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# Smart Cities and Smart Villages - Design Optimization Perspectives

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# Population Trend – Urban Migration

“India is to be found not in its few cities, but in its 700,000 villages.”  
- Mahatma Gandhi

- 2025: 60% of world population will be urban
- 2050: 70% of world population will be urban



Source: <http://www.urbangateway.org>

# Issues Challenging City Sustainability



Pollution



Water Crisis



Energy Crisis



Traffic

# Smart City Technology - As a Solution

- **Smart Cities:** For effective management of limited resource to serve largest possible population to improve:

- Livability
- Workability
- Sustainability

At Different Levels:

- Smart Village
- Smart State
- Smart Country

➤ **Year 2050: 70% of world population will be urban**



Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

# Smart Cities Vs Smart Villages

City - An inhabited place of greater size, population, or importance than a town or village

-- Merriam-Webster

**Smart City:** A city “connecting the physical infrastructure, the information-technology infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city”.

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, “Everything You wanted to Know about Smart Cities”, *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

**Smart Village:** A village that uses information and communication technologies (ICT) for advancing economic and social development to make villages sustainable.

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. XX, No. YY, ZZ 2021, DOI: 10.1109/MCE.2020.3023293.

# Population Urban Migration is not a Problem for Smart Villages – Why to Bother?

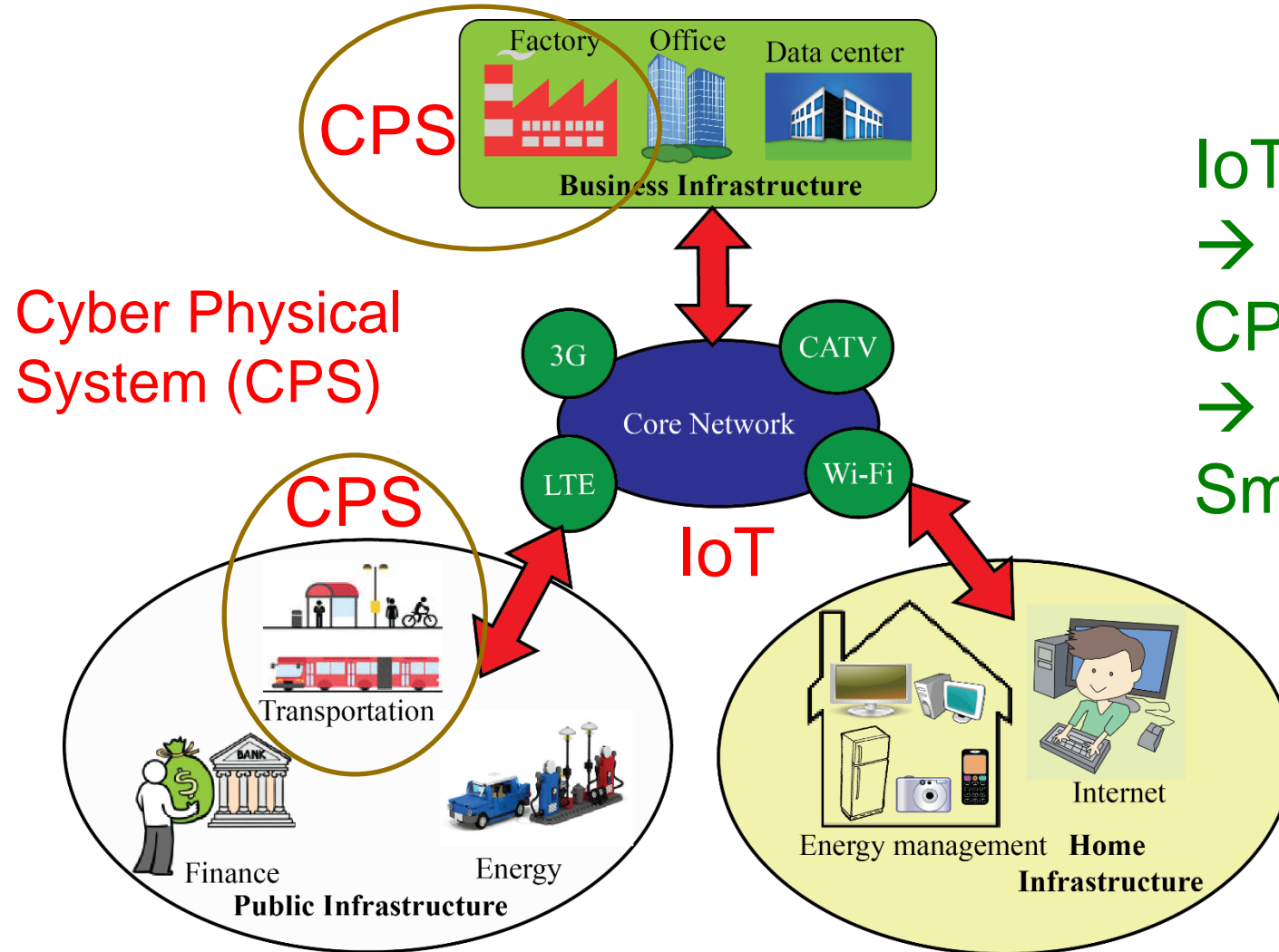
	Societal & Environmental Threats	Sectoral Approach	Synergic Effects	Development Perspectives
Rural areas	Poverty & Marginalized Communities	Education and Health Services	Rural ↔ Urban Migration	Quality of Life Improvement
	Famine & Subsistence Agriculture	Biodiversity Protection	Food Security	Sustainable Agriculture
	Land Degradation & Deforestation	Natural Hazards	Climate Changes	Rural Resilience
	Lack of Basic Utilities	Waste/Water/Sanitation /Energy	Environmental Pollution	Circular Economy
	Underdevelopment Regions	Rural-Urban Gaps	Governance & Territorial Cohesion	Reducing Inequalities

Local /Regional → National → Cross-countries → Global  
 International Cooperation → SDGs → Agenda 2030

- Efficient usage of limited resources
- Sustainability at low-cost
- Reverse urban migration of population

Source: M. Adamowicz and M. Zwolińska-Ligaj, "The "Smart Village" as a Way to Achieve Sustainable Development in Rural Areas of Poland", Sustainability, Vol. 12, No. 16, 2020, DOI: 10.3390/su12166503.

# IoT → CPS → Smart Cities or Smart Villages



Cyber Physical System (CPS)

IoT  
→  
CPS (Smart Components)  
→  
Smart Cities or Smart Villages

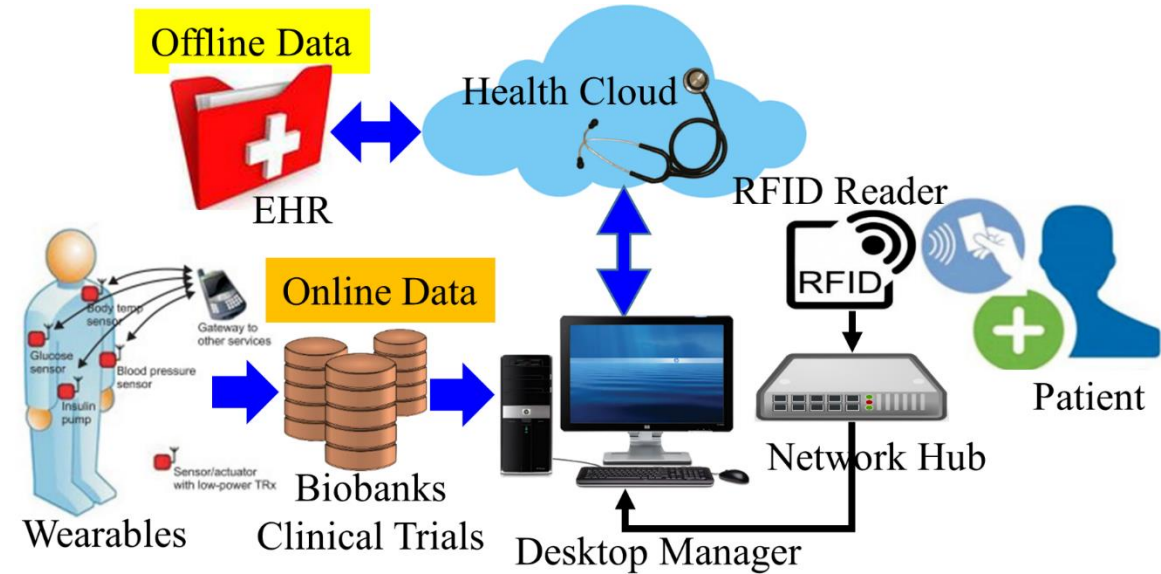
IoT is the backbone

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

# Healthcare Cyber-Physical System (H-CPS)



Internet-of-Medical-Things (IoMT)  
OR  
Internet-of-Health-Things (IoHT)

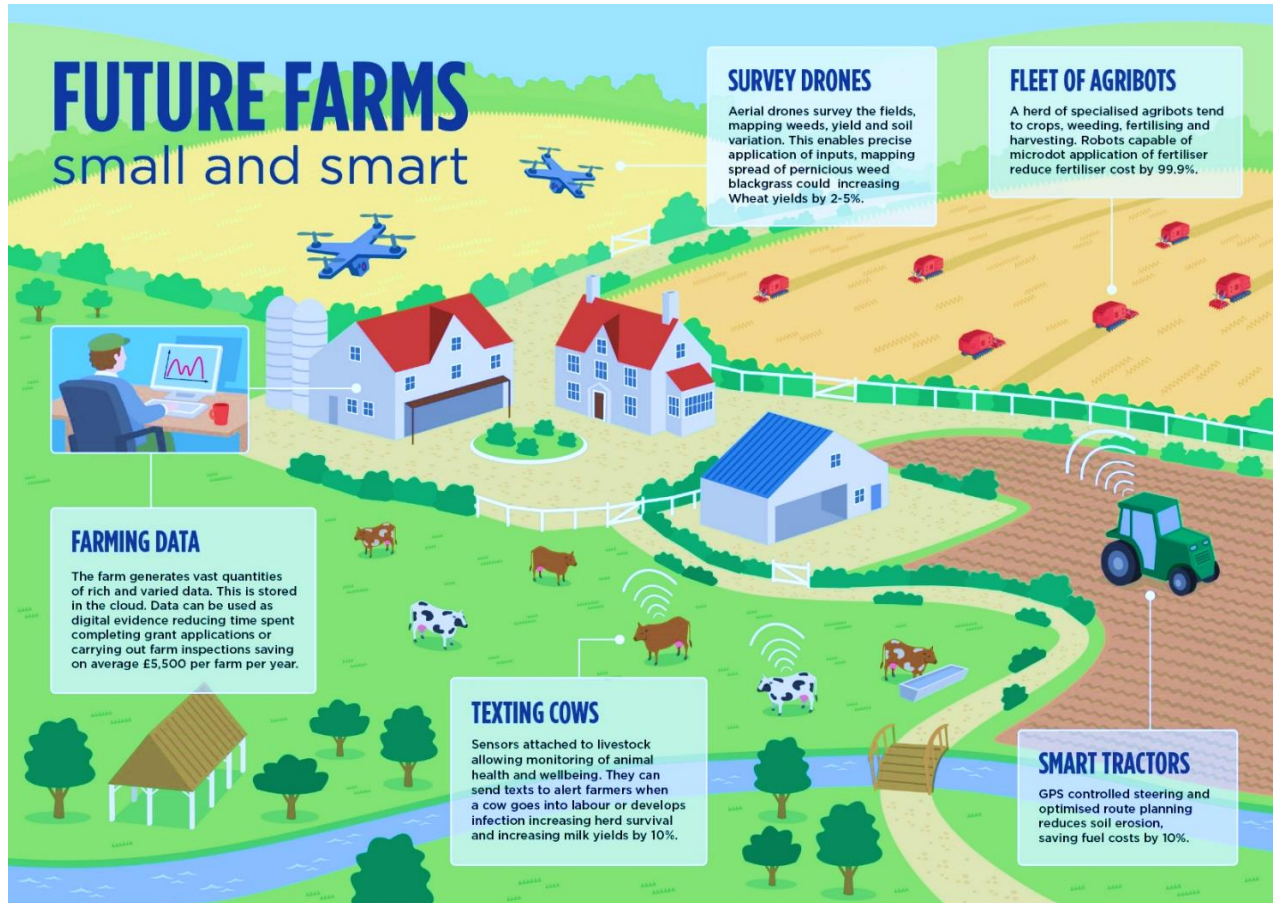


H-CPS ← Biosensors + Medical Devices + Wearable Medical Devices (WMDs) + Implantable Medical Devices (IMDs) + Internet + Healthcare database + AI/ML + Applications that connected through Internet.

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



# Agriculture Cyber-Physical System (A-CPS)



Source: <http://www.nesta.org.uk/blog/precision-agriculture-almost-20-increase-income-possible-smart-farming>

**Smart Agriculture/Farming Market Worth \$18.21 Billion By 2025**

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

Climate-Smart Agriculture Objectives:

- Increasing agricultural productivity
- Resilience to climate change
- Reducing greenhouse gas

<http://www.fao.org>

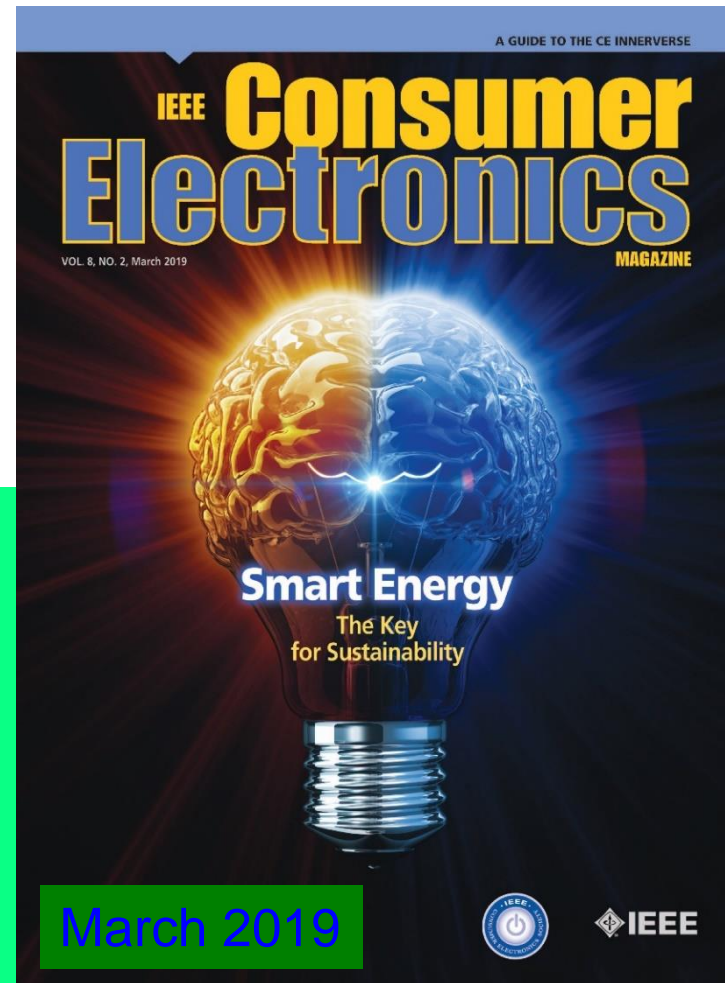
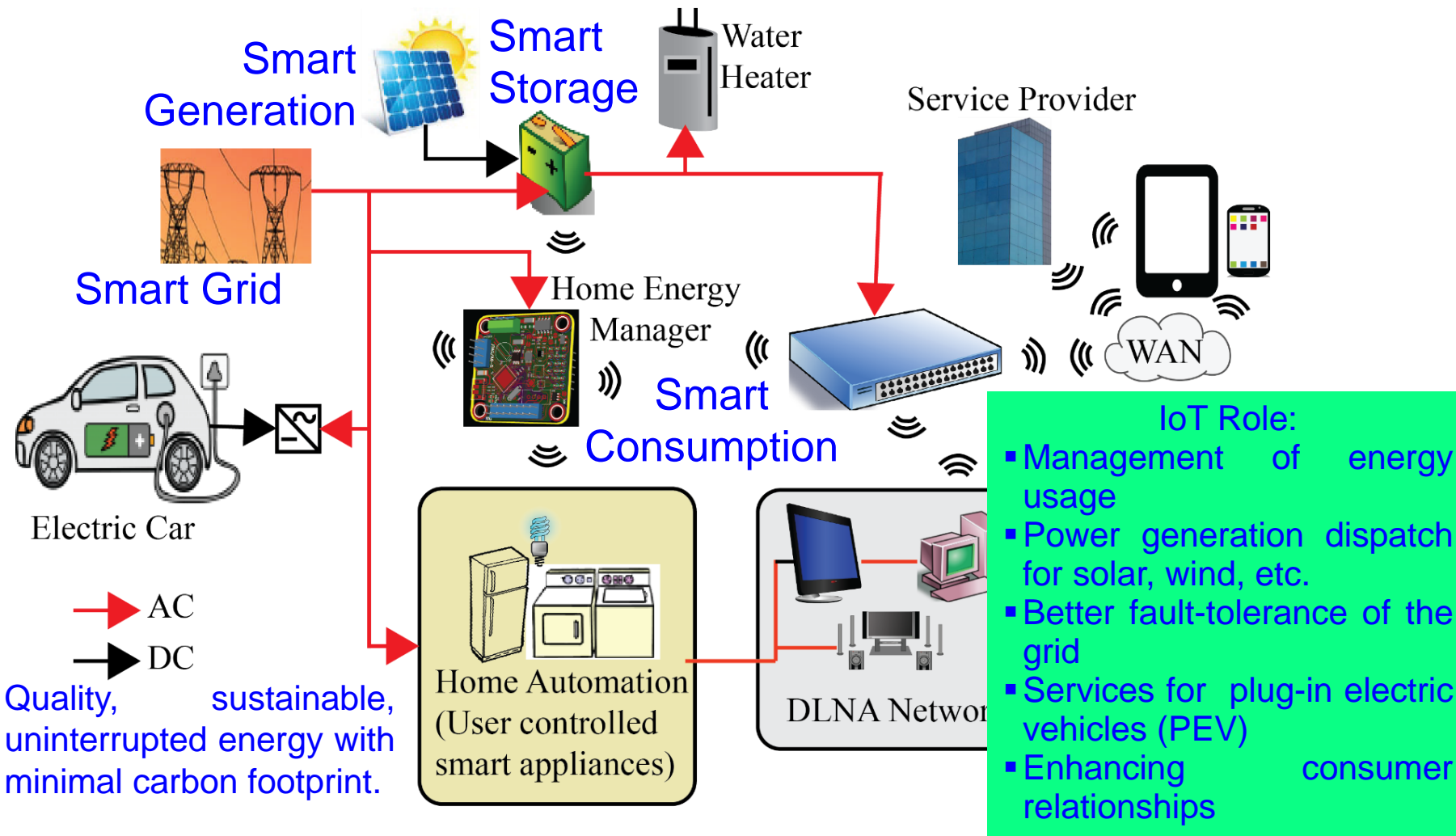
**Internet-of-Agro-Things (IoAT)**

**Automatic Irrigation System**



Source: Maurya 2017, CE Magazine July 2017

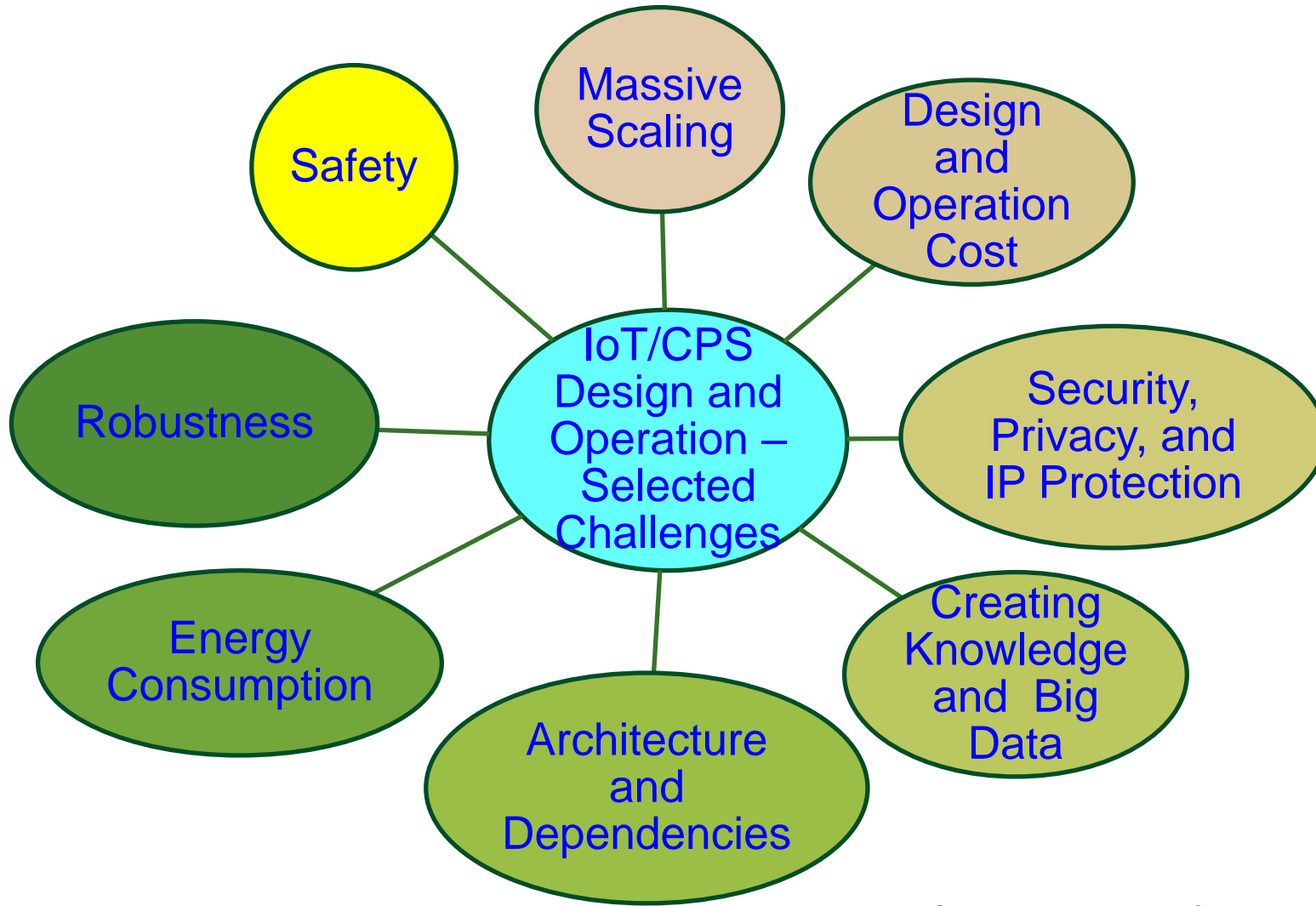
# Energy Cyber-Physical System (E-CPS)



Internet of Energy

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

# IoT/CPS – Selected Challenges



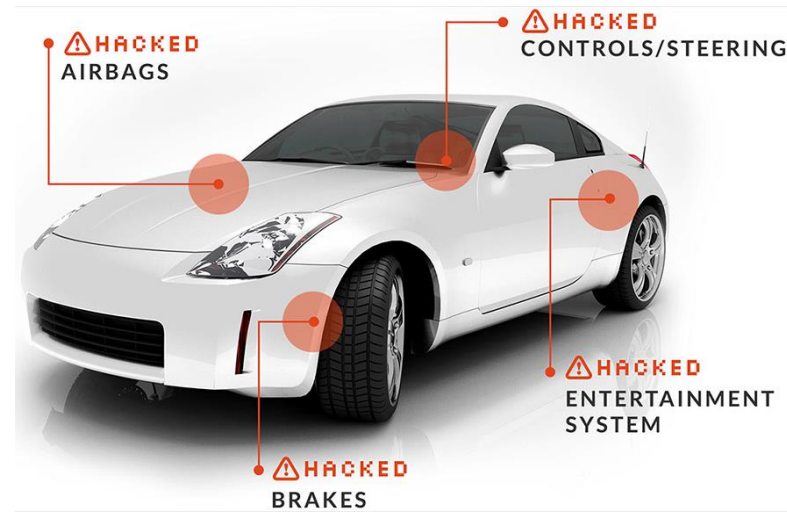
Source: Mohanty ICIT 2017 Keynote

# Security Challenge - System

## Power Grid Attack



Source: <http://www.csoonline.com/article/3177209/security/why-the-ukraine-power-grid-attacks-should-raise-alarm.html>



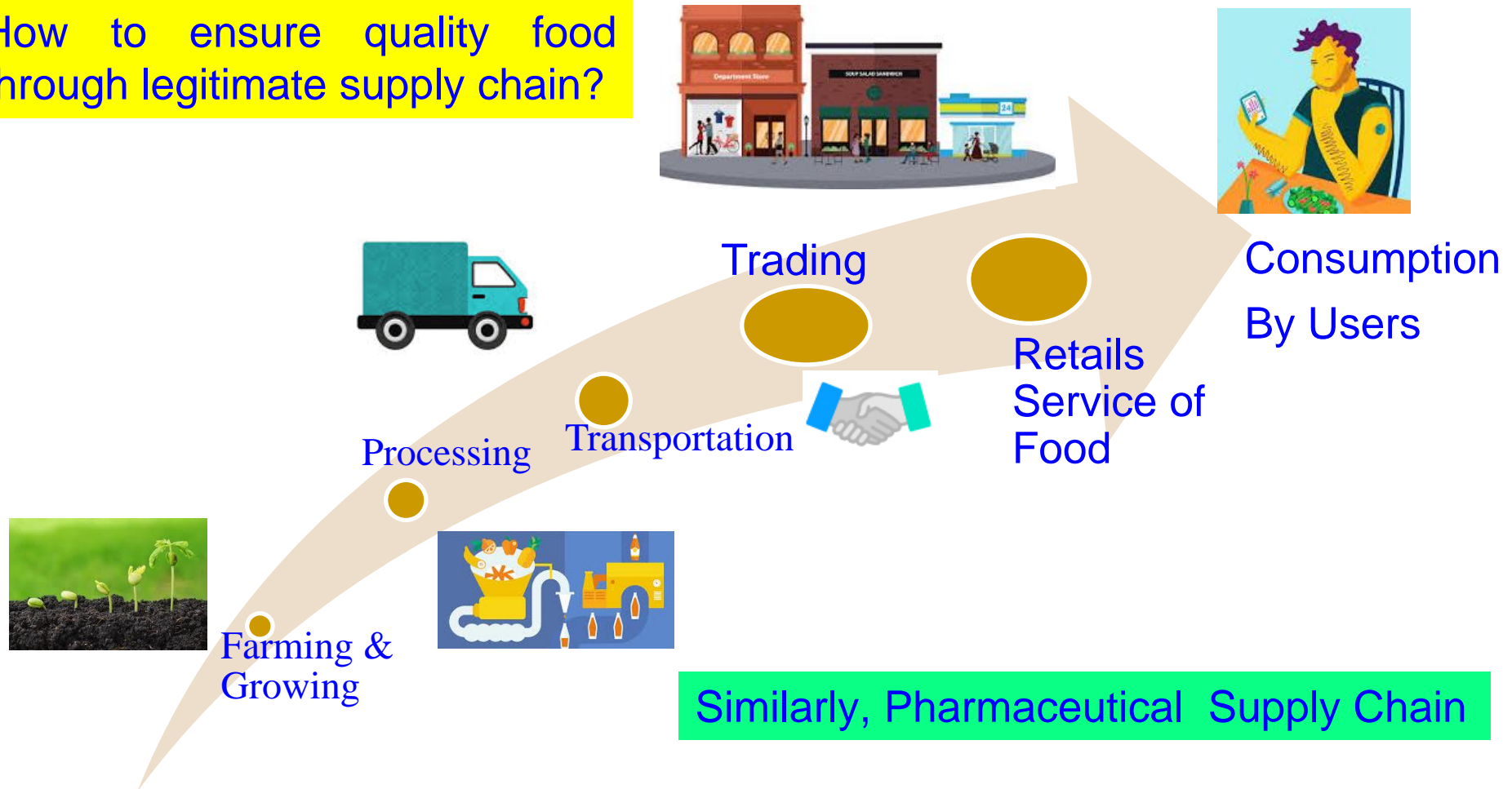
Source: <http://money.cnn.com/2014/06/01/technology/security/car-hack/>



Source: <http://politicalblindspot.com/u-s-drone-hacked-and-hijacked-with-ease/>

# Food Supply Chain: Farm → Dinning

How to ensure quality 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](https://arxiv.org/abs/2008.11153), August 2020, 18-pages.

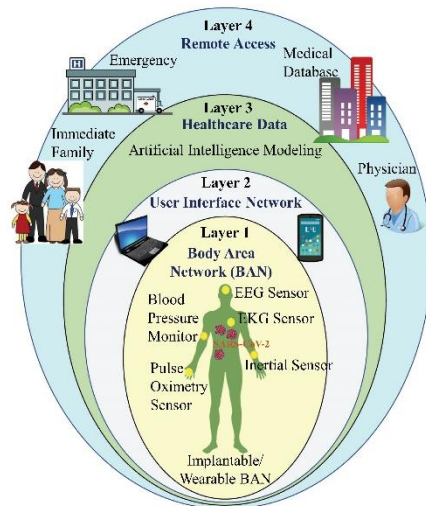
# Smart Healthcare - Security and Privacy Issue

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Healthcare Cyber-Physical System (H-CPS)



<https://ctsoc.ieee.org>



## Selected Smart Healthcare Security/Privacy Challenges

Data Eavesdropping

Data Confidentiality

Data Privacy

Location Privacy

Identity Threats

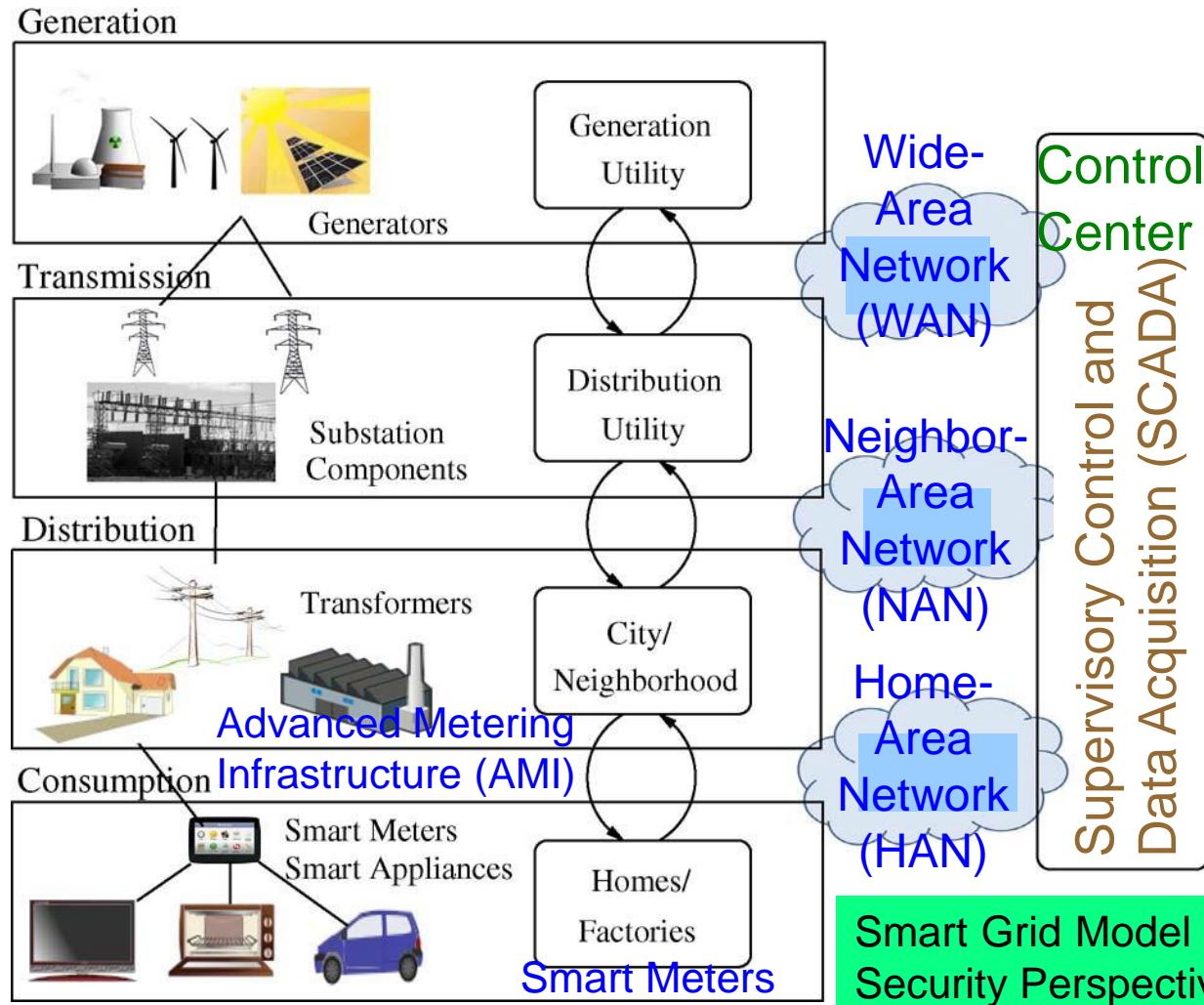
Access Control

Unique Identification

Data Integrity

Device Security

# Smart Grid - Vulnerability



Information and Communication Technology (ICT) components of smart grid is cyber vulnerable.

Data, Application/System Software, Firmware of Embedded System are the loop holes for security/privacy.

- Network/Communication Components
- Phasor Measurement Units (PMU)
- Phasor Data Concentrators (PDC)
- Energy Storage Systems (ESS)
- Programmable Logic Controllers (PLCs)
- Smart Meters

Source: Y. Mo *et al.*, "Cyber-Physical Security of a Smart Grid Infrastructure", *Proceedings of the IEEE*, vol. 100, no. 1, pp. 195-209, Jan. 2012.

# 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



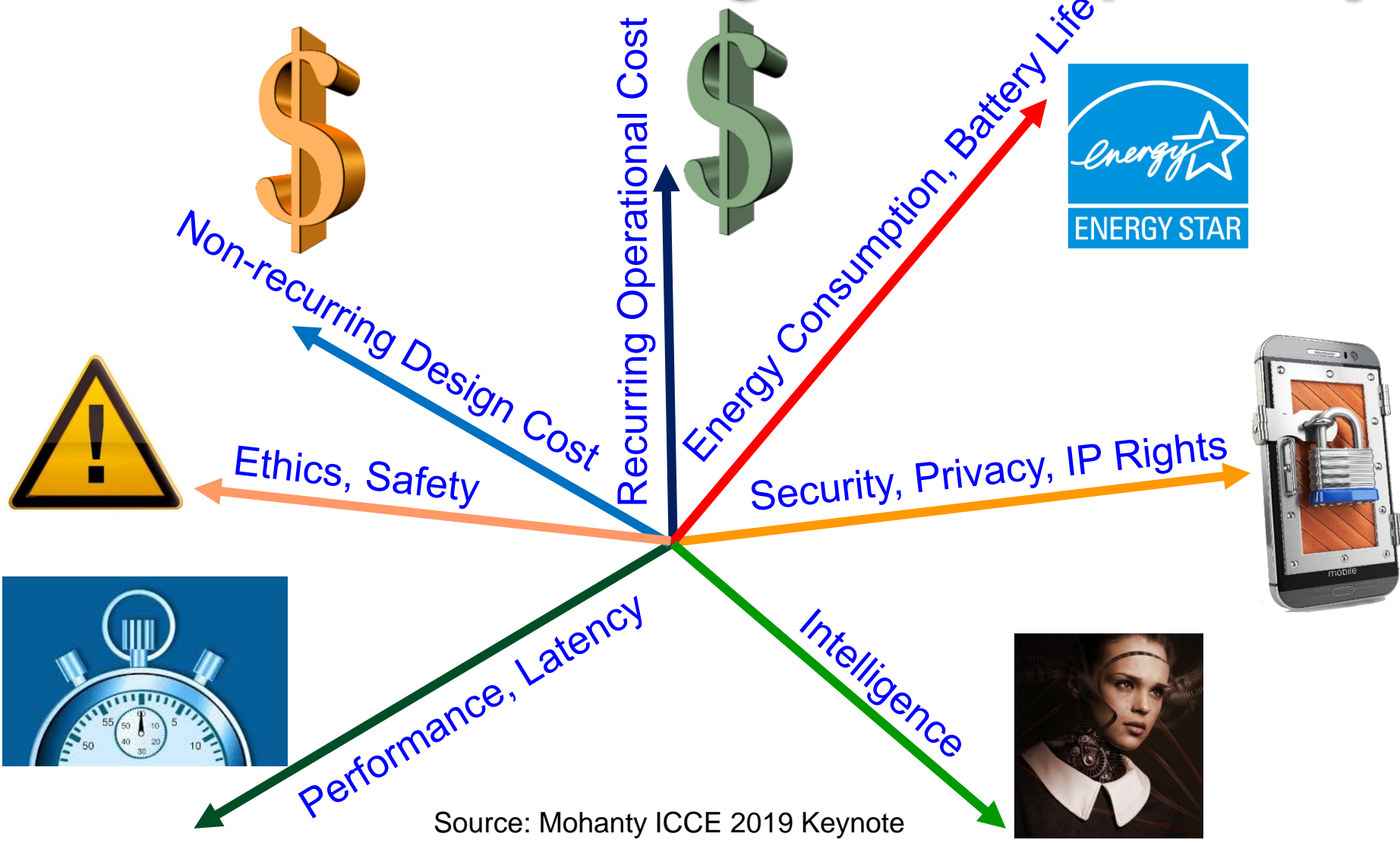
80,000X



Energy consumption of a credit card processing



# IoT/CPS Design – Multiple Objectives



Smart Cities  
Vs  
Smart Villages

Source: Mohanty ICCE 2019 Keynote

# 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/>

IEEE  
**Consumer**

Electronics Magazine

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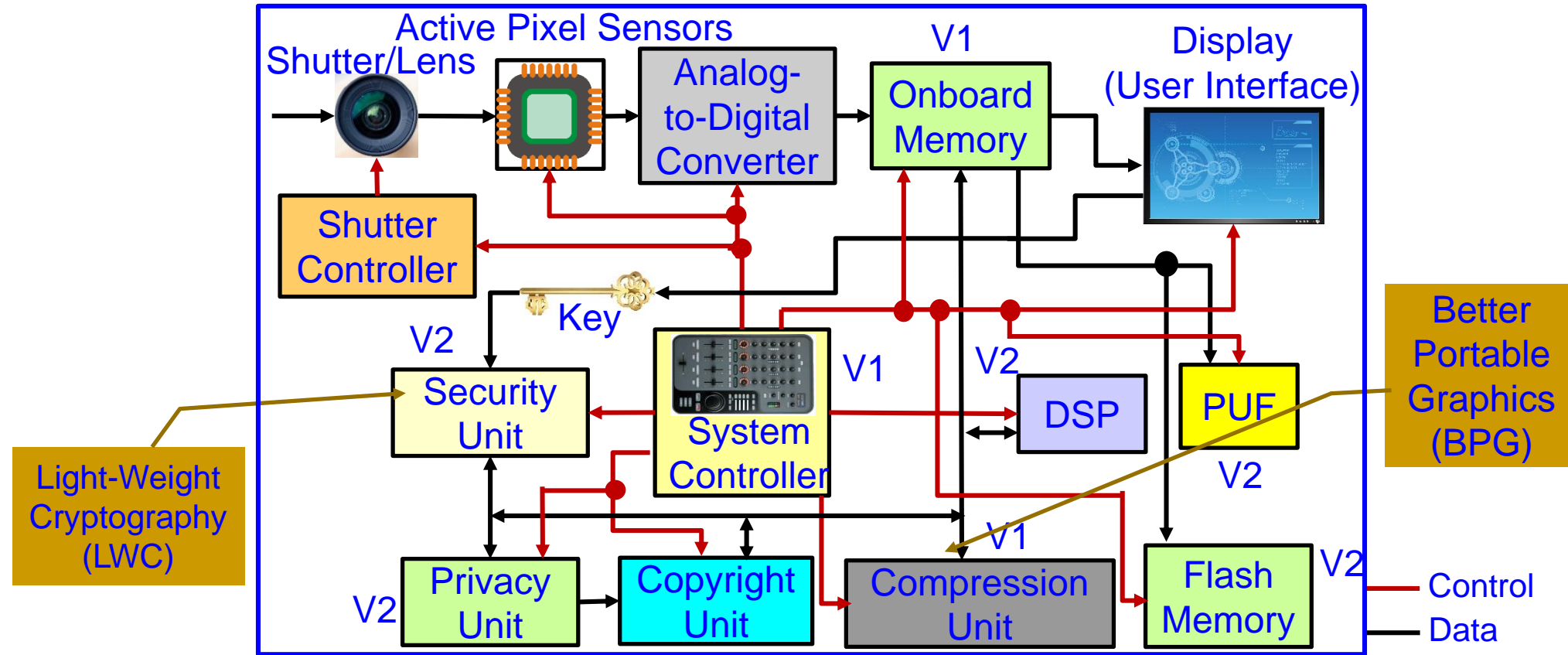
Privacy and Security by Design



<https://cesoc.ieee.org/>



# Secure Digital Camera (SDC) – My Invention

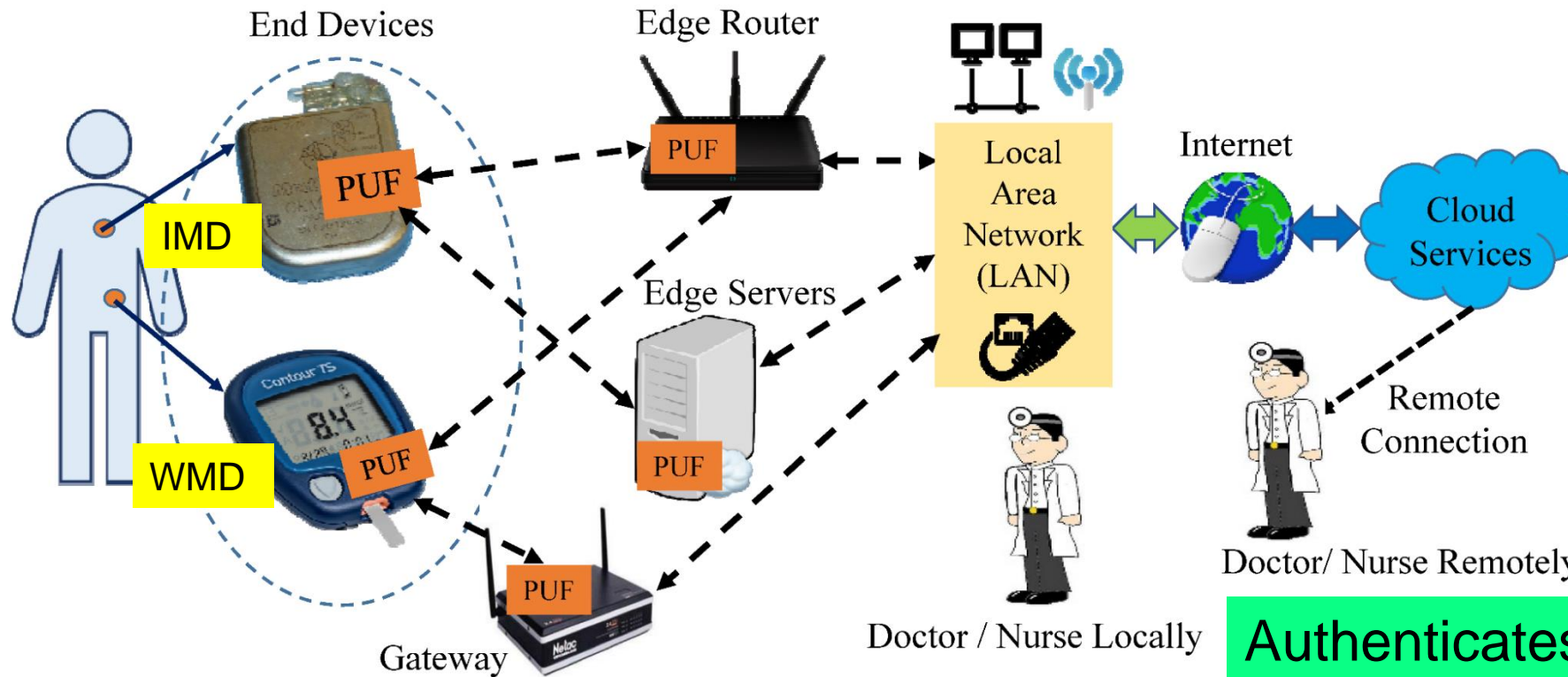


Include additional/alternative hardware/software components and uses DVFS like technology for energy and performance optimization.

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

Source: S. P. Mohanty, "A Secure Digital Camera Architecture for Integrated Real-Time Digital Rights Management", *Elsevier Journal of Systems Architecture (JSA)*, Volume 55, Issues 10-12, October-December 2009, pp. 468-480.

# PMsec: Our Secure by Design Approach for Robust Security in Healthcare CPS



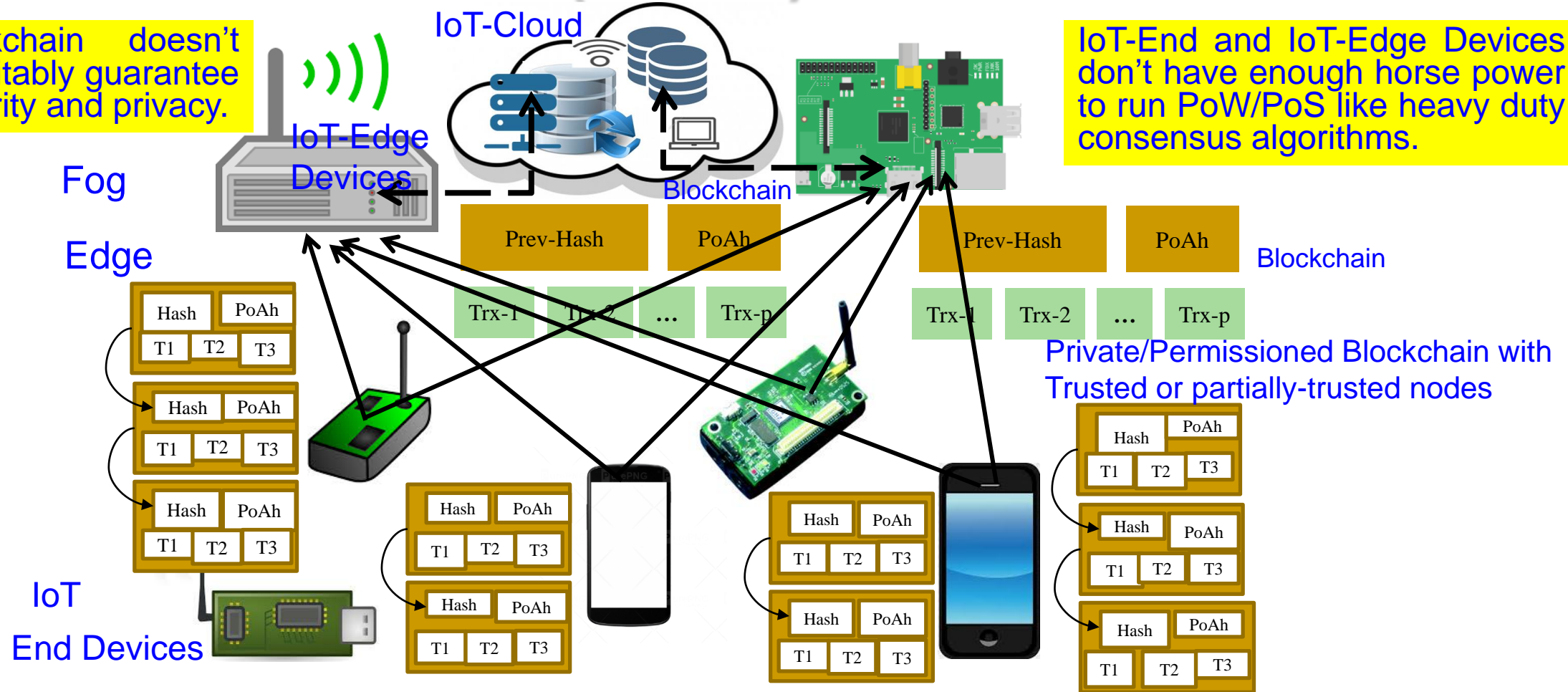
Authenticates Time - 1 sec  
Power Consumption - 200  $\mu$ W

Source: V. P. Yanambaka, S. P. Mohanty, E. Kougianos, and D. Puthal, "PMsec: Physical Unclonable Function-Based Robust and Lightweight Authentication in the Internet of Medical Things", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 388--397.

# IoT-Friendly Blockchain – Our Proof-of-Authentication (PoAh) based Blockchain

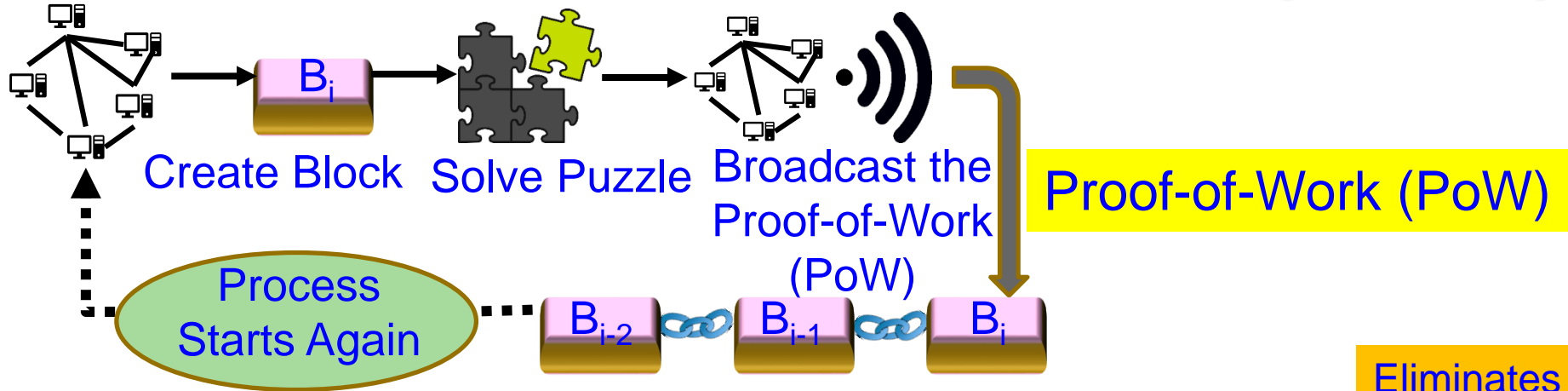
Blockchain doesn't inherently guarantee security and privacy.

IoT-End and IoT-Edge Devices don't have enough horse power to run PoW/PoS like heavy duty consensus algorithms.

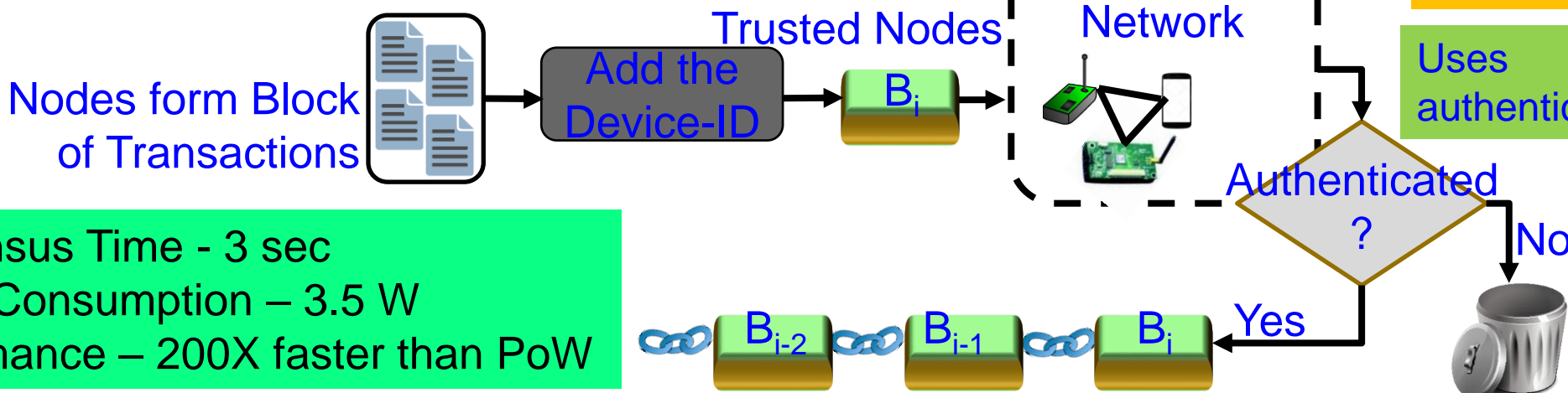


Source: D. Puthal and S. P. Mohanty, "Proof of Authentication: IoT-Friendly Blockchains", *IEEE Potentials Magazine*, Vol. 38, No. 1, January 2019, pp. 26--29.

# Our Proof-of-Authentication (PoAh)



## Proof of Authentication (PoAh)



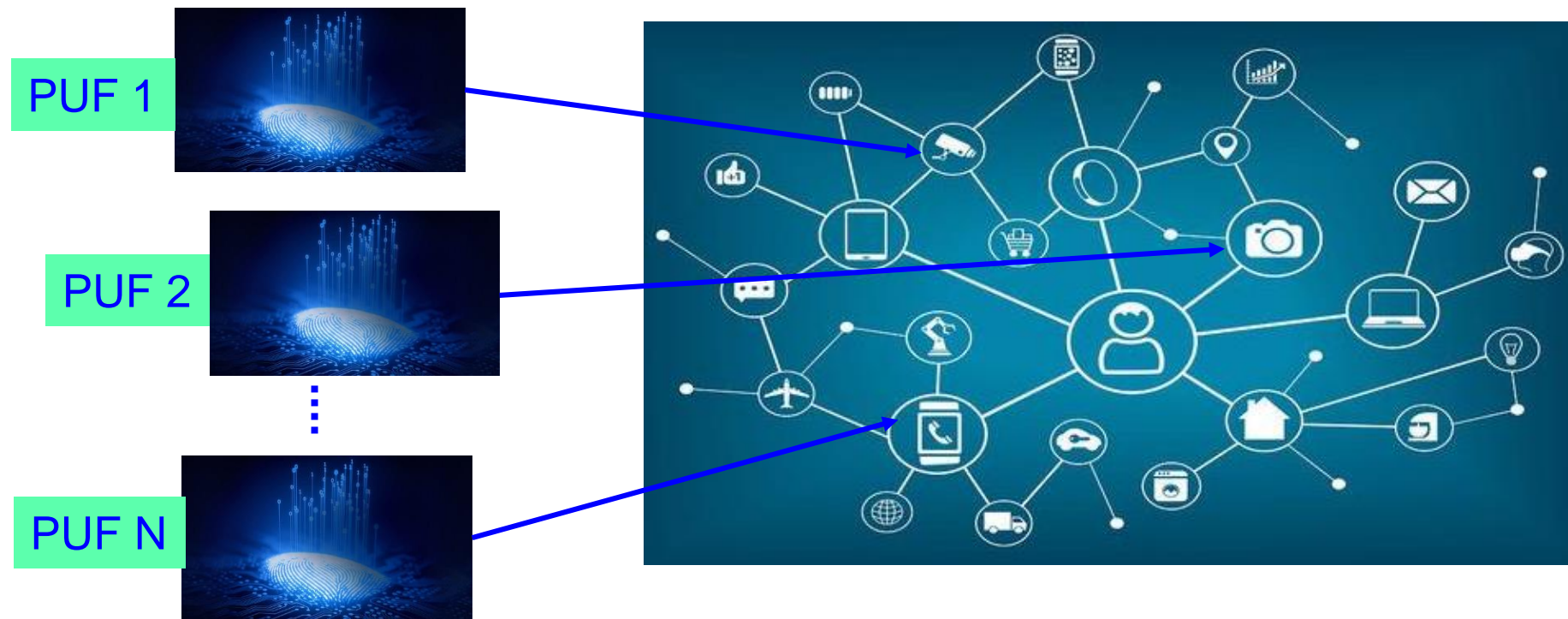
Eliminates cryptographic "puzzle" solving to validate blocks.

Uses a cryptographic authentication mechanism.

Consensus Time - 3 sec  
 Power Consumption – 3.5 W  
 Performance – 200X faster than PoW

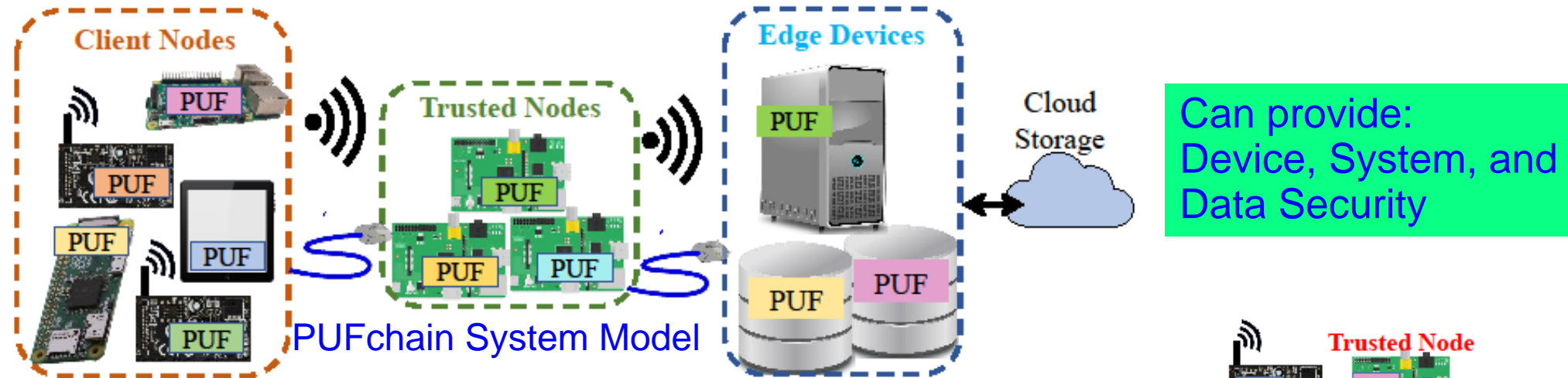
Source: D. Puthal and S. P. Mohanty, "Proof of Authentication: IoT-Friendly Blockchains", *IEEE Potentials Magazine*, Vol. 38, No. 1, January 2019, pp. 26--29.

# 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.

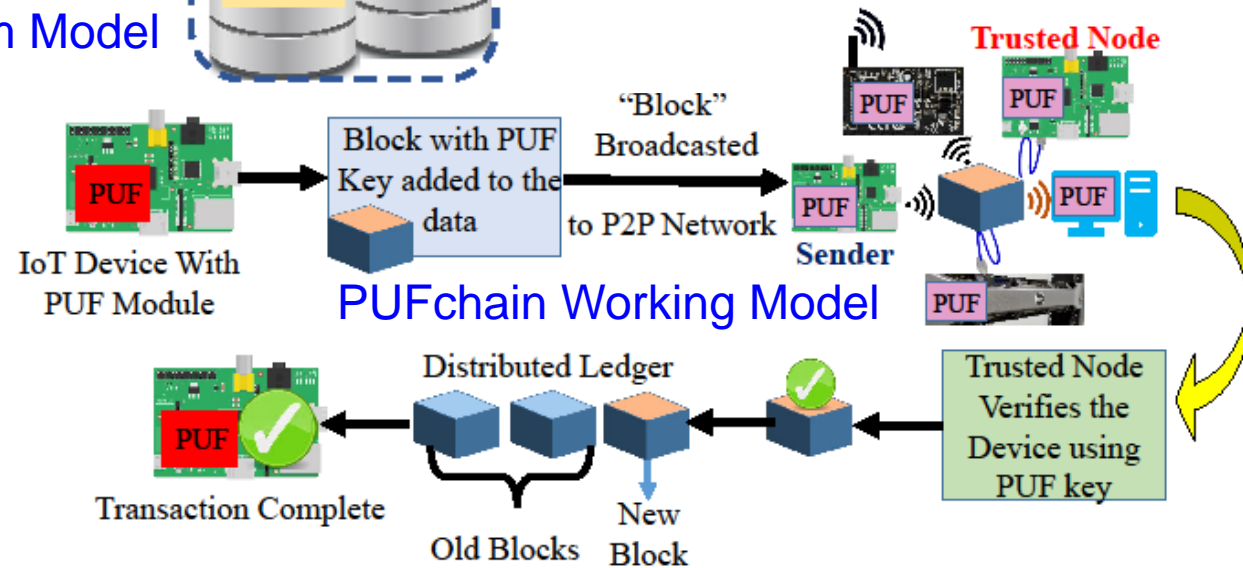
# PUFchain: Our Hardware-Assisted Scalable Blockchain



Can provide:  
Device, System, and  
Data Security

PUFChain 2 Modes:  
(1) PUF Mode and  
(2) PUFChain Mode

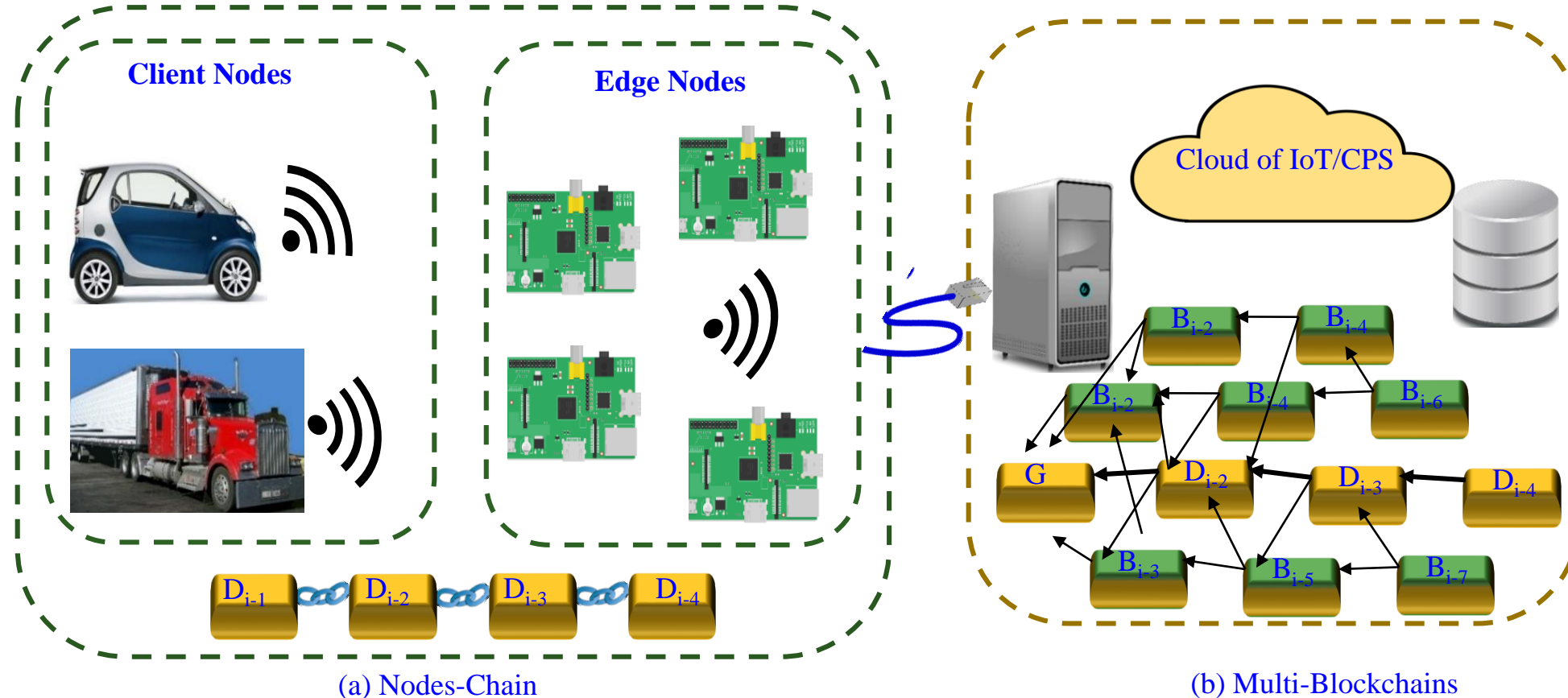
- ✓ PoP is 1,000X faster than PoW
- ✓ PoP is 5X faster than PoAh



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.

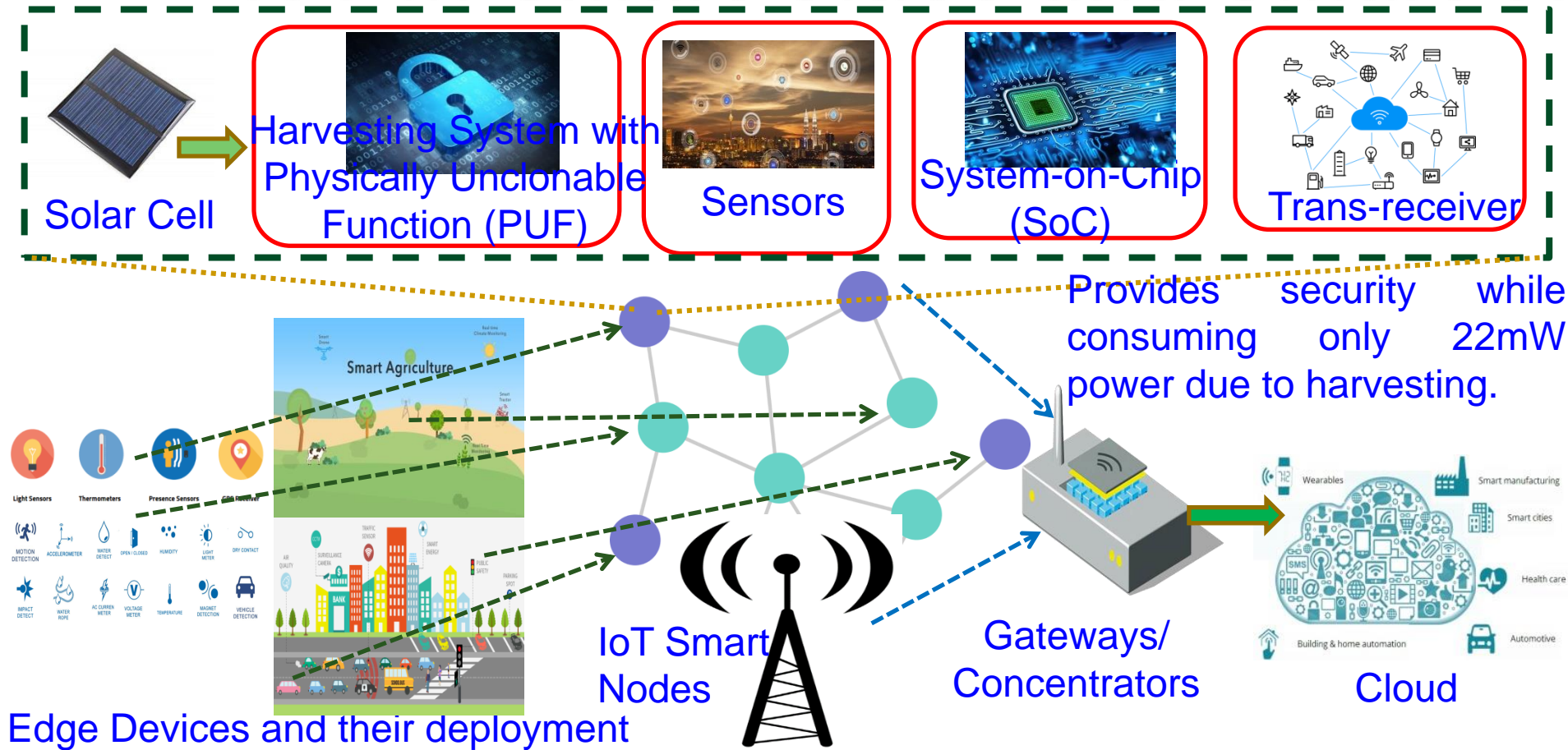


# Our Multi-Chain Technology to Enhance Blockchain Scalability



Source: A. J. Alkhodair, S. P. Mohanty, E. Kougiianos, and D. Puthal, "McPoRA: A Multi-Chain Proof of Rapid Authentication for Post-Blockchain based Security in Large Scale Complex Cyber-Physical Systems", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020, pp. 446--451.

# Our Eternal Thing is Useful for Sustainable IoT in Smart Cities and Smart Villages

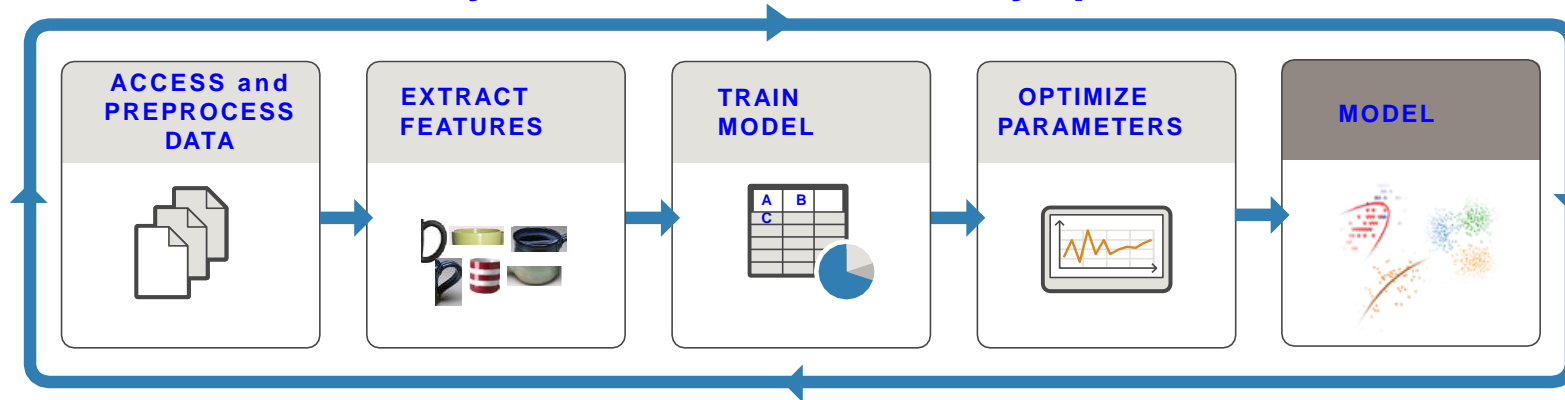


**Eternal-Thing:  
Combines Security and  
Energy Harvesting at  
the IoT-Edge**

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. XX, No. YY, ZZ 2021, pp. Accepted on 08 April 2020, DOI: 10.1109/TSUSC.2020.2987616.

# TinyML - Key for Smart Cities and Smart Villages

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

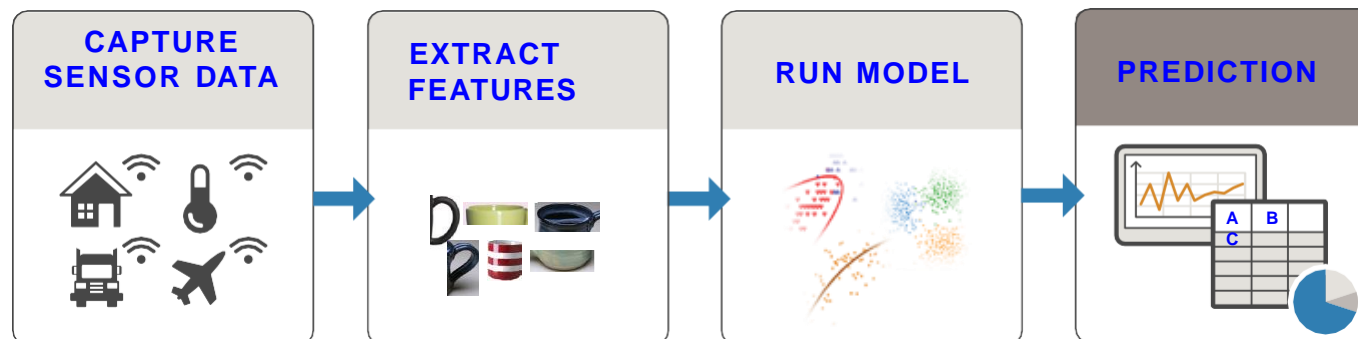


Needs Significant:

- Computational Resource
- Computation Energy

Solution: Reduce Training Time and/or Computational Resource

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



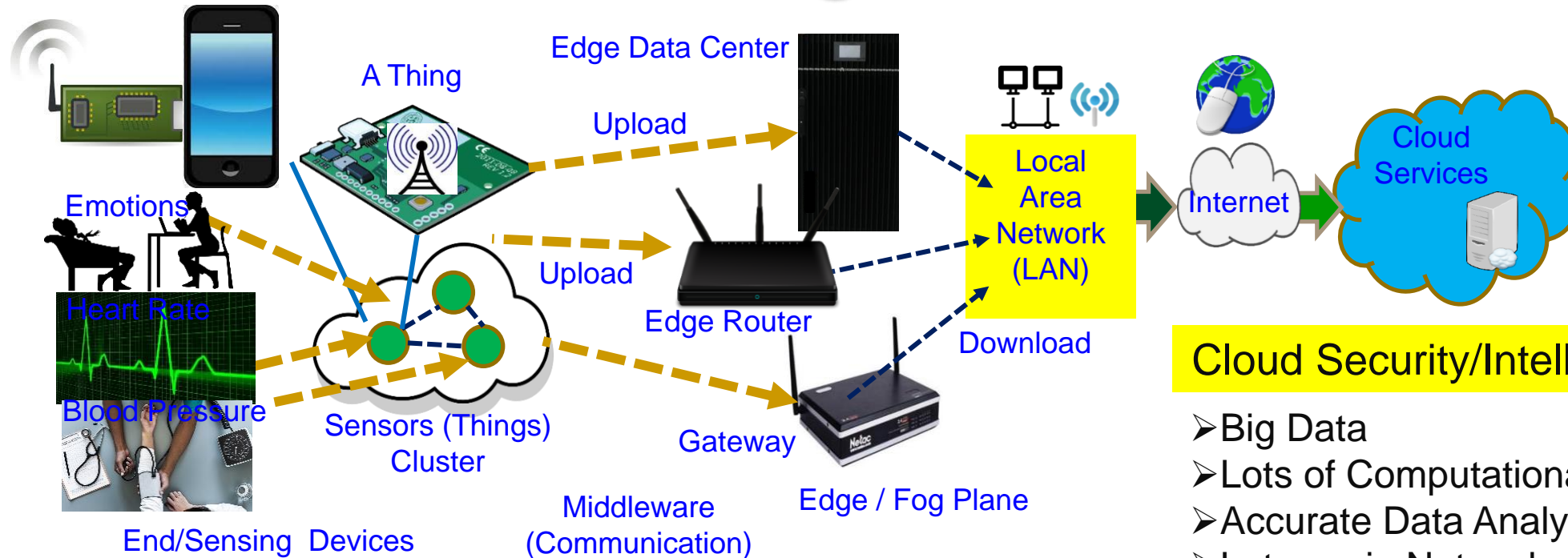
Needs:

- Computational Resource
- Computation Energy

Solution: TinyML

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

# CPS – IoT-Edge Vs IoT-Cloud



## Cloud Security/Intelligence

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

## End Security/Intelligence

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

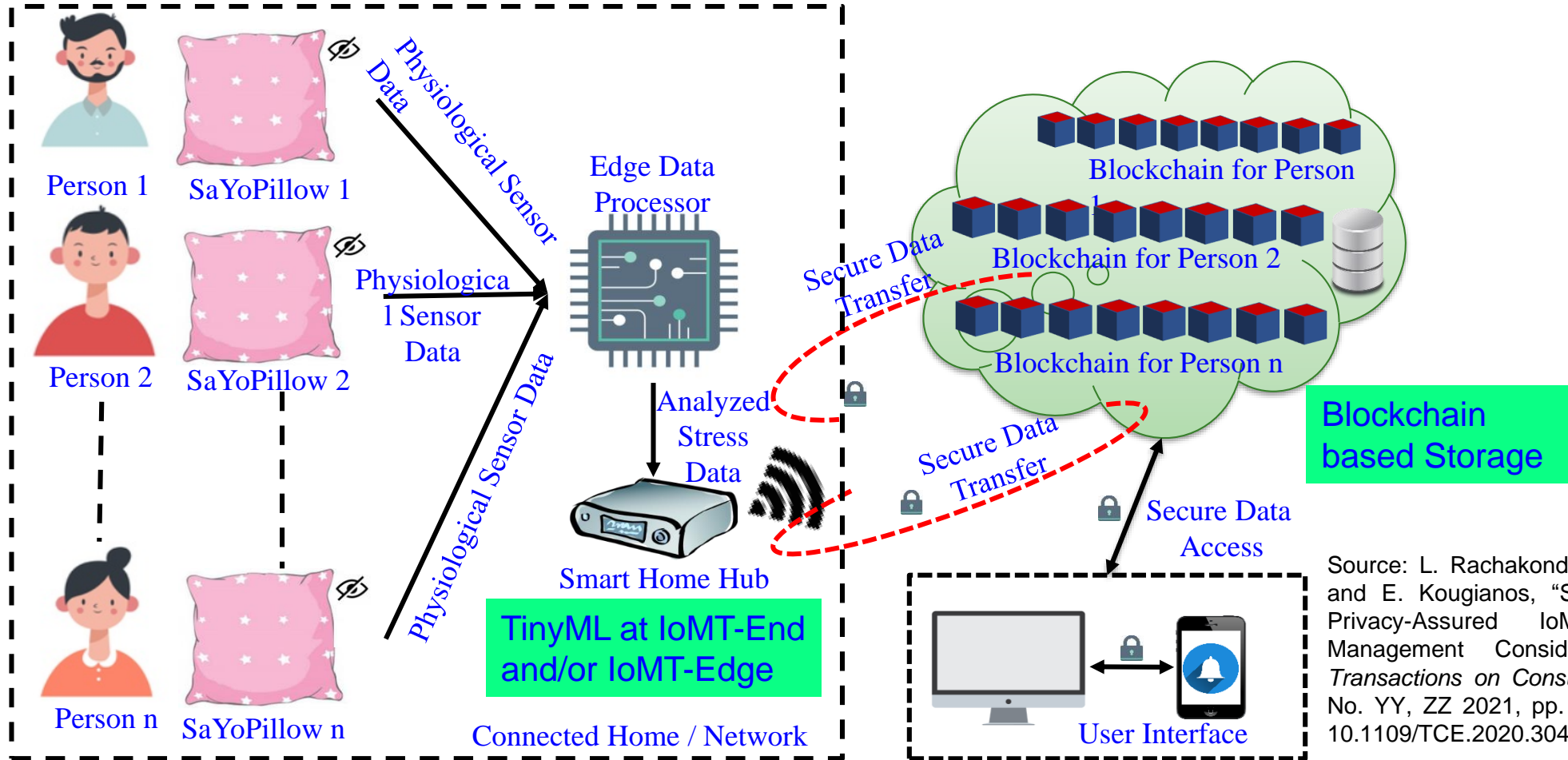
## Edge Security/Intelligence

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

Heavy-Duty ML is more suitable for smart cities

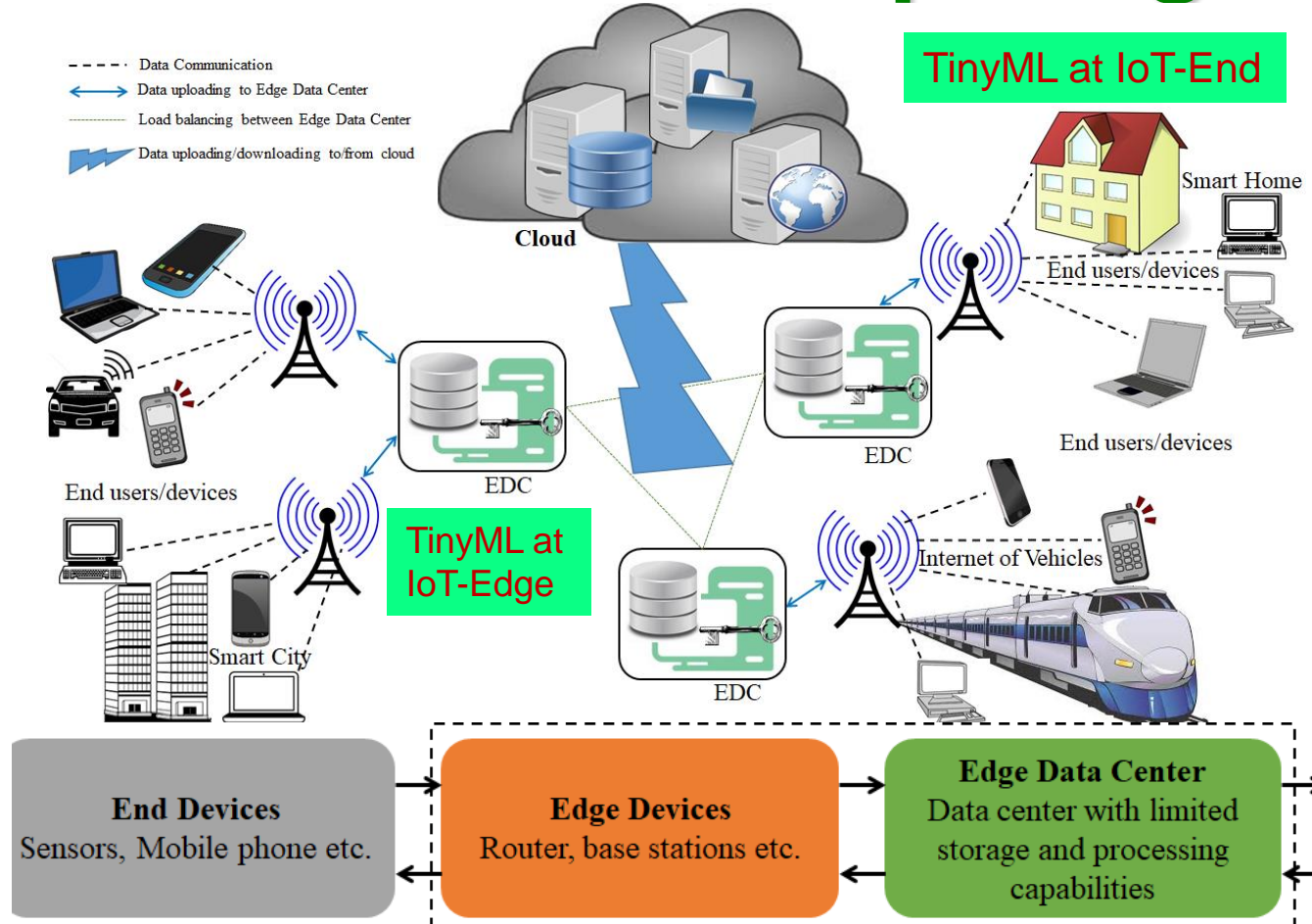
TinyML at End and/or Edge is key for smart villages.

# Our Smart-Yoga Pillow (SaYoPillow) with TinyML and Blockchain based Security



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: Blockchain-Integrated Privacy-Assured IoMT Framework for Stress Management Considering Sleeping Habit", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. XX, No. YY, ZZ 2021, pp. Accepted on 07 Dec 2020, DOI: 10.1109/TCE.2020.3043683.

# 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.