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# TinyML - Key for Smart Cities and Smart Villages

**VAIBHAV 2020**

**Vertical: V6 - Data Sciences – Session V6H5S2**  
**Application of Data Science in Smart Cities,  
Health Care, Management and Agriculture**

**16 Oct 2020 (Fri)**

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Mohanty



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# My background

- My research is on Smart Electronic Systems, the backbone of which is a combination of AI/ML, Data Analytics, Security at the Edge of IoT in the Cyber-Physical Systems (CPS) that make the smart cities.
- My Smart Electronic Systems research can be grouped into the following inter-related thrusts:
  - Security and Energy Aware Cyber-Physical Systems (CPS)
  - IoMT Based Approaches for Smart Healthcare
  - IoT-Enabled Consumer Electronics for Smart Cities
- Existing collaboration with Indian researchers at:
  - IIT Kanpur
  - MNIT Jaipur
  - NIT Rourkela
  - IIIT Naya Raipur

# Smart Cities is a Solution for Urban Migration

- **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.

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# Smart City Data Challenges are Multifold



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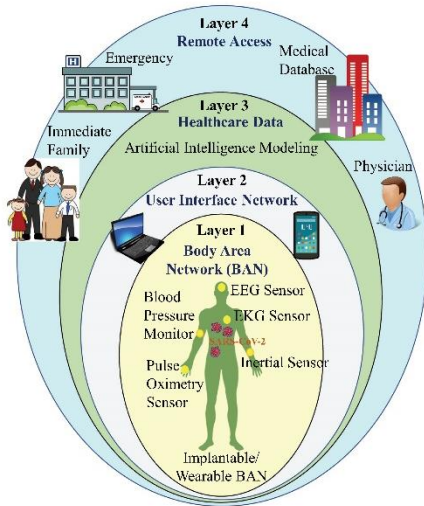
# Smart Healthcare (Healthcare CPS) is Data Dependent

IEEE  
**Consumer**

Electronics Magazine

Volume 9 Number 5

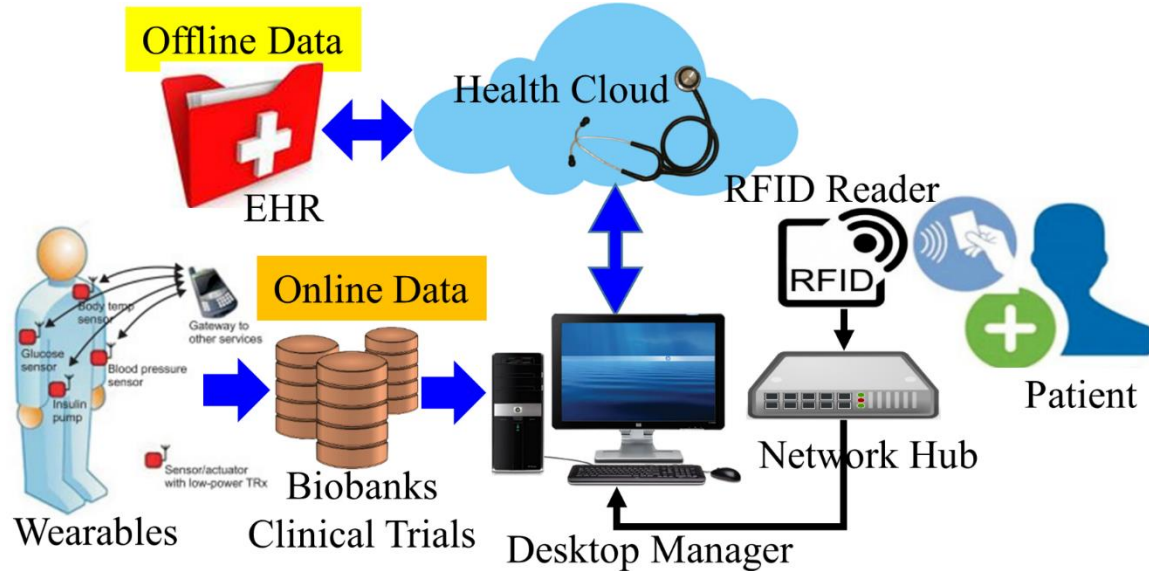
SEPTEMBER/OCTOBER 2020



Healthcare Cyber-Physical System (H-CPS)



<https://ctsoc.ieee.org>



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

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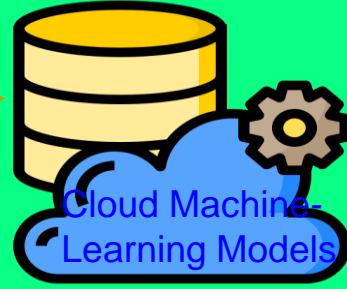




# Smart Agriculture (Agriculture CPS)

Cloud Layer -  
Services for  
Agriculture  
Data Analysis

Agriculture  
Sensor Data,  
Famer Data

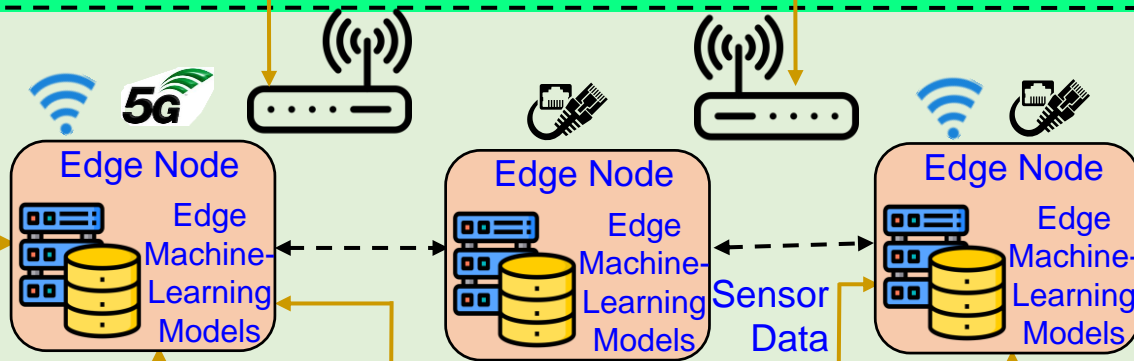


Agriculture Data Analysis  
and Predictions

Solar powered smart  
device for plant disease  
and growth prediction.

Edge Device  
Layer (for Each  
Farm or  
Neighborhood)

Sensor Data



Agriculture  
Device  
Layer

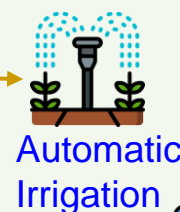


Farmer Data



sCrop App

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Farmer Data



sCrop App

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.

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# Data Modeling - ML Challenges



High Energy Requirements

High Computational Resource Requirements

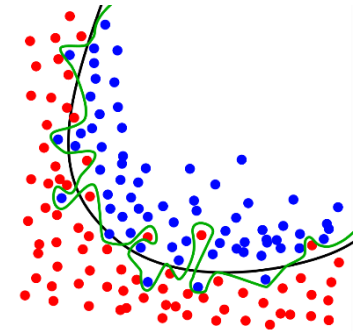
Large Amount of Data Requirements

Machine Learning Issues

Underfitting/Overfitting Issue

Class Imbalance Issue

Fake Data Issue



Source: Mohanty ISCT Keynote 2019

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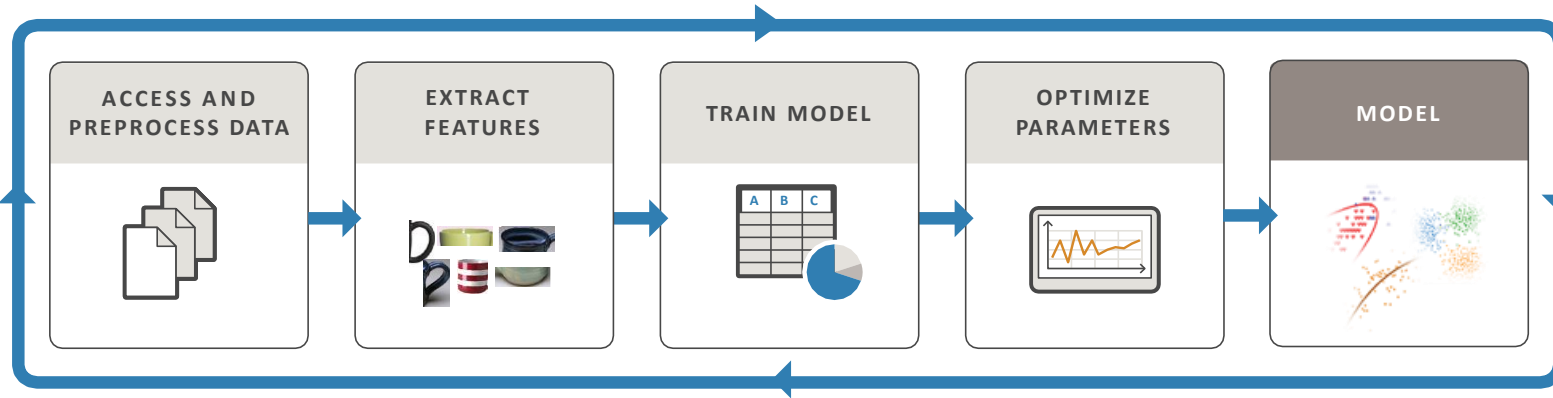


# Deep Neural Network (DNN) - Resource and Energy Costs

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

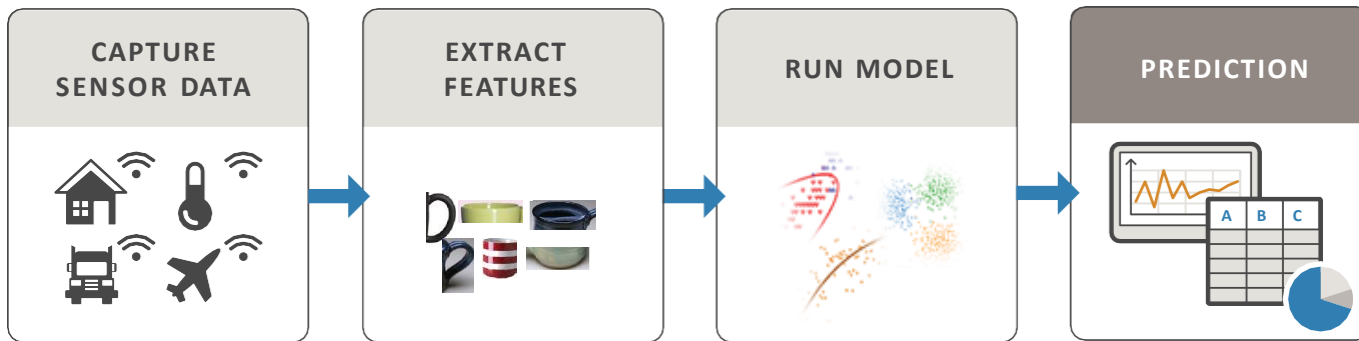
Needs Significant:

- Resource
- Energy



Solution:  
Reduce  
Training  
Time /  
Resource

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



Needs:  
➤ Resource  
➤ Energy

Solution: TinyML

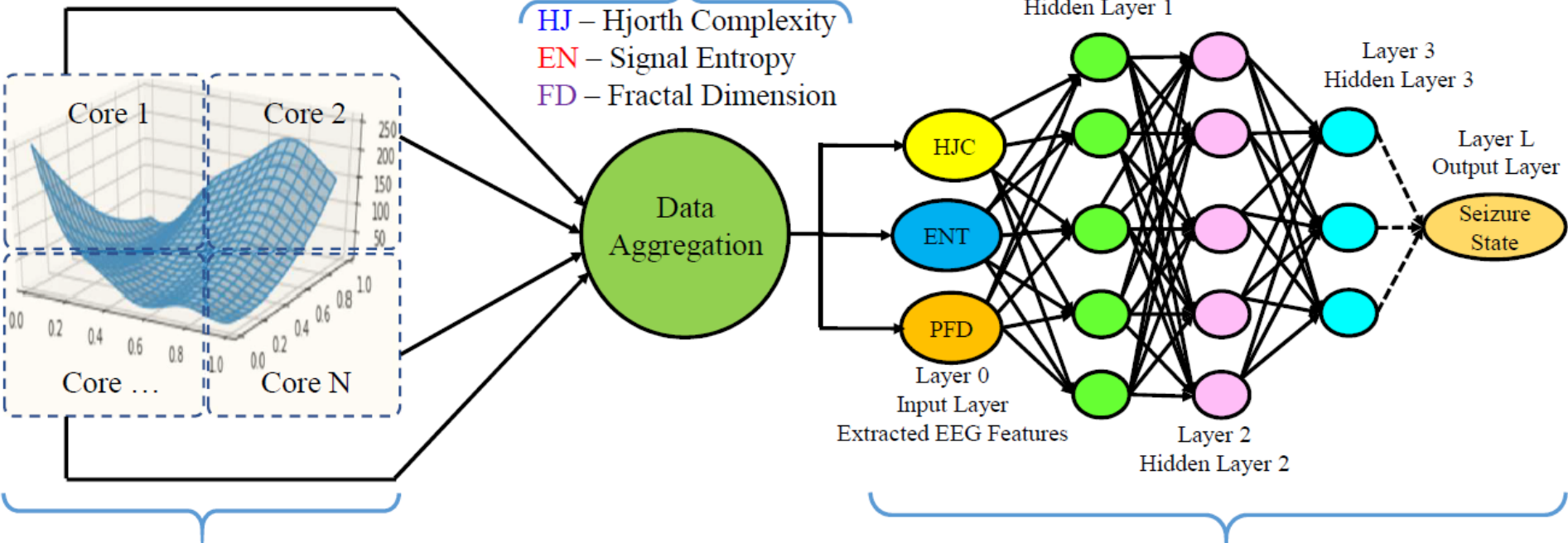
Source: <https://www.mathworks.com/campaigns/offers/mastering-machine-learning-with-matlab.html>



# Our Distributed Kriging- Bootstrapped DNN Modeling for Fast Detection of Seizure

Extracted Features

- HJ – Hjorth Complexity
- EN – Signal Entropy
- FD – Fractal Dimension



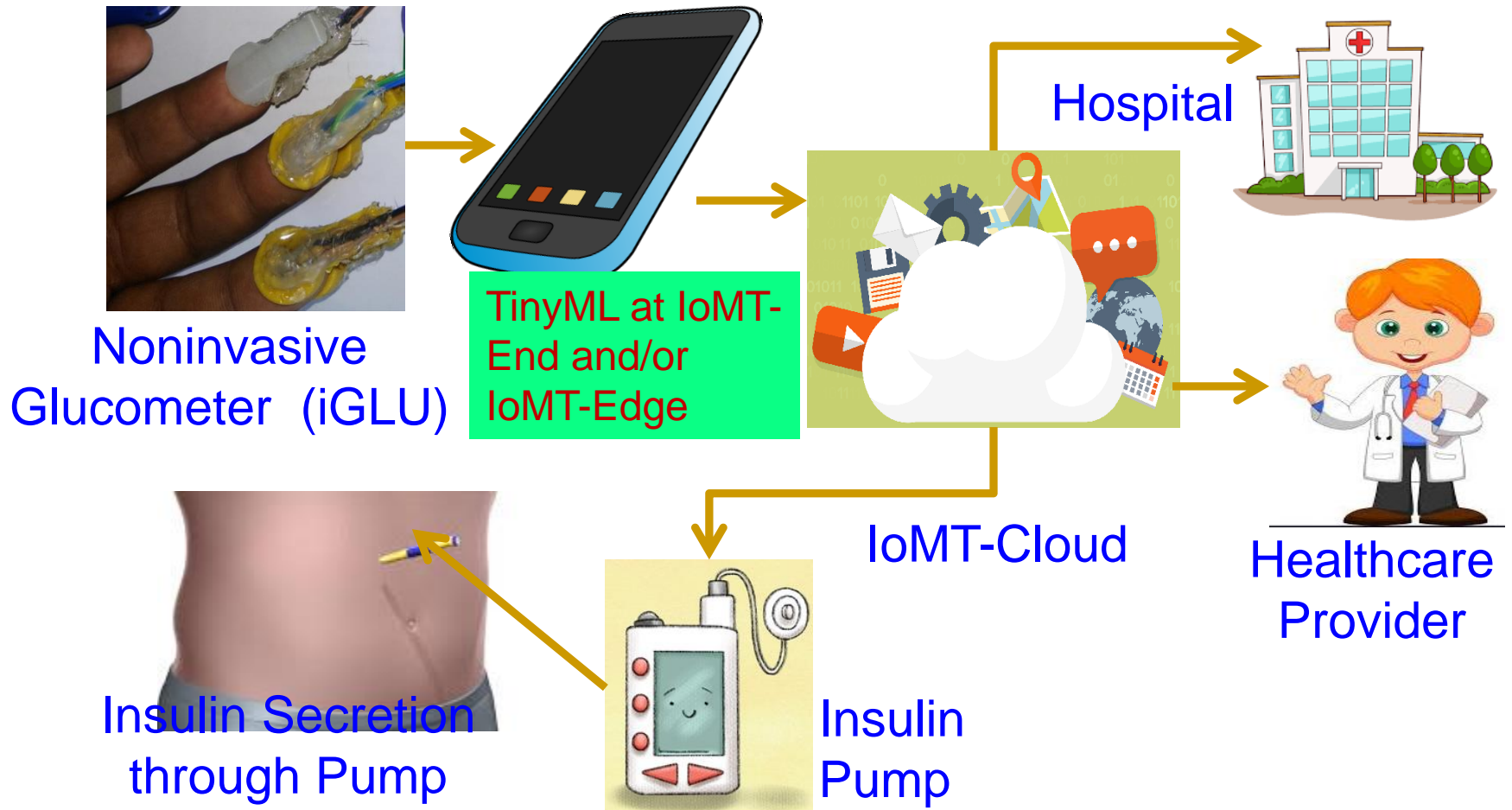
Distributed Kriging Model

L-Layer Deep Neural Network (DNN) Model

**Training Time reduced by 91%**

Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

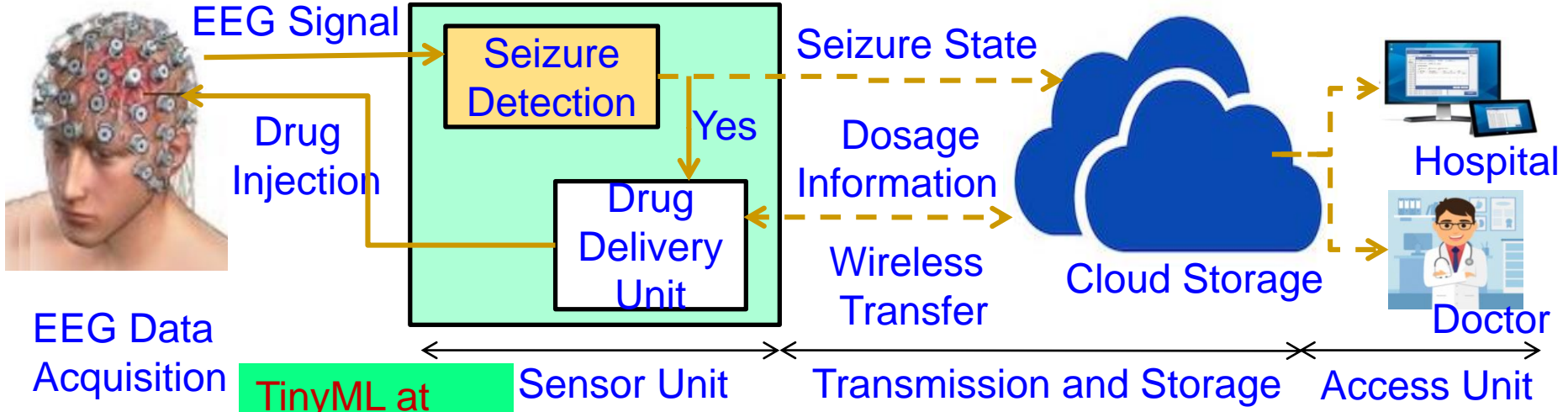
# Our Intelligent Non-Invasive Glucose Monitoring with Insulin Control Device (iGLU)



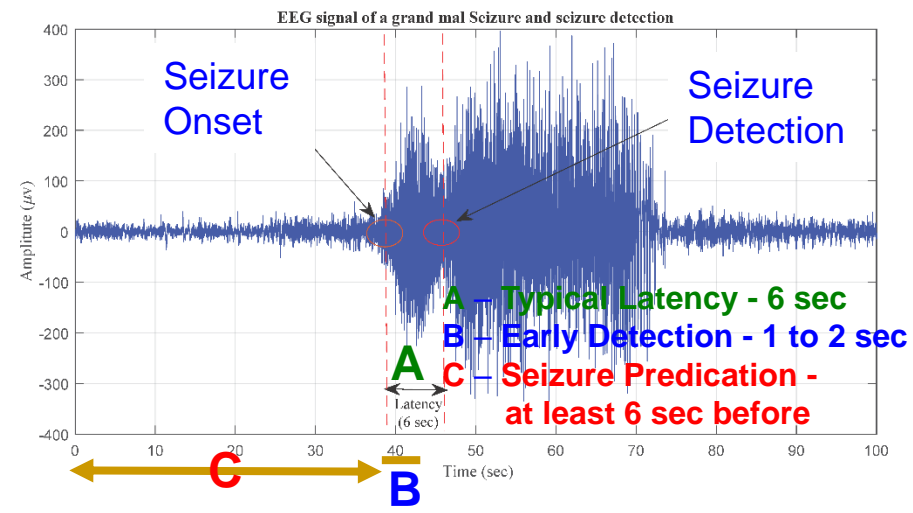
Source: A. M. Joshi, U. P. Shukla and S. P. Mohanty, "Smart Healthcare for Diabetes during COVID-19," *IEEE Consumer Electronics Magazine*, doi: 10.1109/MCE.2020.3018775.

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# Smart Healthcare - Seizure Detection & Control



TinyML at IoMT-End and/or IoMT-Edge



Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "eSeiz: An Edge-Device for Accurate Seizure Detection for Smart Healthcare", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 379--387.

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# Smart Healthcare – Data Quality



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y.Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.



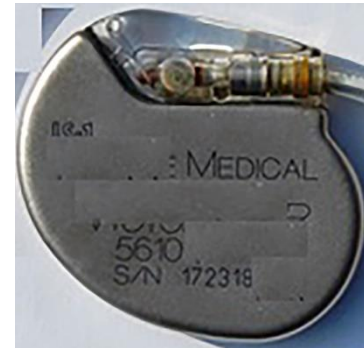
# Fake Data and Fake Hardware – Both are Equally Dangerous in CPS



AI can be fooled by fake data



AI can create fake data (Deepfake)



Authentic



Fake

An implantable medical device



Authentic



Fake

A plug-in for car-engine computers



# Data - Where to Store and Process?



Sensor, Edge, Fog, Cloud?

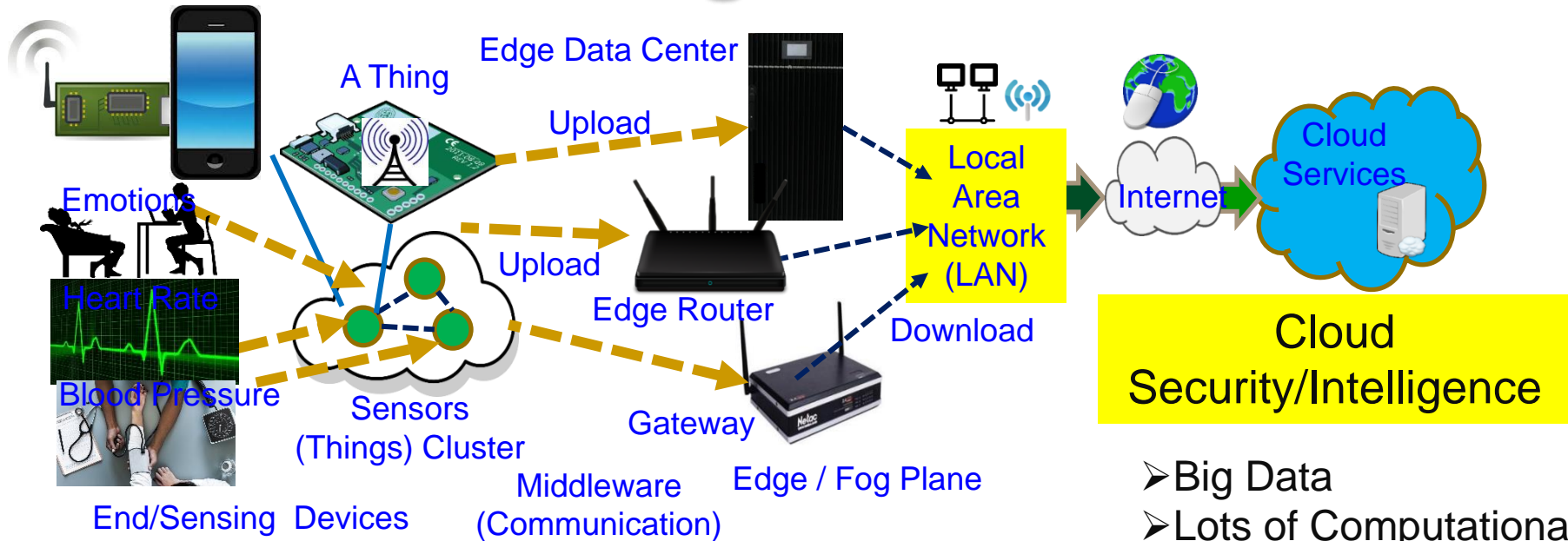


ASIC, FPGA, SoC, FP-SoC, GPU, Neuromorphic, Quantum?

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# CPS – IoT-Edge Vs IoT-Cloud



## End Security/Intelligence

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

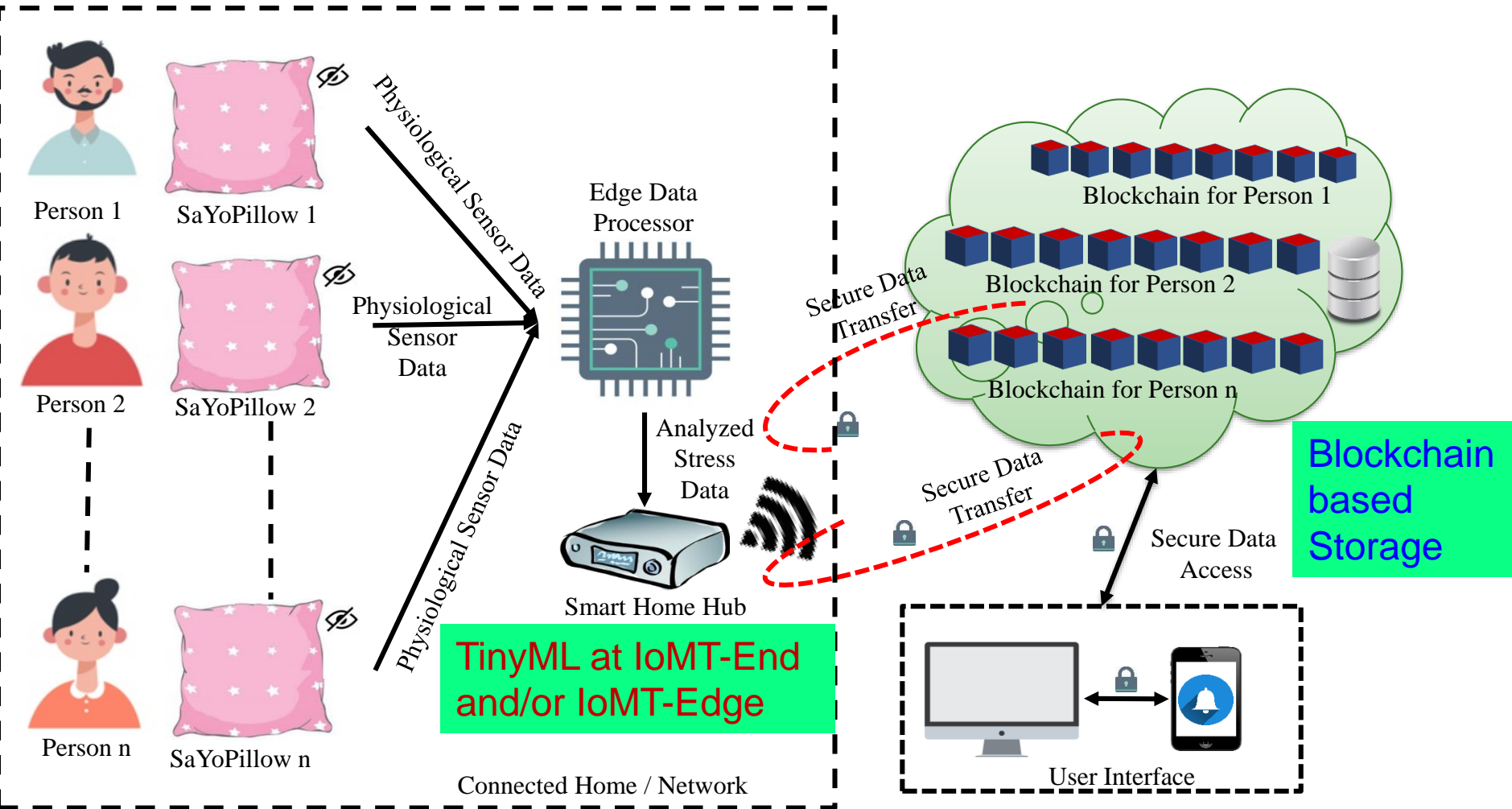
## Edge Security/Intelligence

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

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

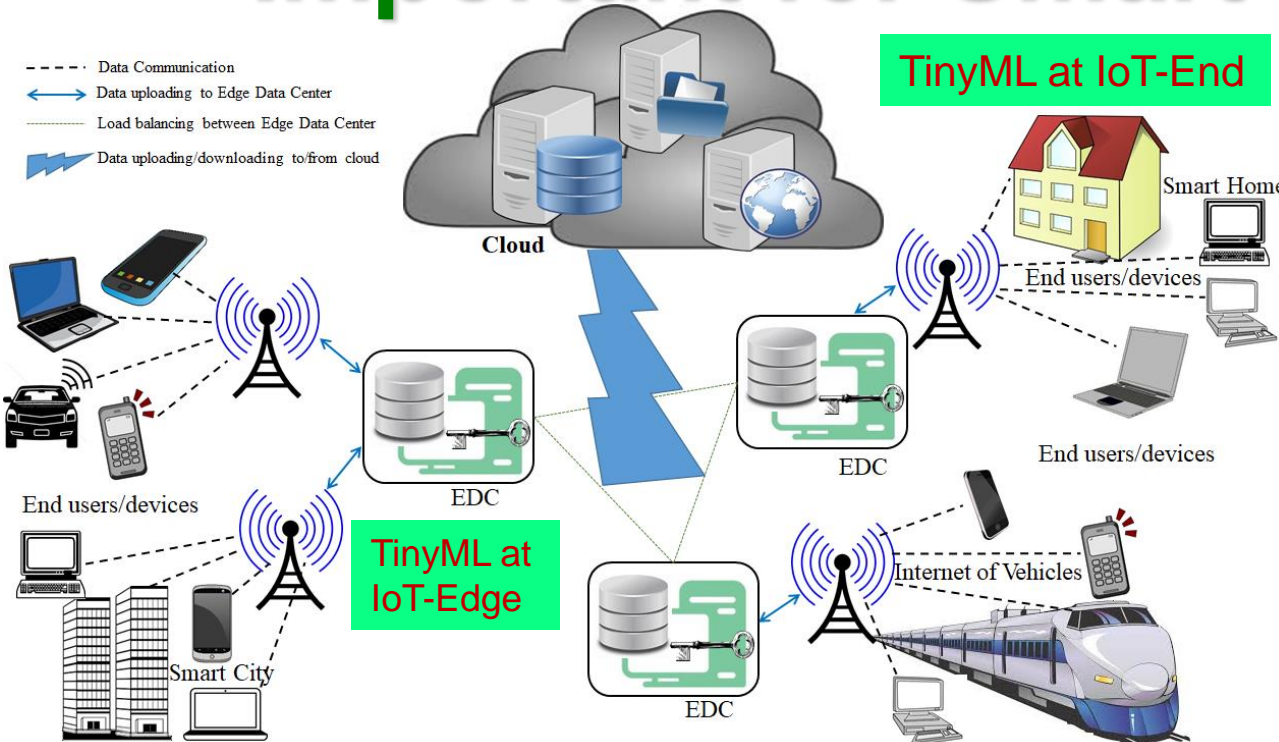
**TinyML at End and/or Edge is key for smart villages and smart cities**

# Our Smart-Yoga Pillow (SaYoPillow)

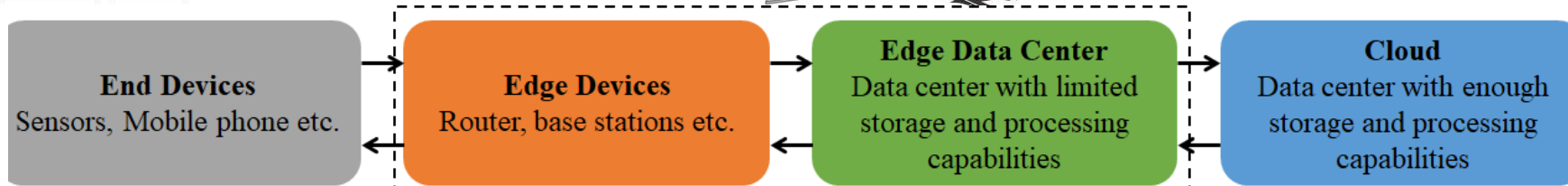


Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", *arXiv Computer Science*, arXiv:2007.07377, July 2020, 38-pages.

# Collaborative Edge Computing Can Important 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.



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 Magazine*, Volume 56, Issue 5, May 2018, pp. 60--65.

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# Suggestions for collaboration

- Potential collaboration modes
  - One to one faculty interactions
  - Serving on Ph.D. students' committee
  - Mentoring junior faculty
  - Indo-USA Science and Technology Forum (IUSSTF)
  - Participating as expert in India Govt. funding
- From my experience **what works**
  - One to one faculty interactions
- From my experience **what are the challenges**
  - Funding to compensate USA faculty time