Smart Agriculture - Demystified

Invited Talk 2023 – SRM University, AP

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Homepage

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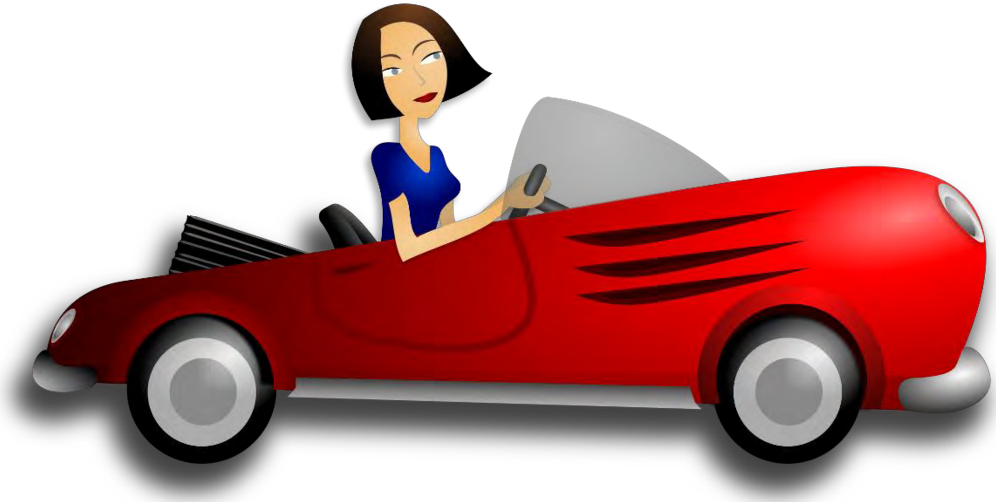
Outline

- 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.

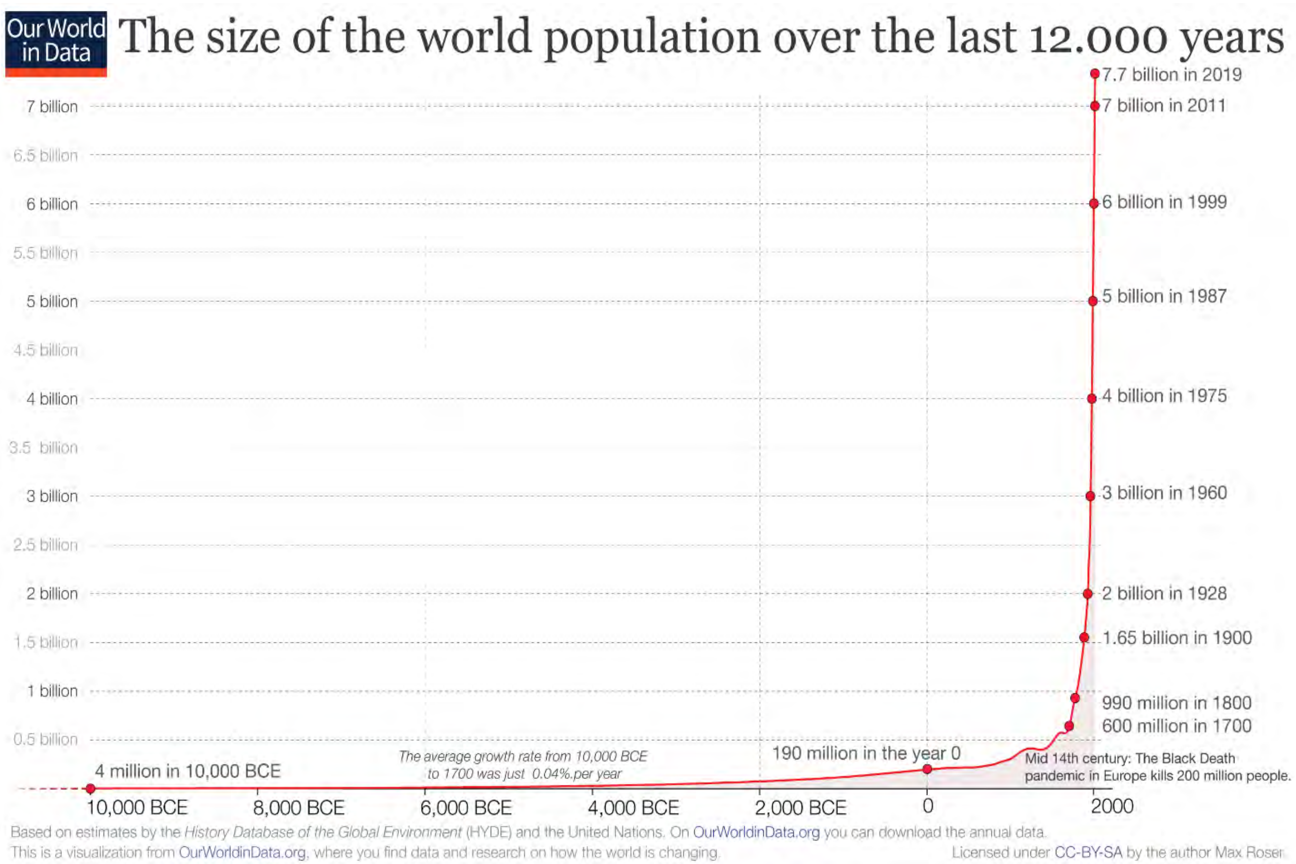


Image Source: https://ourworldindata.org/world-population-growth

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.

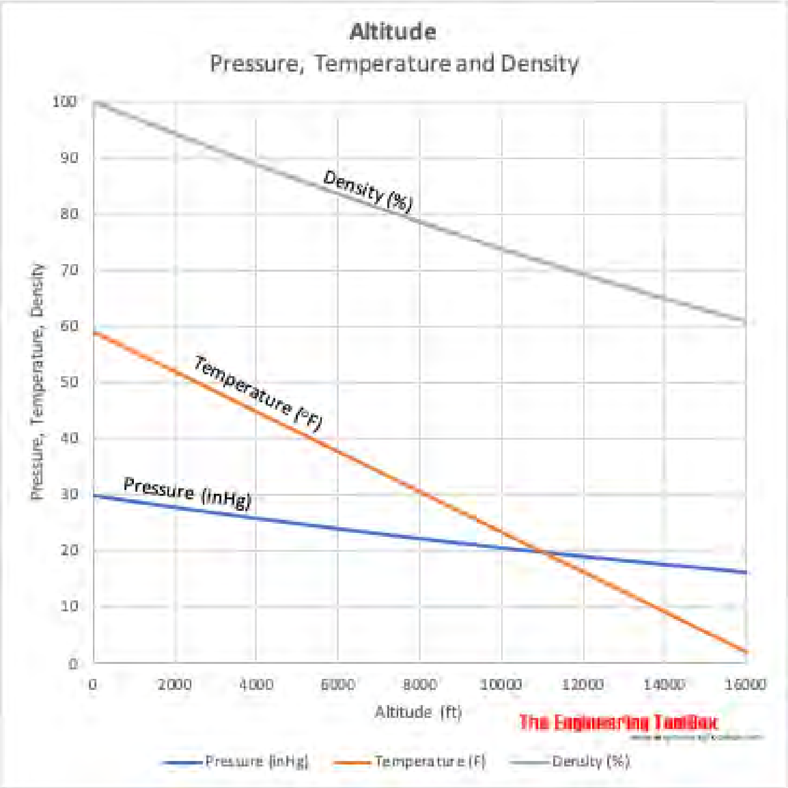
Smart Electronic Systems Laboratory (SESL)
UNT

Can we Have Any Crop, at Any Place?

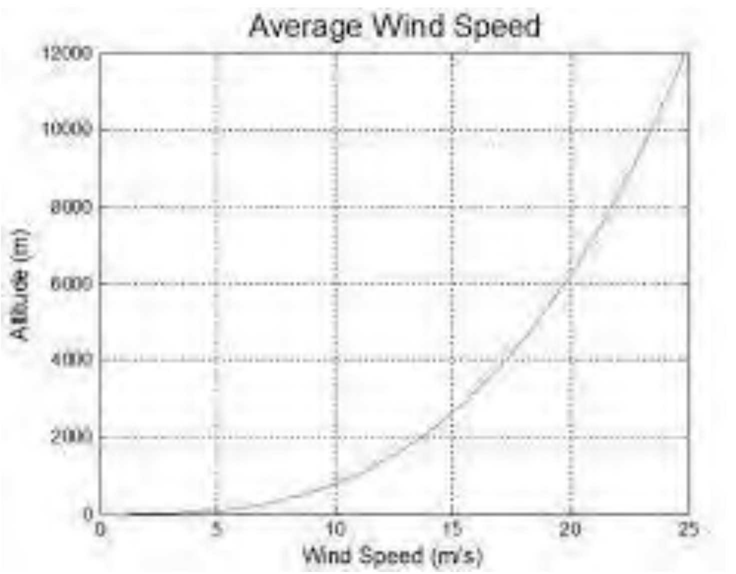
- The factors determine the type of crop that can be farmed based on different environmental properties:
  - Climate
  - Elevation
  - Slope
  - Soil
  - Water availability
  - …
  - …

Any Crop, Any Place: Elevation and Slope

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



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



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

Any Crop, Any Place: Soil

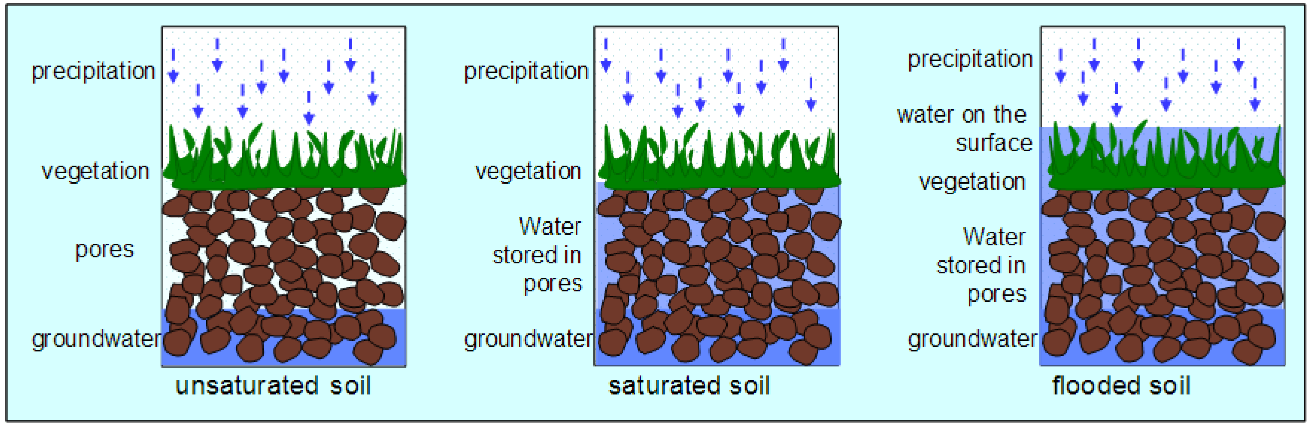
- Formed from weathering rocks (source for minerals needed); Organic-matter contents (source of fertilizers).

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

Soil provides nutrients to the crops.

Any Crop, Any Place: Soil Water

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



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

Any Crop, Any Place: Vicious Negative Feedback Cycle

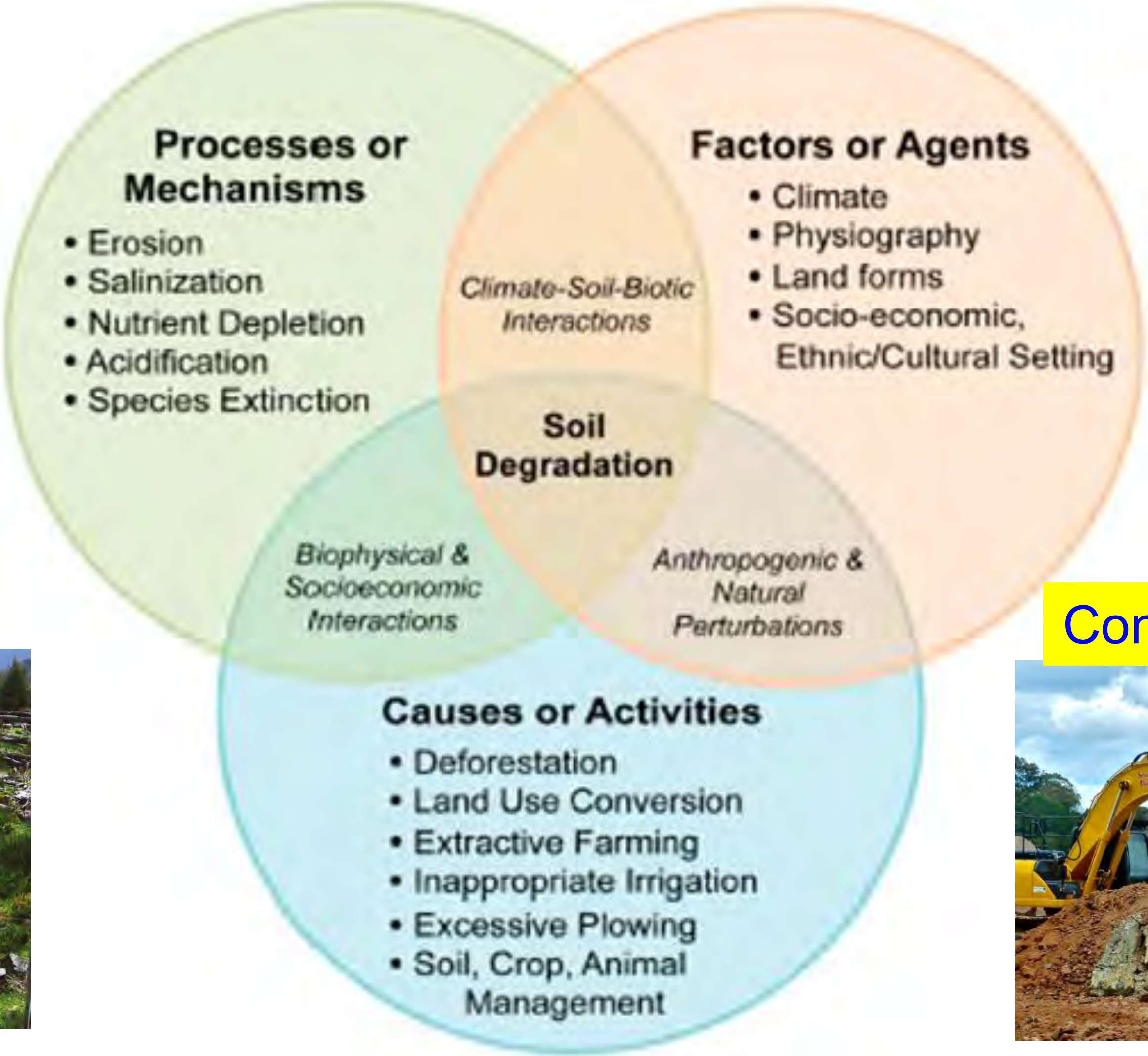
- Land usage for other needs
  - Growth is population is causing the need for residential land which is reducing the amount of arable land available for farming.
  - Growth in population → Need for residential land
  - Growth in population → Demand for farm products
  - Demand for farm products → Need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

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

Agricultural Land Reduction is a Global Crisis

Salination

Soil Erosion



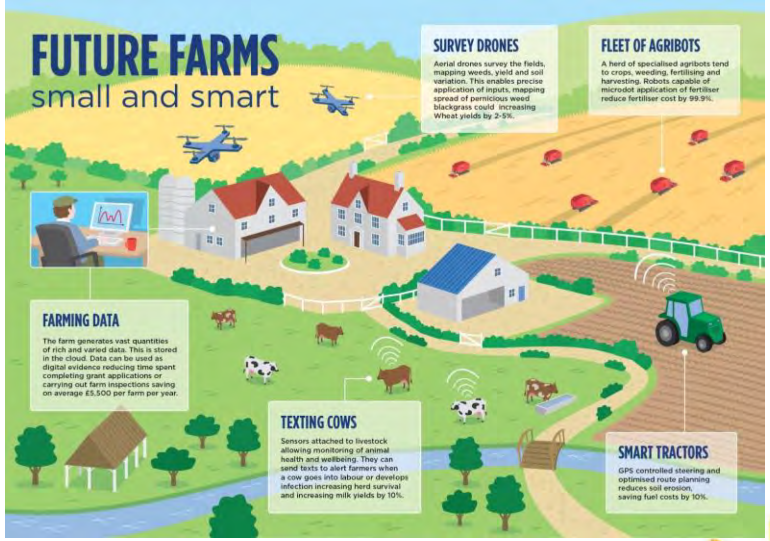
Deforestation

Construction on Farm Land

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

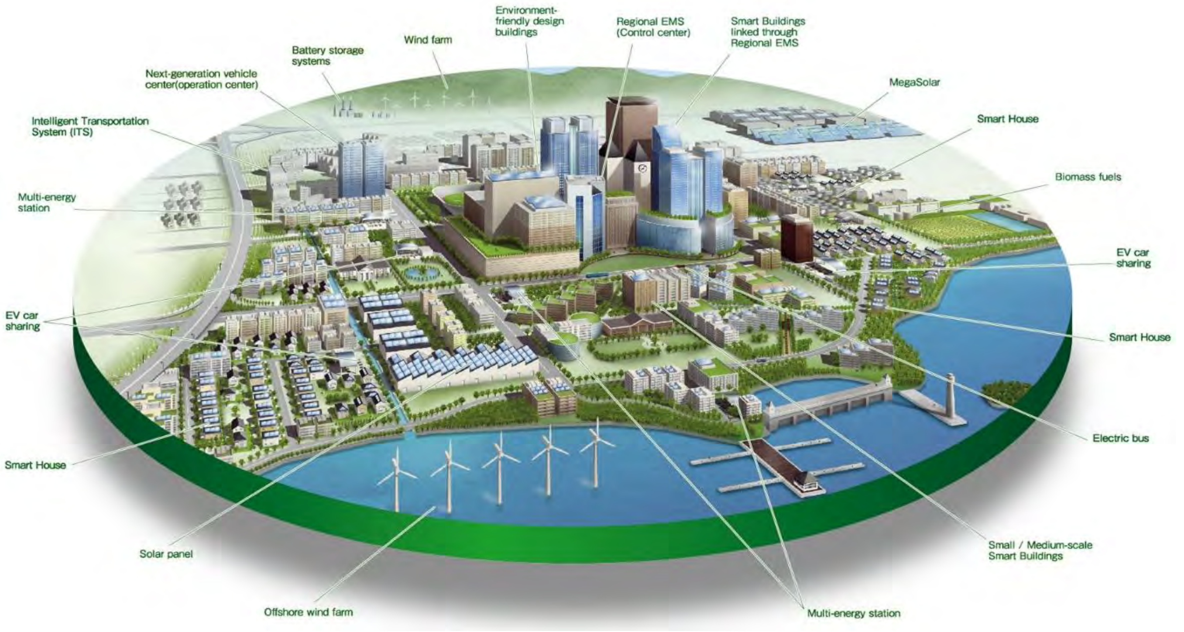
Solution → Smart Agriculture

- 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.

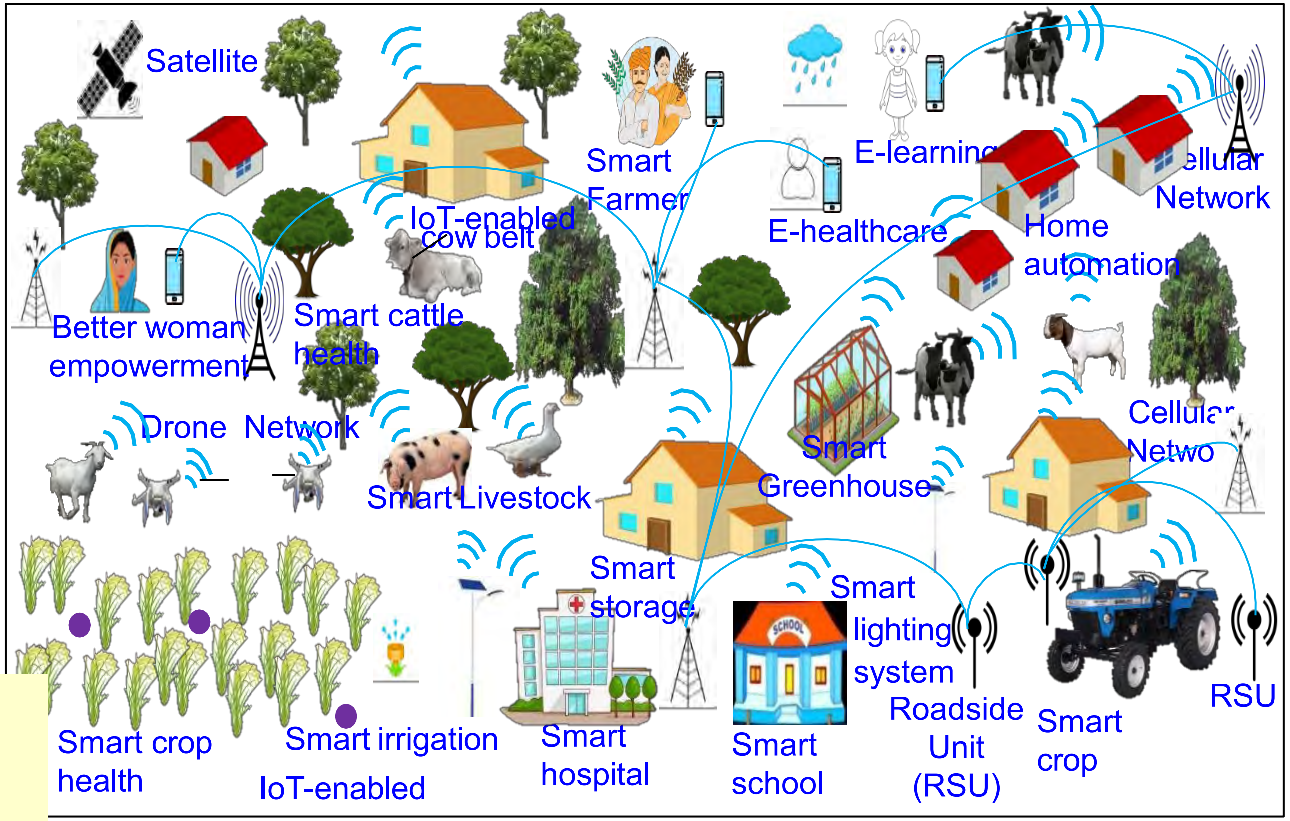


Agriculture or farming is the practice of cultivating plants and livestock.

Crucial for → Smart Cities and Smart Villages



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

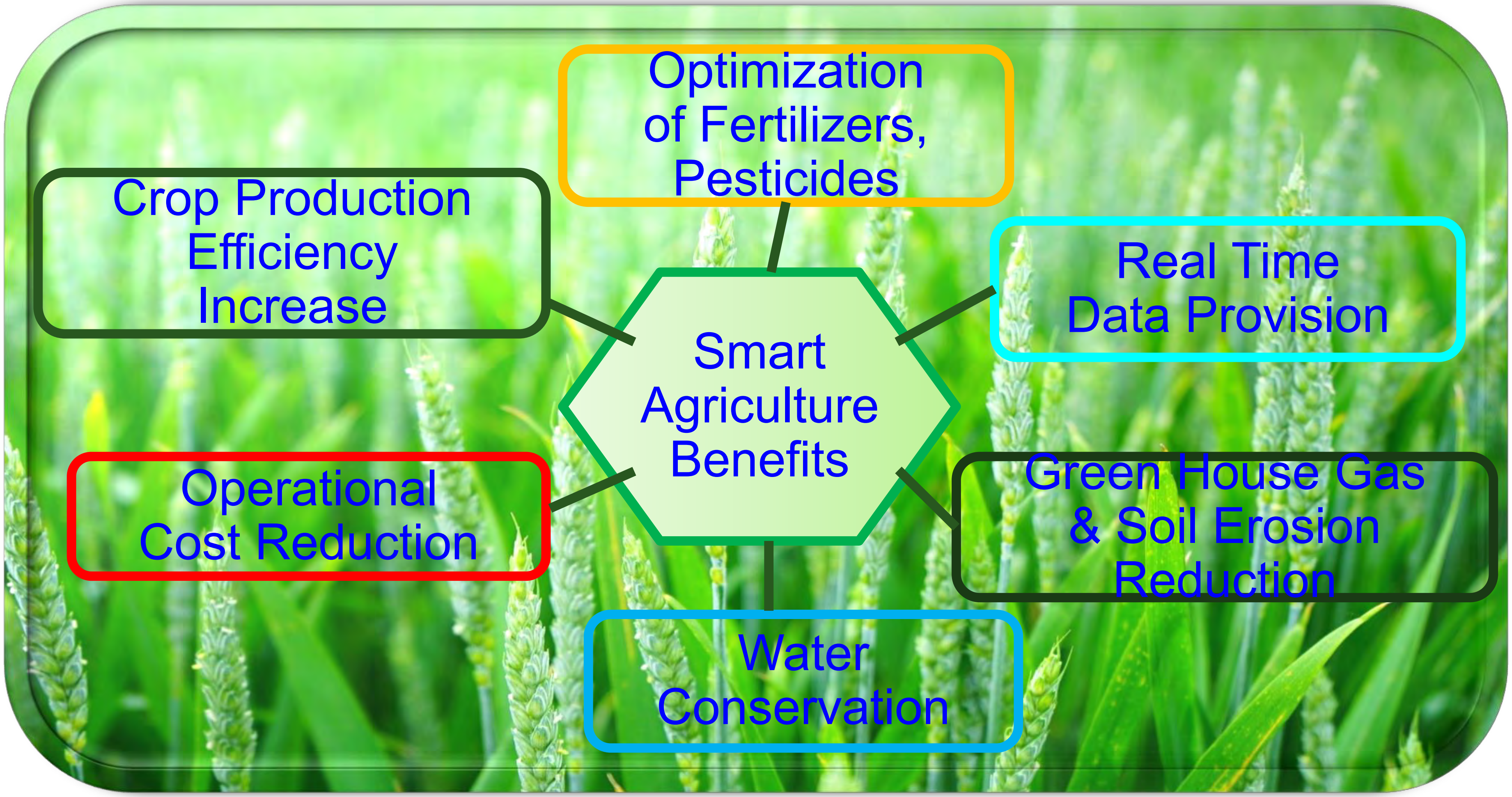


Smart Cities
CPS Types - More
Design Cost - High
Operation Cost – High
Energy Requirement - High

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

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

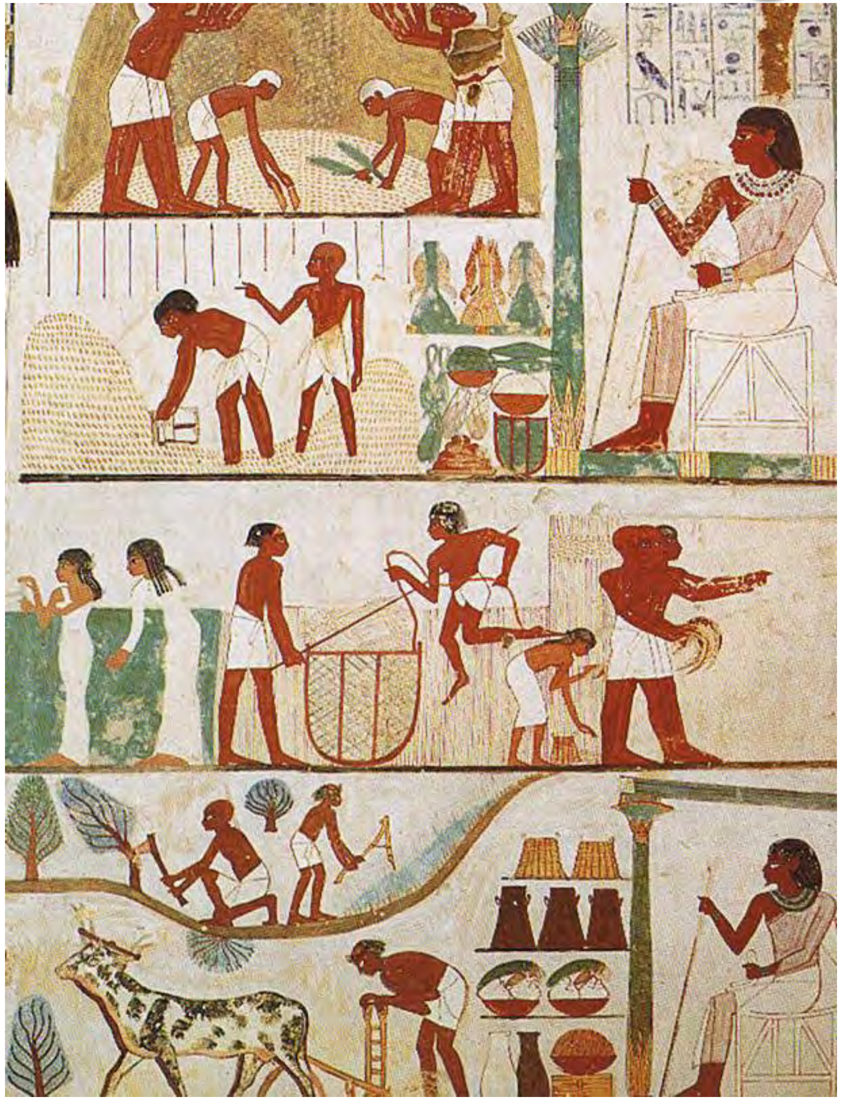
Based on a reconstruction by Orrin C. Shane III

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

Indus Valley Civilization (3300 BCE to 1300 BCE)

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

Agriculture History



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

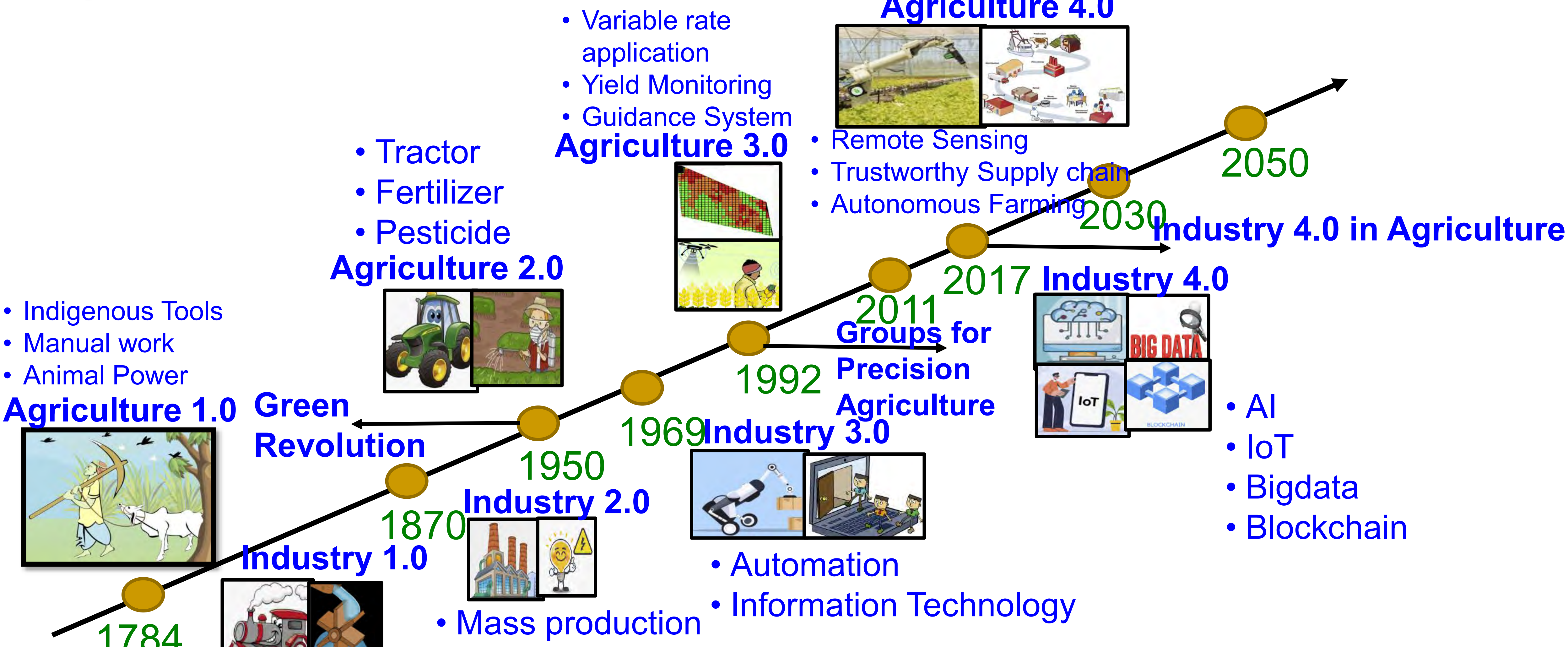
Agriculture played a Key Role in the growth of civilization.

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

Agriculture is the Key Factor of Civilization

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

Agricultural Evolutions & Industrial Revolutions



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

Digital Farming

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

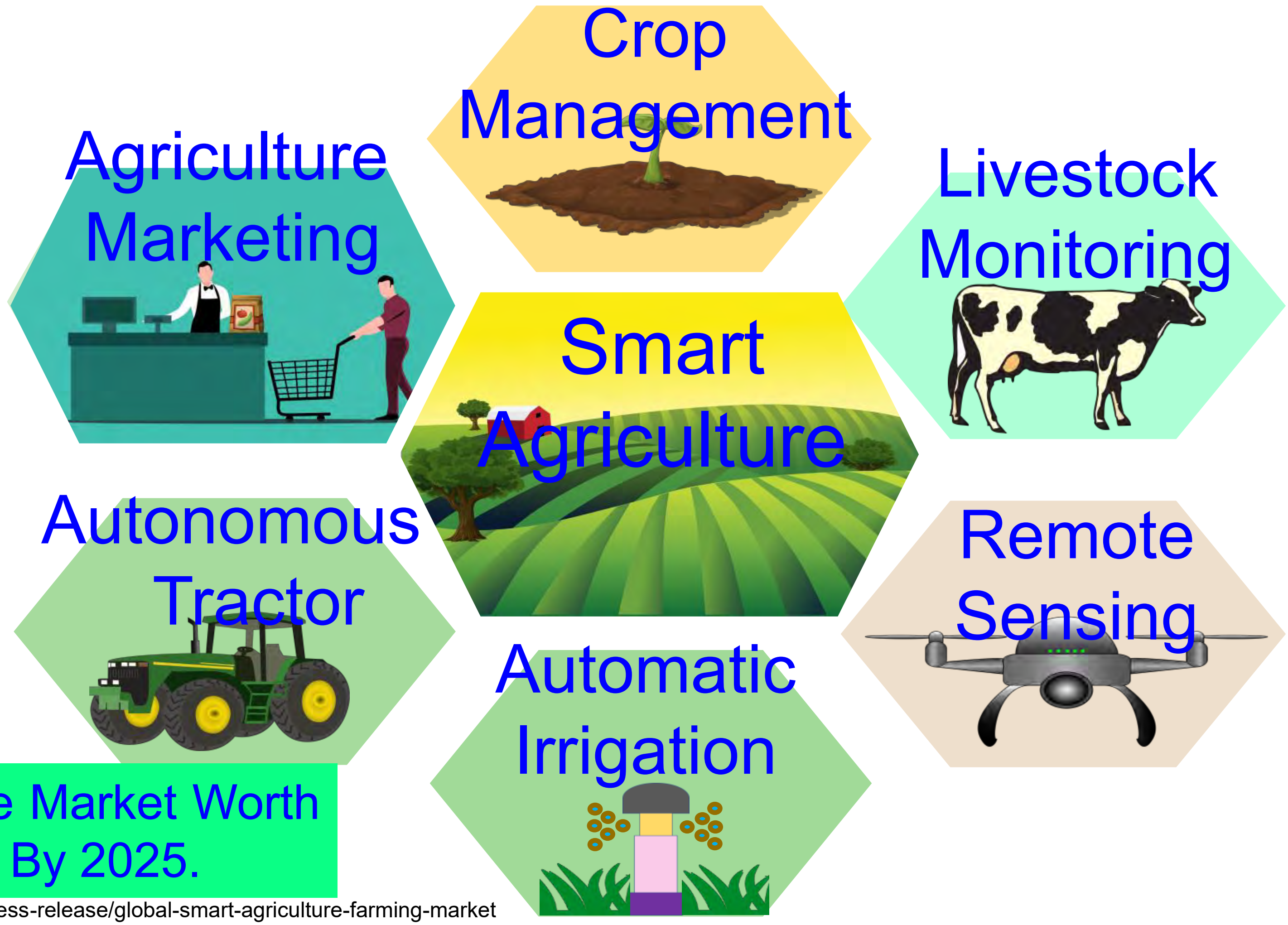
Source: https://www.dtn.com/precision-farming-vs-digital-farming-vs-smart-farming-whats-the-difference/

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

- DLG (German Agricultural Society)

Agriculture to Smart Agriculture

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

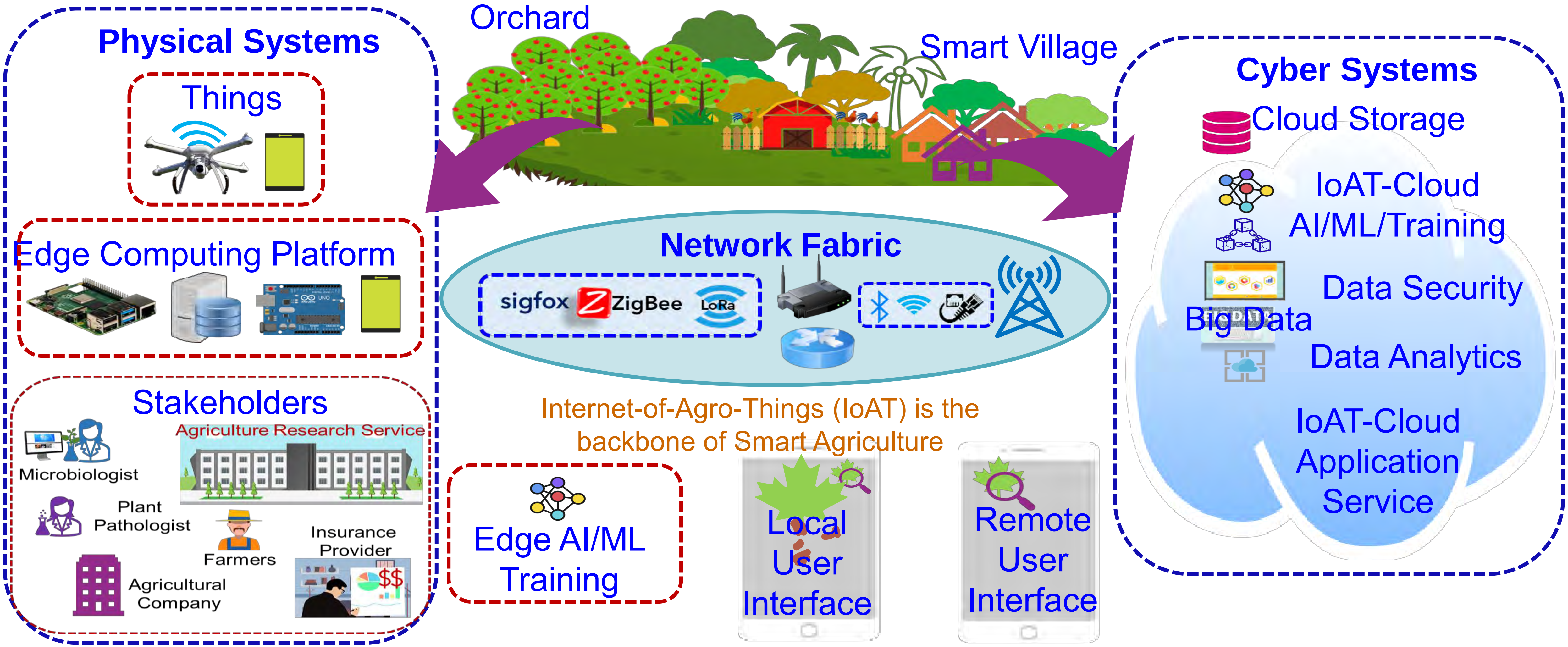


Smart Agriculture Market Worth US$18.21 Billion By 2025.

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)



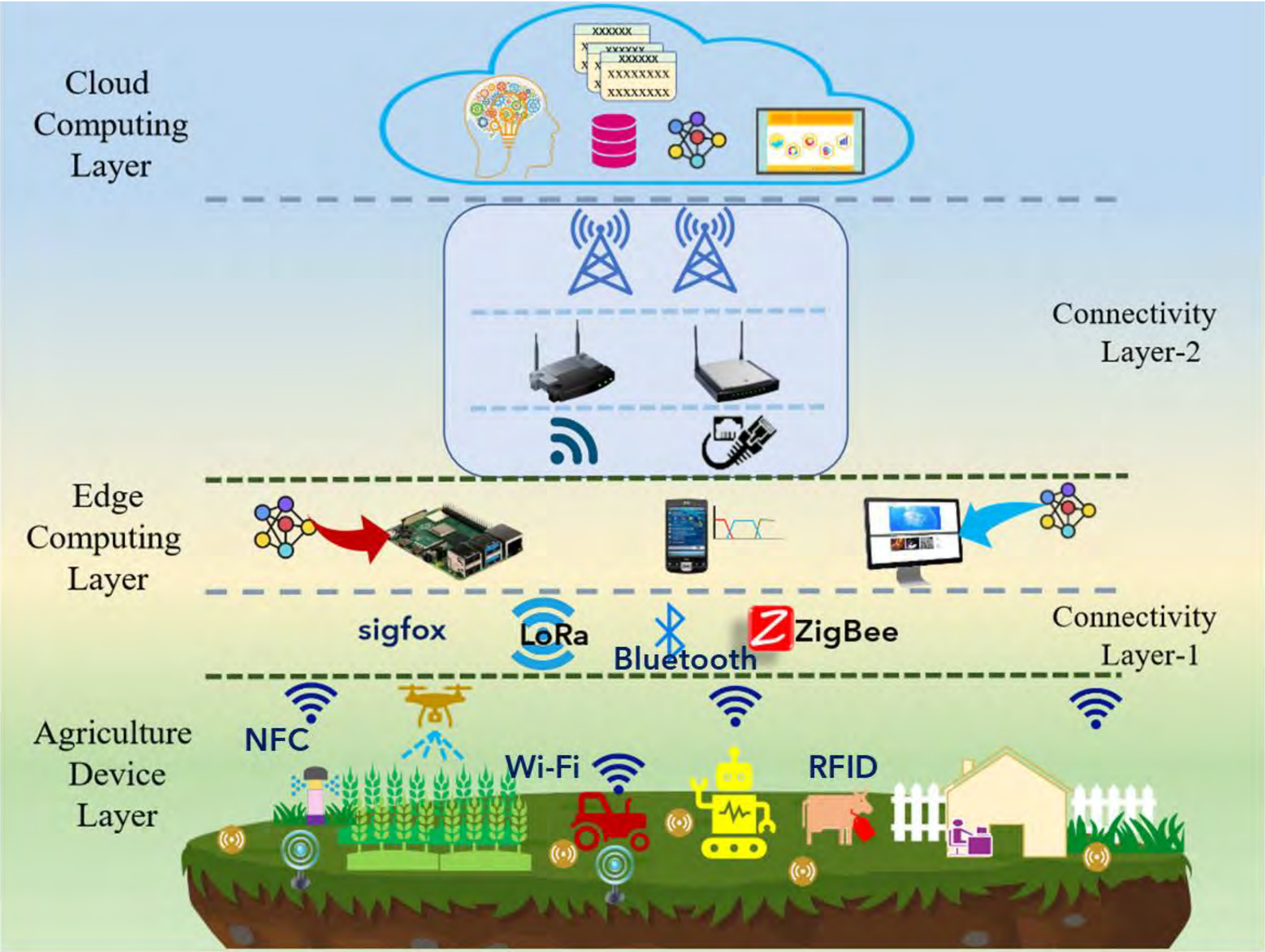
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

Smart Agriculture Architecture

UAVs takes images, sprays fertilizers.

Self-Driving Tractors sow with precision, plant trees at the right depth. **Productivity Increases.**

Smart Collars provides information on cattle health and their movement.



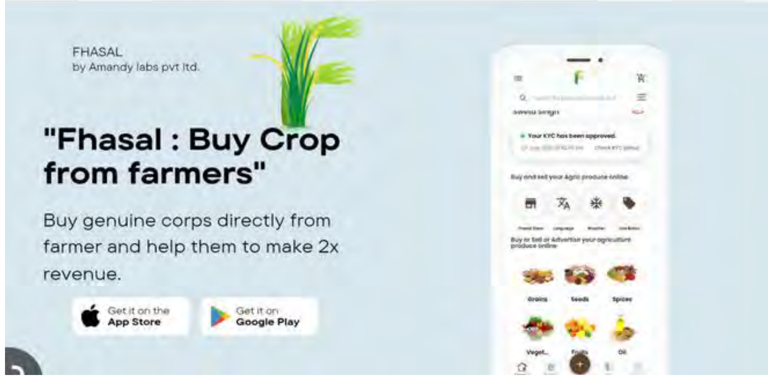
Smart Sensors collect data from soil and air. **Decision taken for irrigation and fertilization.**

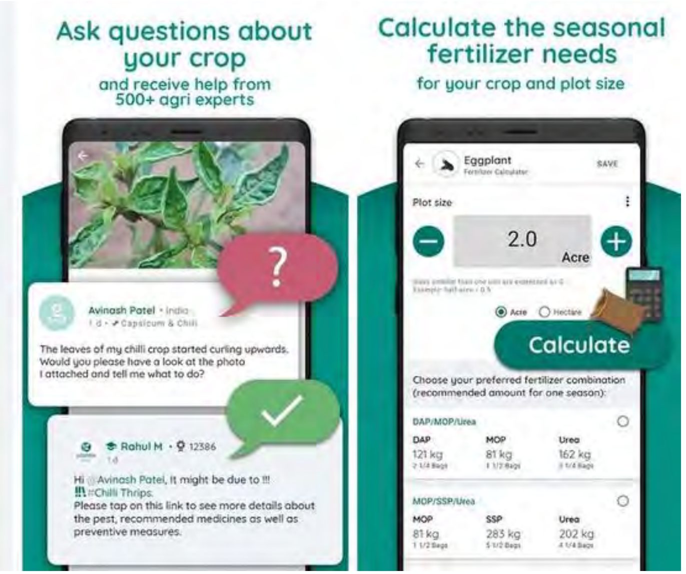
Cloud stores data.

Edge Devices compute locally and take decisions.

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

Smart Agriculture Apps





Soil Sampler

Farmis

Contains ads

4.3★ 1.03K reviews | 100K+ Downloads | Everyone

BoosterAGRO

Booster Ag Tech, Inc.

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

Install | Add to wishlist

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

Crop Farmers App

Bivatec Ltd

Contains ads · In-app purchases

3.9★ 237 reviews | 10K+ Downloads | Everyone

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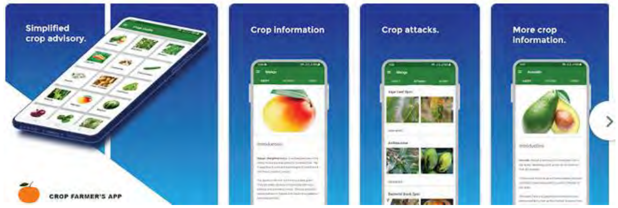
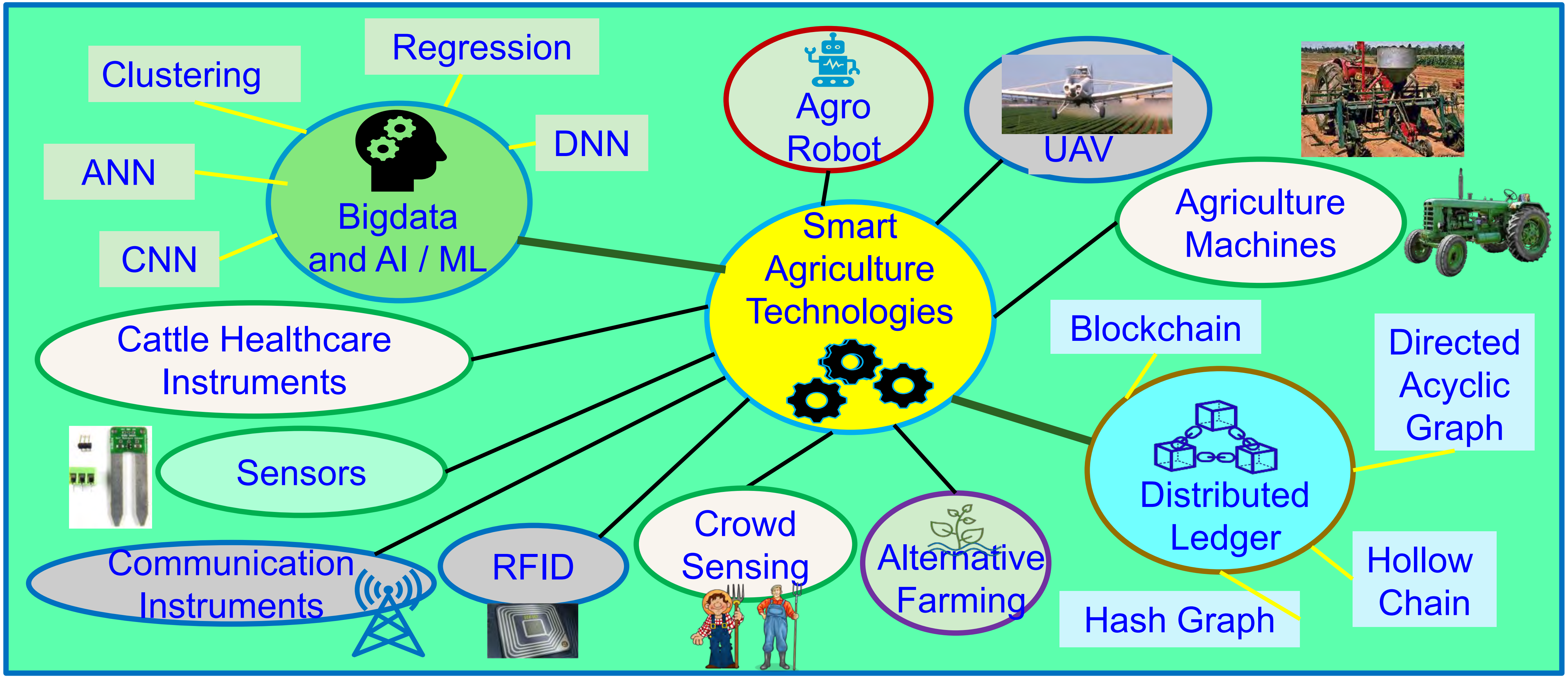


Smart Agriculture – Technologies

Smart Agriculture Technologies



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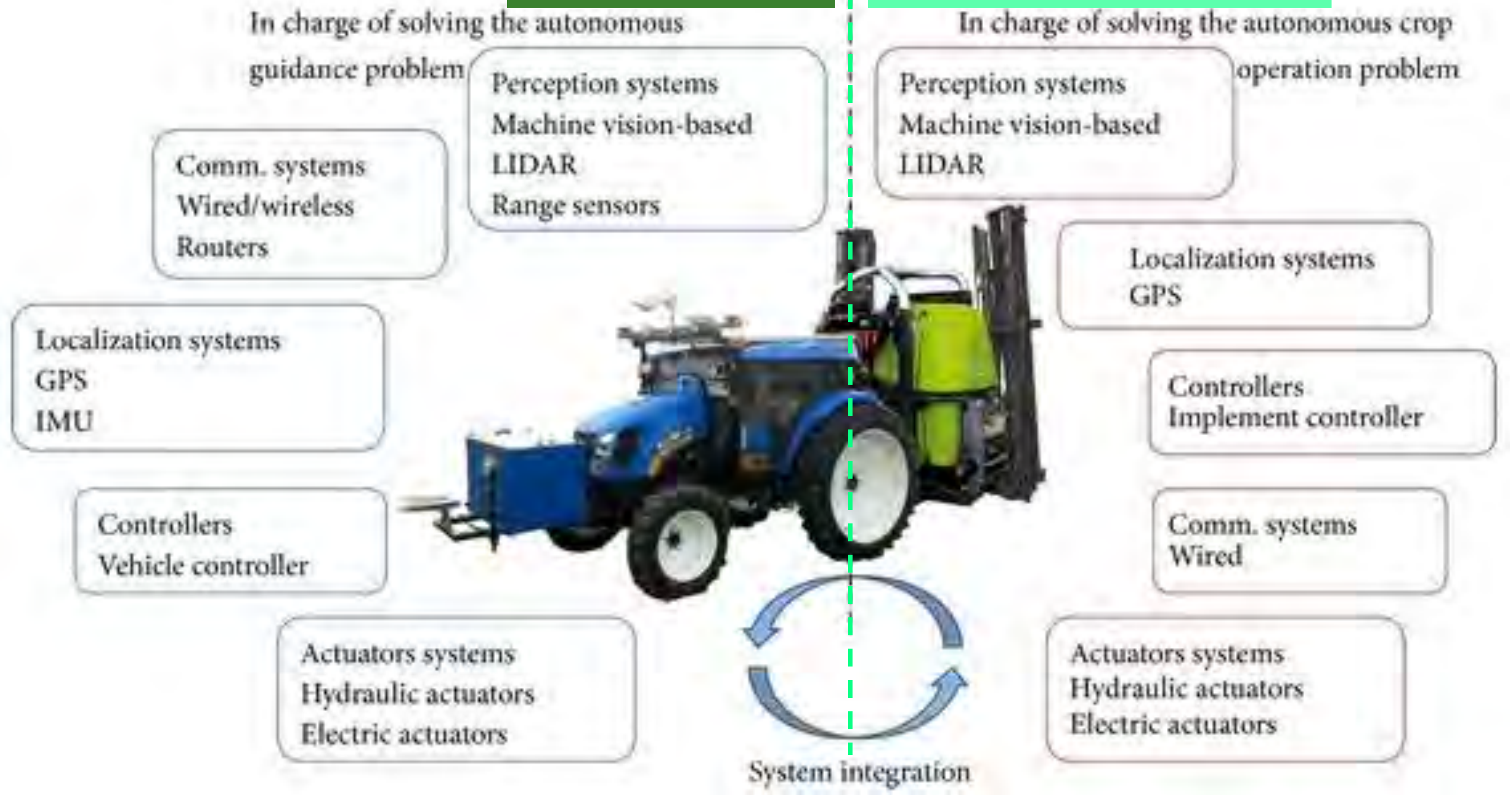
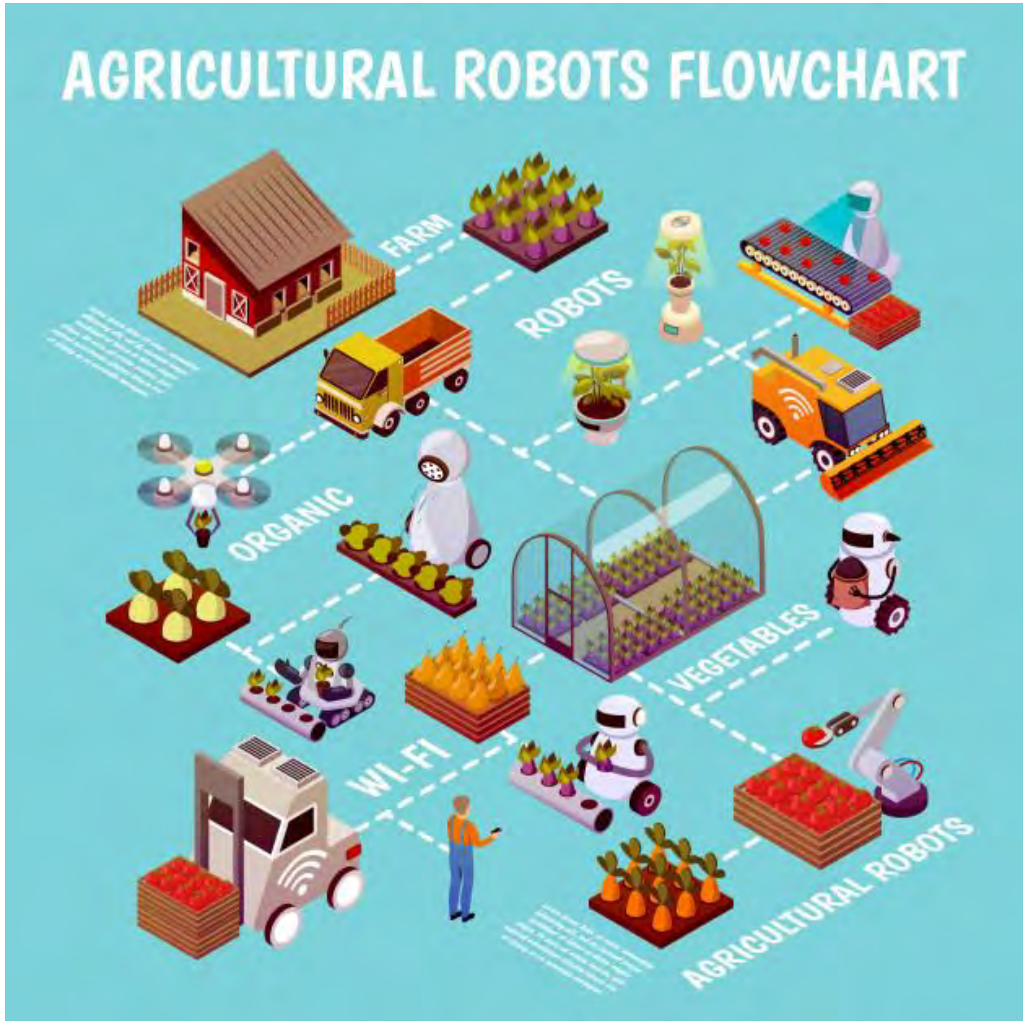
Driverless Tractors

Autonomous Vehicle | Autonomous Implementations



Autonomous and Robotic Labor

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



Drones or UAV for Smart Agriculture

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

Planting and Sowing Tools

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

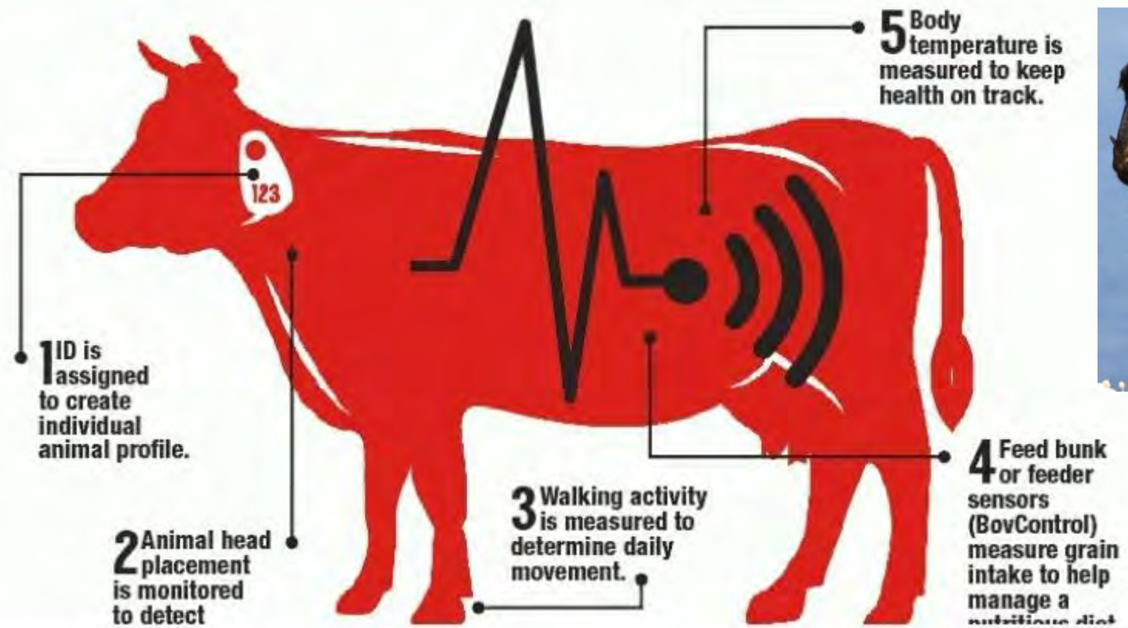
Automatic Irrigation Systems

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

Livestock Monitoring System

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

Livestock Health Monitoring Instruments



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

Thermometer for horses, dogs, sheep, pigs and cows

Cattle Stomach Healthcare

Livestock Heat Stress Monitor

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

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

Smart Agriculture - Sensors

Measured Parameters at Agricultural Devices

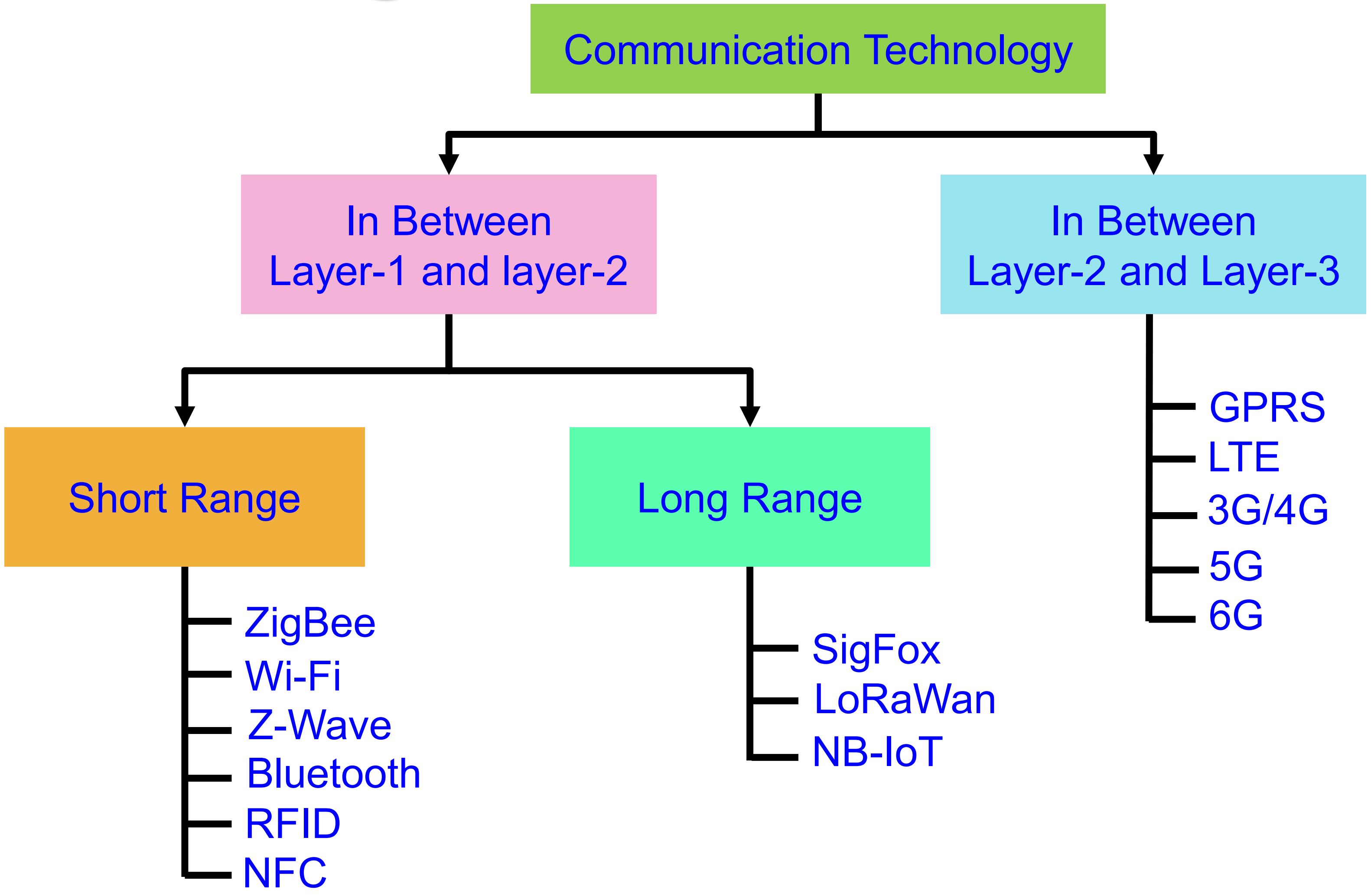
- **Crop**
  - **Underground Sensors**
    - Soil Moisture
    - Soil pH
    - Soil Chemical Composition (N_2, S, Ammonia)
  - **On UAV Sensors/Cameras**
    - **Image**
      - Thermal Image
      - RGB Image
      - Multi Spectral Image
      - LiDAR Image
    - **Environmental Parameters**
      - Air Humidity
      - Air Temperature
      - Wind Speed
      - Solar Radiation
- **Livestock**
  - **Wearable Collar**
    - Location
    - Body vitals
    - Reproductive Cycle
    - Milking Time
    - Feeding Time
- **Greenhouse(GH)**
  - Light Intensity
  - GH Humidity
  - GH Temperature
  - Precipitation
  - GH Quality
  - Soil Moisture
  - Soil pH
  - Wind Speed
  - CO_2
- **Hydroponics**
  - Room Humidity
  - Room Temperature
  - Water Temperature
  - Water Level
  - Soil Moisture
  - Light Intensity
  - Soil pH

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.

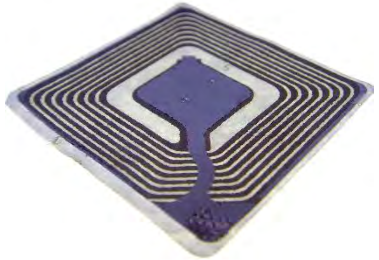
Source: A. Mitra, S. L. T. Vangipuram, A. K. Bapatla, V. K. V. V. Bathalapalli, **S. P. Mohanty**, E. Kougianos, and C. Ray, "Everything You wanted to Know about Smart Agriculture", *arXiv Computer Science*, arXiv:2201.04754, Jan 2022, 45-pages.

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

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



Numerous Applications

Source: Khattab 2017: Springer 2017 RFID Security

Smart Agriculture – AI/ML Technology

Crop Management

Soil Management

Smart Irrigation

Pest / Disease Control

Weed Control

Livestock Management

Alternative Farming

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

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

Agriculture Data – Crowd Sensing

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

Agriculture Data – Acquisition Interface

- Data Acquisition is an interface that is used to collect the data from the external environment and send it to the internal systems. Data acquisition technologies mainly includes:
  - Serial ports for connecting multiple instruments for automatic data acquisition.
  - USB interface.
  - Wireless communication modules.
  - Sensors and Actuators.
  - Satellite systems.

Agriculture Data – Storage

- Data Storage Technology
  - Direct Attached Storage (DAS): A storage device is attached directly to the host system to record data.
  - Network Attached Storage (NAS): A device is connected to the network which serves the purpose of storage.
  - Storage Area Network (SAN): A network of storage devices are connected to network of servers.
- Databases are the software application used for performing data storage operations:
  - Relational database : follows relational model
  - Non-relational databases

Agriculture Data – Processing Technologies

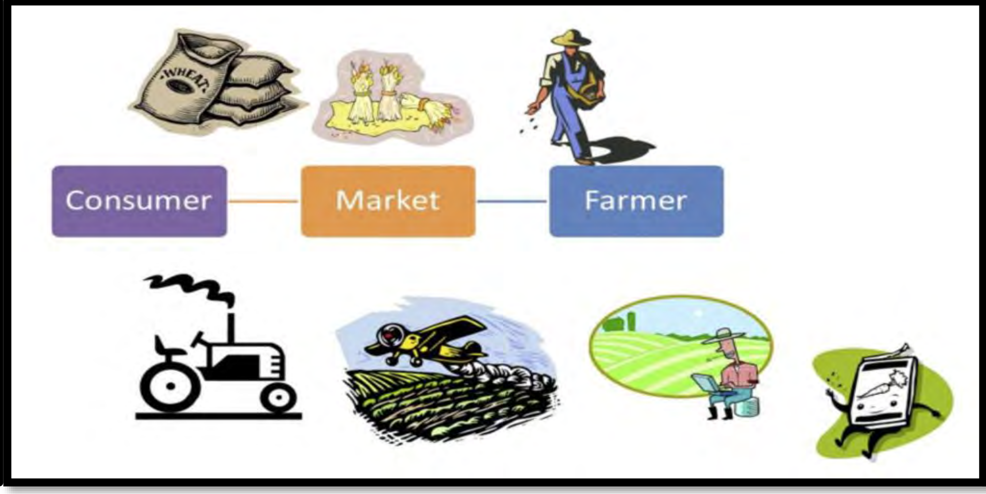
- Millions of IoT devices → generates large amounts of data
- Need for efficient Big data analytics methods
- Artificial Intelligence plays a major role in extracting information from such large data.
- Conventional AI methods are resource intensive
- Tiny ML is a promising application in IoT based systems.

Roles of Blockchain in A-CPS

Visibility Food Safety Provenance Traceability Farm Supervision



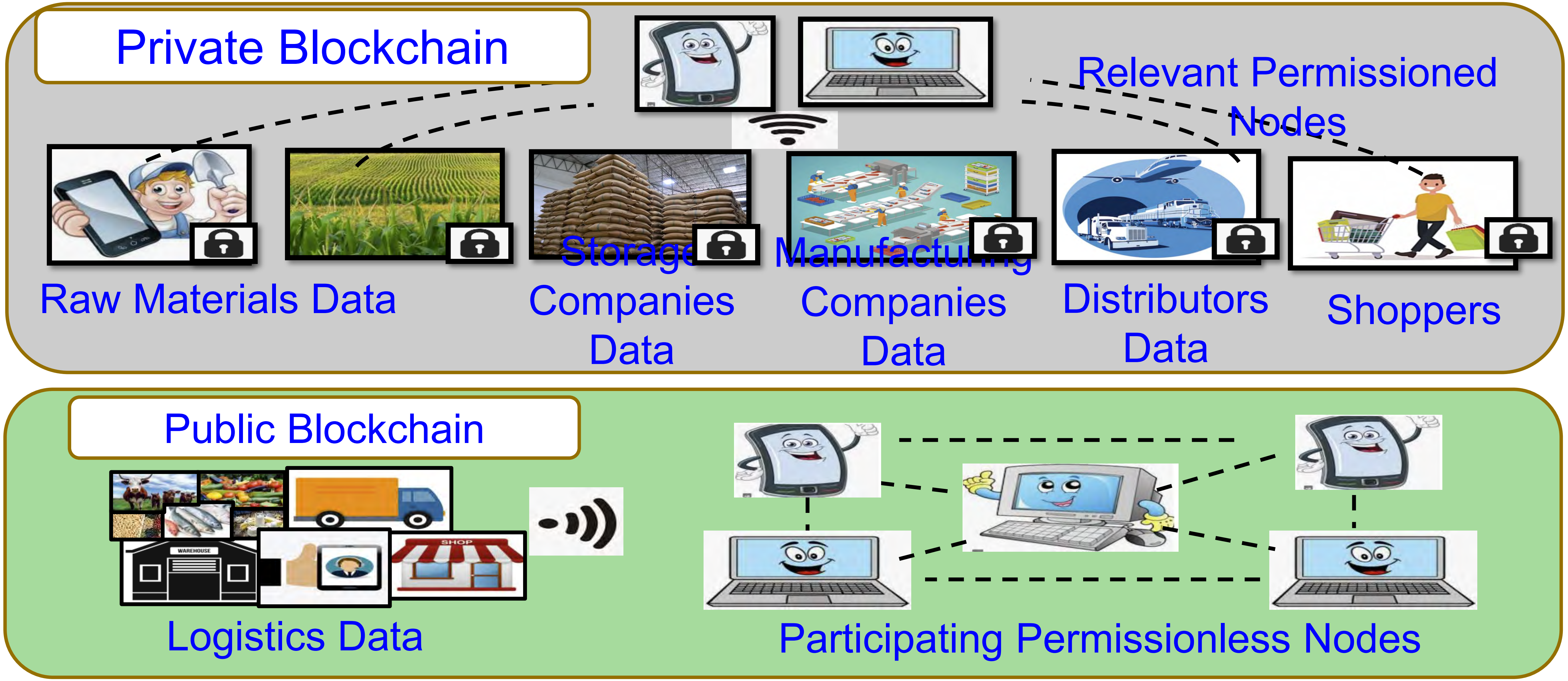


Land Registration Supply Chain Farmer Incentives

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

Roles of Blockchain in A-CPS - Private Vs Public



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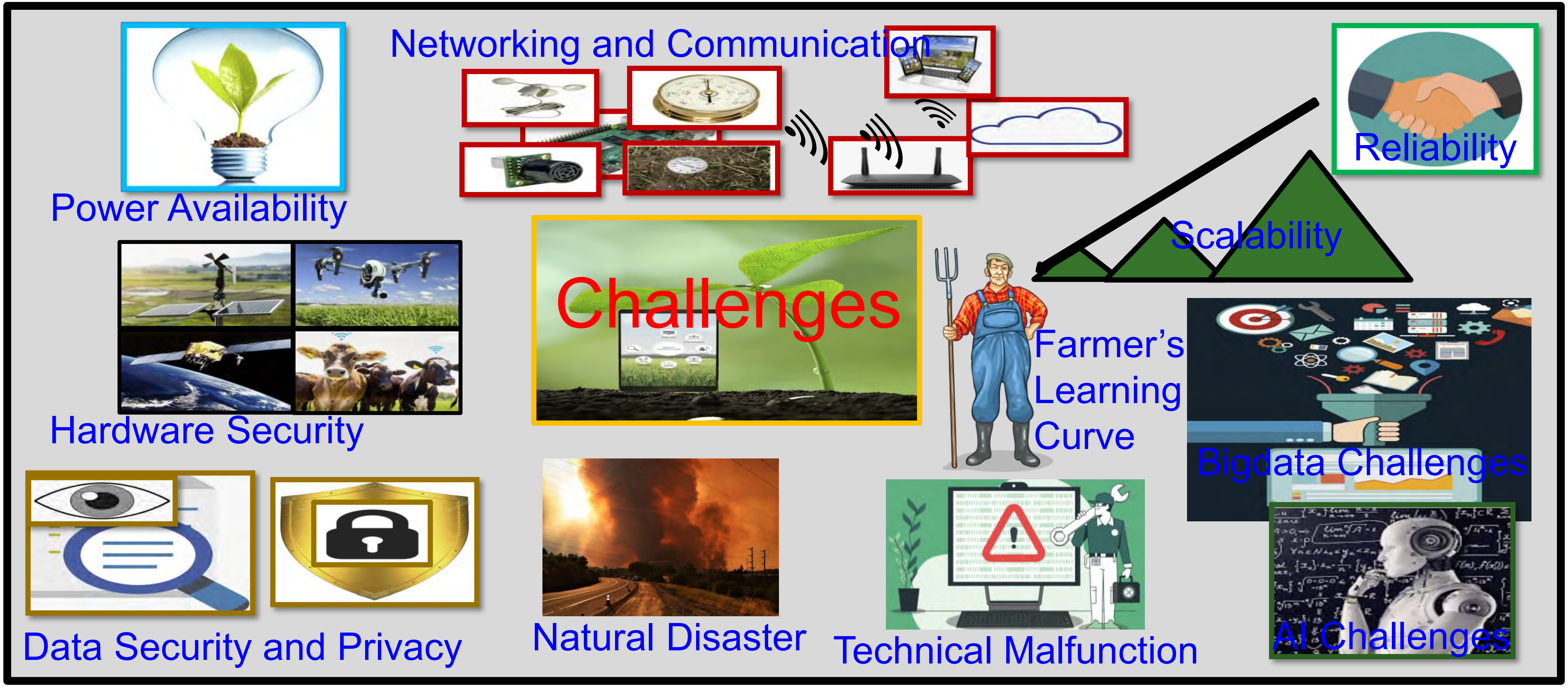
Smart Agriculture – Some Challenges

Smart Agriculture – Challenges



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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

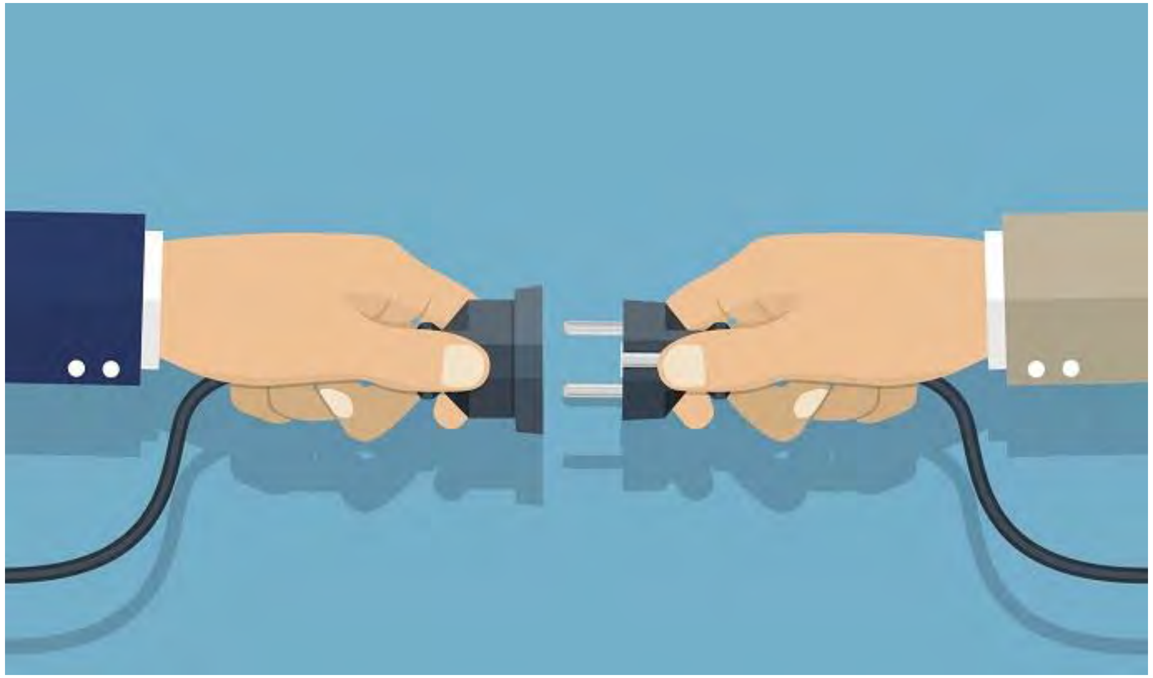
- Reliable internet connectivity is not possible in many of the remote villages in the world.
- Network performance and bandwidth requirements may not be achieved because lack of the infrastructure as in urban areas.
- Delay in real-time applications if computing is dependent on IoT-cloud.

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.

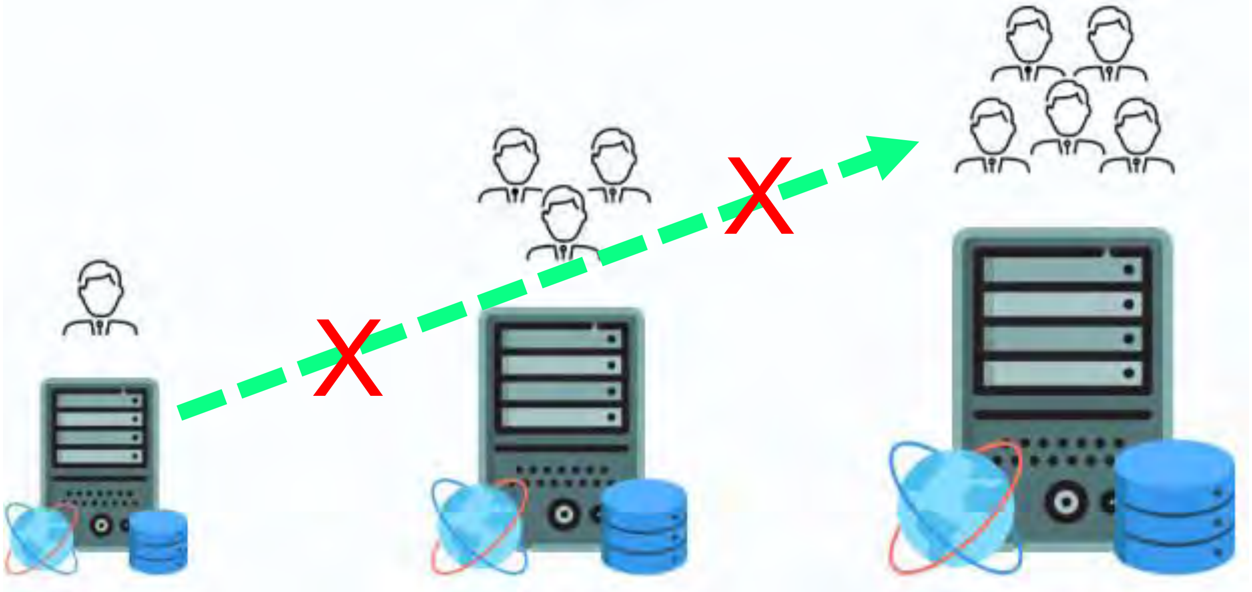
Interoperability Can be an Issue for the Smart Agriculture Equipment

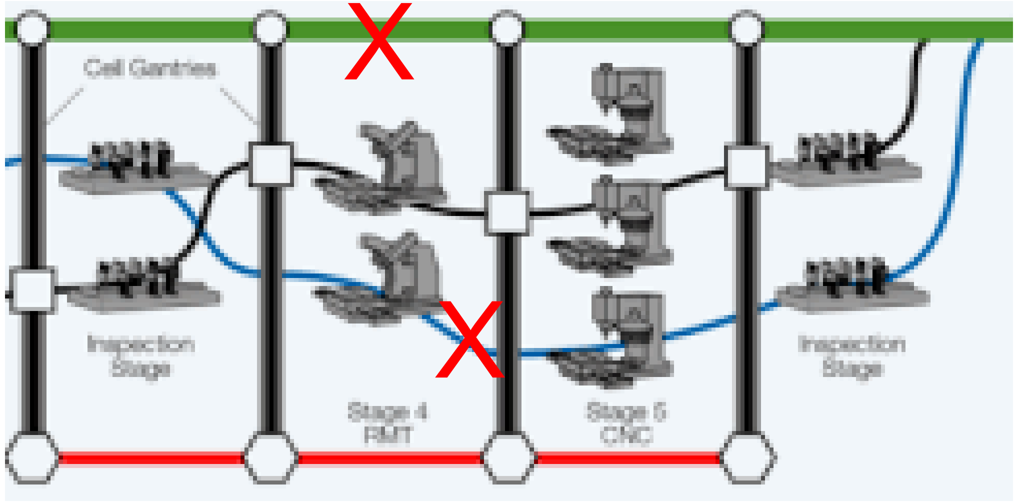
- Technologies used in Smart Agriculture are developing rapidly.
- Lack of technology standards → Interoperability issues.
- Creation of additional gateways to translate data between two systems is more common.
- Solution lies in making the standalone devices and gateways to farmer-friendly platforms.



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 Flow in Smart Agriculture

Data Generation
- Enormous and Wide Variety of Data from Smart Agriculture

Data Acquisition
- Collection
- Transmission
- Preprocessing

Data Storage
- Direct Attached Storage (DAS)
- Network Attached Storage (NAS)
- Storage Area Network (SAN)

Data Analysis

Traditional Analysis
- Cluster
- Factor
- Correlation
- Regression
- Bucket Testing
- Statistical
- Data Mining

Bigdata Analysis
- Hashing
- Index
- Triel
- Parallel Computing

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.

Security Issues in IoAT

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

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

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

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

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

Smart Agriculture - Security Challenges

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

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

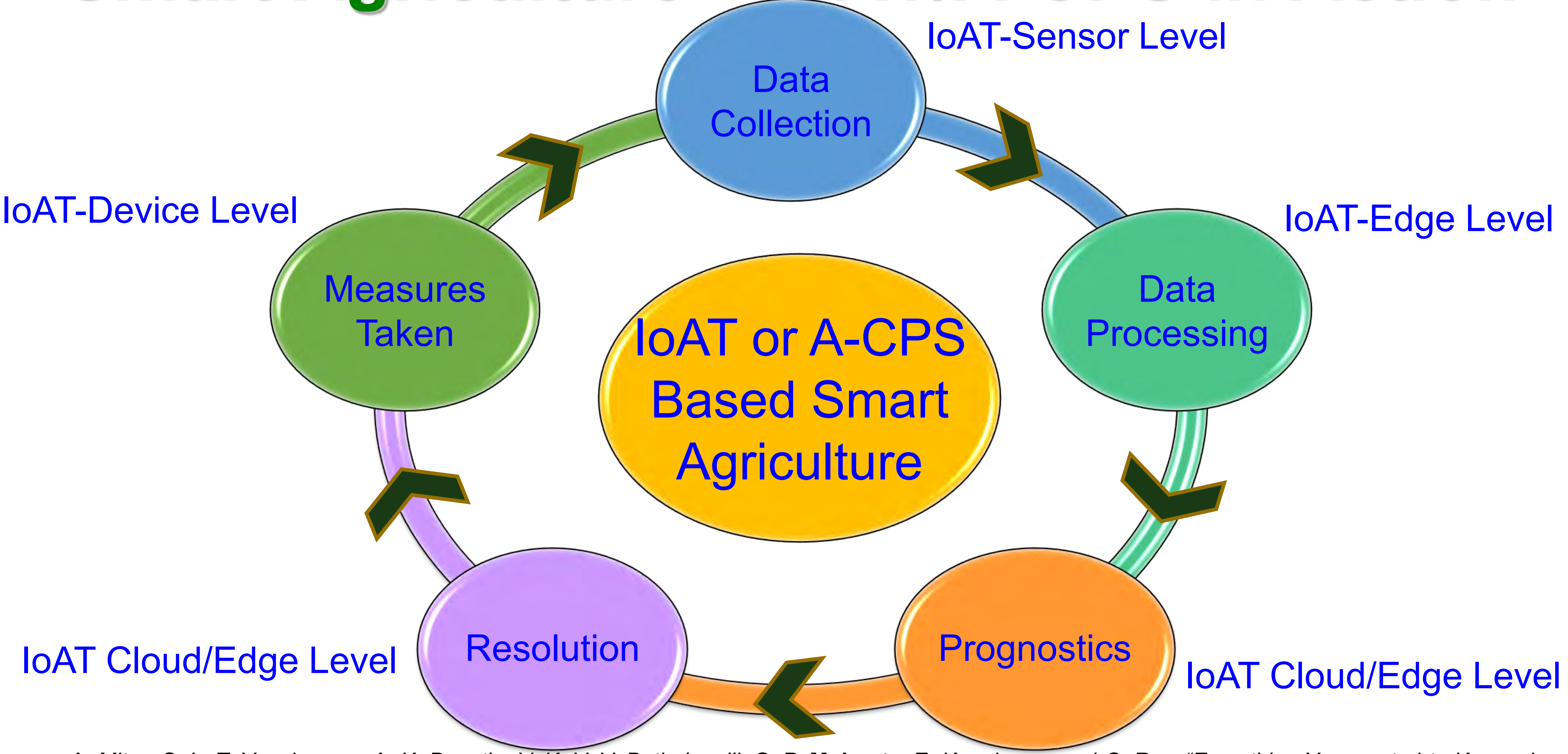
Smart Agriculture - Security Challenges

- Cyber Attacks
  - Data Attacks
    - Insider Data Leakage
    - Cloud Data Leakage
    - False Injection
  - Network and Equipment Attacks
    - Radio Jamming
    - Malware Injection
    - Denial of Service
  - Supply Chain Attacks
    - Third Party Attack
    - Software Update Attacks
    - Data Fabrication
  - Other Attacks
    - Cloud Computing
    - Cyber Terrorism
    - Compliance and Regulation Invalidation

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

Smart Agriculture Case Studies – AI/ML Solutions

Smart Agriculture – IoAT/A-CPS in Action



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

Crop Damage and Disease Problem

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

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

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

Leave Diseases in Various Crops

Apple Scab

Grape Black Rot

Bell Pepper Bacterial Spot

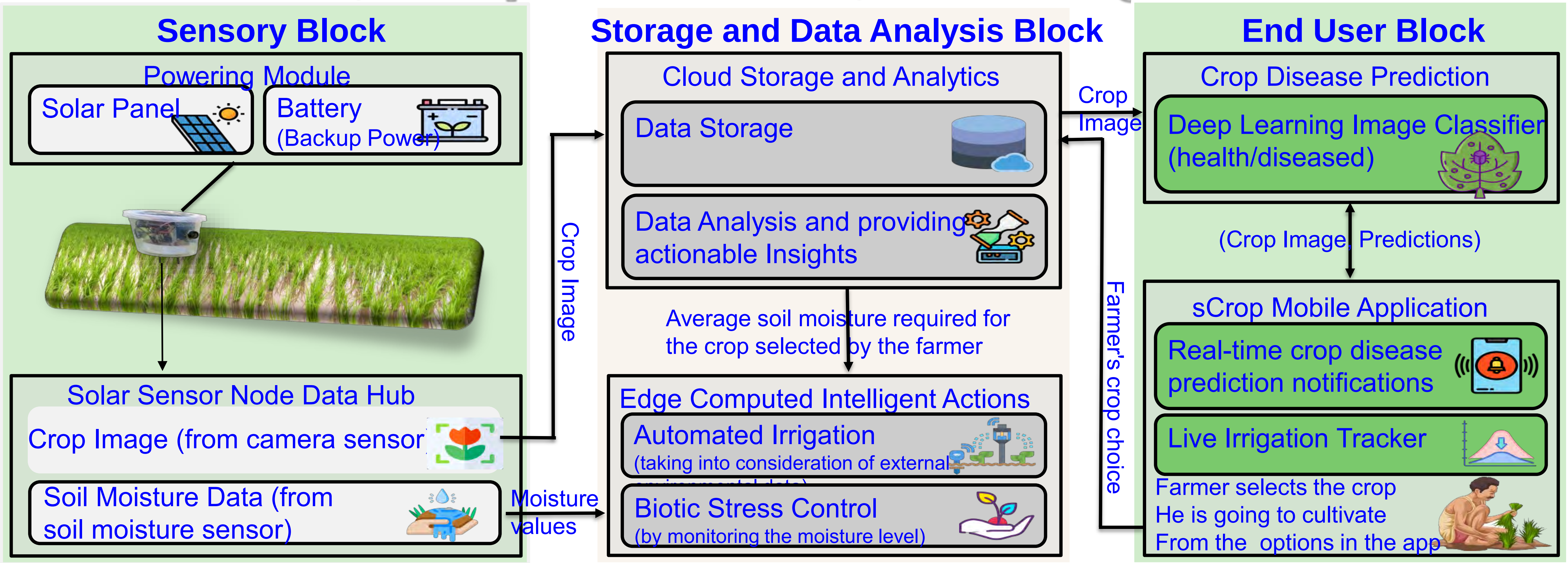
Orange Haunglongbing

Potato Early Blight

Tomato Early Blight

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

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



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

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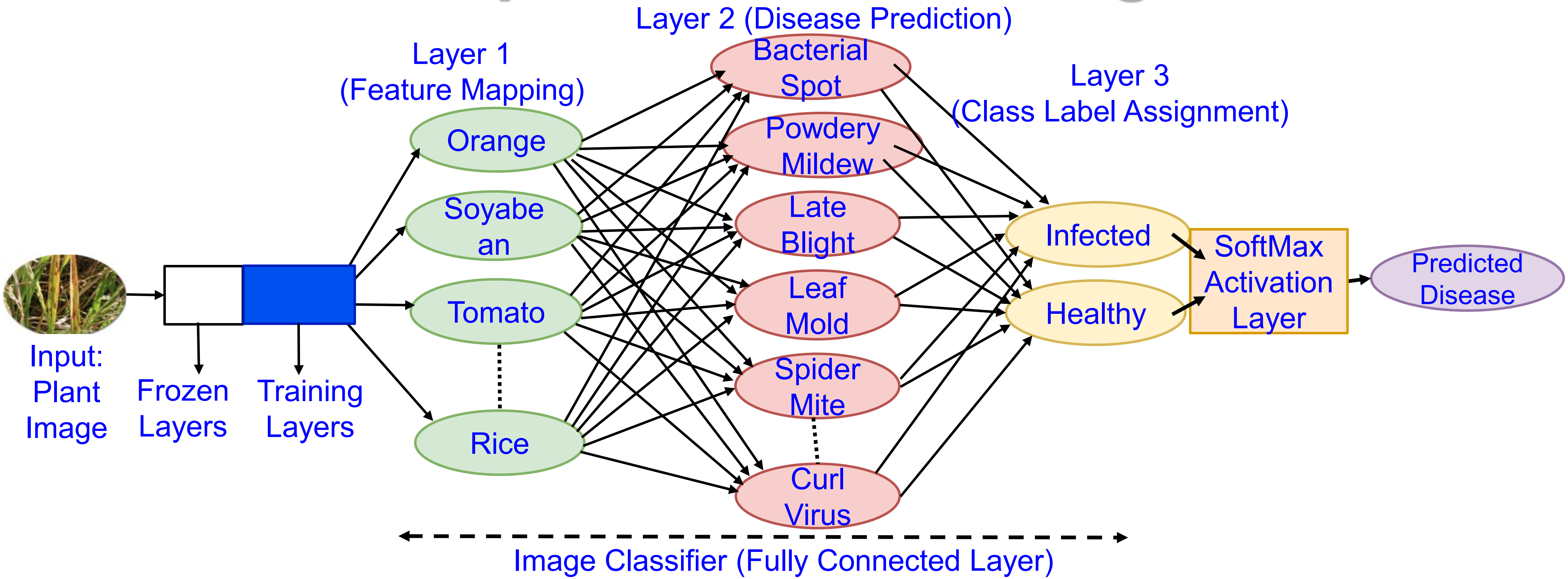

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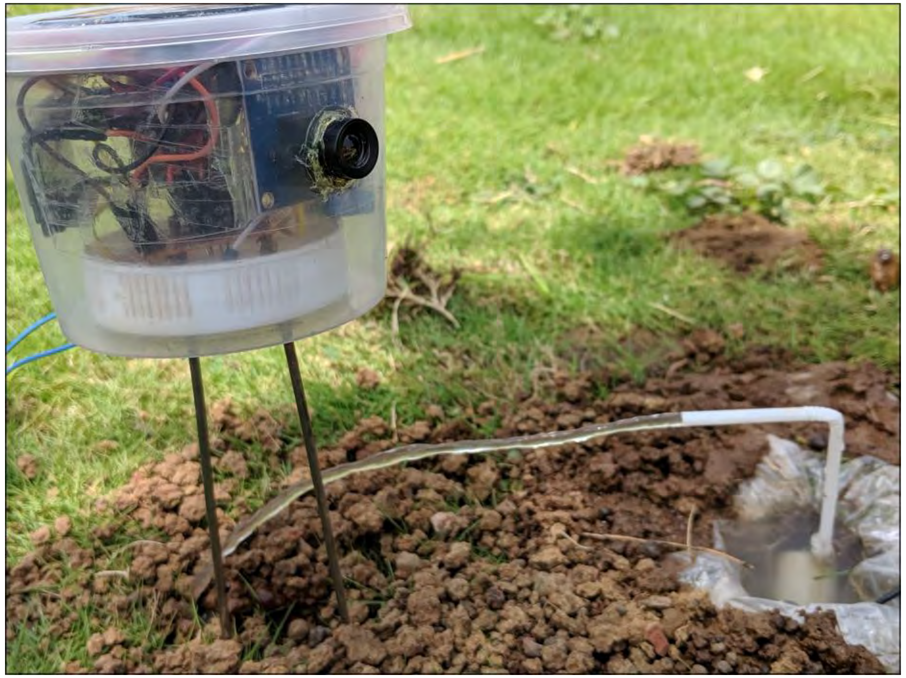


sCrop Device Prototype with Irrigation

sCrop App

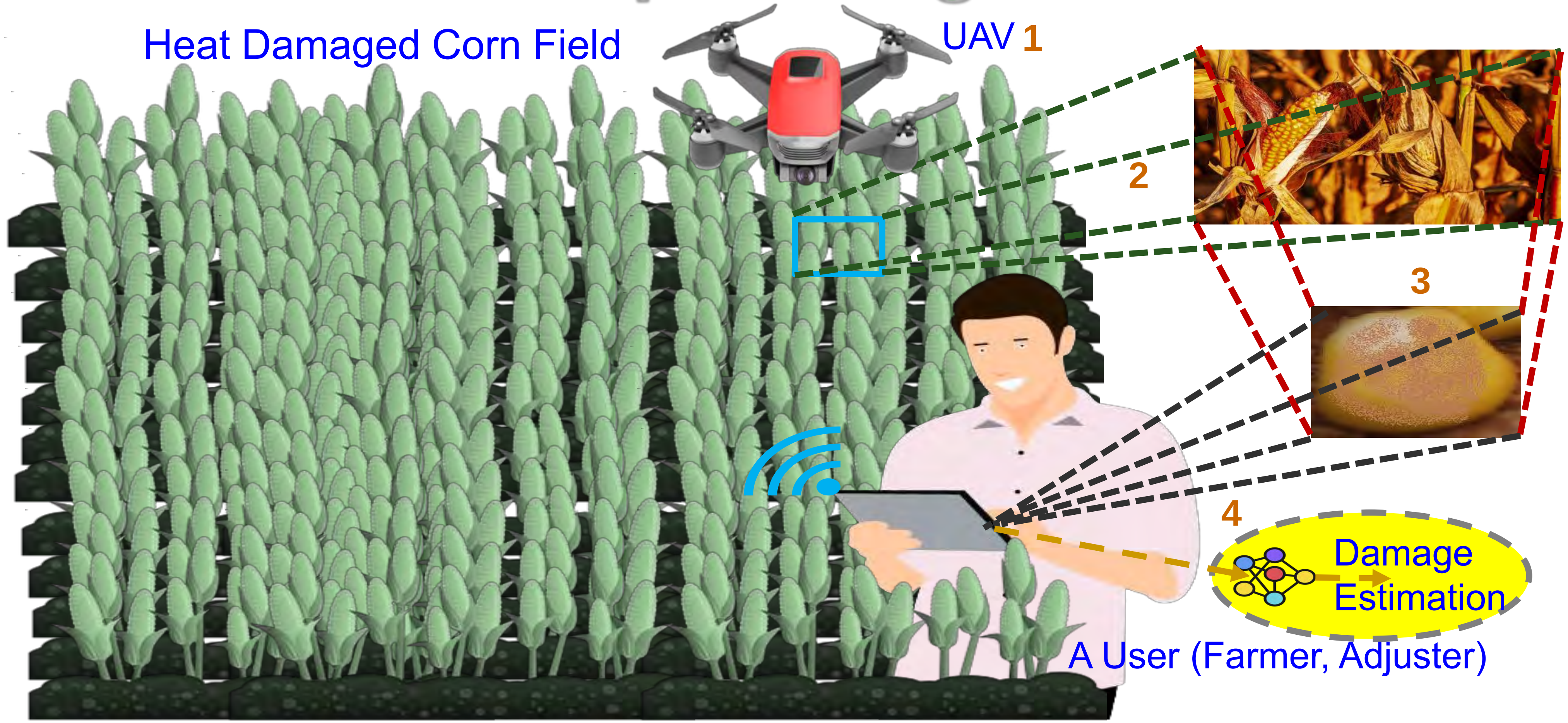
Healthy Tomato

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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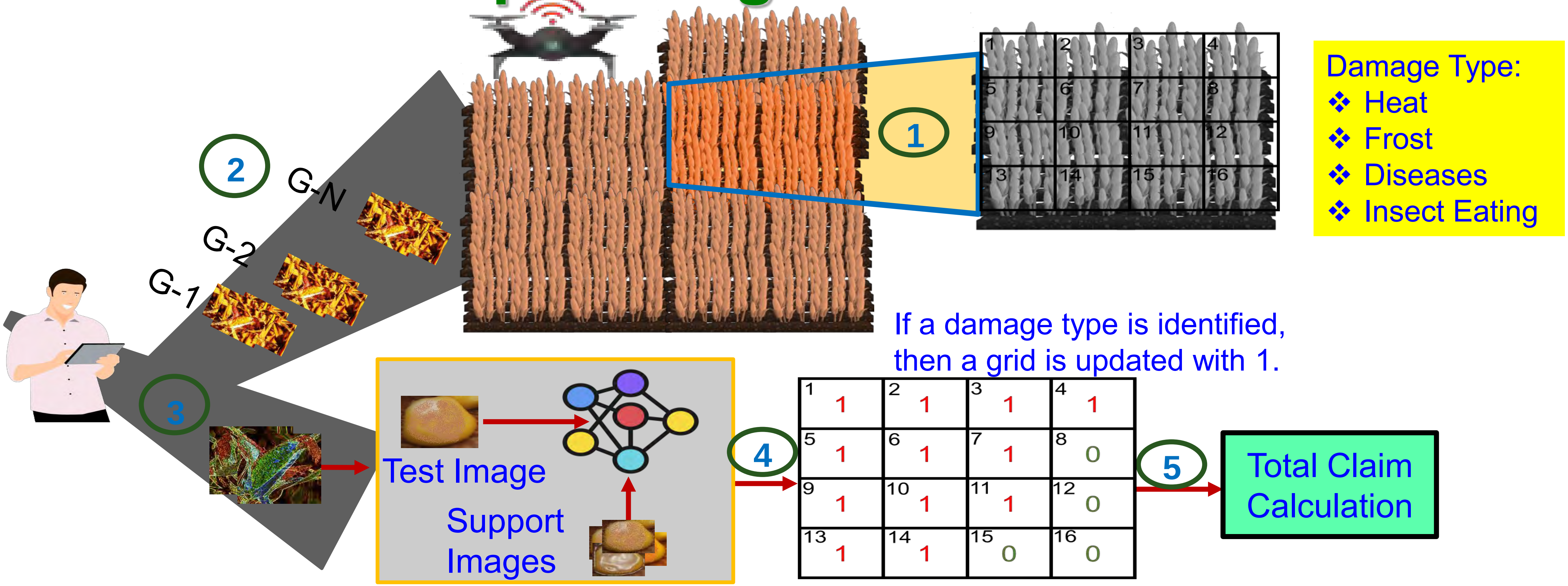


A. Mitra, A. Singhal, **S. P. Mohanty**, E. Kougianos, and C. Ray, "eCrop: A Novel Framework for Automatic Crop Damage Estimation in Smart Agriculture", *Springer Nature Computer Science (SN-CS)*, Vol. 3, No. 4, July 2022, Article: 319, 16-pages, DOI: https://doi.org/10.1007/s42979-022-01216-8.

Our eCrop: Comparative Perspective

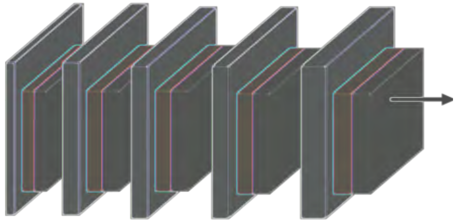
Works	Year	Damage Type	Accuracy (%)	Real Time
Sosa et al. [202]	2021	Hail	87.01	No
Sawant et al. [195]	2019	Cyclone, earthquakes, hail storms, and flood	87.23, 92.22	No
Yang et al. [245]	2019	Cold	82.19	No
Pallagani et al. [174]	2019	Crop disease	99.24	Yes
Di et al. [67]	2018	Natural Disaster	95.00	No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

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

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

- Detect plant diseases.
- Estimate corresponding leaf damage.

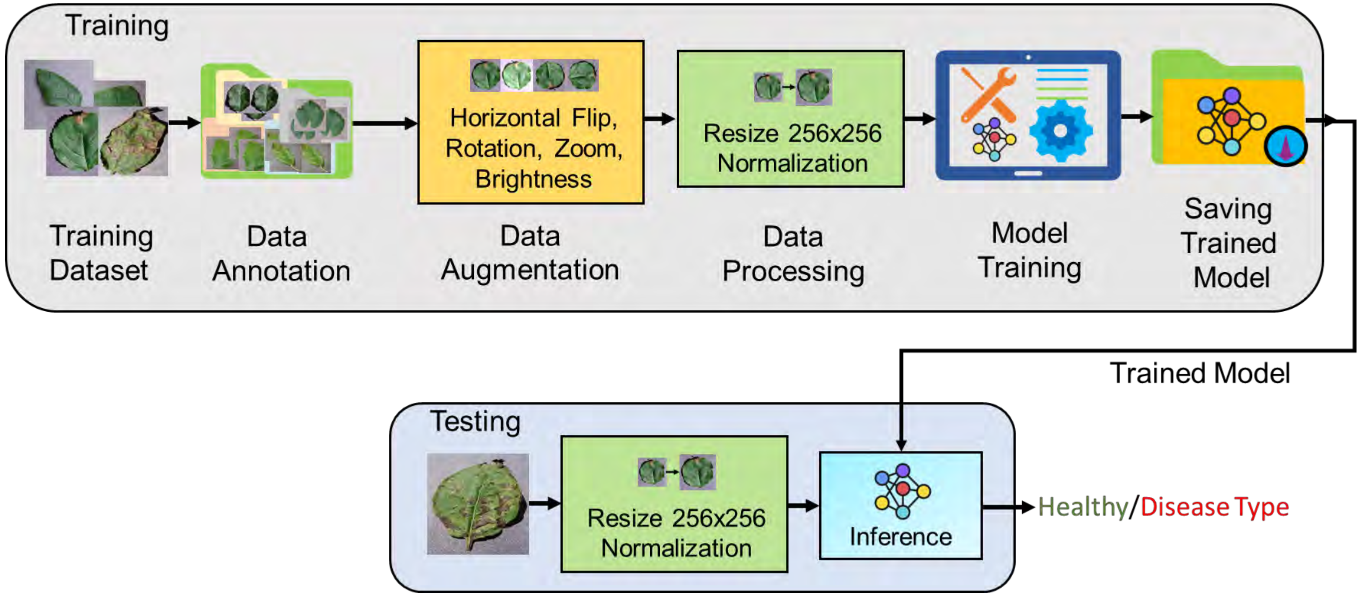
- Identification of the disease -
  - Convolutional neural network-based method.
- Estimation of the severity of leaf damage –
  - Pixel-based thresholding method.



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

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

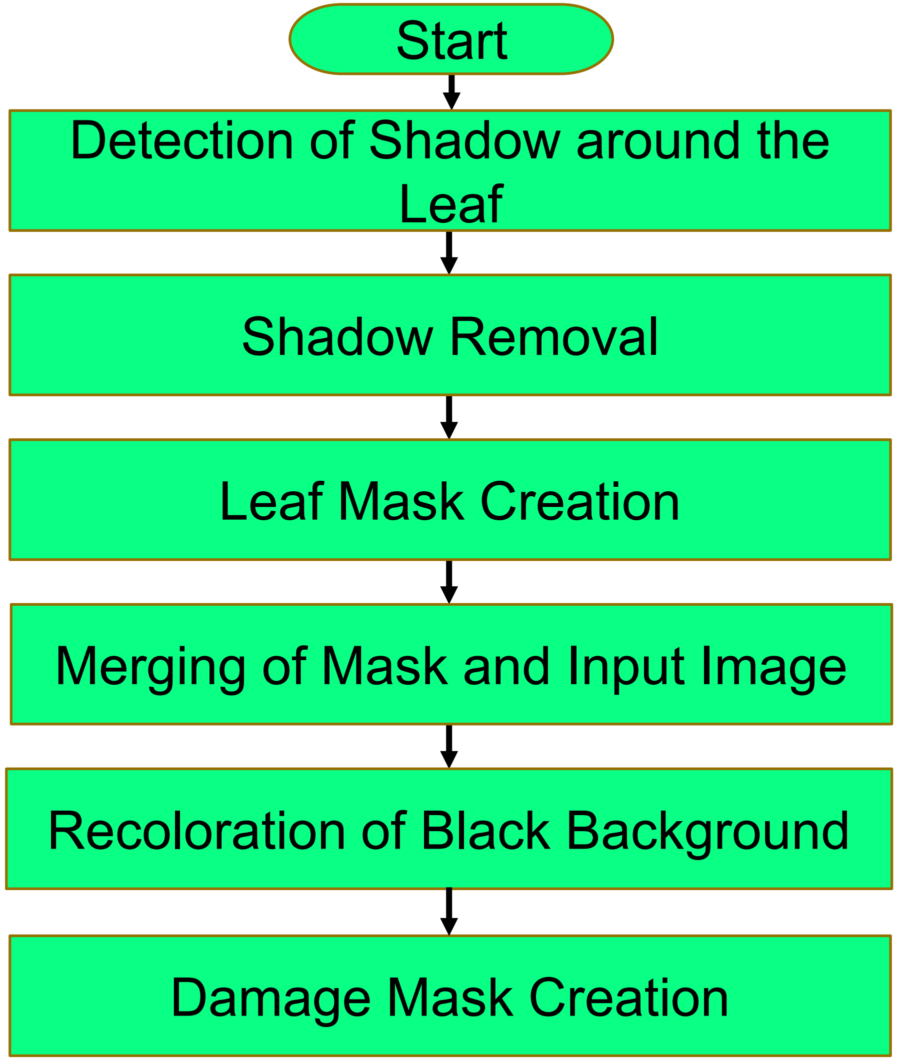
Our aGROdet: Plant Disease Detection

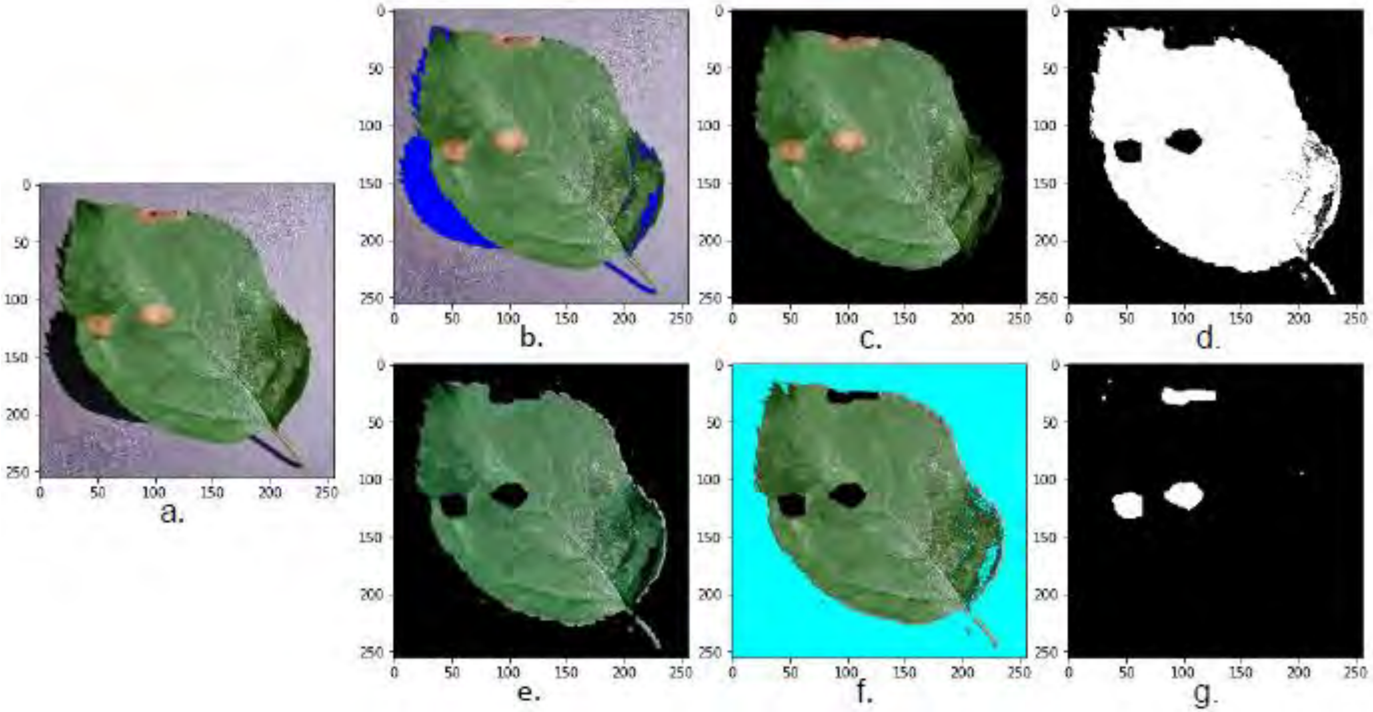


- The augmented and preprocessed data is used for training the network.
- Adam optimizer with an initial learning rate of 0.001.
- Model trained for 75 epochs.
- Model trained with and without a reduced learning rate of factor 0.1.
- Trained model is saved for future inference.
- Model evaluated using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

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

Our aGROdet: Damage Area Detection





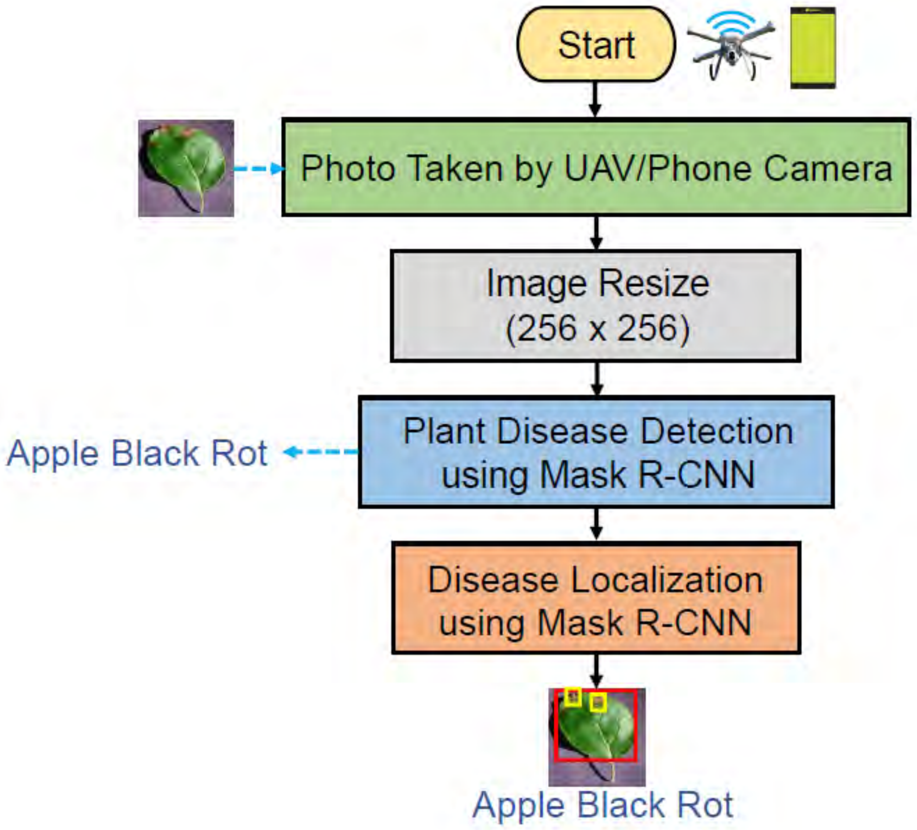
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "aGROdet: A Novel Framework for Plant Disease Detection and Leaf Damage Estimation", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 3--22, DOI: https://doi.org/10.1007/978-3-031-18872-5_1.

Our aGROdet 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.

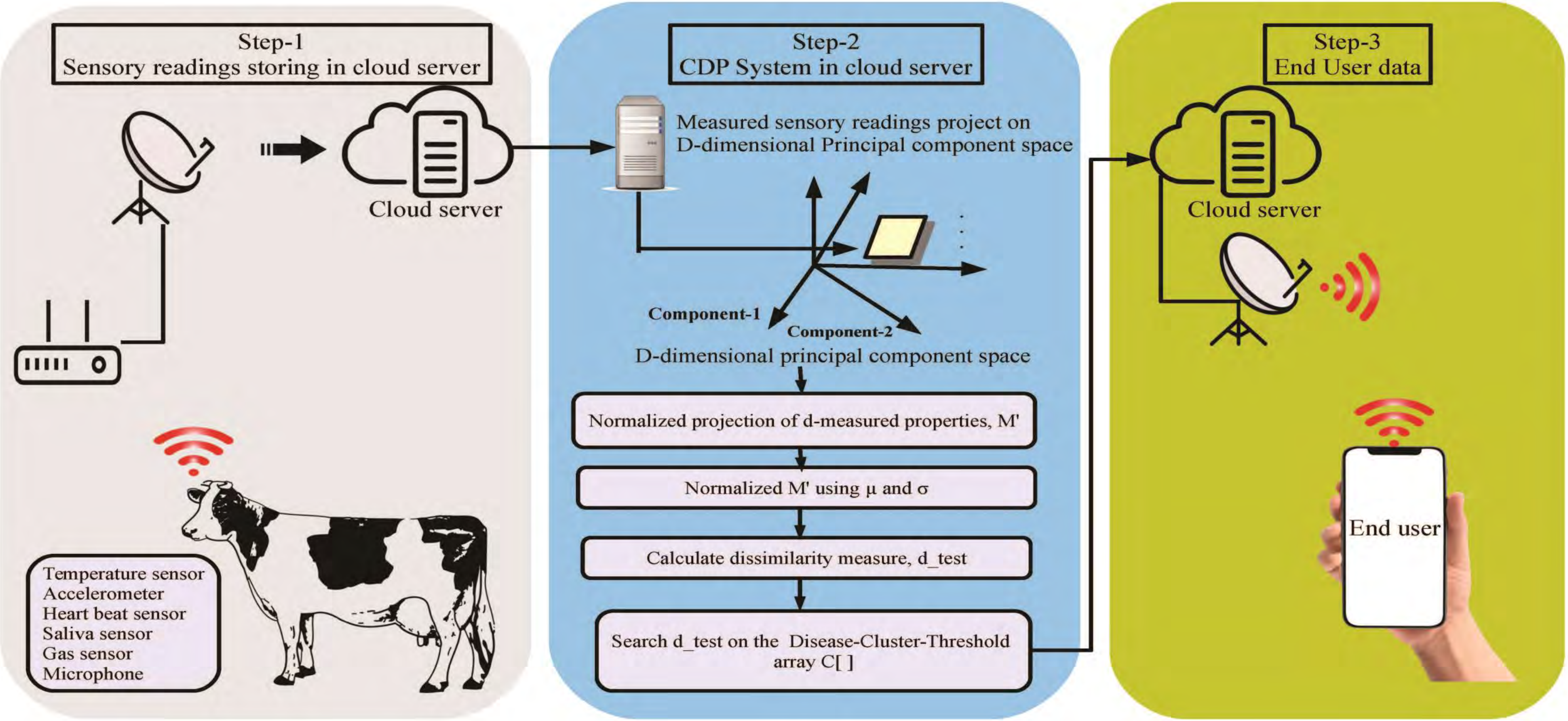
Our aGROdet 2.0: An Automated Real-Time Approach for Multiclass Plant Disease Detection



- 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.

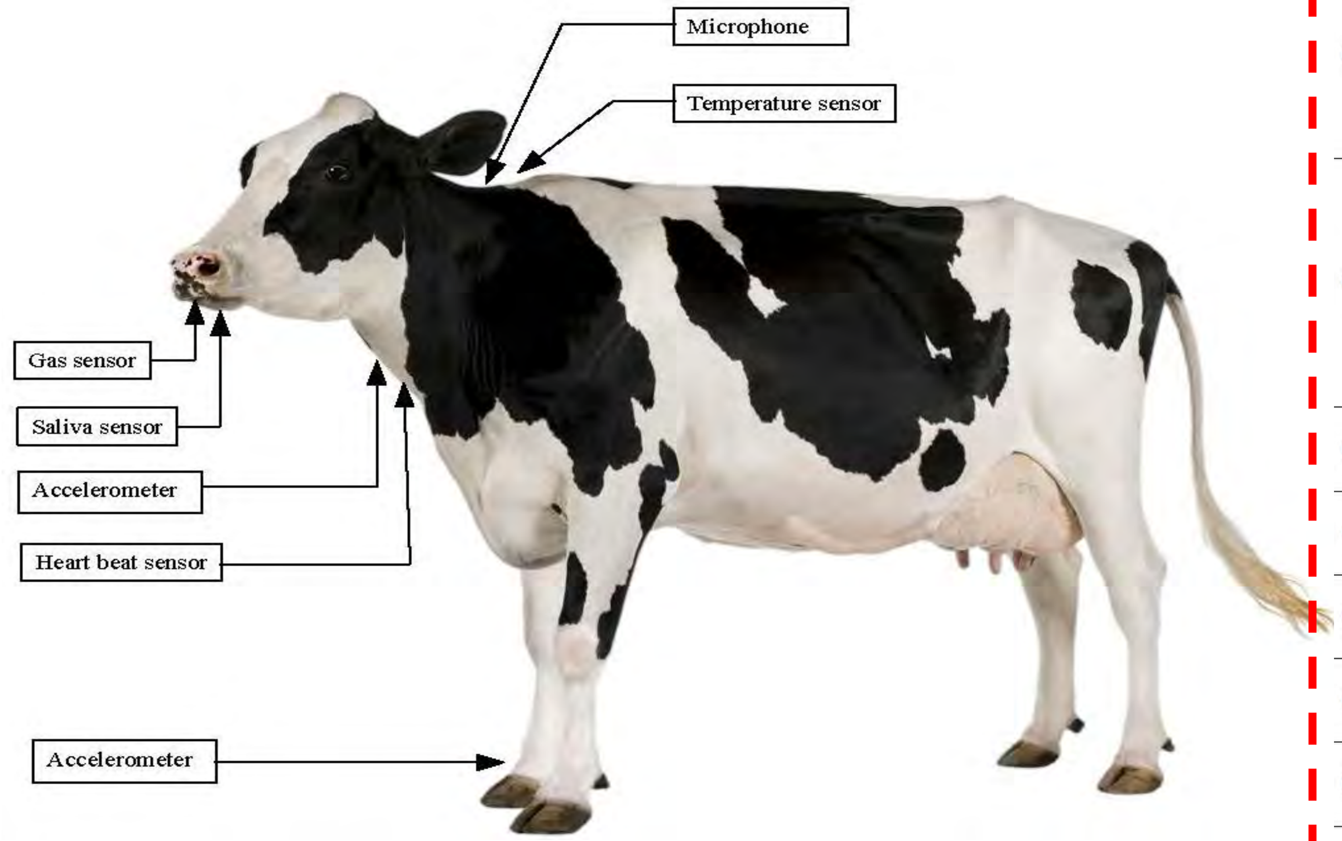
Source: A. Mitra, **S. P. Mohanty**, and E. Kougianos, "A Smart Agriculture Framework to Automatically Track the Spread of Plant Diseases using Mask Region-based Convolutional Neural Network", in *Proceedings of the IFIP International Internet of Things Conference (IFIP-IoT)*, 2022, pp. 68--85, DOI: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

Our LiveCare - IoT-Based Cattle Healthcare Framework



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

Our LiveCare - IoT-Based Cattle Healthcare Framework



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

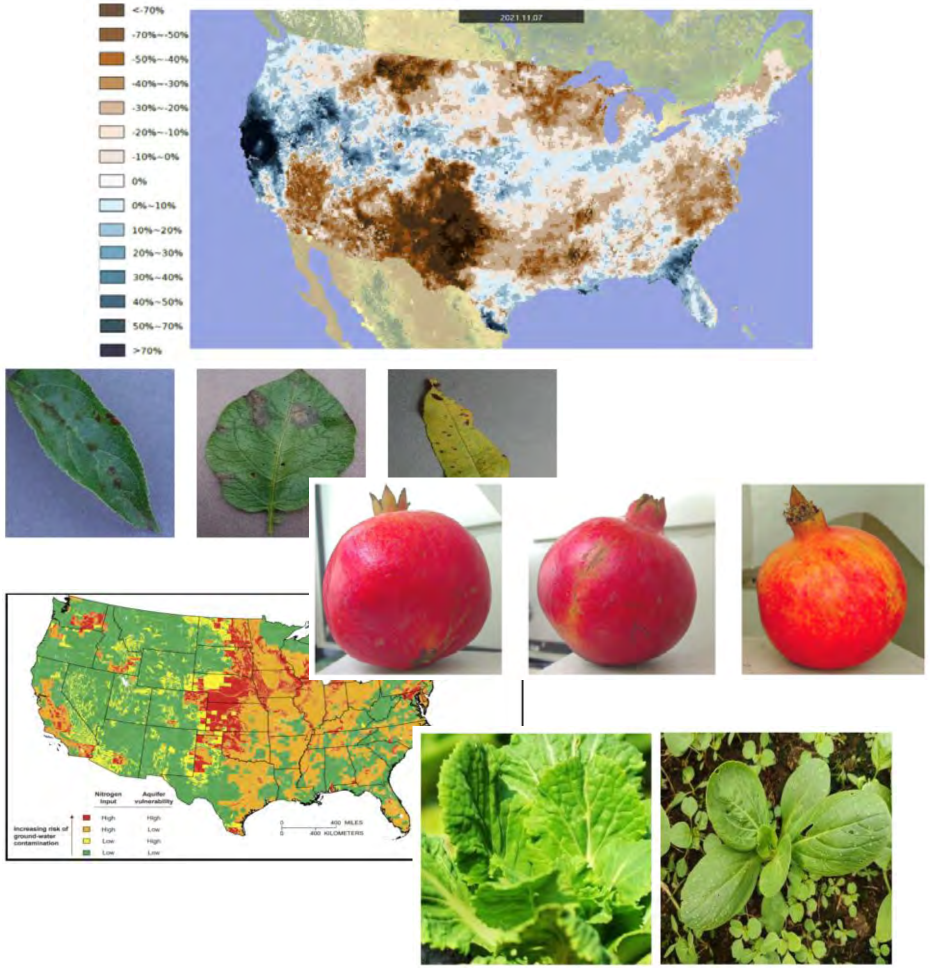
Source: P. S. Chatterjee, N. K. Ray, and **S. P. Mohanty**, "LiveCare: An IoT based Healthcare Framework for Livestocks in Smart Agriculture", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 67, No. 4, Nov 2021, pp. 257—265, DOI: https://doi.org/10.1109/TCE.2021.3128236.

Our LiveCare - IoT-Based Cattle Healthcare Framework

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

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

Smart Agriculture- Datasets for AI

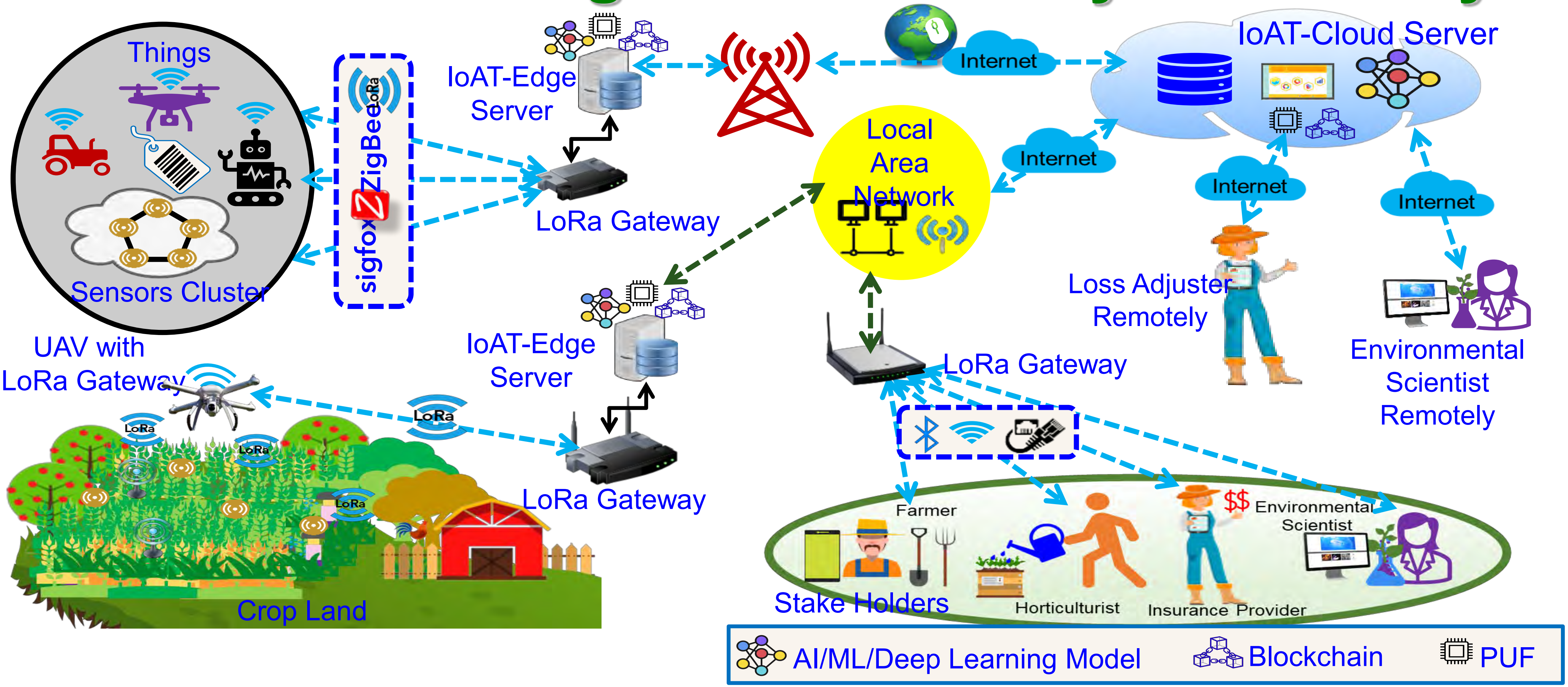


Dataset	Source	Dataset Format	Link
Crop Yield & Production	USDA & NASS	.php	https://www.nass.usda.gov/Charts_and_Maps/
Crop Condition & Soil Moisture	Crop-CASMA	.gis	https://nassgeo.csiss.gmu.edu/CropCASMA/
Plant Diseases	Kaggle	.jpg	https://www.kaggle.com/saroz014/plant-diseases
Soil Health & Characterization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

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

Smart Agriculture Case Studies - Cybersecurity Solutions

A-CPS with Integrated AI and Cybersecurity



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

Smart Agriculture Cybersecurity - Solutions

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

Our Security-by-Design Approach for Robust IoAT

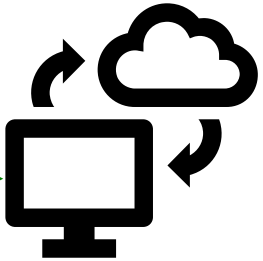
IoAT Devices

Air Hygrometer

Drone

Temperature Sensor

IoAT-Edge Server

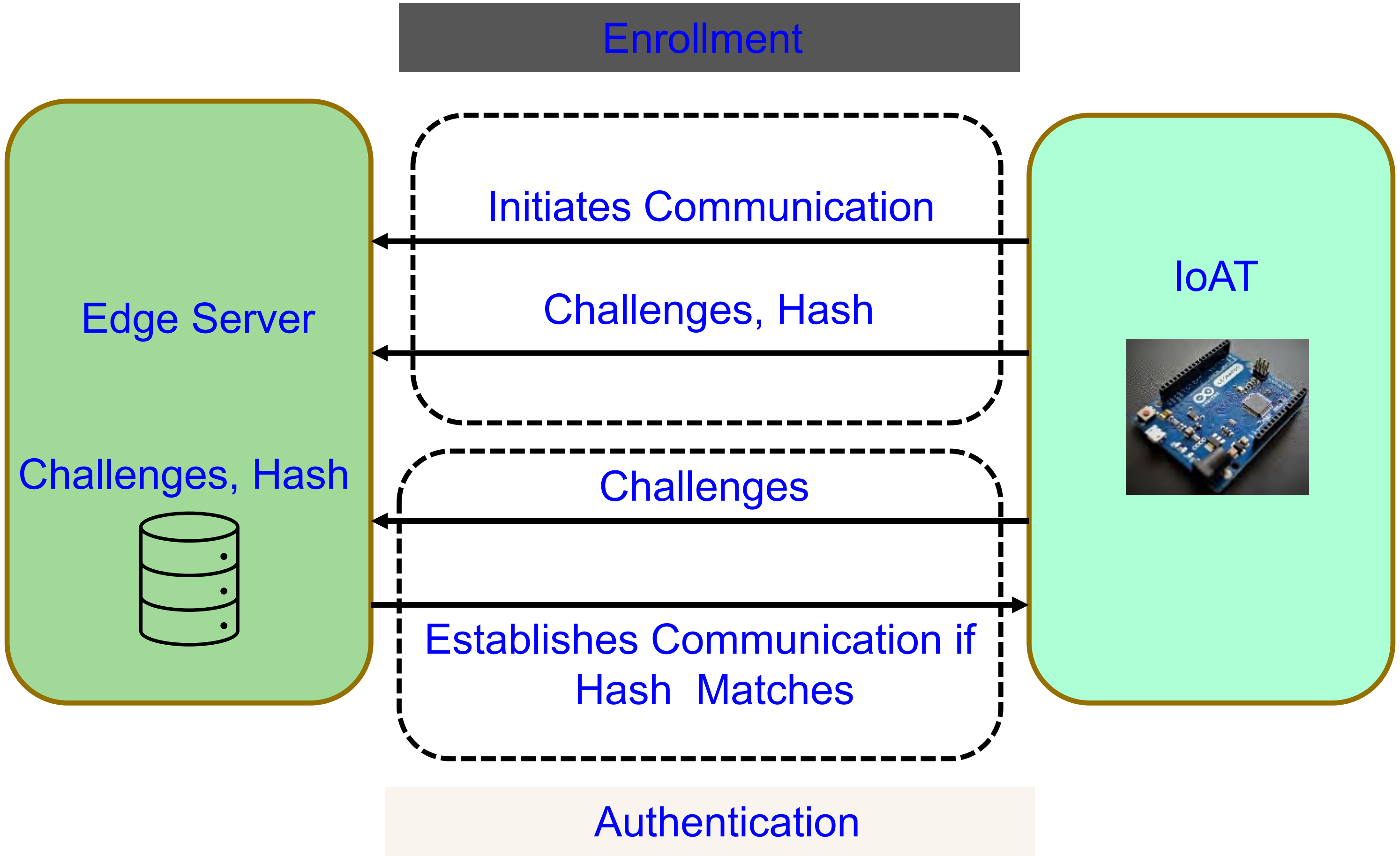


Secure Communication between PUF Embedded IoAT device and Edge Server

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.

Authentication Process for IoAT



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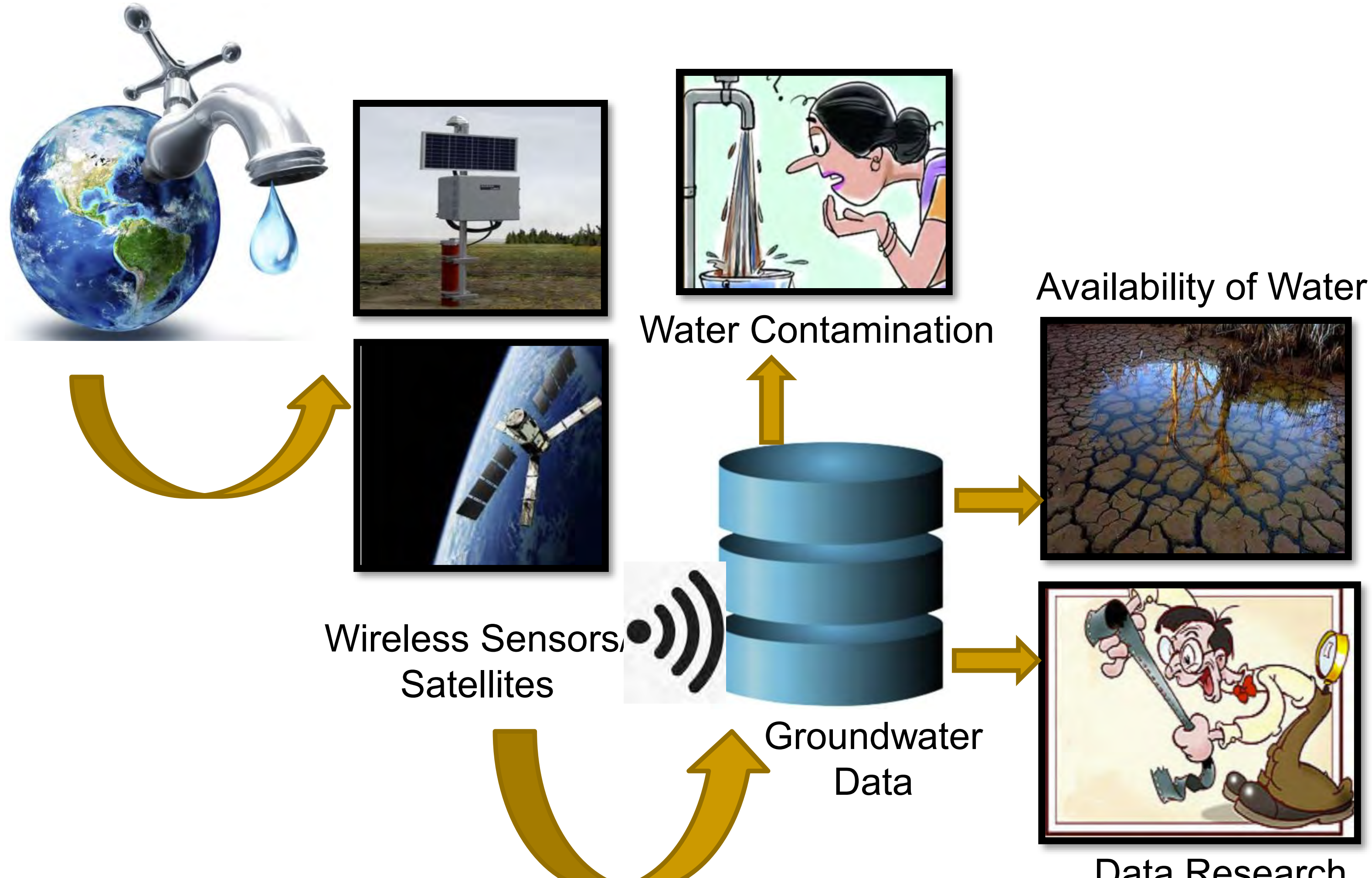
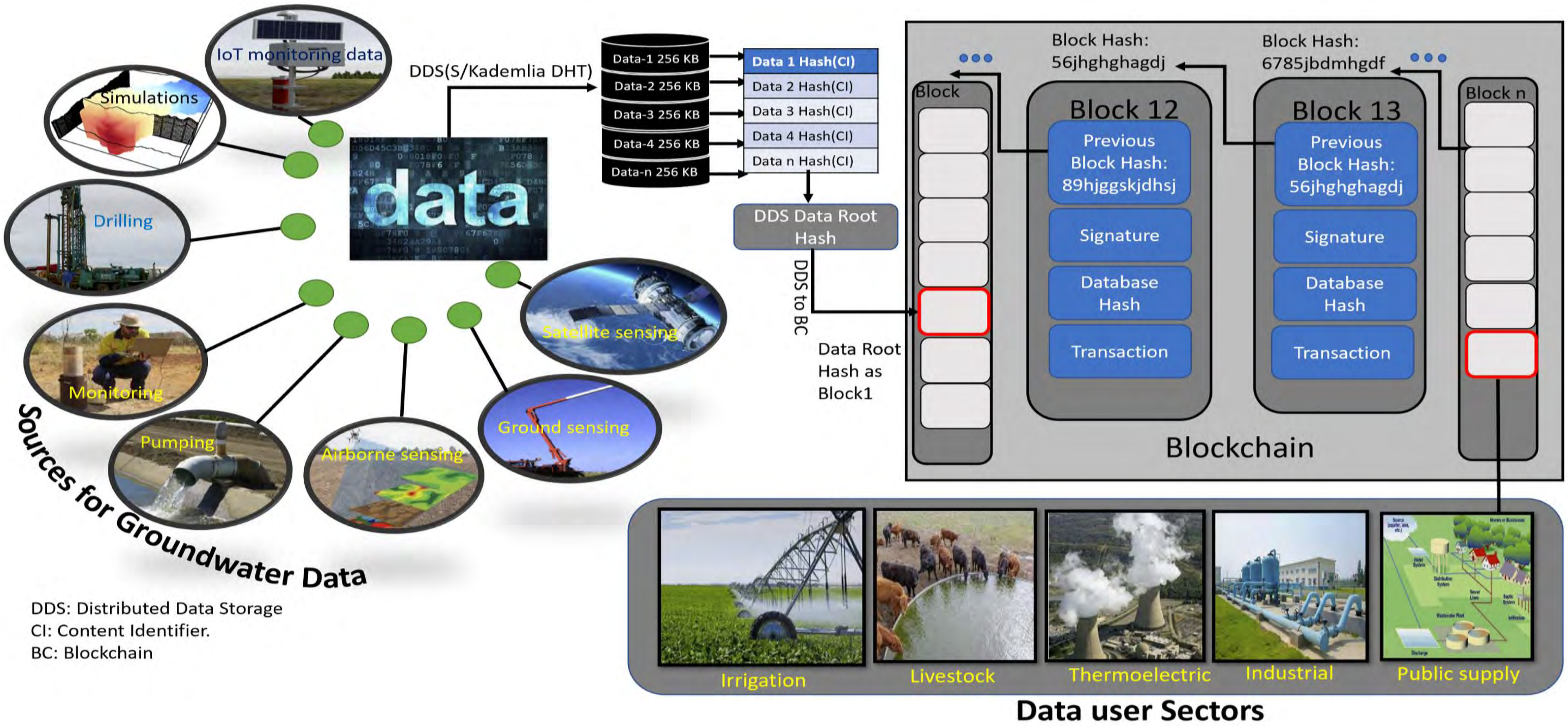
Our G-DaM: Introduction-Ground Water Data



- 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 .

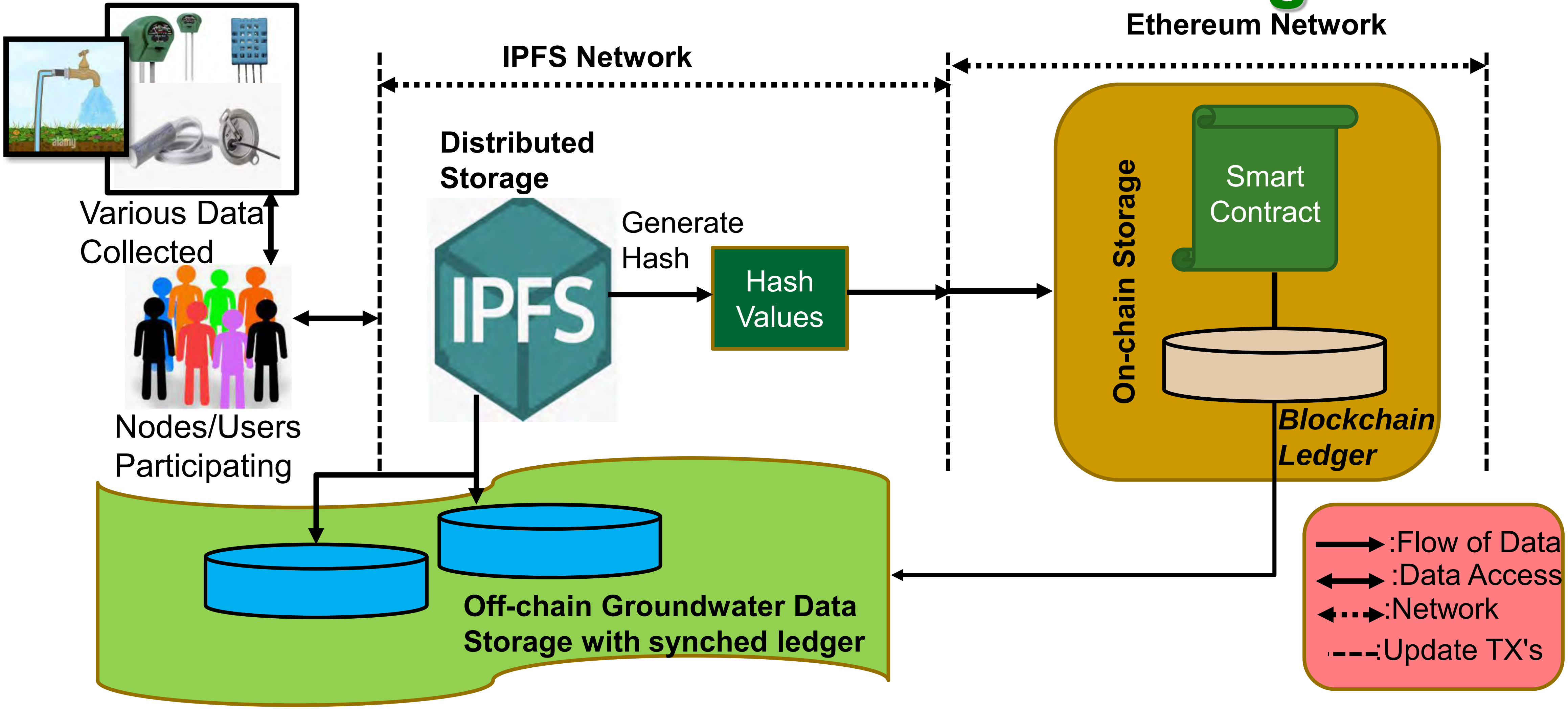
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

Our G-DaM: Proposed Architecture



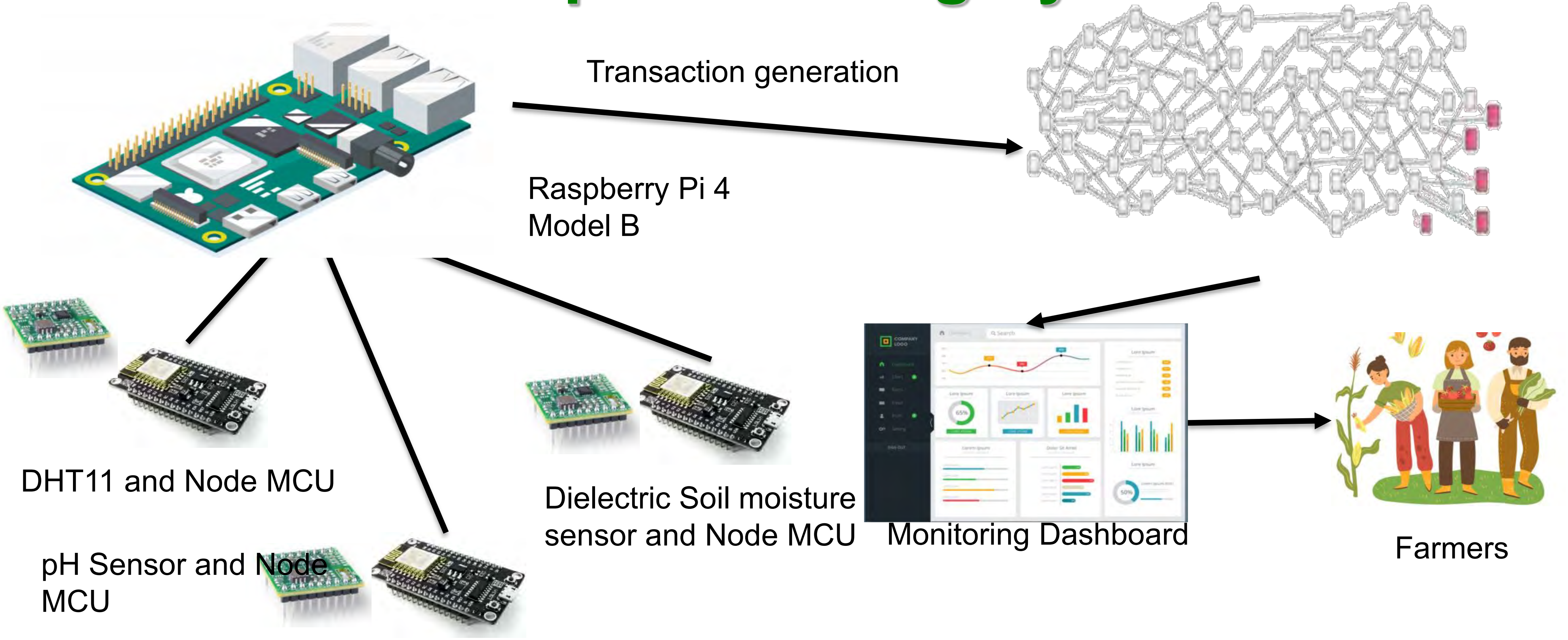
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "G-DaM: A Distributed Data Storage with Blockchain Framework for Management of Groundwater Quality Data", *MDPI Sensors*, Vol. 22, No. 22, Nov 2022, 20-pages, DOI: https://doi.org/10.3390/s22228725.

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", *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

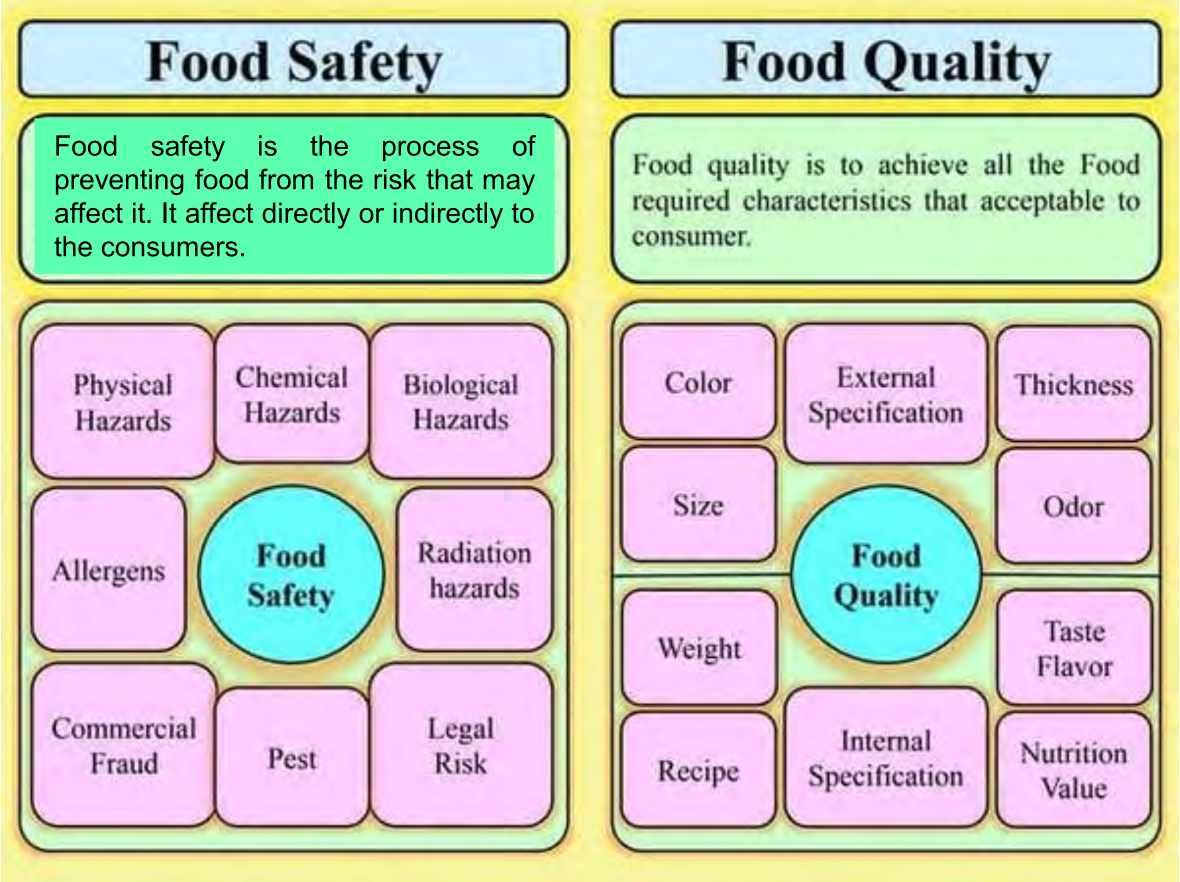
Our sFarm: Solution

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

Food Safety and Quality

Food Safety Vs Food Quality

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

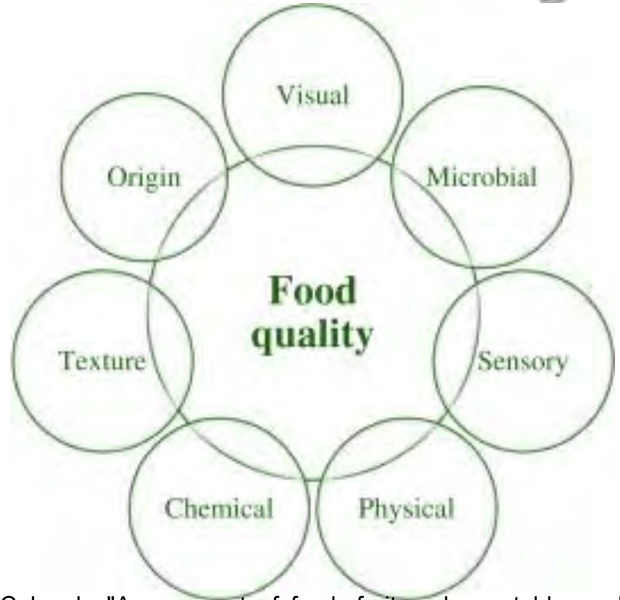


Source: https://www.slideshare.net/ijazulhaqrana/food-safety-vs-food-quality

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



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

Is this Chicken Meat safe to eat?

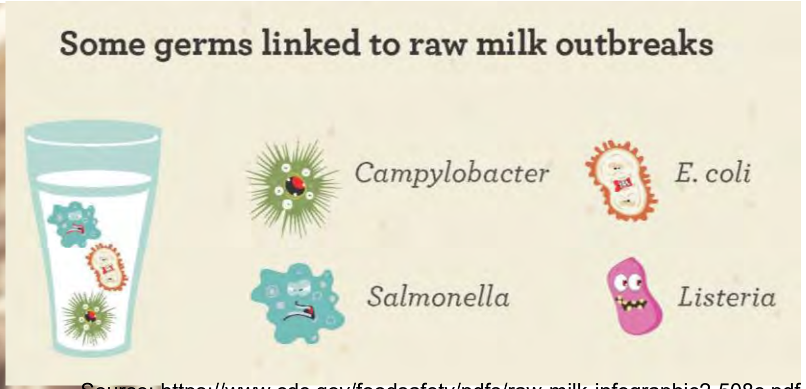
Source: https://hgic.clemson.edu/factsheet/safe-handling-of-poultry/

Is this Egg safe to use?

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

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

Milk Safety and Quality?



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

+ Spoilage in the supply chain

How Safe is the Milk that I am Drinking?

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

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

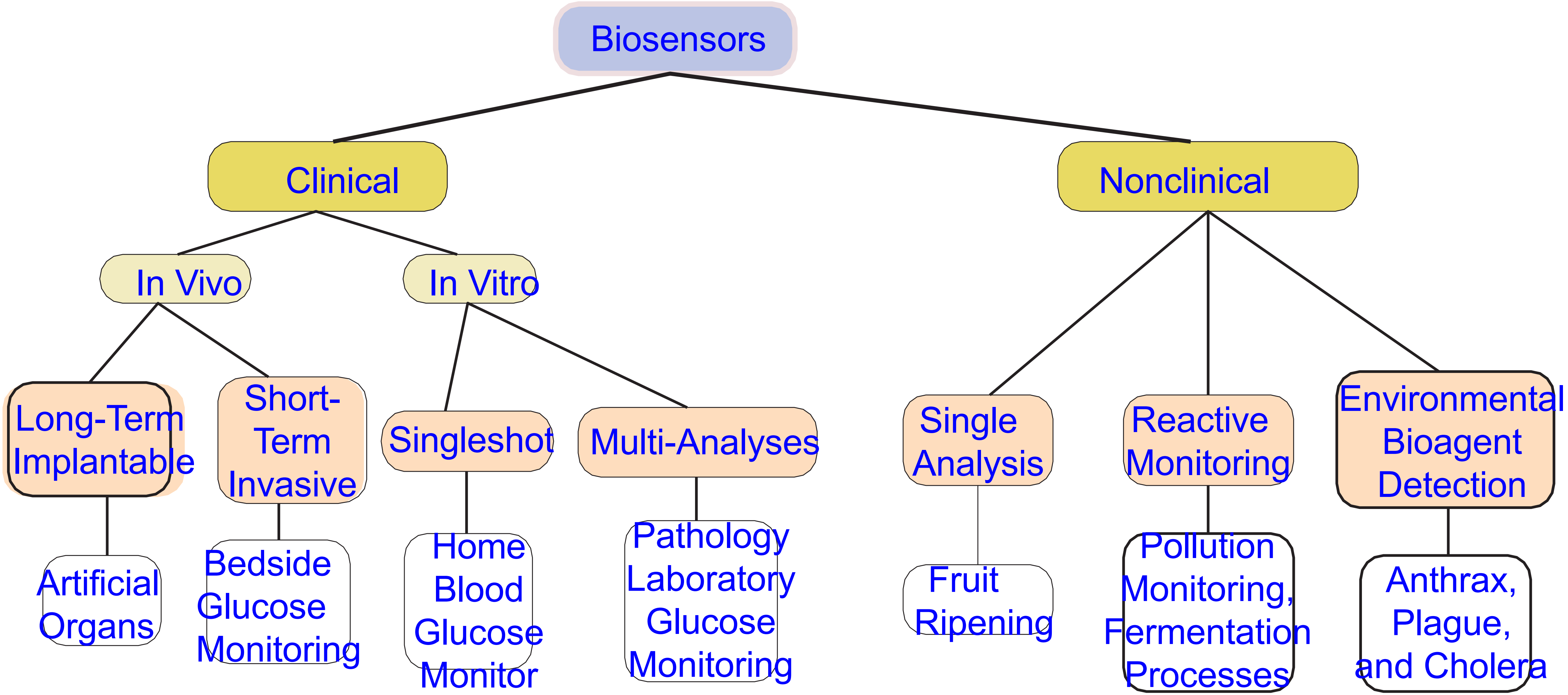
Source: S. L. T. Vangipuram, **S. P. Mohanty**, E. Kougianos, and C. Ray, "agroString: Visibility and Provenance through a Private Blockchain Platform for Agricultural Dispense towards Consumers", *MDPI Sensors*, Vol. 22, No. 21, Oct 2022, 20-pages, DOI: https://doi.org/10.3390/s22218227.

Food Supply Chain: Farm → Dinning

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

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.

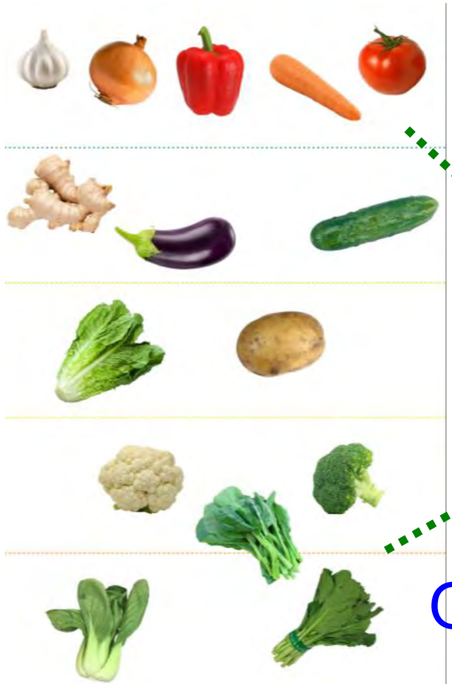
Food Safety and Security

- 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

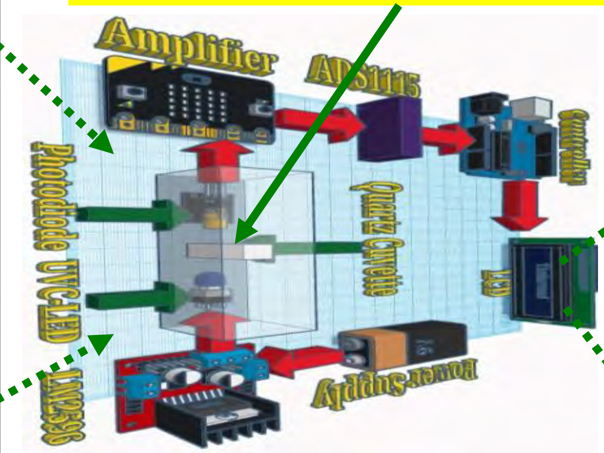
Our Food-Care: A Device for Detection of Fertilizer Contamination in Fruits and Vegetables



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

Fruit and Vegetables - Nitride Contaminated?

Quartz cuvettes of length 10mm for sample solution.

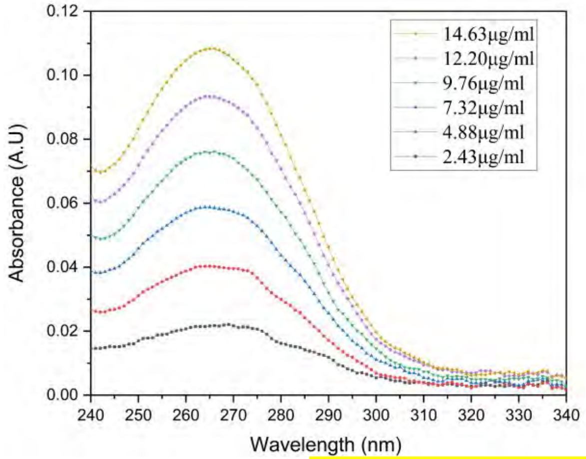


Our Food-Care Device

Contamination Level

- ➢ Acceptable
- ➢ Moderate
- ➢ Severe
- ➢ Dangerous

Peak absorbance spectrum of 265nm at different nitrate concentrations.



Need for Device which is:

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

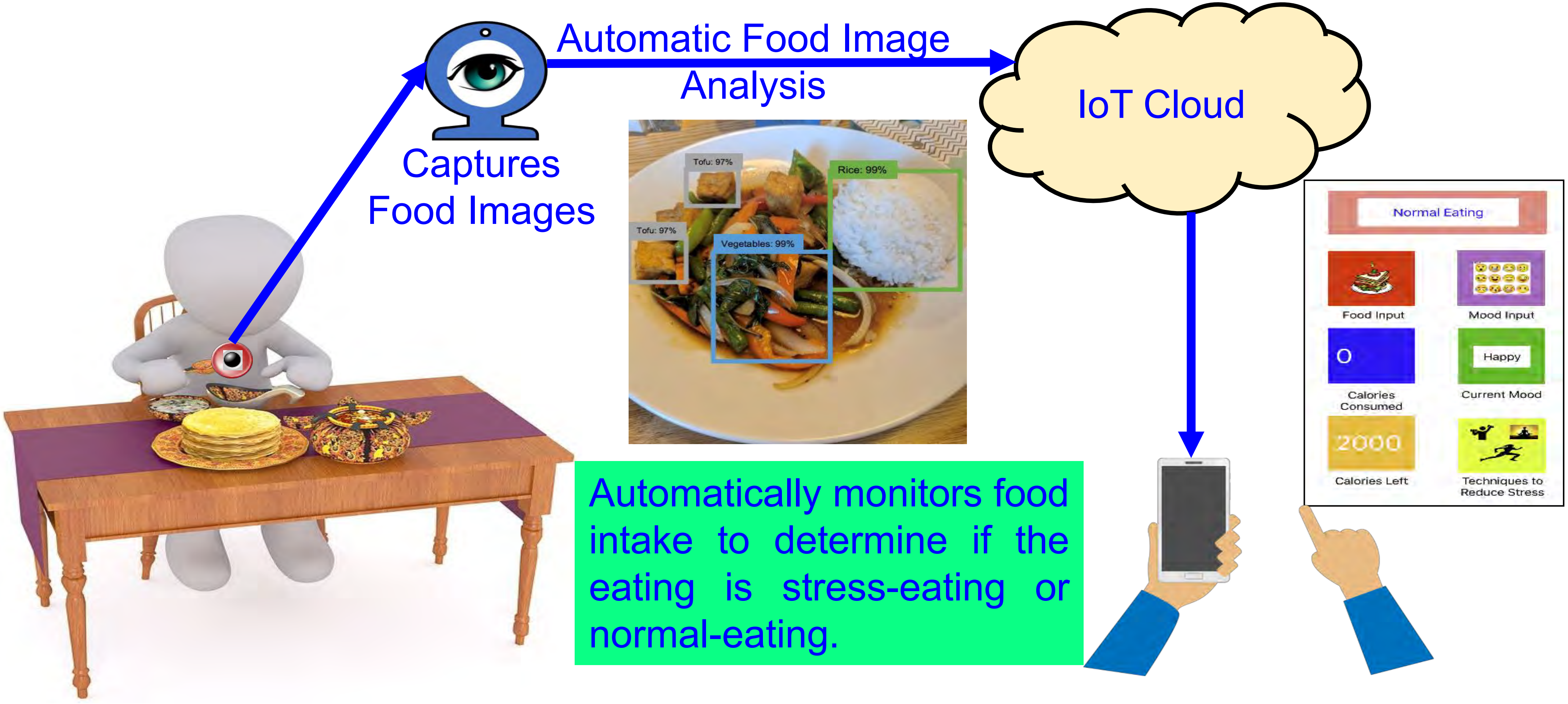
Source: G. Saxena, C. Sahu, A. Joshi, and **S. P. Mohanty**, “Food-Care: An Optoelectronic Device for Detection of Fertilizer Contamination in Fruits and Vegetables in Smart Agriculture Framework”, in *Proc. of IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted as demo.

Imbalance Diet is a Global Issue

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

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

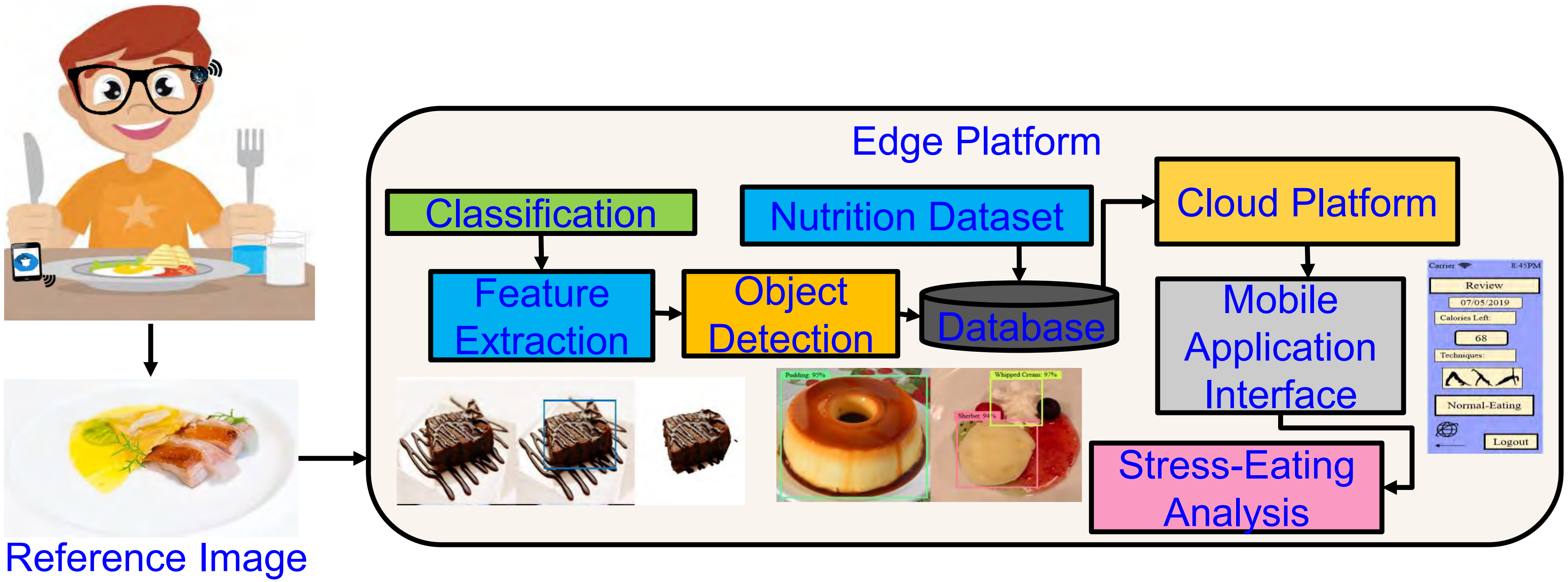
Automatic Diet Monitoring & Control - Our Vision



Automatically monitors food intake to determine if the eating is stress-eating or normal-eating.

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.

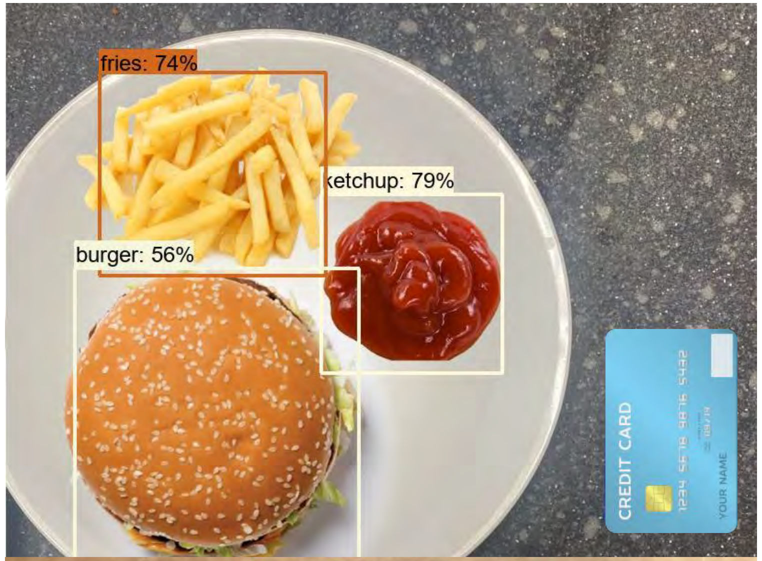
Smart Healthcare – Diet Monitoring - iLog



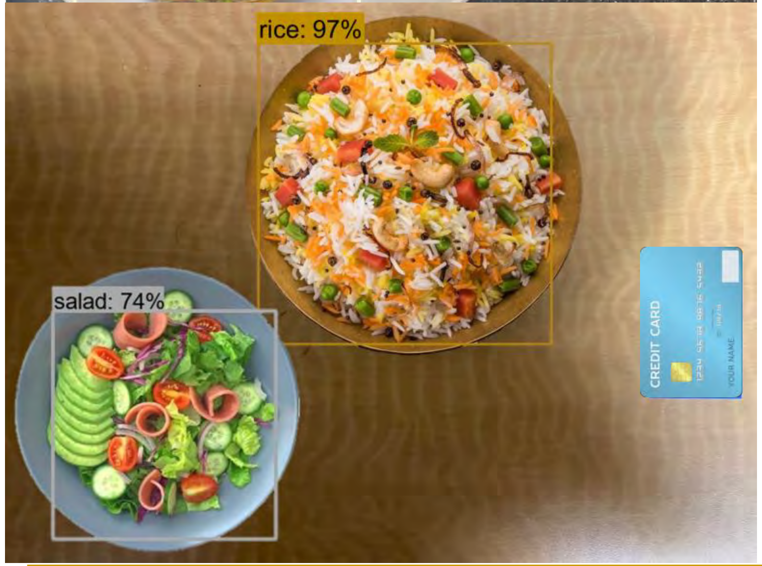
iLog- Fully Automated Detection System with 98% accuracy.

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



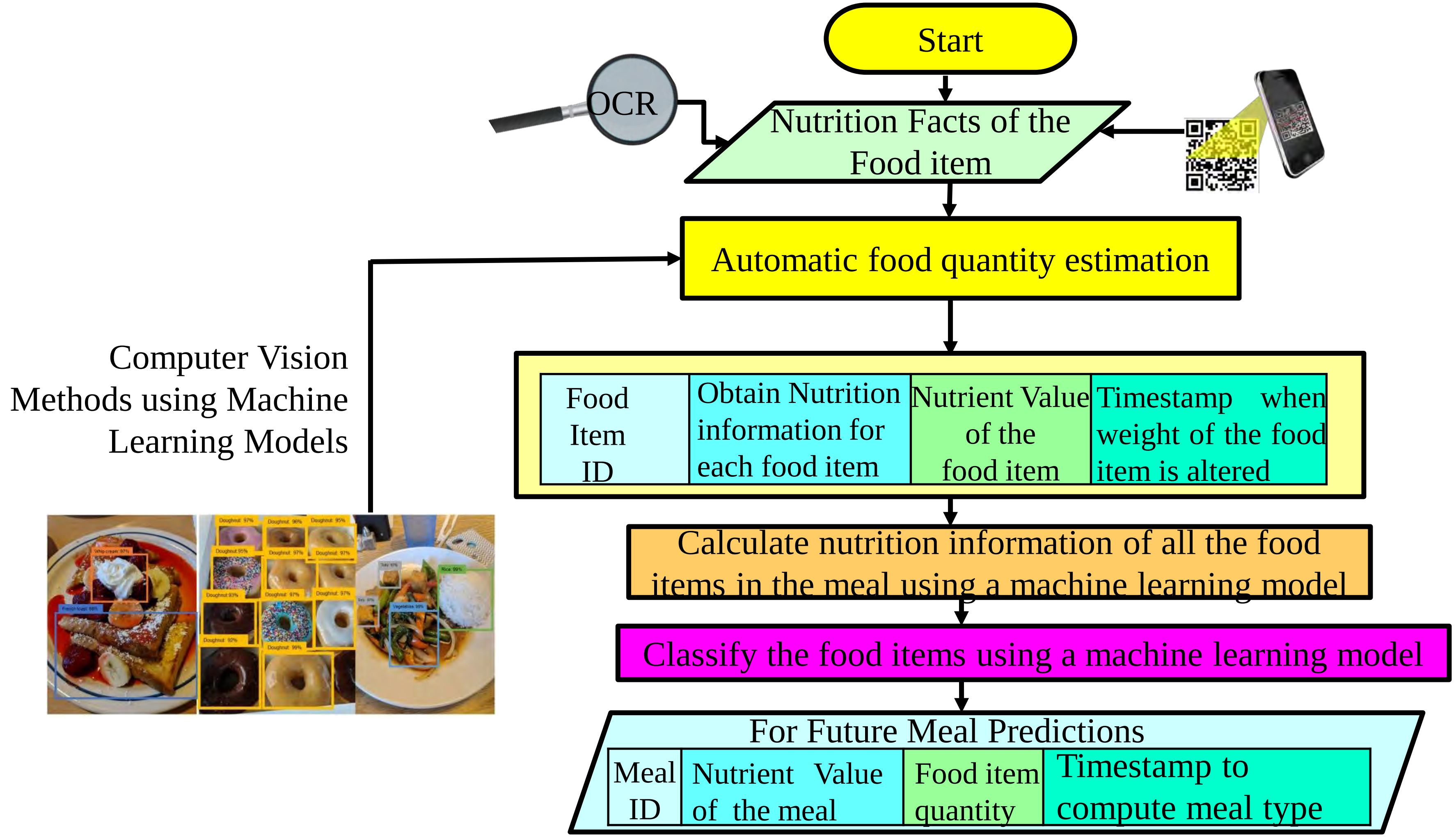
Food Item	Saturated Fat (g)	Sugar (g)	Sodium (mg)	Protein (g)	Carbohydrates (g)
Fries	6.44	1.56	244	4.03	34.84
Burger	6.87	4.67	481	17.29	48.14
Ketchup	0	3.2	136	0.2	4.13
Total	13.31	9.43	861	21.52	87.11



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

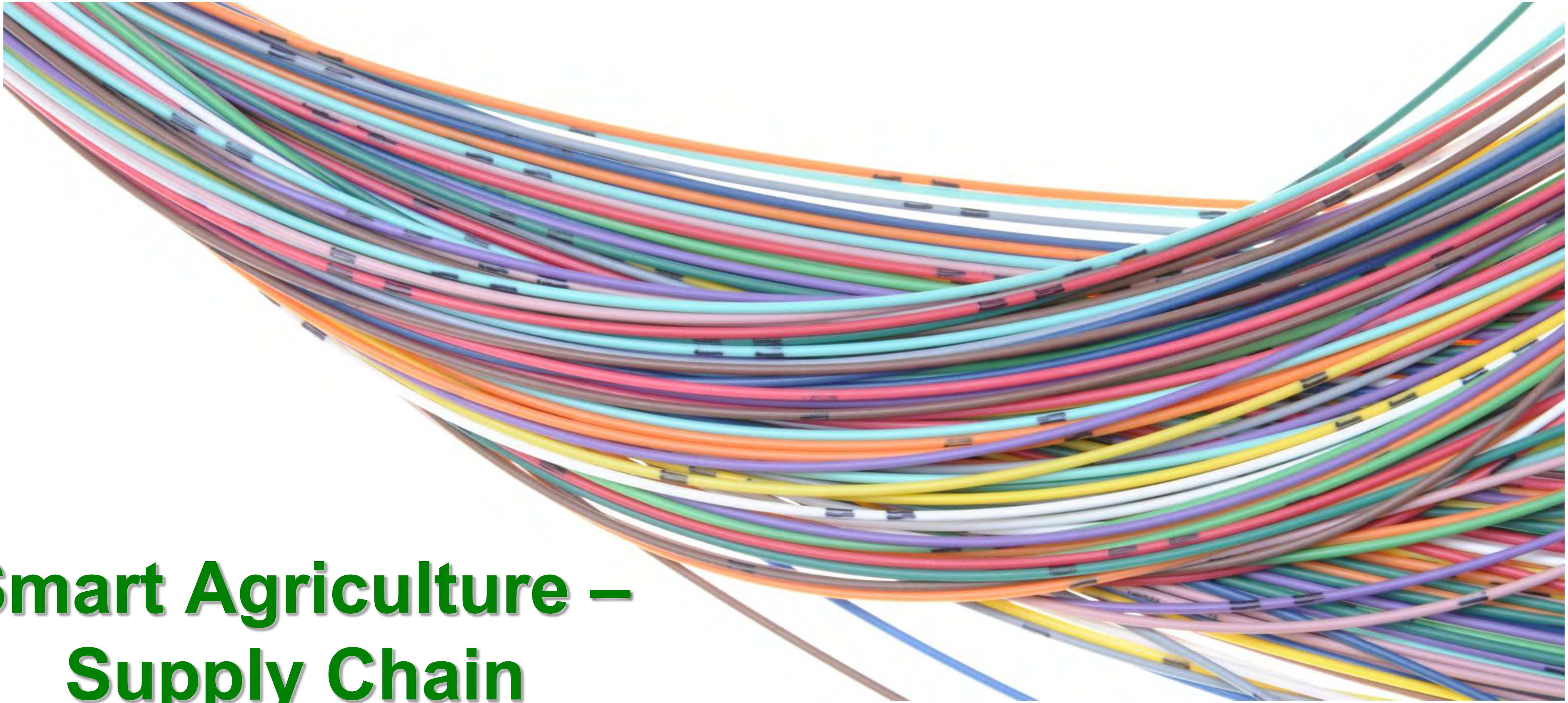
Source: A. Mitra, S. Goel, **S. P. Mohanty**, E. Kougianos, and L. Rachakonda, “iLog 2.0: A Novel Method for Food Nutritional Value Automatic Quantification in Smart Healthcare”, in *Proceedings of the IEEE International Symposium on Smart Electronic Systems (iSES)*, 2022, pp. Accepted.

Smart Healthcare – Diet Prediction – Smart-Log



Smart-Log Prediction Accuracy - 98.6%

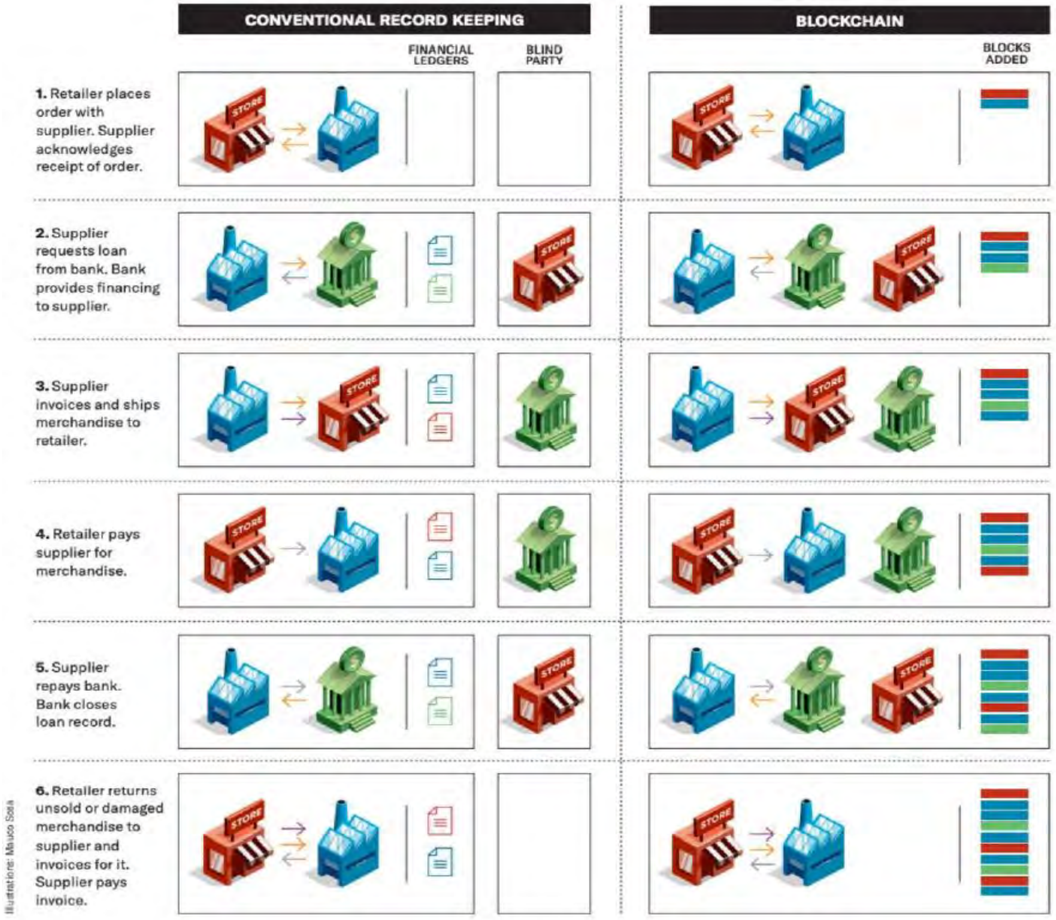
Source: P. Sundaravadivel, K. Kesavan, L. Kesavan, **S. P. Mohanty**, and E. Kougianos, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 64, Issue 3, Aug 2018, pp. 390-398.



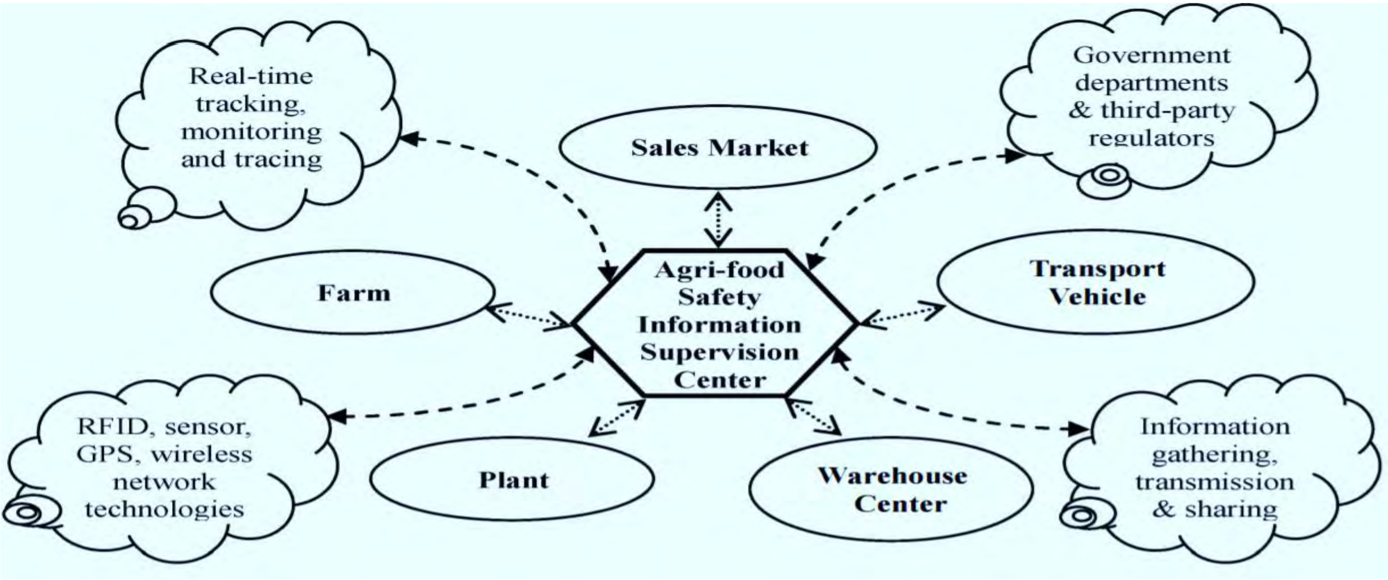
Smart Agriculture – Supply Chain

Transparent Supply Chain

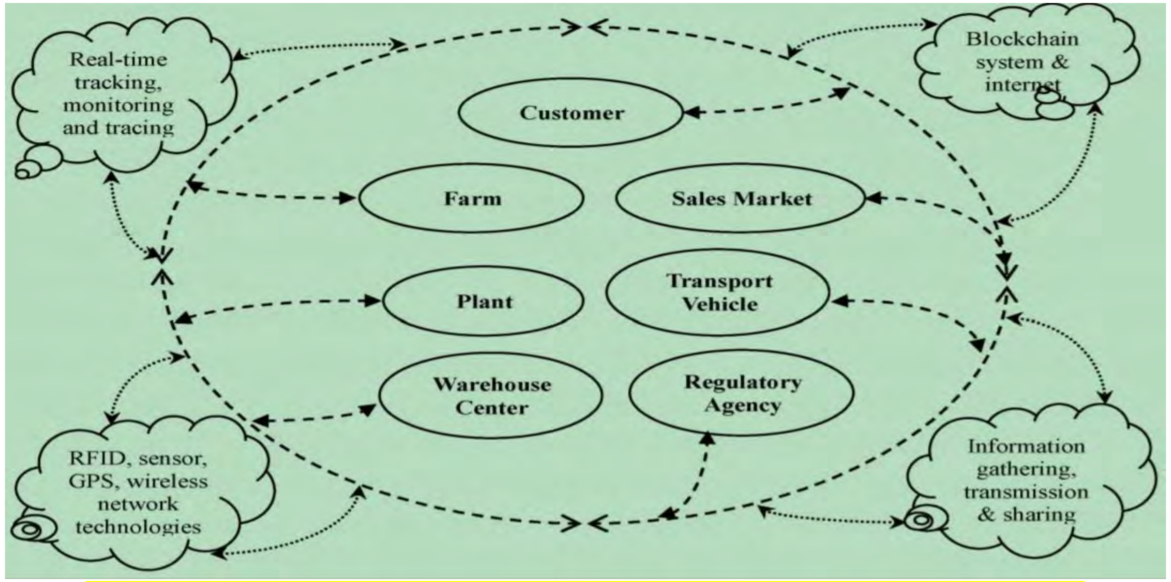
- Execution errors – like mistakes in inventory data, Missing shipments and duplicate payments are difficult to detect in real-time.
- For companies with large number of transactions each day, it is difficult to assess and fix these issues.



Food Traceability Using Efficient Supply Chain



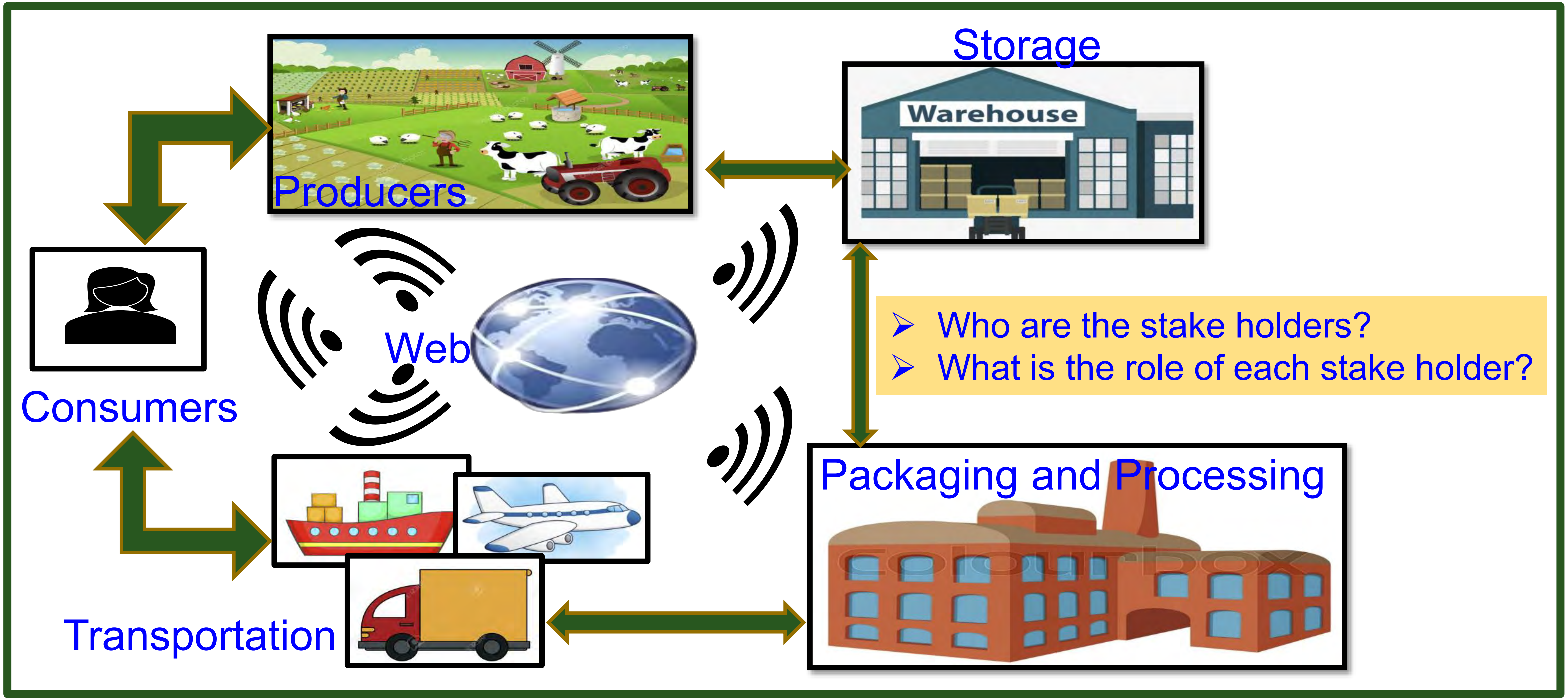
Centralized System



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.

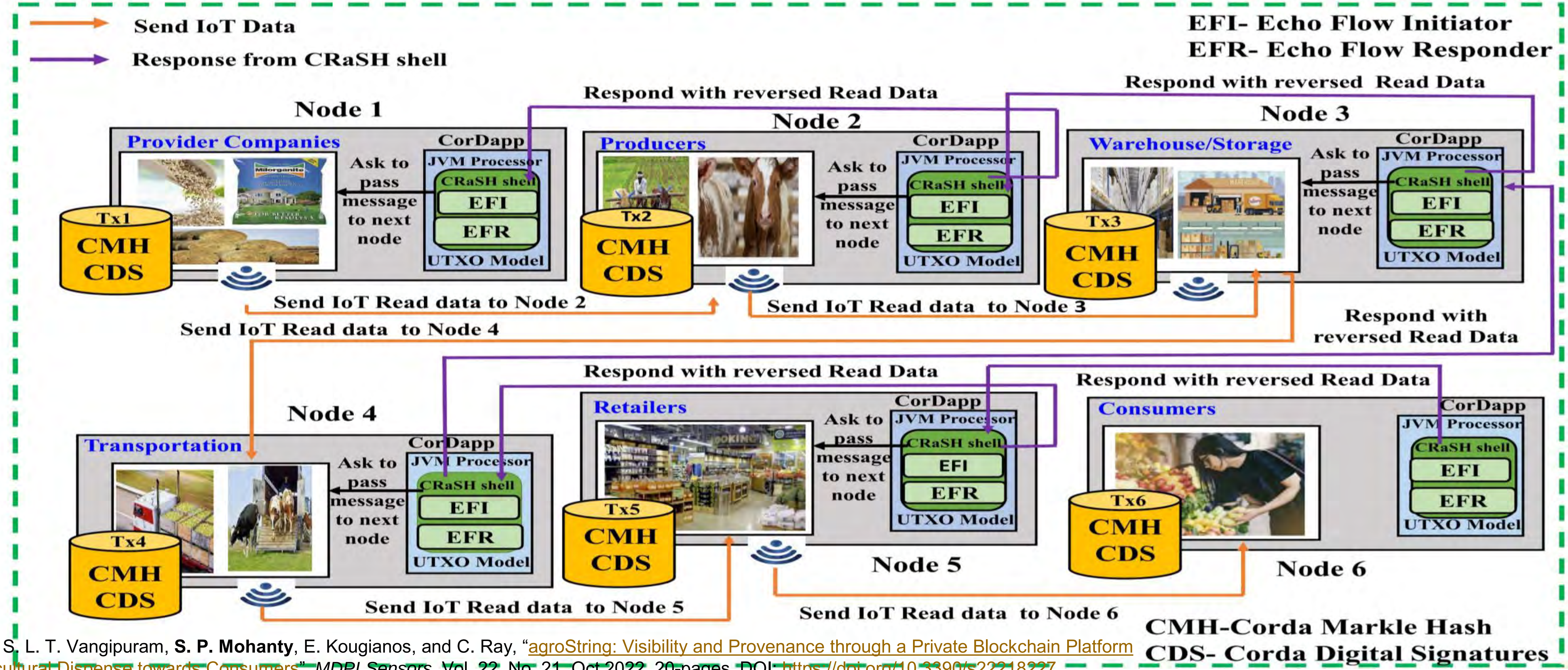
Agriculture Supply Chain



- Who are the stake holders?
- What is the role of each stake holder?

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

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



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

Our agroString: Comparative Perspectives

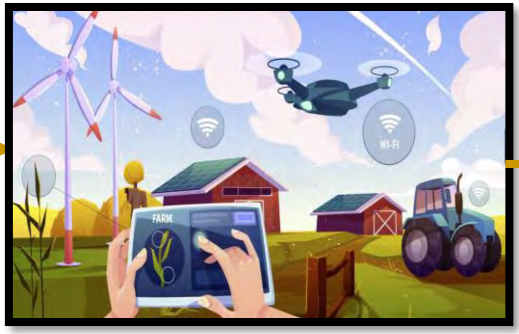
Application	Blockchain	Latency	Off-chain Storage	Transaction Cost	Financial Application
Fish Supplychain [16]	RFID	Not used	High	Centralized	Low
agro food Supplychain [17]	RFID	Ethereum	High	Decentralized	High
Cow Tracking [18]	IoT	Not Used	High	Centralized	Low
Traceability System [21]	Hyperledger	0.5 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

Agricultural Finance

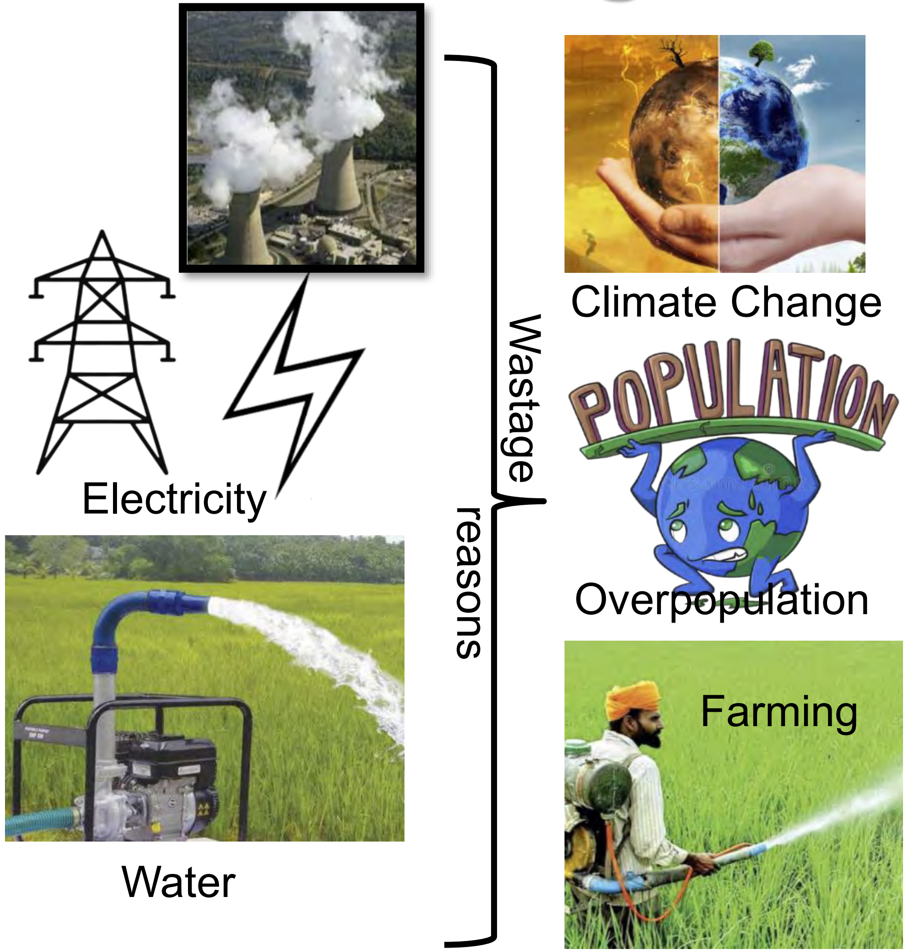
Direct Financing

- 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.

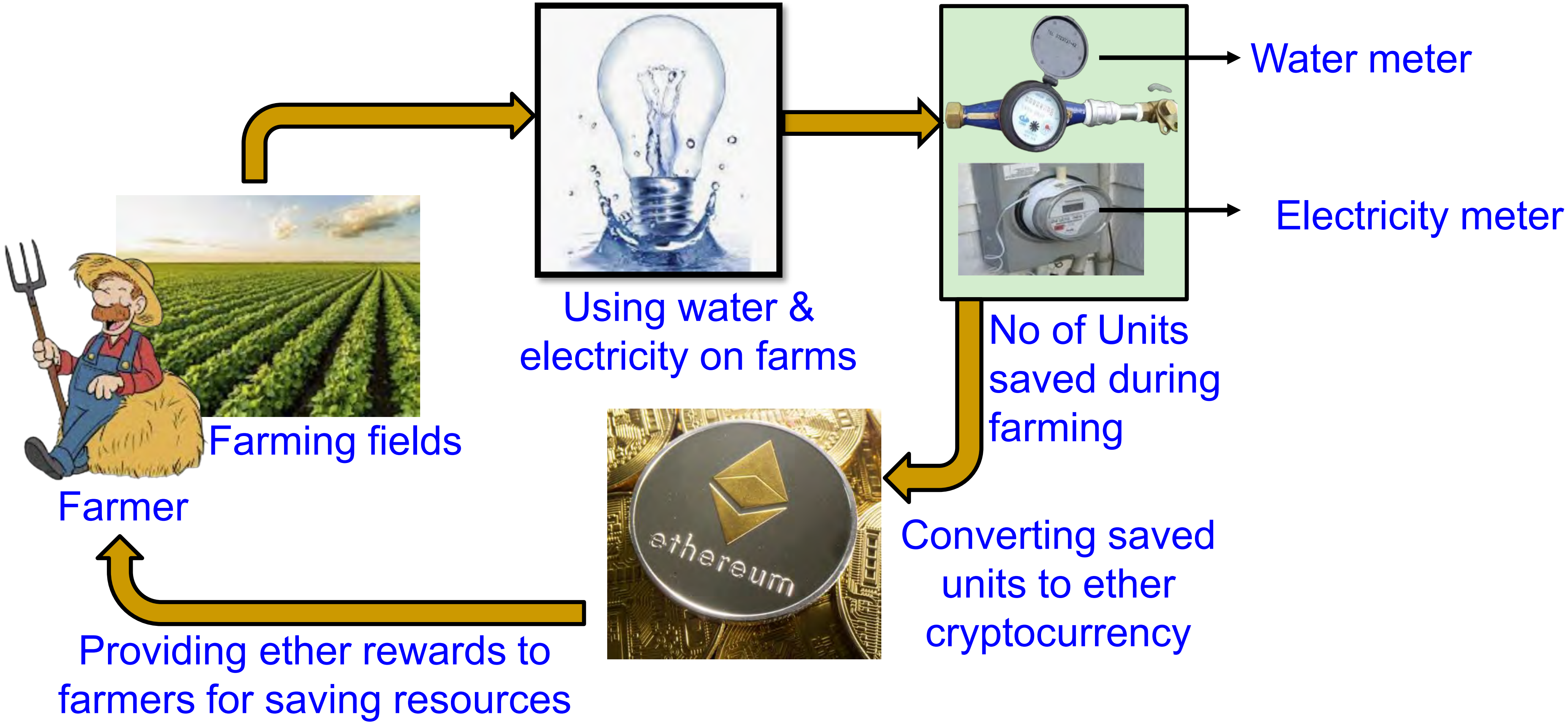
Our IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming



- 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.

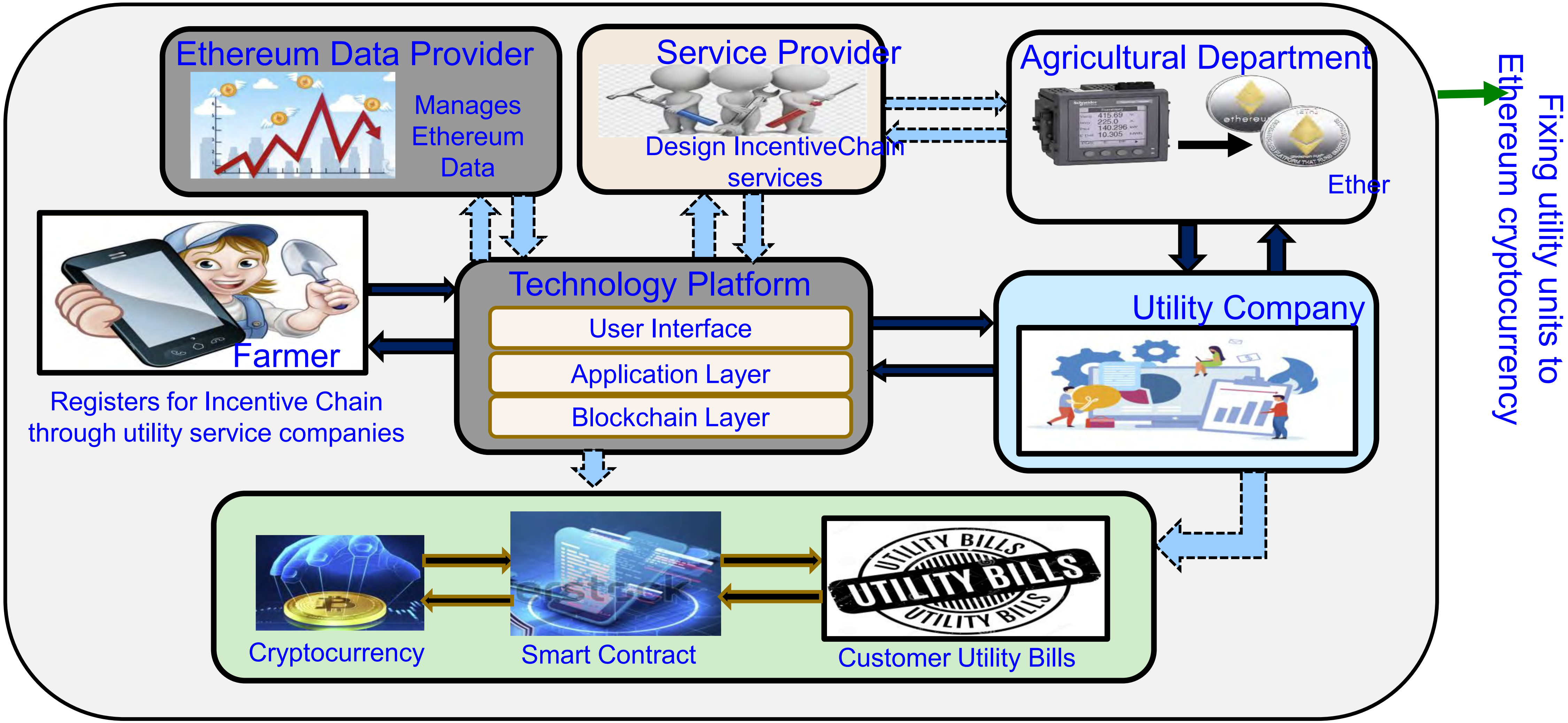
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, "IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming", in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

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.

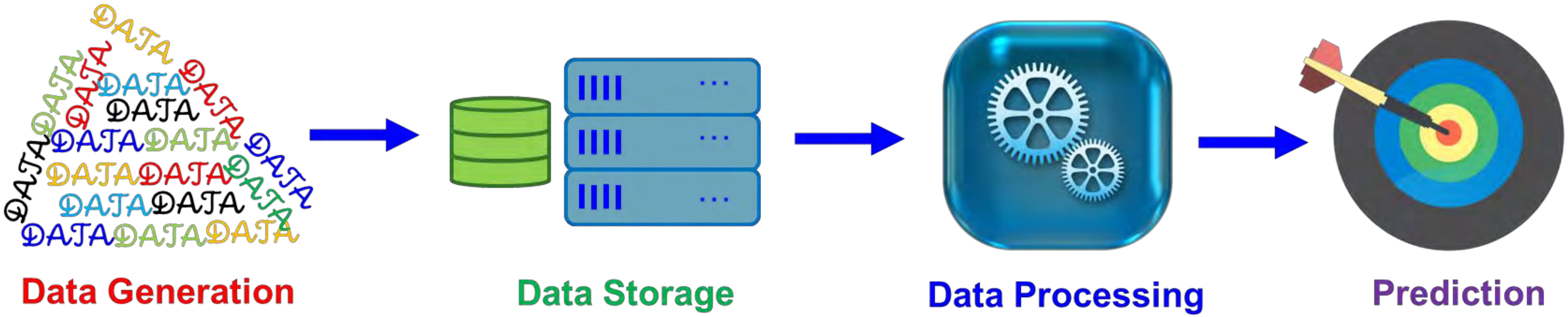
Our IncentiveChain: Architecture



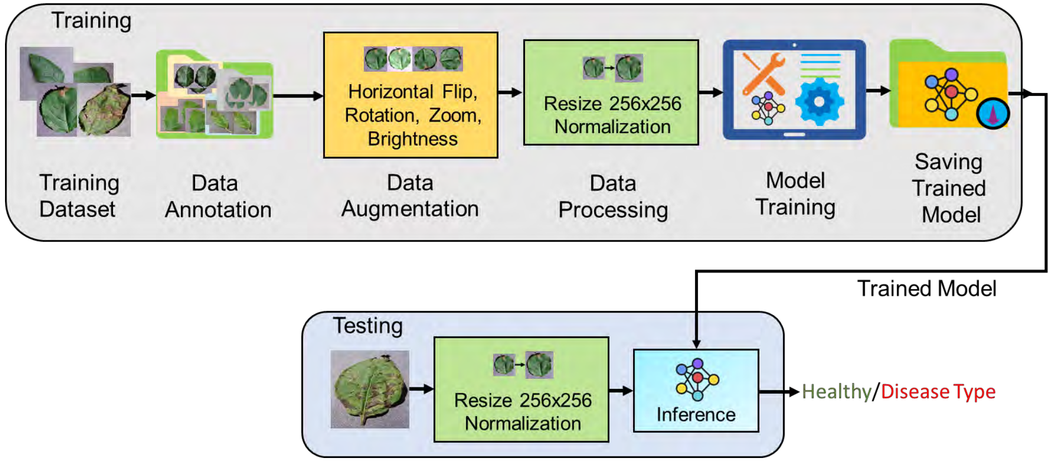
Source: S. L. T. Vangipuram, **S. P. Mohanty**, and E. Kougianos, “IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming”, in *Proceedings of the OITS International Conference on Information Technology (OCIT)*, 2022, pp. Accepted.

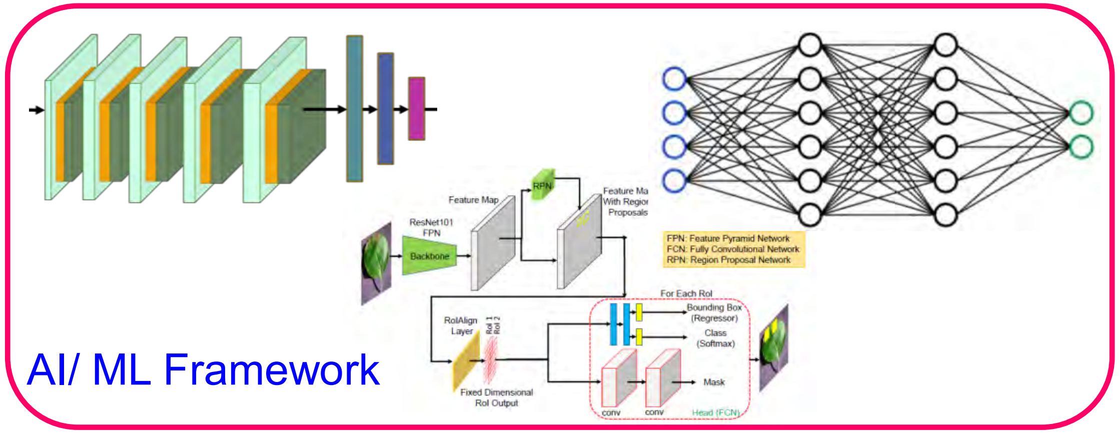
Smart Agriculture and Federated Learning

Smart Agriculture – AI/ML Workflow



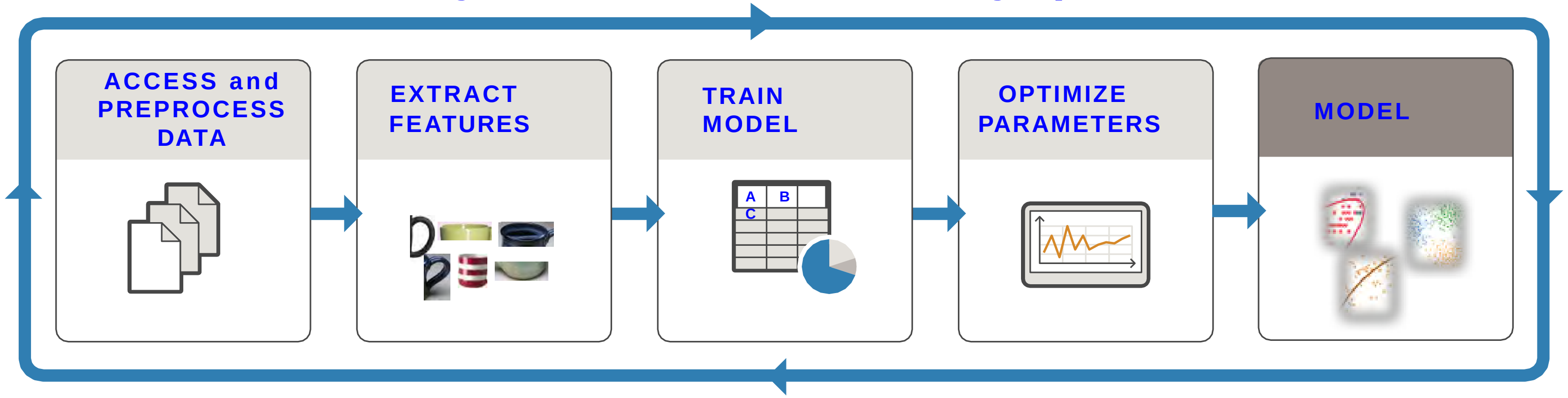
[Source: Alakananda Mitra, "Machine Learning Methods for Data Quality Aspects in Edge Computing Platforms," PhD Dissertation, UNT, 2022.]





TinyML - Key for Smart Cities and Smart Villages

TRAIN: Iterate until you achieve satisfactory performance.

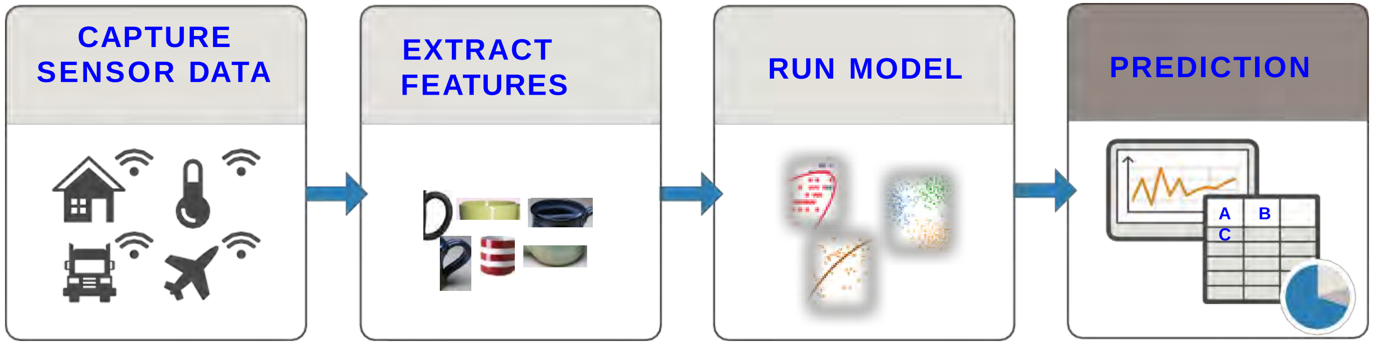


Needs Significant:

- ➢ 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

What is Federated Learning (FL) ?

- Federated Learning is way of model training in ML for heterogeneous and distributed data.
- It preserves the Privacy of data.
- Data does not come to the Model. Here Model is taken to the data.

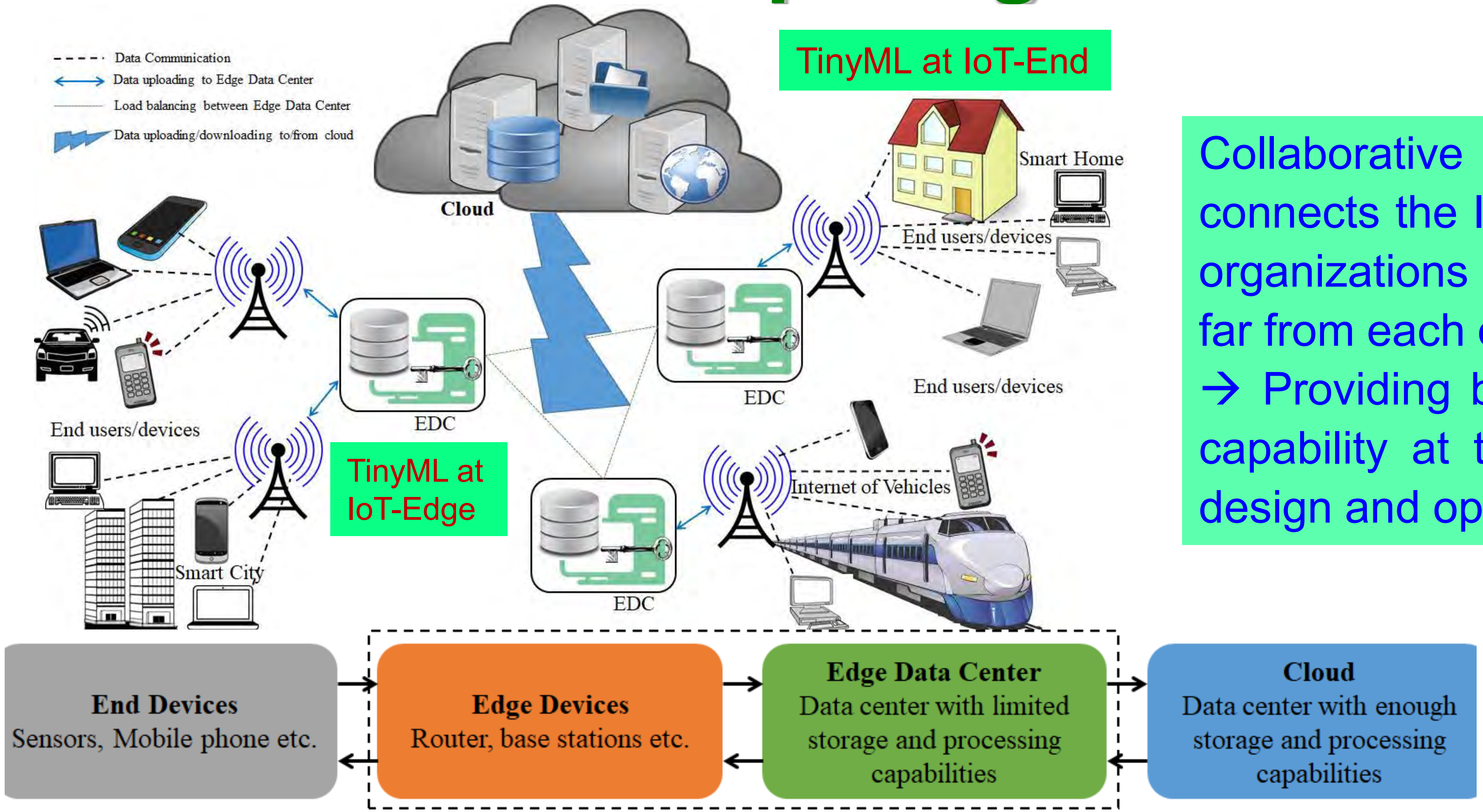
Source: Z. Li, V. Sharma, and S. P. Mohanty, "Preserving Data Privacy via Federated Learning: Challenges and Solutions", *IEEE Consumer Electronics Magazine*, Vol. 9, No. 3, May 2020, pp. 8--16.

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

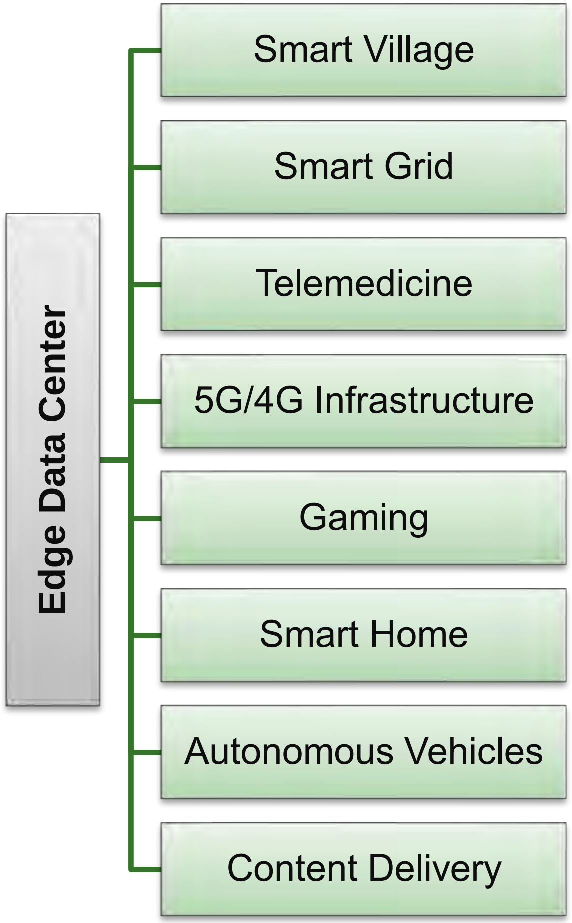


Collaborative edge computing connects the IoT-edges of multiple organizations that can be near or far from each other
→ Providing bigger computational capability at the edge with lower design and operation cost.

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.

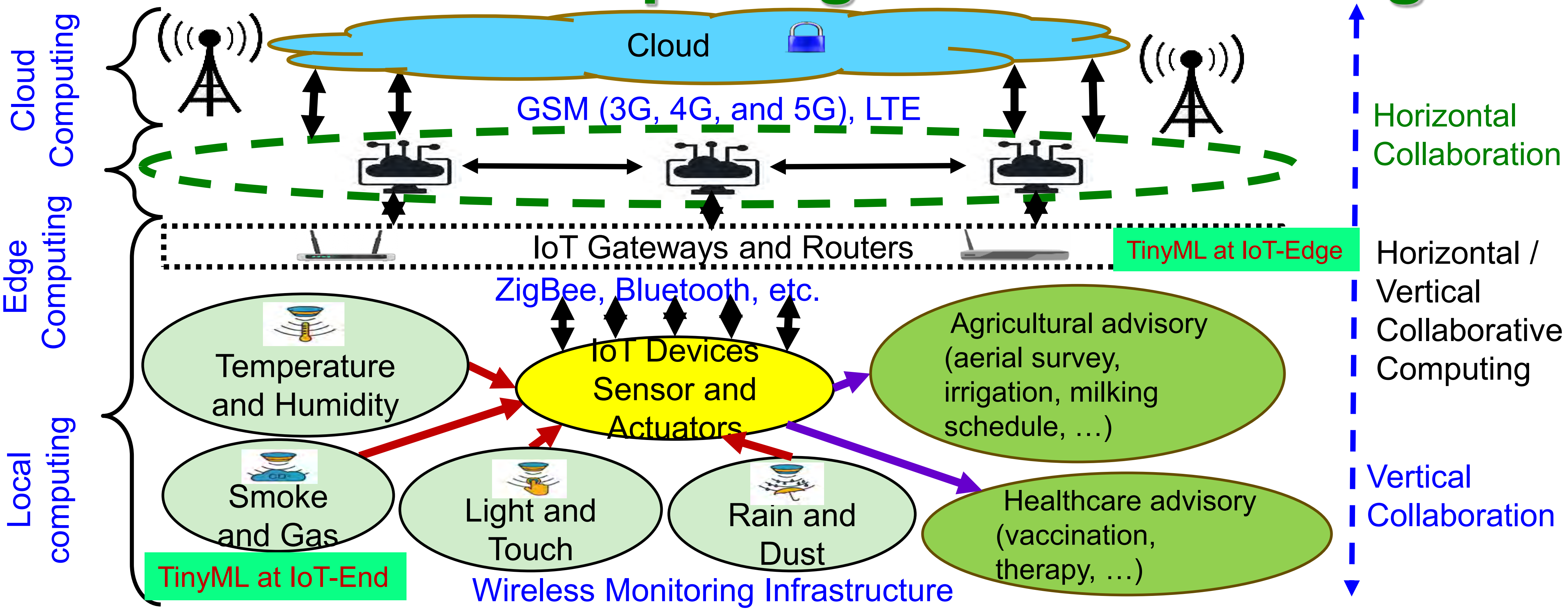
Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages

- Collaborative Edge Computing is a distributed processing environment
- CEC is a collaboration of distributed edge
- Smart control of heterogenous network
- Reduced Bandwidth and Transmission costs
- CEC enables seamless processing through load balancing



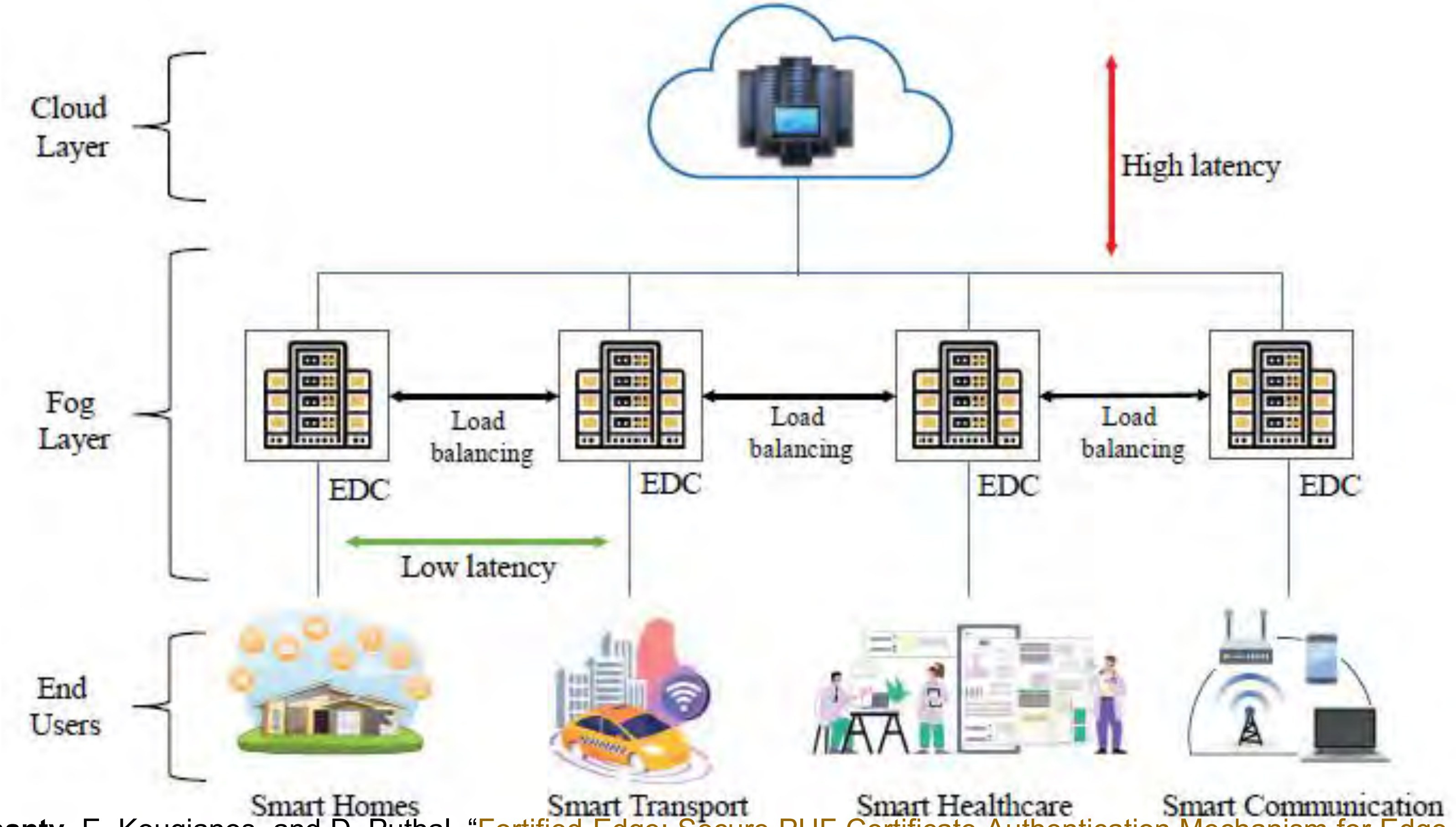
Source: S. G. Aarella, **S. P. Mohanty**, E. Kougianos, and D. Puthal, Fortified-Edge 2.0: Machine Learning based Monitoring and Authentication of PUF-Integrated Secure Edge Data Center", in *Proceedings of the IEEE-CS Symposium on VLSI (ISVLSI)*, 2023, pp. XXX, DOI: XXX.

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.

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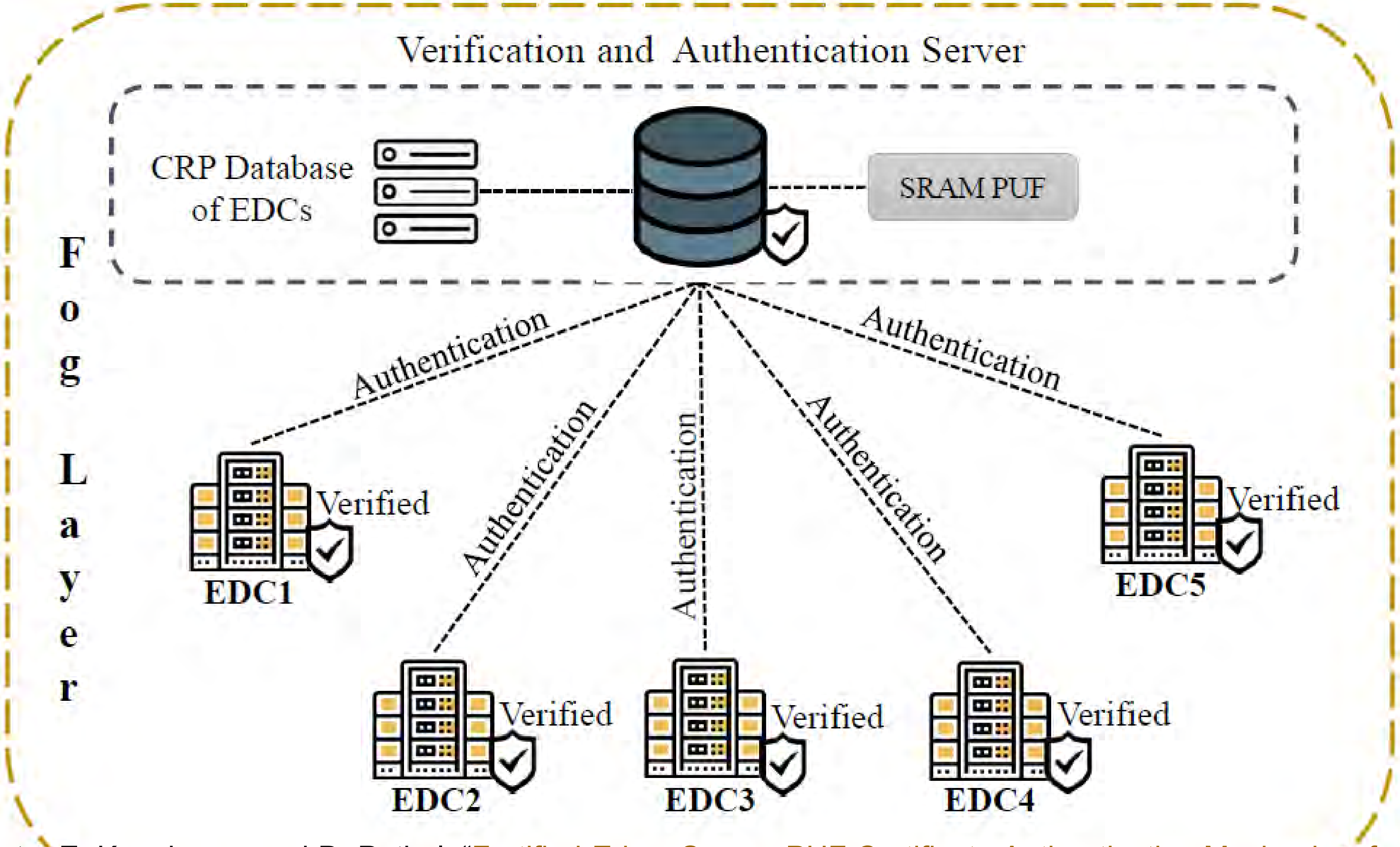

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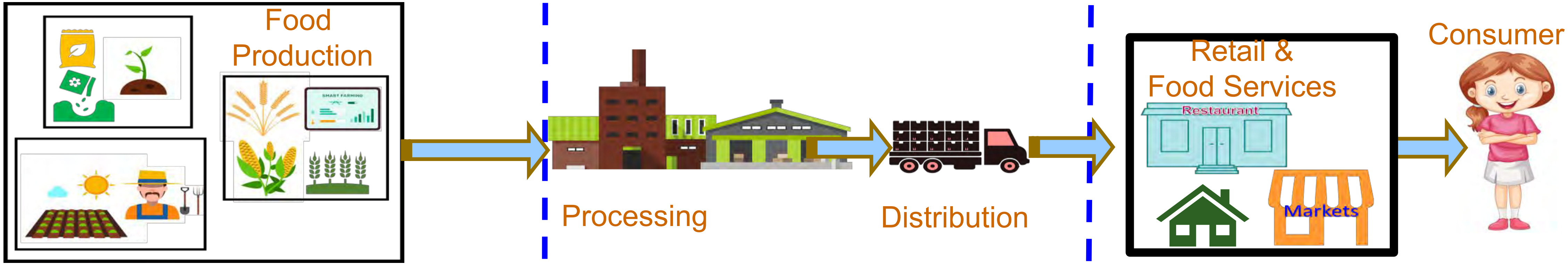
Conclusions and Future Research

Smart Agriculture - Multifold Research Possibility

Planting, Growth, Harvesting



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

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

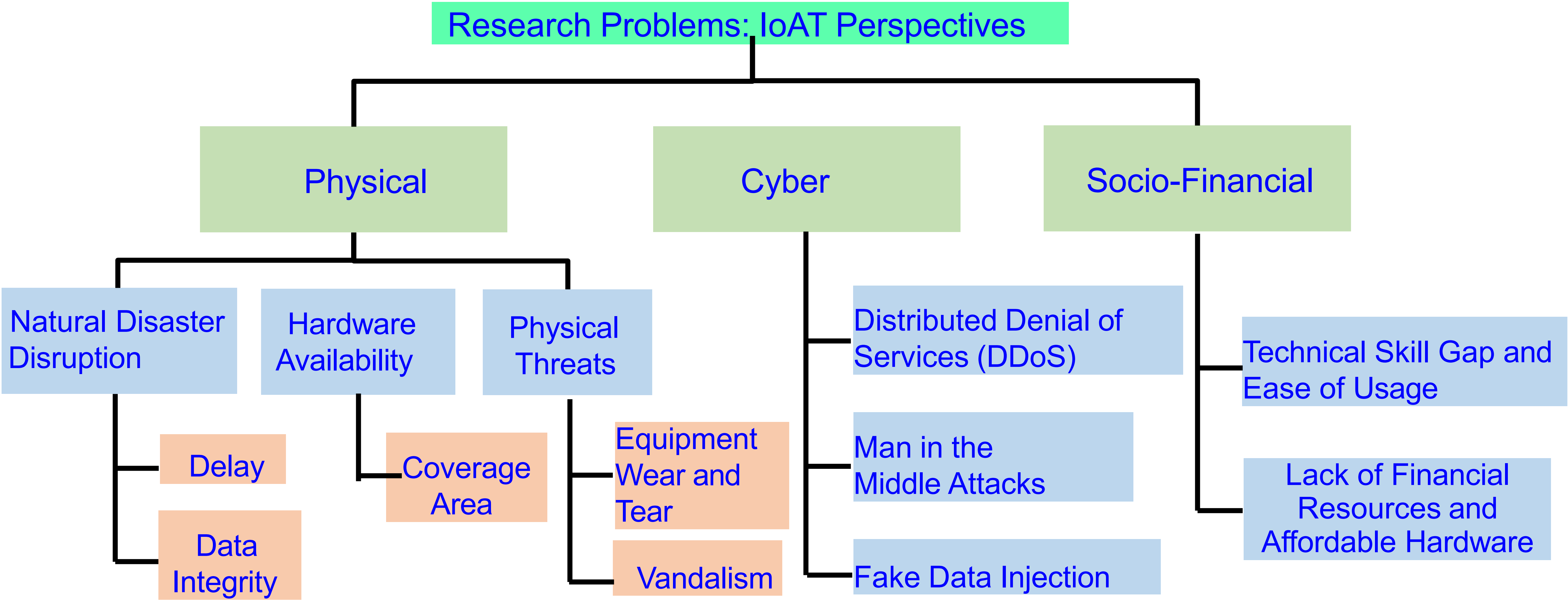
Smart Agriculture - Research Problems

Research Problems: A-CPS Perspective

- **AI / ML**
  - Extreme Temperatures Operable Sensors
  - Real Time Data Analysis and Decision
  - Thermal and Infrared Image Dataset for Crop Field
  - UAV Taken Image Dataset Creation
  - TinyML Device
  - Low computational decision methods
  - Data Compression Methods
  - Use of Unsupervised and Semi-supervised Learning Methods
  - Public Dataset Creation
- **Blockchain**
  - Immutable Data Storage Mechanisms
  - Optimizing Computational Resource
  - Optimizing Design time
  - Optimizing Energy Efficiency
- **PUF Based**
  - PUF's Impact to Environmental Effects
  - Reliability and Tamper Resistance

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.