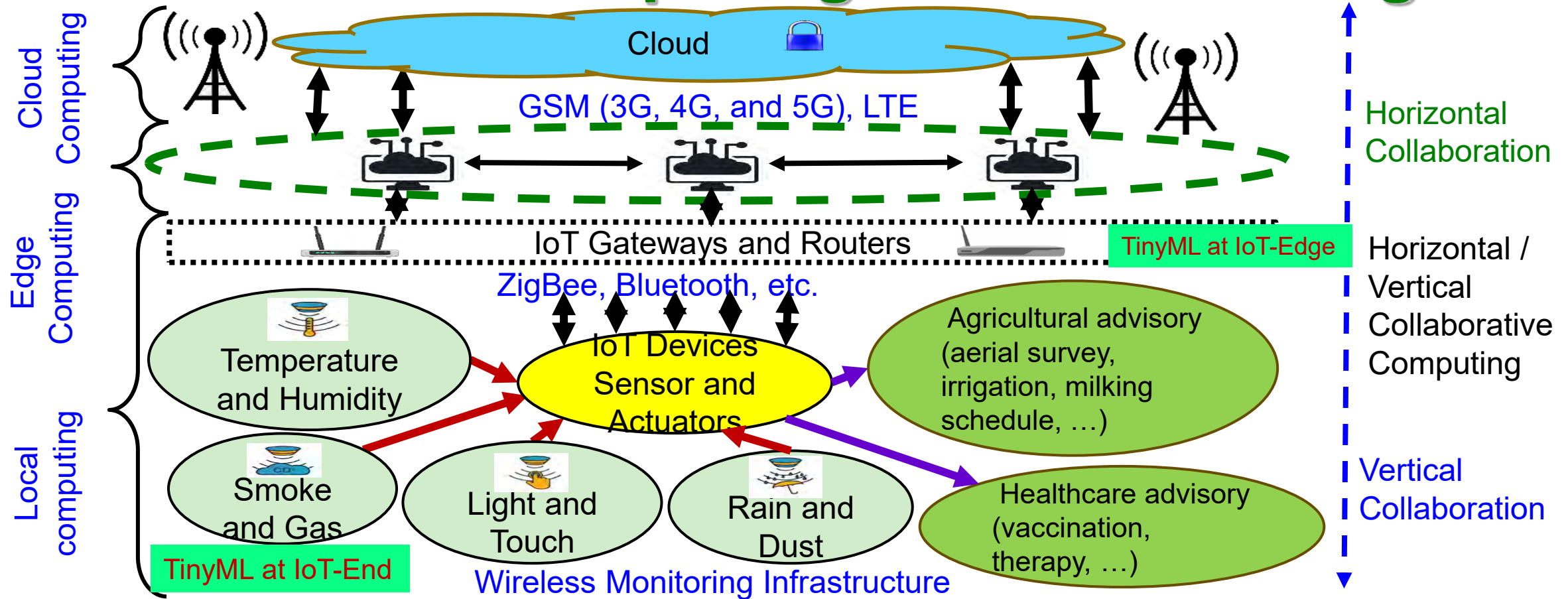
# Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages



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.

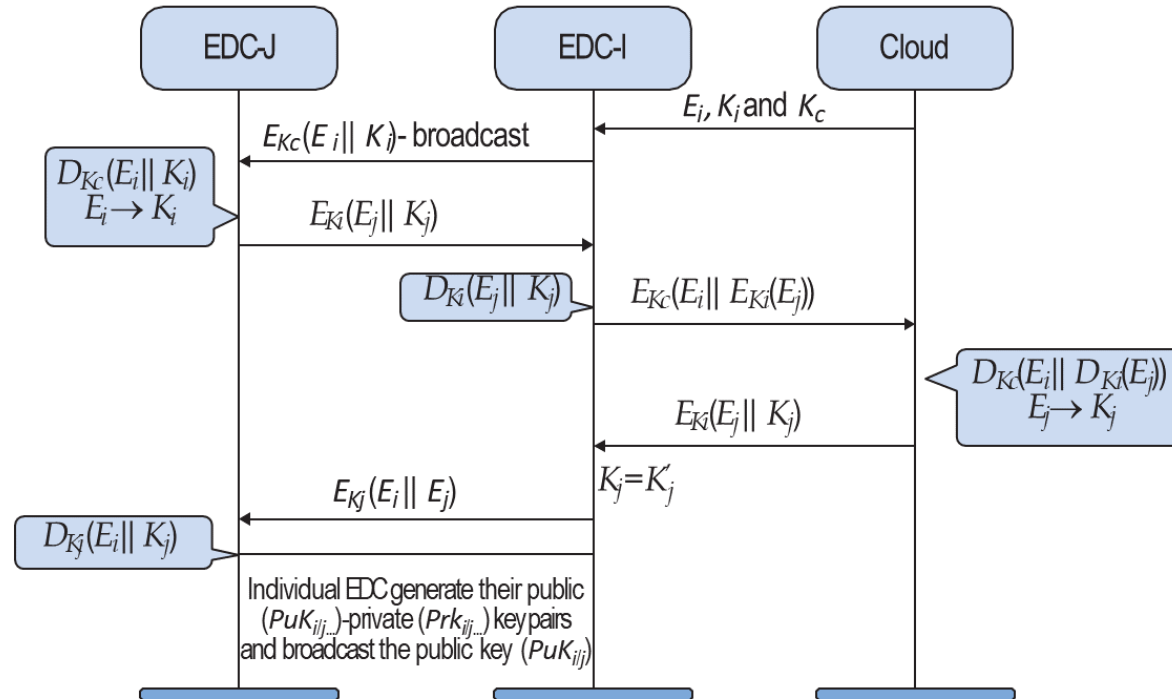
Source: D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya, "Secure and Sustainable Load Balancing of Edge Data Centers in Fog Computing", *IEEE Communications Mag*, Vol. 56, No 5, May 2018, pp. 60--65.

# 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) & ( $p \leq 0.6 \& L_i \ll (n-m)$ )
5. Response  $E_{K_{pu_i}}(E_j || K_j || p)$
6. EDC-I perform  $D_{K_{pr_i}}(E_j || K_j || p)$
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 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 be 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 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 not 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 Question – 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 by 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.

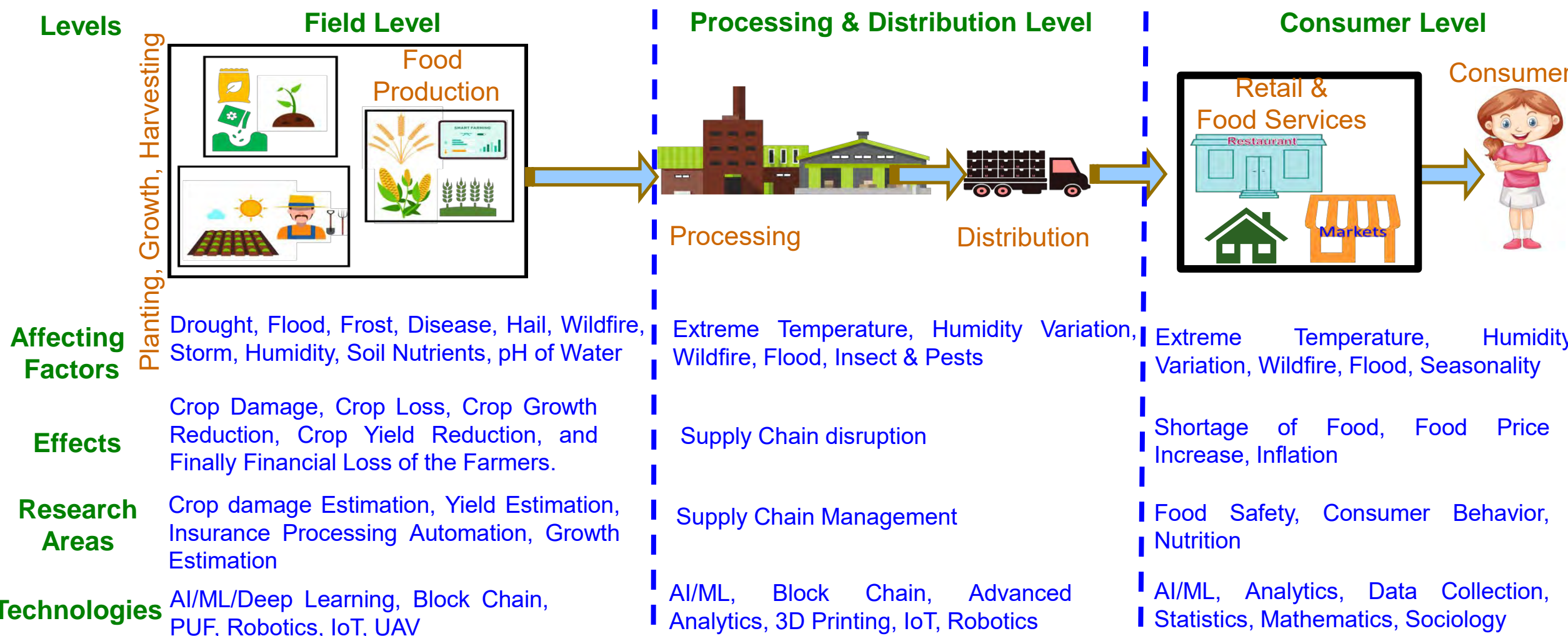
---

# Conclusions and Future Research





# Smart Agriculture - Multifold Research Possibility

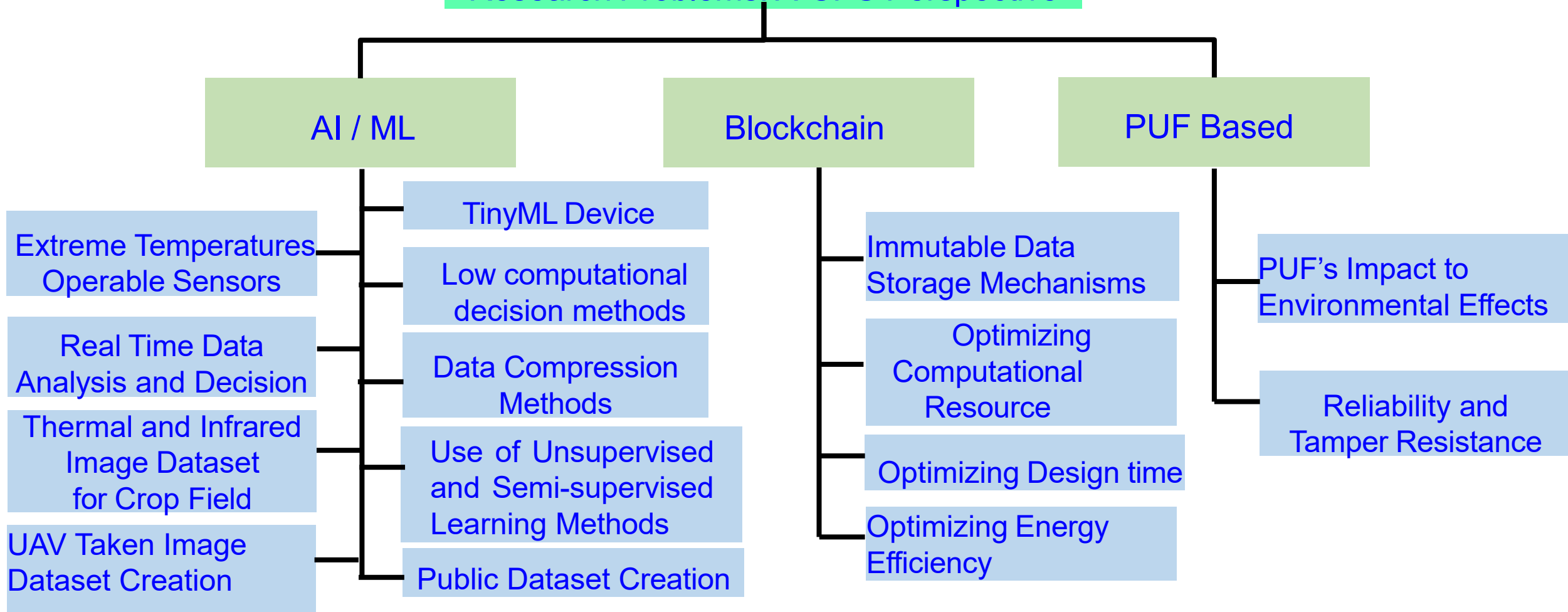


Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.



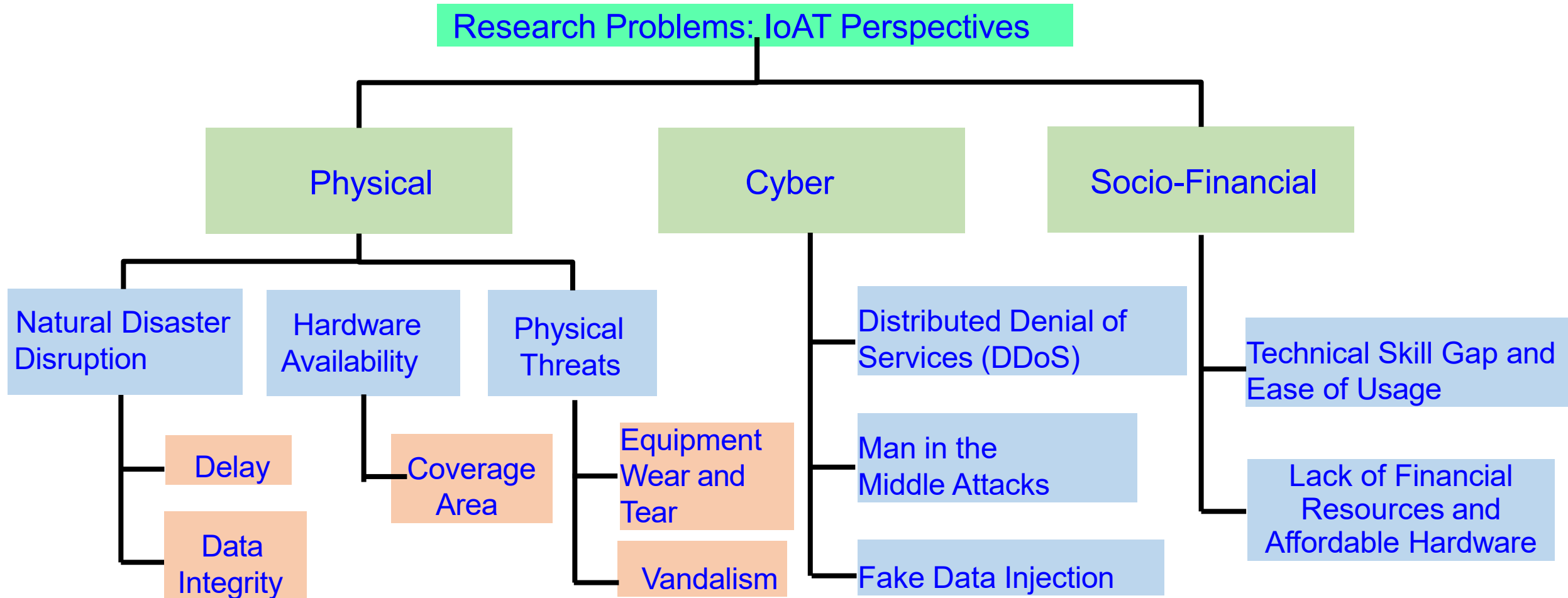
# Smart Agriculture - Research Problems

## Research Problems: A-CPS Perspective



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.



# 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.