Everything You Wanted to Know About Smart Agriculture

Keynote – 18th Annual Wilmington Information Technology eXchange (WITX) 2024

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Homepage:
www.smohanty.org

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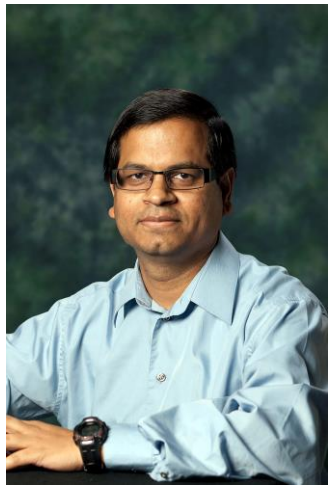


Outline

- Need for Smart Agriculture
- Agriculture → Smart Agriculture
- Factors Affecting Farming
- Technologies used in Smart Agriculture
- Smart Agriculture – Case Studies
- Challenges and Issues in Smart Agriculture
- Smart Agriculture Applications
- Federated Learning for Smart Agriculture
- Agriculture Supply Chain
- Cybersecurity Challenges in Smart Agriculture

Smart Agriculture – Drivers → The Need

Global Population Explosion

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

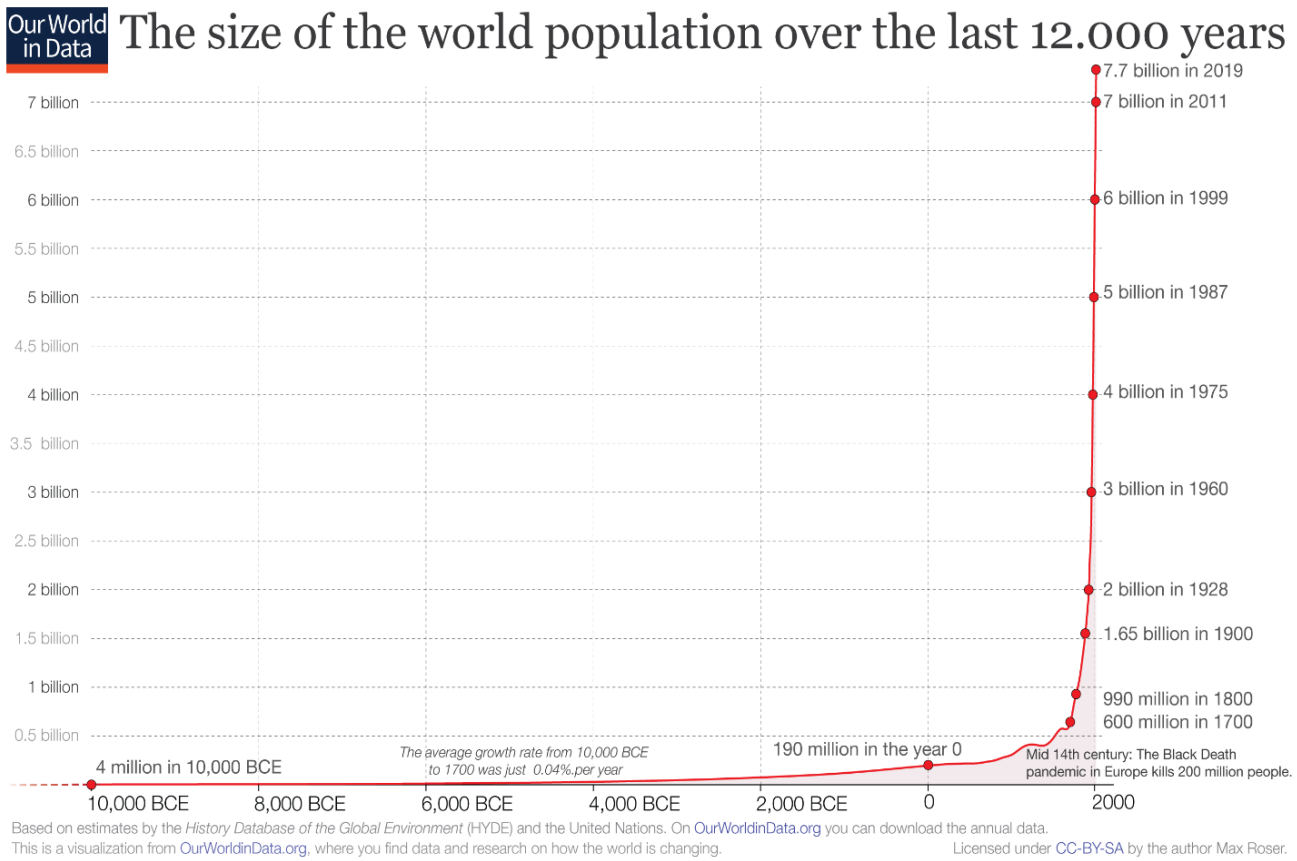


Image Source: https://ourworldindata.org/world-population-growth

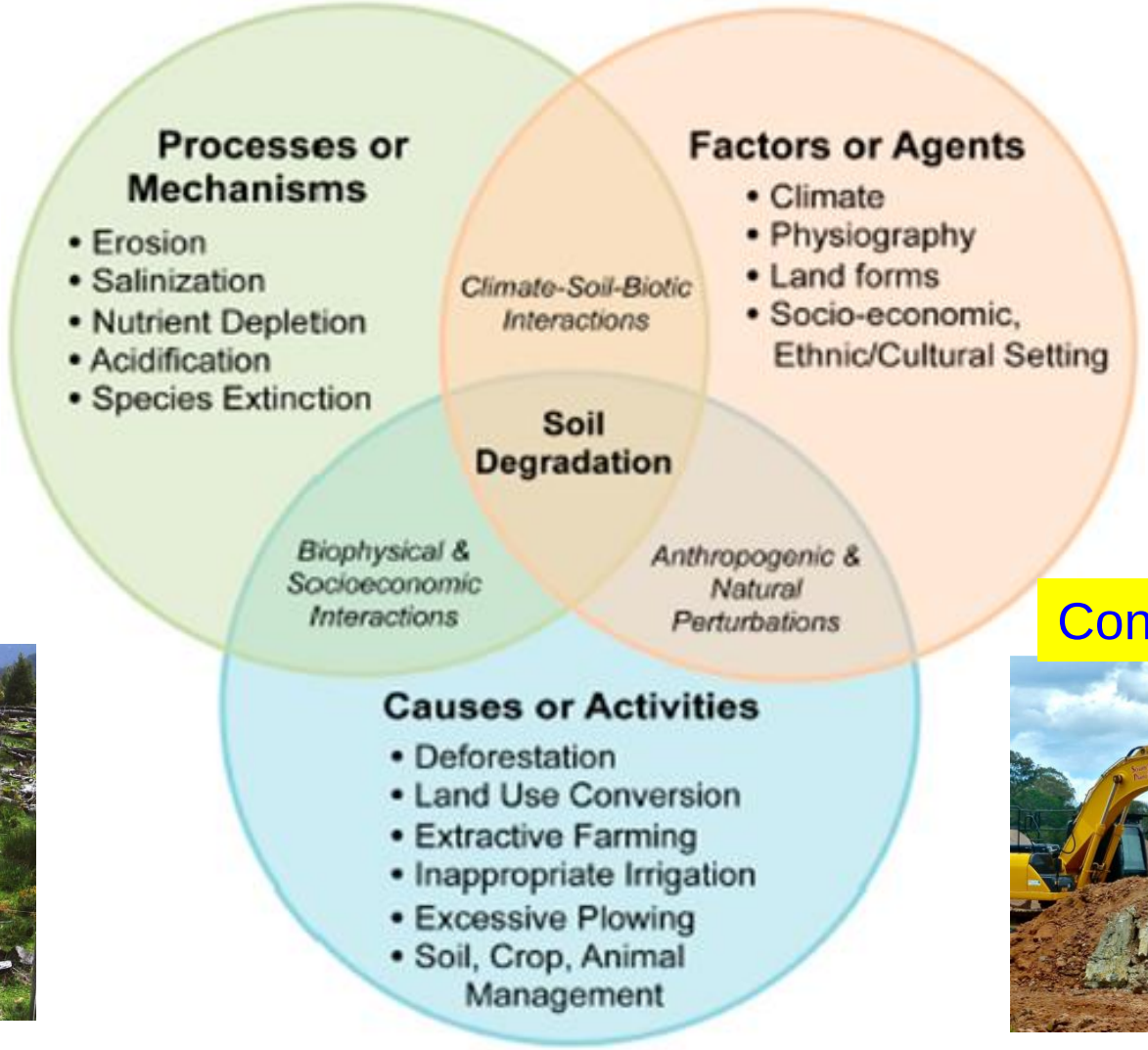
Can we Have Any Crop, at Any Place?

- Environmental factors that determine the types of crop that can be cultivated includes:
  - Climate
  - Elevation
  - Slope
  - Soil
  - Water Availability
  - …
  - …

Agricultural Land Reduction is a Global Crisis

Salination

Deforestation



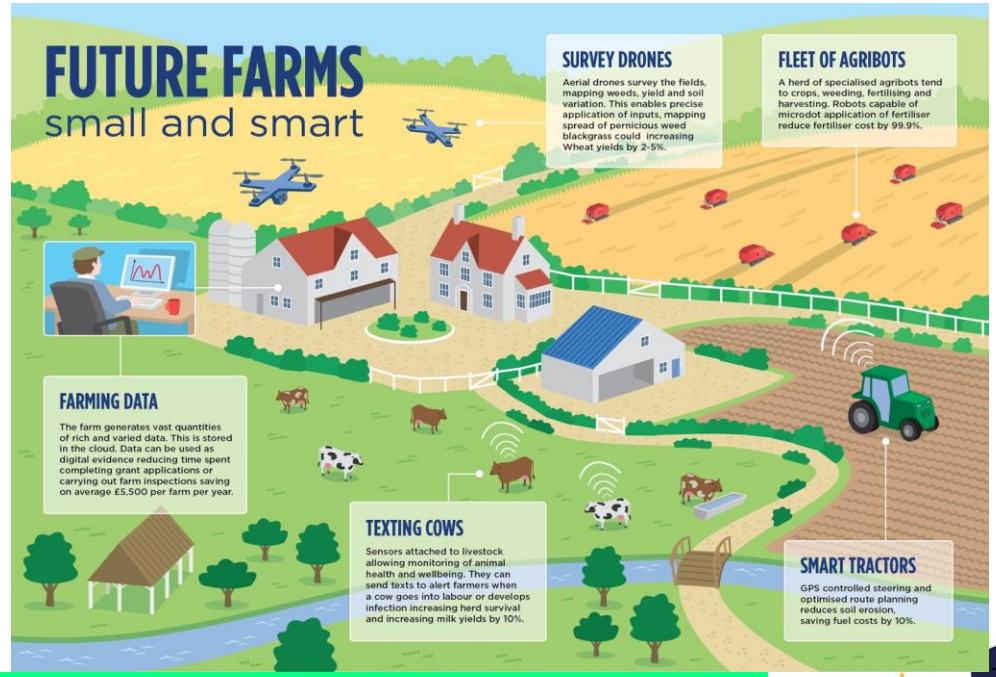
Soil Erosion

Construction on Farm Land

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

Solution → Smart Agriculture

- 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, water, and manual labor.

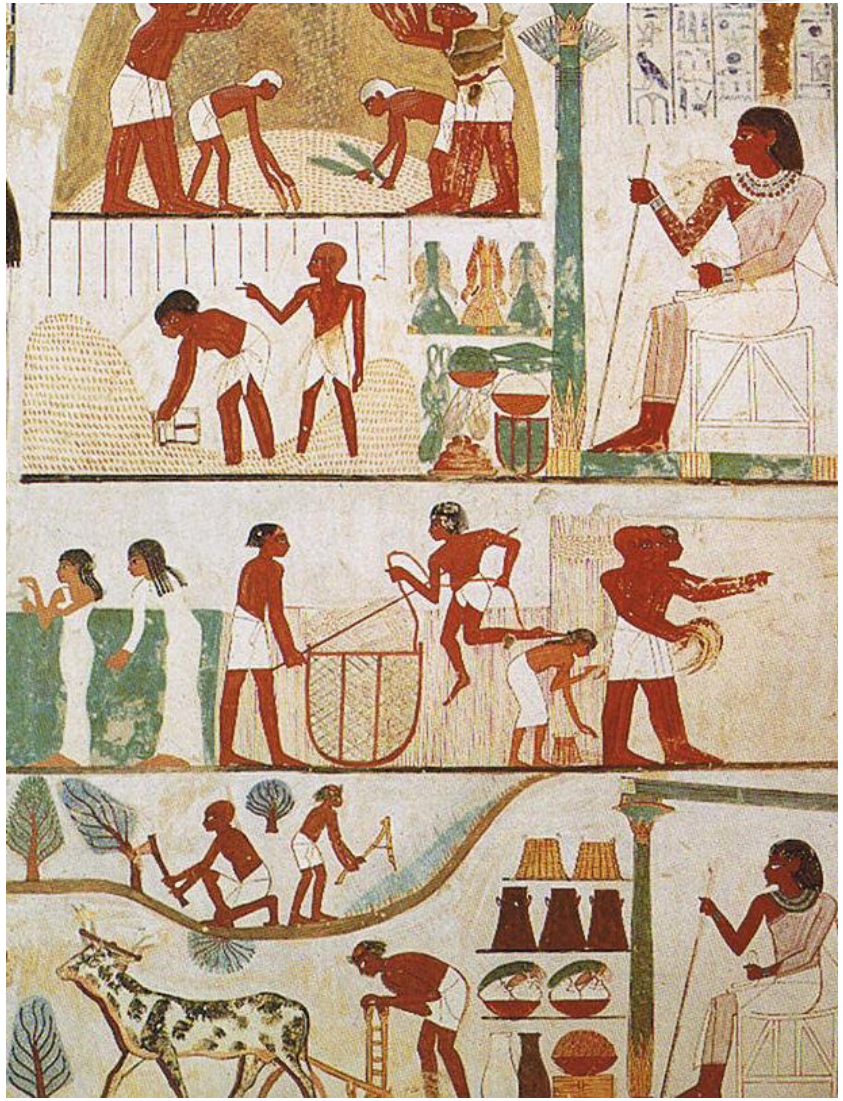


Agriculture is the practice of cultivating plants and livestock.

"Smart Agriculture" refers to the usage of technology including AI, sensors, robots, and communications, on the farm to improve productivity while optimizing the usage of resources.

Agriculture → Smart Agriculture: Broad Overview

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)

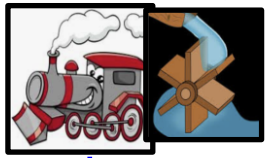
Agricultural Evolutions & Industrial Revolutions

- Indigenous Tools
- Manual work
- Animal Power

Agriculture 1.0

1784

Industry 1.0



Steam engine and waterpower

Green Revolution

1870

Industry 2.0

- Mass production
- Electrical Energy

1950

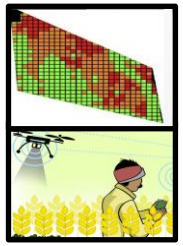
- Tractor
- Fertilizer
- Pesticide

Agriculture 2.0

1969

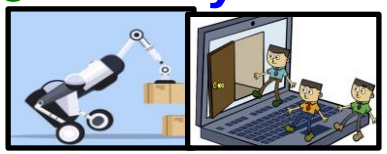
- Variable rate application
- Yield Monitoring
- Guidance System

Agriculture 3.0



1992

Industry 3.0



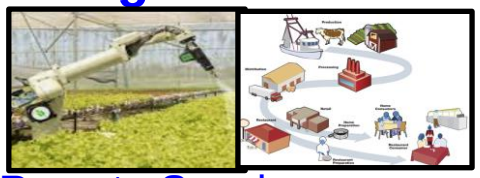
- Automation
- Information Technology

2011

Groups for Precision Agriculture

- Remote Sensing
- Trustworthy Supply chain
- Autonomous Farming

Agriculture 4.0



2017 **Industry 4.0**

- AI
- IoT
- Bigdata
- Blockchain

2030

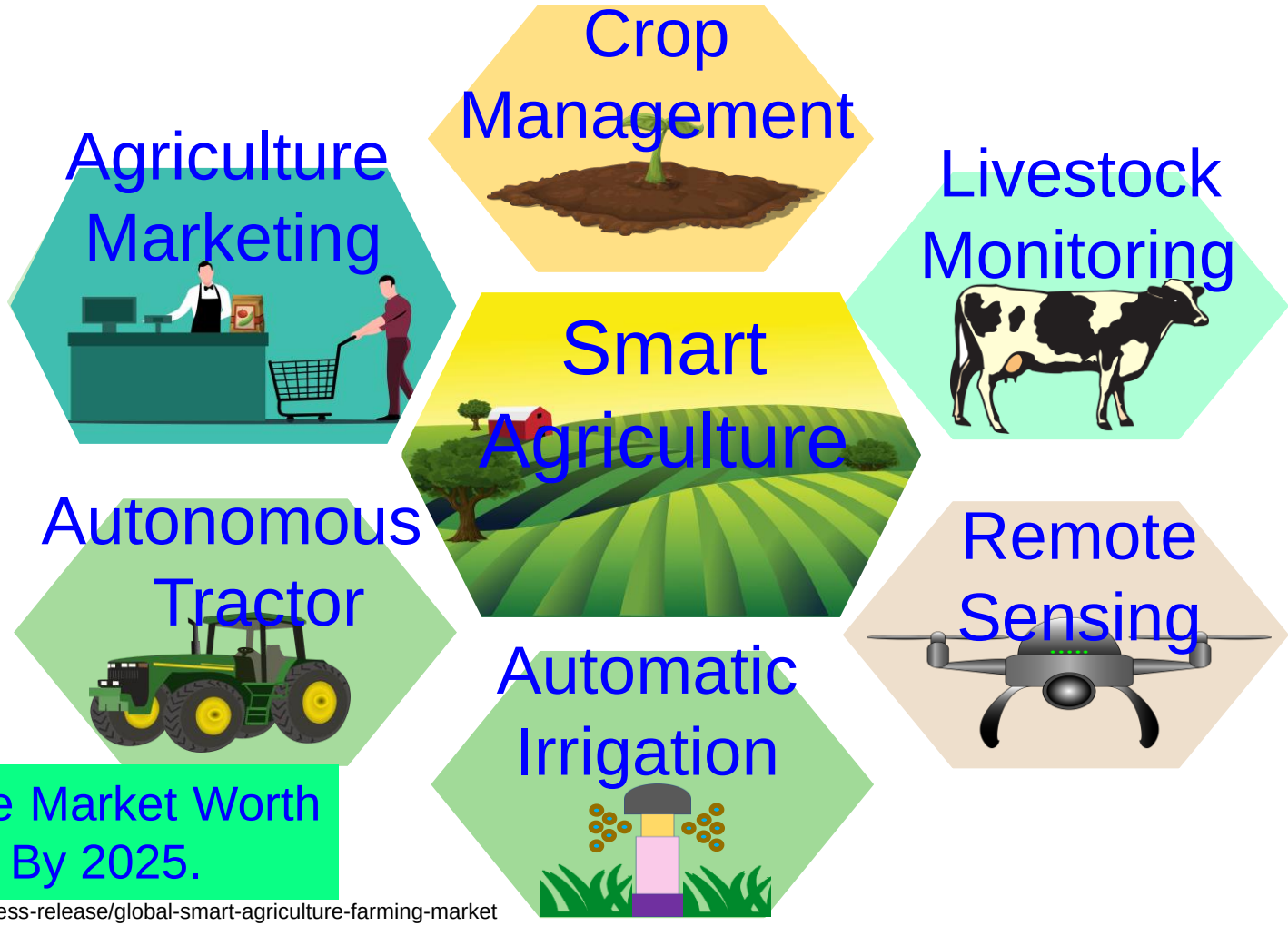
Industry 4.0 in Agriculture

2050

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

Agriculture to Smart Agriculture

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

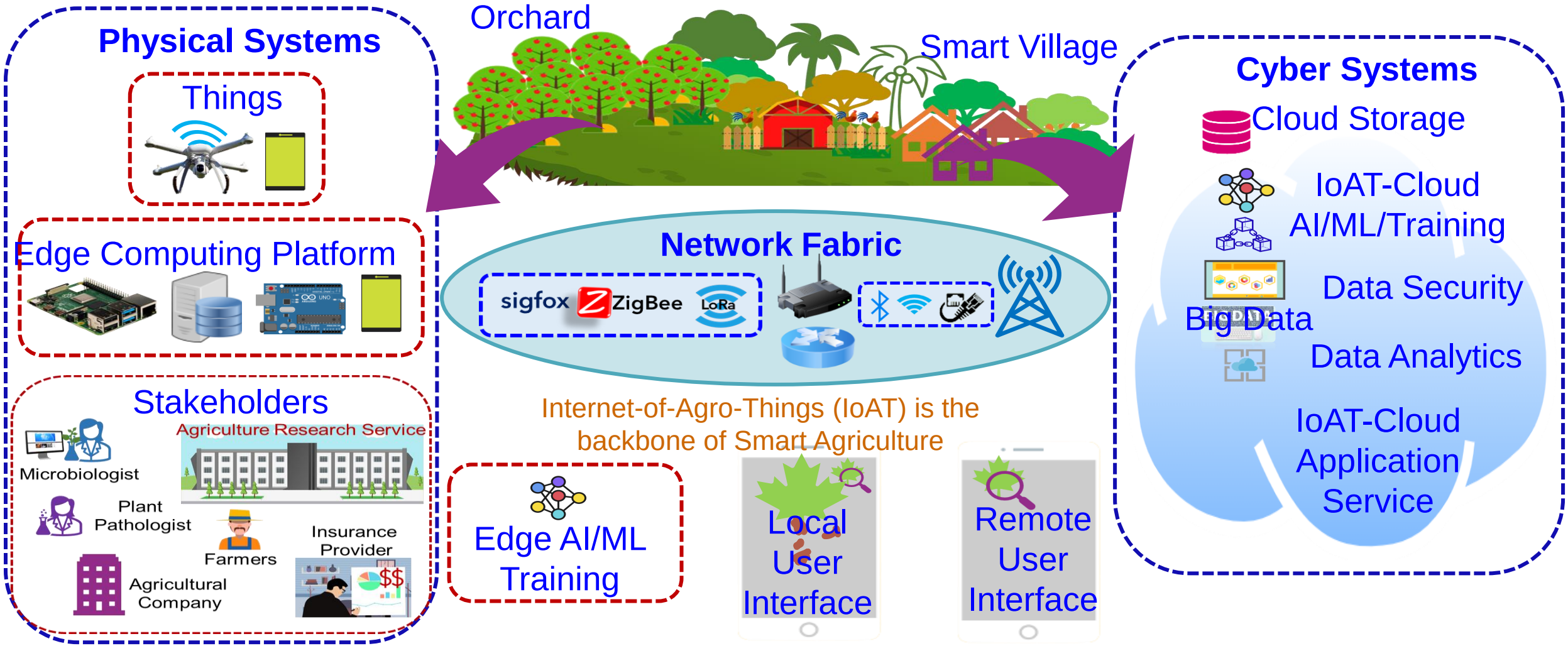


Smart Agriculture Market Worth US$18.21 Billion By 2025.

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

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

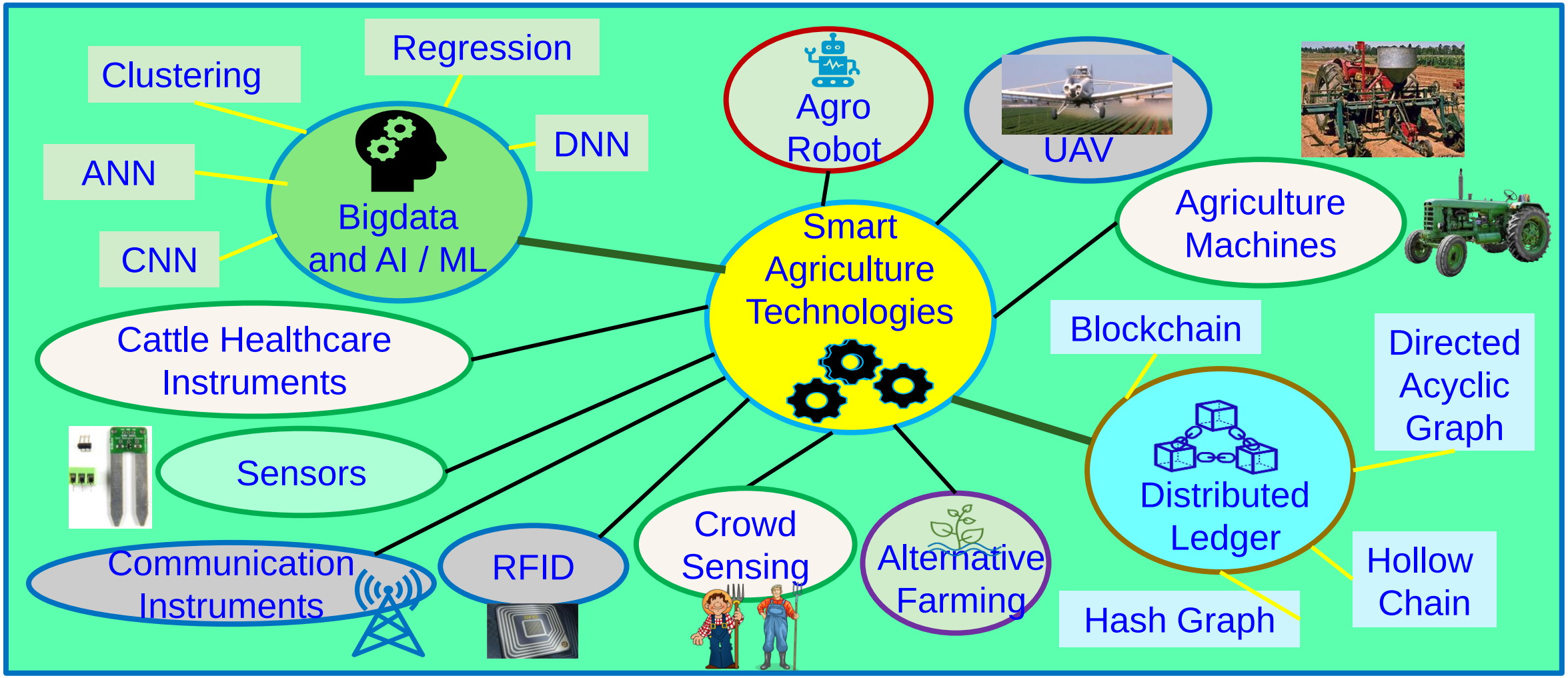
Agriculture Cyber Physical System (A-CPS)



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.

Smart Agriculture – Technologies

Smart Agriculture Technologies



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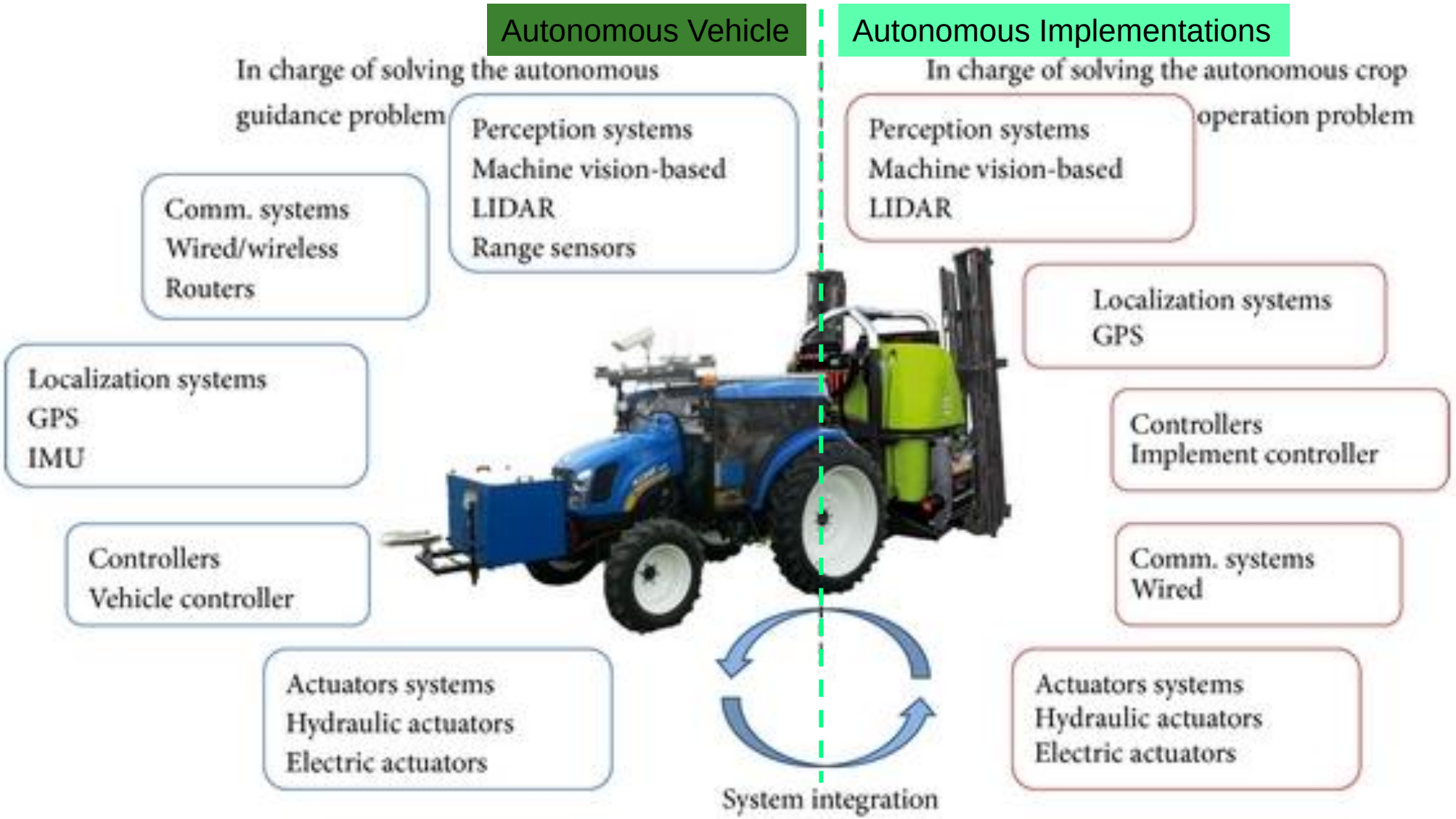
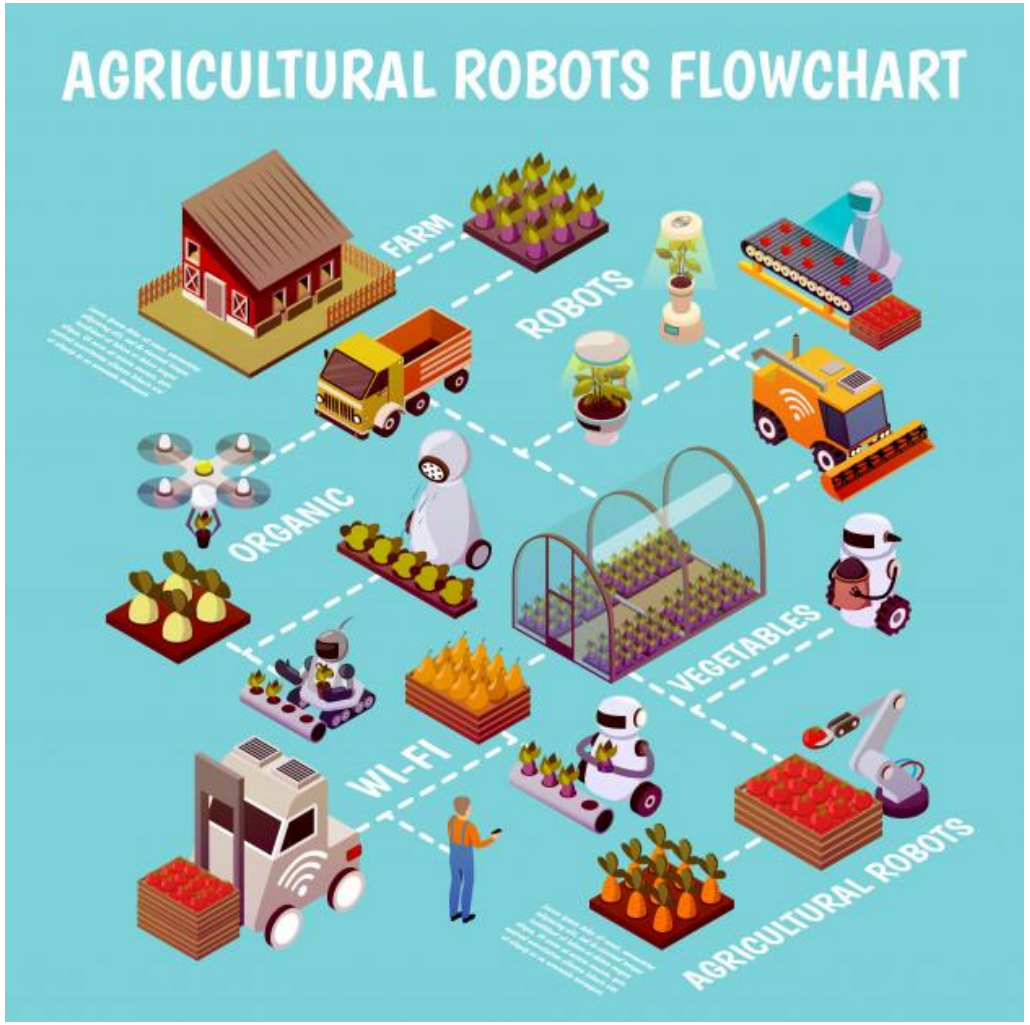
Driverless Tractors



Autonomous and Robotic Labor

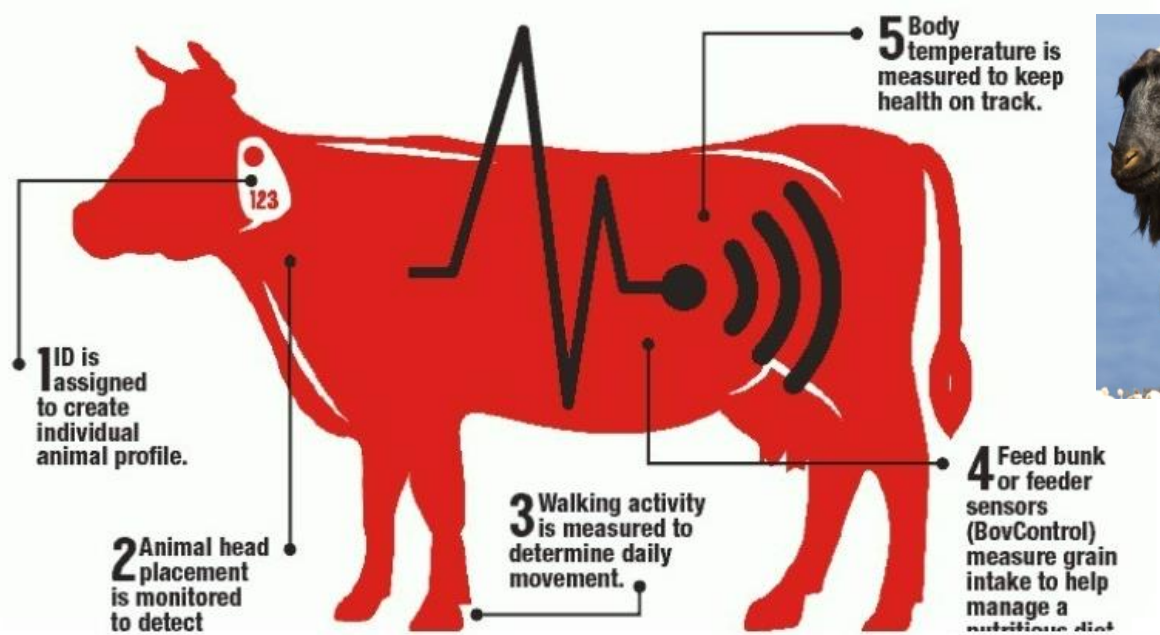
- Due to migration of people from rural areas to urban areas, there is shortage in labor for farming.
- Use of Autonomous and Robotic labor can increase the productivity and quality of work.



Drones or UAV for Smart Agriculture

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

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

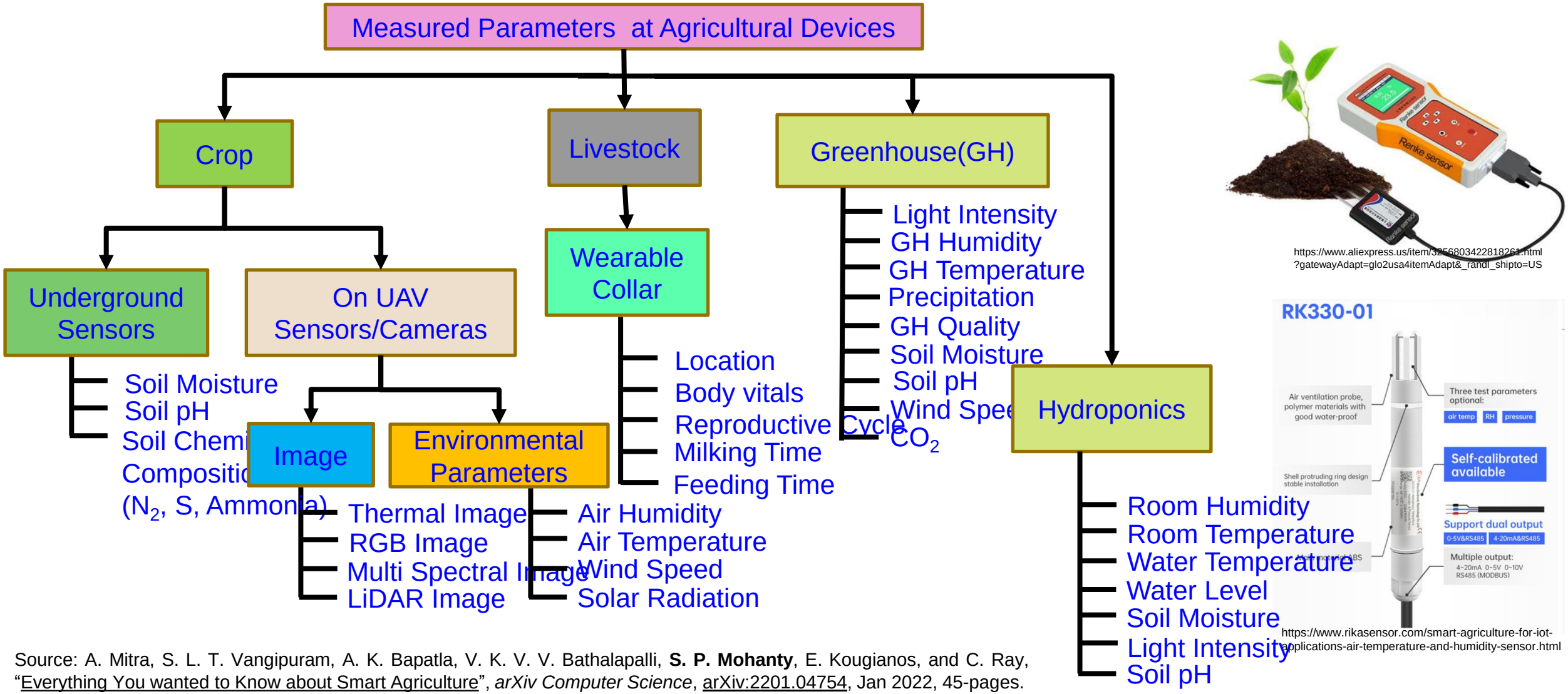
Cattle Stomach Healthcare

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 – Sensor Technology

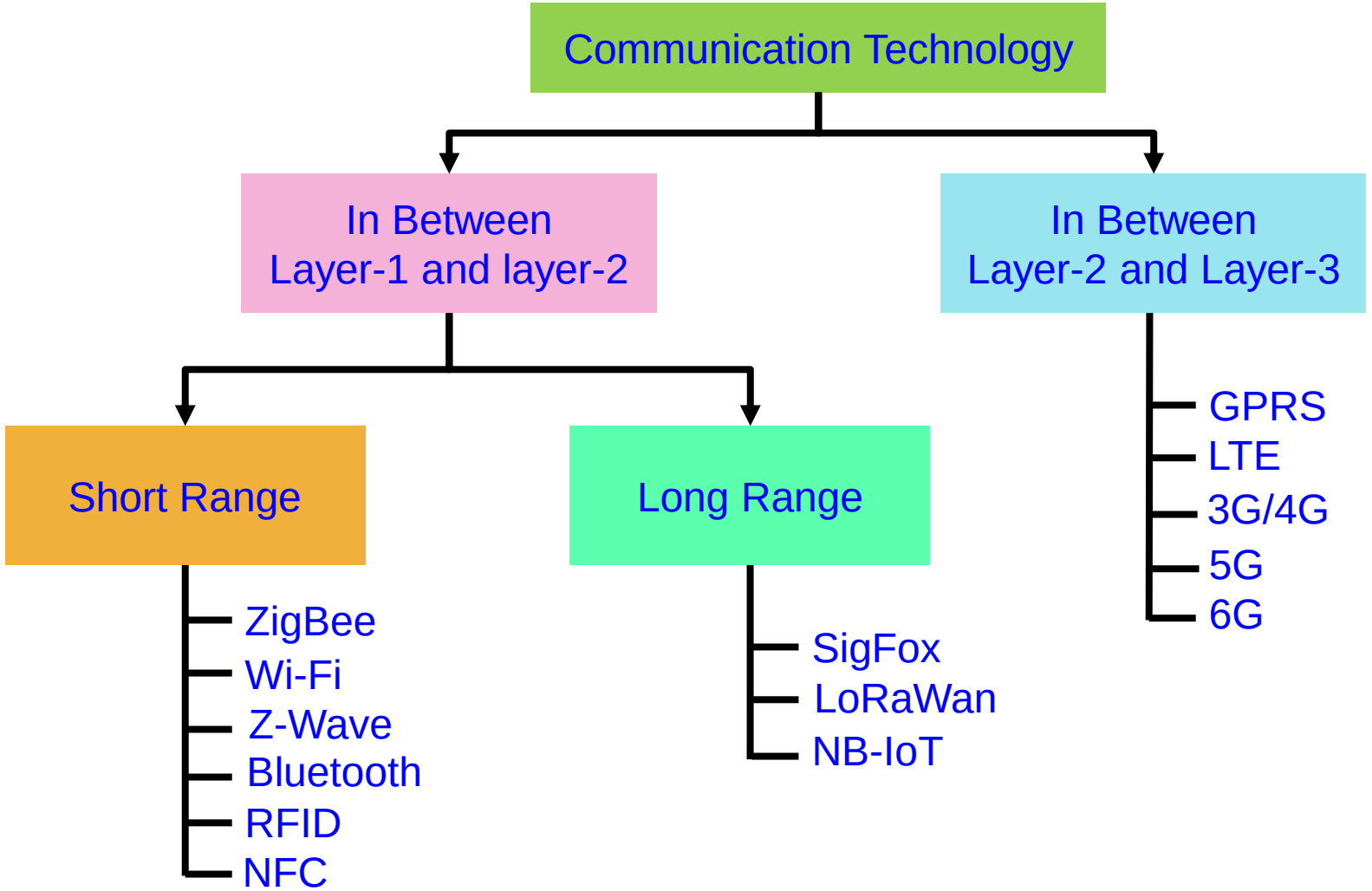


https://www.aliexpress.us/item/3256803422818261.html?gatewayAdapt=glo2usa4itemAdapt&_randl_shipto=US

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

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

Smart Agriculture – Communication Technology



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

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

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

Smart Agriculture – AI/ML Technology

Crop Management

Soil Management

Smart Irrigation

Pest / Disease Control

Weed Control

Livestock Management

Alternative Farming

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

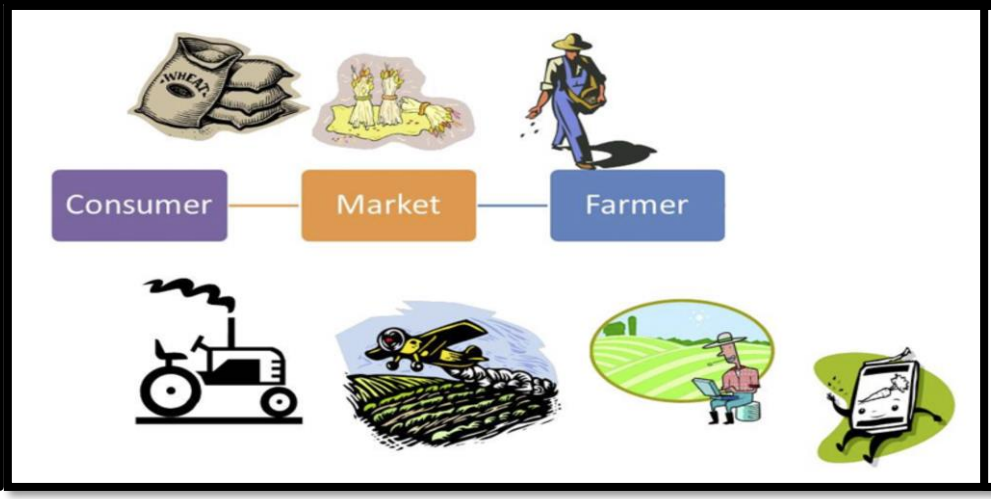
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

Blockchain Technology in A-CPS

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







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

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

Smart Agriculture – Some Challenges

Smart Agriculture – Challenges

Power Availability

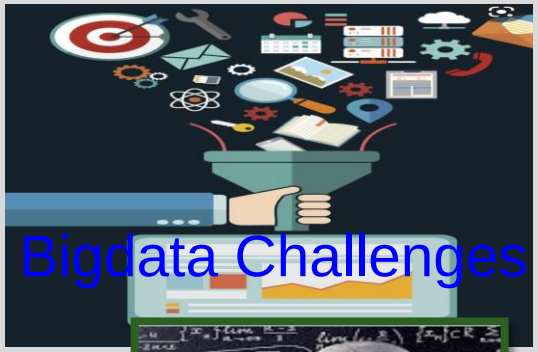
Networking and Communication

Reliability

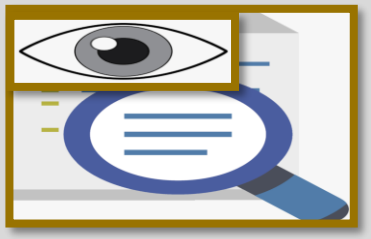
Scalability

Hardware Security

Farmer's Learning Curve



Bigdata Challenges



Data Security and Privacy

Natural Disaster

Technical Malfunction

AI Challenges

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

Learning Curve for Smart Agriculture can be Long

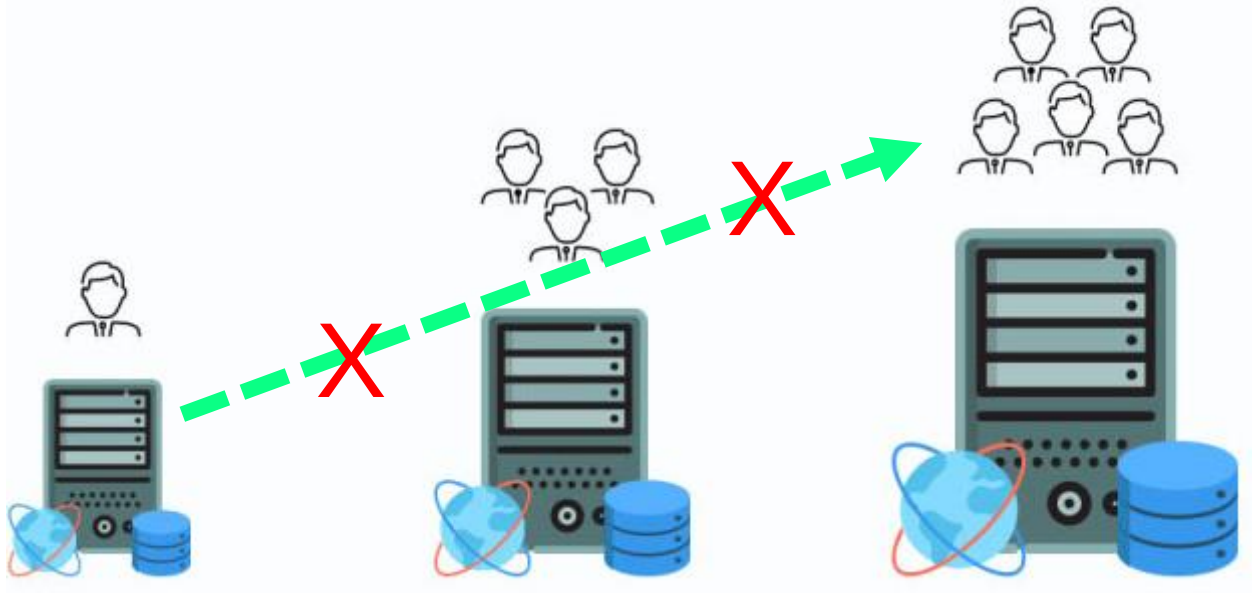
- Smart Agriculture requires setting up of IoT architecture and sensor networks.
- Errors in such setup can lead to drastic losses in the farms.
- Farmers should be thoroughly acquainted with usage of this technology.

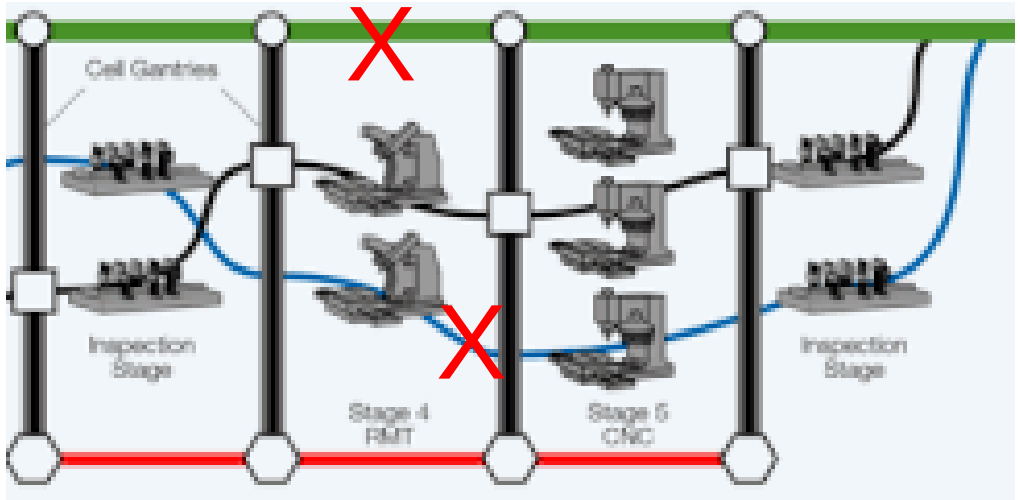
Connectivity can be an Issue in Rural Areas

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

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.

Bigdata in Smart Agriculture

- Millions of IoT devices work in smart agriculture and generate large amounts of data.
- Inferring and extracting information from such large data is impossible and needs efficient data analytics tools.

Bigdata

1. Technical Issues
2. Social Issues

Security Issues in IoAT

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

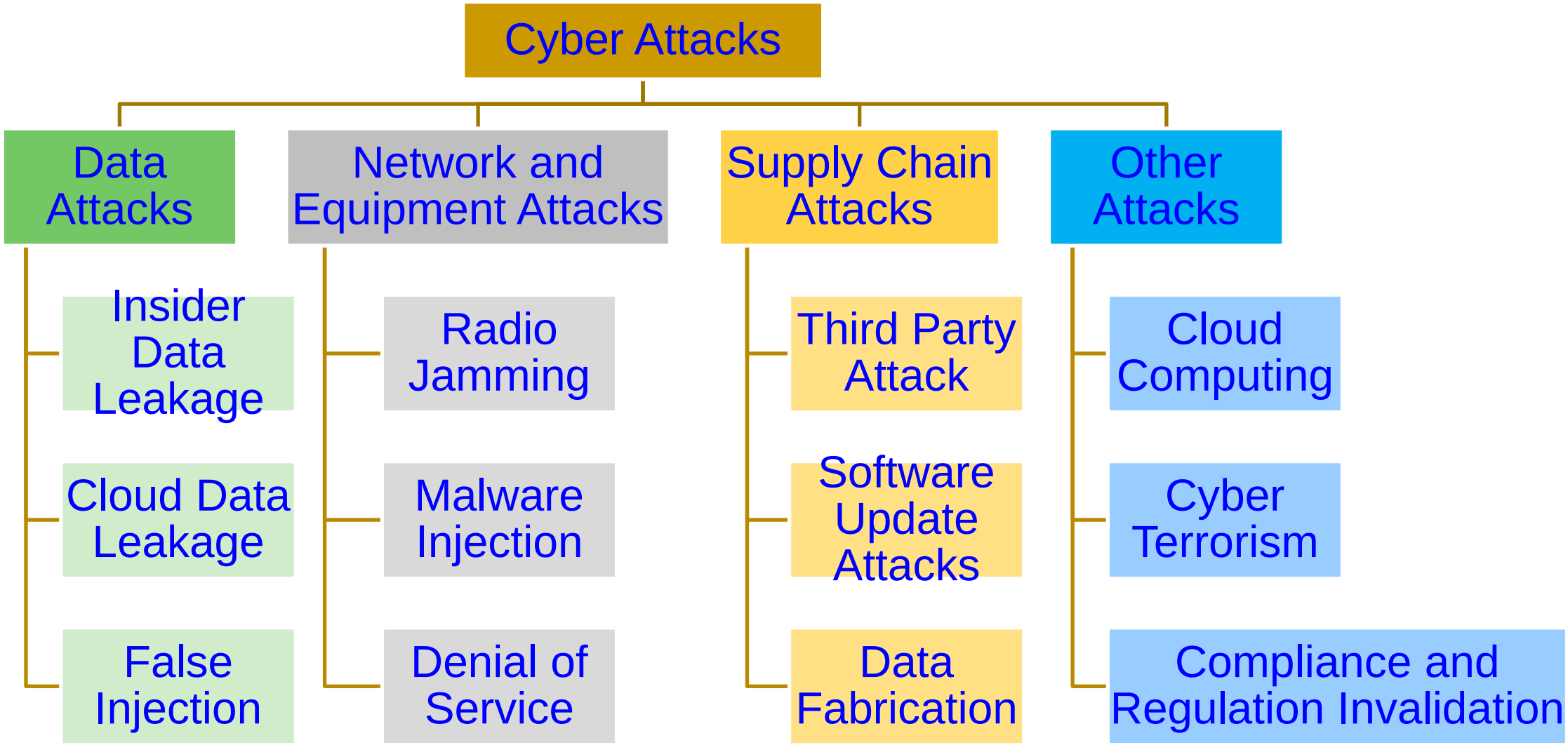
  https://spectrum.ieee.org/cybersecurity-report-how-smart-farming-can-be-hacked

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

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

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

Smart Agriculture - Security Challenges

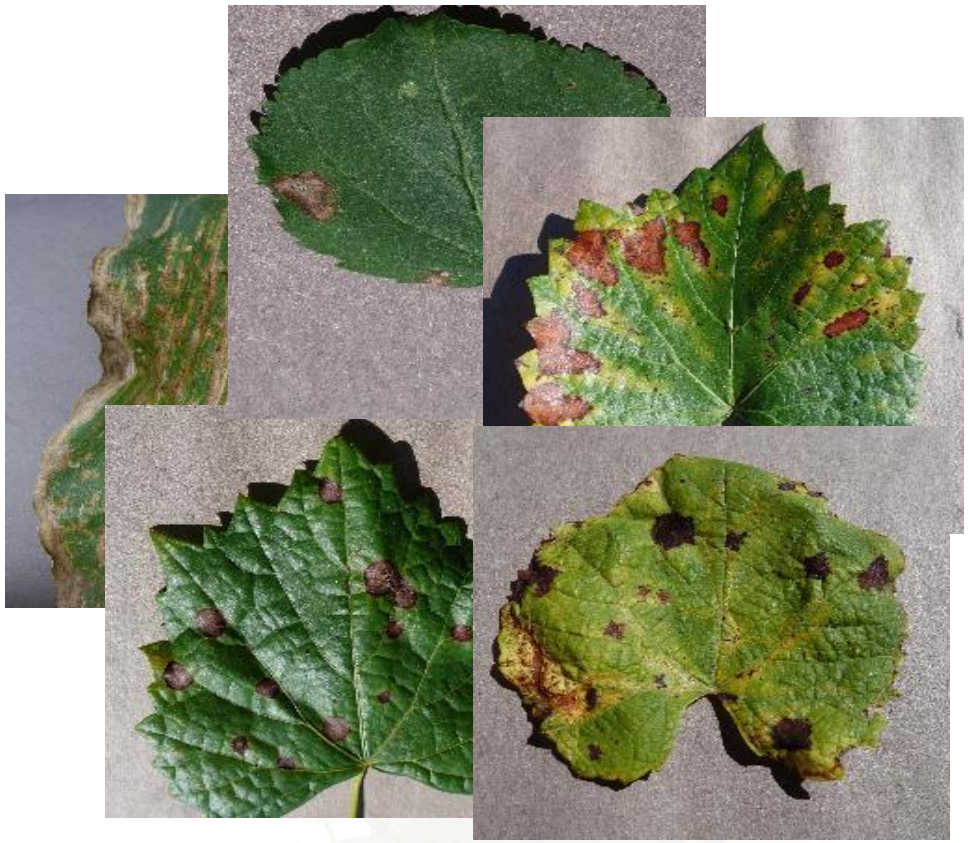


Source: M. Gupta, M. Abdelsalam, S. Khorsandroo and S. Mittal, "Security and Privacy in Smart Farming: Challenges and Opportunities," *IEEE Access*, vol. 8, pp. 34564-34584

Smart Agriculture Case Studies – AI/ML Solutions

Crop Damage and Disease Problem

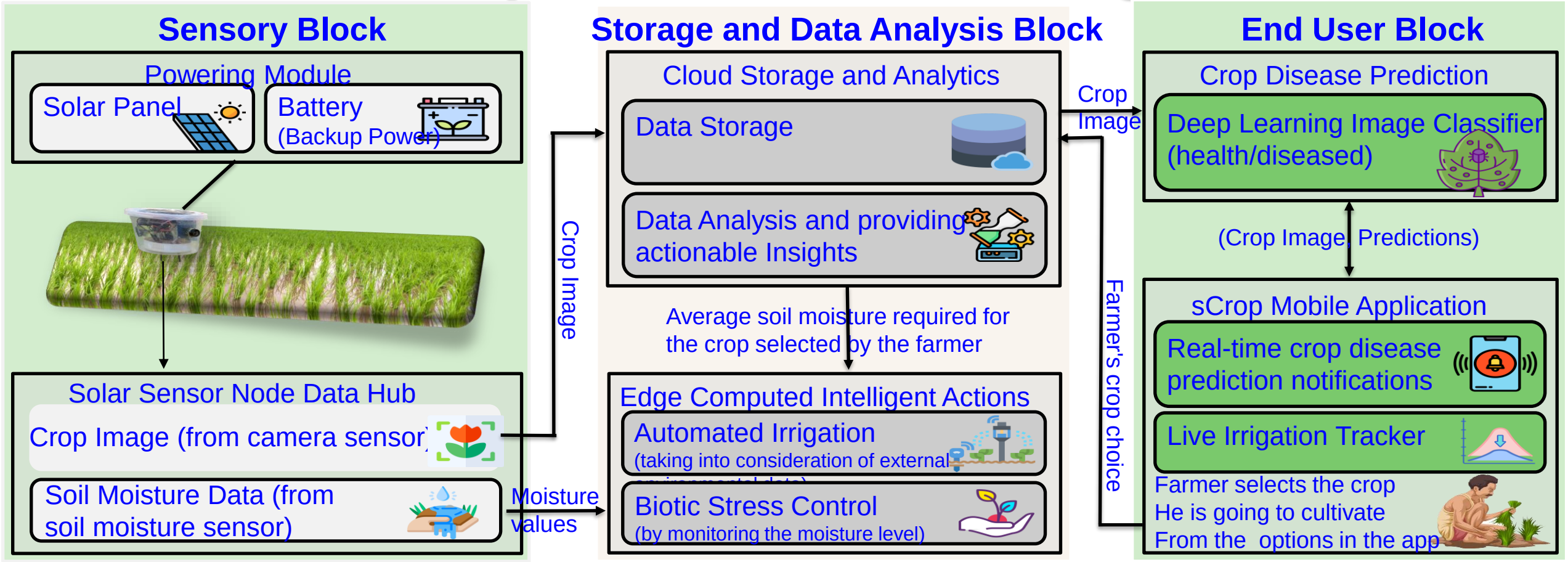
- Disease prevents the growth of plants.
  - Affect quality of the crop.
  - Reduce final yield.



- 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.

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



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

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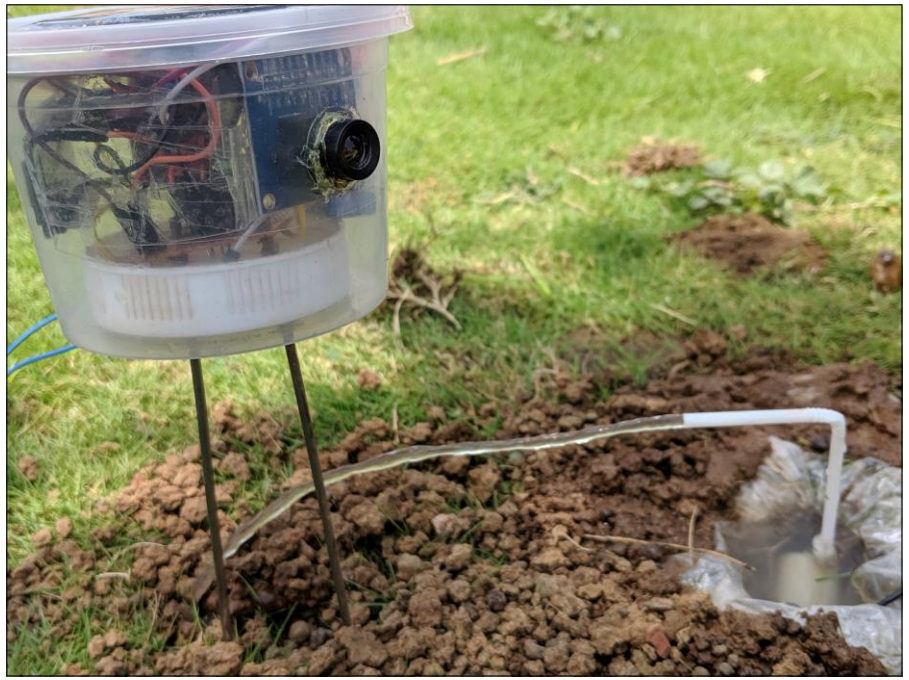
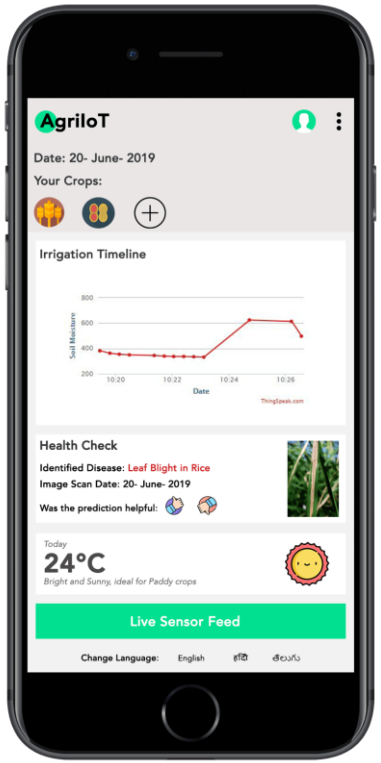


sCrop Device Prototype with Irrigation



sCrop App

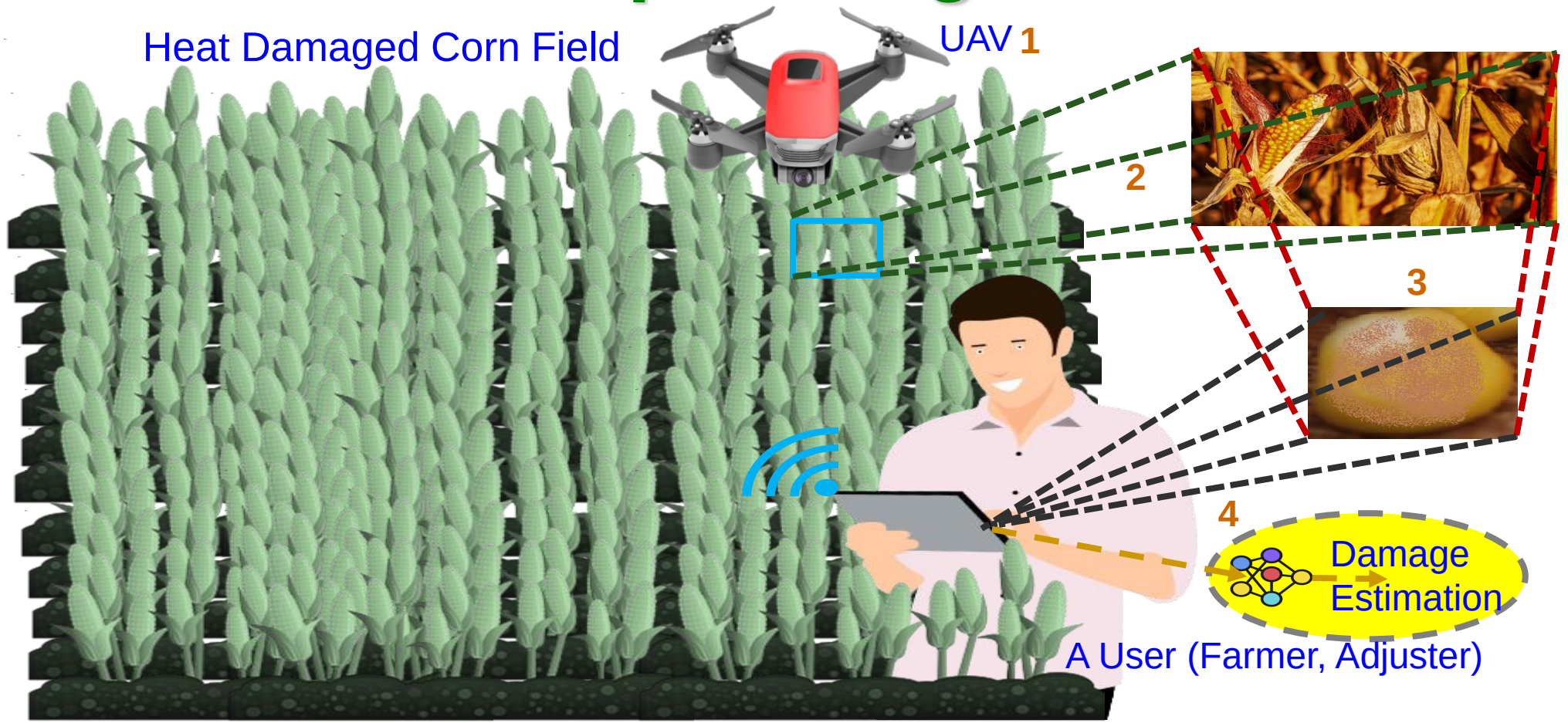
Healthy Tomato

Infected Tomato

sCrop Accuracy – 99.24%

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

Our eCrop: A Framework for Automatic Crop Damage Estimation



1 → UAV takes Photo of Corn Ear

2 → Damage Area Detection of Corn Ear

3 → 50% of Damaged Area Selection

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

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

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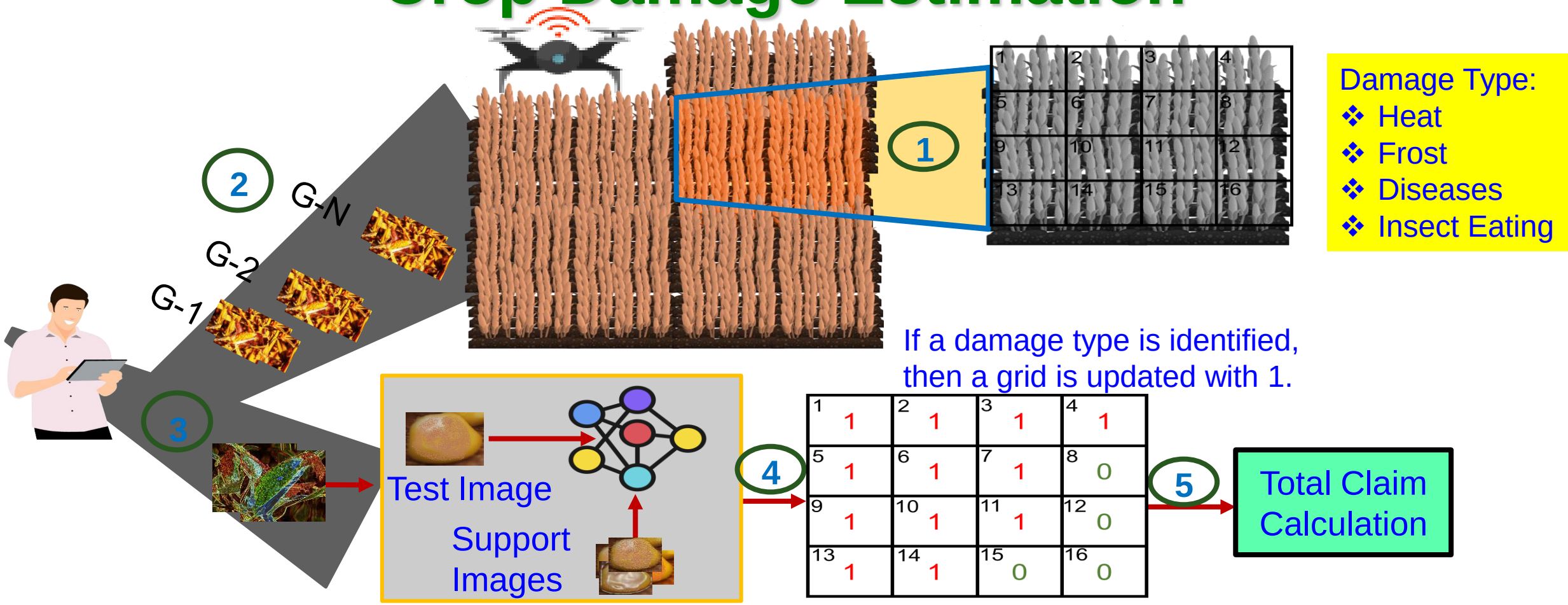

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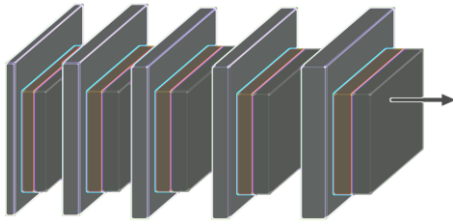
Our aGROdet: A Framework for Plant Disease Detection and Leaf Damage Estimation

- Detect plant diseases.
- Estimate corresponding leaf damage.

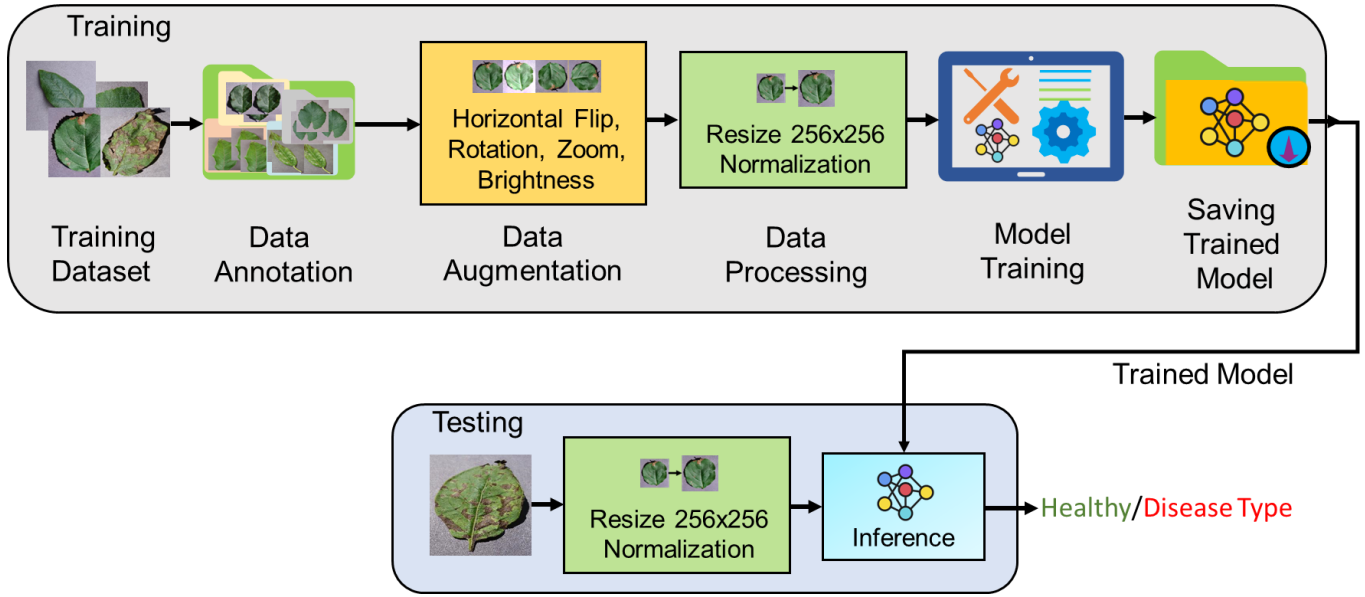
- Identification of the disease -
  - Convolutional neural network-based method.
- Estimation of the severity of leaf damage –
  - Pixel-based thresholding method.



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

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

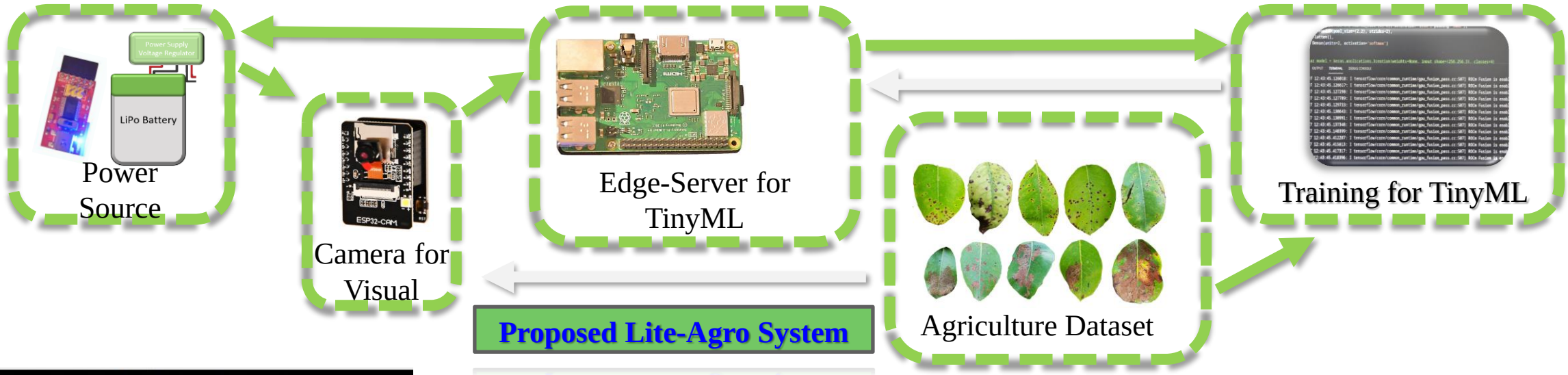
Our aGROdet: Plant Disease Detection



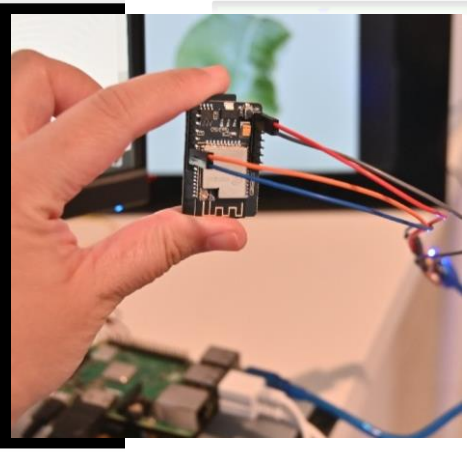
- The augmented and preprocessed data is used for training the network.
- Adam optimizer with an initial learning rate of 0.001.
- Model trained for 75 epochs.
- Model trained with and without a reduced learning rate of factor 0.1.
- Trained model is saved for future inference.
- Model evaluated using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

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

Lite-Agro: Our Light-Duty IoAT-Edge AI



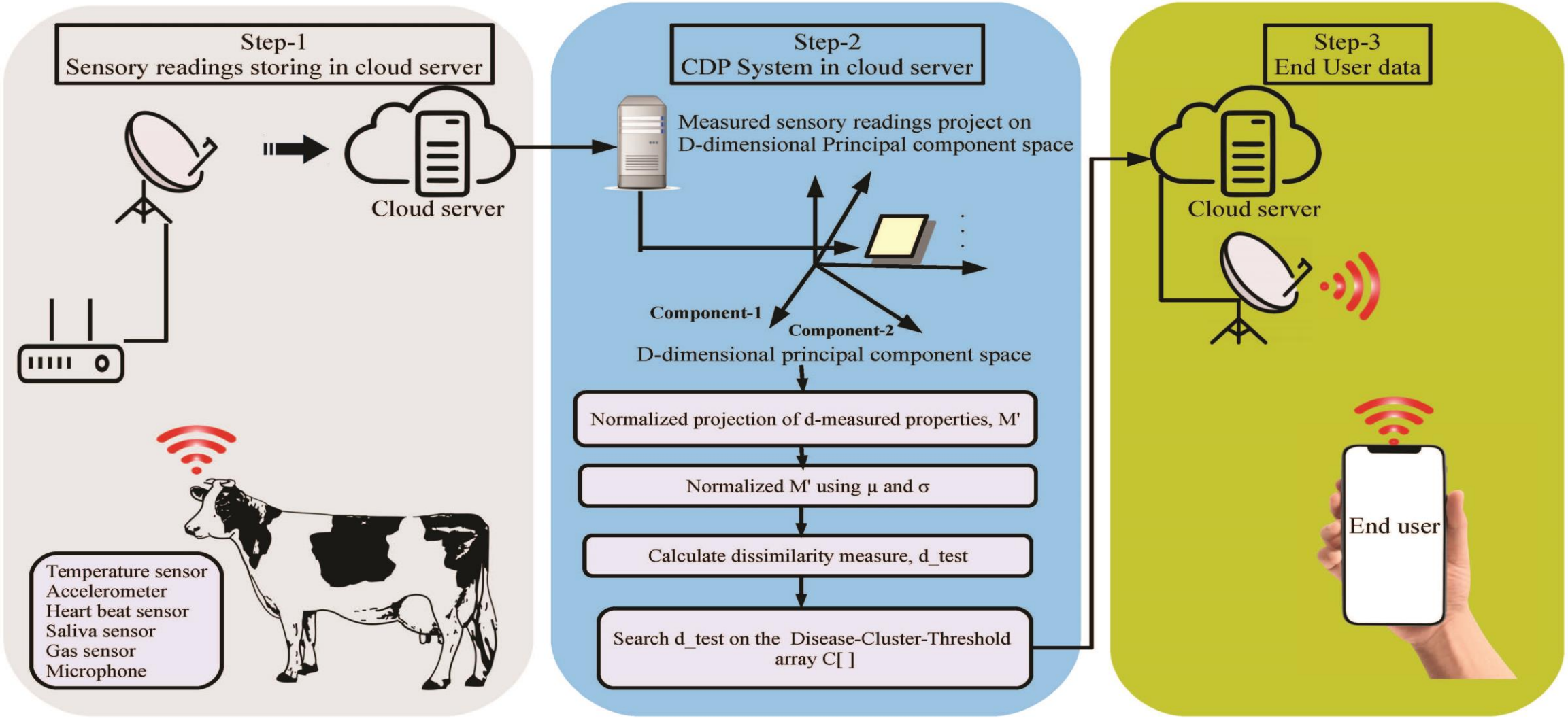

```
healthy score:109 disease score 212
Image Captured

healthy score:119 disease score 205
Image Captured

healthy score:107 disease score 212
Image Captured

healthy score:86 disease score 226
Image Captured

healthy score:107 disease score 213
Image Captured
```



Works	Dataset	Resolution Size	Model	Recognition Accuracy
Yang, et al.	PDD2018	600 x 600	Resnet50	98.7%
Fenu, at al.	DiaMOS	224 x 224	EfficientNetB0 + InceptionV3	91.14%
Lite-Agro	DiaMOS	256 x 256	Xception	99.73%

Source: C. Dockendorf, A. Mitra, **S. P. Mohanty**, and E. Kougianos, "Lite-Agro: Exploring Light-Duty Computing Platforms for IoAT-Edge AI in Plant Disease Identification", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2023, pp. 371--380, DOI: https://doi.org/10.1007/978-3-031-45882-8_25.

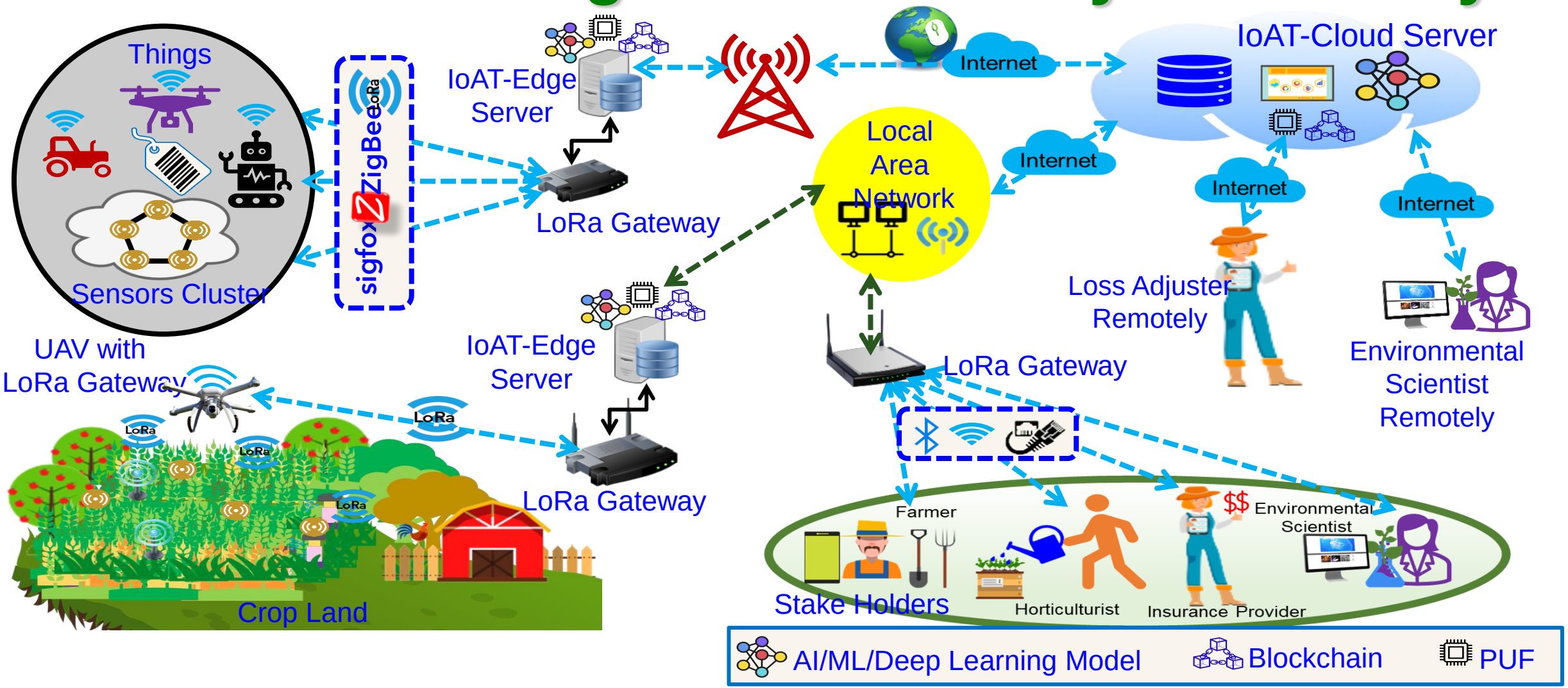
Our LiveCare - IoT-Based Cattle Healthcare Framework



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.

Smart Agriculture Case Studies - Cybersecurity Solutions

A-CPS with Integrated AI and Cybersecurity

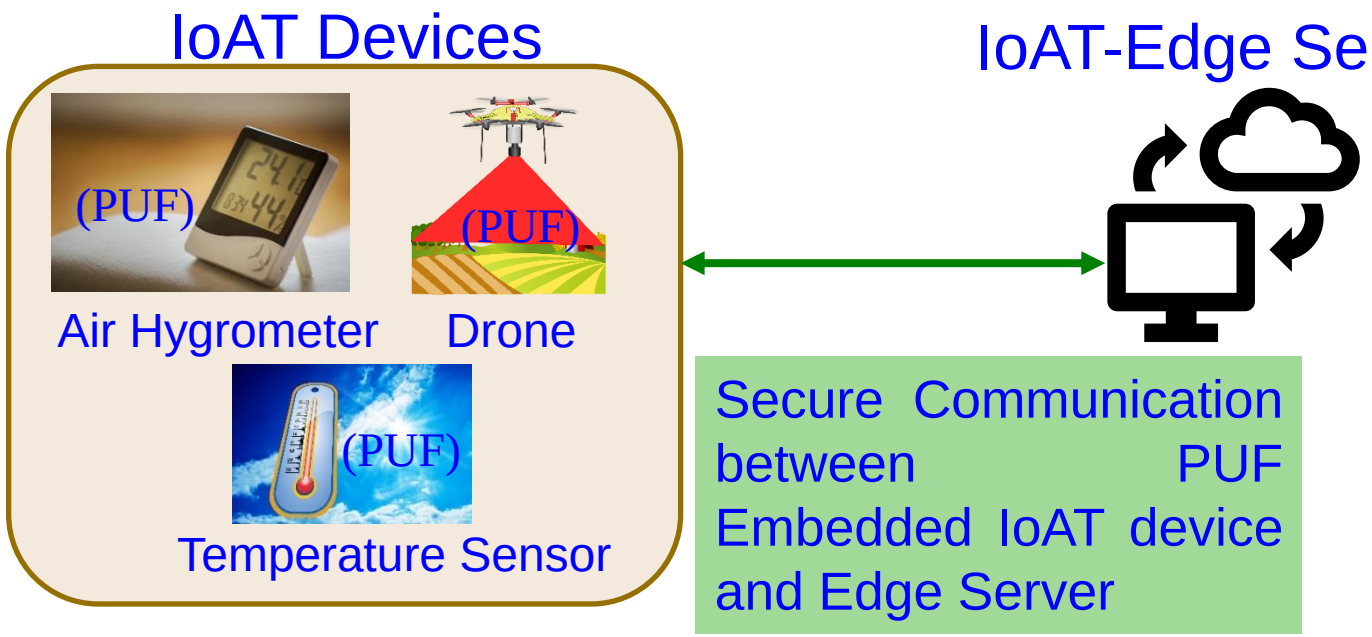


Source: A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, "eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture", *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: https://doi.org/10.1007/s42979-022-01216-8.

Smart Agriculture Cybersecurity - Solutions

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

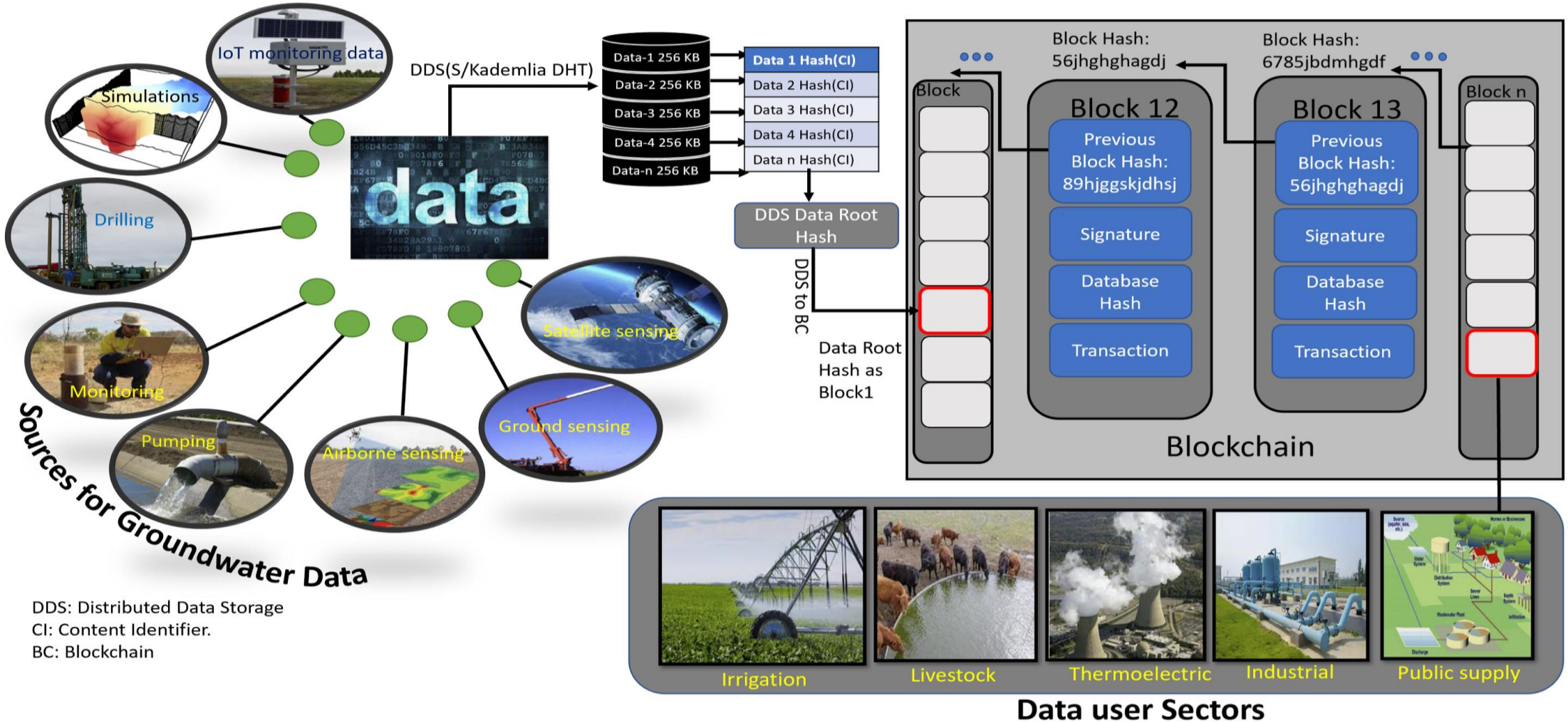
Our Security-by-Design Approach for Robust IoAT



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

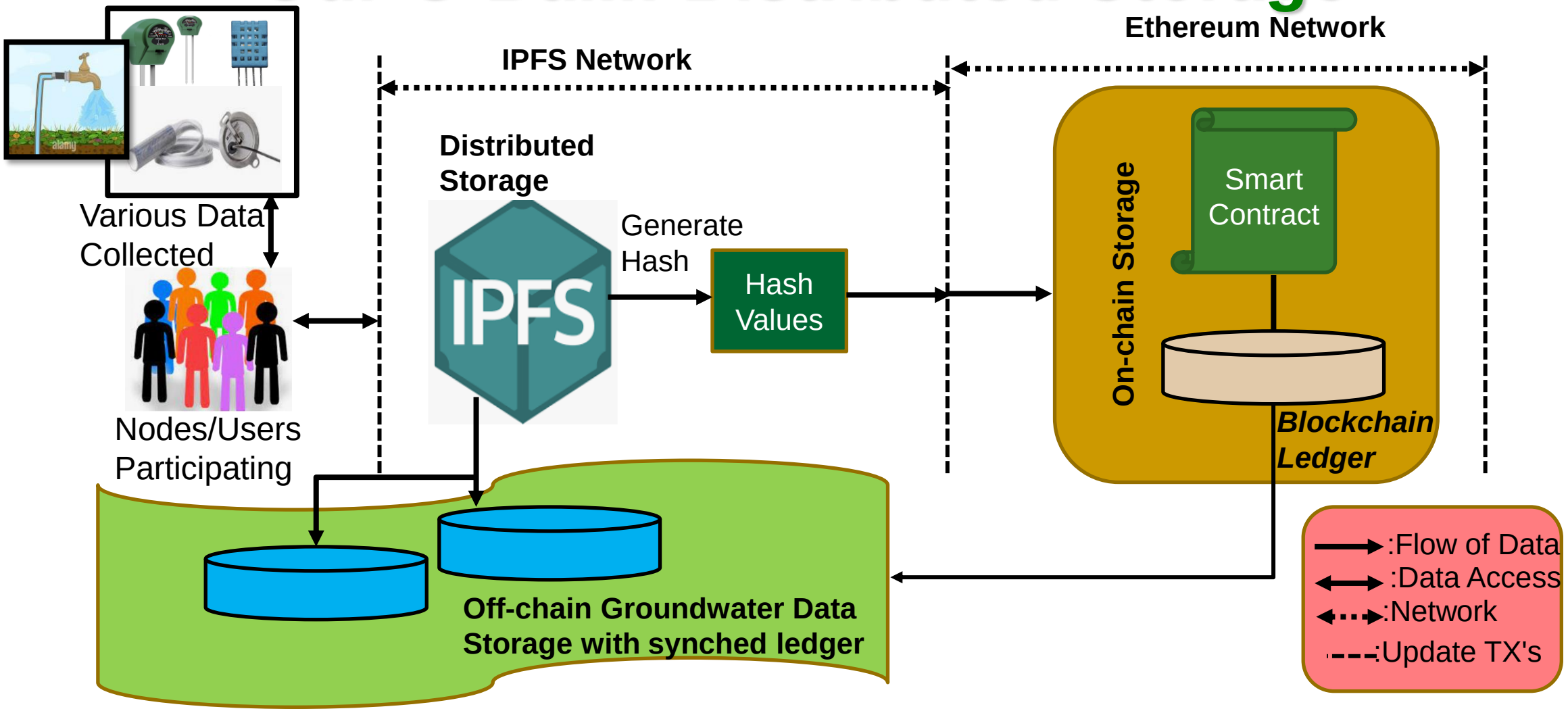
Source: V. K. V. V. Bathalapalli, S. P. Mohanty, E. Kougianos, V. P. Yanambaka, B. K. Baniya and B. Rout, "A PUF-based Approach for Sustainable Cybersecurity in Smart Agriculture," in *Proc. 19th OITS International Conference on Information Technology (OCIT)*, 2021, pp. 375-380, doi: 10.1109/OCIT53463.2021.00080.

Our G-DaM: Proposed Architecture



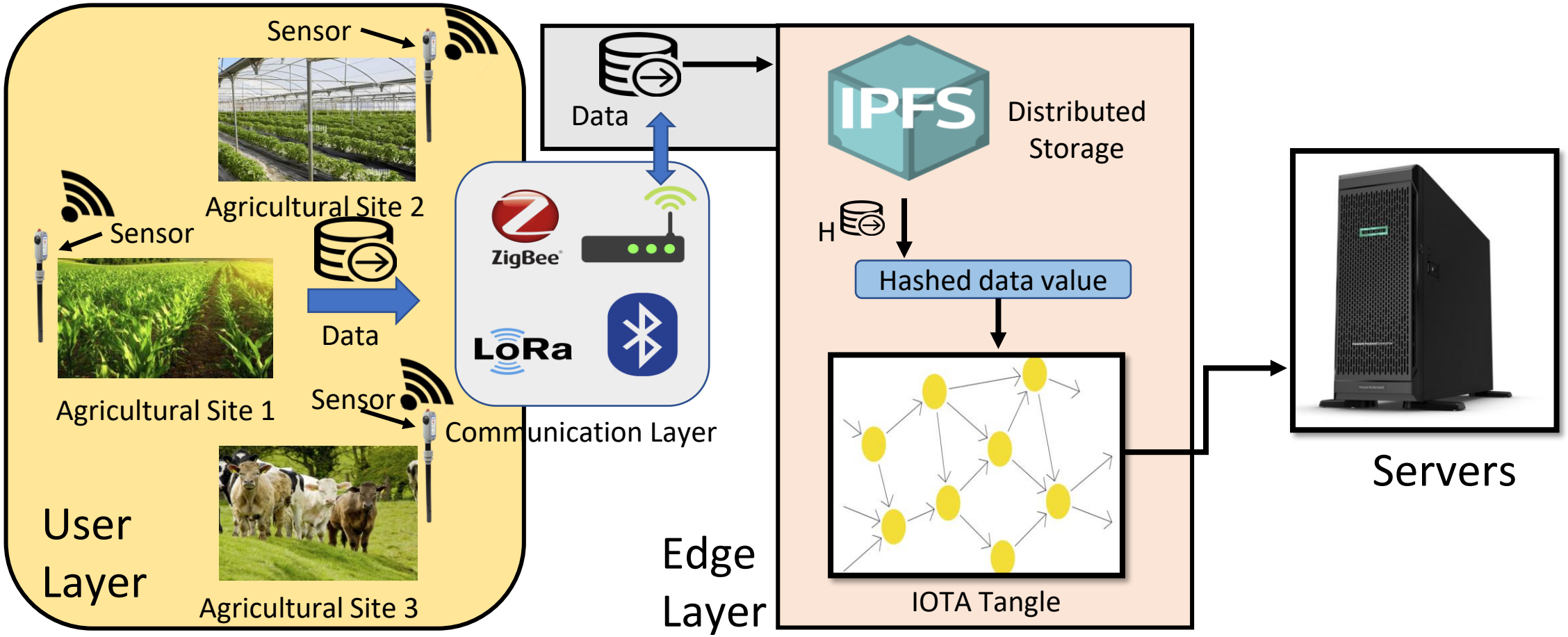
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

Our G-DaM: Distributed Storage



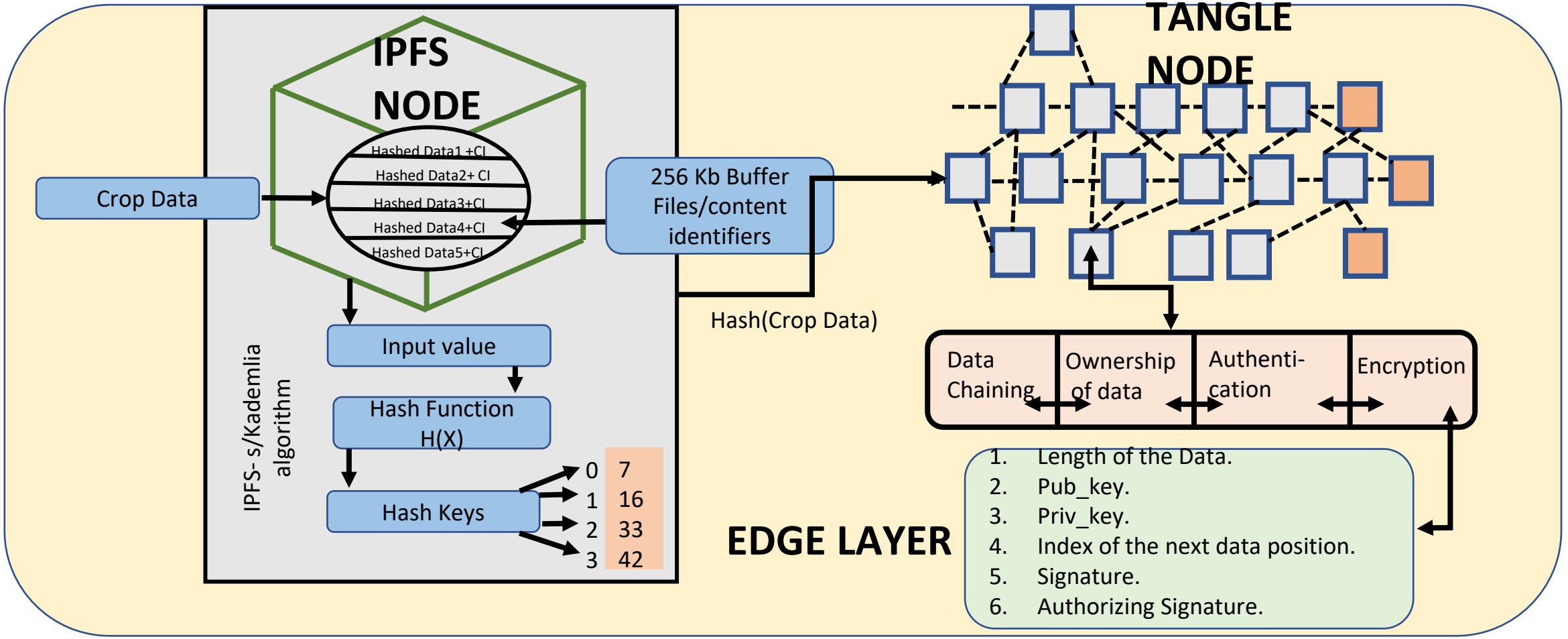
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

CroPAiD: Our Novel Framework for Protection of Information in A-CPS



Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "CroPAiD: Protection of Information in Agriculture Cyber-Physical Systems Using Distributed Storage and Ledger", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2023, pp. 375--394, DOI: https://doi.org/10.1007/978-3-031-45878-1_26.

CroPAiD: Our Novel Framework for Protection of Information in A-CPS



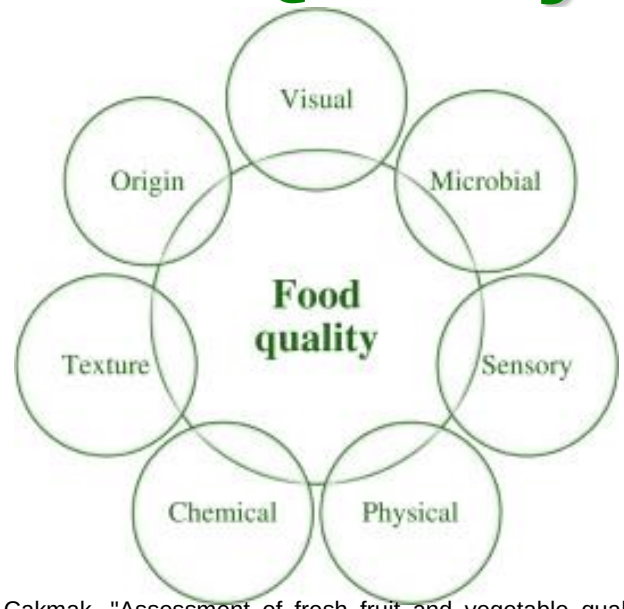
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "CroPAiD: Protection of Information in Agriculture Cyber-Physical Systems Using Distributed Storage and Ledger", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2023, pp. 375--394, DOI: https://doi.org/10.1007/978-3-031-45878-1_26.

Food Safety and Quality

Fruit and Vegetable Safety and Quality?

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

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



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

Am I really eating
what I think I am eating?

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

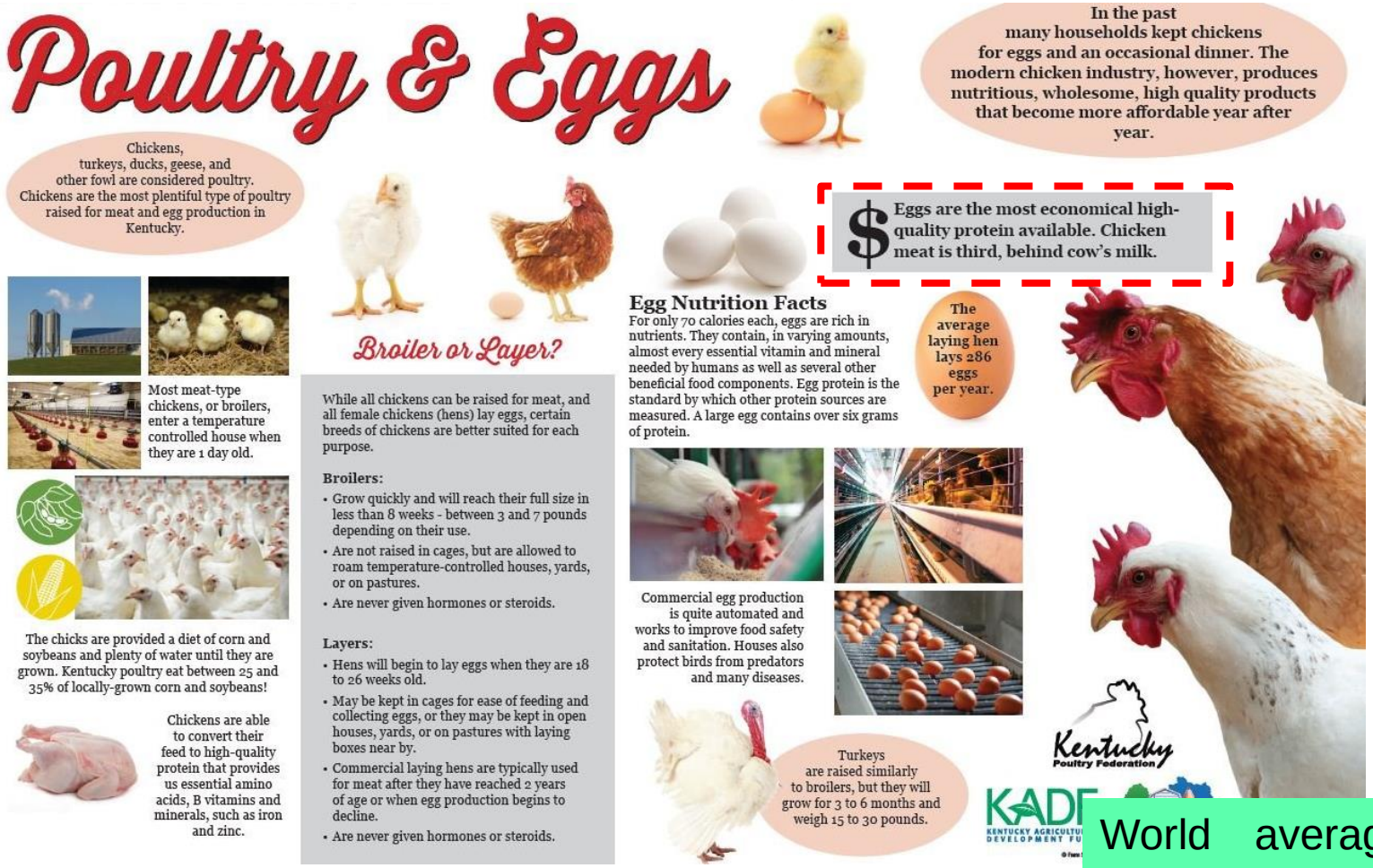
Fish Safety and Quality?

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

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

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

Poultry Safety and Quality?



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

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

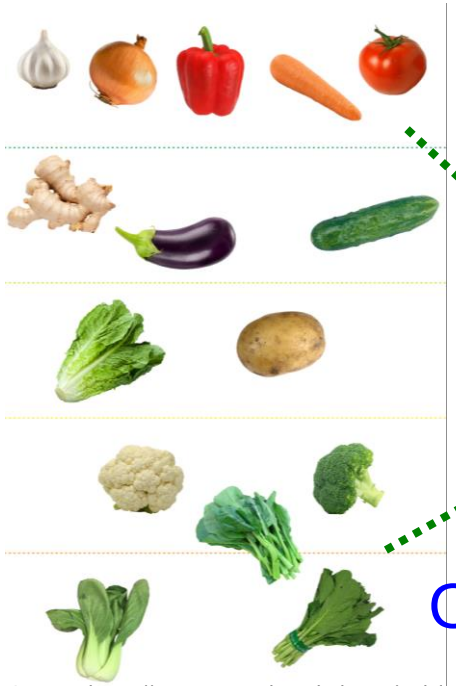
Is this Egg safe to use?

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

Is this Chicken Meat safe to eat?

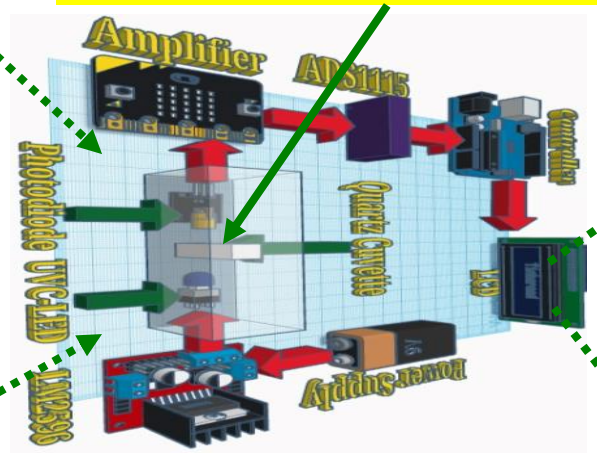
World average consumption per person per year: 161 eggs (2018 data)

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



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

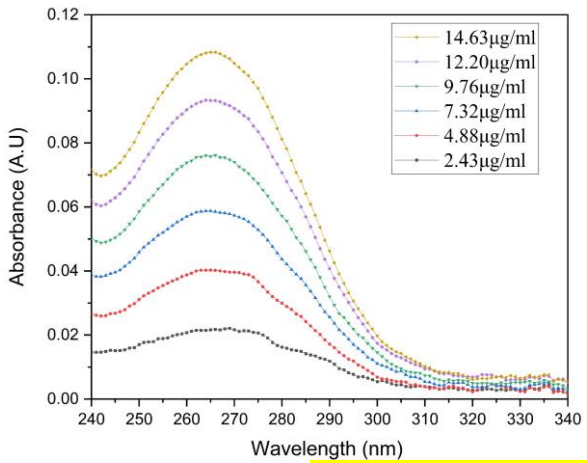
Quartz cuvettes of length 10mm for sample solution.



Our Food-Care Device

Contamination Level
- Acceptable
- Moderate
- Severe
- Dangerous

Peak absorbance spectrum of 265nm at different nitrate concentrations.



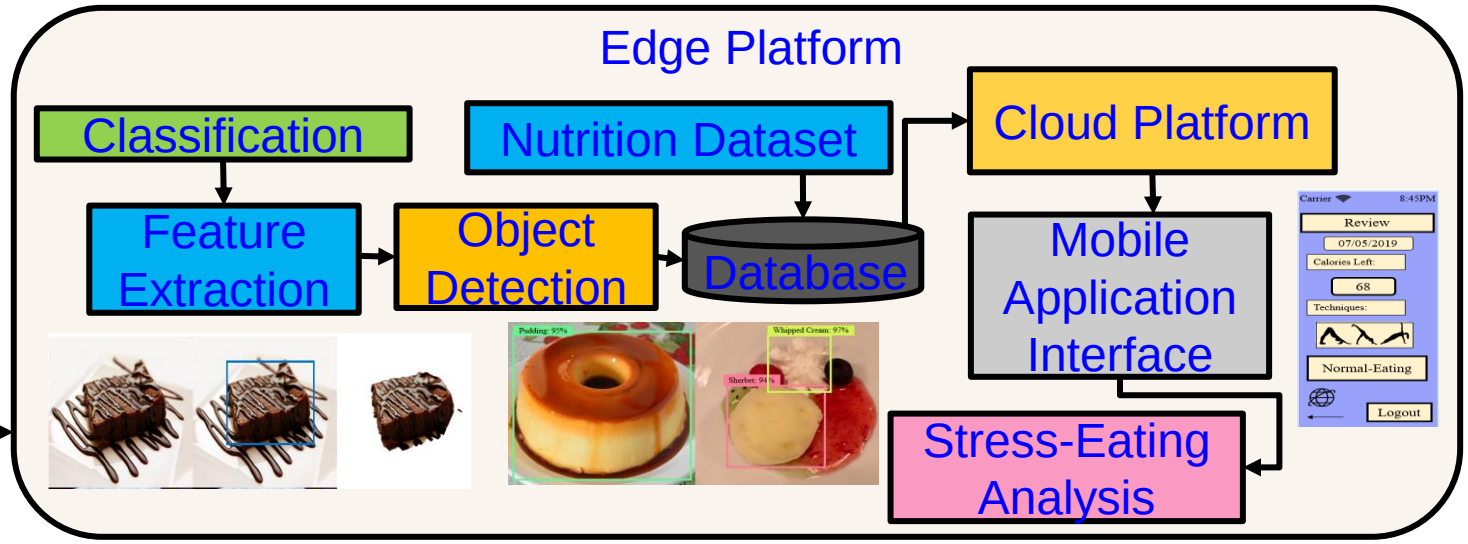
Need for Device which is:
- ✓ Portable
- ✓ Works with dry or wet samples
- ✓ User safe
- ✓ Accurate
- ✓ IoT-Enable

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.

Smart Healthcare – Diet Monitoring - iLog

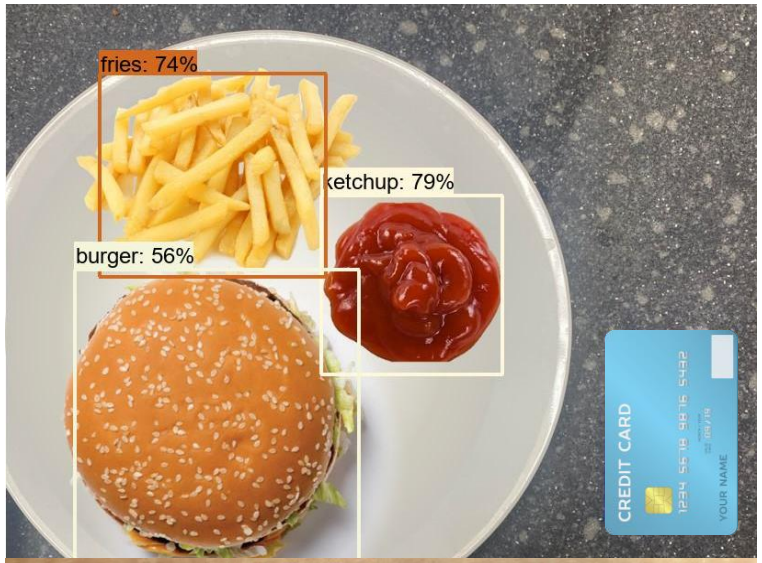
Reference Image



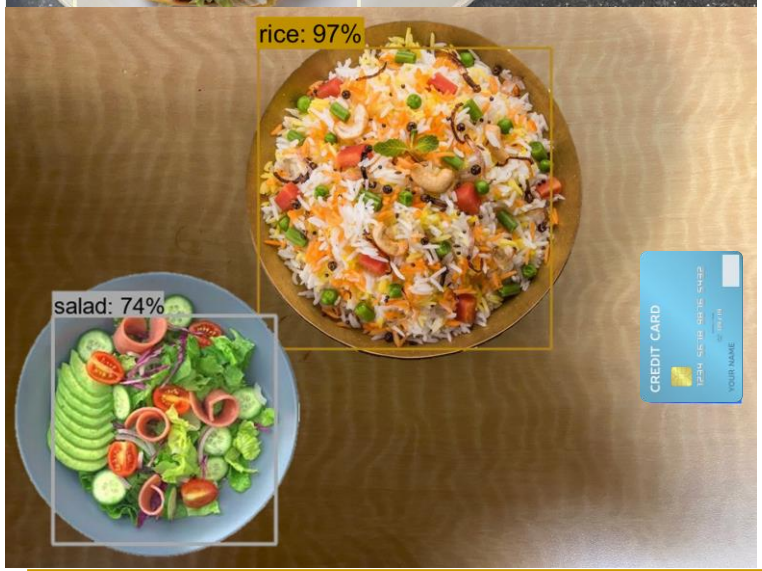
iLog- Fully Automated Detection System with 98% accuracy.

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

Smart Healthcare - Diet Monitoring - iLog 2.0



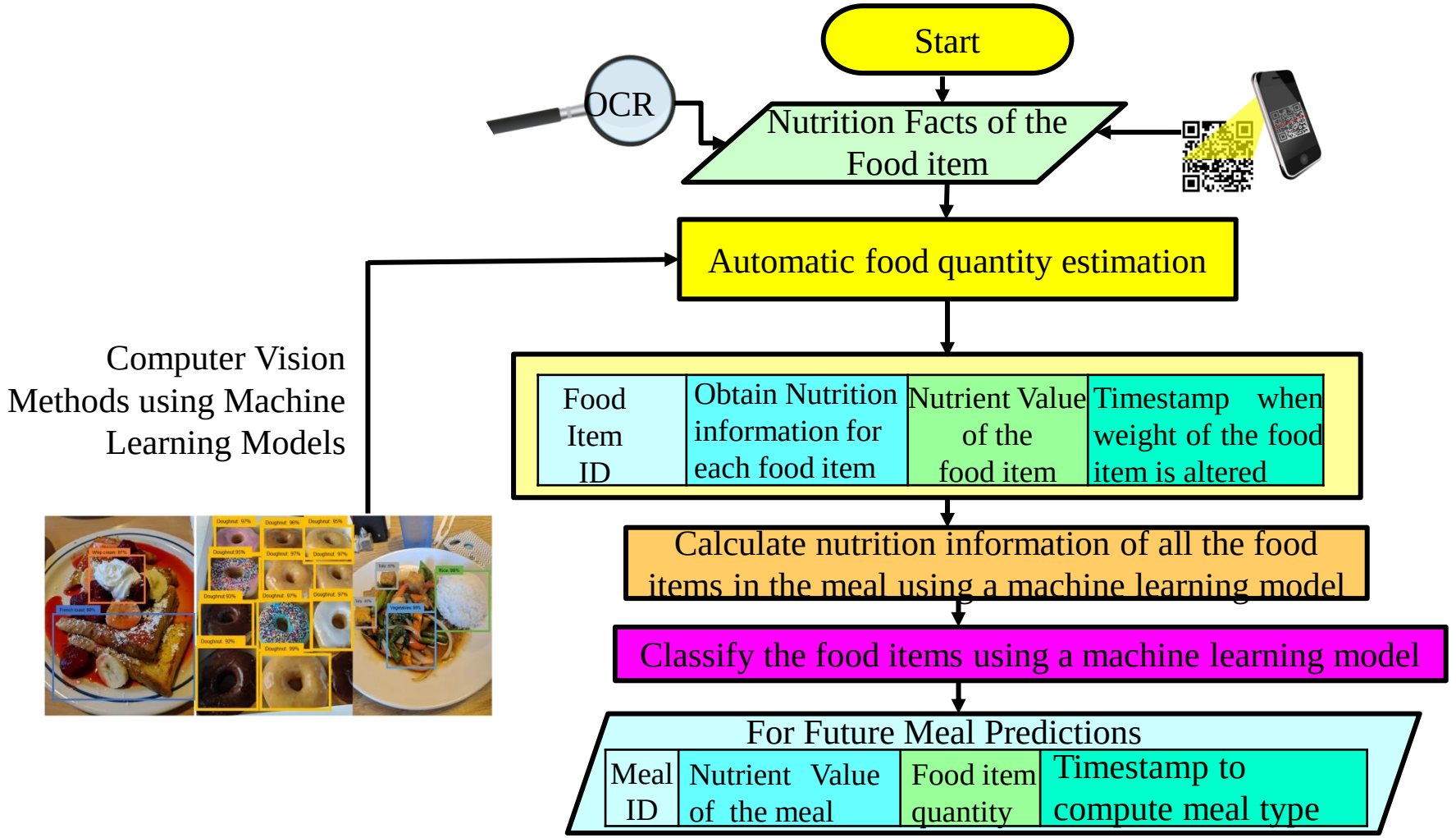
Food Item	Saturated Fat (g)	Sugar (g)	Sodium (mg)	Protein (g)	Carbohydrates (g)
Fries	6.44	1.56	244	4.03	34.84
Burger	6.87	4.67	481	17.29	48.14
Ketchup	0	3.2	136	0.2	4.13
Total	13.31	9.43	861	21.52	87.11



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

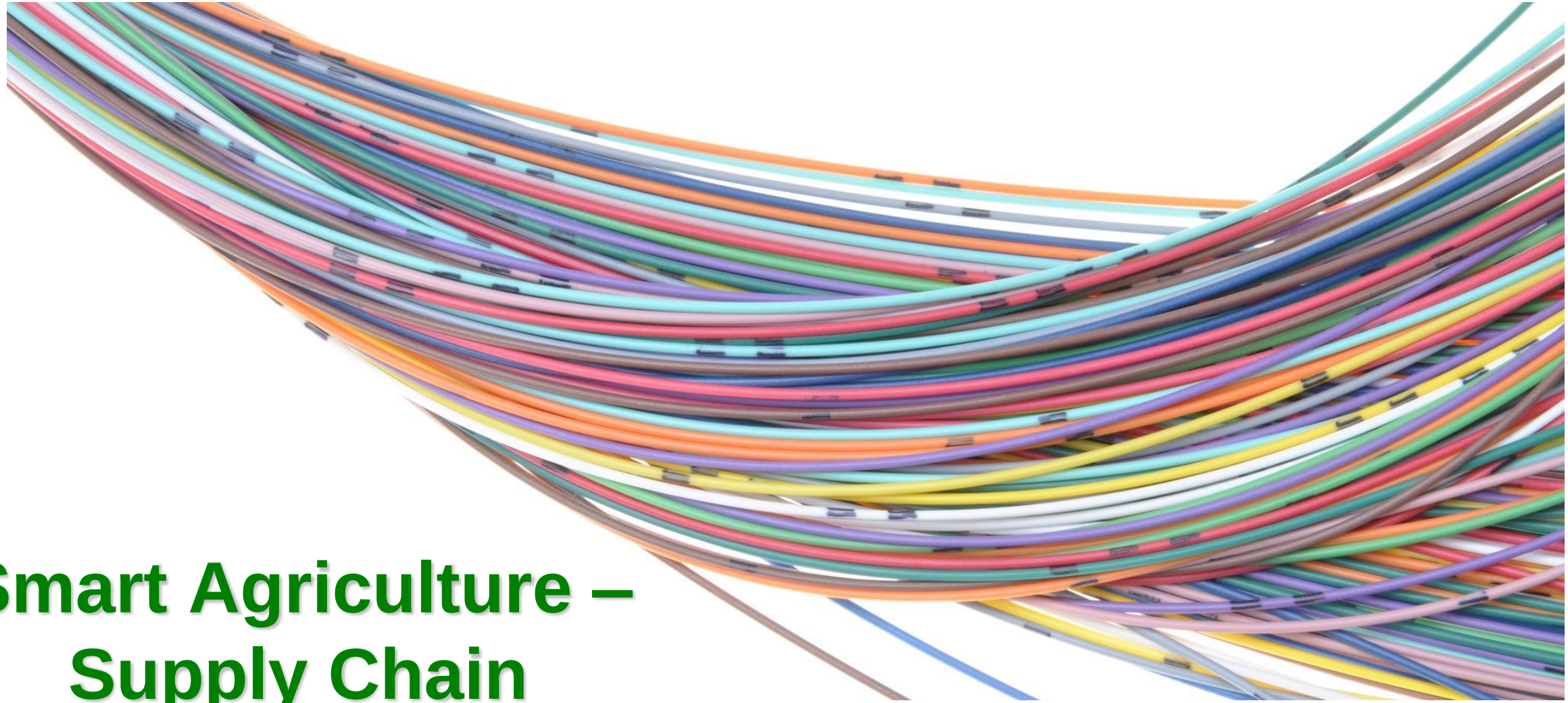
Source: A. Mitra, S. Goel, **S. P. Mohanty**, E. Kougianos, and L. Rachakonda, "iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare", in *Proceedings of the IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted.

Smart Healthcare – Diet Prediction – Smart-Log



Smart-Log Prediction Accuracy - 98.6%

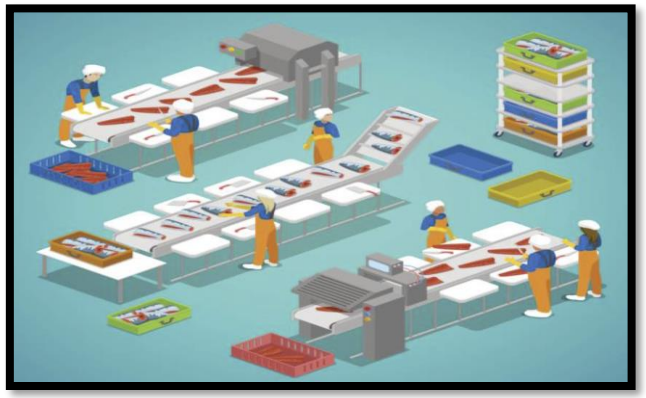
Source: P. Sundaravadivel, K. Kesavan, L. Kesavan, **S. P. Mohanty**, and E. Kougianos, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 64, Issue 3, Aug 2018, pp. 390-398.



Smart Agriculture – Supply Chain

Stages in Agricultural Product Distribution

Storage



Packing and Processing

Transportation

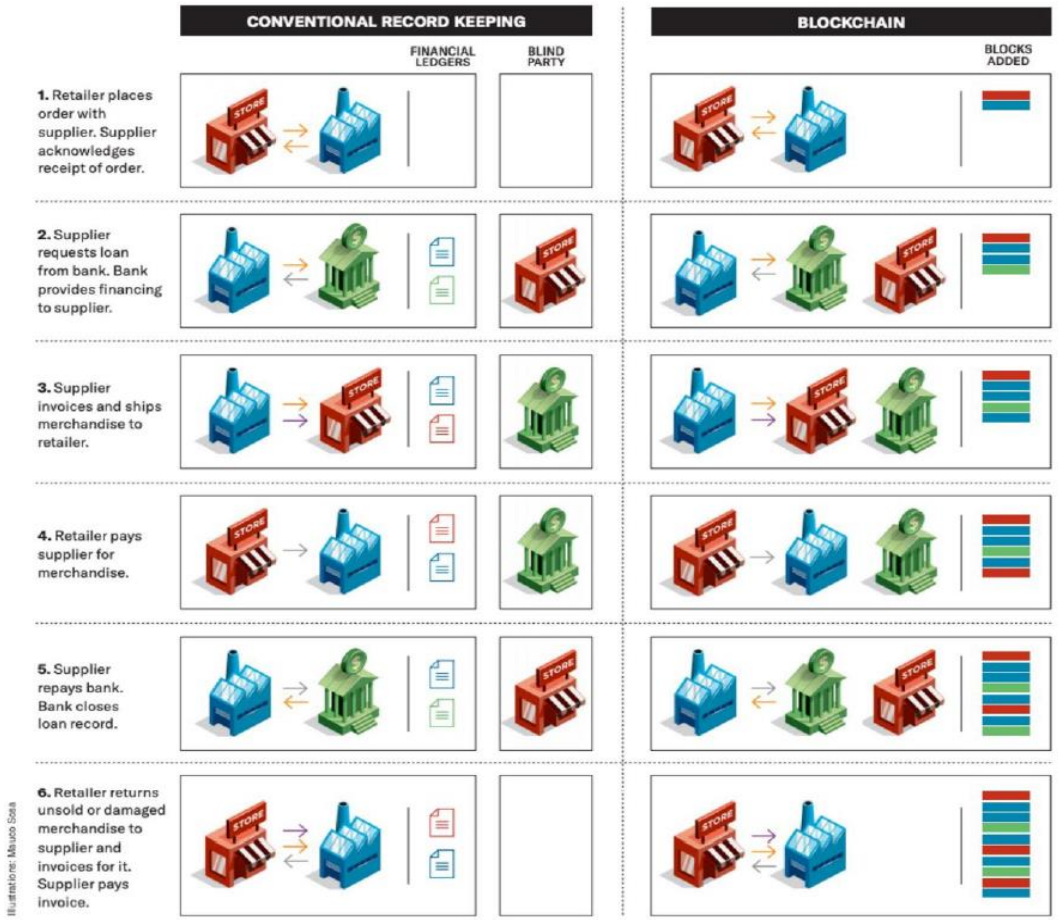
Produce

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

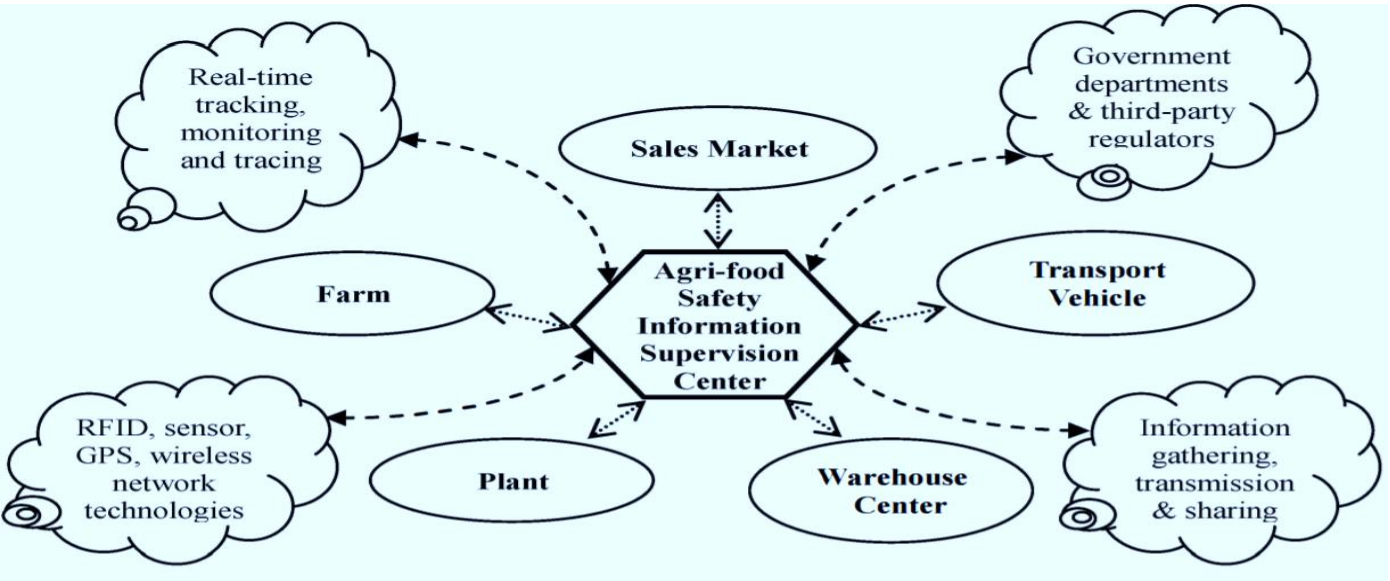
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

Transparent Supply Chain

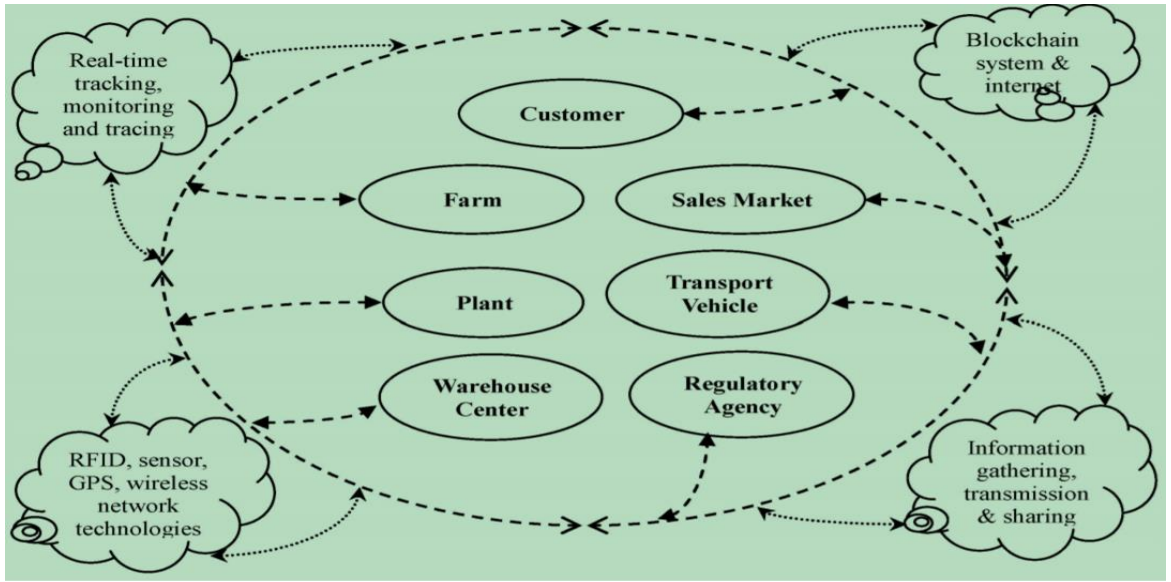
- Execution errors – like mistakes in inventory data, Missing shipments and duplicate payments are difficult to detect in real-time.
- For companies with large number of transactions each day, it is difficult to assess and fix these issues.



Food Traceability Using Efficient Supply Chain



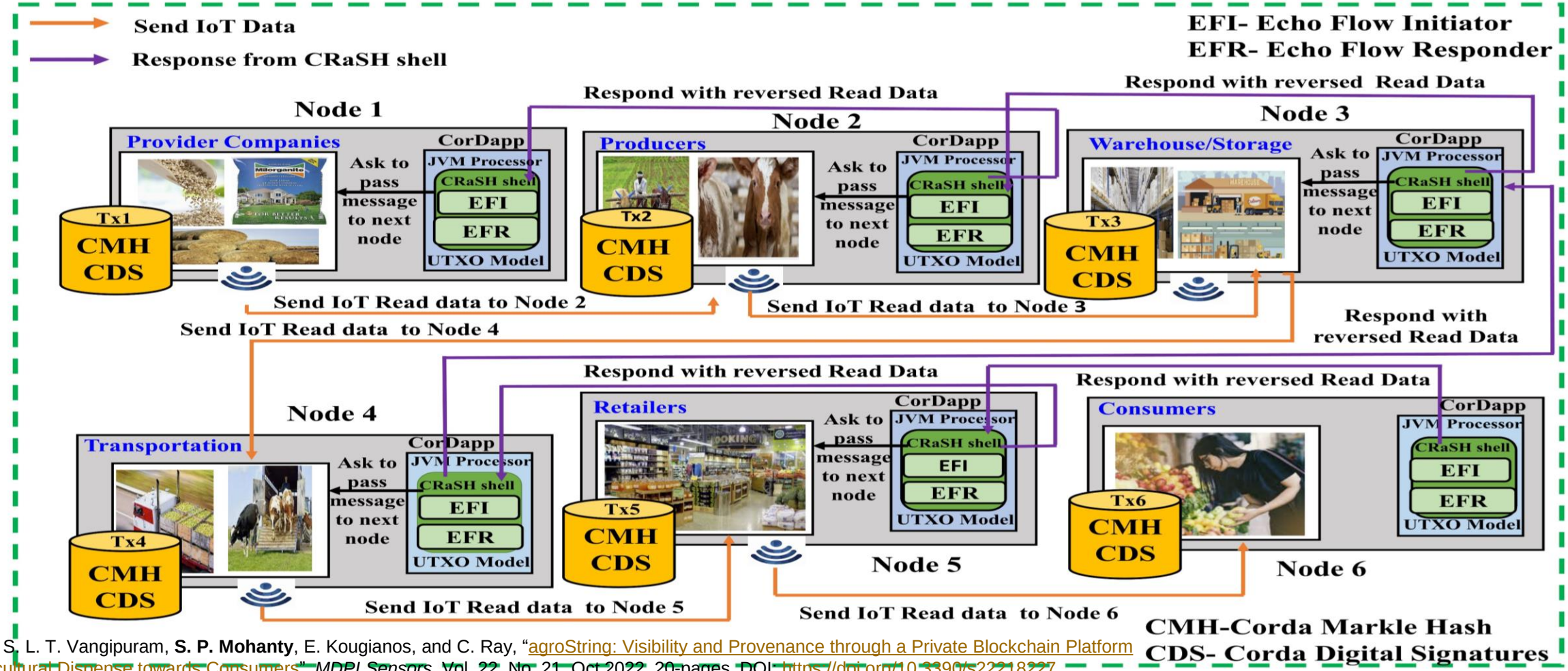
Centralized System



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.

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

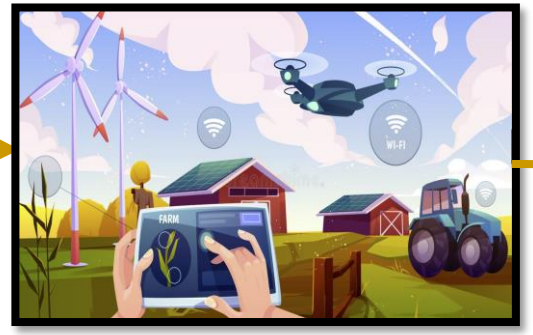


Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

Is there a Reward for Doing Great Job in Farming?

Impact of Agriculture Finance on Farm Yield

Value Chain Financing



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

- Increased crop production
- Income is Increased

Agricultural Finance

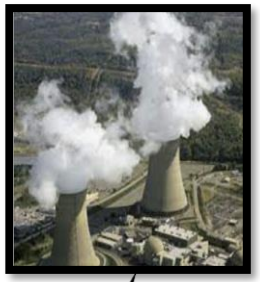
Direct Financing

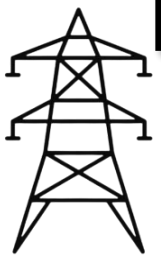
- Use of Traditional Tools
- Separation from the financial Services
- Isolation from financing

- Decreased crop production
- Low Yield
- Reduced Income

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

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





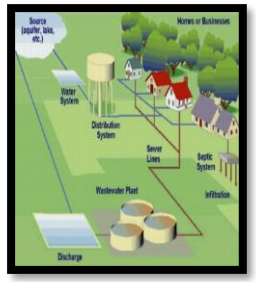
Electricity

Water

Wastage reasons

Climate Change

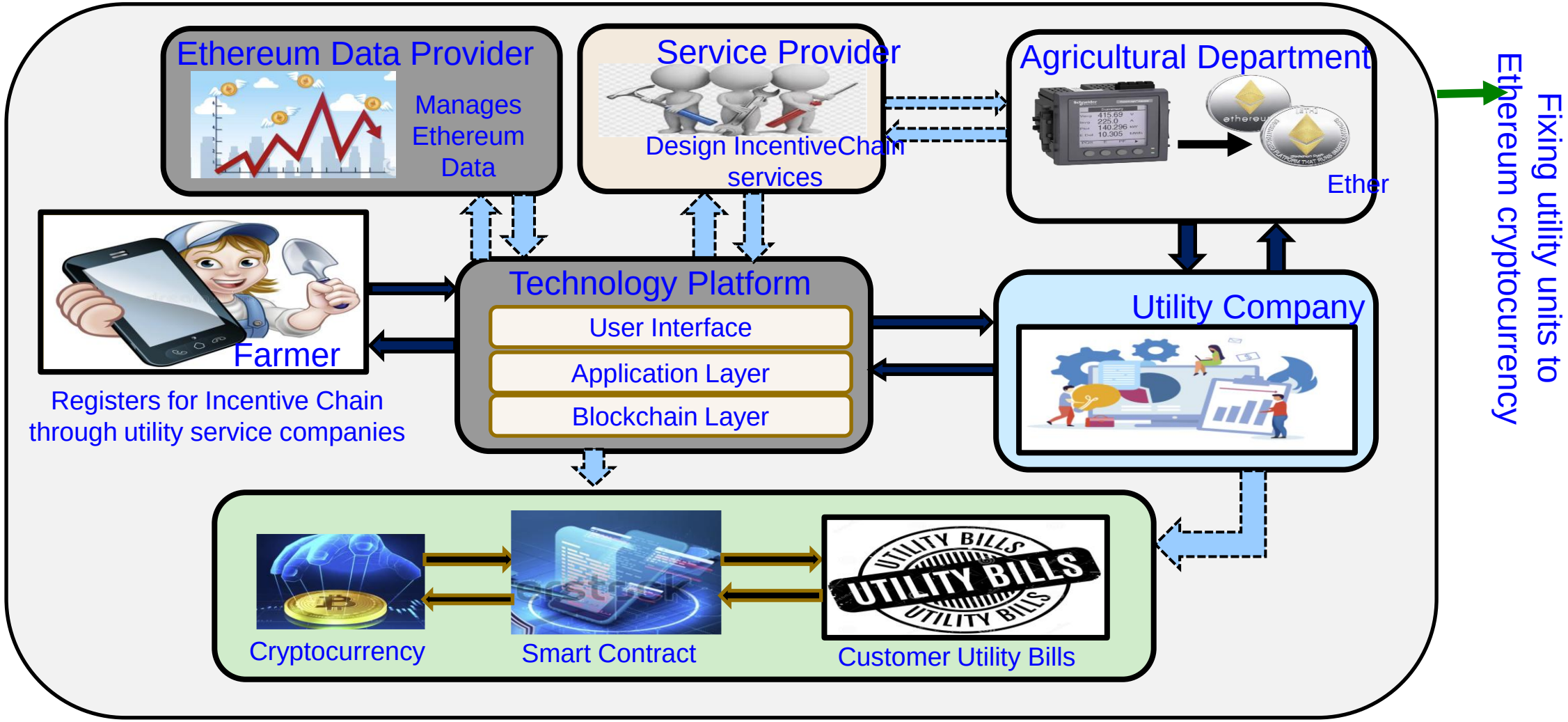
Overpopulation



- Water and Energy use in different domains.
- Present Scenario: Electricity and 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.

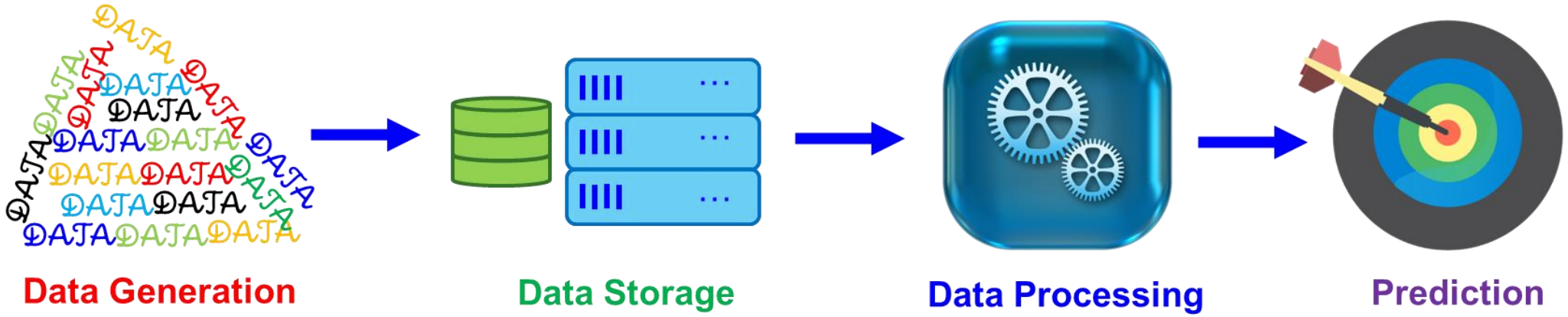
Our IncentiveChain: Architecture

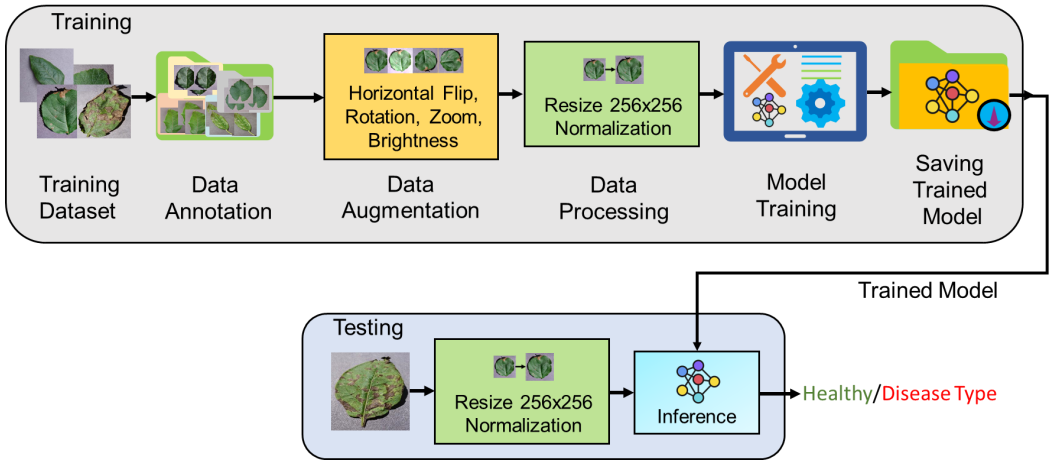


Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

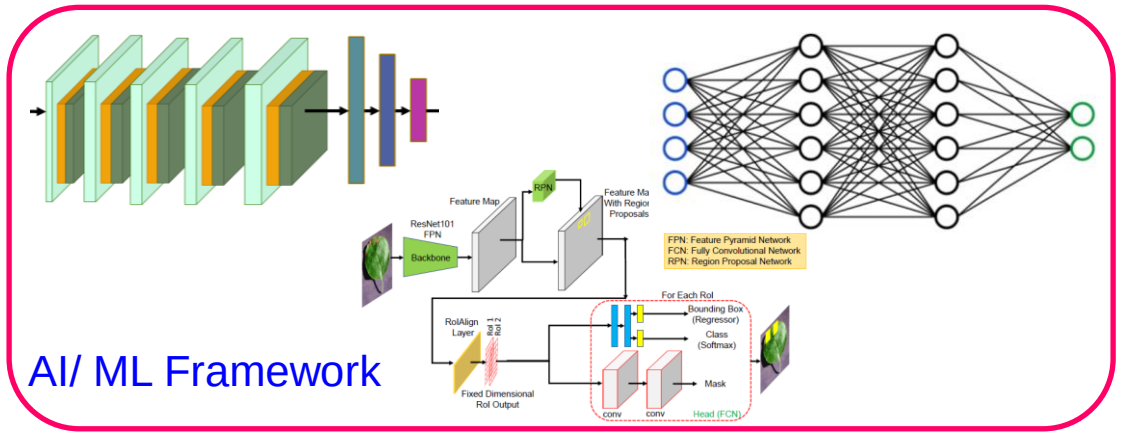
Smart Agriculture and Federated Learning

Smart Agriculture – AI/ML Workflow

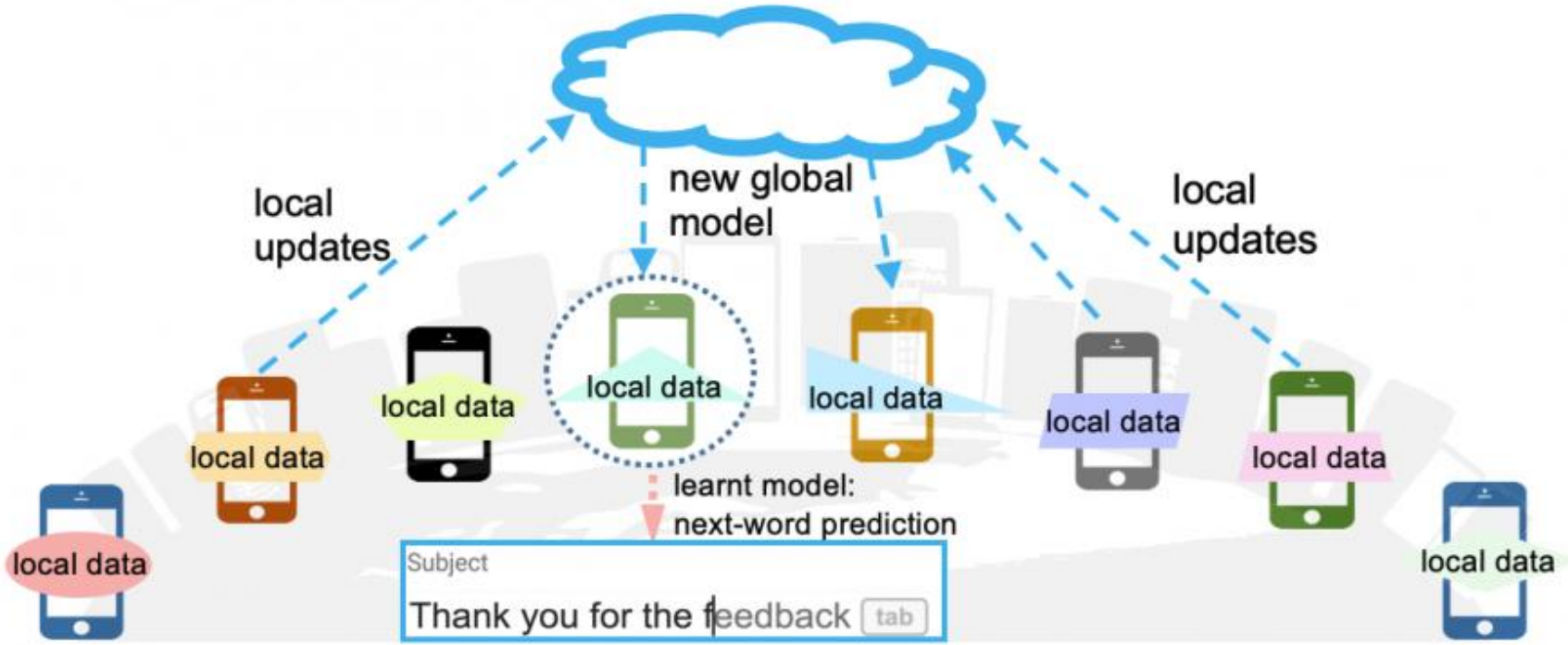




[Source: Alakananda Mitra, "Machine Learning Methods for Data Quality Aspects in Edge Computing Platforms," PhD Dissertation, UNT, 2022.]



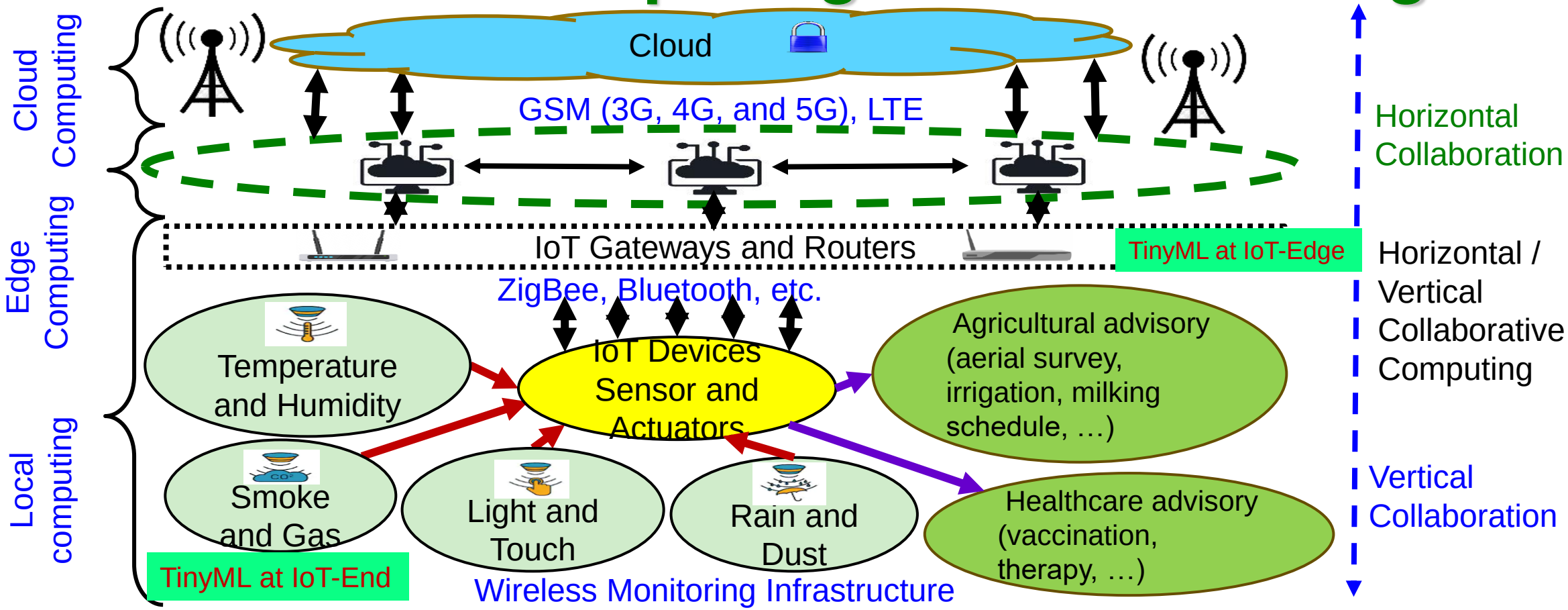
Motivation of Federated Learning (FL)



- Quality data exists at different location on various edge devices.
- Data privacy laws control the movement of data.
- FL is the way to provide ML solution without breaking privacy laws.

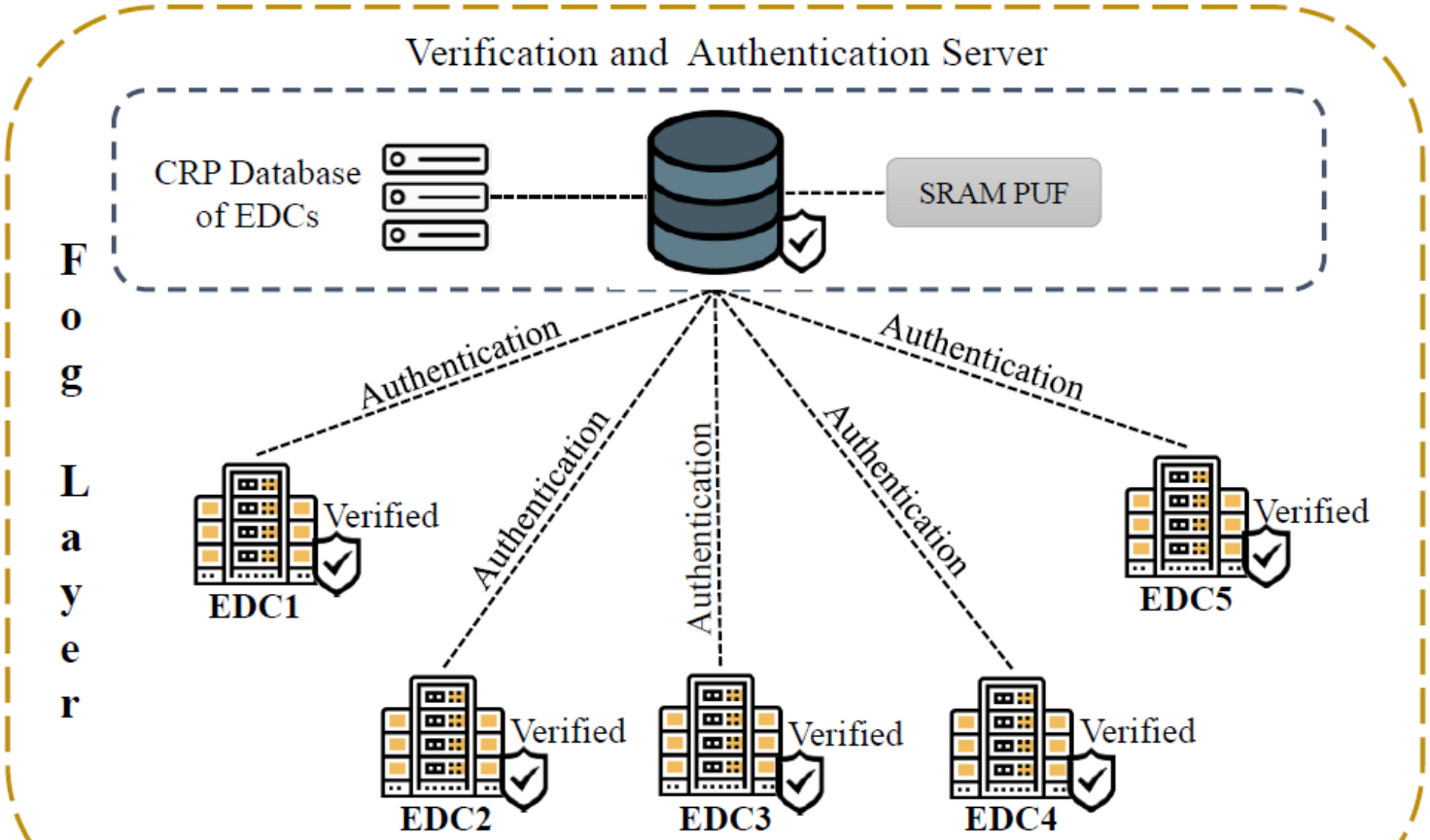
Source: Z. Li, V. Sharma, and S. P. Mohanty, "Preserving Data Privacy via Federated Learning: Challenges and Solutions", *IEEE Consumer Electronics Magazine*, Vol. 9, No. 3, May 2020, pp. 8--16.

Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages



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 Fortified-Edge: PUF based Authentication in Collaborative Edge Computing



Source: S. G. Aarella, **S. P. Mohanty**, E. Kougianos, and D. Puthal, "Fortified-Edge: Secure PUF Certificate Authentication Mechanism for Edge Data Centers in Collaborative Edge Computing", in *Proceedings of the ACM Great Lakes Symposium on VLSI (GLSVLSI)*, 2023, pp. 249--254, DOI: https://doi.org/10.1145/3583781.3590249.

Conclusions and Future Research

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.

Smart Agriculture - Multifold Research Possibility

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

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