IoT and AI Will Develop Revolutionary Solutions to Critical Global Problems: A Real Promise or Just a Hype?

ISVLSI 2021 Panel Session

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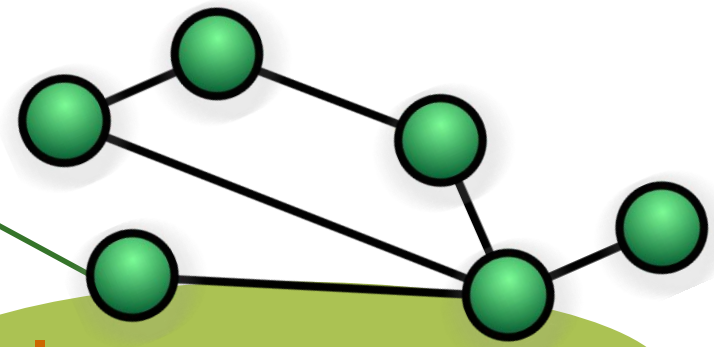
Smart Cities - 3 Is

Instrumentation

The 3Is are provided by the Internet of Things (IoT).

Smart Cities



Intelligence

Interconnection

Source: Mohanty IEEE Smart Cities Conference 2019 Keynote Address (Security and Energy Trade-Offs in Smart City Cyber-Physical Systems)

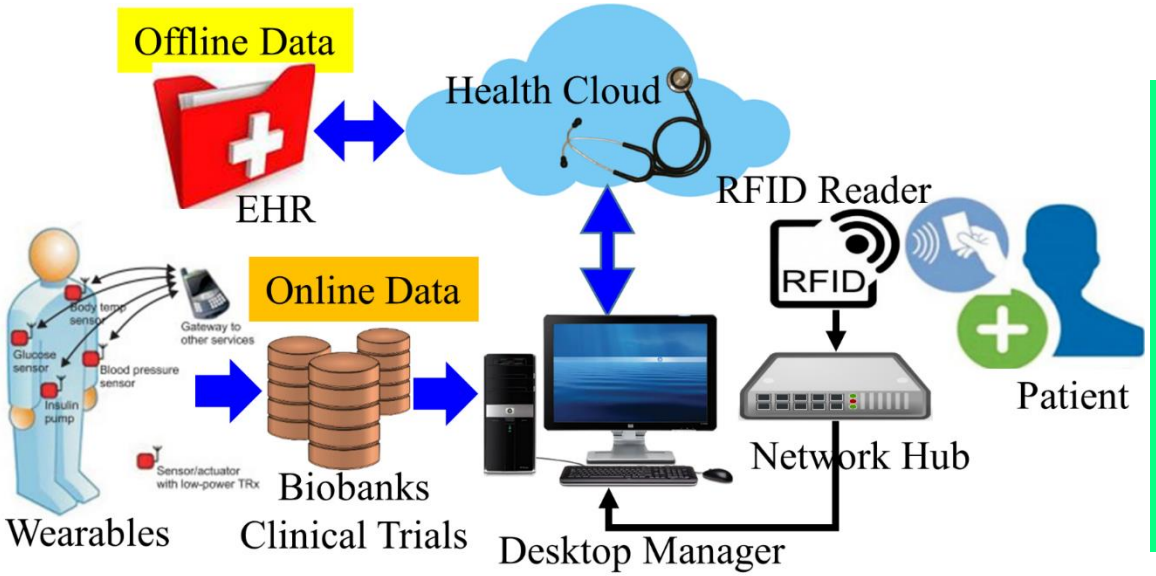
Frost and Sullivan predicts smart city development worldwide will create business opportunities worth US$2.46 trillion by 2025.

Services in Smart Cities and Smart Village

In Smart Cities	In Smart Village	Communication Type	Energy Source	Feasibility
Waste Management	Waste Management	WiFi, Sigfox, Neul, LoRaWAN	Battery Powered and Energy Harvesting	Feasible but smart containers adds in cost
Air Quality Monitoring	Smart Weather and Irrigation	BLE, ZigBee, 6LoWPAN, WiFi, Cellular, Sigfox, LoRaWAN	Solar Panels, Battery Power and Energy Harvesting	Feasible
Smart Surveillance	NA	BLE, WiFi, ZigBee, Cellular, Sigfox, LoRaWAN	Battery Power and Energy Harvesting	Feasible but additional sensors needed
Smart Energy	Smart Energy	ZigBee, Z-Wave, 6LoWPAN, Sigfox, LoRaWAN	PowerGrid, Solar Power, Wind Power, Energy Harvesting	Feasible
Smart Lighting	Smart Lighting	WiFi, ZigBee, Z-Wave, Sigfox, LoRaWAN	Power Grid, Solar Power, Energy Harvesting	Feasible
Smart Healthcare	Smart Healthcare	BLE, Bluetooth, WiFi, Cellular, Sigfox	Power Grid, Battery Power, and Energy Harvesting	Feasible
Smart Education	Smart Education	LR-WPAN, WiFi and Ethernet	Power Grid, Battery Power, and Energy Harvesting	Feasible
Smart Parking	NA	Z-Wave, WiFi, Cellular, Sigfox, LoRaWAN	Power Grid, Solar Power, Energy Harvesting	Feasible
Structural Health Monitoring	NA	BLE, WiFi, ZigBee, 6LoW-PAN, Sigfox	Power Grid, Solar Power, Battery Power, Energy Harvesting	Energy harvesting can be useful for power specs
Noise Monitoring	NA	6LoWPAN, WiFi, Cellular	Battery Power, Energy Harvesting, and Energy Scavenging	Sound pattern identification is a bottleneck
NA	Smart Farming	BLE, Bluetooth, WiFi, 6LoW-PAN, Sigfox, LoRaWAN	Power Grid, Battery Power and Energy Harvesting	Feasible
NA	Smart Diary	Bluetooth, WiFi, ZigBee, 6LoWPAN, LoRaWAN	Power Grid, Battery Power and Energy Harvesting	Feasible

Source: S. K. Ram, B. B. Das, K. K. Mahapatra, S. P. Mohanty, and U. Choppali, "Energy Perspectives in IoT Driven Smart Villages and Smart Cities", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 10, No. 03, May 2021, pp. 19-28.

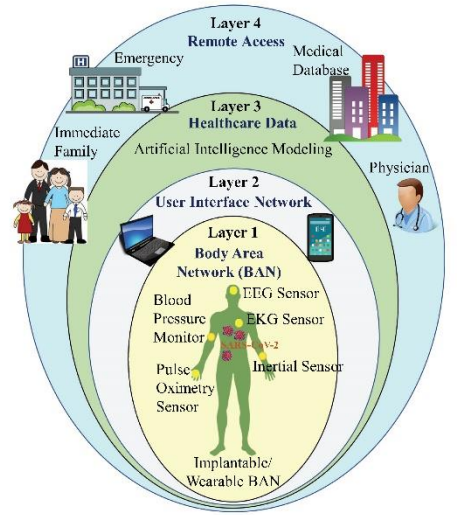
Healthcare Cyber-Physical System (H-CPS)



Internet-of-Medical-Things (IoMT)

OR

Internet-of-Health-Things (IoHT)



Healthcare Cyber-Physical System (H-CPS)

H-CPS ← Biosensors + Medical Devices + Wearable Medical Devices (WMDs) + Implantable Medical Devices (IMDs) + Internet + Healthcare database + AI/ML + Applications that connected through Internet.

Requires:

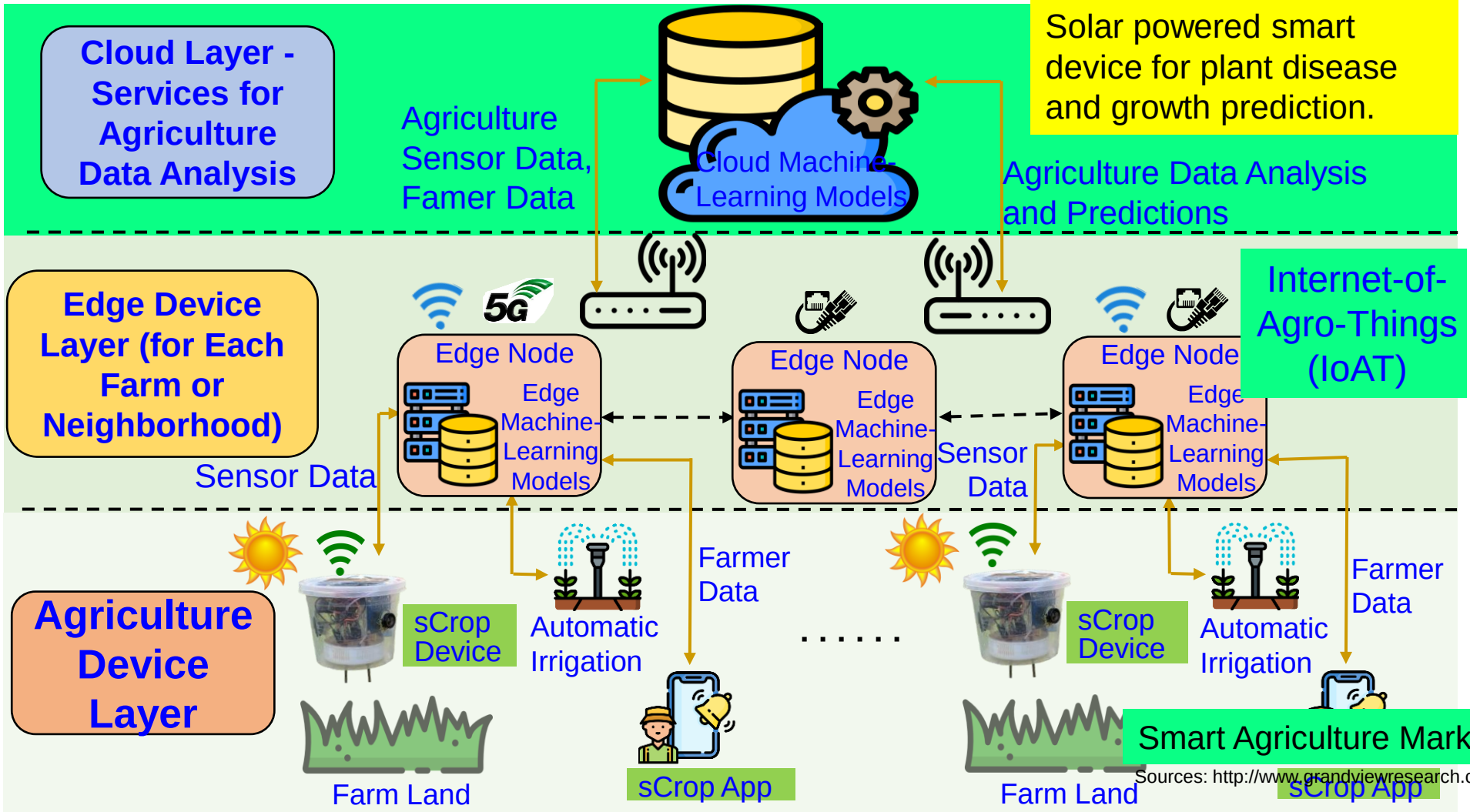
- Data and Device Security
- Data Privacy

Frost and Sullivan predicts smart healthcare market value to reach US$348.5 billion by 2025.

IEEE CTSoc CONSUMER TECHNOLOGY SOCIETY
http://ctsoc.ieee.org

IEEE

Agriculture Cyber-Physical System (A-CPS)



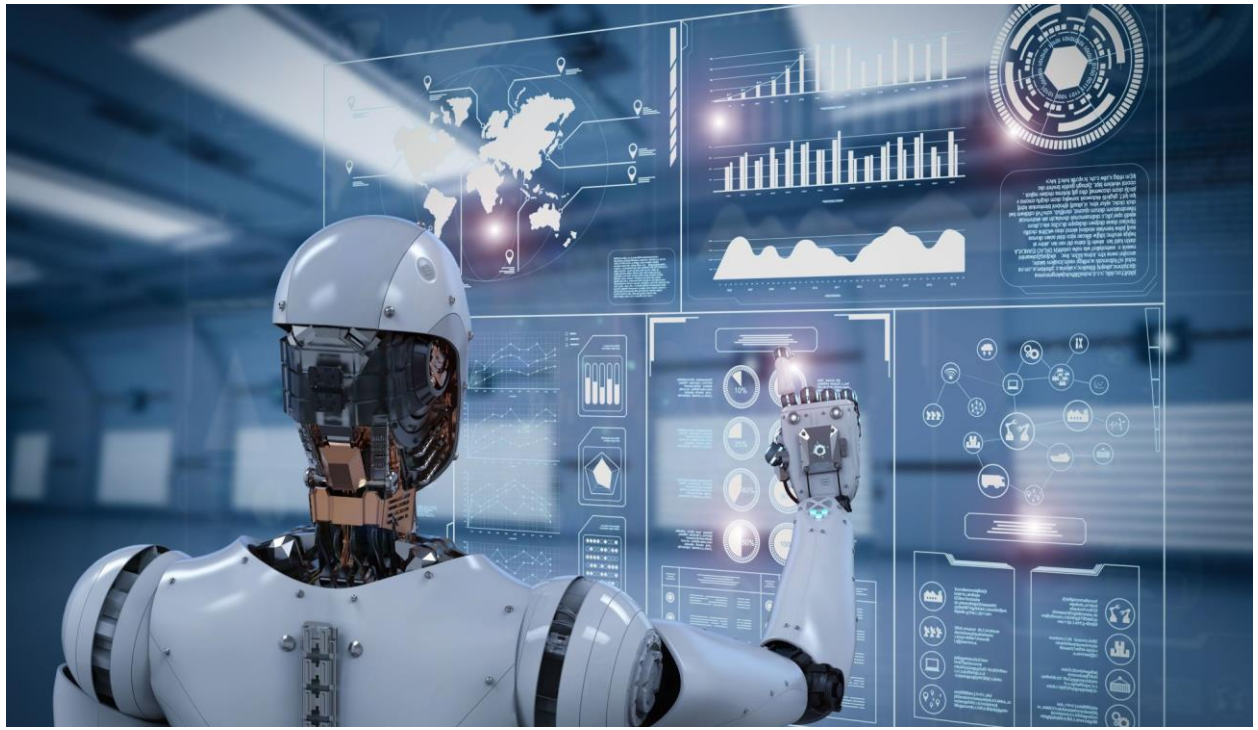
Smart Agriculture Market Worth $18.21 Billion By 2025.

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

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*, Vol. XX, No. YY, ZZ 2020, pp. Accepted on 14 Oct 2020, DOI: 10.1109/JSEN.2020.3032438.

What is Smart?

- Ability to take decisions based on the data, circumstances, situations?
- AI plays the role in making decisions automatic based on modeling of data.

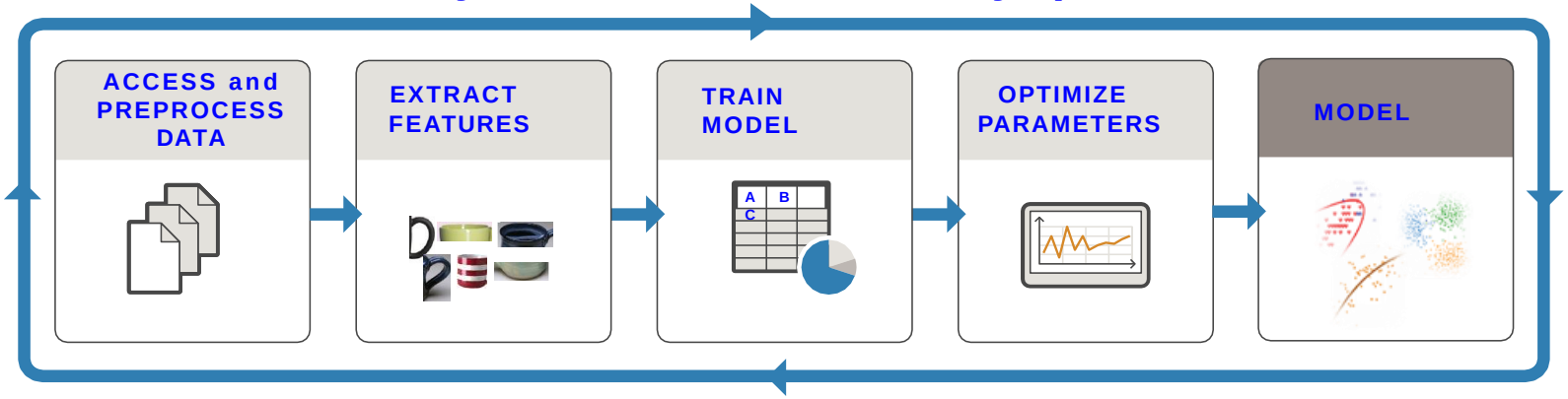


Source: https://matmatch.com/blog/the-age-of-artificial-intelligence-in-materials-science-part-one/

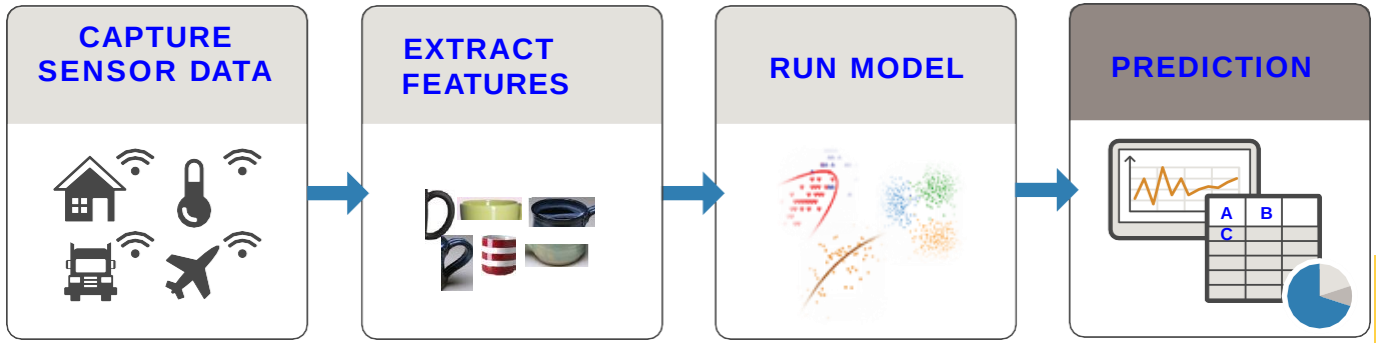
Large Amount of Data Processing for AI

TinyML - Key for Smart Cities and Smart Villages

TRAIN: Iterate until you achieve satisfactory performance.



PREDICT: Integrate trained models into applications.



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

Needs Significant:

- Computational Resource
- Computation Energy

Solution: Reduce Training Time and/or Computational Resource

How complex AI models run in IoT-end devices?

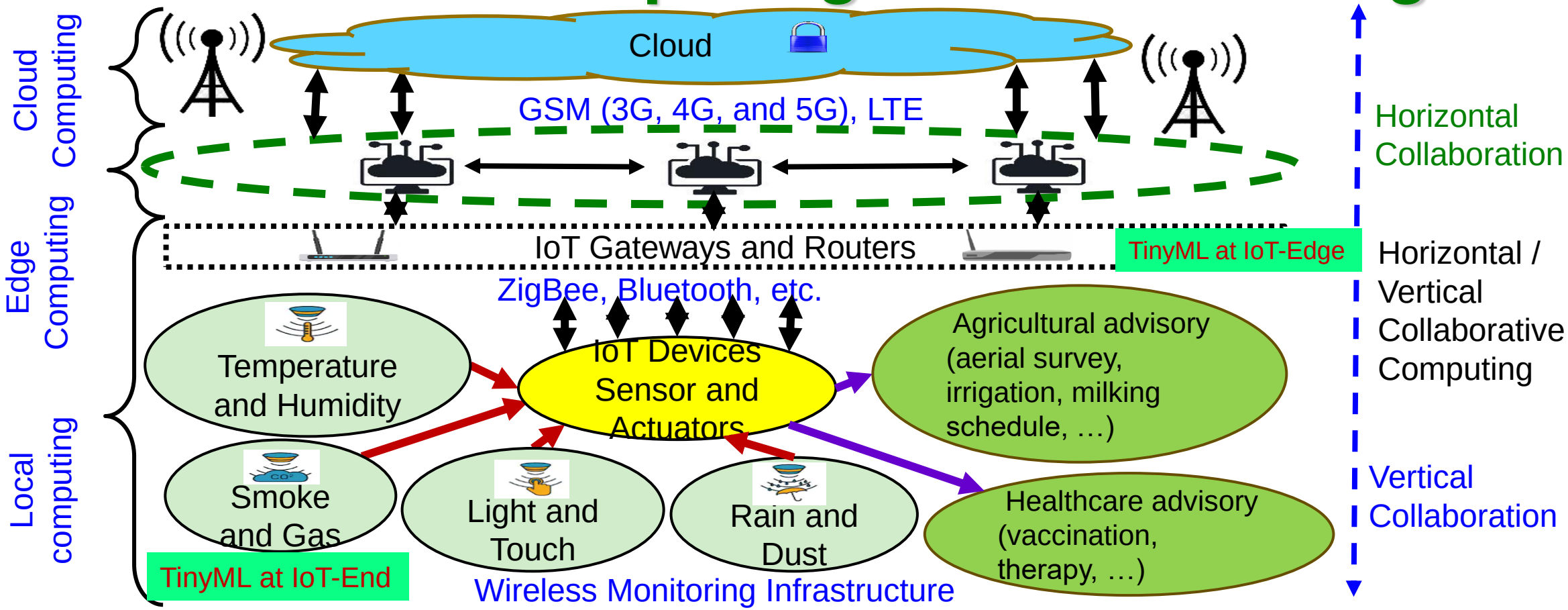
Source: www-cnx--software-com.cdn.ampproject.org.html

Needs:

- Computational Resource
- Computation Energy

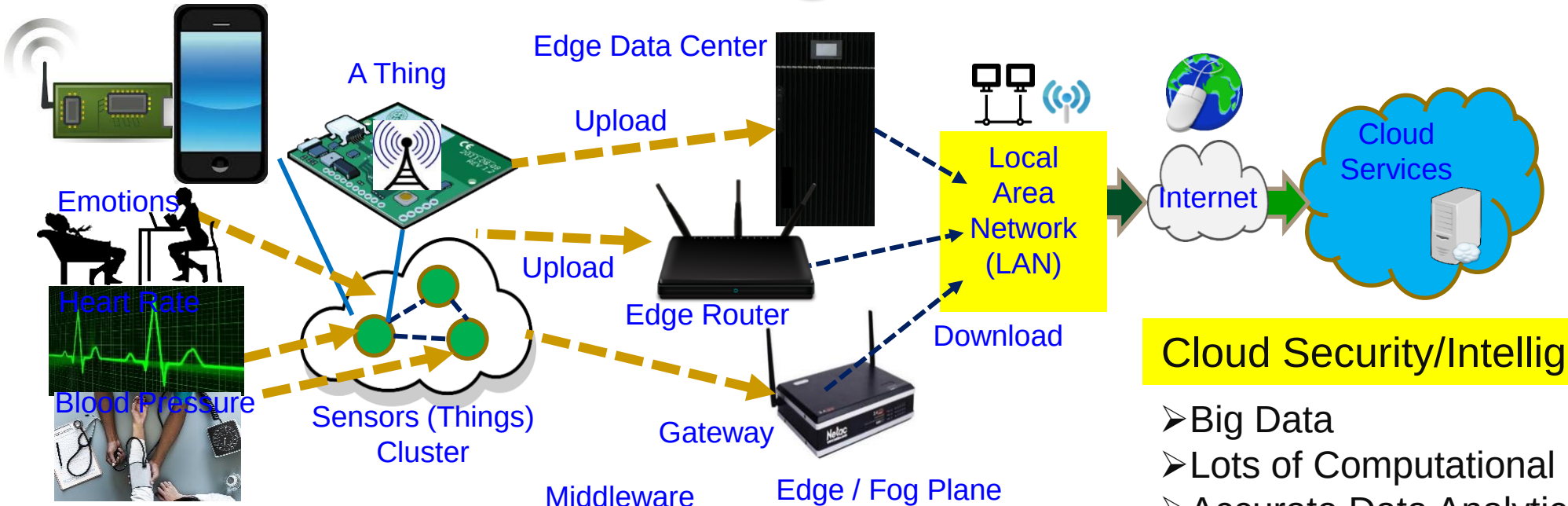
Solution: TinyML

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.

CPS – IoT-Edge Vs IoT-Cloud



End Security/Intelligence

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

Edge Security/Intelligence

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

Cloud Security/Intelligence

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

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

Heavy-Duty ML is more suitable for smart cities

Blockchain Energy Need is Huge

Energy for mining of 1 bitcoin

=

Energy consumption 2 years of a US household

Energy consumption for each bitcoin transaction

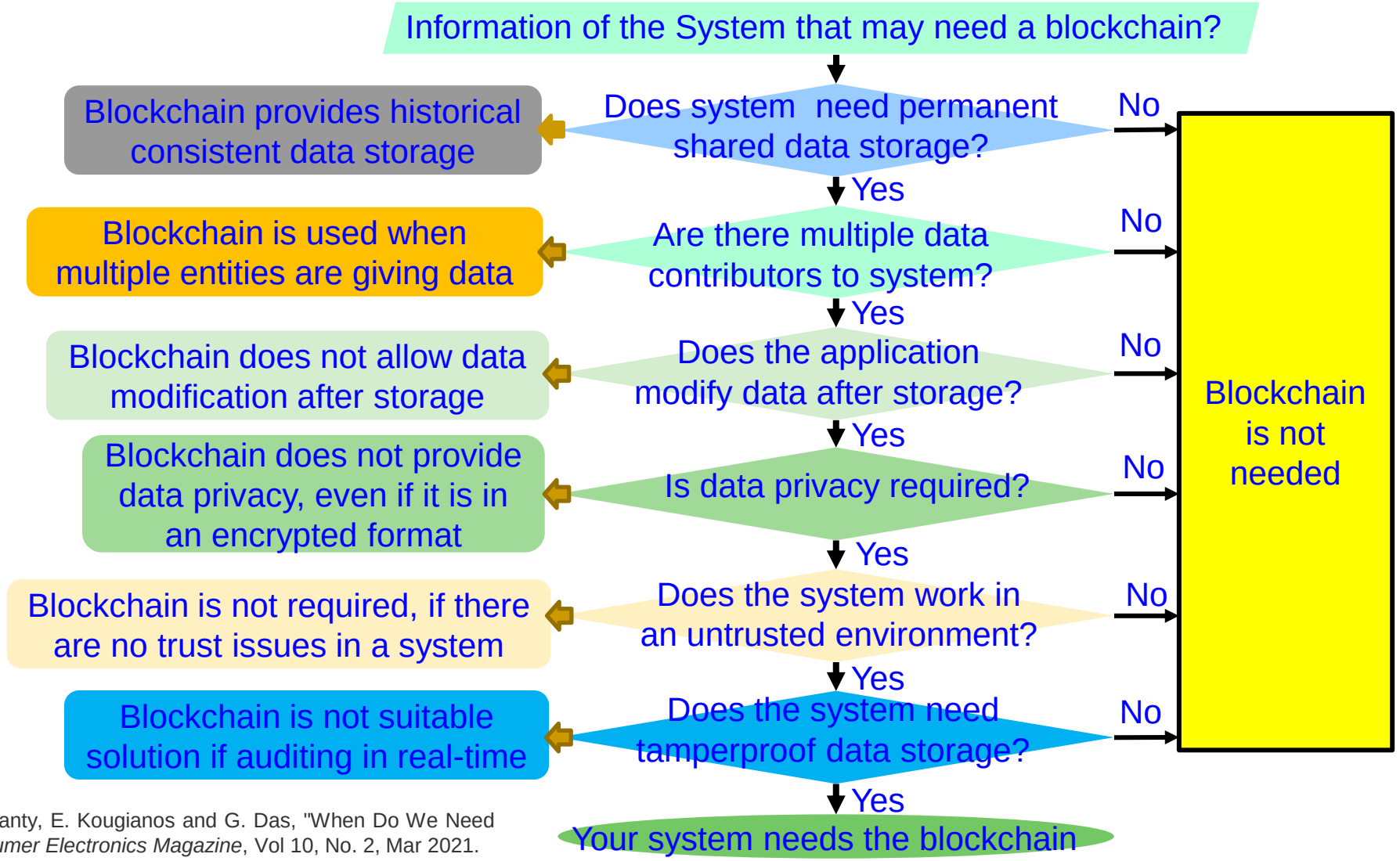
=

80,000X

Energy consumption of a credit card processing

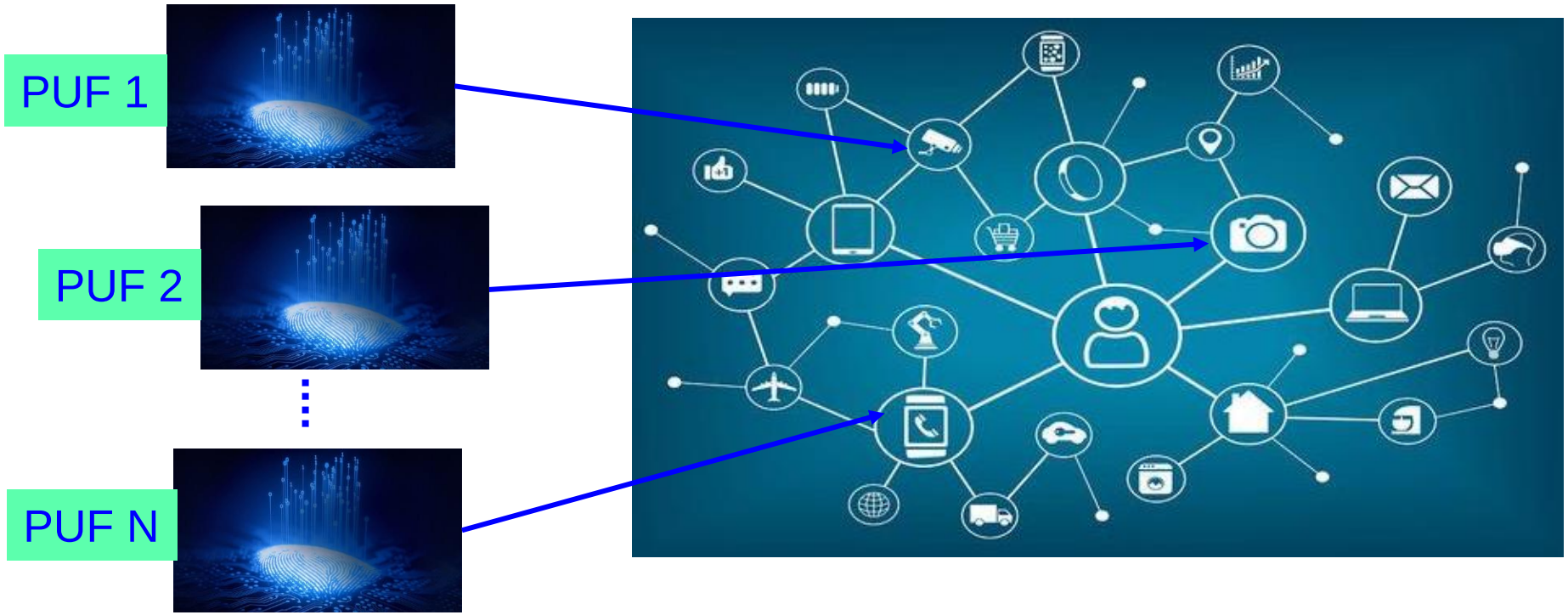
Source: D. Puthal, S. P. Mohanty, E. Kougianos and G. Das, "When Do We Need the Blockchain?," *IEEE Consumer Electronics Magazine*, Vol 10, No. 2, Mar 2021.

When do You Need the Blockchain?



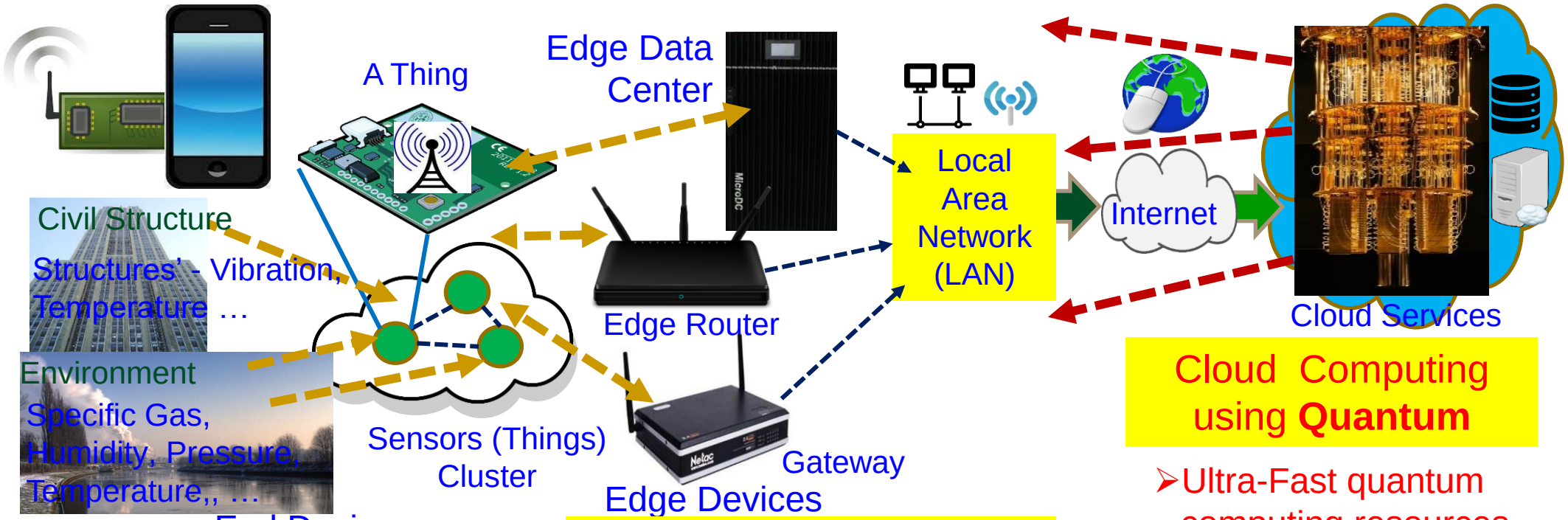
Source: D. Puthal, S. P. Mohanty, E. Kougianos and G. Das, "When Do We Need the Blockchain?," *IEEE Consumer Electronics Magazine*, Vol 10, No. 2, Mar 2021.

We Proposed World's First Hardware-Integrated Blockchain (PUFchain) that is Scalable, Energy-Efficient, and Fast



Source: S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "PUFchain: Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in Internet of Everything (IoE)", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 2, March 2020, pp. 8-16.

A Security Nightmare - by Quantum Computing



In-Sensor/End-Device Computing

- Minimal computational resource
- Negligible latency in network
- Very lightweight security

Edge Computing

- Less computational resource
- Minimal latency in network
- Lightweight security

Cloud Computing using **Quantum**

- Ultra-Fast quantum computing resources
- High latency in network
- Breaks every encryption in no time

A quantum computer could break a 2048-bit RSA encryption in 8 hours.

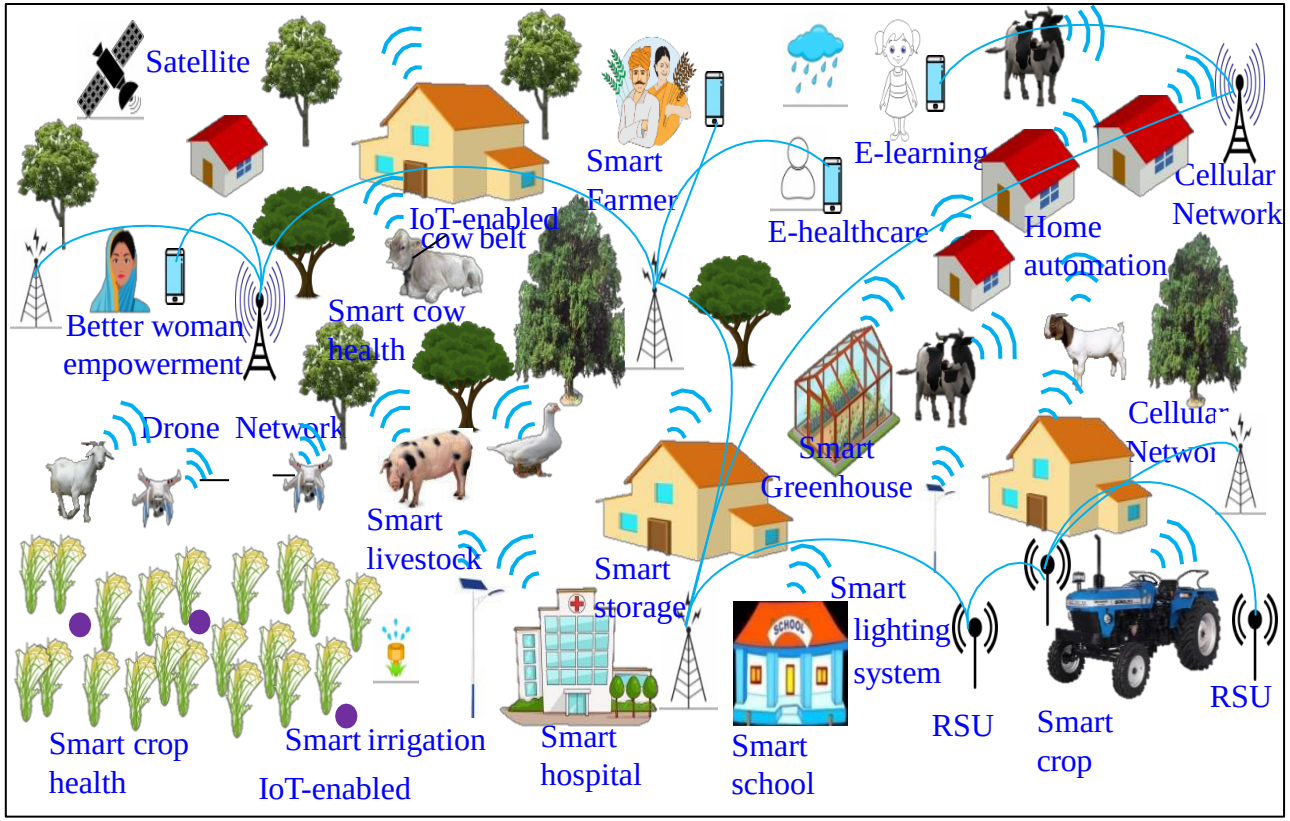
Security by Design (SbD) and/or Privacy by Design (PbD)

Embedding of security/privacy into the architecture (hardware+software) of various products, programs, or services.

Retrofitting: Difficult → Impossible!

Source: https://teachprivacy.com/tag/privacy-by-design/

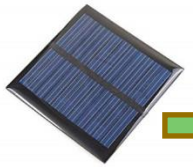
Villages – May not have Electricity, Connectivity…



Source; P. Chanak and I. Banerjee, "Internet of Things-enabled Smart Villages: Recent Advances and Challenges," *IEEE Consumer Electronics Magazine*, vol. 10, no. 3, pp. 12-18, May 2021.

- How to be connected?
- How to run AI?

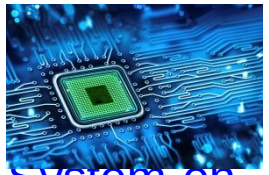
Eternal-Thing: Combines Security and Energy Harvesting at the IoT-Edge



Solar Cell

Harvesting System with Physically Unclonable Function (PUF)

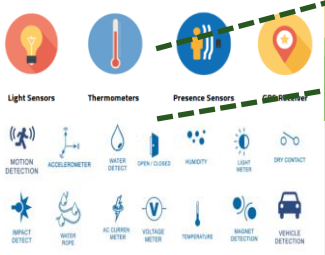
Sensors

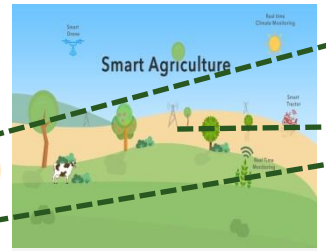


System-on-Chip (SoC)

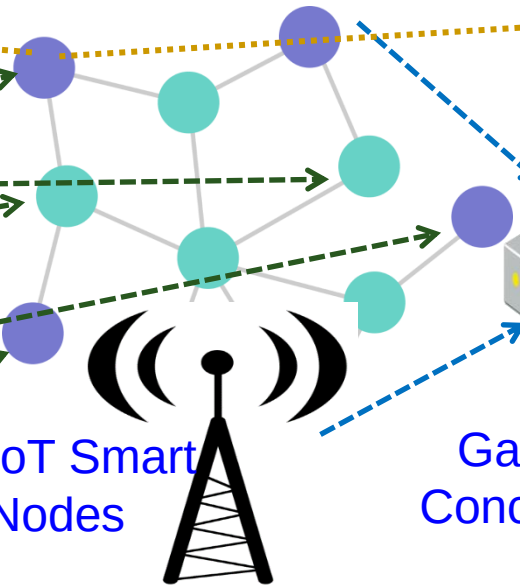
Trans-receiver

Provides security using PUFs while consuming only 22μW power due to harvesting.

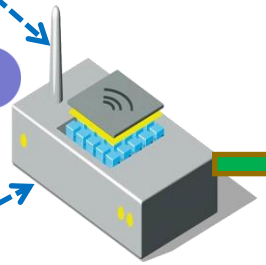




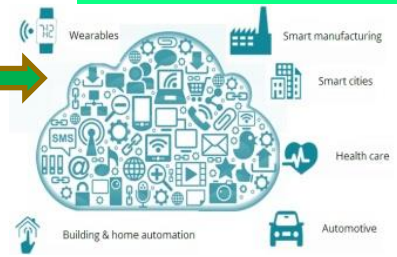
Edge Devices and their deployment



IoT Smart Nodes



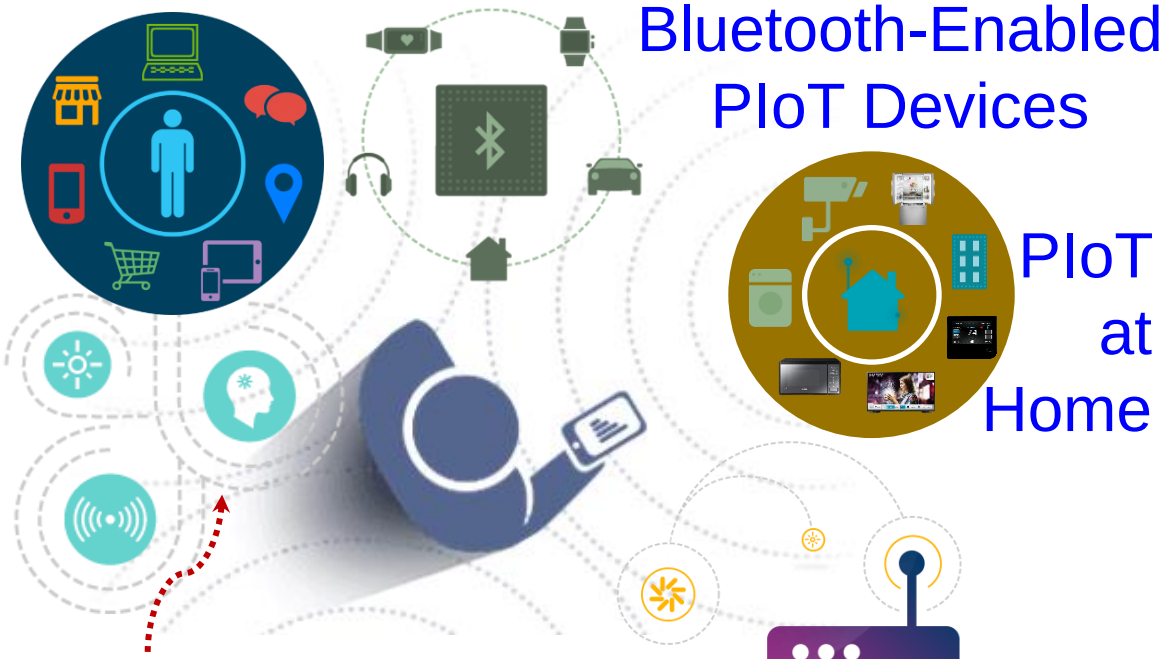
Gateways/ Concentrators

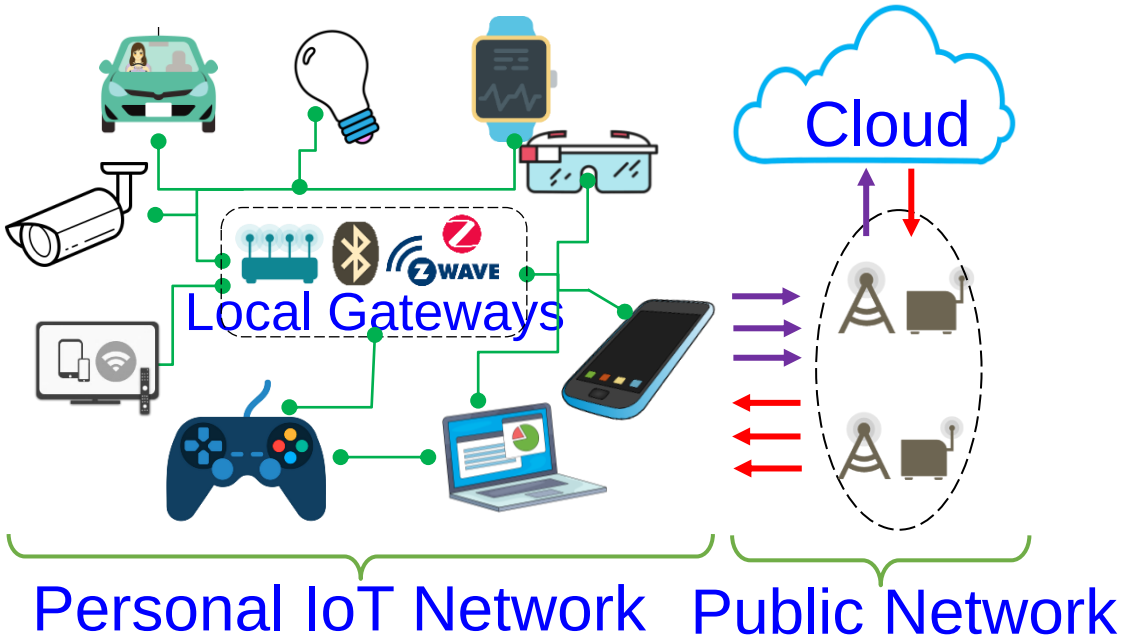


IoT-Cloud

Source: S. K. Ram, S. R. Sahoo, Banee, B.Das, K. K. Mahapatra, and **S. P. Mohanty**, "Eternal-Thing: A Secure Aging-Aware Solar-Energy Harvester Thing for Sustainable IoT", *IEEE Transactions on Sustainable Computing*, Vol. 6, No. 2, April 2021, pp. 320-333, doi: 10.1109/TSUSC.2020.2987616.

Personal IoT (PIoT) May Help?





Source: B. P. S. Sahoo, S. P. Mohanty, D. Puthal and P. Pillai, "Personal Internet of Things (PIoT): What is it Exactly," *IEEE Consumer Electronics Magazine*, doi: 10.1109/MCE.2021.3077721.

PIoT - A group of connected devices focused mainly in homes and the immediate proximity of an individual.

Can Any Smartness/Intelligence/IoT Solve?

Source: https://www.wilsoncenter.org/article/building-slum-free-mumbai