

Agriculture Cyber-Physical Systems (A-CPS) - Demystified

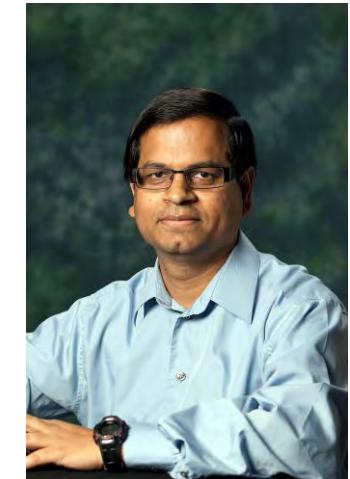
Keynote – International Conference on Artificial Intelligence and Applications (ICAIA 2024)

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19-20 Mar 2024



Homepage:
www.smohanty.org

Prof./Dr. Saraju Mohanty
University of North Texas, USA.



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

Smart Agriculture – Drivers → The Need



Global Population Explosion

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

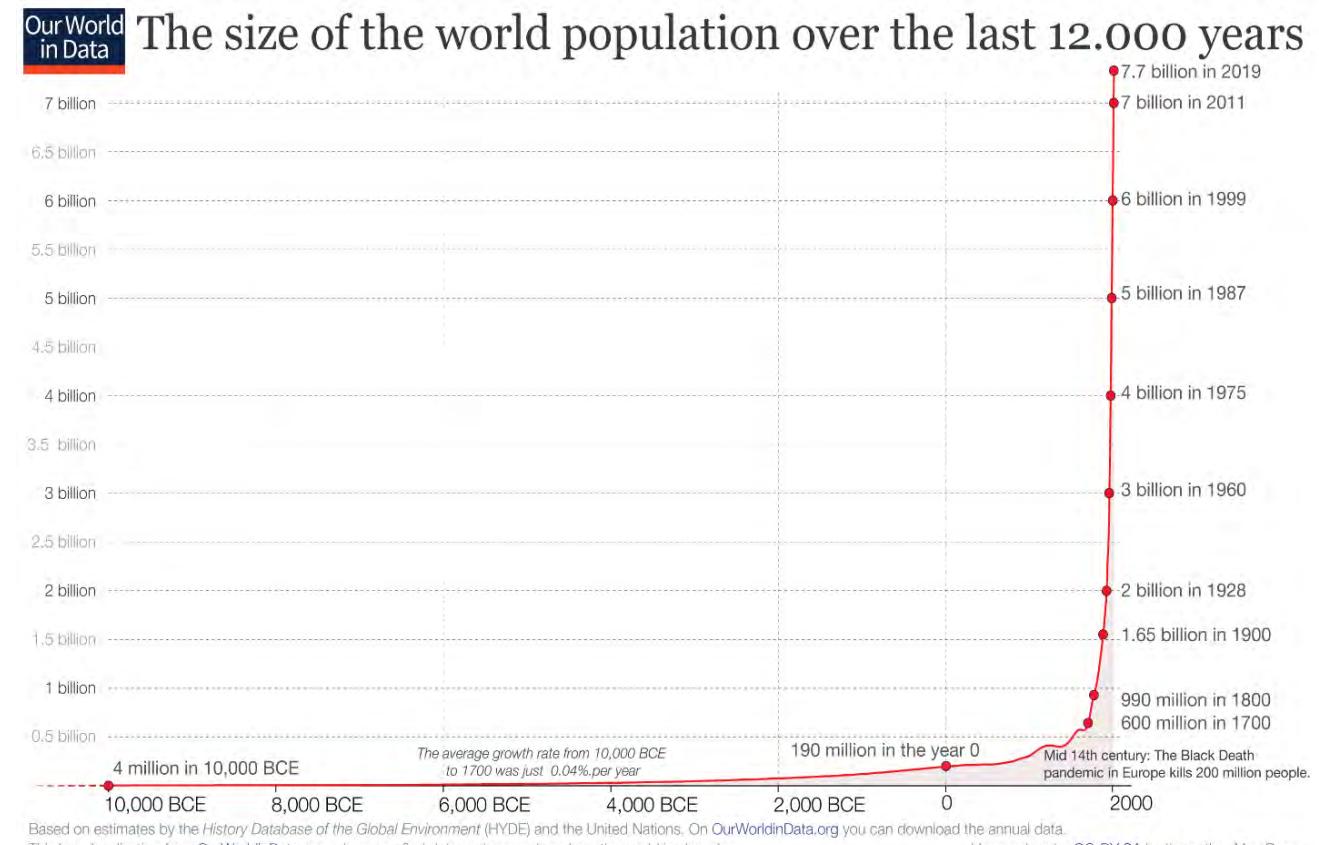


Image Source: <https://ourworldindata.org/world-population-growth>

World Hunger

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



Can we Have Any Crop, at Any Place?

- The factors determine the type of crop that can be farmed based on different environmental properties:

- Climate
- Elevation
- Slope
- Soil
- Water availability
- ...
- ...



Any Crop, Any Place: 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

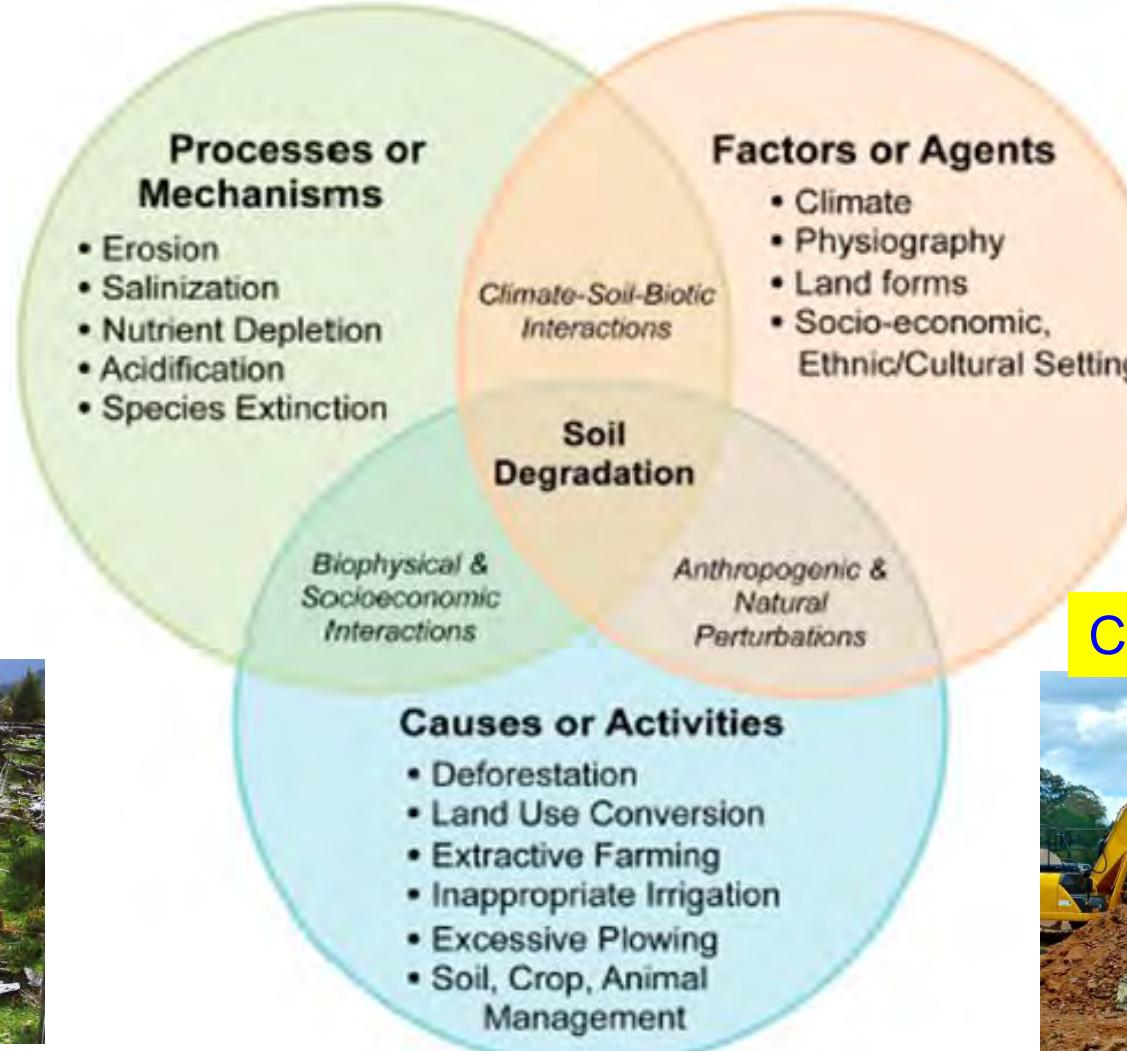
Salination



Soil Erosion



Deforestation



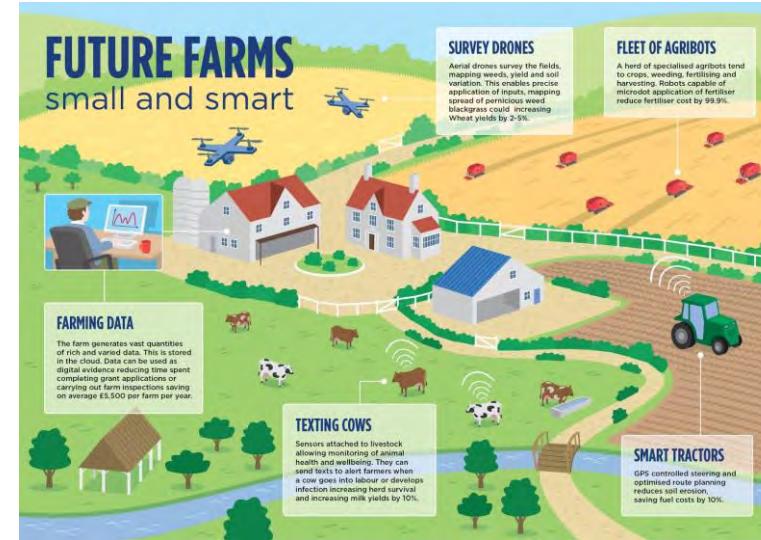
Construction on Farm Land



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.

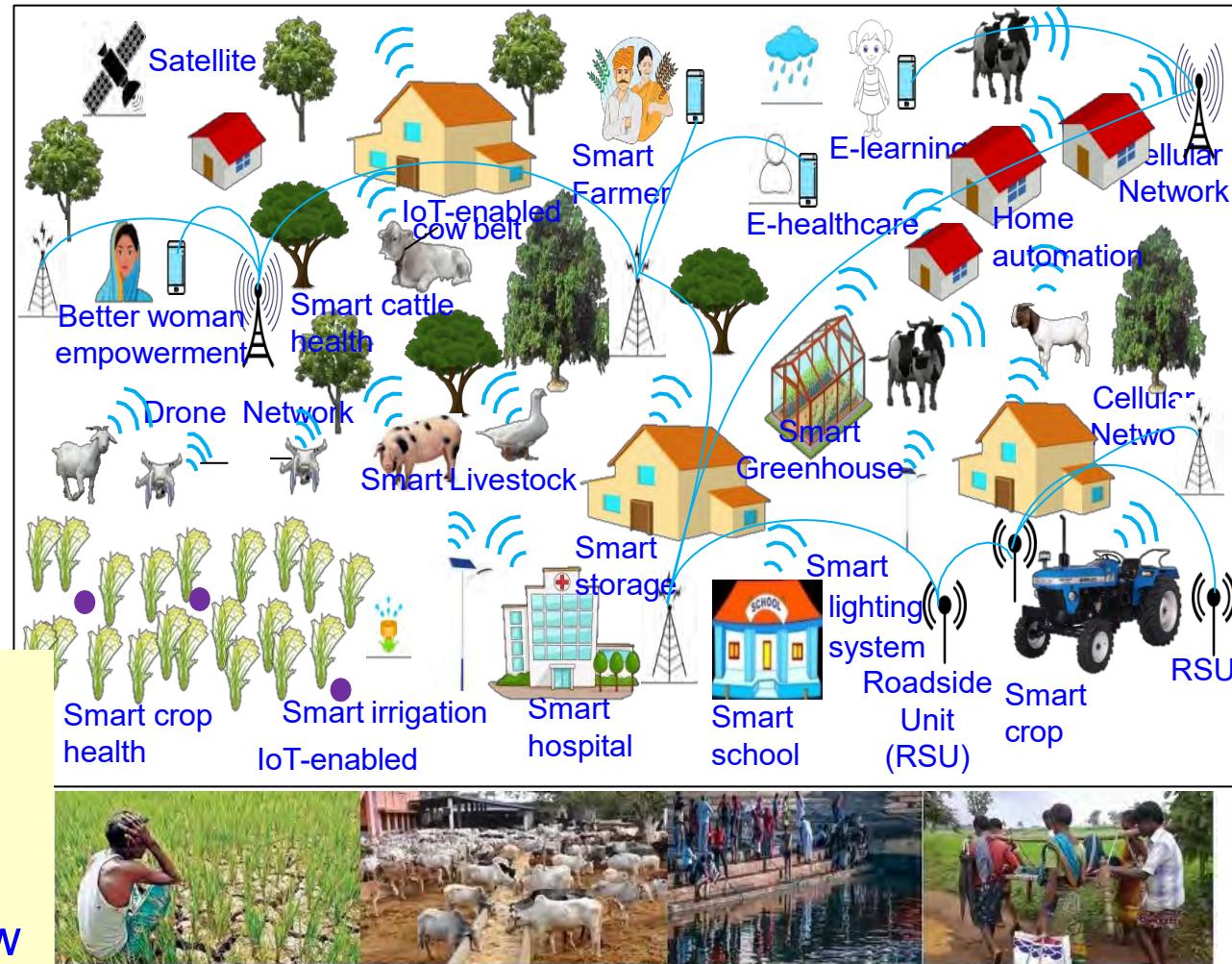
Crucial for → Smart Cities and Smart Villages



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

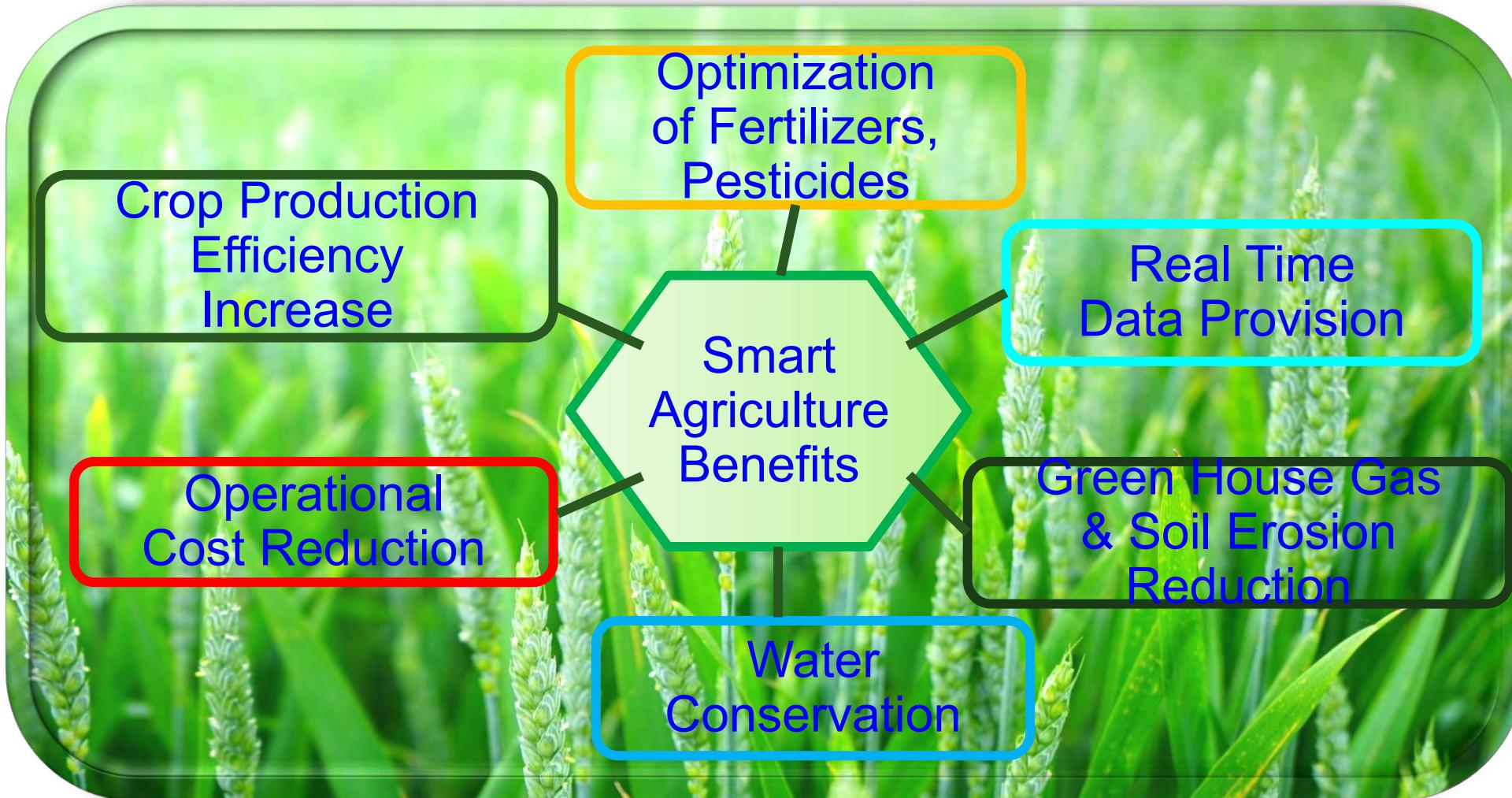
Smart Cities
CPS Types - More
Design Cost - High
Operation Cost – High
Energy Requirement - High

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



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

Benefits of Smart Agriculture



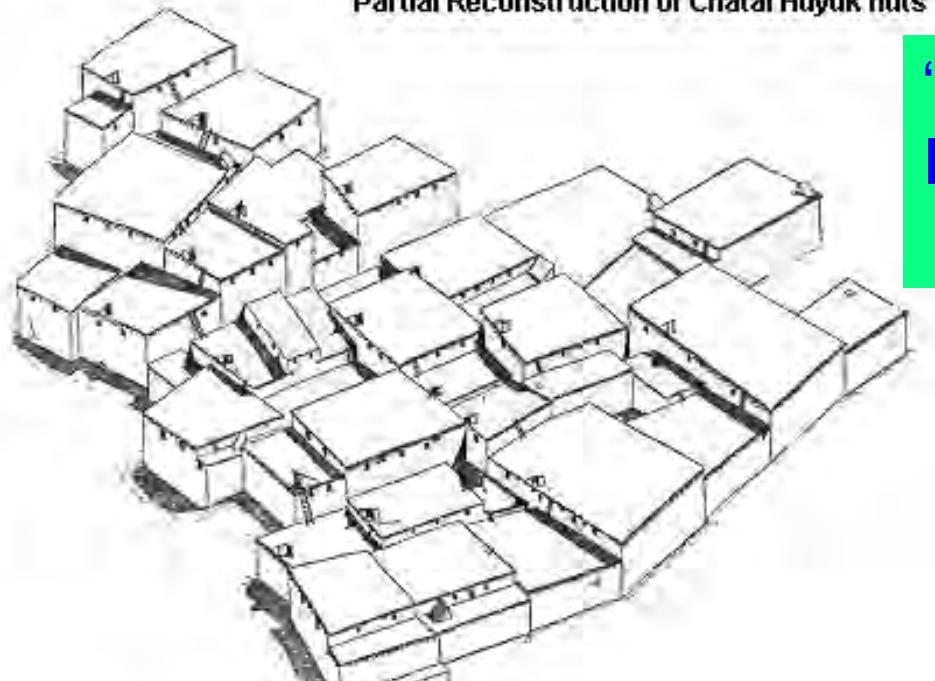
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "[Everything You wanted to Know about Smart Agriculture](#)", *arXiv Computer Science*, [arXiv:2201.04754](#), Jan 2022, 45-pages.

Agriculture → Smart Agriculture: Broad Overview



Cities and Villages - History

Partial Reconstruction of Chatal Huyuk huts

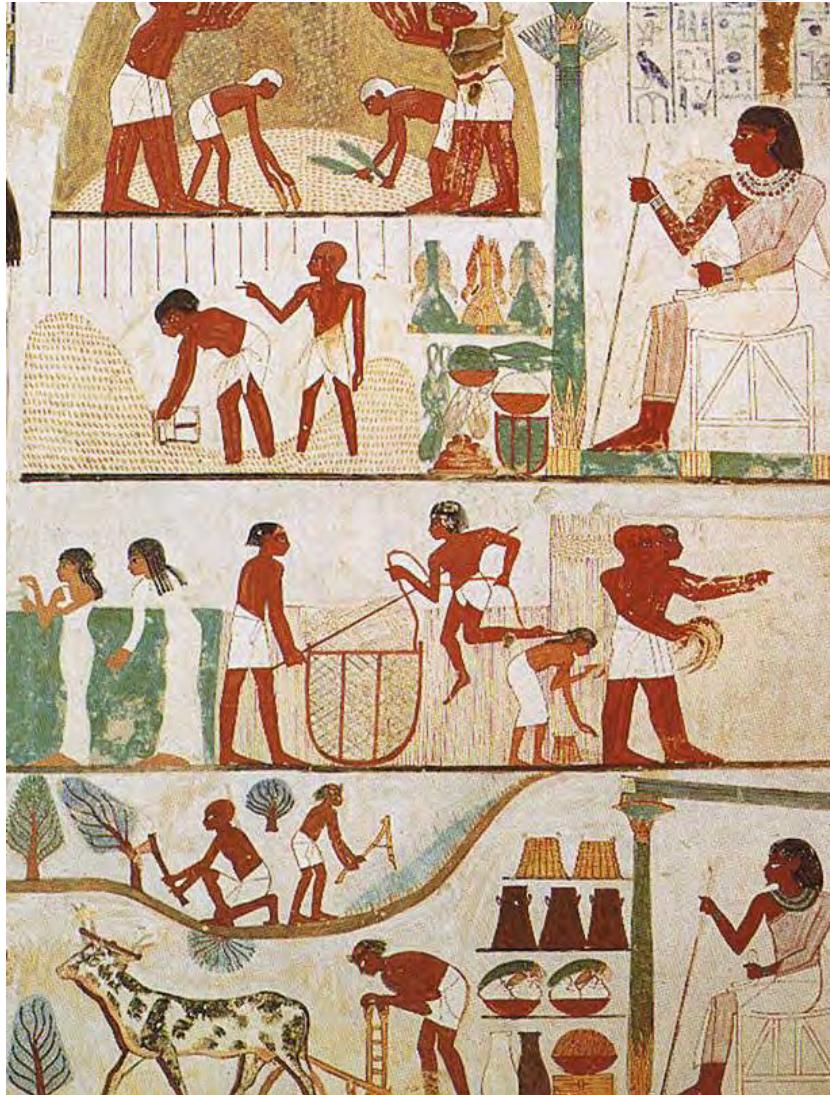


Source: <https://www1.biologie.uni-hamburg.de/b-online/library/darwin/prerm5.htm>

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 hectares built in 7,000 BC.
- ✓ Partial reconstruction of the village gives an idea of buildings.

Agriculture History



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

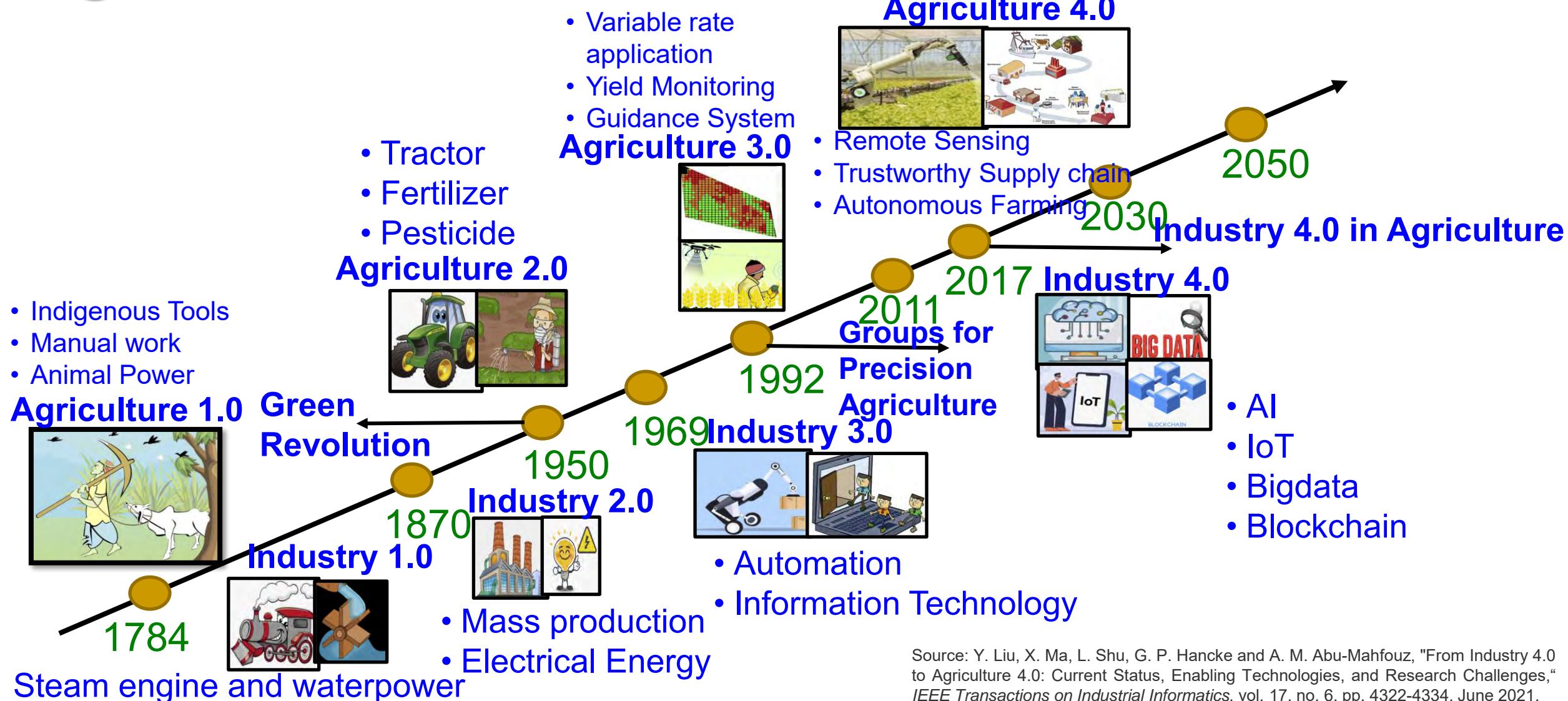
Agriculture played a Key Role in the growth of civilization.

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

Agriculture is the Key Factor of Civilization

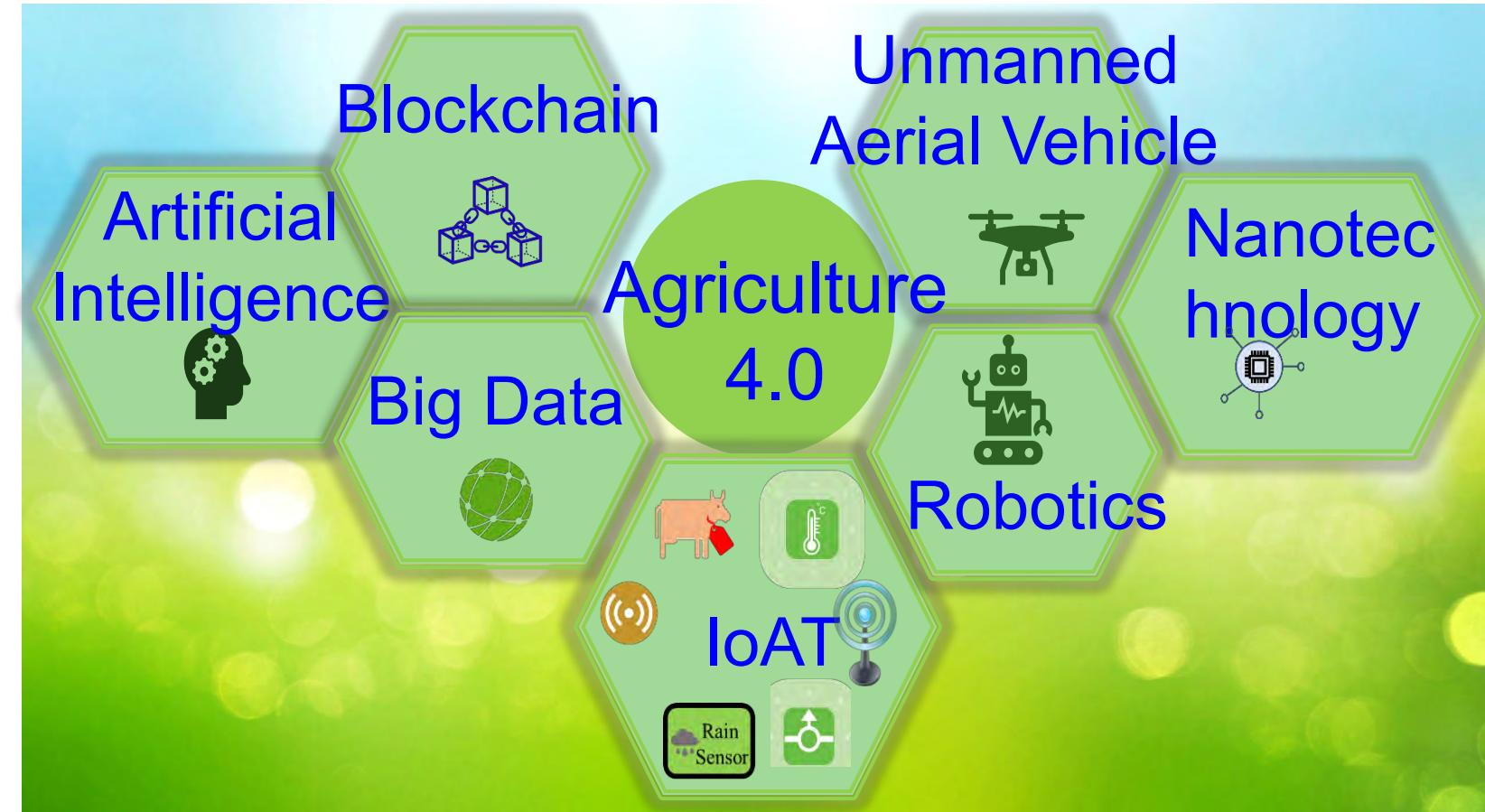
- 10,000 BC: Farming started by Ancient Egyptian Civilization on the Nile River.
- 9,000 BC: Indus Valley civilization started wheat and barley.
- 8,000 BC: Sumerians started to live in villages near the Tigris and Euphrates rivers and made a canal system for irrigation.
- 8,000 BC: Asian rice was domesticated 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



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. Koulianou, and C. Ray, “[Everything You wanted to Know about Smart Agriculture](#)”, arXiv Computer Science, arXiv:2201.04754, Jan 2022, 45-pages.

Agriculture to Smart Agriculture

■ Traditional agriculture:

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

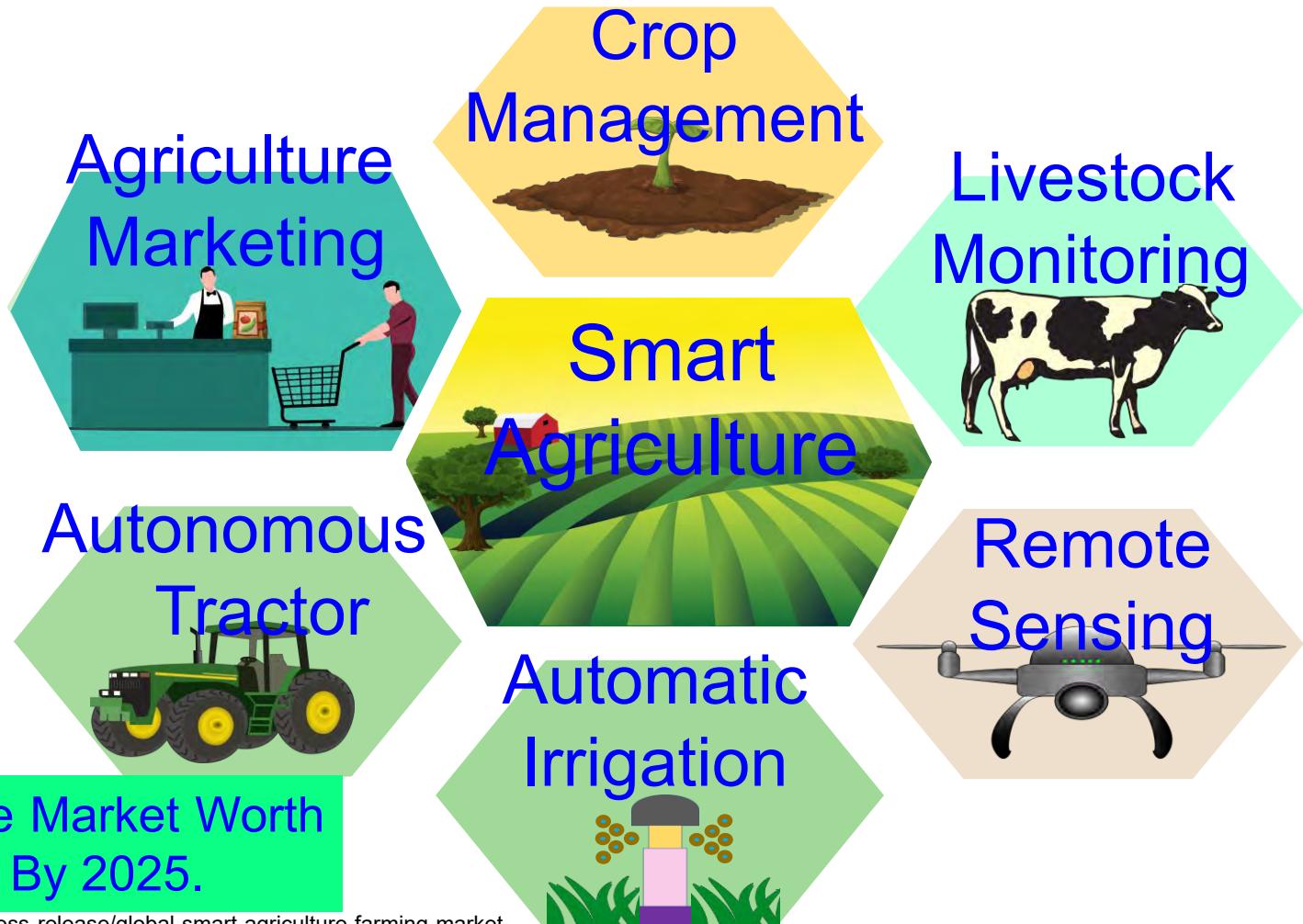
■ Smart Agriculture:

- Sustainable
- Intelligent
- Efficient
- Eco-friendly

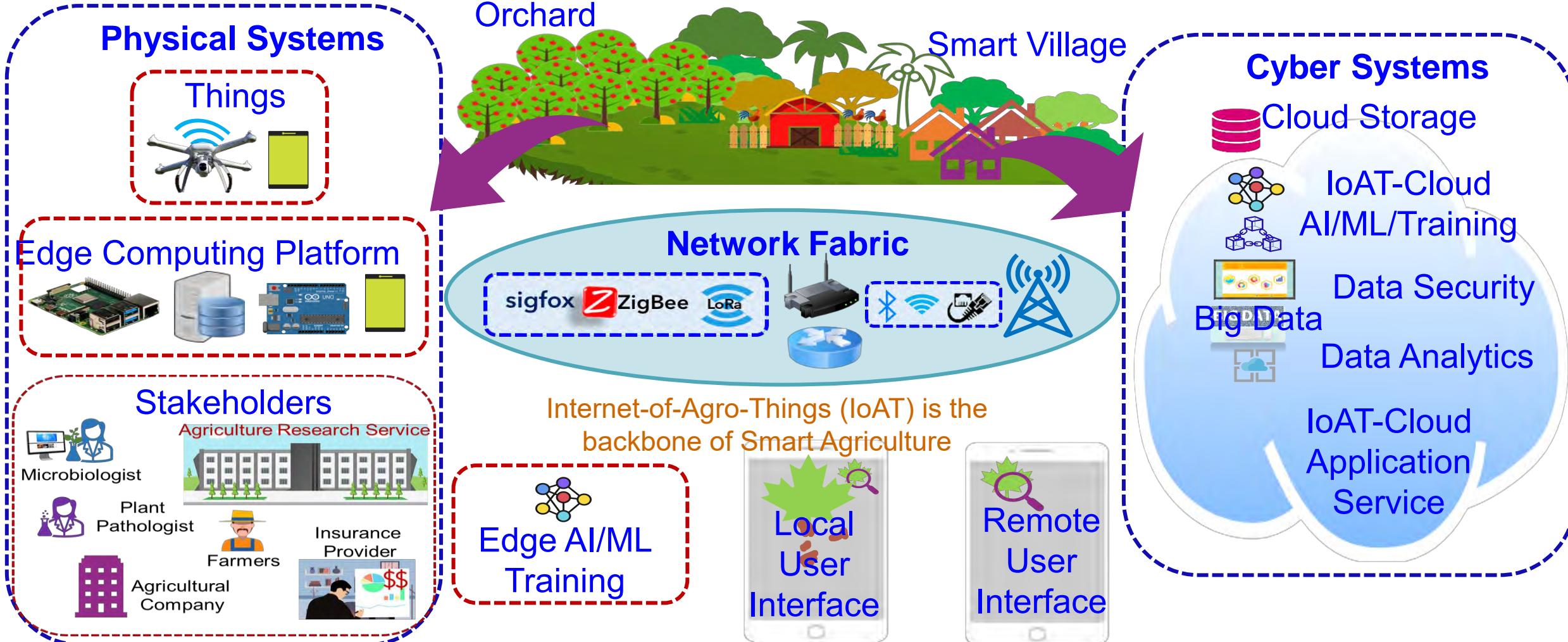
Smart Agriculture Market Worth
US\$18.21 Billion By 2025.

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.

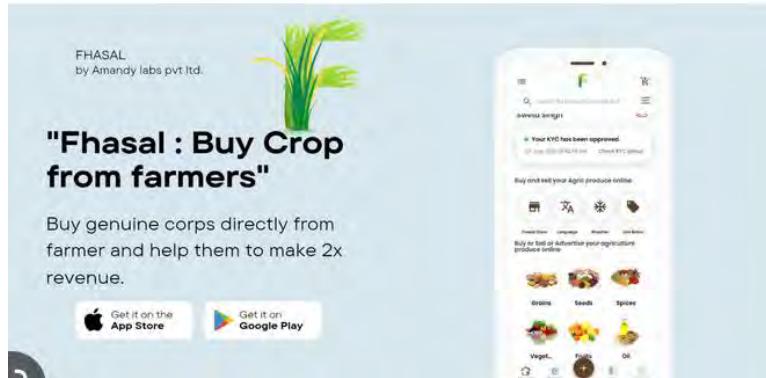


Agriculture Cyber Physical System (A-CPS)



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.

Smart Agriculture Apps



Ask questions about your crop
and receive help from 500+ agri experts

Avinash Patel • India
1 ⚡ Capitom & Chili
The leaves of my chili crop started curling upwards. Would you please have a look at the photo I attached and tell me what to do?

Rahul M • 12386
Hi Avinash Patel, It might be due to !!!
Chilli Thrips.
Please tap on this link to see more details about the pest, recommended medicines as well as preventive measures.

Calculate the seasonal fertilizer needs
for your crop and plot size

Plot size
2.0 Acre
Calculate

DAP/MOP/Urea
DAP 121 kg
MOP 81 kg
Urea 162 kg
Choose your preferred fertilizer combination (recommended amount for one season):

MOP/SSP/Urea
MOP 81 kg
SSP 285 kg
Urea 202 kg

Soil Sampler

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Contains ads

4.3★
1.03K reviews 100K+ Downloads Everyone

BoosterAGRO

Booster Ag Tech, Inc.

4.4★
2.54K reviews 100K+ Downloads Everyone

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Crop Farmers App

Bivatec Ltd
Contains ads · In-app purchases

3.9★
237 reviews 10K+ Downloads Everyone

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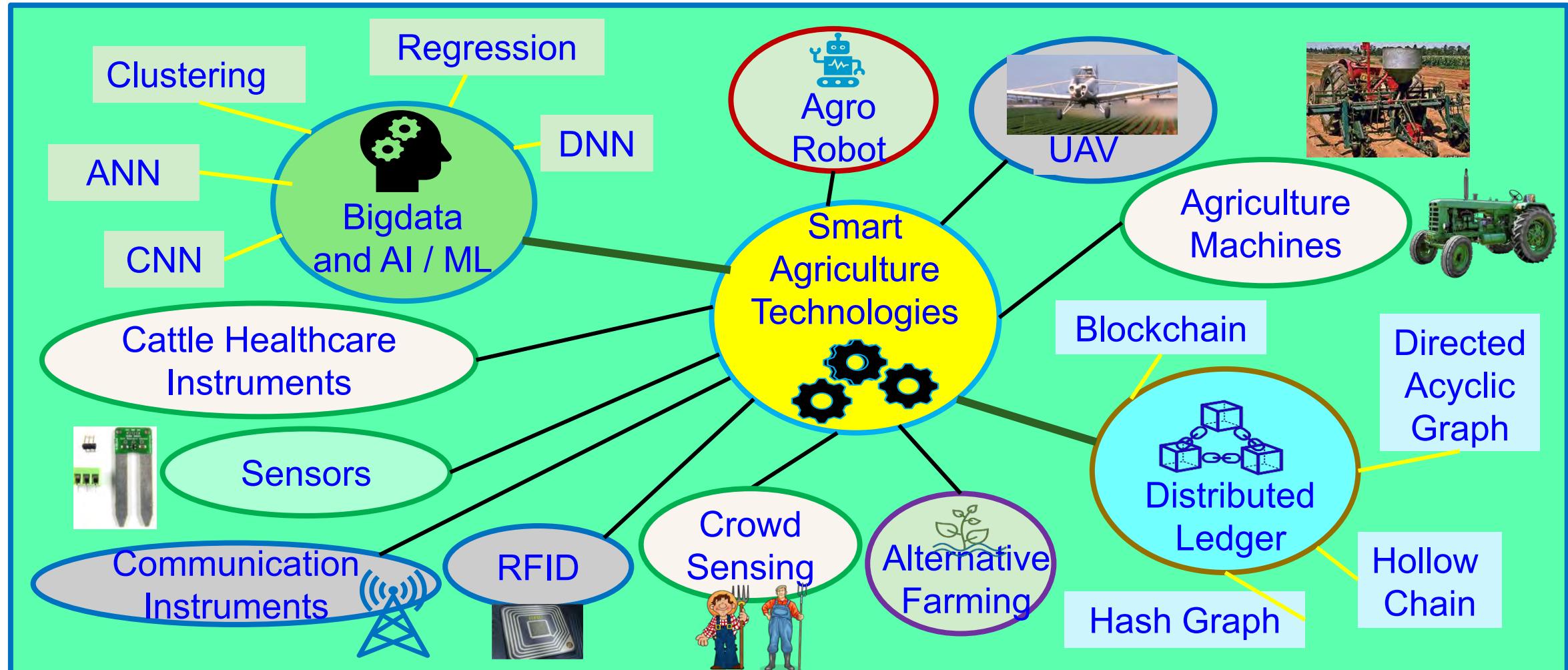


Smart Agriculture – Technologies

Agriculture CPS - Prof./Dr. Saraju Mohanty

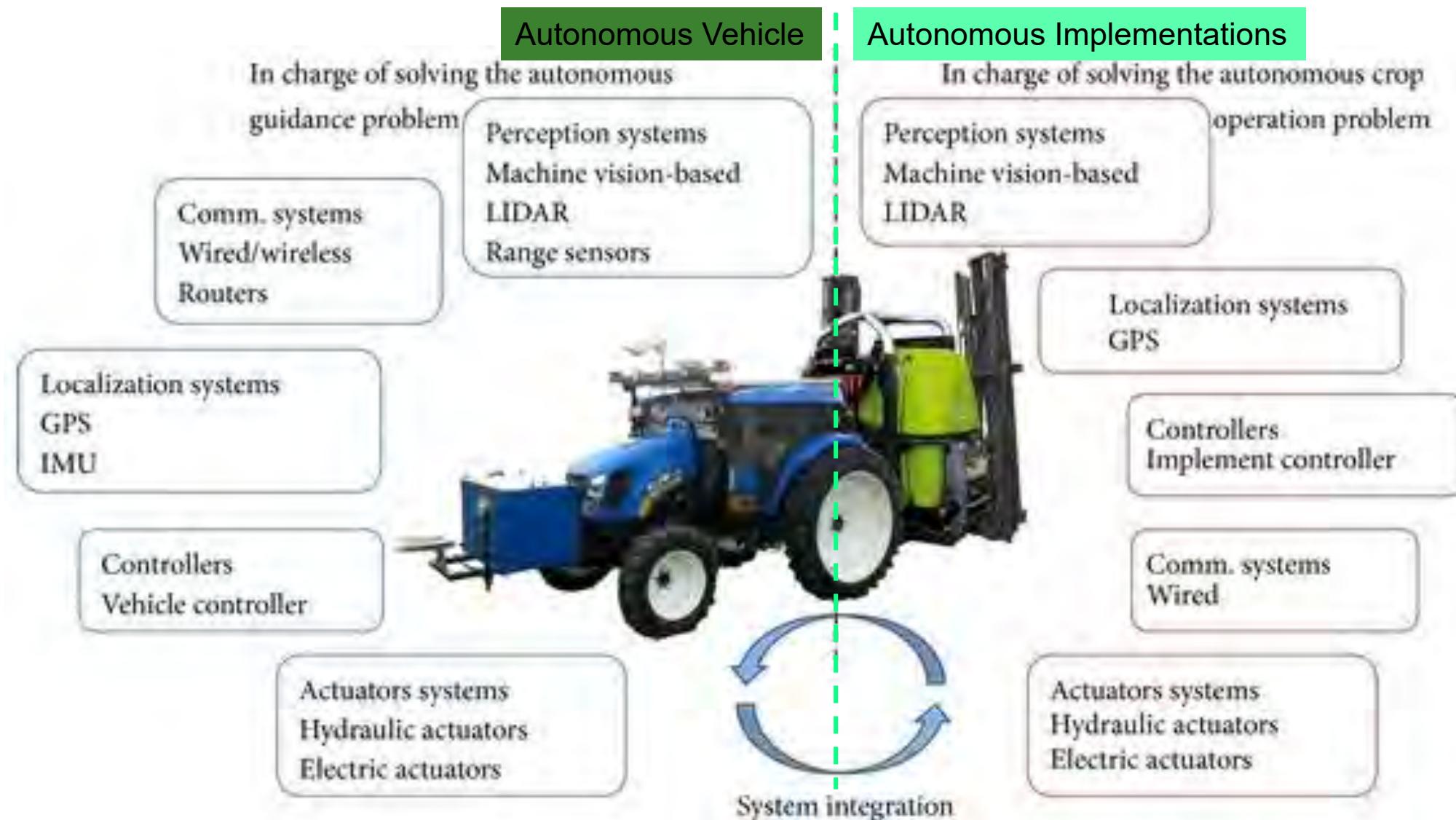


Smart Agriculture Technologies



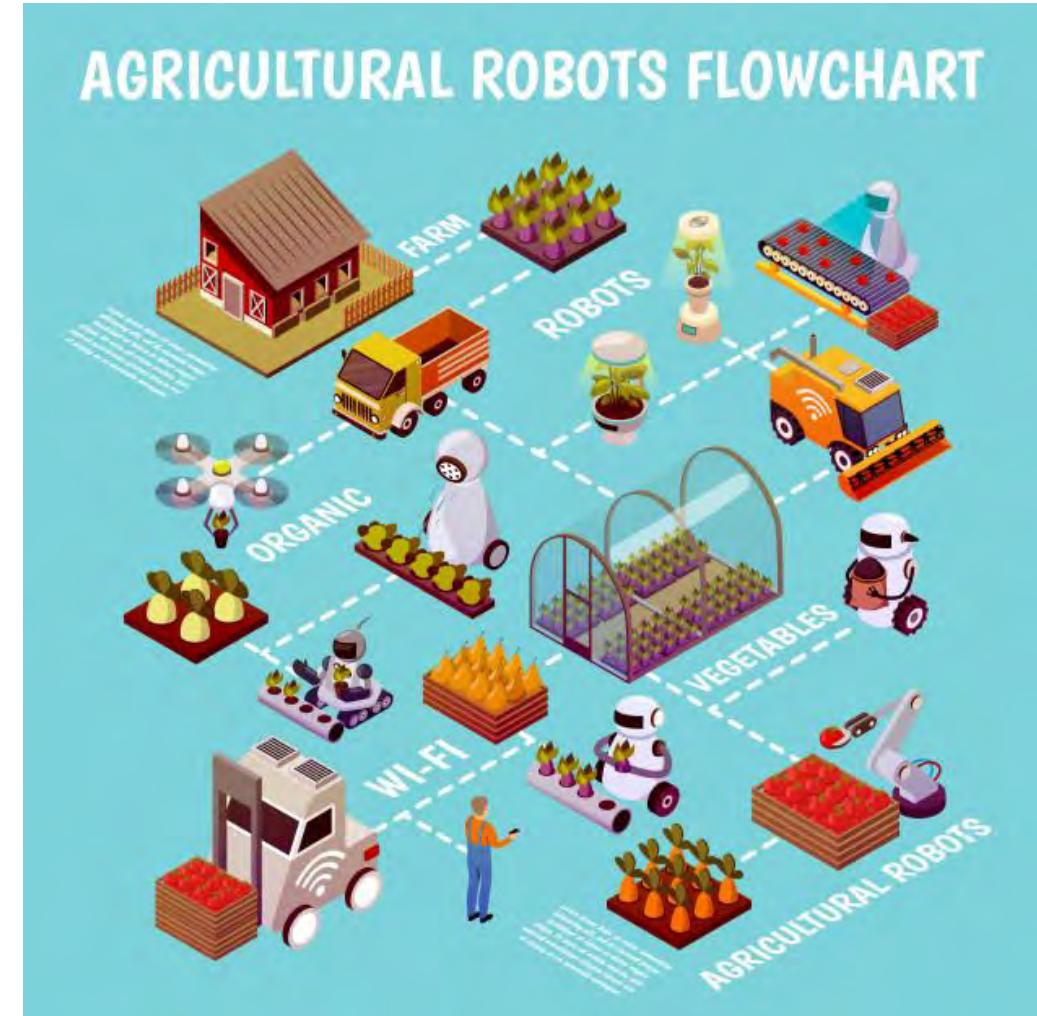
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "[Everything You wanted to Know about Smart Agriculture](#)", arXiv Computer Science, [arXiv:2201.04754](#), Jan 2022, 45-pages.

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).

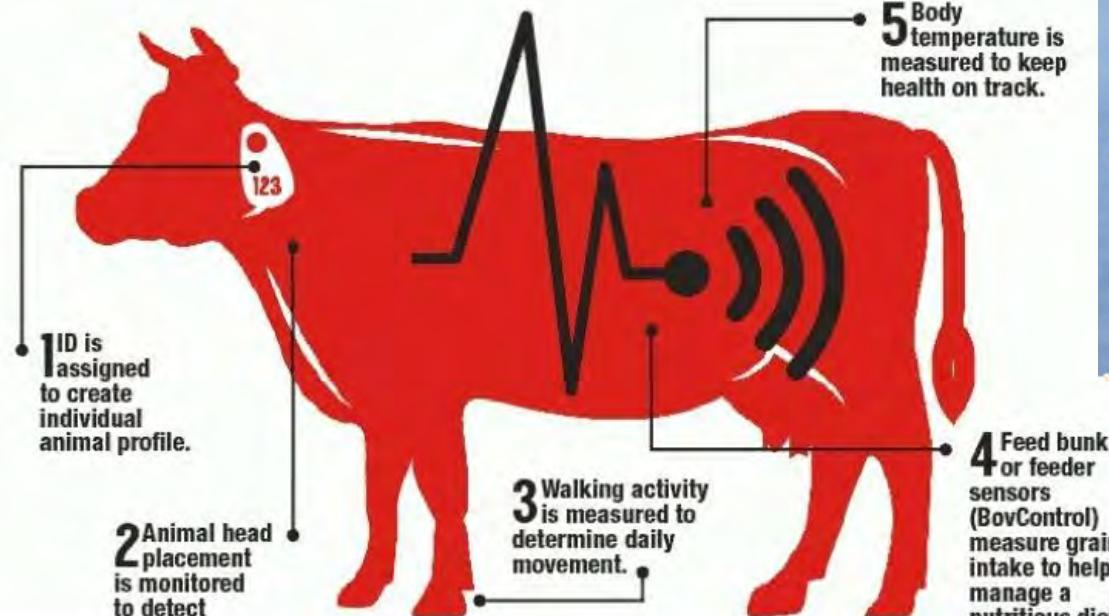


Livestock Monitoring System



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

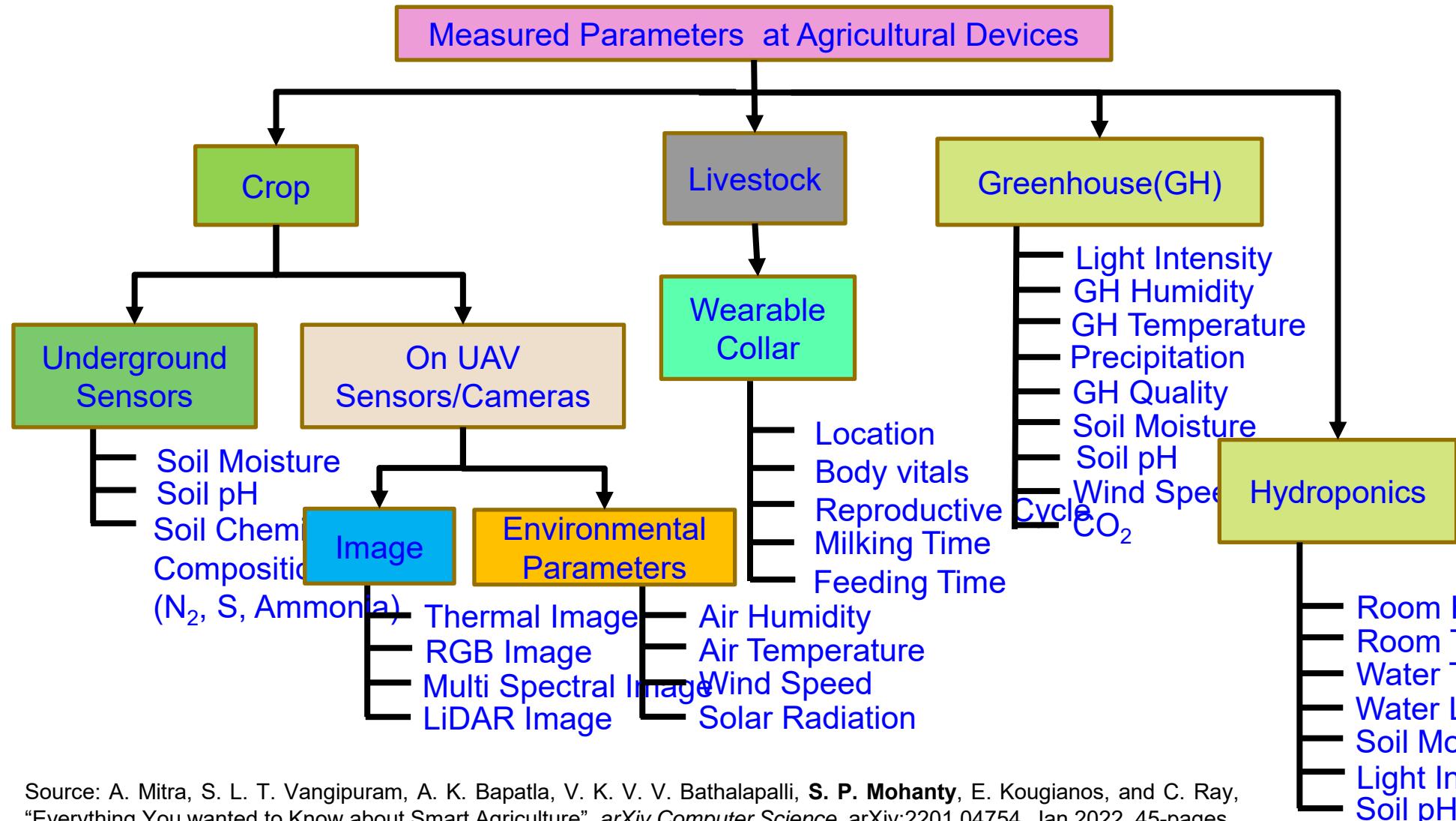
Livestock Health Monitoring Instruments



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>

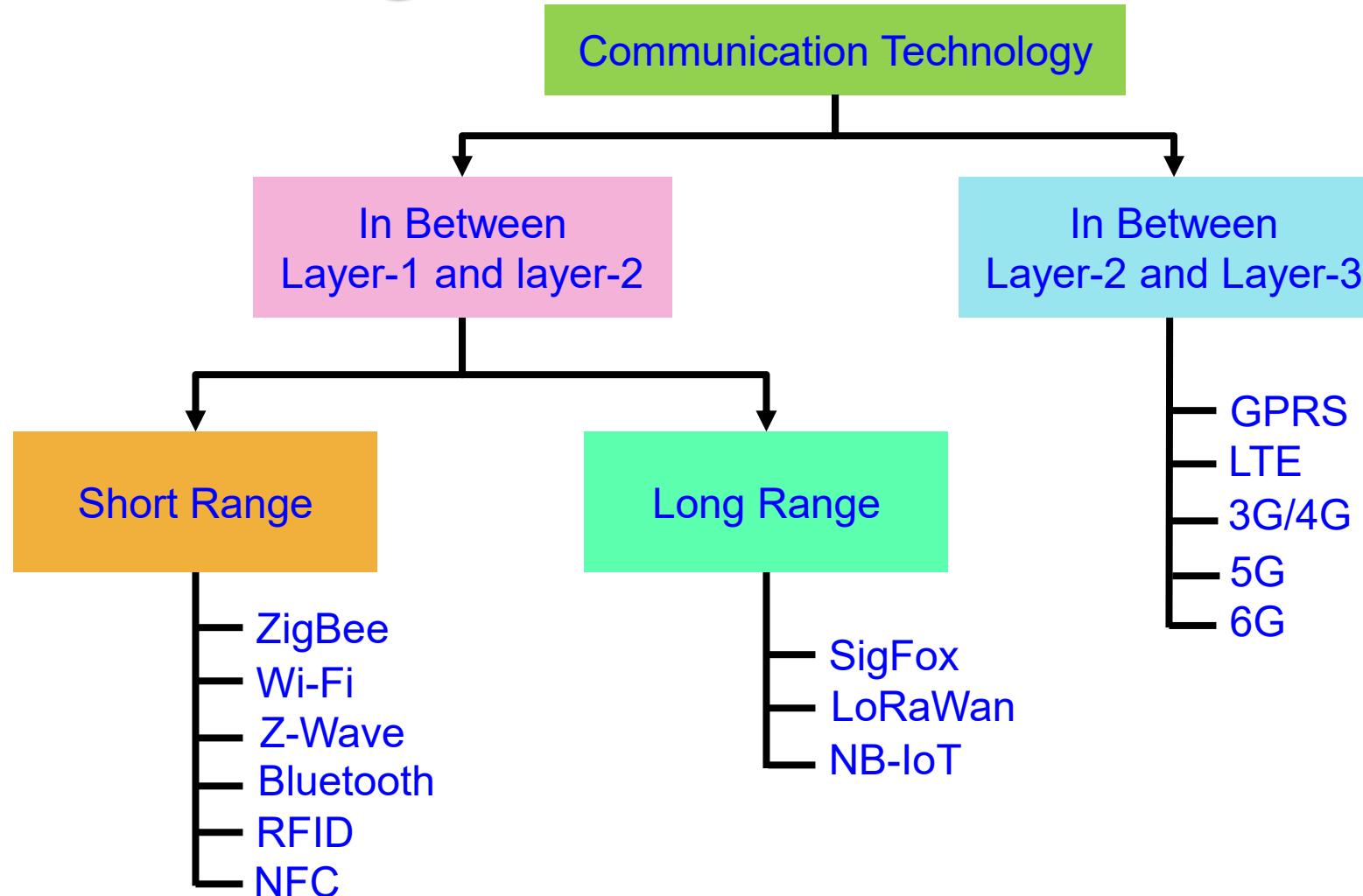


Smart Agriculture - Sensors



Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Koulianou, 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).

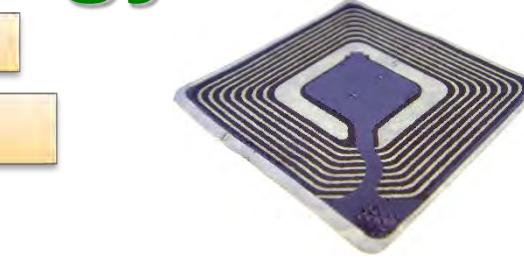
Connectivity Layer-2 : Cellular Technologies like Ground Penetrating Radar Services (GPRS), Long-Term Evolution (LTE), 3G/4G, and 5G.

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.

Crop Health, Weeding and Spraying

- Integration of image processing and artificial intelligence techniques into the farming for monitoring the health of the field by detecting disease patches, weed patches.
- This helps in spraying the herbicides, pesticides.

RFID Technology



Source: Khattab 2017; Springer 2017 RFID Security

Smart Agriculture – AI/ML Technology



Crop Management



Soil Management



Smart Irrigation



Pest / Disease Control



Weed Control



Livestock Management



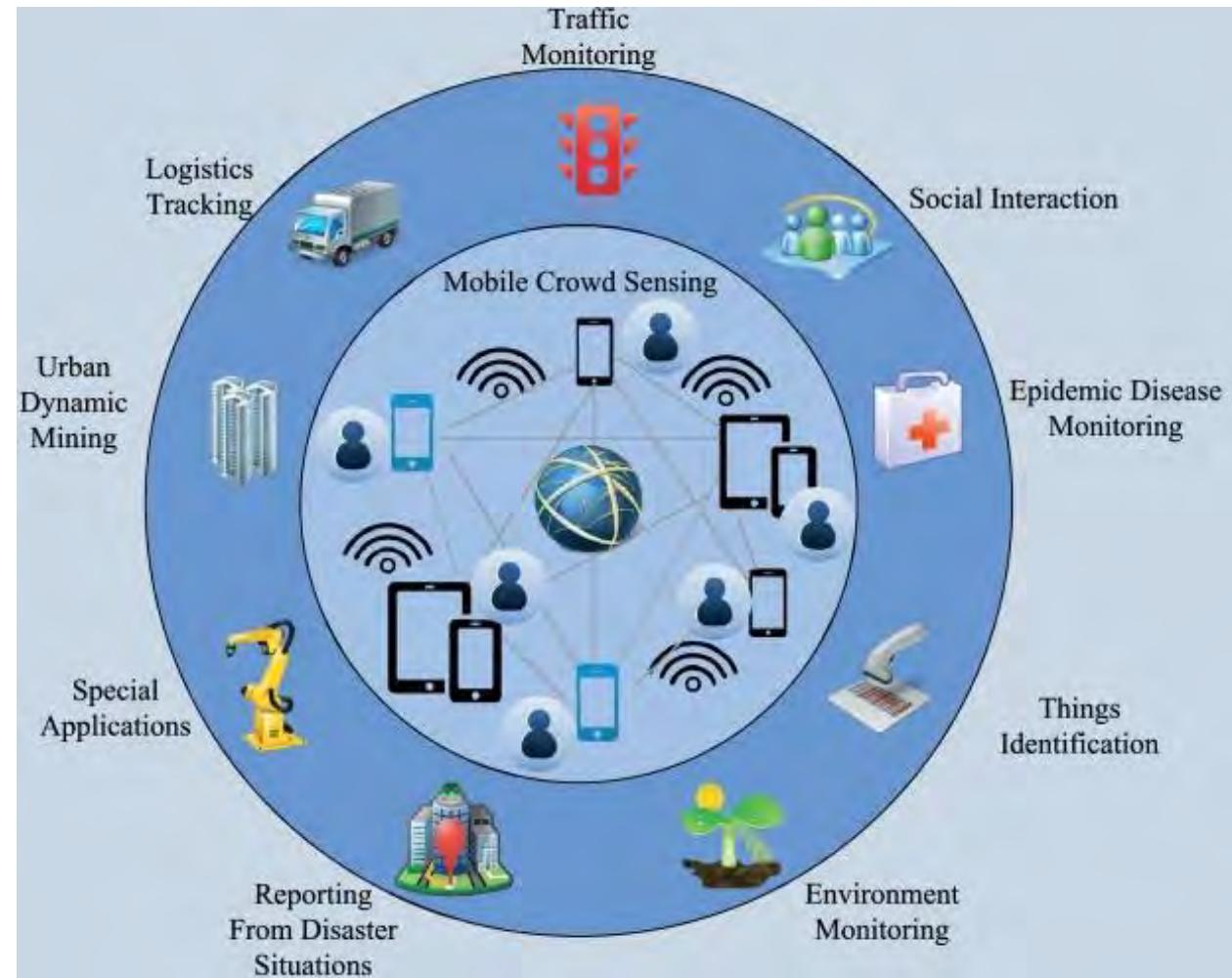
Alternative Farming

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

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

Agriculture Data – Crowd Sensing

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



Roles of Blockchain in A-CPS

Visibility

Food Safety

Provenance

Traceability

Farm Supervision



Land Registration

Supply Chain

Farmer Incentives

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

Smart Agriculture – Some Challenges

Agriculture CPS - Prof./Dr. Saraju Mohanty



Smart Agriculture – Challenges



Power Availability



Hardware Security



Data Security and Privacy

Networking and Communication



Natural Disaster



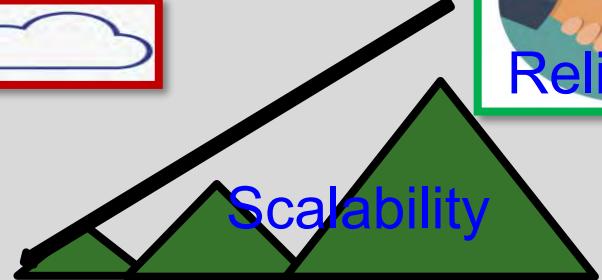
Farmer's Learning Curve



Technical Malfunction



Reliability



Bigdata Challenges



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.



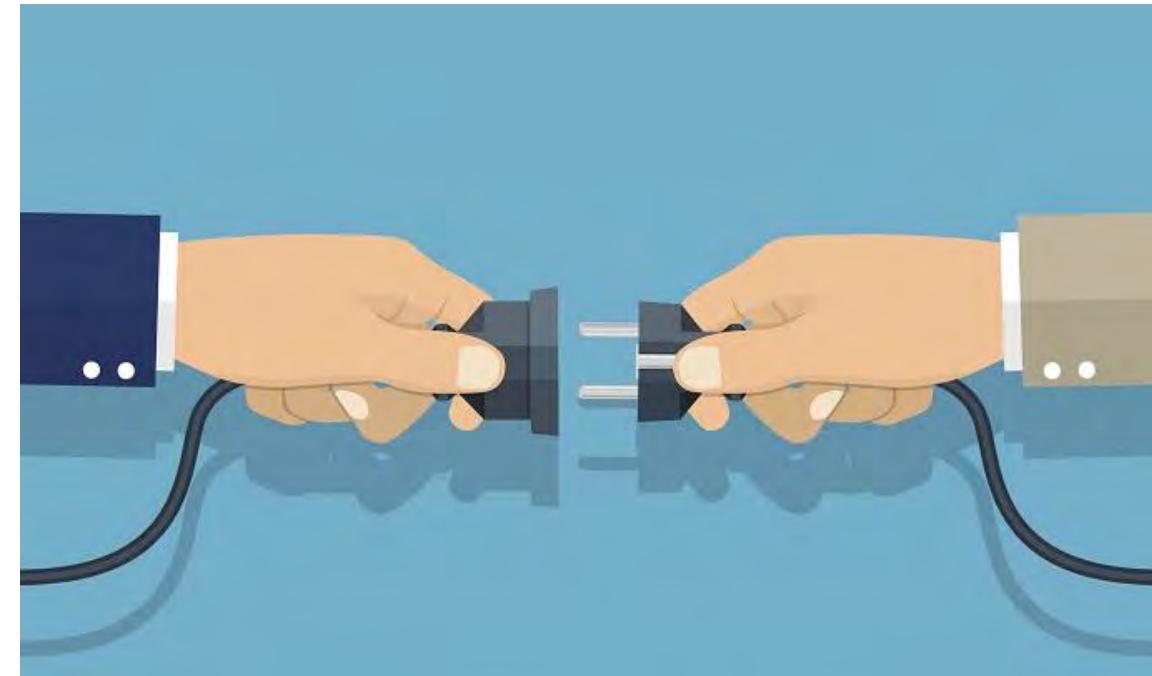
Energy Depletion Risks

- 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.



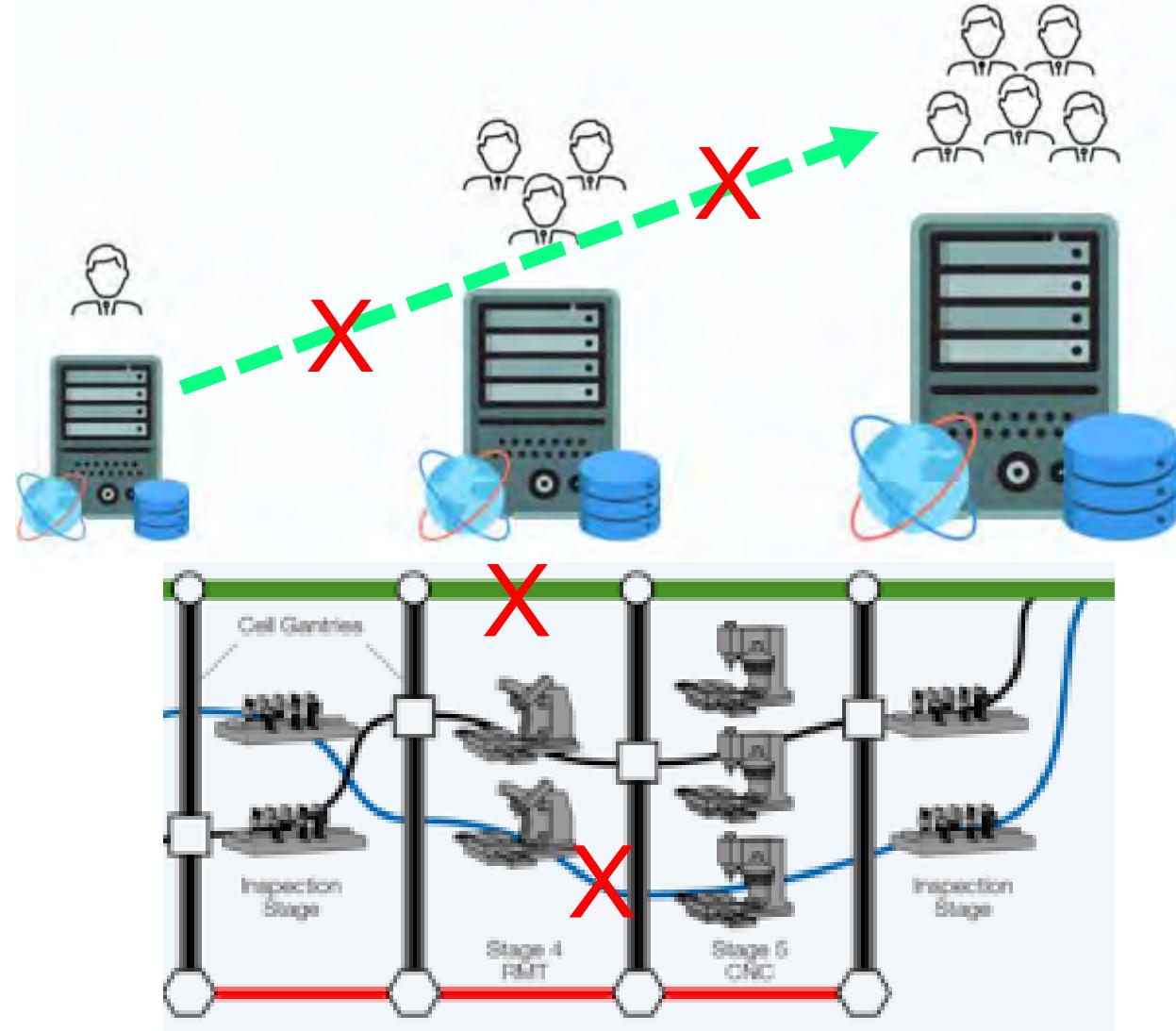
Interoperability Can be an Issue for the Smart Agriculture Equipment

- 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.



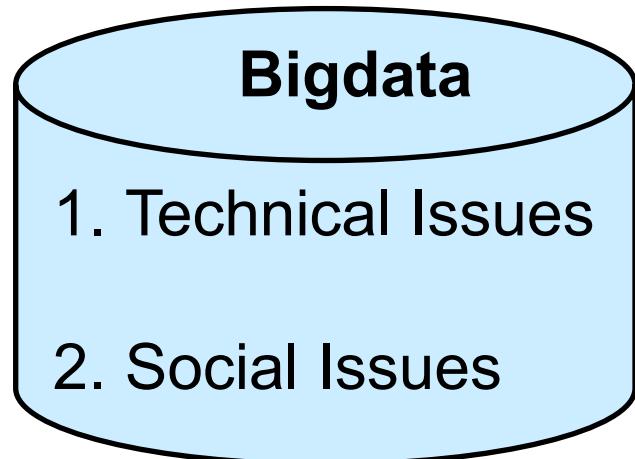
Technical Failures

- 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.



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.



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

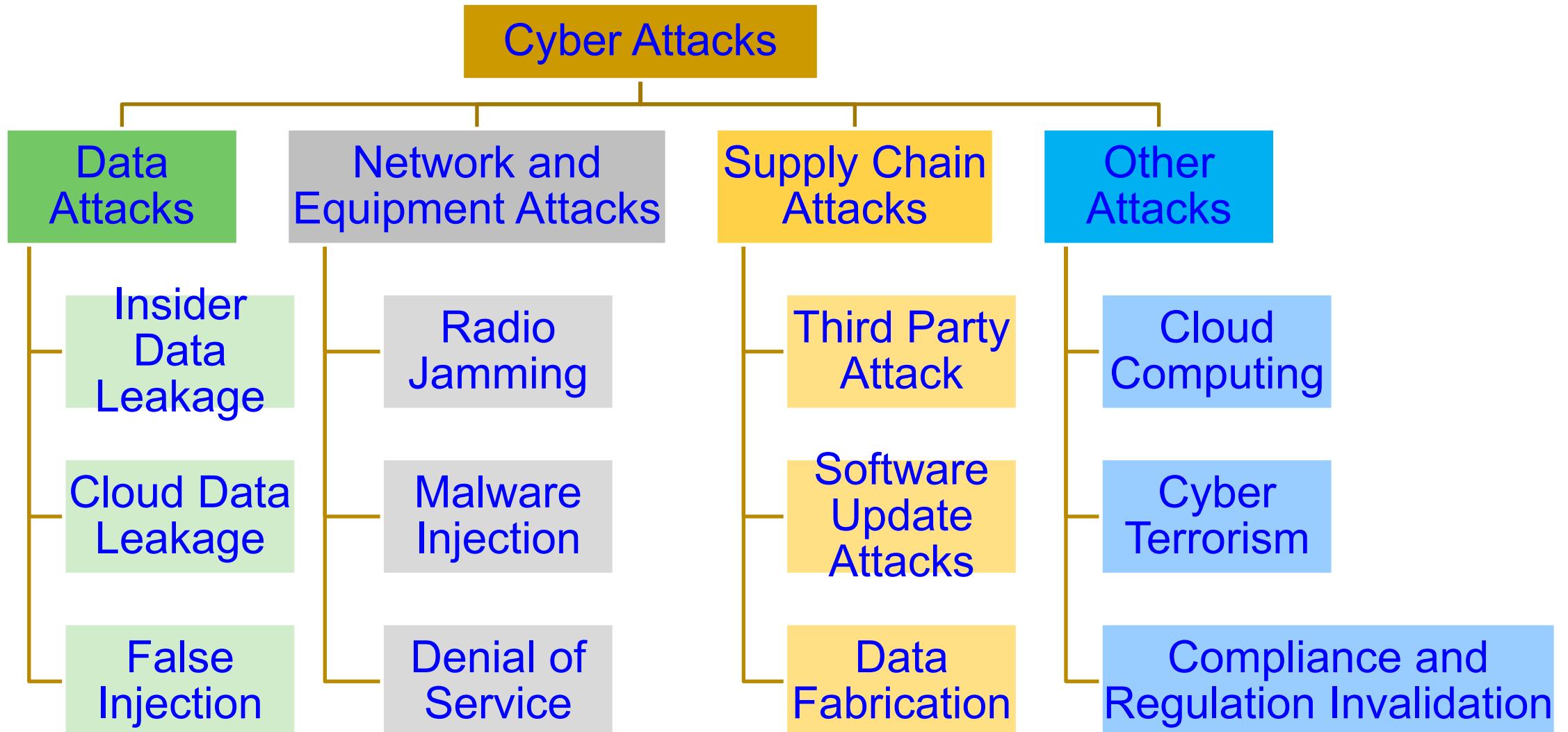
[https://www.dhs.gov/sites/default/files/publications/2018%20AEP_ Threats to Precision Agriculture.pdf](https://www.dhs.gov/sites/default/files/publications/2018%20AEP_Threats_to_Precision_Agriculture.pdf)

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. Khorsandrou 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

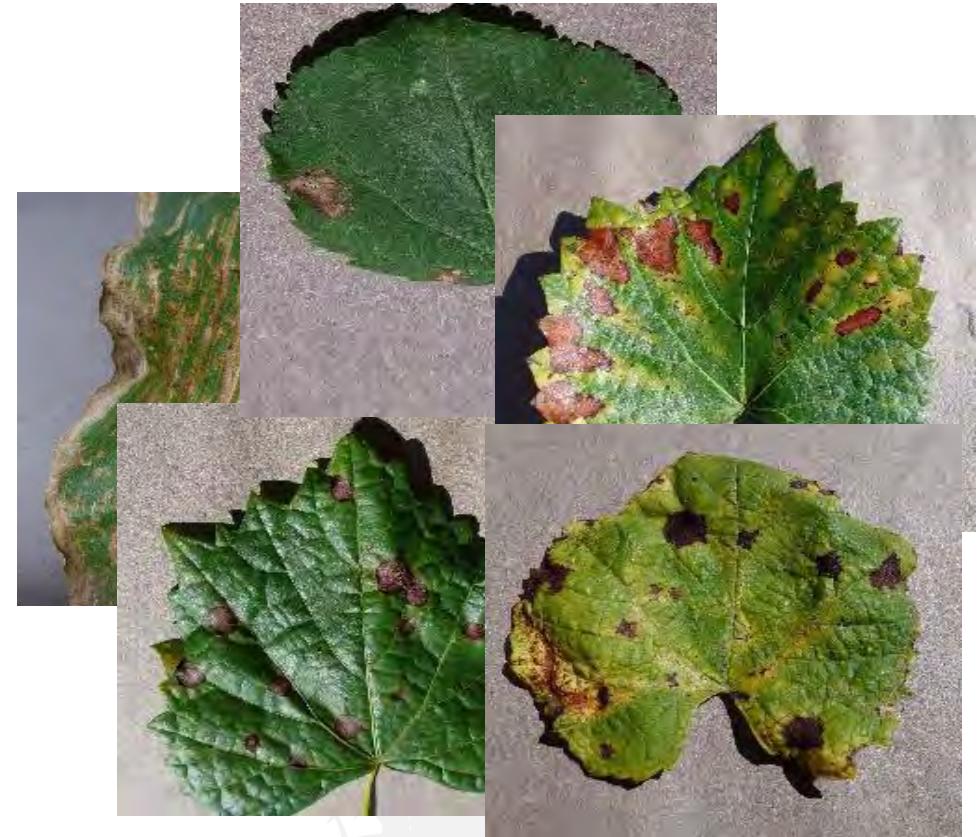
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Crop Damage and Disease Problem

- Disease prevents the growth of plants.

- Affect quality of the crop.
 - Reduce final yield.

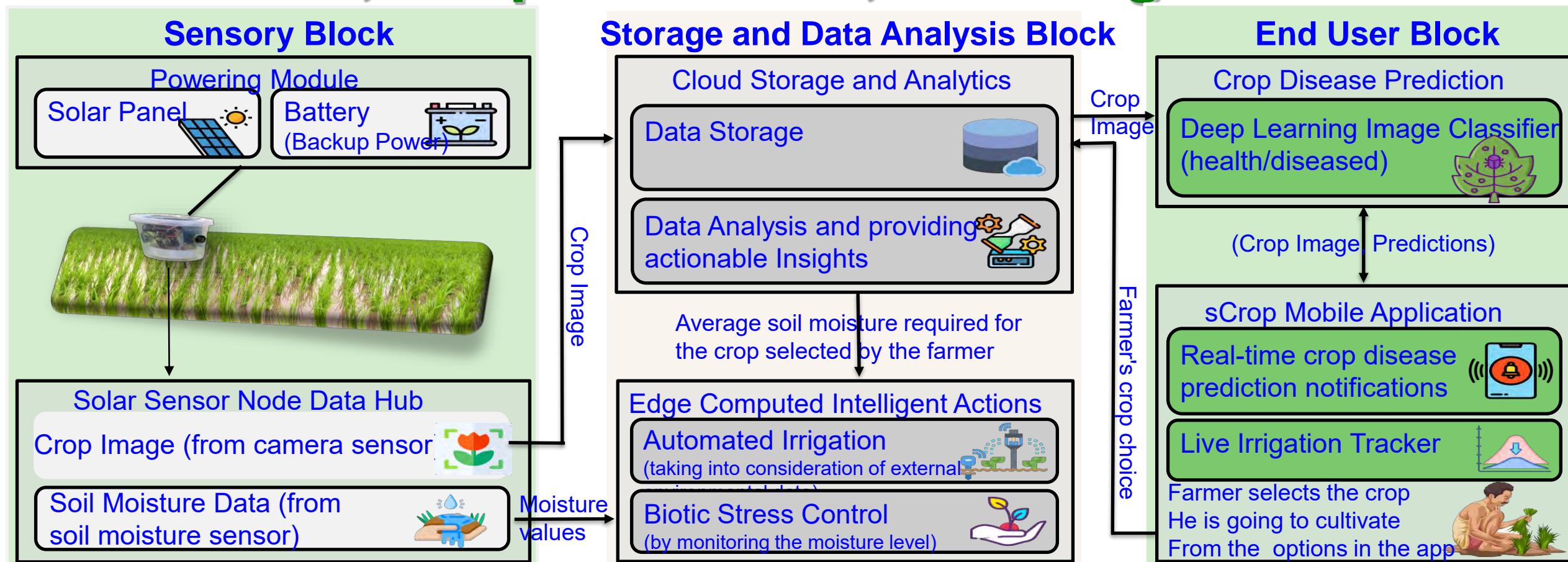


- Farmers need to –

- 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. Uddalapally, **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



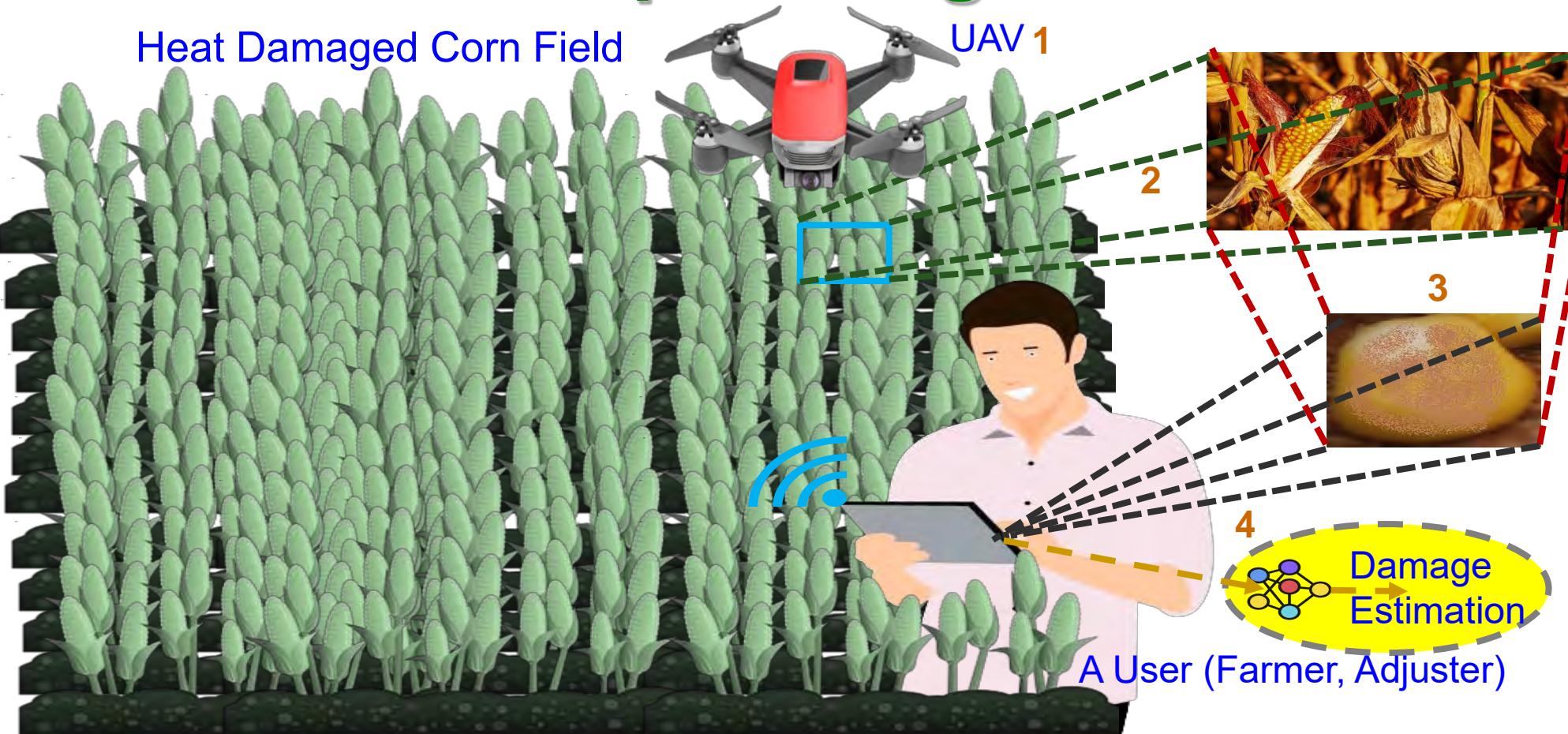
Infected Tomato

sCrop Accuracy – 99.24%

Source: V. Udutoalapally, **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>.

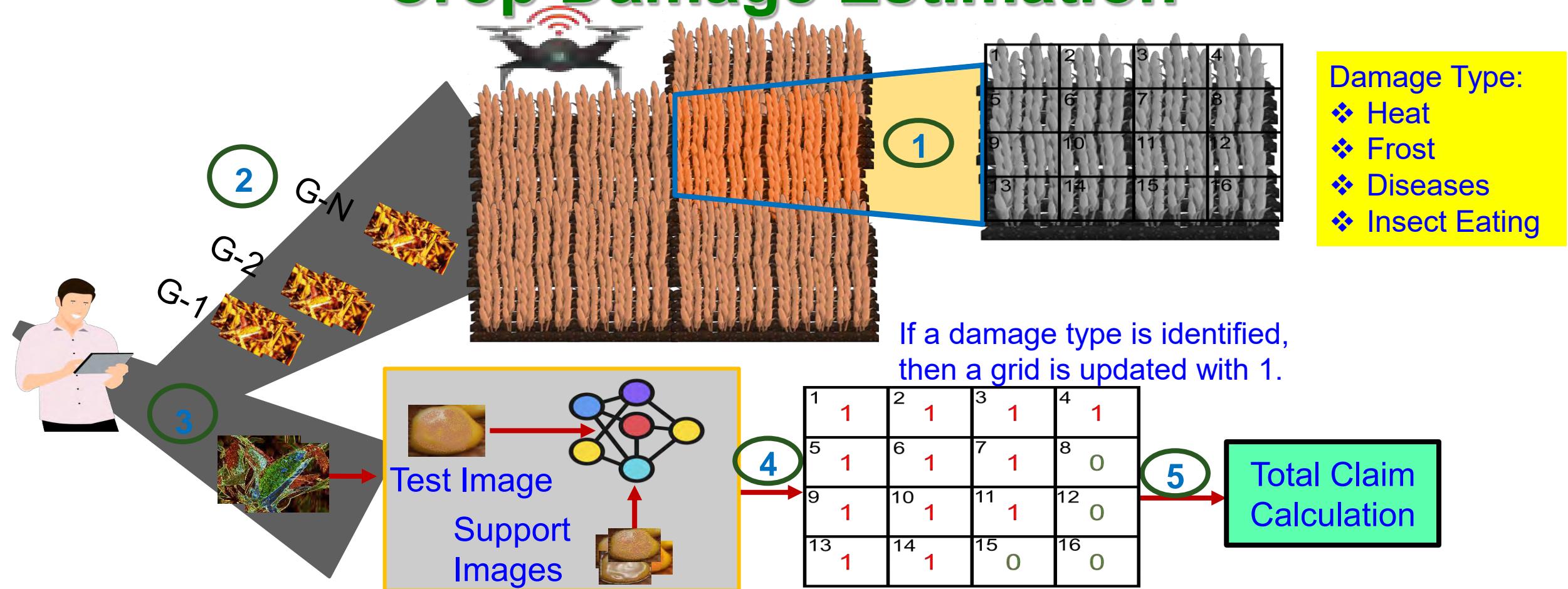
Our eCrop: A Framework for Automatic Crop Damage Estimation

Heat Damaged Corn Field



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>.

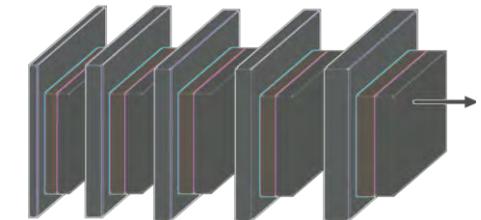
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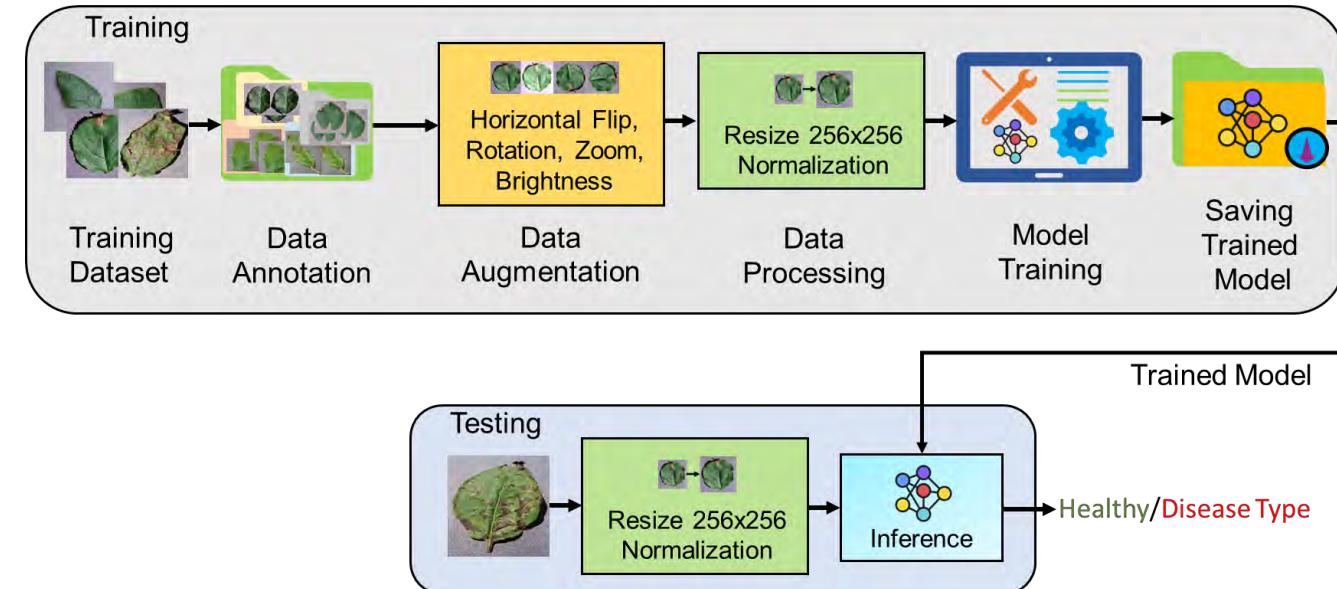
Our aGROdet: A Framework for Plant Disease Detection and Leaf Damage Estimation

- 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.

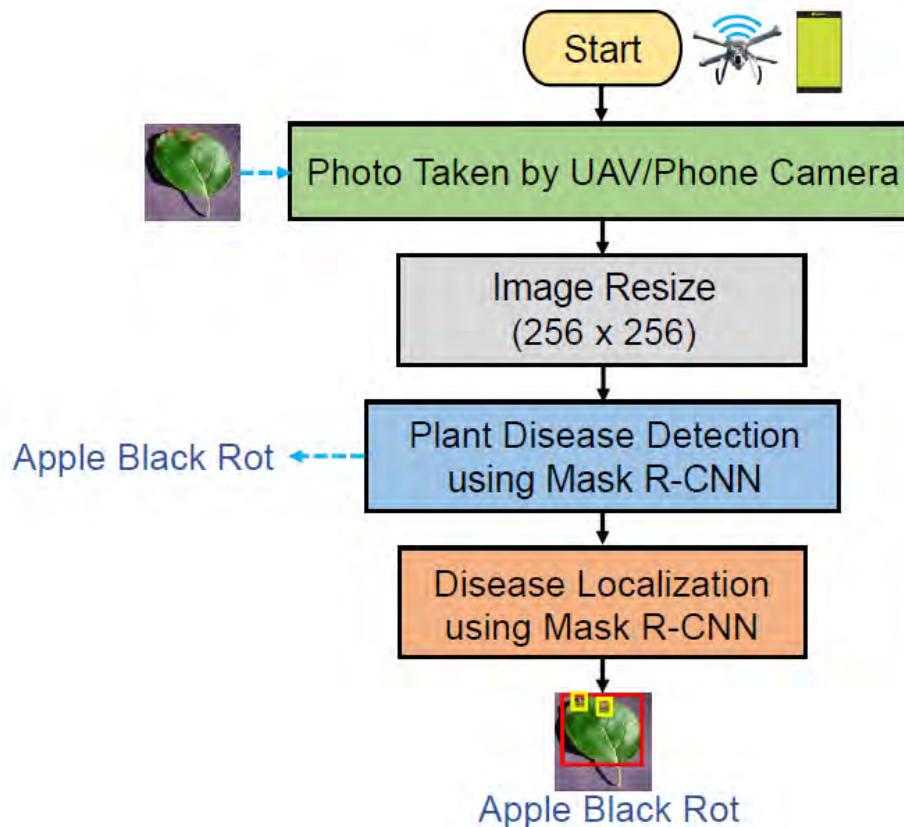
Source: A. Mitra, **S. P. Mohanty**, and E. Koulianou, “aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3–22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

Our aGROdet 2.0: An Automated Real Time Approach for Multiclass Plant Disease Detection

- Manual observation is still the most common method of detecting plant diseases.
 - Labor intensive.
 - Ineffective.
 - Requires expert services.
 - Expensive.
- Wrong identification causes wrong use of pesticides.
 - Causes secondary damage.
- Automatic and accurate monitoring of plant disease and damage estimation are necessary along with disease identification.

Source: A. Mitra, S. P. Mohanty, and E. Kougianos, “[A Smart Agriculture Framework to Automatically Track the Spread of Plant Diseases using Mask Region-based Convolutional Neural Network](#)”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 68–85, DOI: https://doi.org/10.1007/978-3-031-18872-5_5.

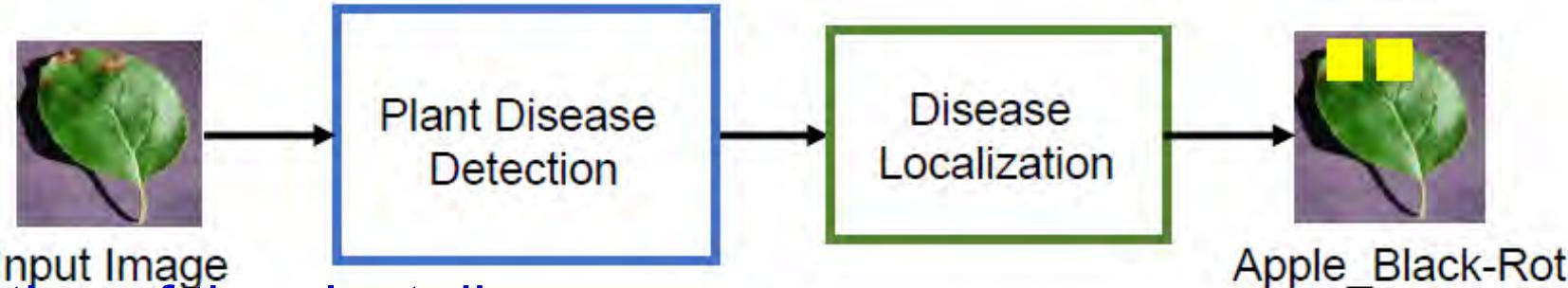
Our aGROdet 2.0: An Automated Real Time Approach for Multiclass Plant Disease Detection



- Photo of the leaves are taken.
- They are resized to 256x256 to be detected using the trained model.
- A Mask Region-based Convolutional Neural Network (R-CNN) is used to detect the disease along with the disease localization.
- Here, the problem is considered as an object detection problem.
- Object detection is a task in computer vision that involves identifying the presence of one or more items in each image as well as their location and the category of object that they belong to.

Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, “[A Smart Agriculture Framework to Automatically Track the Spread of Plant Diseases using Mask Region-based Convolutional Neural Network](#)”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 68–85, DOI: https://doi.org/10.1007/978-3-031-18872-5_5.

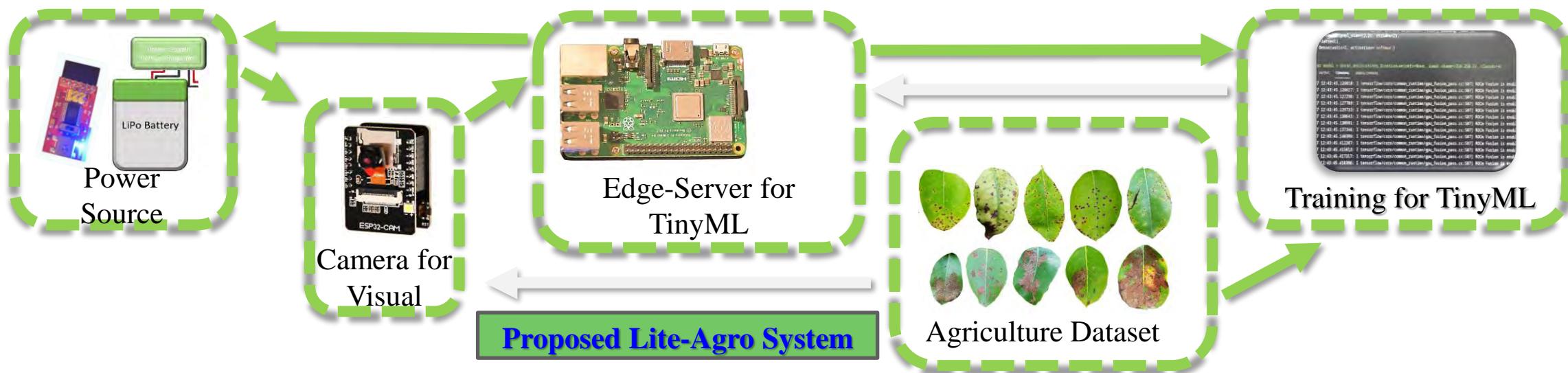
Our aGROdet 2.0: An Automated Real Time Approach for Multiclass Plant Disease Detection



- Early detection of the plant diseases.
- Fully automatic method.
- No expert service is needed for disease detection.
- Very little effort is needed from the users' side. Users only need to take pictures of the damaged leaves.
- This process is the first step of disease severity estimation.
- Estimation of disease severity plays a pivotal role in calculating the optimal quantity of pesticides.

Source: A. Mitra, S. P. Mohanty, and E. Kougianos, “[A Smart Agriculture Framework to Automatically Track the Spread of Plant Diseases using Mask Region-based Convolutional Neural Network](#)”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 68–85, DOI: https://doi.org/10.1007/978-3-031-18872-5_5.

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



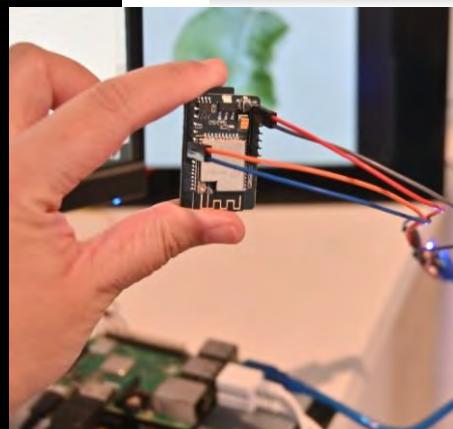
```
healthy score:109 disease score 212
Image Captured

healthy score:119 disease score 205
Image Captured

healthy score:107 disease score 212
Image Captured

healthy score:86 disease score 226
Image Captured

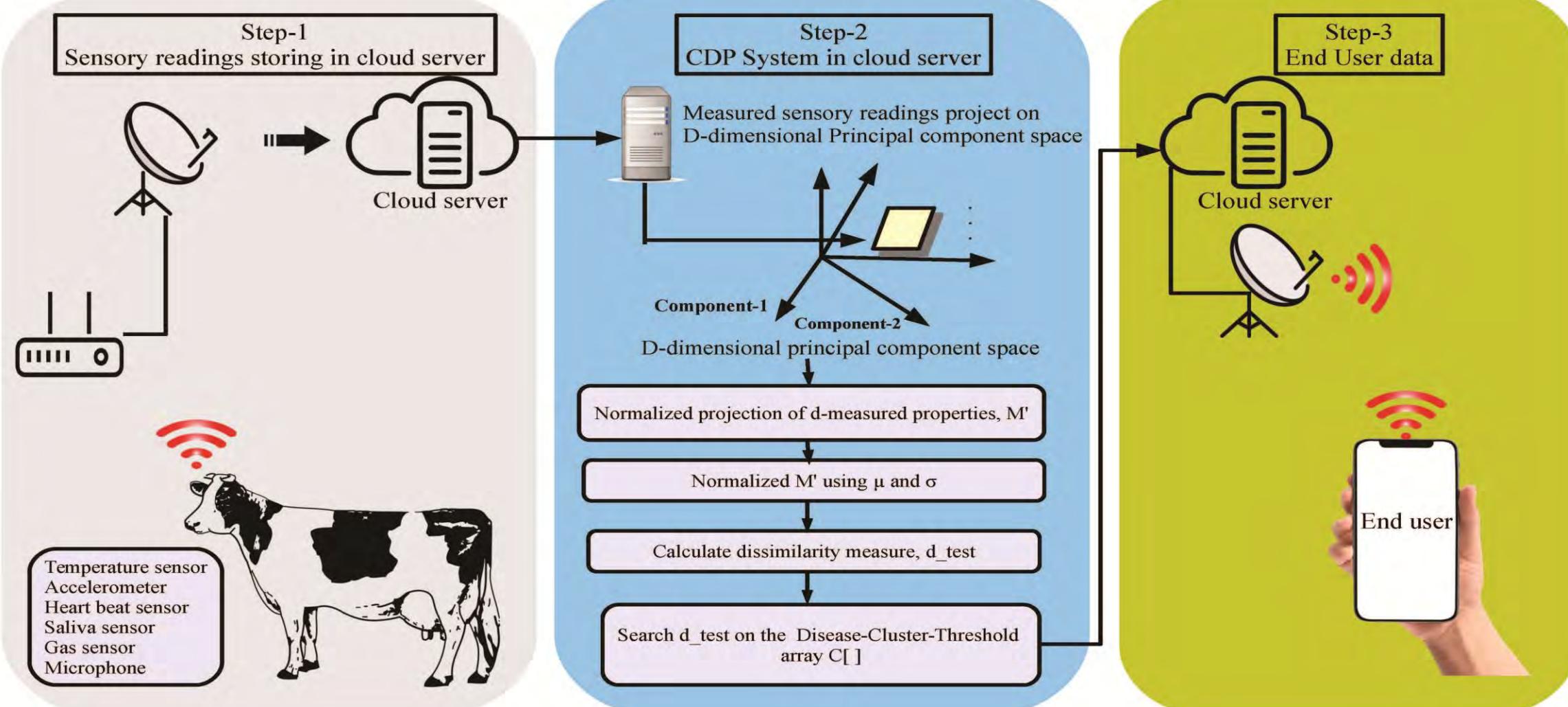
healthy score:107 disease score 213
Image Captured
```



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%

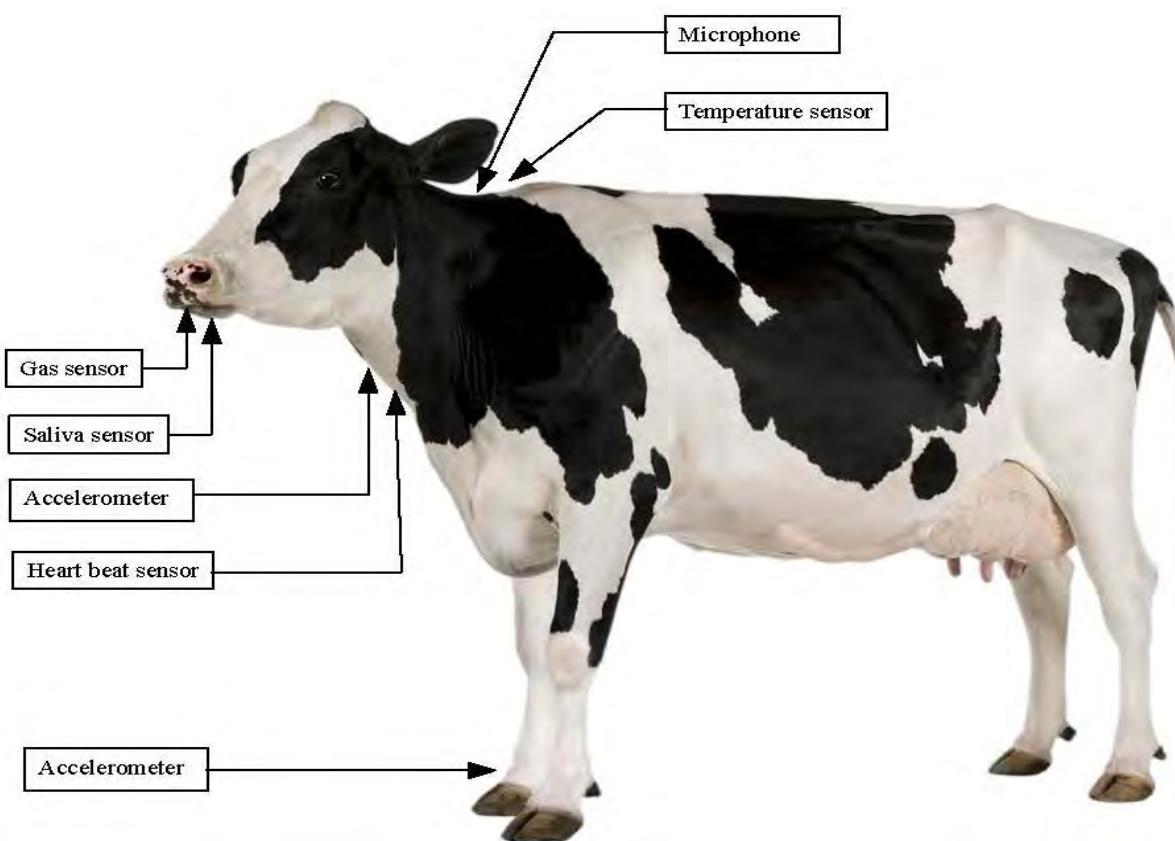
Source: C. Dockendorf, A. Mitra, **S. P. Mohanty**, and E. Kougianos, “[Lite-Agro: Exploring Light-Duty Computing Platforms for IoAT-Edge AI in Plant Disease Identification](#)”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2023, pp. 371–380, DOI: https://doi.org/10.1007/978-3-031-45882-8_25.

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>.

Our LiveCare - IoT-Based Cattle Healthcare Framework

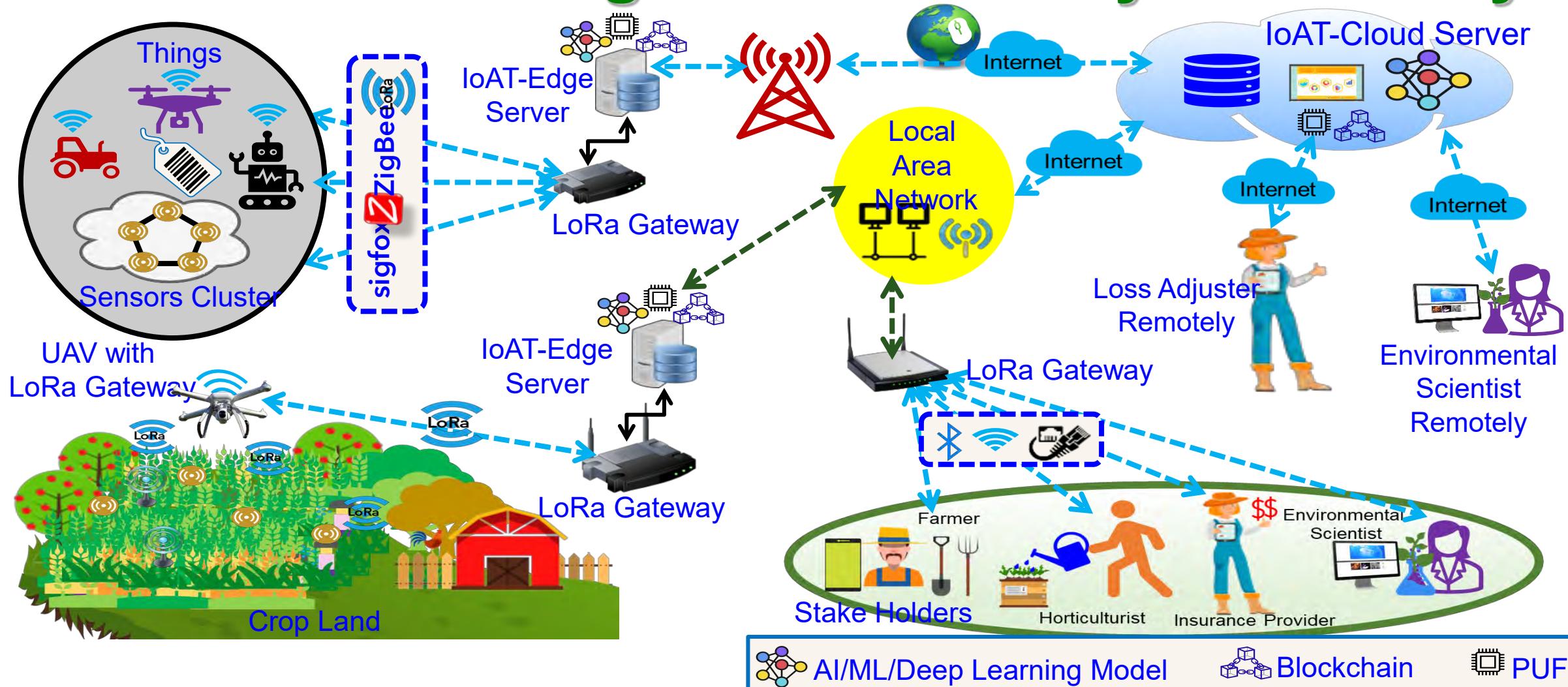


Sensor	Behavior	Value [9][29]		
		X	Y	Z
(1) Temperature Sensor	Cold Normal Low fever Middle fever High fever	35.5°C to 38.5°C 38.5°C to 39.5°C 39.5°C to 40.5°C 40.5°C to 41.5°C Above 41.5°C		
(2) Three-axis Accelerometer	Standing still Moving Prostration Lameness Discomfort	constant variable constant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

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

Smart Agriculture Case Studies - Cybersecurity Solutions

A-CPS with Integrated AI and Cybersecurity

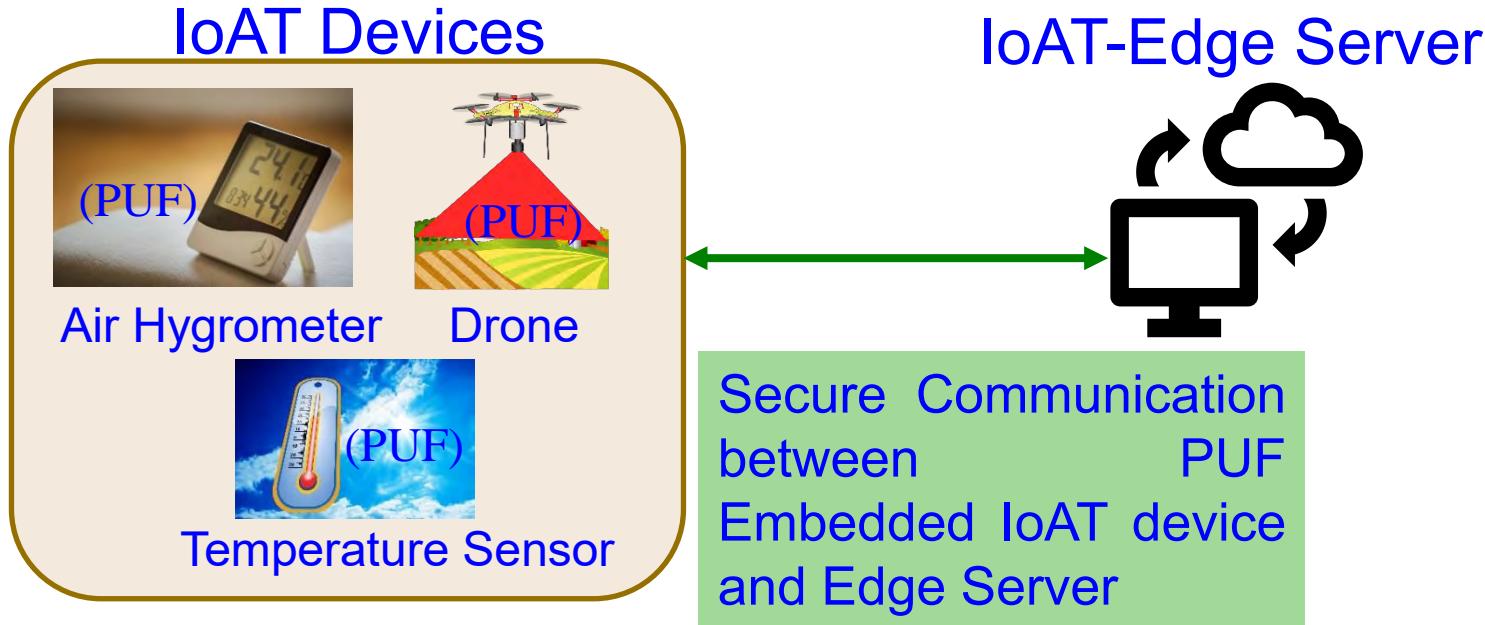


Source: A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, “[eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture](#)”, Springer Nature Computer Science (SN-CS), Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: <https://doi.org/10.1007/s42979-022-01216-8>.

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

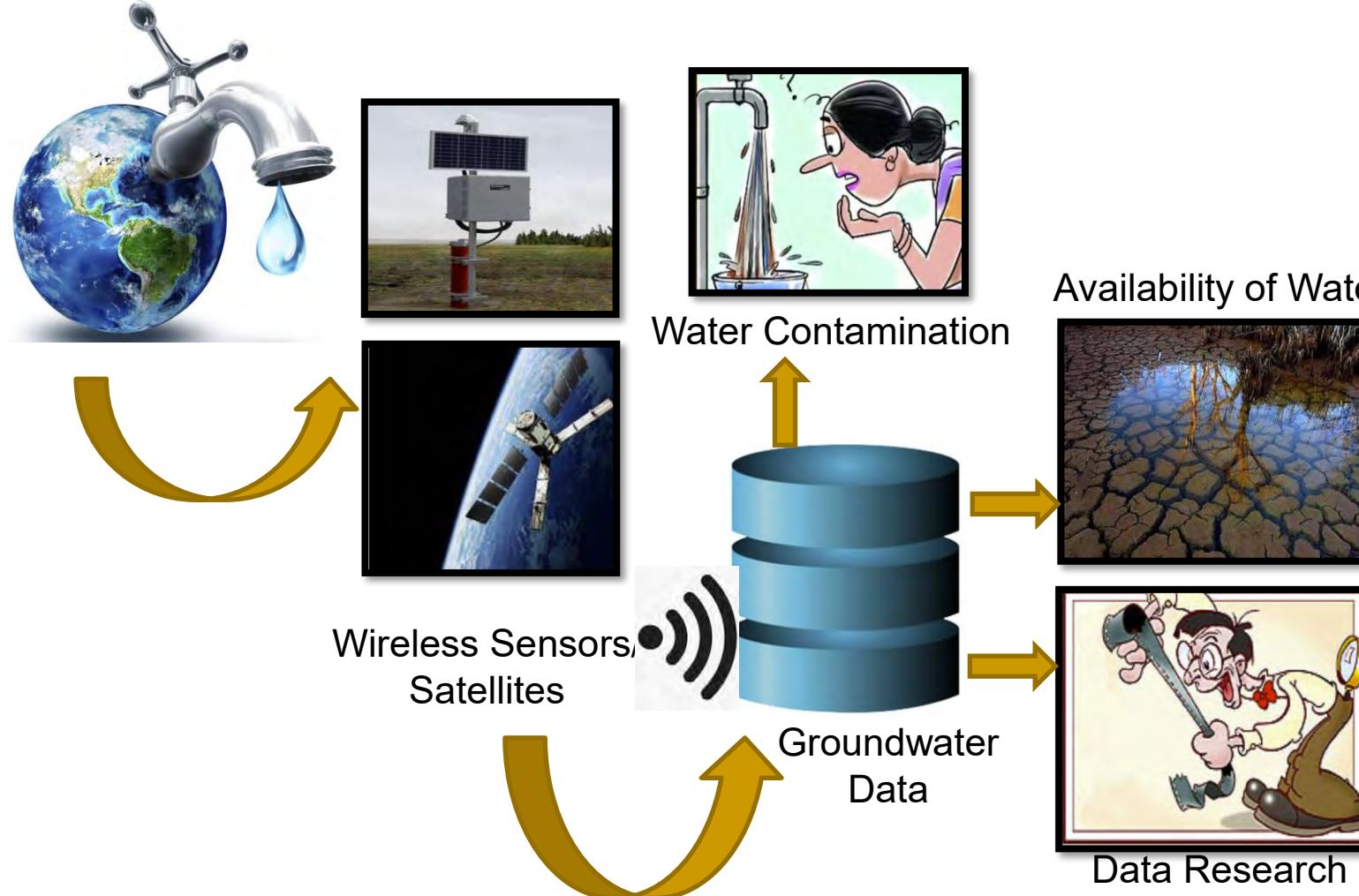
Our Security-by-Design Approach for Robust IoAT



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.

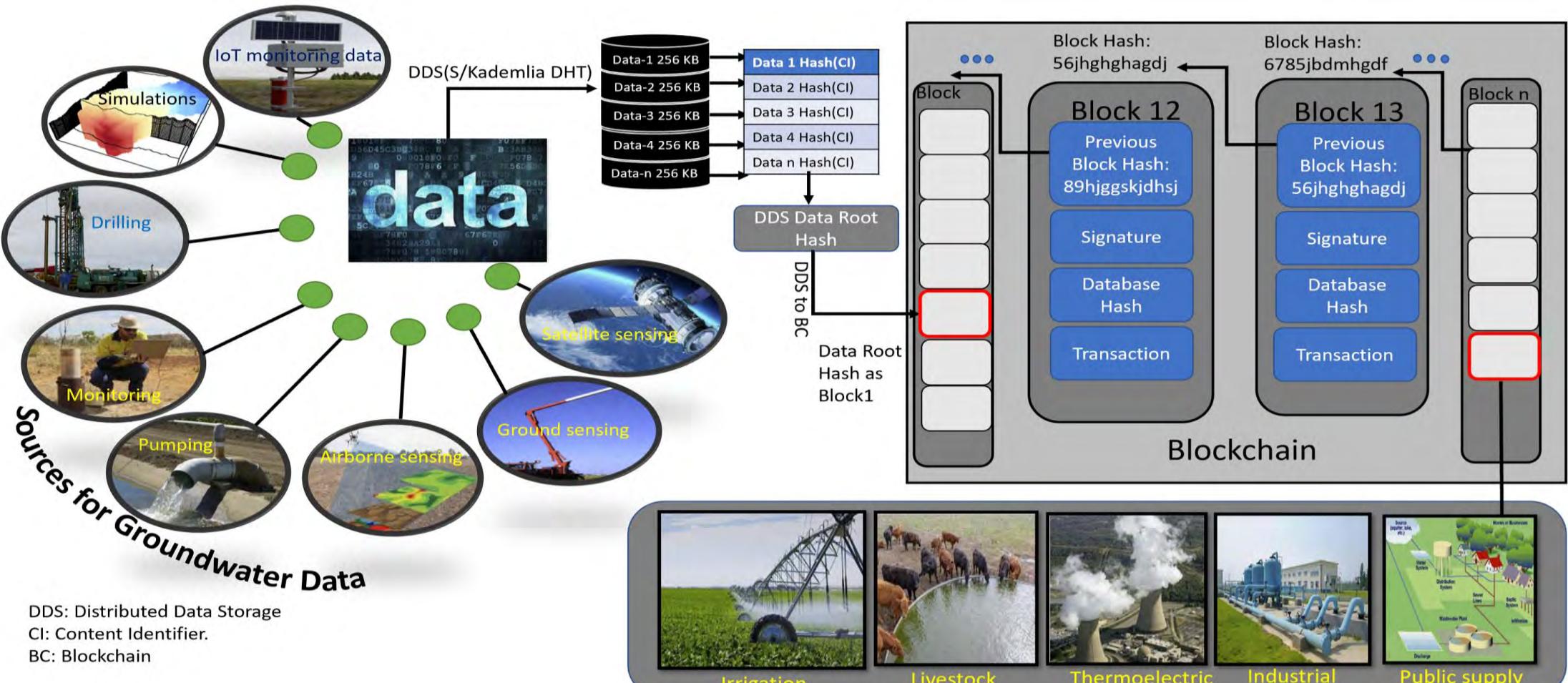
Our G-DaM: Introduction-Ground Water Data



- 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 .

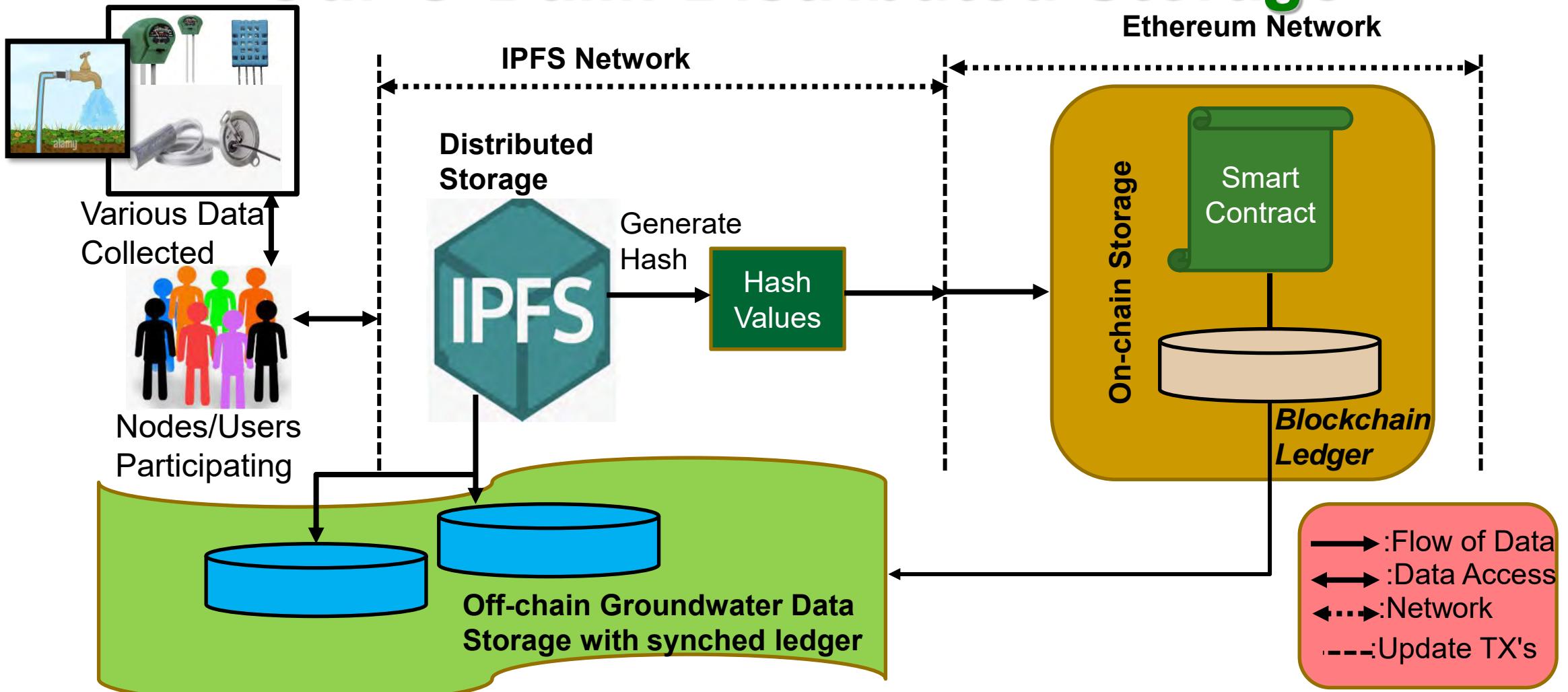
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "[G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data](#)", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: <https://doi.org/10.3390/s22228725>.

Our G-DaM: Proposed Architecture



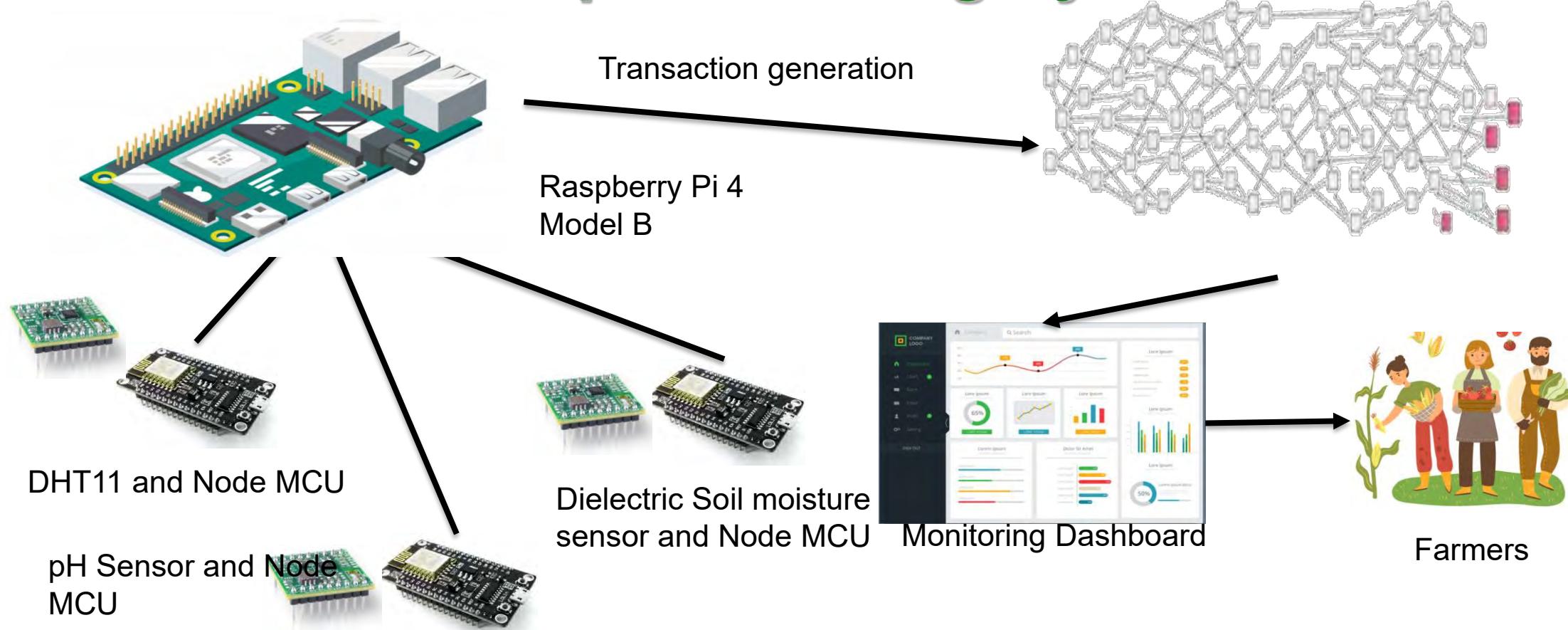
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, “[G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data](#)”, MDPI Sensors, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: <https://doi.org/10.3390/s22228725>.

Our G-DaM: Distributed Storage



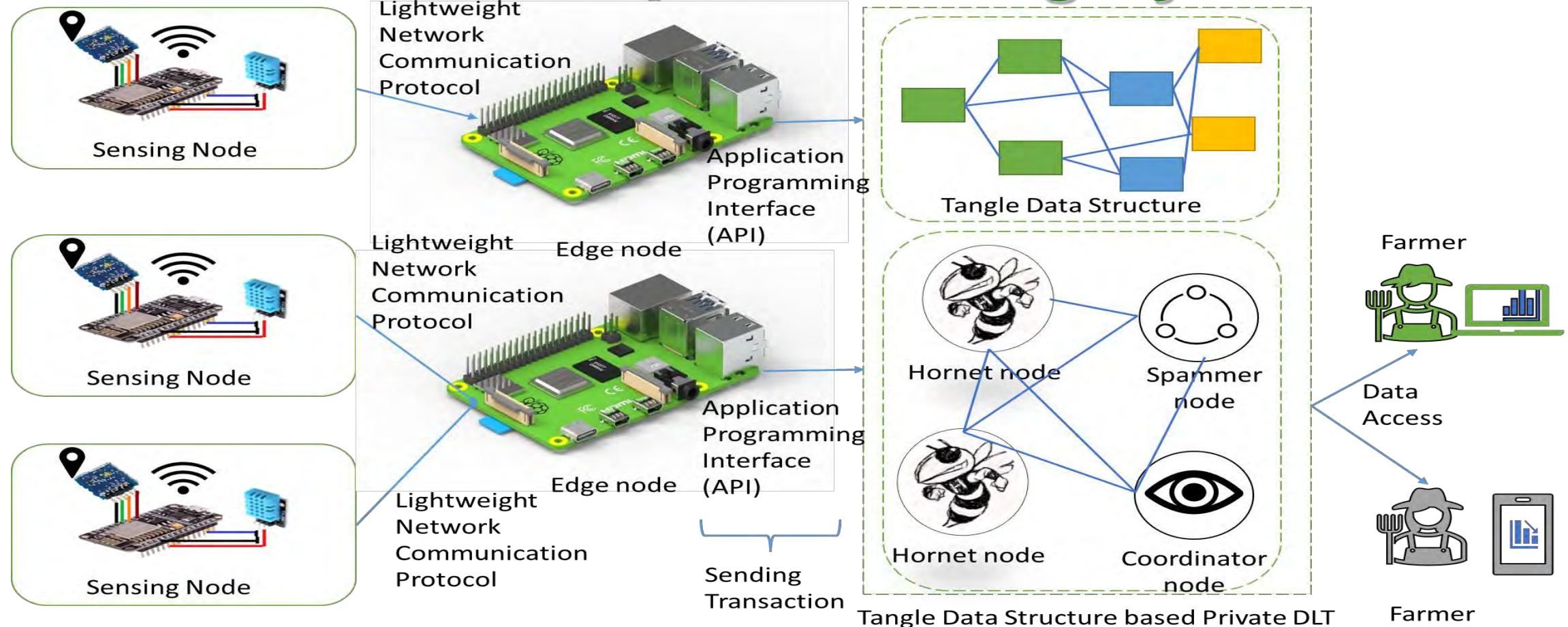
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "[G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data](https://doi.org/10.3390/s22228725)", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: <https://doi.org/10.3390/s22228725>.

Our sFarm: A Distributed Ledger based Remote Crop Monitoring System



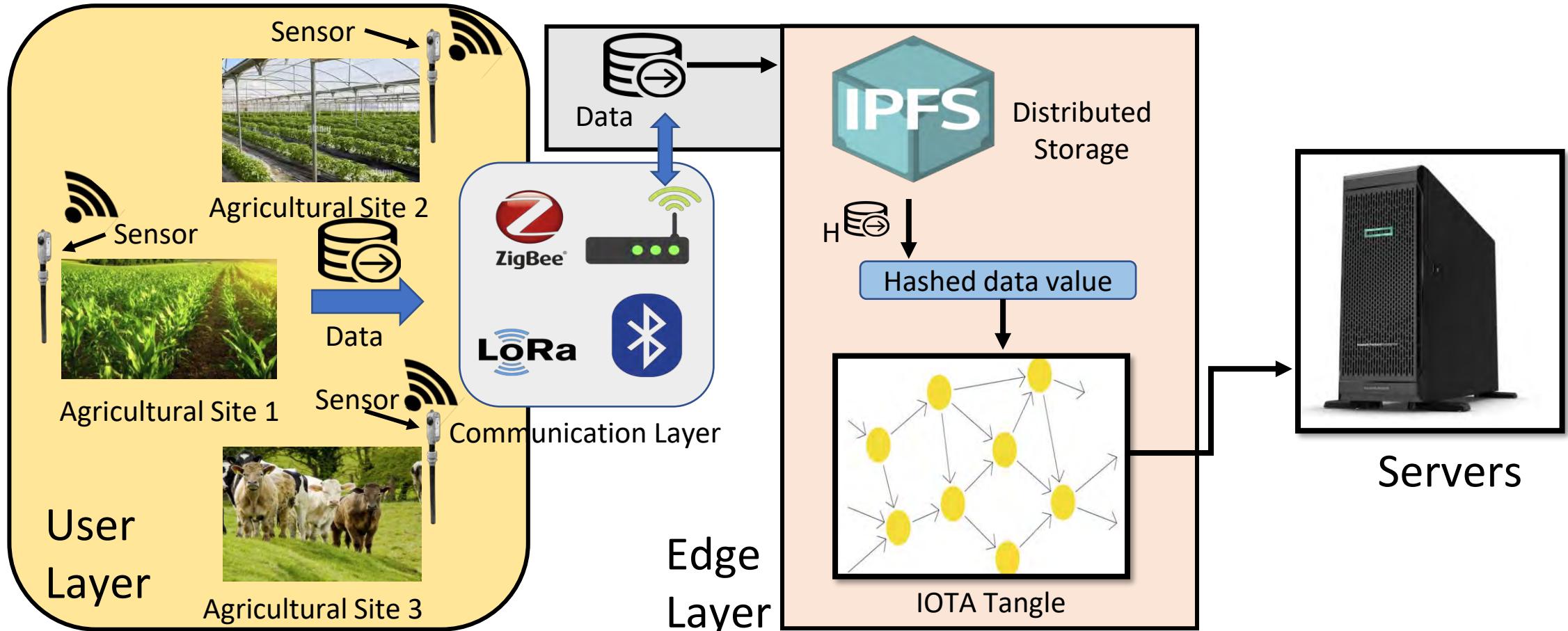
Source: A. K. Bapatla, **S. P. Mohanty**, and E. Kougianos, "[sFarm: A Distributed Ledger based Remote Crop Monitoring System for Smart Farming](#)", in *Proceedings of the 4th IFIP International Internet of Things Conference (IFIP-IoT)*, 2021, pp. 13–31, DOI: https://doi.org/10.1007/978-3-030-96466-5_2

Our sFarm: A Distributed Ledger based Remote Crop Monitoring System



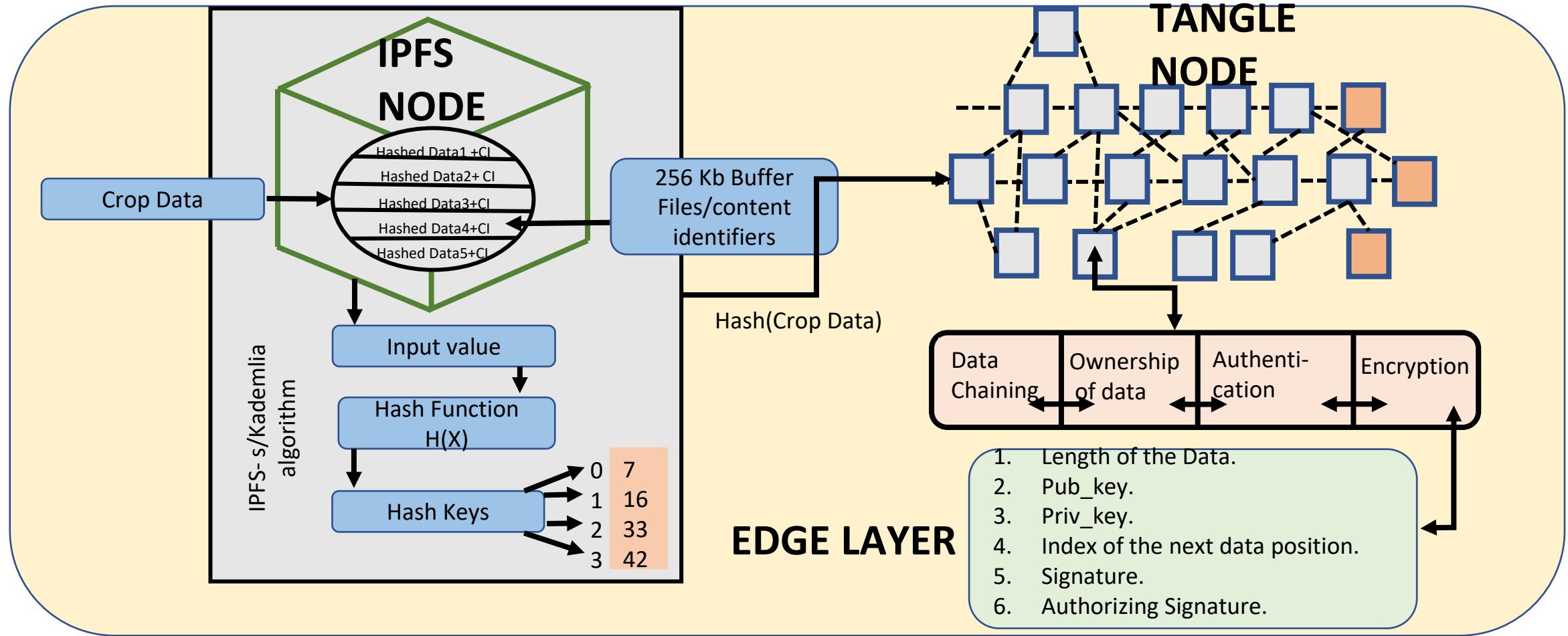
Source: A. K. Bapatla, **S. P. Mohanty**, and E. Kougianos, “[sFarm: A Distributed Ledger based Remote Crop Monitoring System for Smart Farming](#)”, in *Proceedings of the 4th IFIP International Internet of Things Conference (IFIP-IoT)*, 2021, pp. 13–31, DOI: https://doi.org/10.1007/978-3-030-96466-5_2

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](https://doi.org/10.1007/978-3-031-45878-1_26)”, 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.

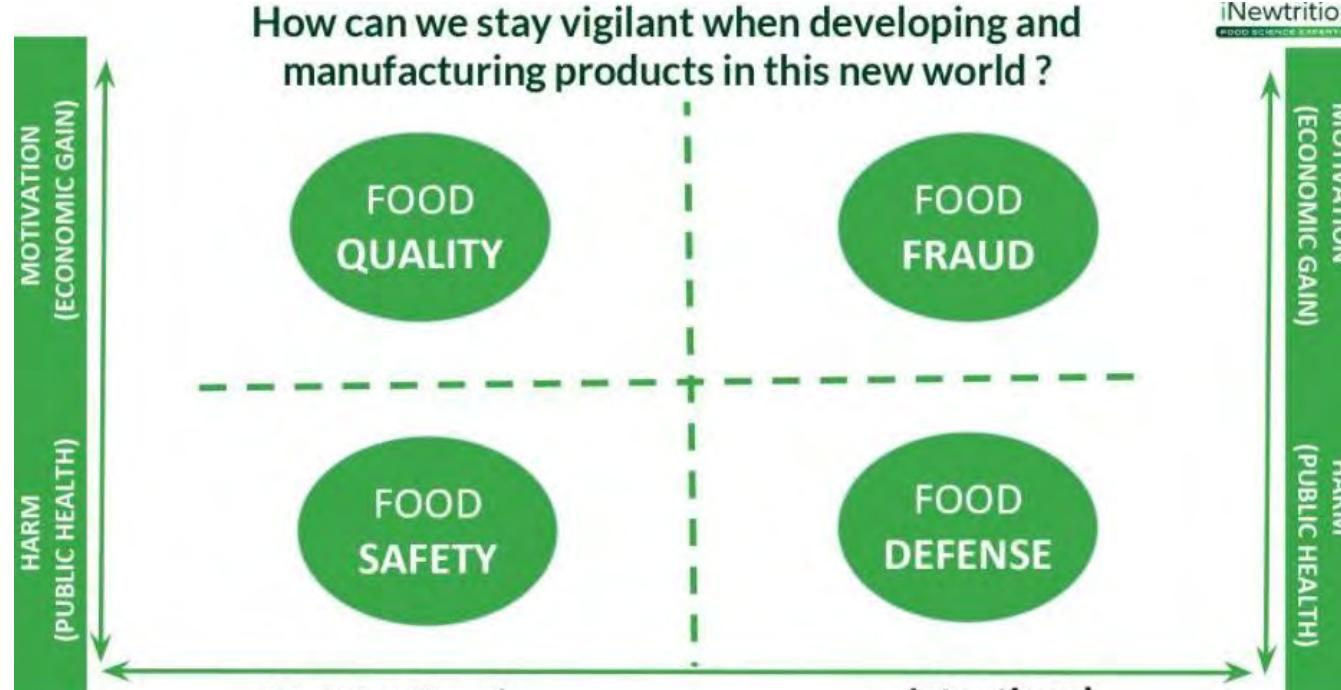
CroPAiD: Our Novel Framework for Protection of Information in A-CPS



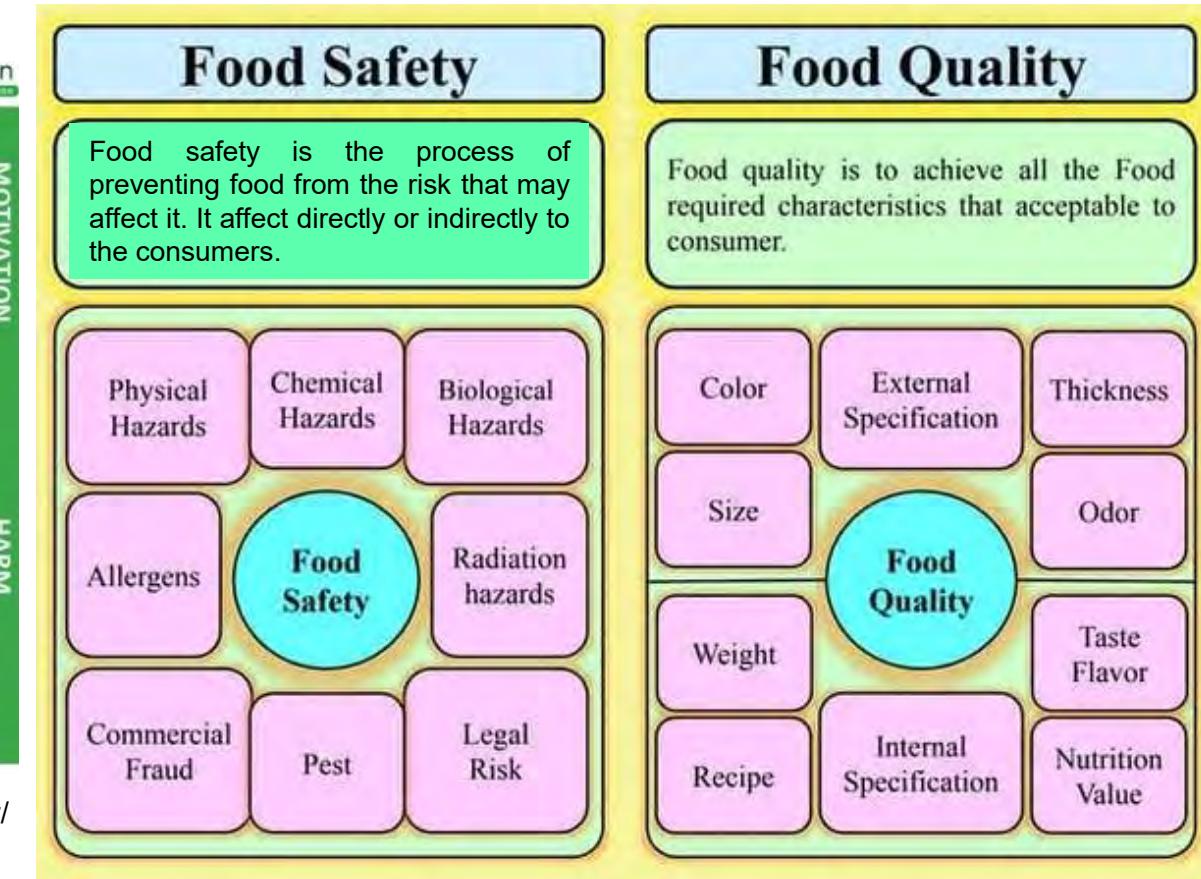
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, “[CroPAiD: Protection of Information in Agriculture Cyber-Physical Systems Using Distributed Storage and Ledger](#)”, in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2023, pp. 375–394, DOI: https://doi.org/10.1007/978-3-031-45878-1_26.

Food Safety and Quality

Food Safety Vs Food Quality



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



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

Fruit and Vegetable Safety and Quality?

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



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

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?



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.



Broiler or Layer?

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.

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

Is this Chicken Meat safe to eat?



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.

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.



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.



Agriculture CPS - Prof./Dr. Saraju Mohanty



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>

Milk Safety and Quality?



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

Some germs linked to raw milk outbreaks



Campylobacter

Salmonella

E. coli

Listeria

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

How Safe is the Milk
that I am Drinking?



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

Stages in Agricultural Product Distribution



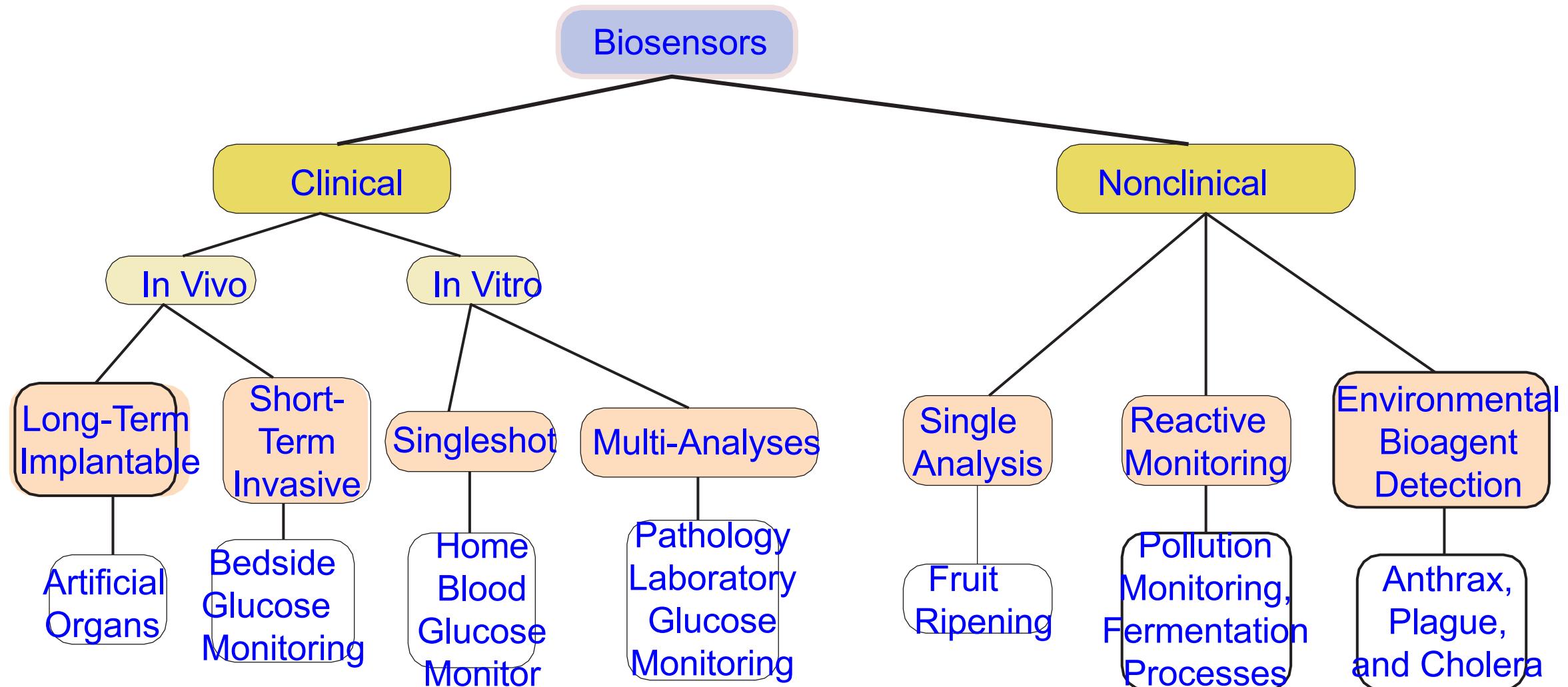
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "[agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers](https://doi.org/10.3390/s22218227)", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: <https://doi.org/10.3390/s22218227>.

Food Supply Chain: Farm → Dinning



Source: A. M. Joshi, U. P. Shukla, and S. P. Mohanty, "Smart Healthcare for Diabetes: A COVID-19 Perspective", arXiv Quantitative Biology, arXiv:2008.11153, August 2020, 18-pages.

Time to Go Back to the Basics of Biosensors



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

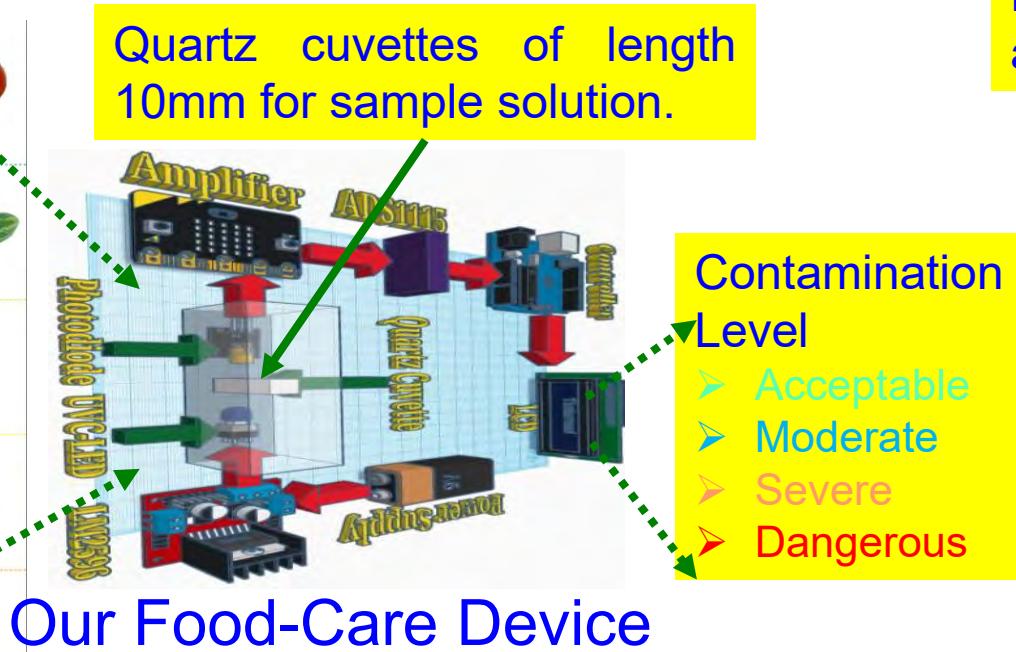
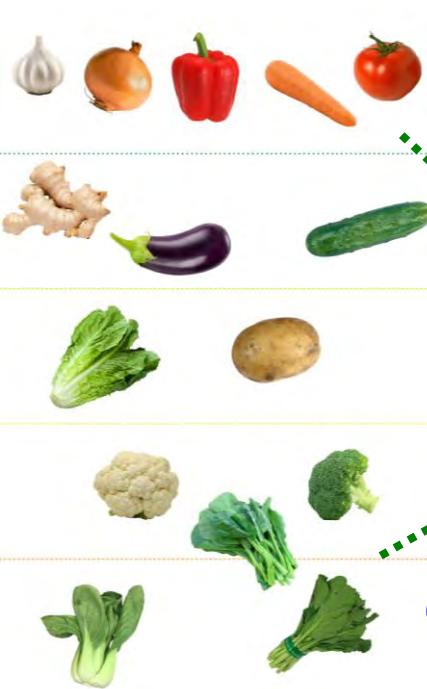
Food Safety and Security

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

Food Labelling

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

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

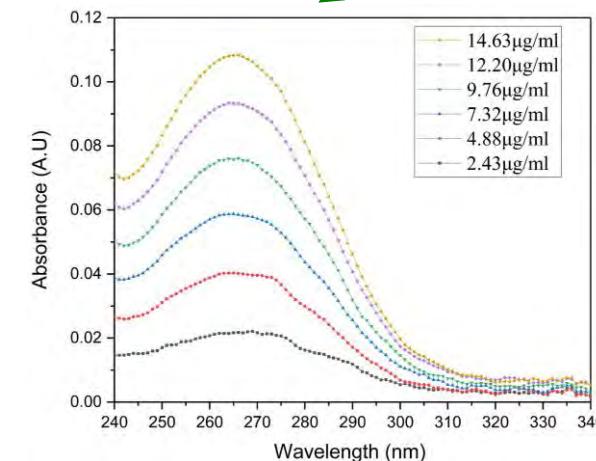


Source: <https://www.smartshanghai.com/articles/wellbeing/are-your-fruits-veggies-safe-nitrate-testing>

Fruit and Vegetables - Nitrate 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.

Peak absorbance spectrum of 265nm at different nitrate concentrations.



Need for Device which is:

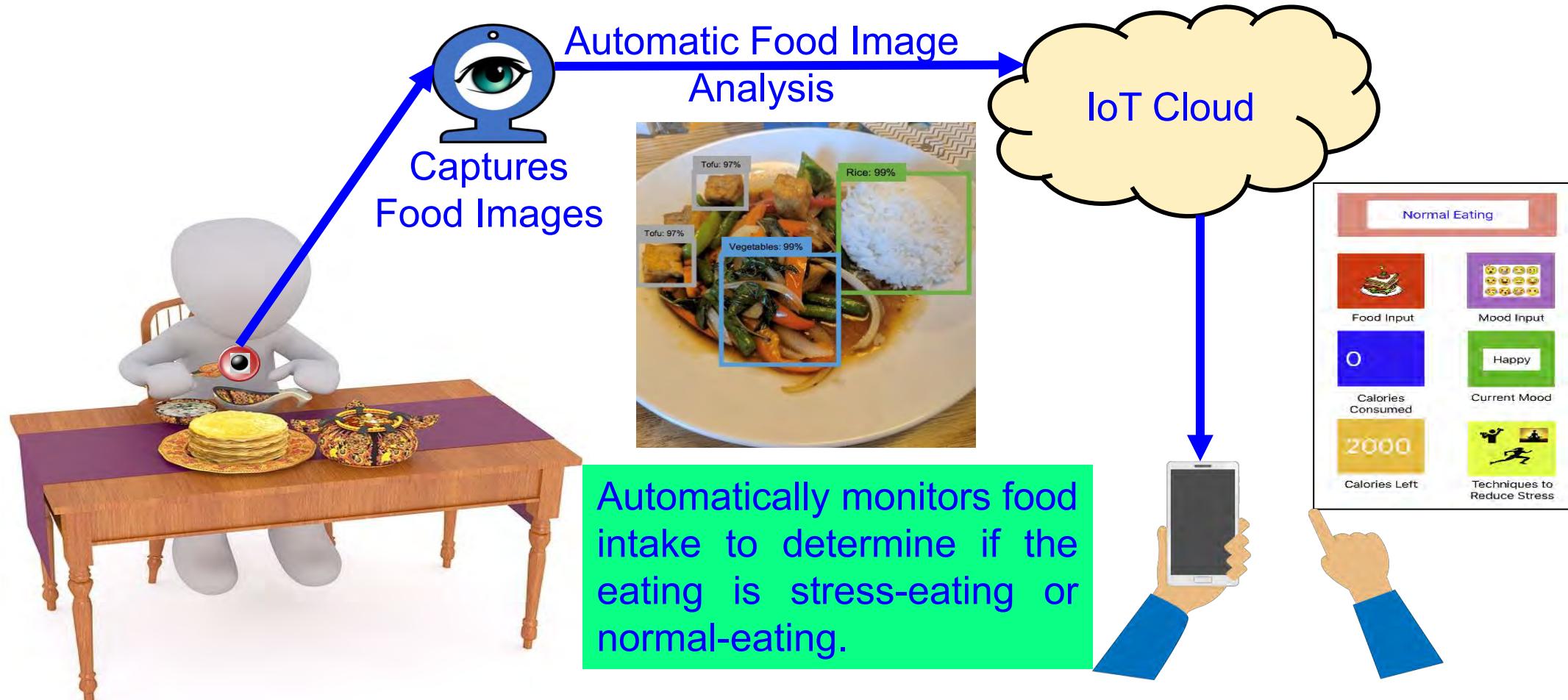
- ✓ Portable
- ✓ Works with dry or wet samples
- ✓ User safe
- ✓ Accurate
- ✓ IoT-Enable

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:

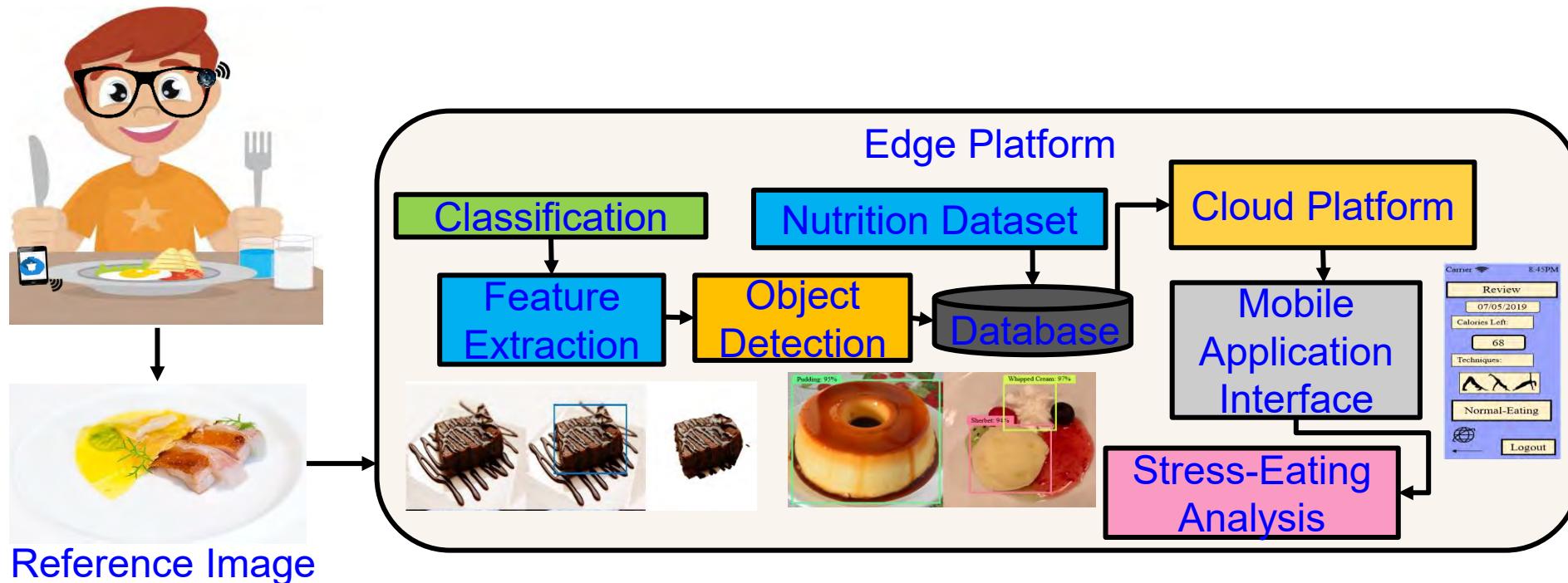
Source: <https://obesity-diet.nutritionalconference.com/events-list/imbalanced-diet-effects-and-causes>
[https://www.thelancet.com/article/S0140-6736\(19\)30041-8/fulltext](https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext)

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.

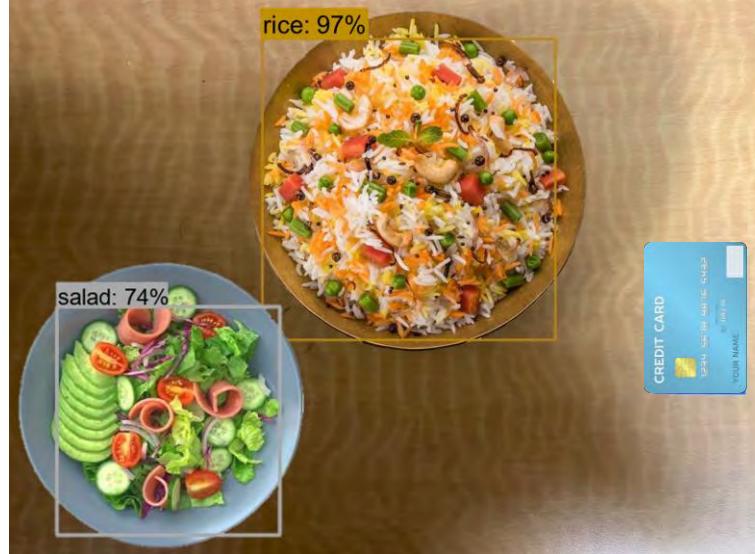
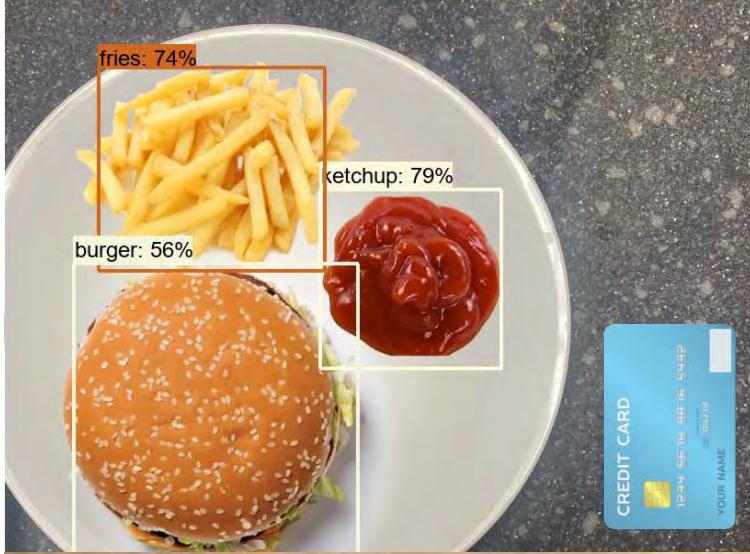
Smart Healthcare – Diet Monitoring - iLog



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 - Diet Monitoring - iLog 2.0

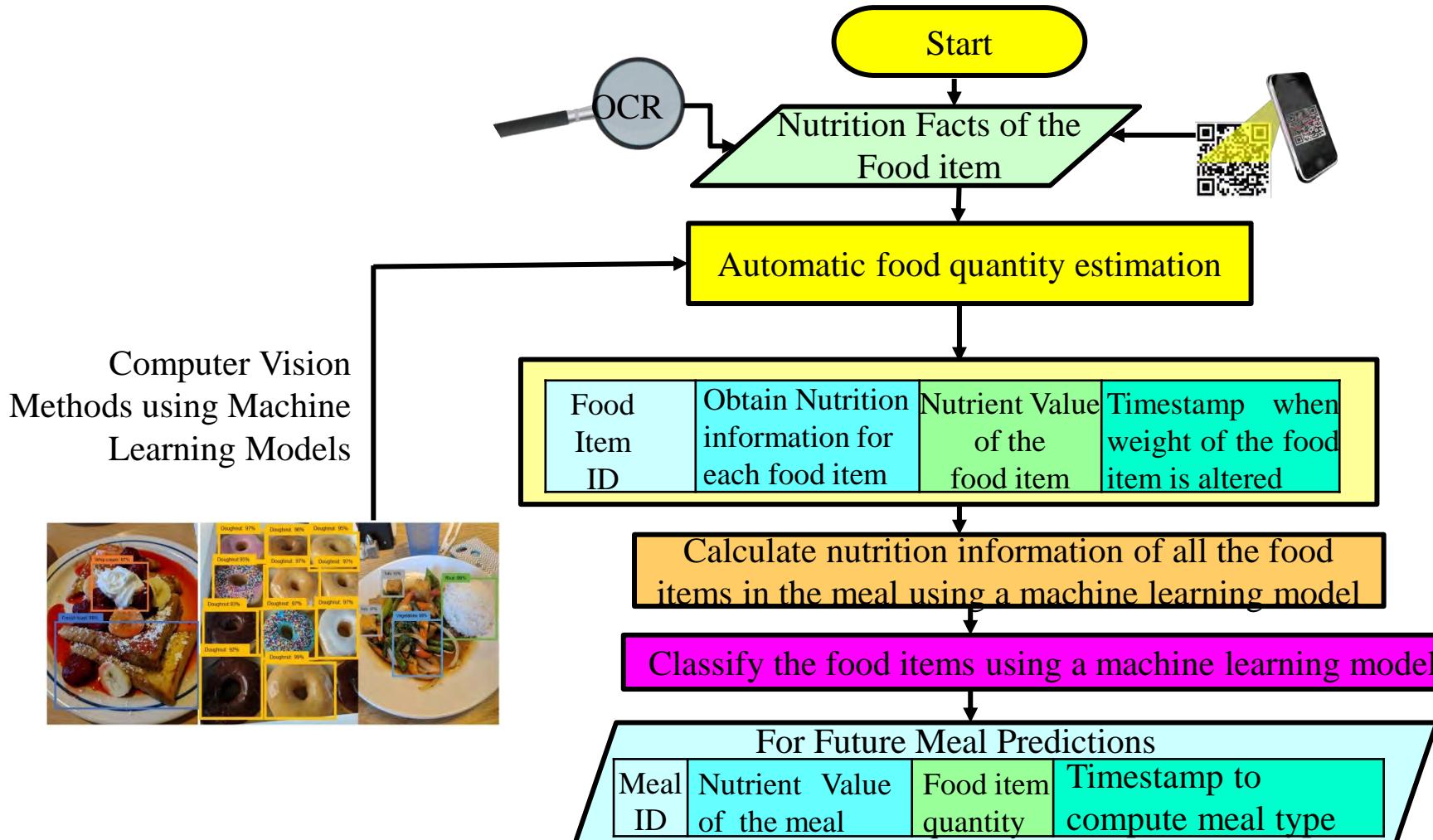


Food Item	Saturated Fat (g)	Sugar (g)	Sodium (mg)	Protein (g)	Carbohydrates (g)
Fries	6.44	1.56	244	4.03	34.84
Burger	6.87	4.67	481	17.29	48.14
Ketchup	0	3.2	136	0.2	4.13
Total	13.31	9.43	861	21.52	87.11

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

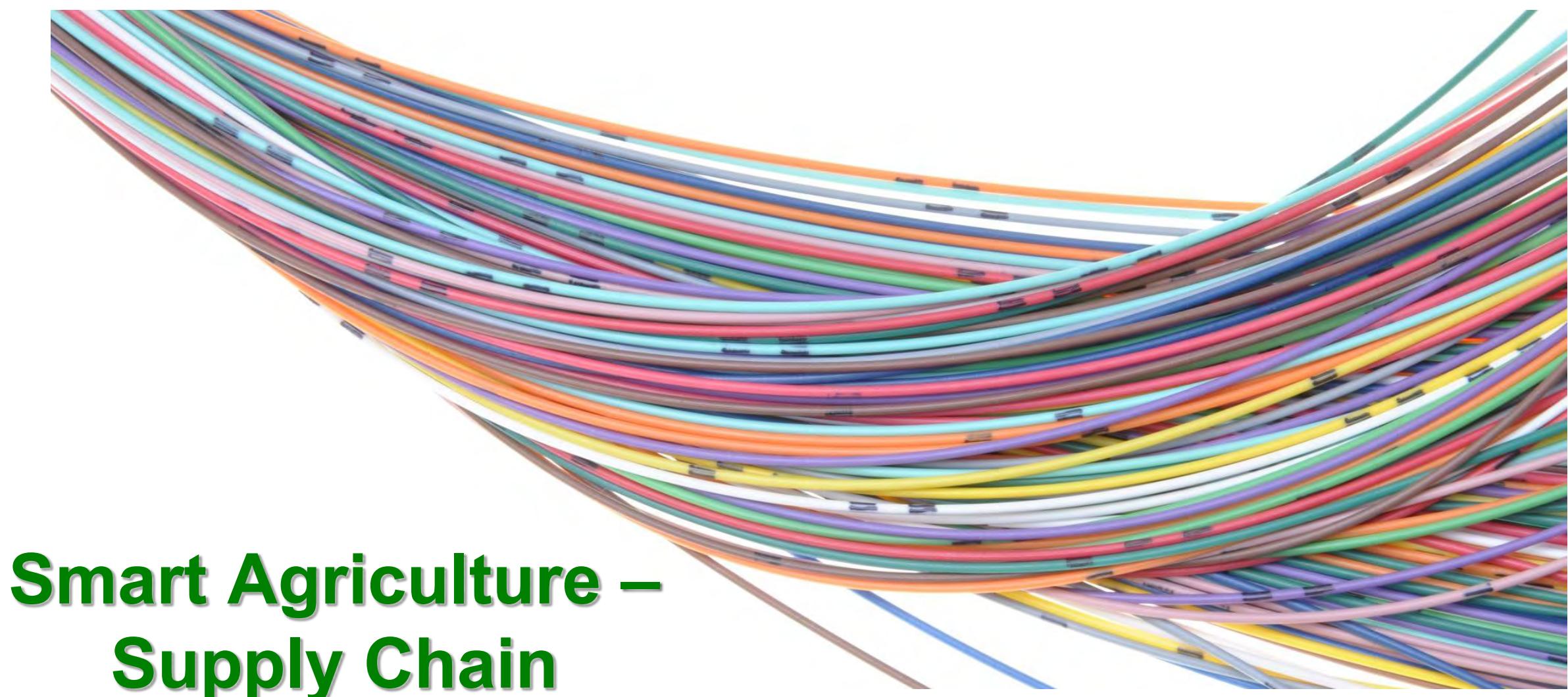
Source: A. Mitra, S. Goel, **S. P. Mohanty**, E. Kougianos, and L. Rachakonda, "iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare", in *Proceedings of the IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted.

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.

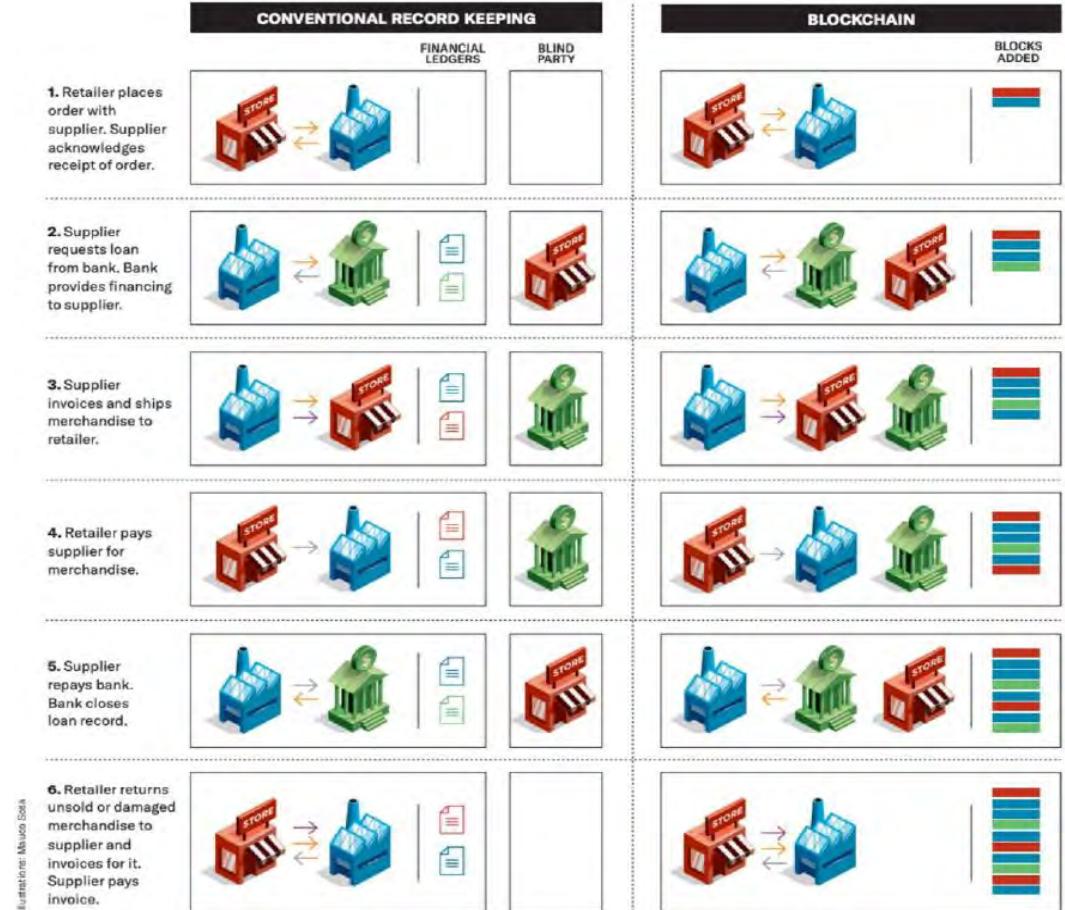


Smart Agriculture – Supply Chain

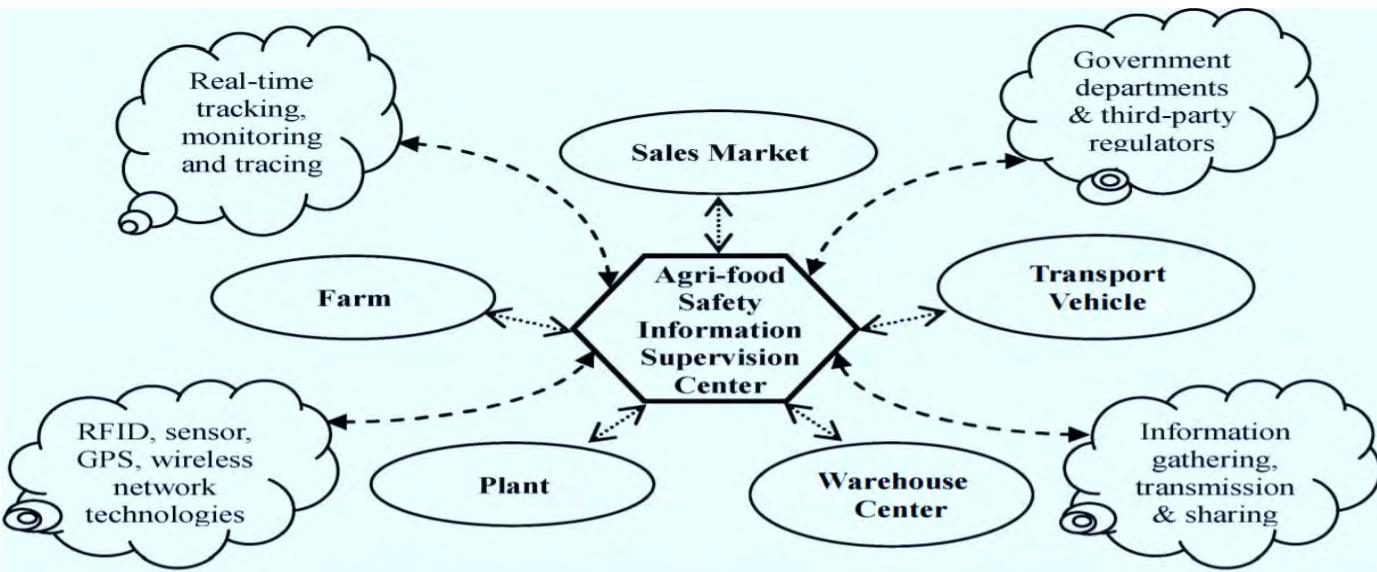
Agriculture CPS - Prof./Dr. Saraju Mohanty

Transparent Supply Chain

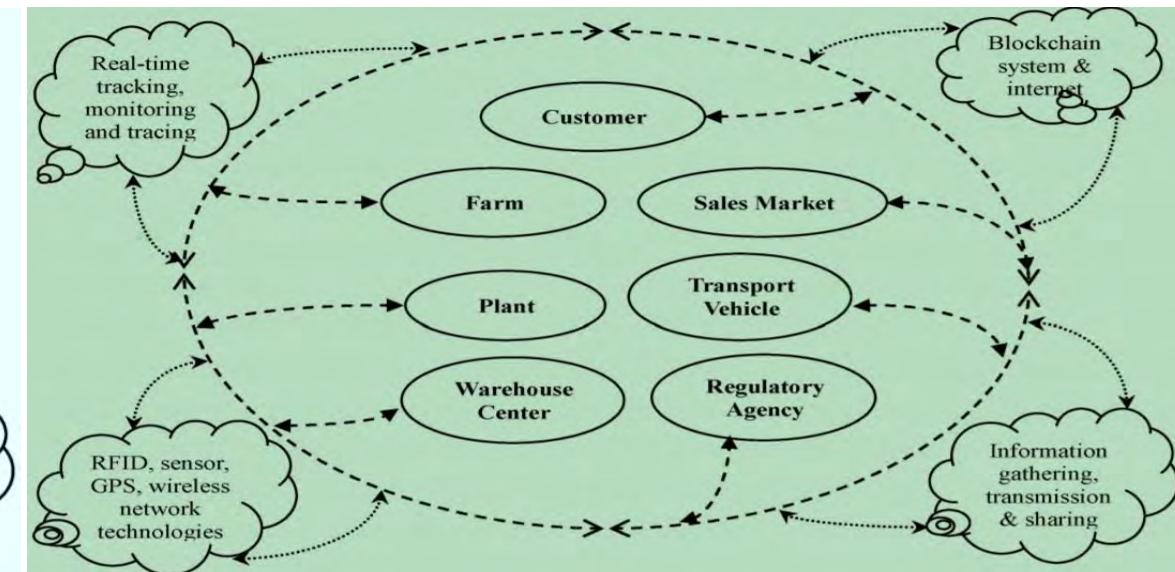
- Execution errors – like mistakes in inventory data, Missing shipments and duplicate payments are difficult to detect in real-time.
- For companies with large number of transactions each day, it is difficult to assess and fix these issues.



Food Traceability Using Efficient Supply Chain



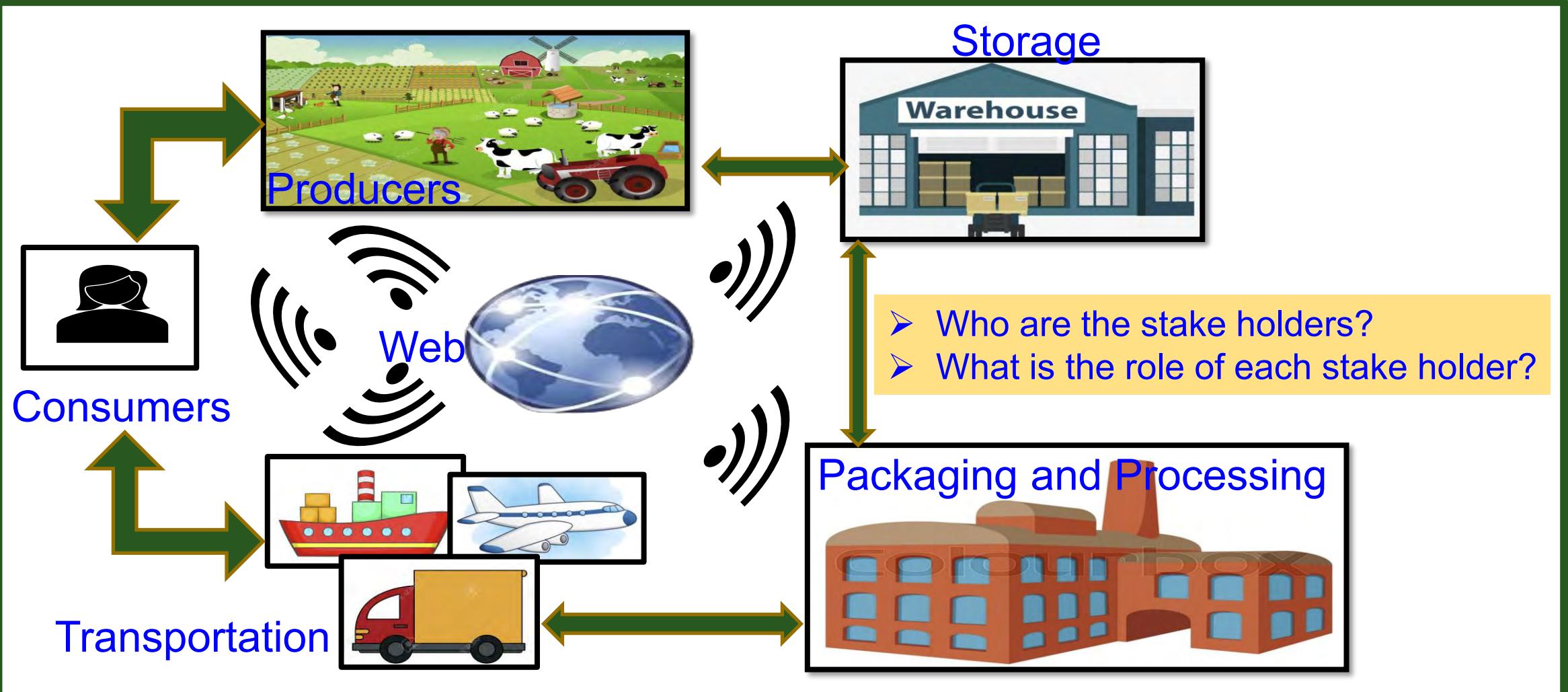
Centralized System



Blockchain based Decentralized System

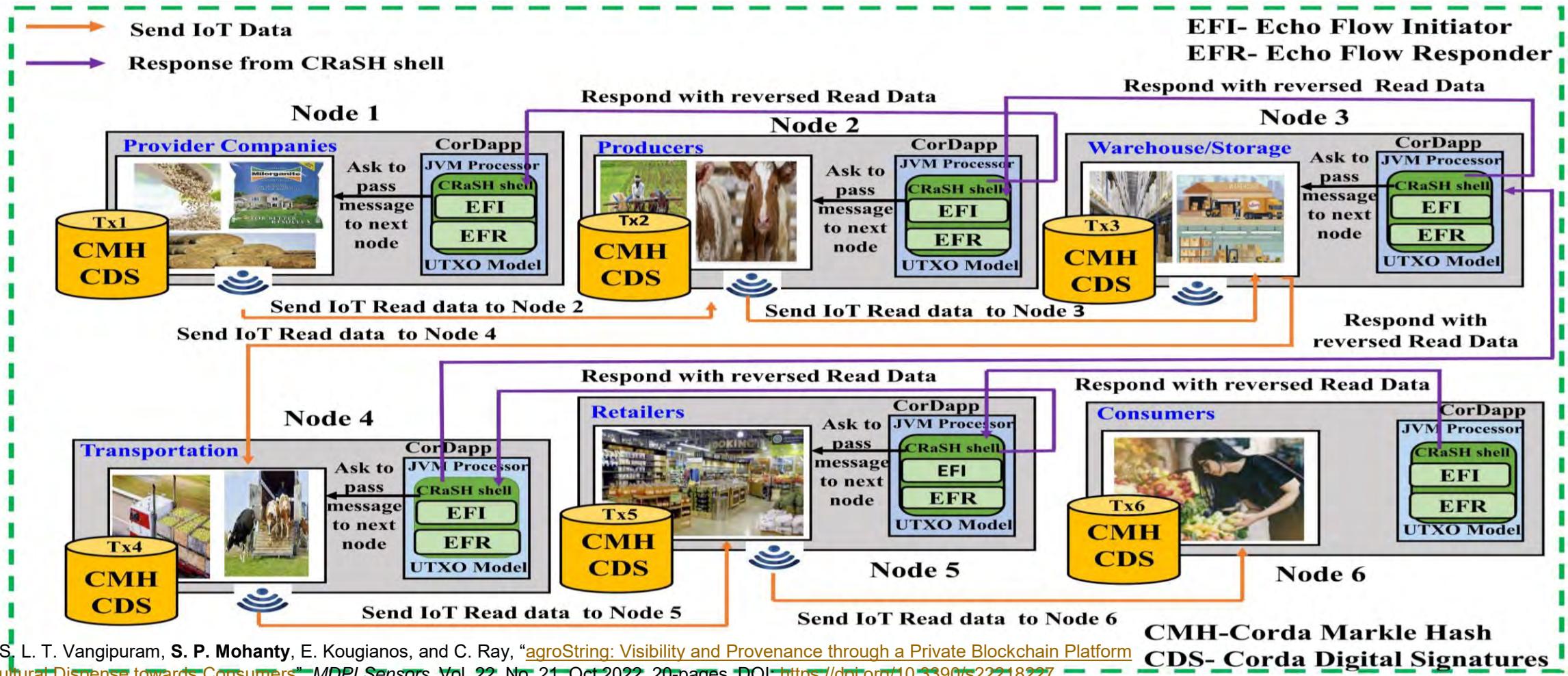
Source: Feng Tian, "An agri-food supply chain traceability system for China based on RFID & blockchain technology," in *Proc. 13th International Conference on Service Systems and Service Management (ICSSSM)*, 2016, pp. 1-6, doi: 10.1109/ICSSSM.2016.7538424.

Agriculture Supply Chain



Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kouglanos, 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: Comparative Perspectives

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

1 KB = 0.032 Eth [40] 1MB= 32.768 1Eth= 1944.84 [38]

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

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

Direct Financing

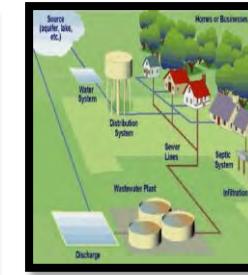
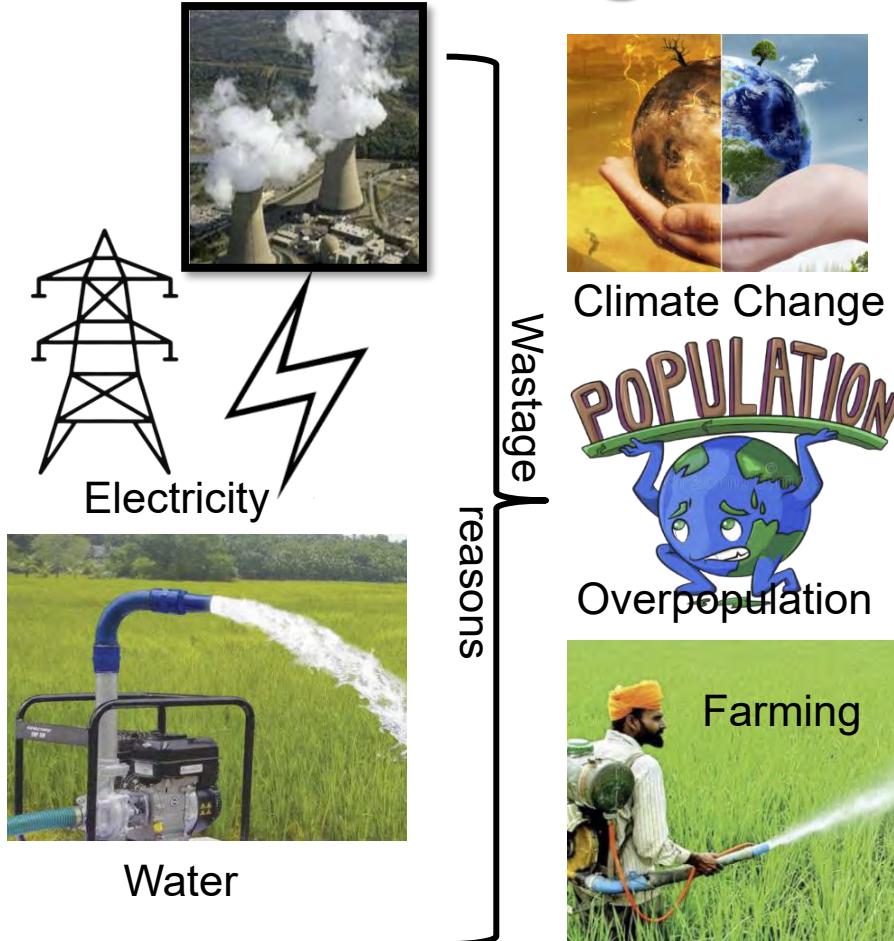


- Use of Traditional Tools
- Separation from the financial Services
- Isolation from financing

- Decreased crop production
- Low Yield
- Reduced Income

Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kouglanos, 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>.

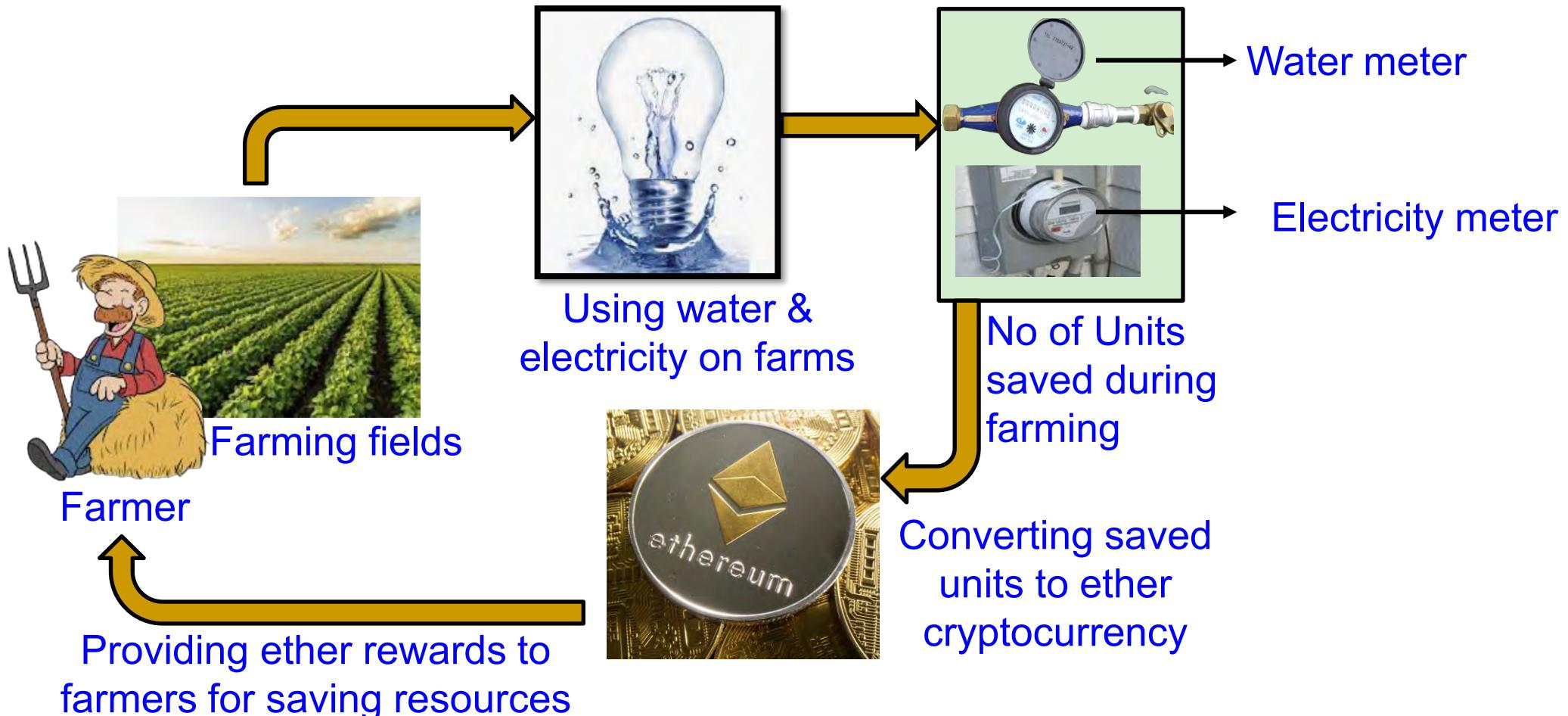
Our IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming



- 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.

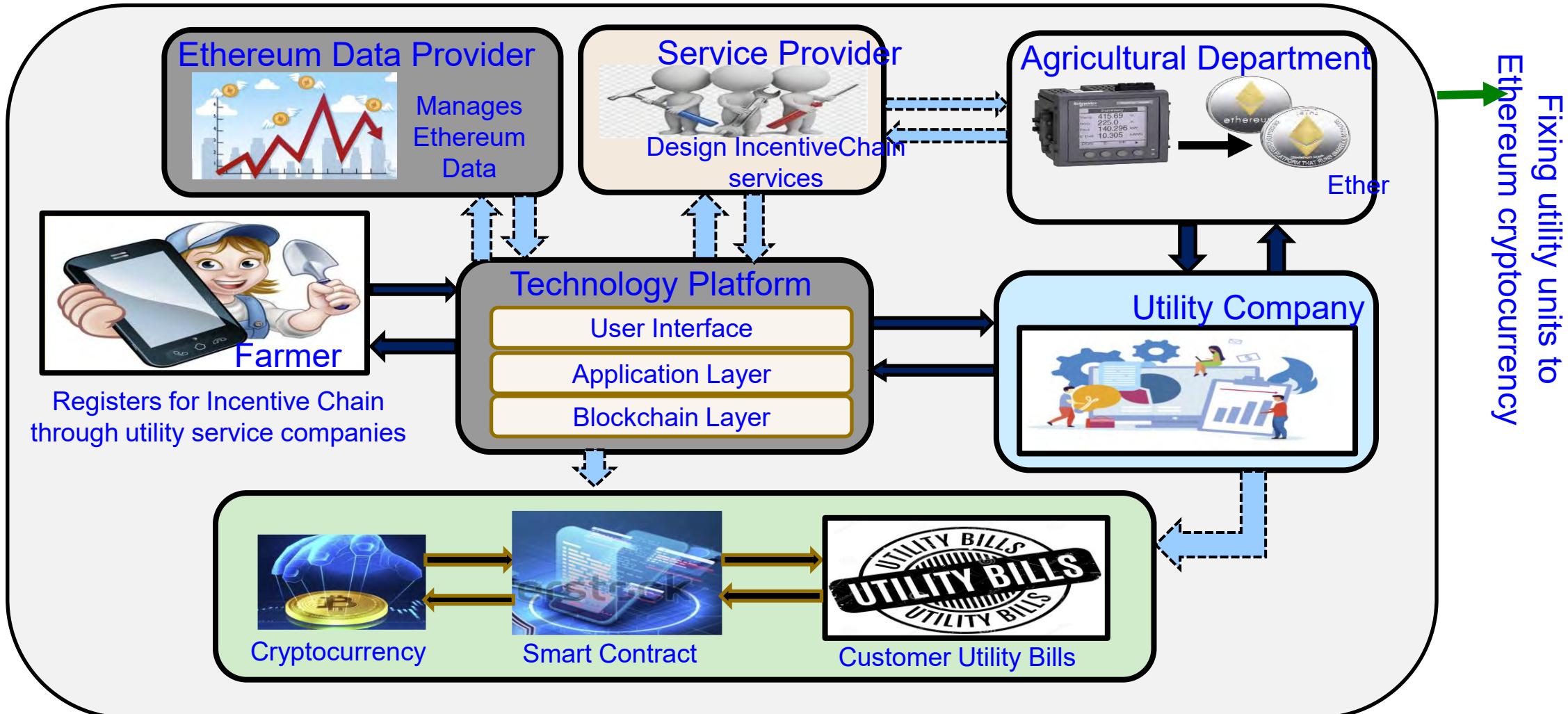
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

Our IncentiveChain: 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



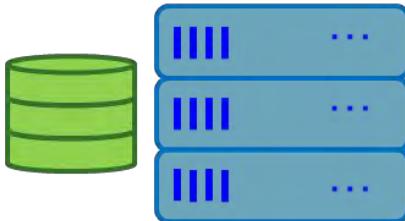
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

Smart Agriculture and Federated Learning

Smart Agriculture – AI/ML Workflow



Data Generation



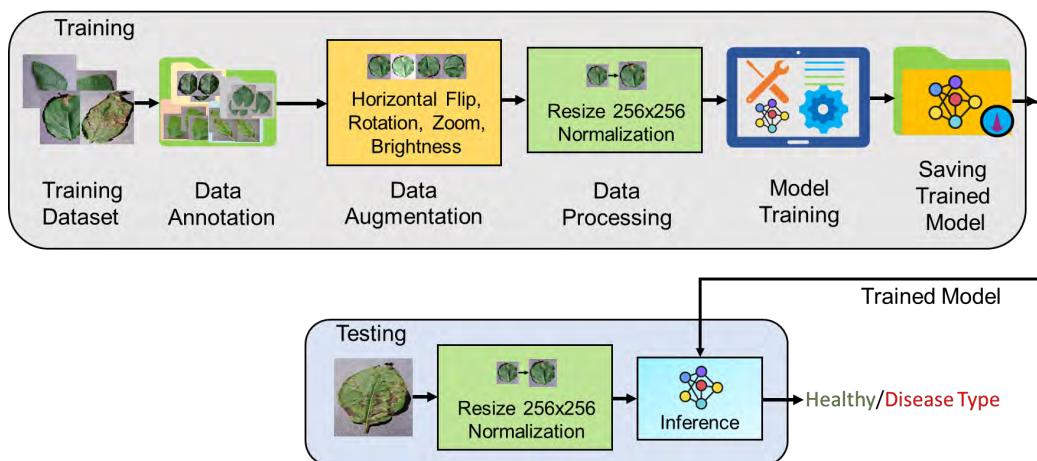
Data Storage



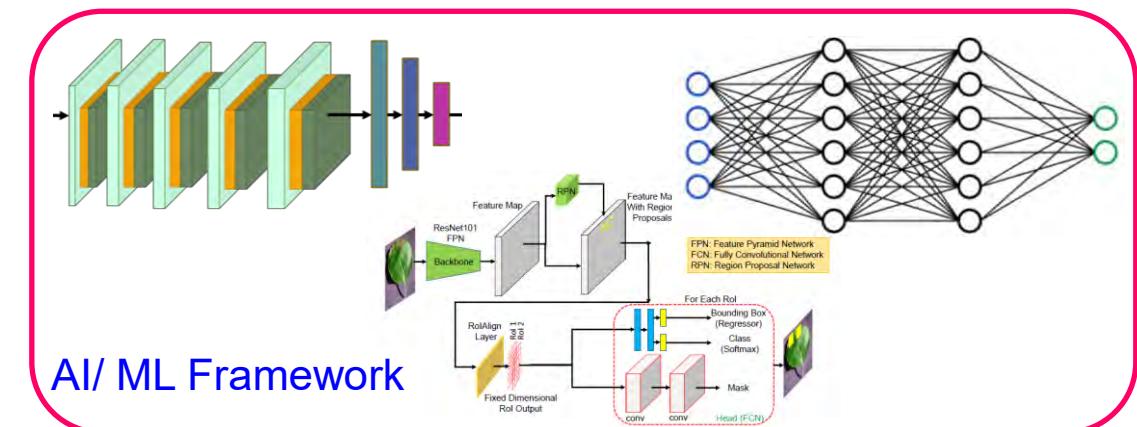
Data Processing



Prediction

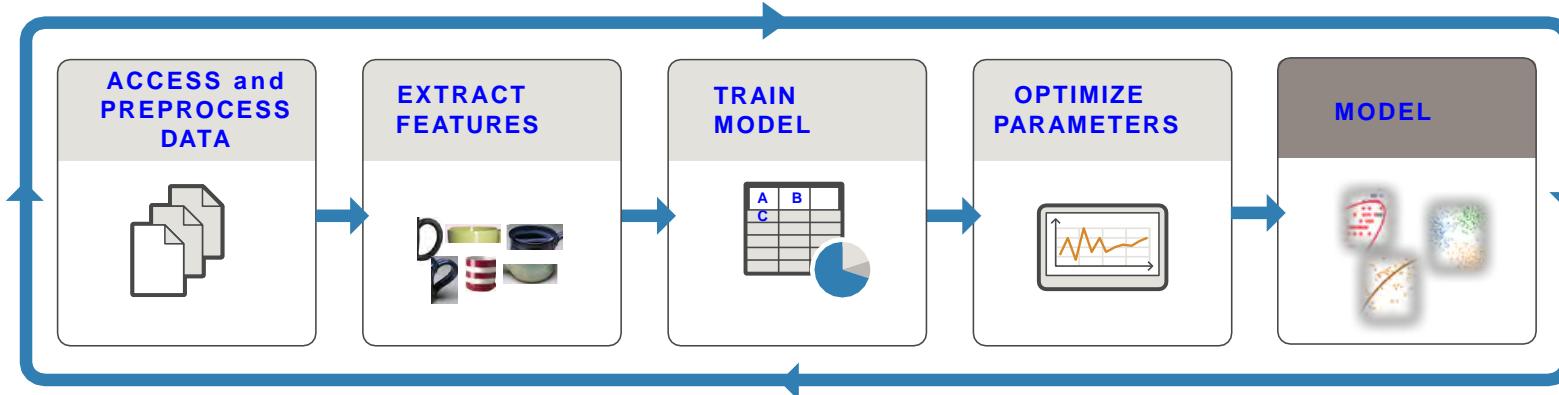


[Source: Alakananda Mitra, "Machine Learning Methods for Data Quality Aspects in Edge Computing Platforms," PhD Dissertation, UNT, 2022.]



TinyML - Key for Smart Cities and Smart Villages

TRAIN: Iterate until you achieve satisfactory performance.

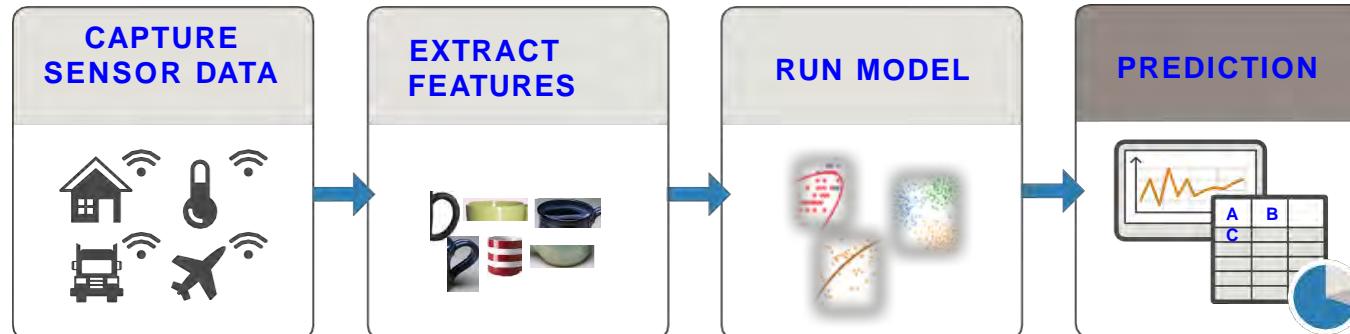


Needs Significant:

- 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>

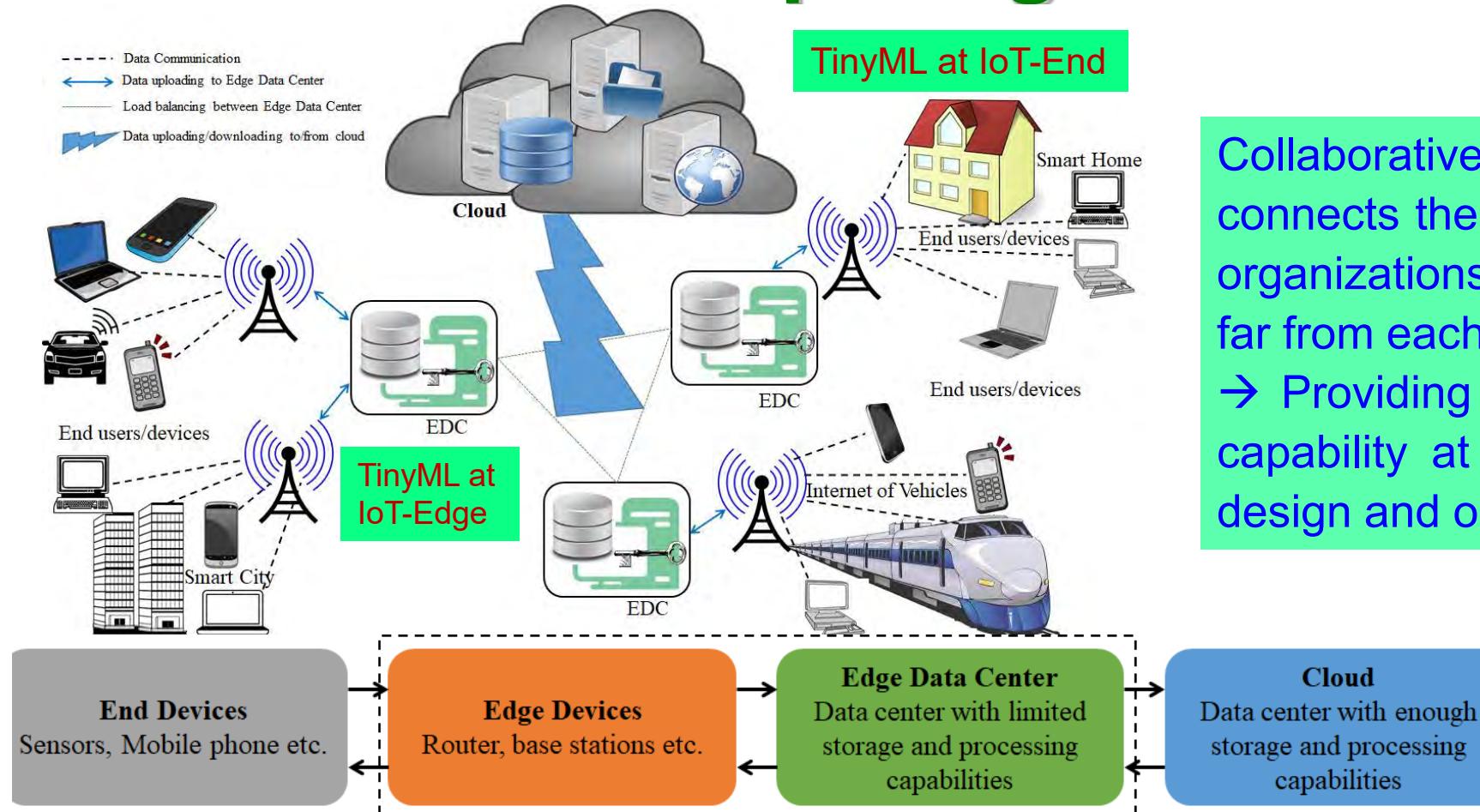
Motivation of Federated Learning (FL)



- 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.

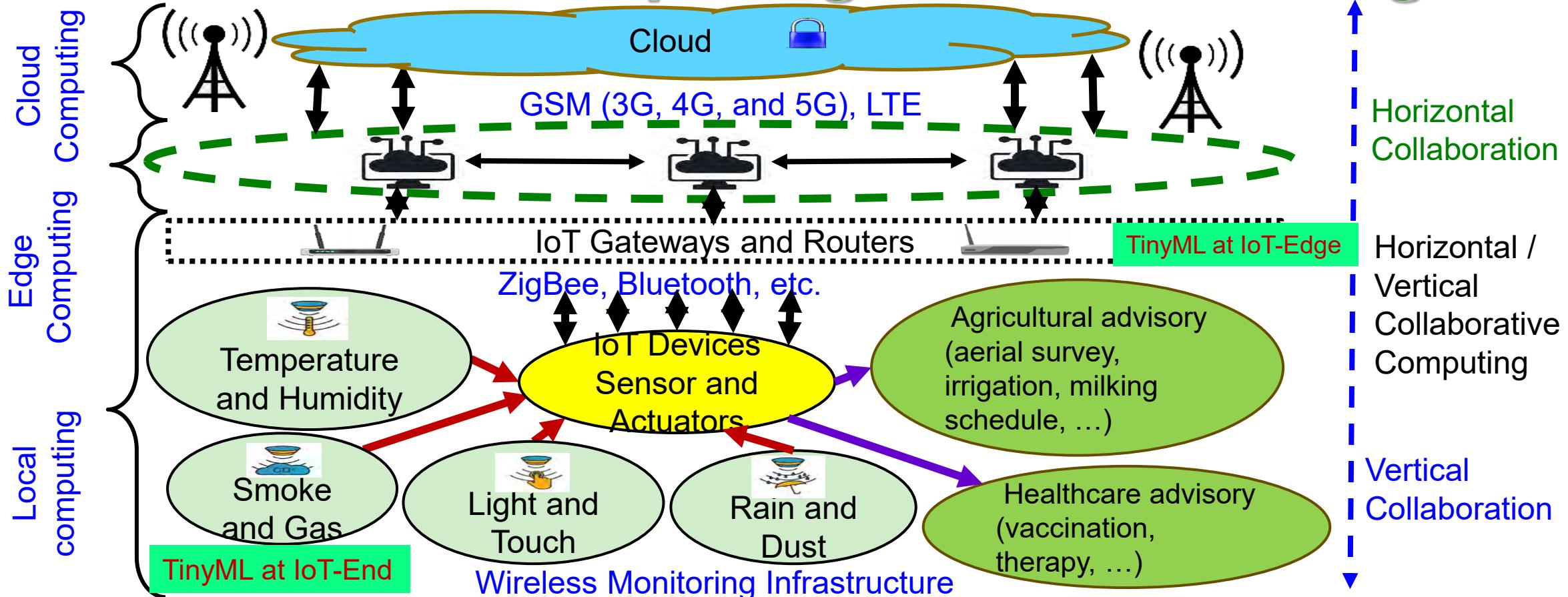
Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages



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.

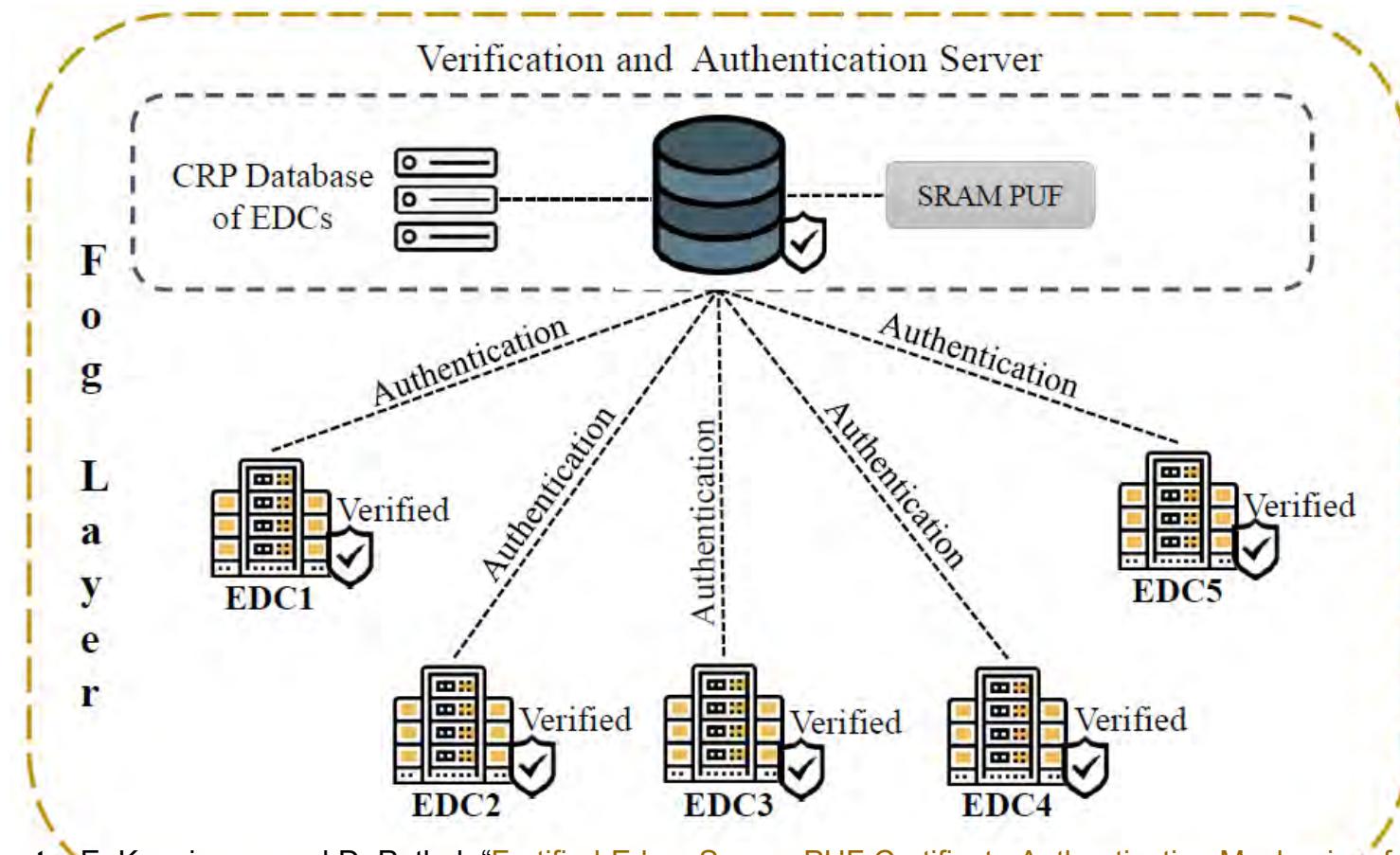
Source: D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya, "Secure and Sustainable Load Balancing of Edge Data Centers in Fog Computing", *IEEE Communications Mag*, Vol. 56, No 5, May 2018, pp. 60--65.

Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages



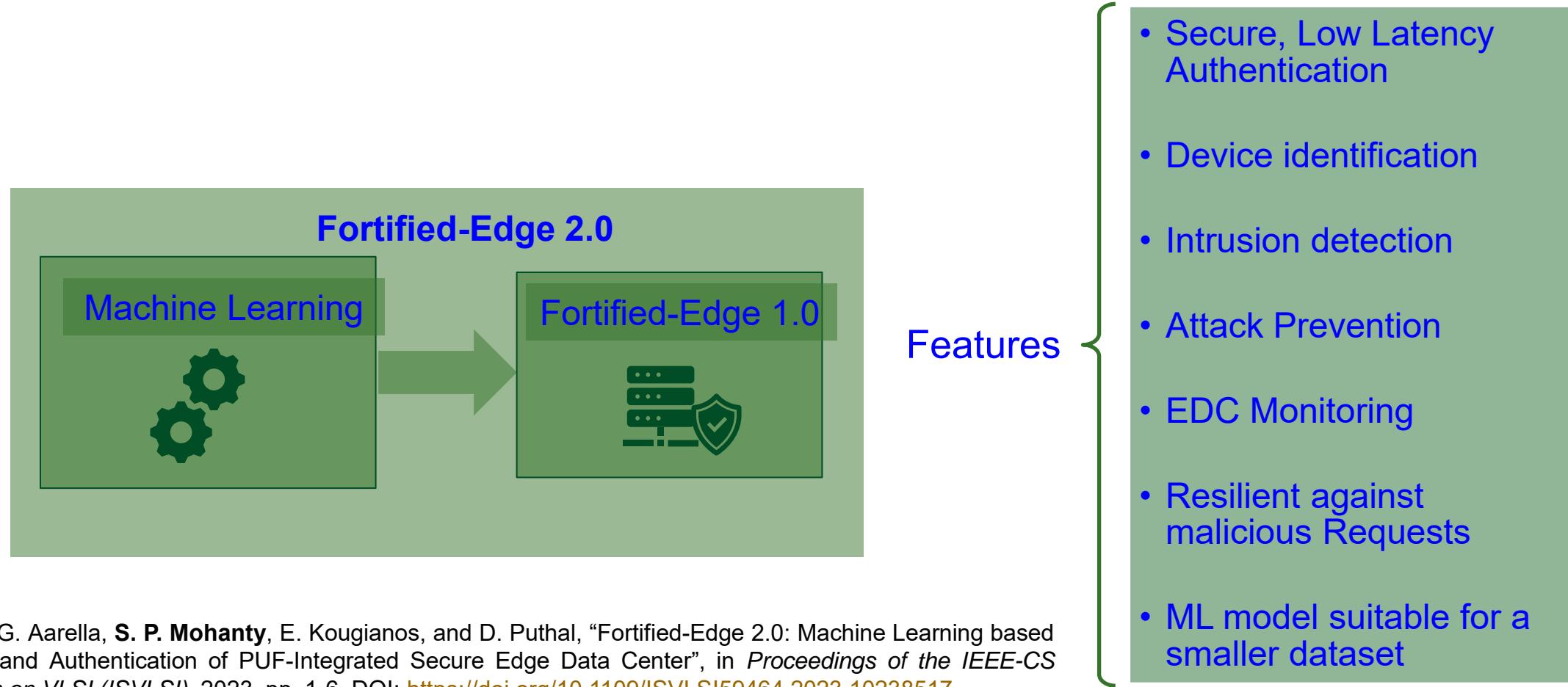
Source: D. Puthal, S. P. Mohanty, S. Wilson and U. Choppali, "Collaborative Edge Computing for Smart Villages", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 10, No. 03, May 2021, pp. 68-71.

Our Fortified-Edge: PUF based Authentication in Collaborative Edge Computing



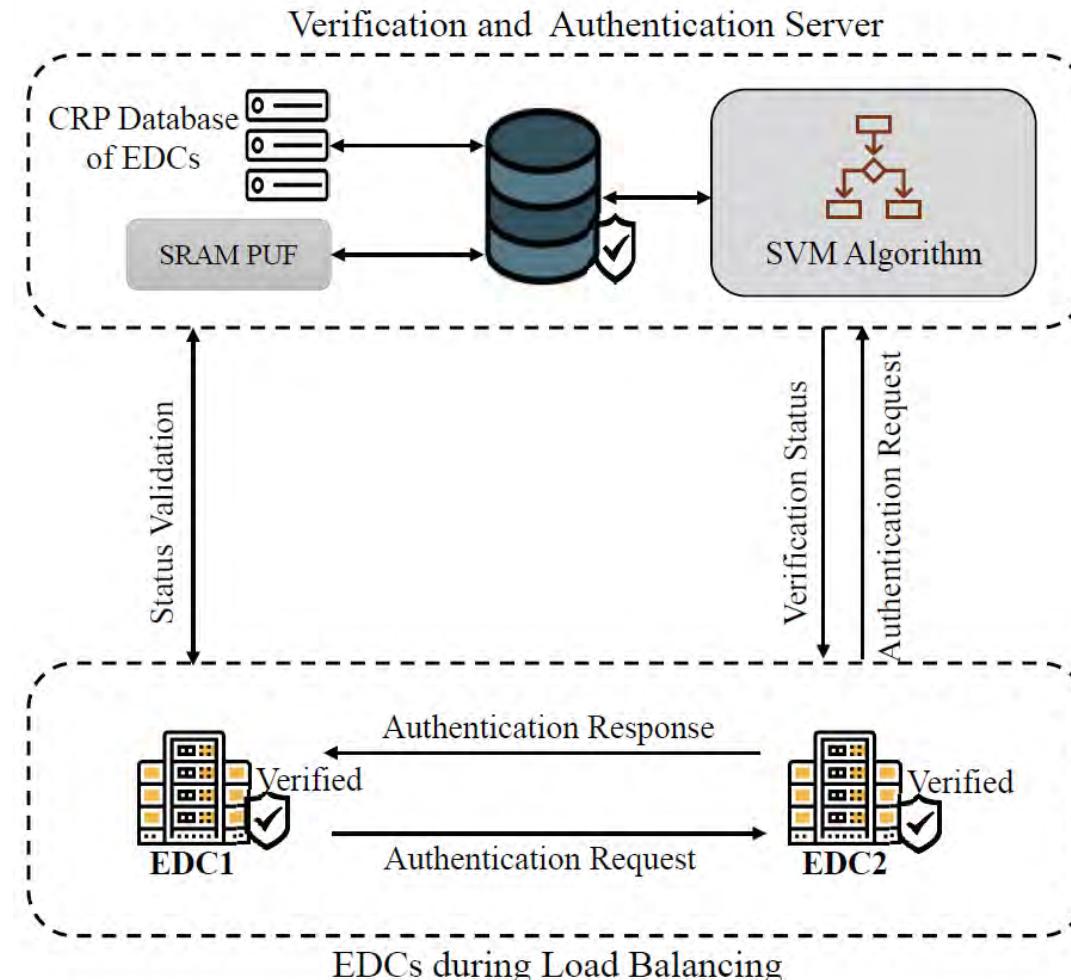
Source: S. G. Aarella, **S. P. Mohanty**, E. Kougianos, and D. Puthal, "[Fortified-Edge: Secure PUF Certificate Authentication Mechanism for Edge Data Centers in Collaborative Edge Computing](#)", in *Proceedings of the ACM Great Lakes Symposium on VLSI (GLSVLSI)*, 2023, pp. 249–254, DOI: <https://doi.org/10.1145/3583781.3590249>.

Our Fortified-Edge 2.0: ML based Monitoring and Authentication of PUF-Integrated Secure EDC



Source: S. G. Aarella, **S. P. Mohanty**, E. Kougianos, and D. Puthal, "Fortified-Edge 2.0: Machine Learning based Monitoring and Authentication of PUF-Integrated Secure Edge Data Center", in *Proceedings of the IEEE-CS Symposium on VLSI (ISVLSI)*, 2023, pp. 1-6, DOI: <https://doi.org/10.1109/ISVLSI59464.2023.10238517>.

Our Fortified-Edge 2.0: ML based Monitoring and Authentication of PUF-Integrated Secure EDC



Source: S. G. Aarella, **S. P. Mohanty**, E. Kougianos, and D. Puthal, "Fortified-Edge 2.0: Machine Learning based Monitoring and Authentication of PUF-Integrated Secure Edge Data Center", in *Proceedings of the IEEE-CS Symposium on VLSI (ISVLSI)*, 2023, pp. 1-6, DOI: <https://doi.org/10.1109/ISVLSI59464.2023.10238517>.

Conclusion and Future Research



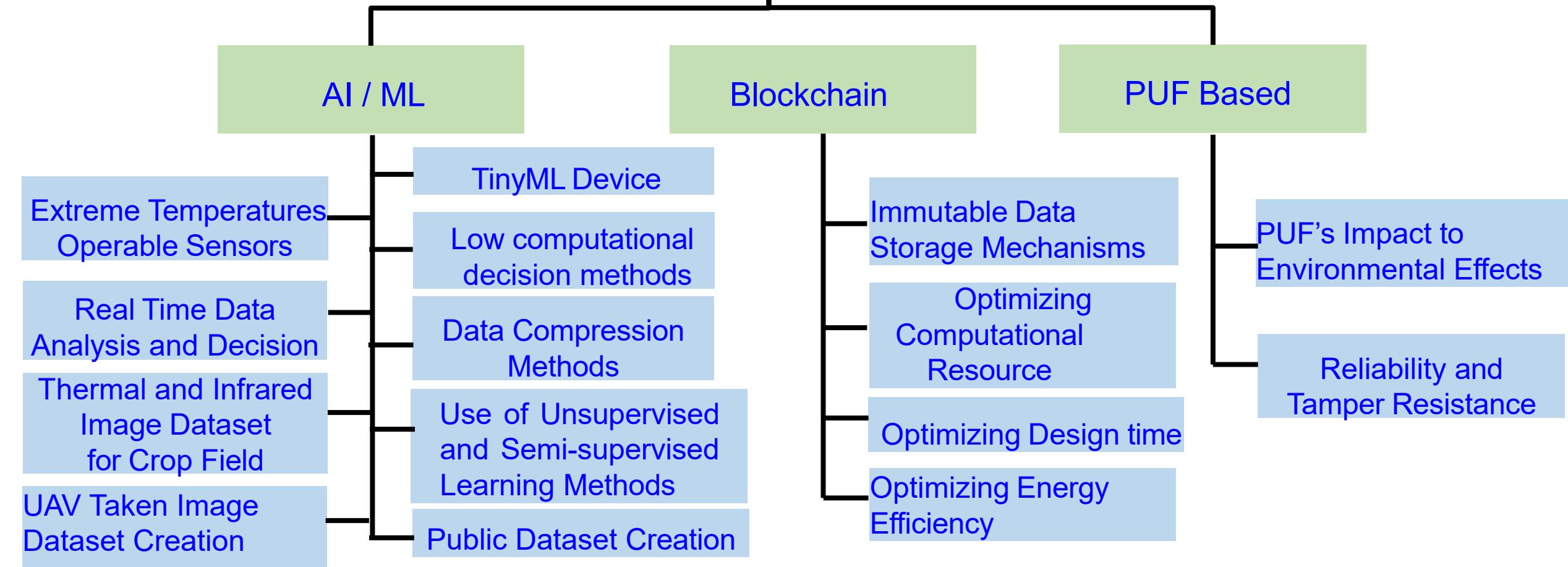
Smart Agriculture - Multifold Research Possibility

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

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

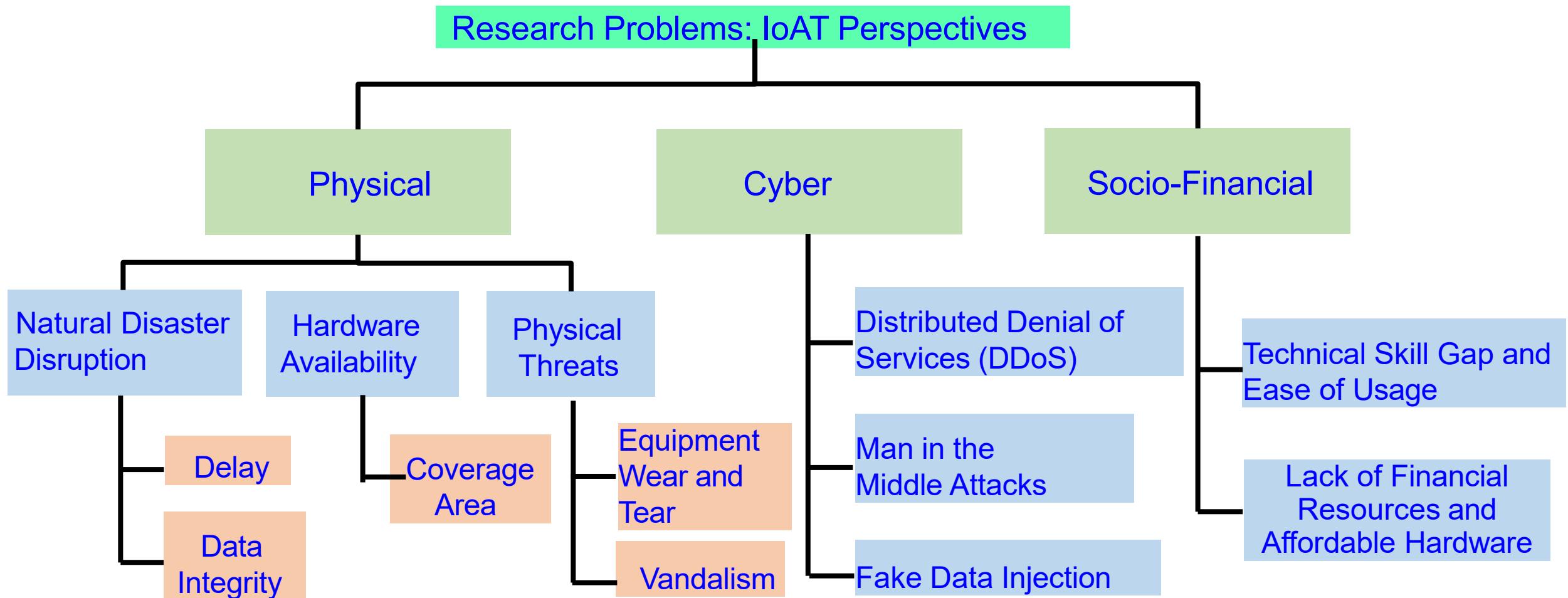
Smart Agriculture - Research Problems

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



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Conclusion

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

Future Research

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