Smart Cities – Are We There Yet?

ICCE 2019 Keynote

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Talk - Outline

- Smarty City Drivers
- Smarty City Technologies & Components
- Challenges and Research on Smarty Cities
- Design and Operation of Smarty Cities
- Tools and Solutions for Smarty Cities
- Standards for Smarty Cities
- Initiatives on Smarty Cities
- Conclusions and Future Directions

Drivers

Population Trend – Urban Migration

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

Source: http://www.urbangateway.org

Issues Challenging Sustainability

- Pollution

- Water crisis

- Energy crisis

- Traffic

The Problem

- Uncontrolled growth of urban population
- Limited natural and man-made resources

Source: https://humanitycollege.org

The Solution – Smart Cities

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

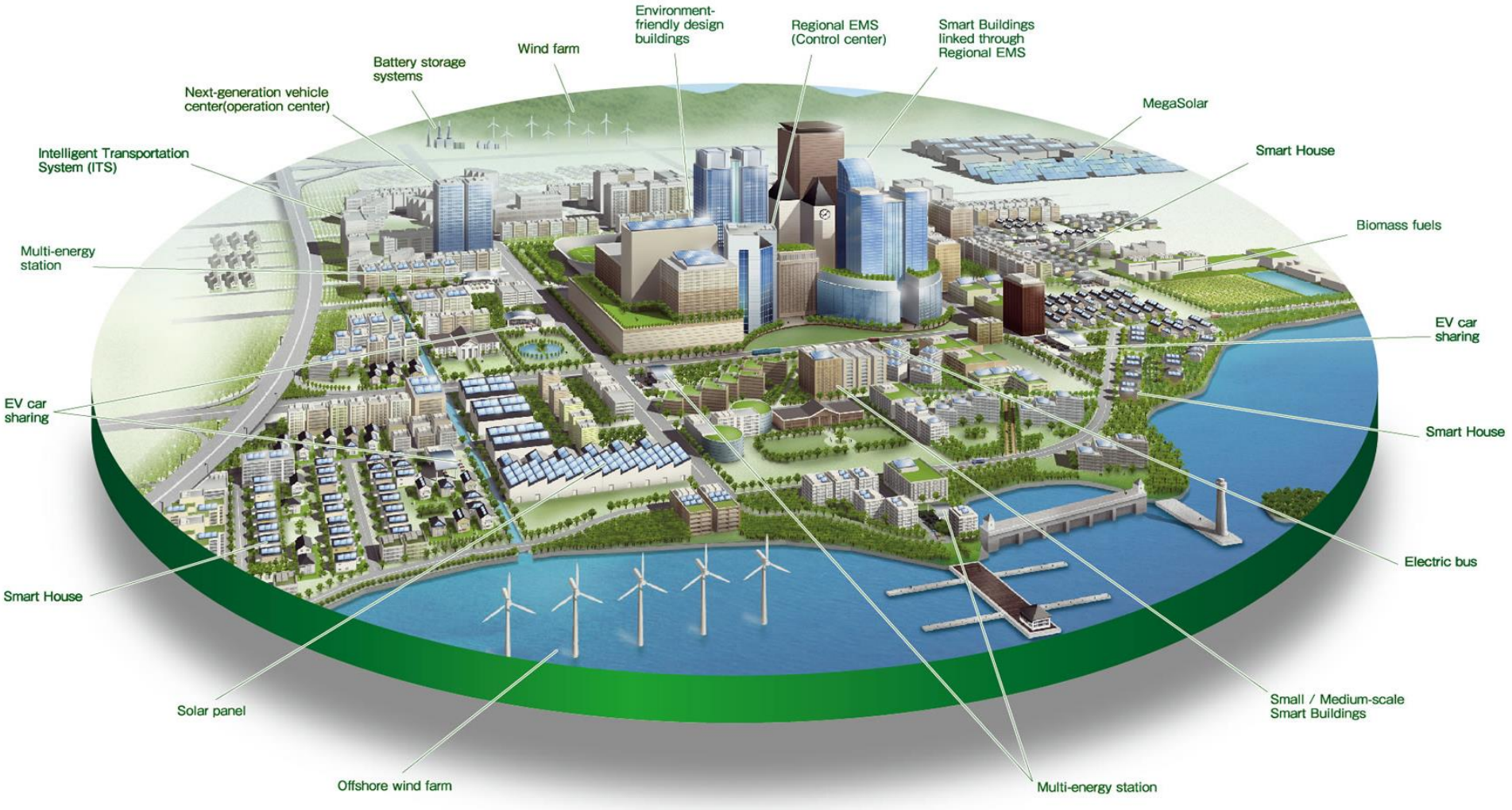
At Different Levels:
- Smart Village
- Smart State
- Smart Country

Other Drivers …

- Managing vital services
  - Waste management
  - Traffic management
  - Healthcare
  - Crime prevention
- Making the city competitive
  - Investment
  - Tourism
- Technology push
  - IoT, CPS, Sensor, Wireless

Source: Sangiovanni-Vincentelli 2016, ISC2 2016

Smart Cities – A Broad View



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

Smart Cities - Formal Definition

- Definition - 1: 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".

- Definition - 2: "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects".

Source: Mohanty 2016, CE Magazine July 2016

Cities - History

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

-- Merriam-Webster

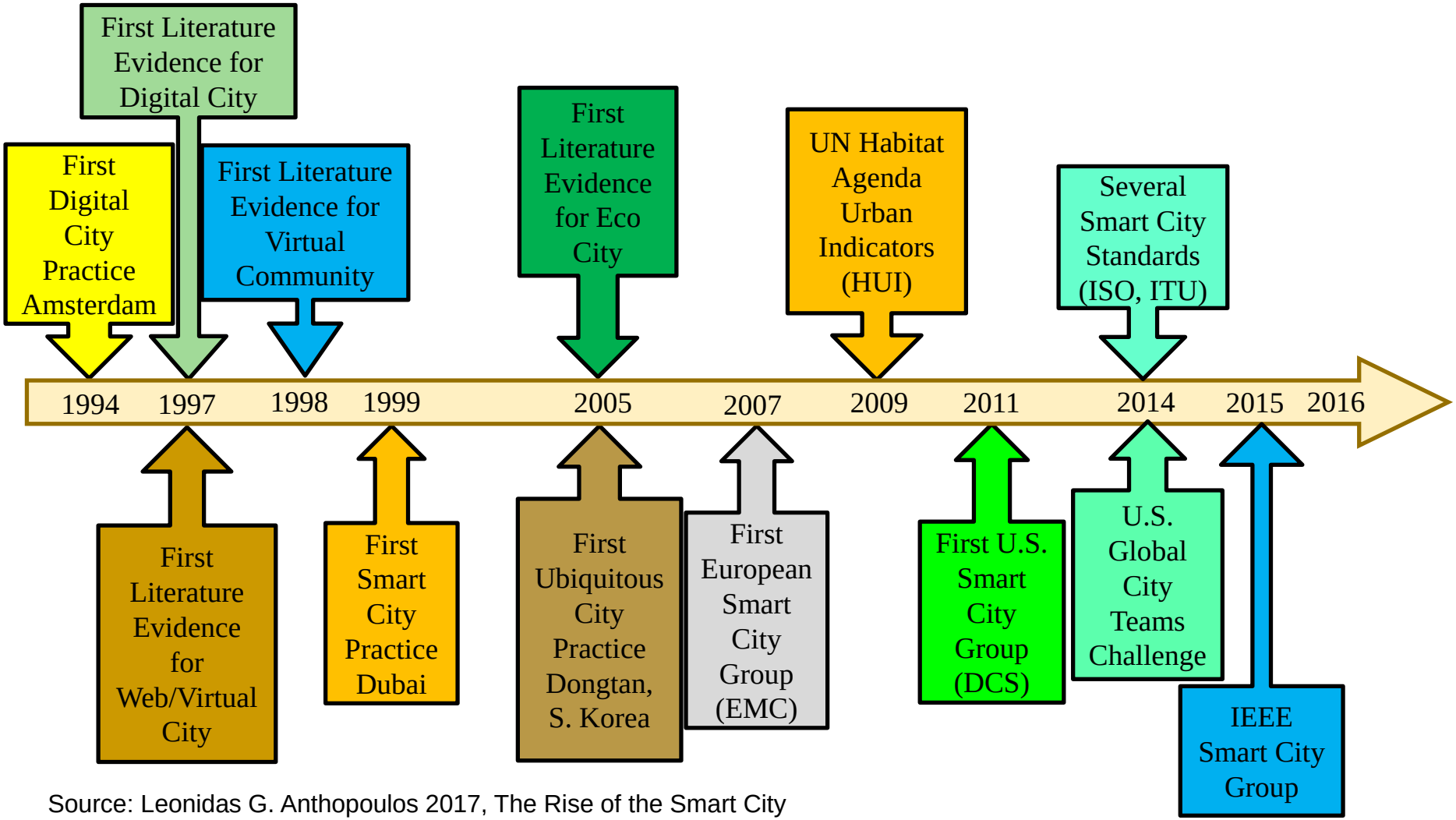
"First true cities arose in Mesopotamia, and in the Indus and Nile valleys sometime around 3500 BCE."

-- LeGates and Stout 2016, The City Reader

Hippodamus of Miletus, 498-408 BC, the first Greek city planner, considered as "the Father of European Urban Planning".

-- Edward Glaeser - 2011, Triumph of the City

Smart Cities - History



Source: Leonidas G. Anthopoulos 2017, The Rise of the Smart City

Technologies

Smart Cities

Smart Cities ←

Regular Cities

+ Information and Communication Technology (ICT)

+ Smart Components

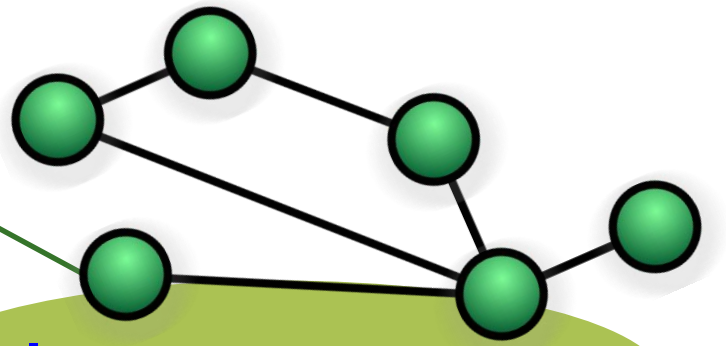
+ Smart Technologies

Smart Cities - 3 Is

Instrumentation

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

Smart Cities



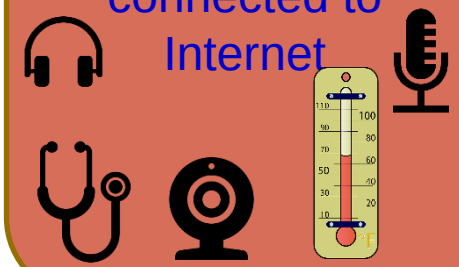
Intelligence

Interconnection

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

Internet of Things (IoT) – Concept

Things
Sensors/actuators with IP address that can be connected to Internet



Local Network
Can be wired or wireless: LAN, Body Area Network (BAN), Personal Area Network (PAN), Controller Area Network (CAN)

Cloud Services
Data either sent to or received from cloud (e.g. machine activation, workflow, and analytics)

Global Network
Connecting bridge between the local network, cloud services and connected consumer devices

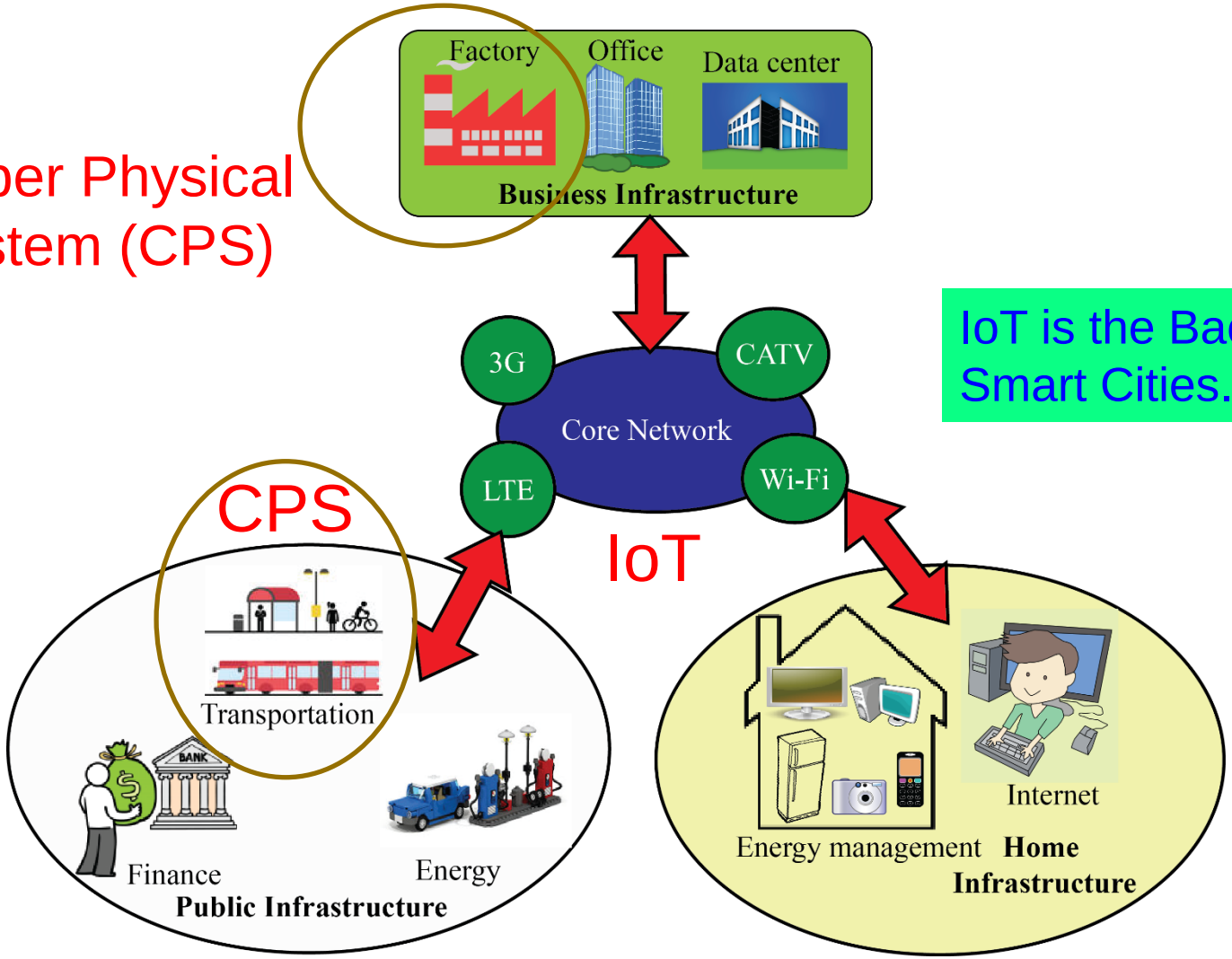
Connected Consumer Electronics
Smart phones, devices, cars, wearables which are connected to the Things

Overall architecture:
- A configurable dynamic global network of networks
- Systems-of-Systems

Source: Mohanty ICIT 2017 Keynote

Smart Infrastructure

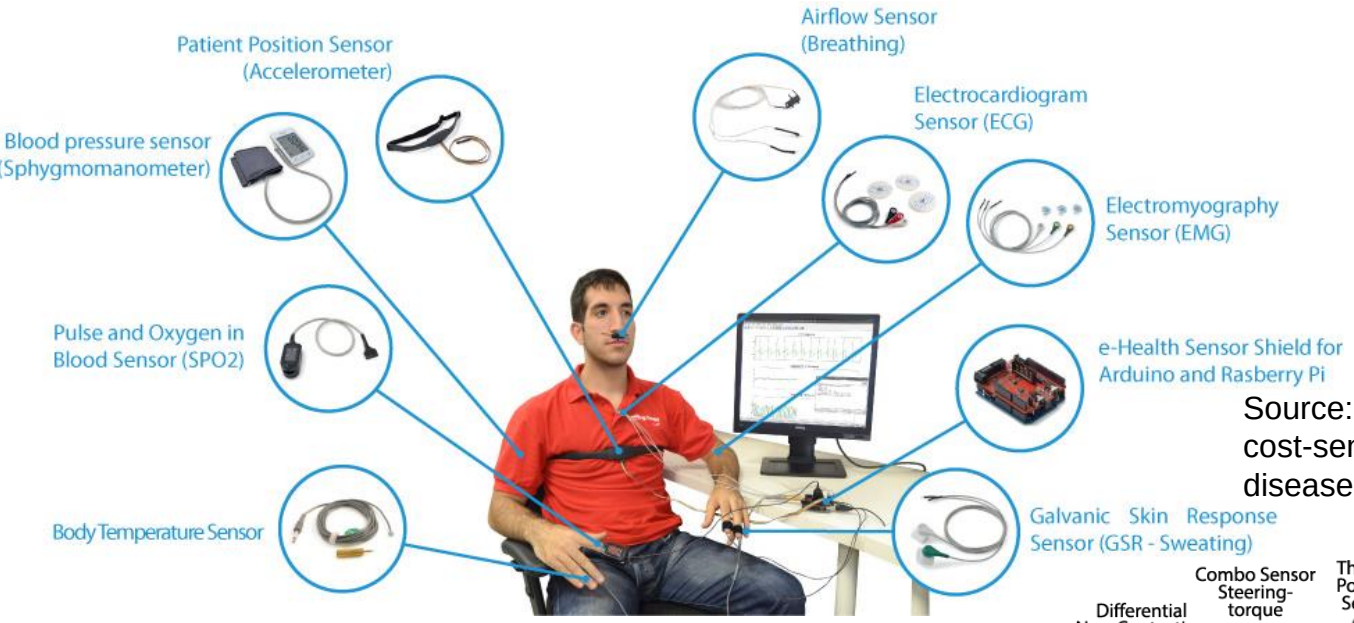
Cyber Physical System (CPS)



IoT is the Backbone Smart Cities.

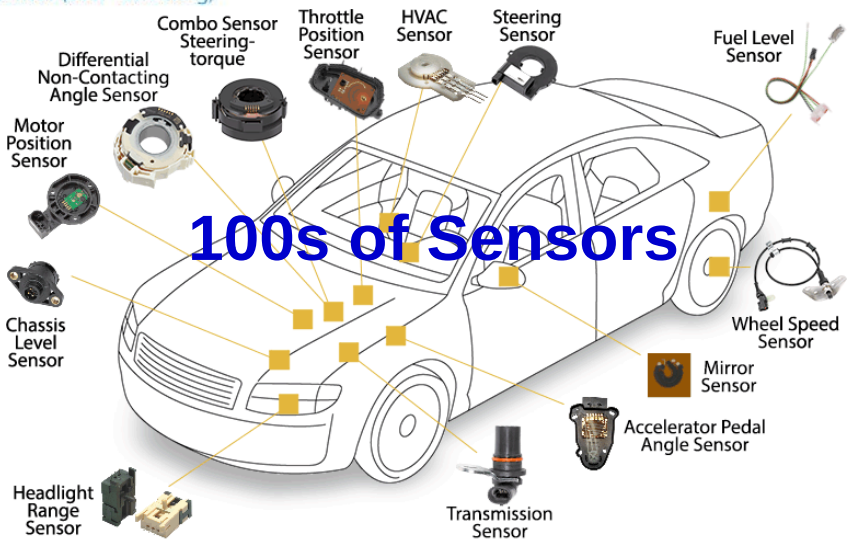
Source: Mohanty 2016, CE Magazine July 2016

Sensor Technology – Variety of Them



Source: http://www.libelium.com/e-health-low-cost-sensors-for-early-detection-of-childhood-disease-inspire-project-hope/

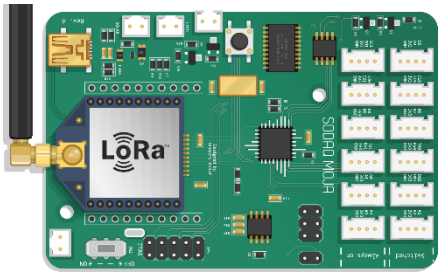
Thing ← Sensor
+ Device with its own IP address



Communications – Energy, Data Rate, and Range Tradeoffs

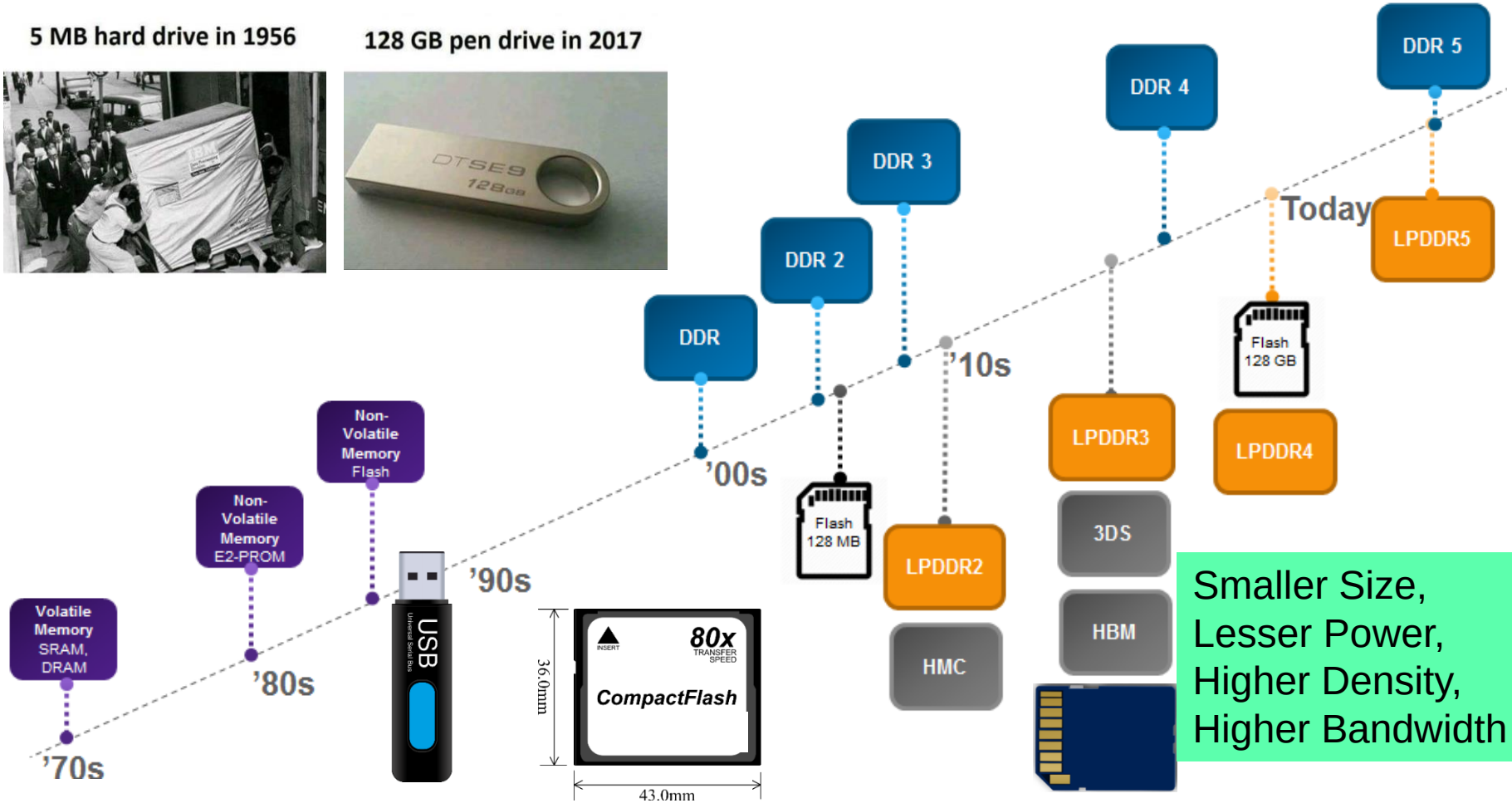
- LoRa: Long Range, low-powered, low-bandwidth, IoT communications as compared to 5G or Bluetooth.
- SigFox: SigFox utilizes an ultra-narrowband wide-reaching signal that can pass through solid objects.

Technology	Protocol	Maximum Data Rate	Coverage Range
ZigBee	ZigBee Pro	250 kbps	1 mile
WLAN	802.11x	2-600 Mbps	0.06 mile
Cellular	5G	1 Gbps	Short - Medium
LoRa	LoRa	50 kbps	3-12 miles
SigFox	SigFox	1 kbps	6-30 miles



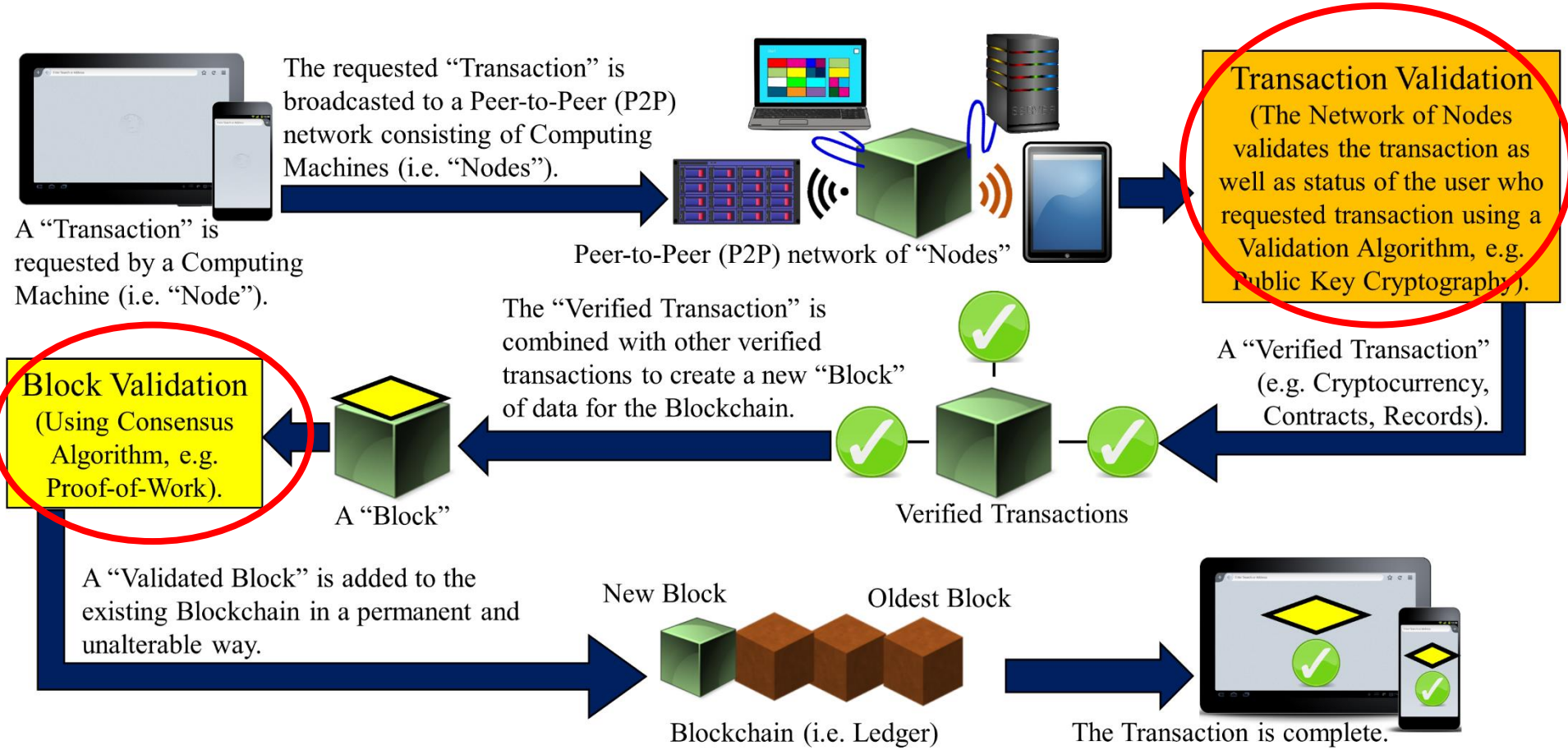
Source: Mohanty iSES Keynote 2018

Memory Technology - Cheaper, Larger, Faster, Energy-Efficient



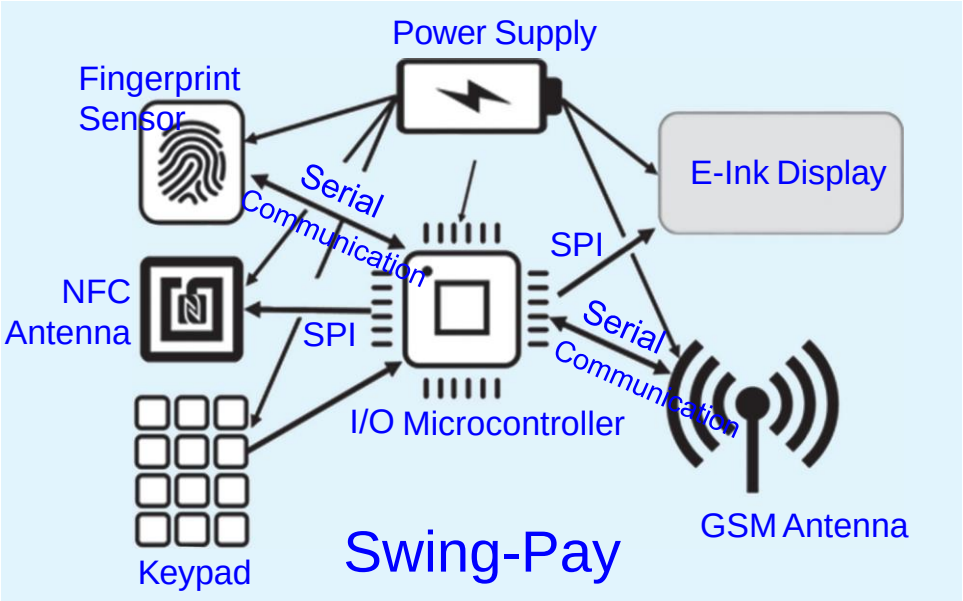
Source: https://blogs.synopsys.com/vip-central/2015/12/01/keeping-pace-with-memory-technology-using-advanced-verification/

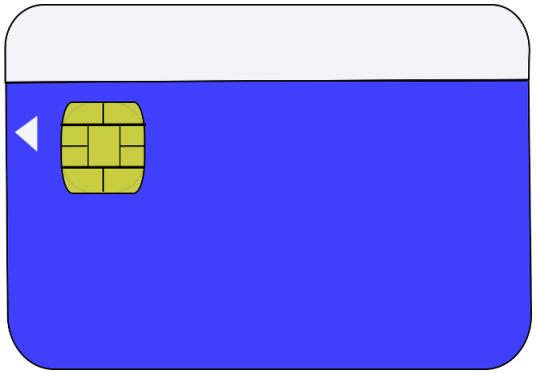
Blockchain Technology



Source: Puthal, Mohanty 2018, CE Magazine July 2018

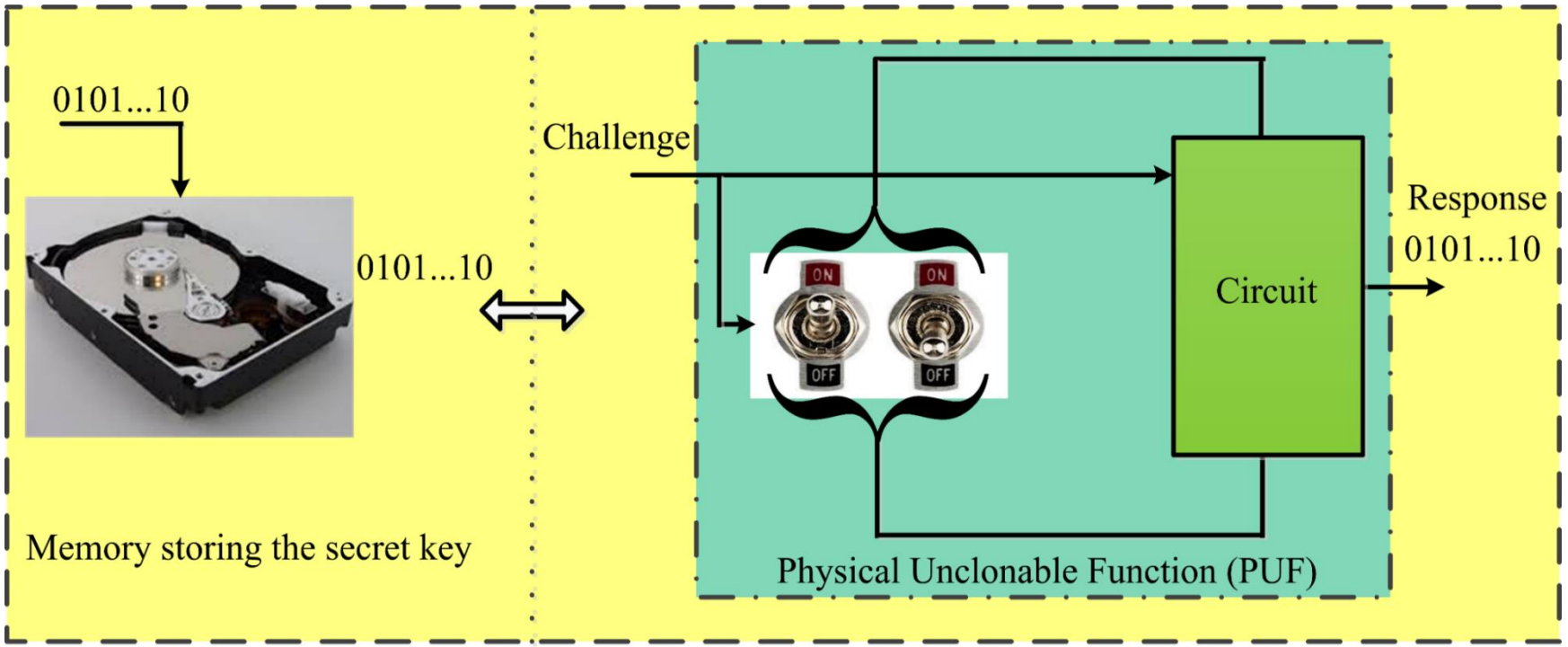
Cashless Payment Technology – A Biometric based Security Example





Source: Majumder, Mohanty 2017, CE Magazine Jan 2017

Security Primitives - PUF



PUFs don't store keys in digital memory, rather derive a key based on the physical characteristics of the hardware; thus secure.

Source: Mohanty 2017, IEEE Potentials Nov-Dec 2017

Artificial Intelligence Technology

Source: http://transmitter.ieee.org/impact-aimachine-learning-iot-various-industries/

Machine Learning

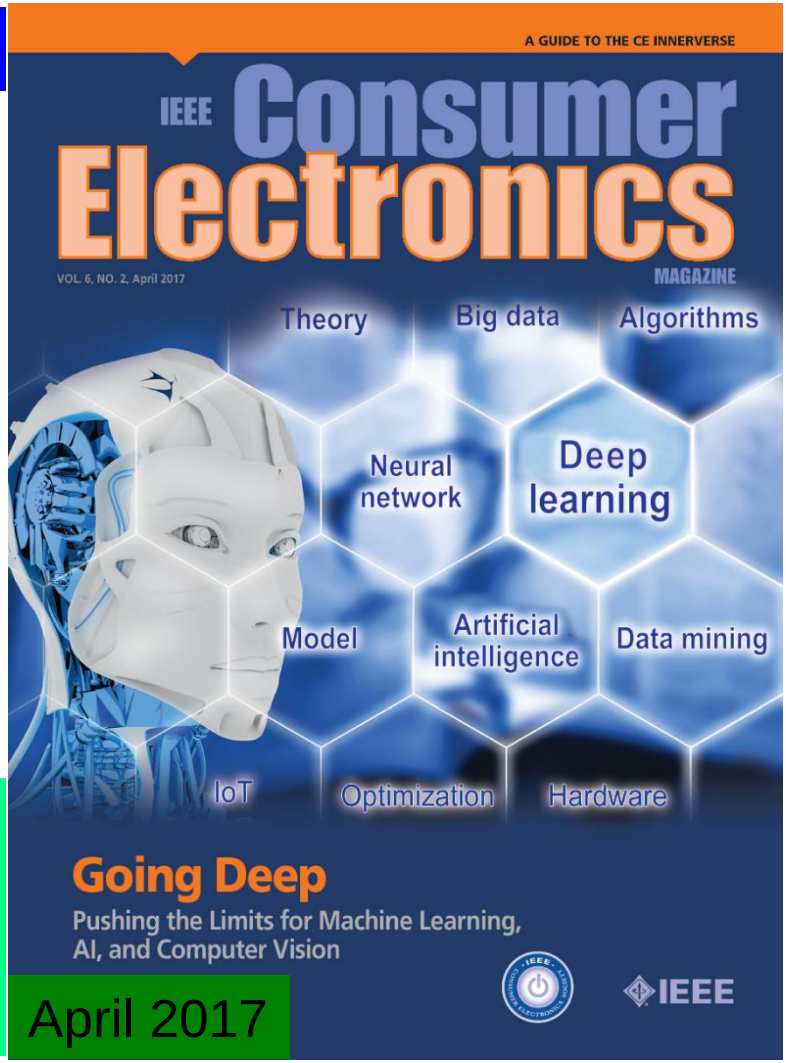
Deep Learning

Tensor Processing Unit (TPU)

Source: https://fossbytes.com/googles-home-made-ai-processor-is-30x-faster-than-cpus-and-gpus/

Smart City Use:

- Better analytics
- Better decision
- Faster response



Virtual and Augmented Reality Technology

Virtual Reality

Smart City Use:

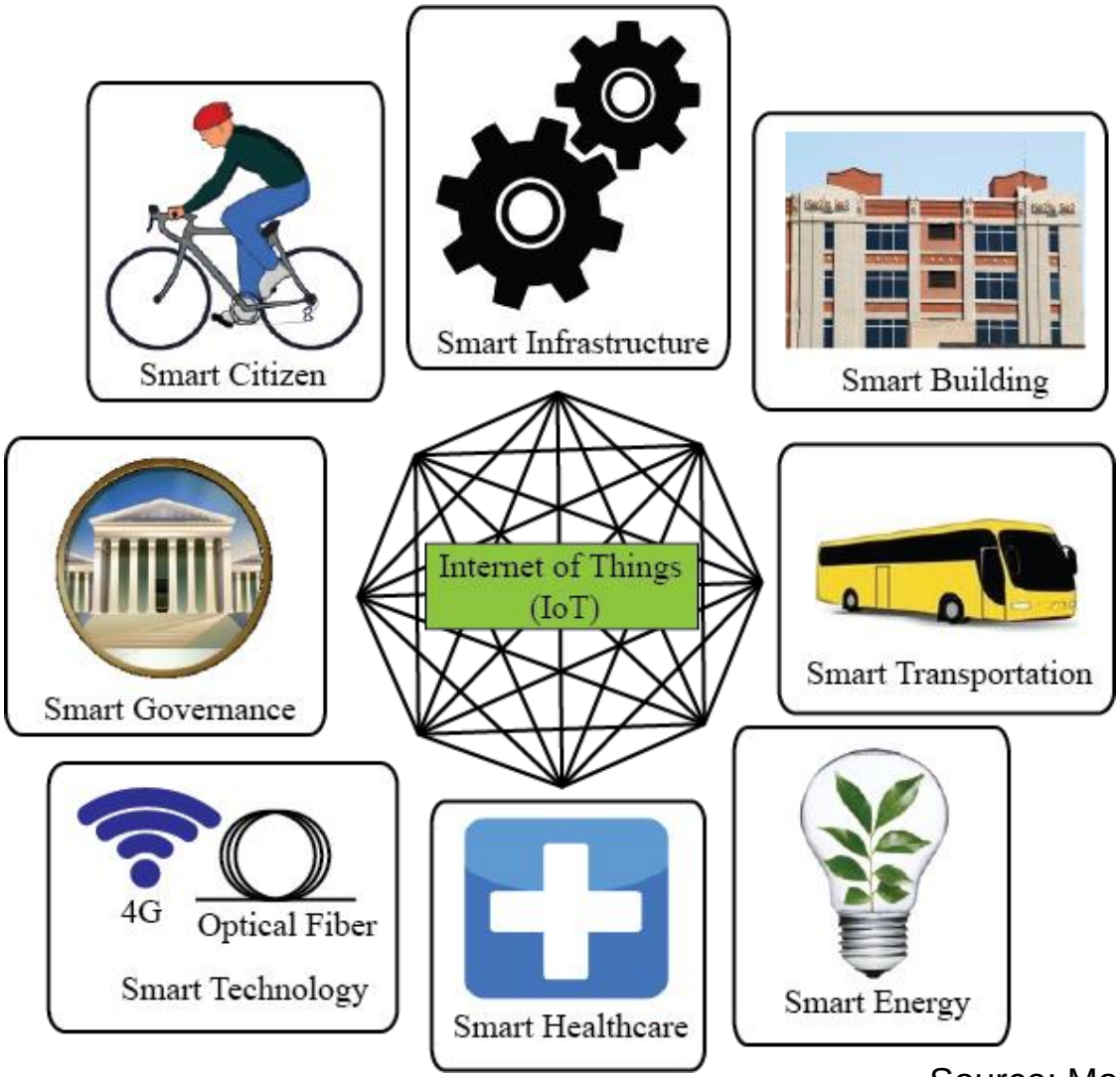
- Healthcare - Therapy, Surgery
- Tourism - Recreate History
- Entertainment - Movies

Augmented Reality

Source: http://www.prweb.com/releases/2011/5/prweb8462670.htm

Components

Smart Cities - Components



A smart city can have one or more of the smart components.

Source: Mohanty 2016, CE Magazine July 2016

Smart Healthcare

Healthy Living

- Fitness Tracking
- Disease Prevention
- Food monitoring

Home Care

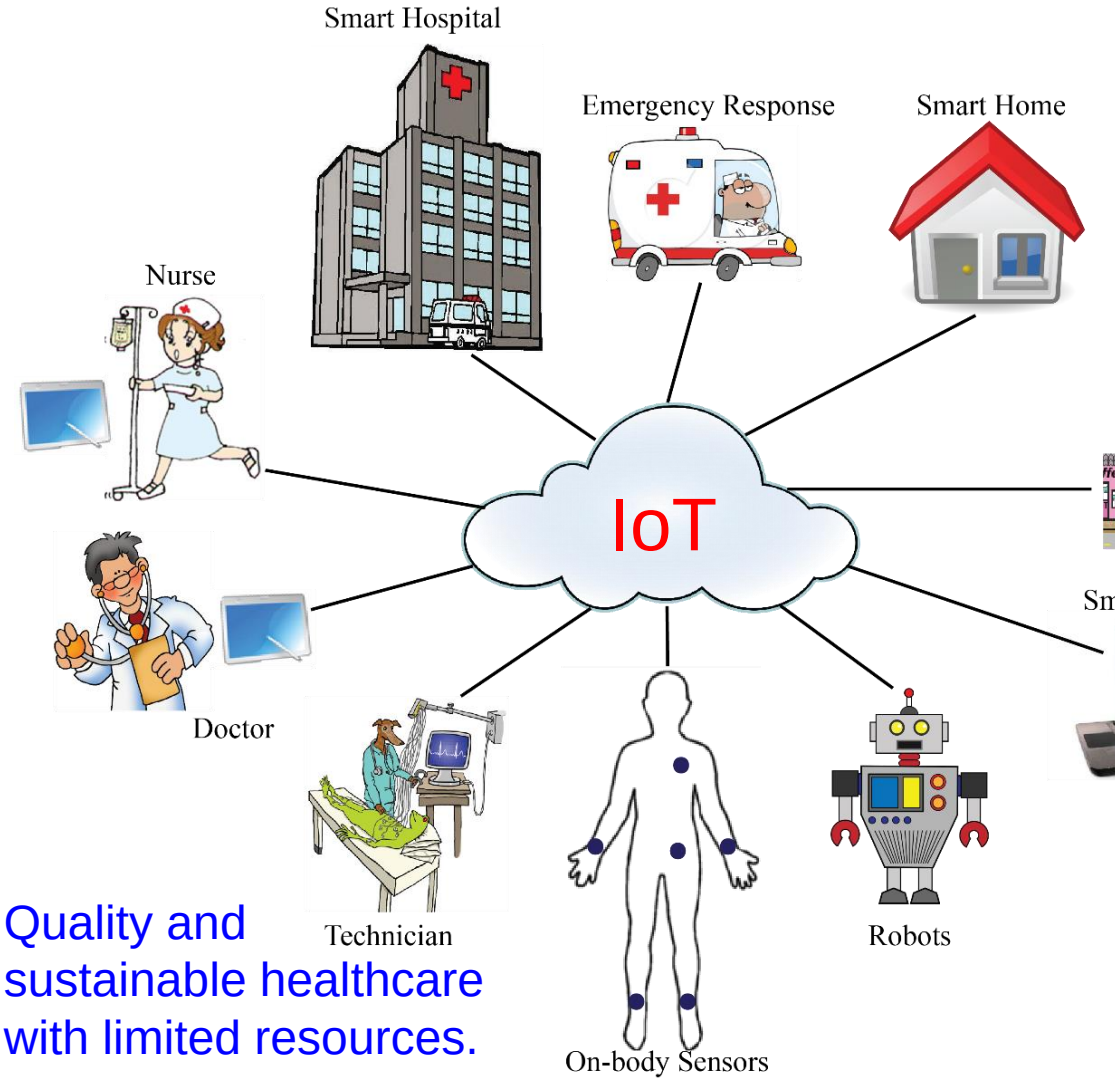
- Mobile health
- Telemedicine
- Self-management
- Assisted Living

Acute care

- Hospital
- Specialty clinic
- Nursing Home
- Community Hospital

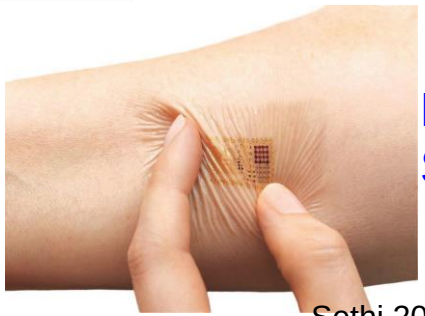
Source: Mohanty 2018, CE Magazine January 2018

Smart Healthcare



Fitness Trackers

Headband with Embedded Neurosensors



Embedded Skin Patches

Quality and sustainable healthcare with limited resources.

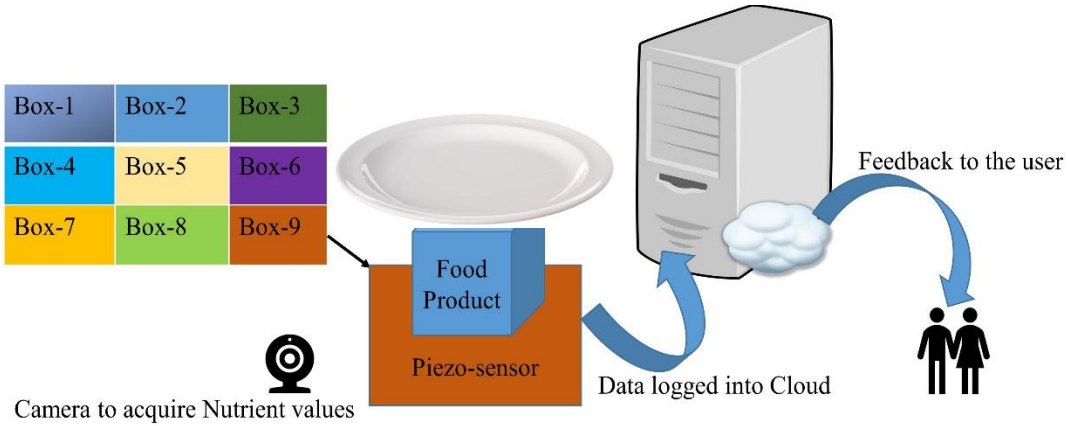
Source: Mohanty 2016, CE Magazine July 2016

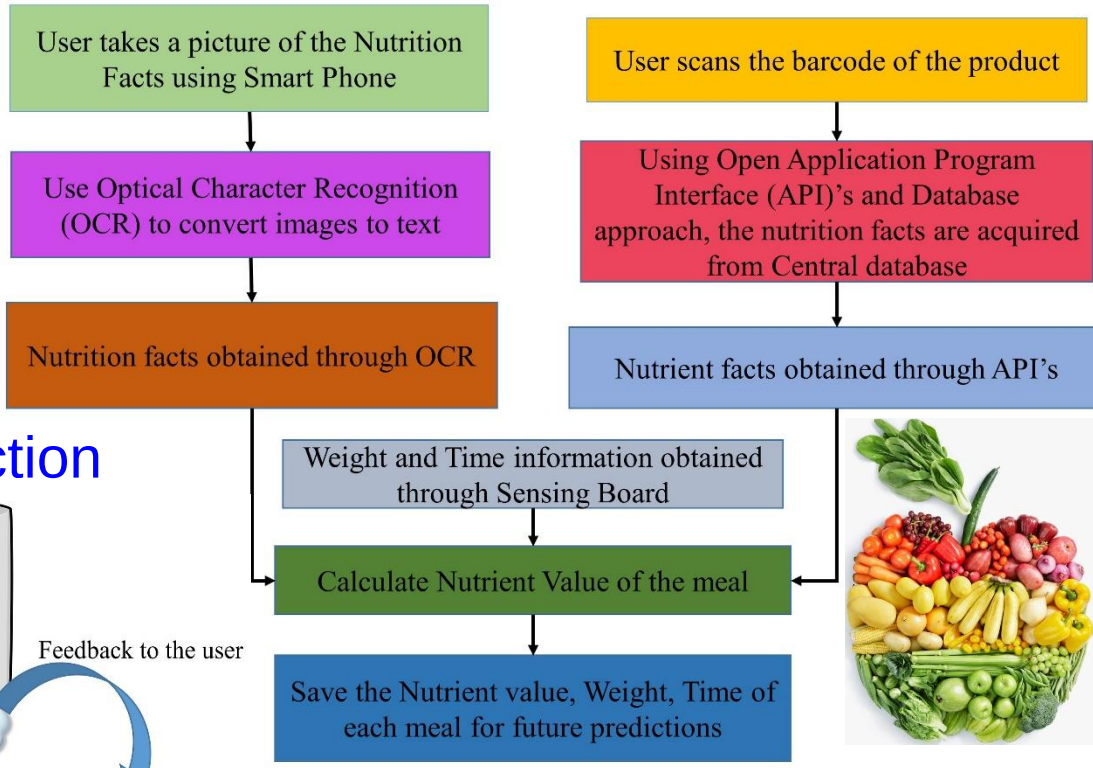
Sethi 2017: JECE 2017

Smart Healthcare - Smart-Log

Automated Food intake Monitoring and Diet Prediction System

- Smart plate
- Data acquisition using mobile
- ML based Future Meal Prediction





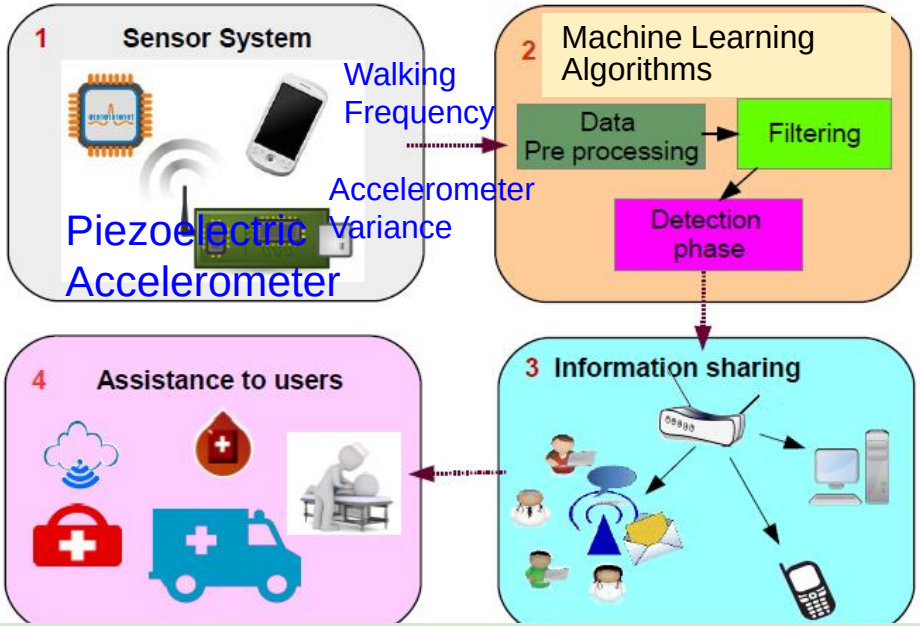
USDA National Nutrient Database for Standard Reference is used for nutrient values of 8791 items.

Research Works	Food Recognition Method	Efficiency (%)
This Work	Mapping nutrition facts to a database	98.4

8172 user instances were considered

Source: Mohanty ICCE 2018

Smart Healthcare - Smart-Walk



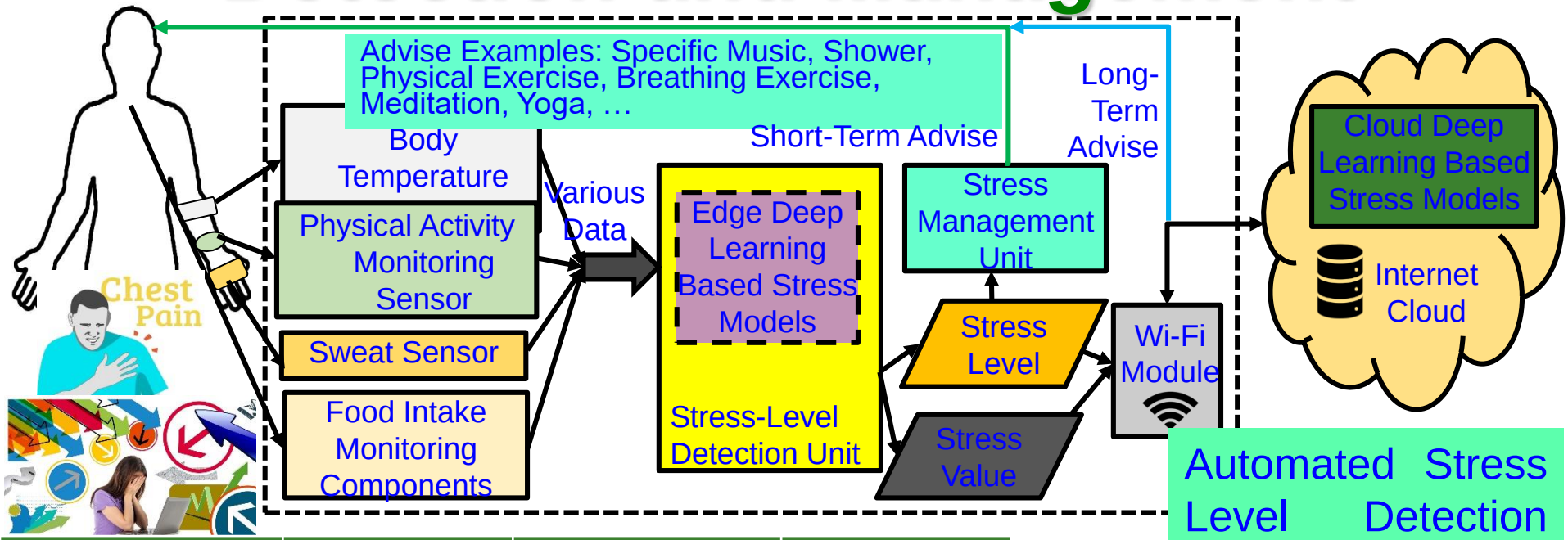
Automated Physiological Monitoring System

10291 Instances Grouped Under 6 Activities - Kaggle

Research Works	Method	Features considered	Activities	Accuracy (%)
This Work	Adaptive algorithm based on feature extraction (WEKA)	Step detection and Step length estimation	Walking, sitting, standing, etc.	97.9

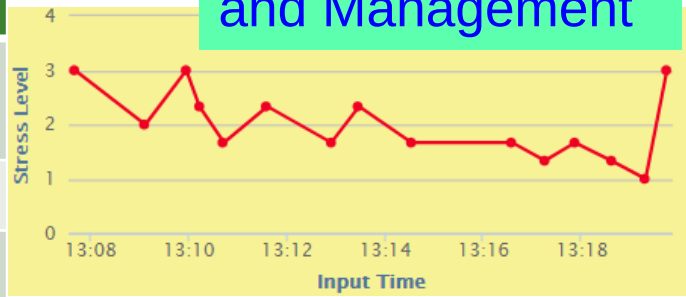
Source: Mohanty ICCE 2018

Smart Healthcare – Stress Level Detection and Management



Sensor	Low Stress	Normal Stress	High Stress
Accelerometer (steps/min)	0-75	75-100	101-200
Humidity (RH%)	27-65	66-91	91-120
Temperature ℉	98-100	90-97	80-90

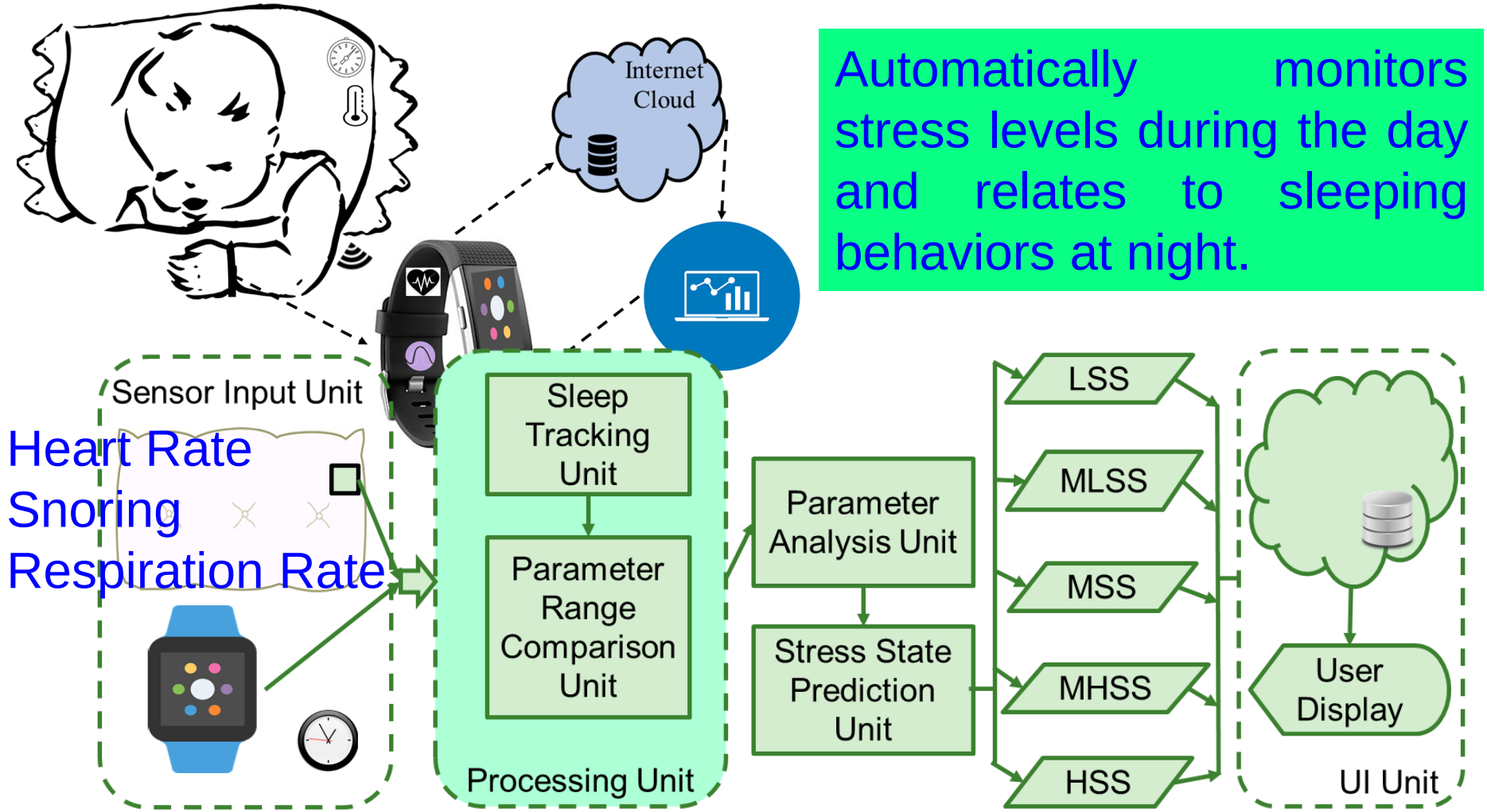
Automated Stress Level Detection and Management



Source: Mohanty iSES 2018 and Mohanty ICCE 2019

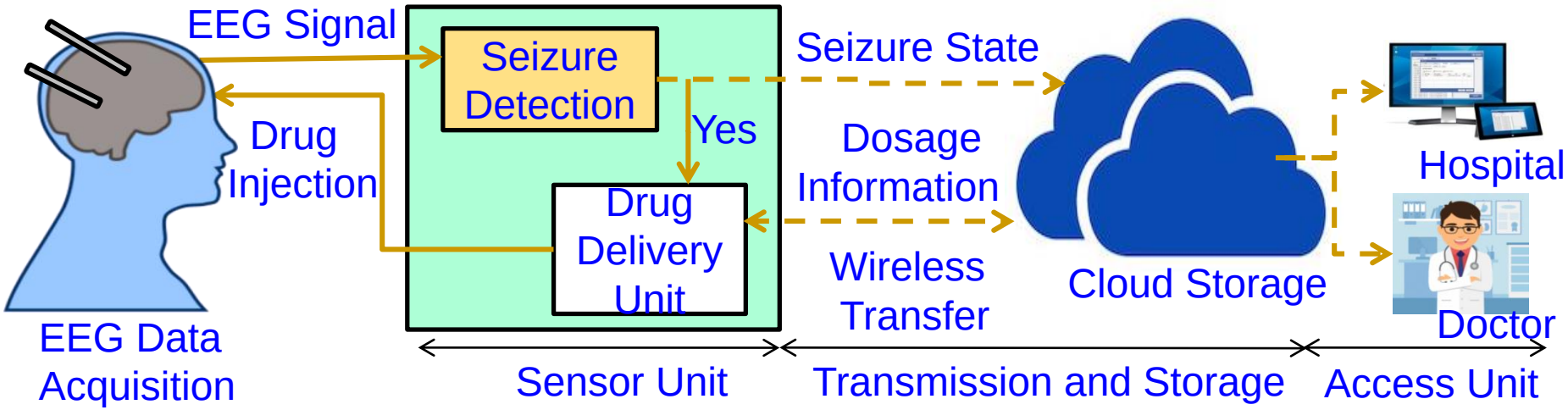
Smart Healthcare – Smart-Pillow

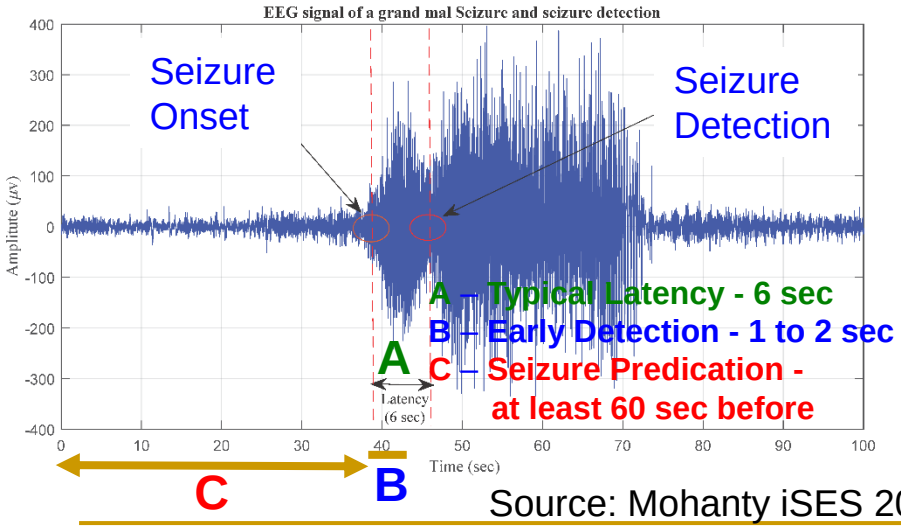
Automatically monitors stress levels during the day and relates to sleeping behaviors at night.



Source: Mohanty iSES 2018: "Smart-Pillow: An IoT based Device for Stress Detection Considering Sleeping Habits", in *Proc. of 4th IEEE International Symposium on Smart Electronic Systems (iSES)* 2018.

Smart Healthcare – Seizure Detection and Control



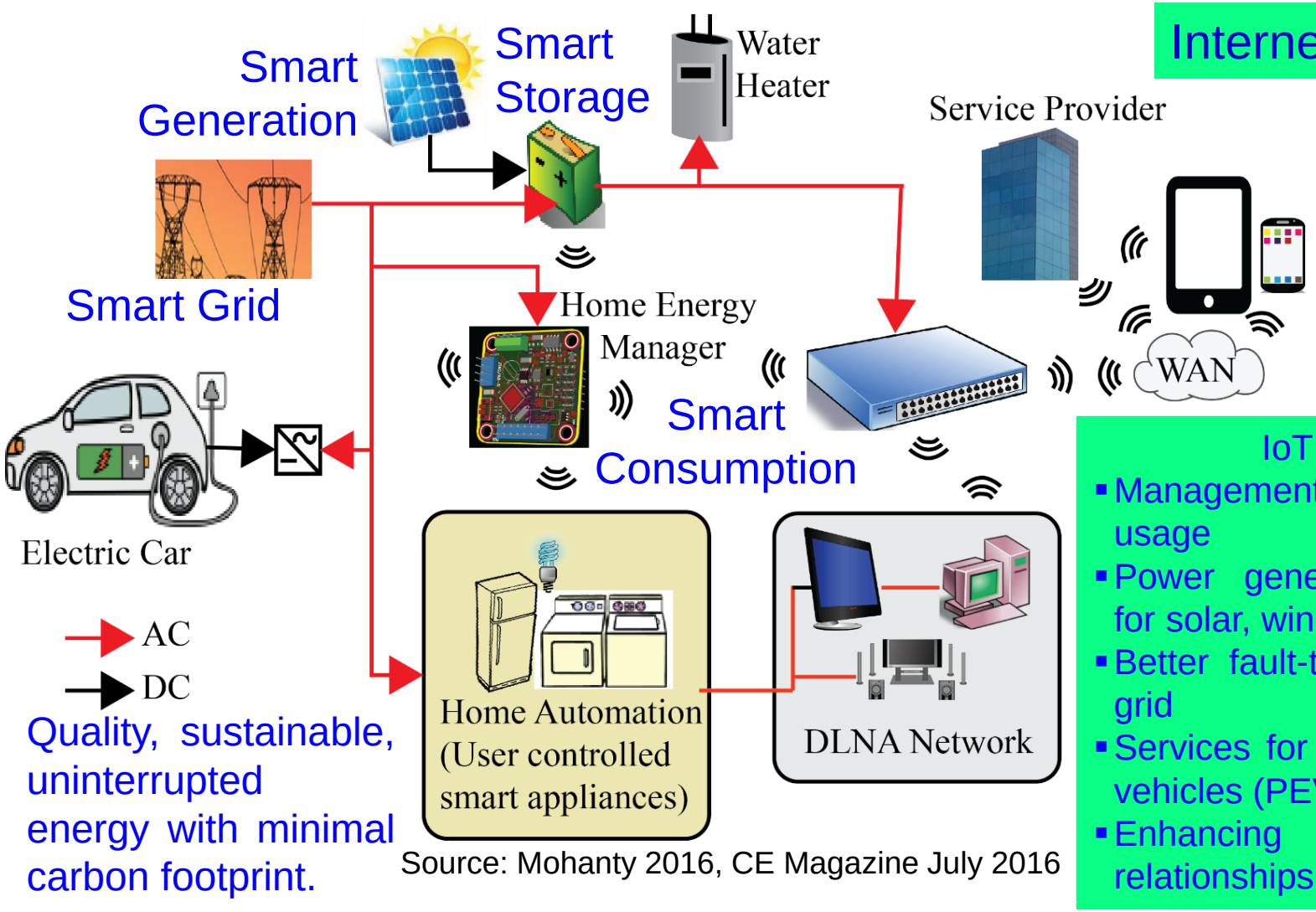


Automated Epileptic Seizure Detection and Control System

Cloud Vs Edge	Latency	Accuracy
Cloud-IoT based Detection	2.5 sec	98.65%
Edge-IoT based Detection	1.4 sec	98.65%

Source: Mohanty iSES 2018, IEEE Smart Cities 2018, and Mohanty ICCE 2019

Smart Energy



Quality, sustainable, uninterrupted energy with minimal carbon footprint.

Source: Mohanty 2016, CE Magazine July 2016

Internet of Energy

IoT Role:

- Management of energy usage
- Power generation dispatch for solar, wind, etc.
- Better fault-tolerance of the grid
- Services for plug-in electric vehicles (PEV)
- Enhancing consumer relationships

EV Charging System …

Mix-Energy-Source Electric Vehicle Charging System Design and its Impact on Indian Smart-distribution-grid

As Electric Vehicles become mainstream, chargers will play an important role in the success of this idea. This project will try to answer a part of this question by looking into the optimal EV charger suitable for Indian condition.

India

IIT Kanpur
Dr. Shantanu K. Mishra

IIT Kharagpur
Dr. Souvik Chattopadhyay

IIT BHU
Dr. Rajeev K. Singh

International

University of Texas
Dr. Saraju P. Mohanty

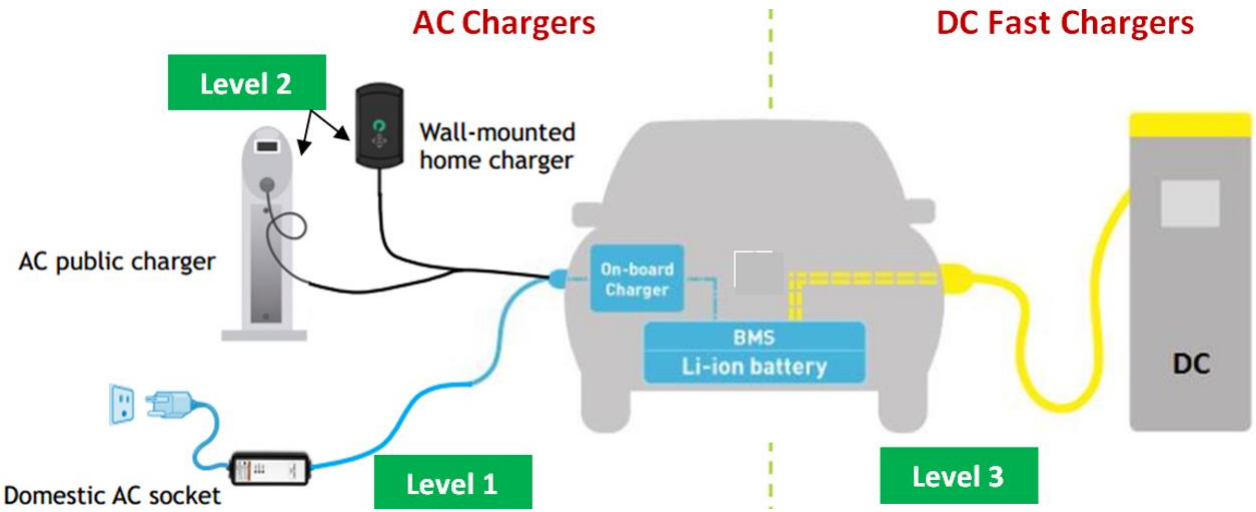
Virginia Tech
Dr. Khai D. T. Ngo

Concordia University
Dr. Akshay K. Rathore

Imperial College London
Dr. Balarko Chaudhuri

Source: Mission Innovation Project 2018-2021: Senior Personnel - Mohanty, PI - Mishra

EV Charging System

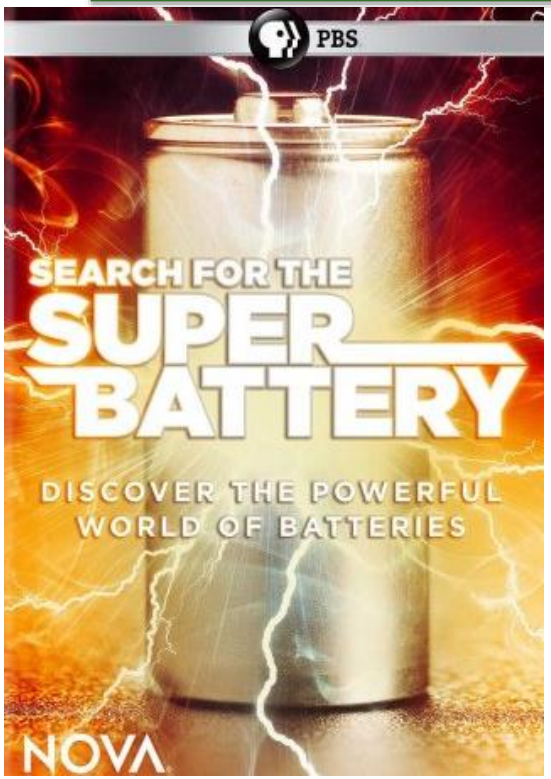


- Design and deployment of Level 2 (AC) and combined charging system
- Design and deployment of hybrid input DC Fast charger
  - (a) with multi-input source and single-output
  - (b) with 5-10 kW output EV charger for E-Rickshaws
  - (c) universal charger design and implementation
- Impact study of storage on EV chargers
- Study the impact of EV chargers on Indian distribution system
- Techno-economic study of EV chargers

Source: Mission Innovation Project 2018-2021: Senior Personnel - Mohanty, PI - Mishra

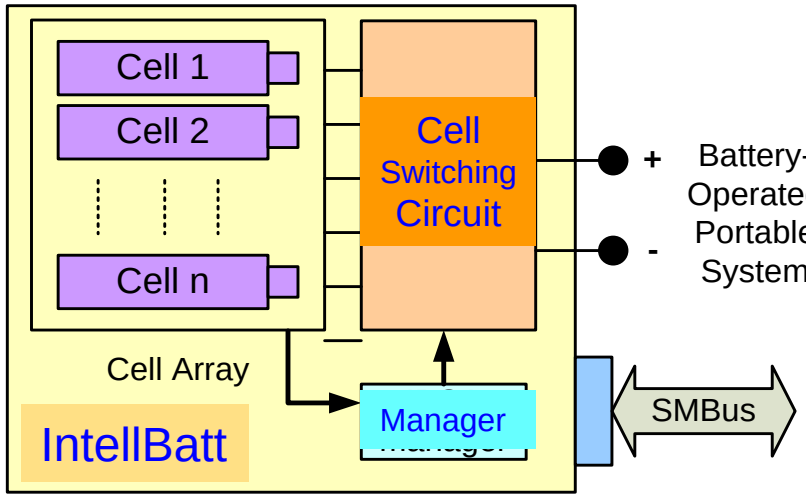
Energy Storage - High Capacity and Efficiency Needed

Battery	Conversion Efficiency
Li-ion	80% - 90%
Lead-Acid	50% - 92%
NiMH	66%



Source: Mohanty MAMI 2017 Keynote

Intelligent Battery

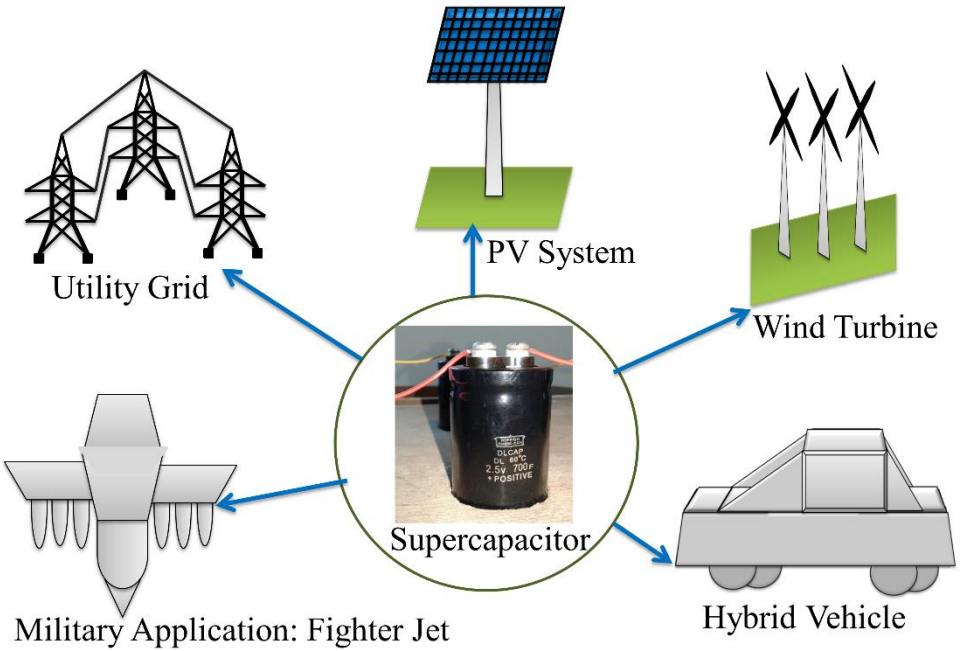


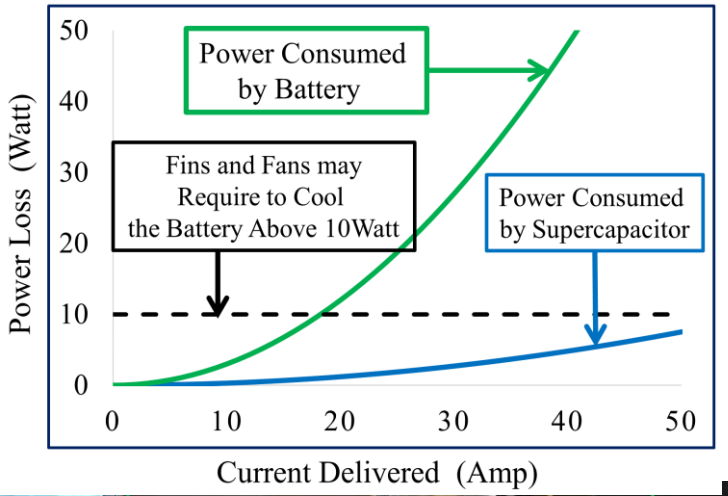
Mohanty 2010: IEEE Computer, March 2010
Mohanty 2018: ICCE 2018

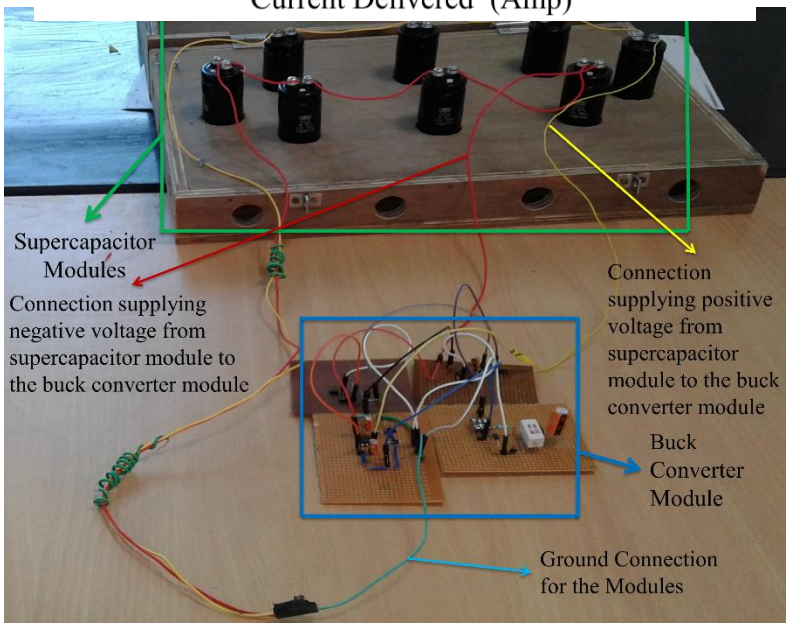
Lithium Polymer Battery

Supercapacitor

Supercapacitor based Power for CE

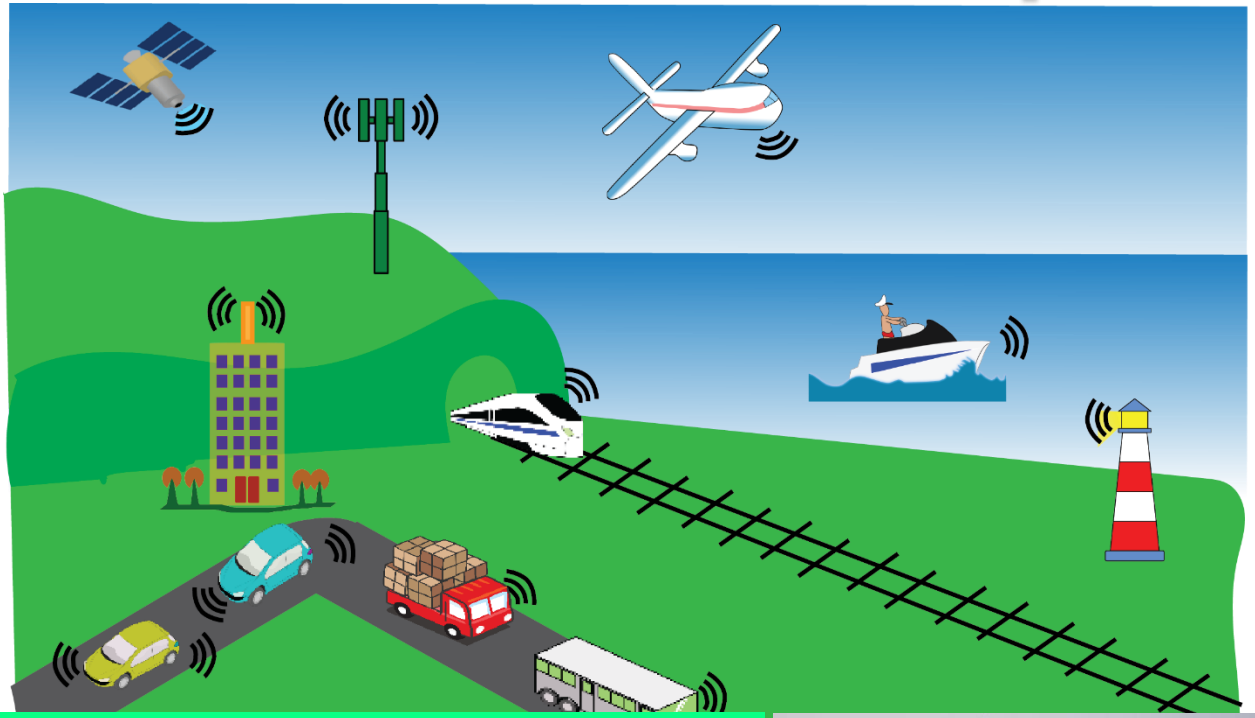






Source: Mohanty 2018, CEM Sep 2018

Smart Transportation



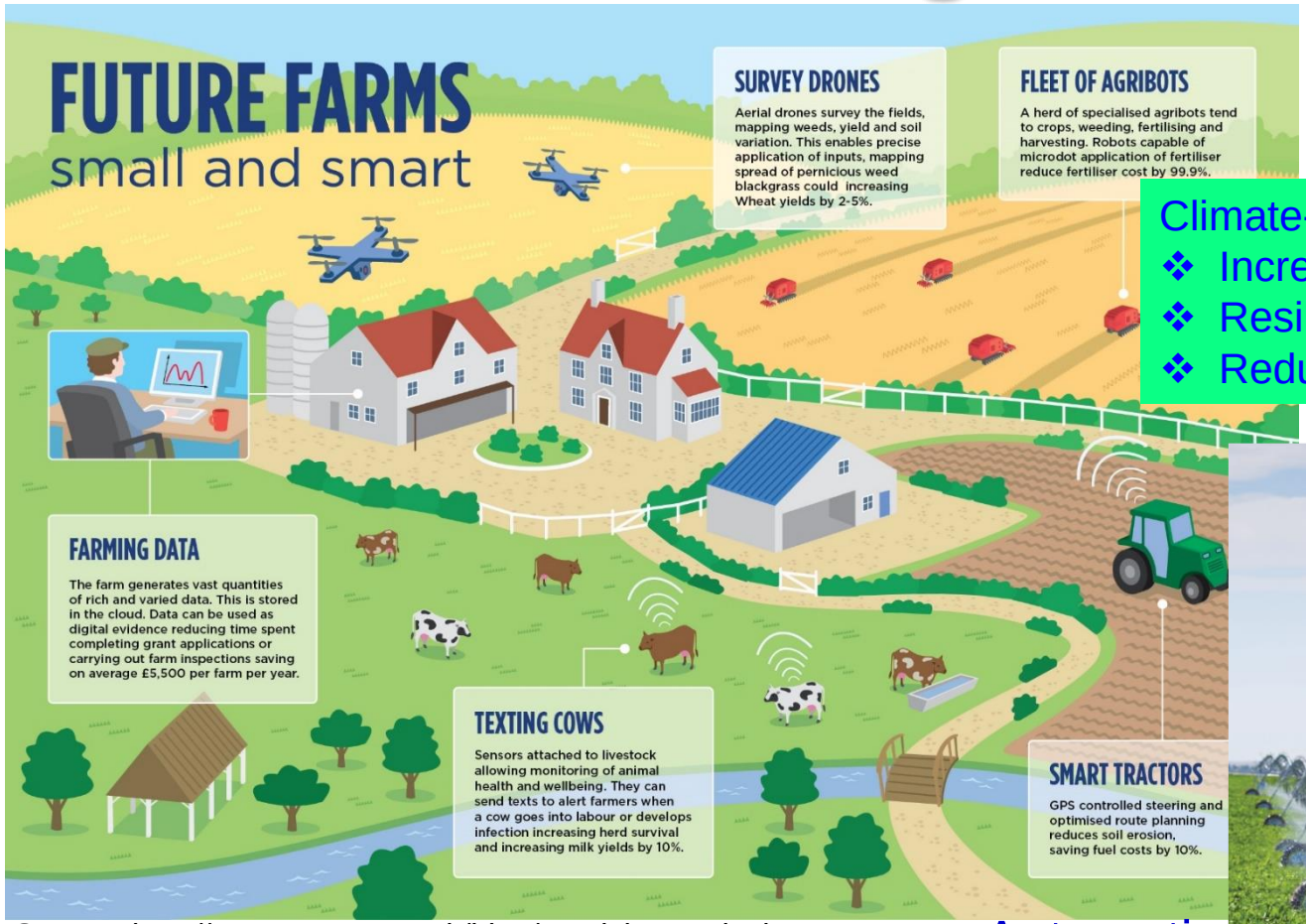
Smart Transportation Features:

- Autonomous driving
- Effective traffic management
- Real-time vehicle tracking
- Vehicle safety – Automatic brake
- Vehicle-to-Vehicle communication
- Better scheduling of train, aircraft
- Easy payment system

"The smart transportation system allows passengers to easily select different transportation options for lowest cost, shortest distance, or fastest route."

Source: Mohanty 2016, CE Magazine July 2016

Smart Agriculture



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

Climate-Smart Agriculture Objectives:

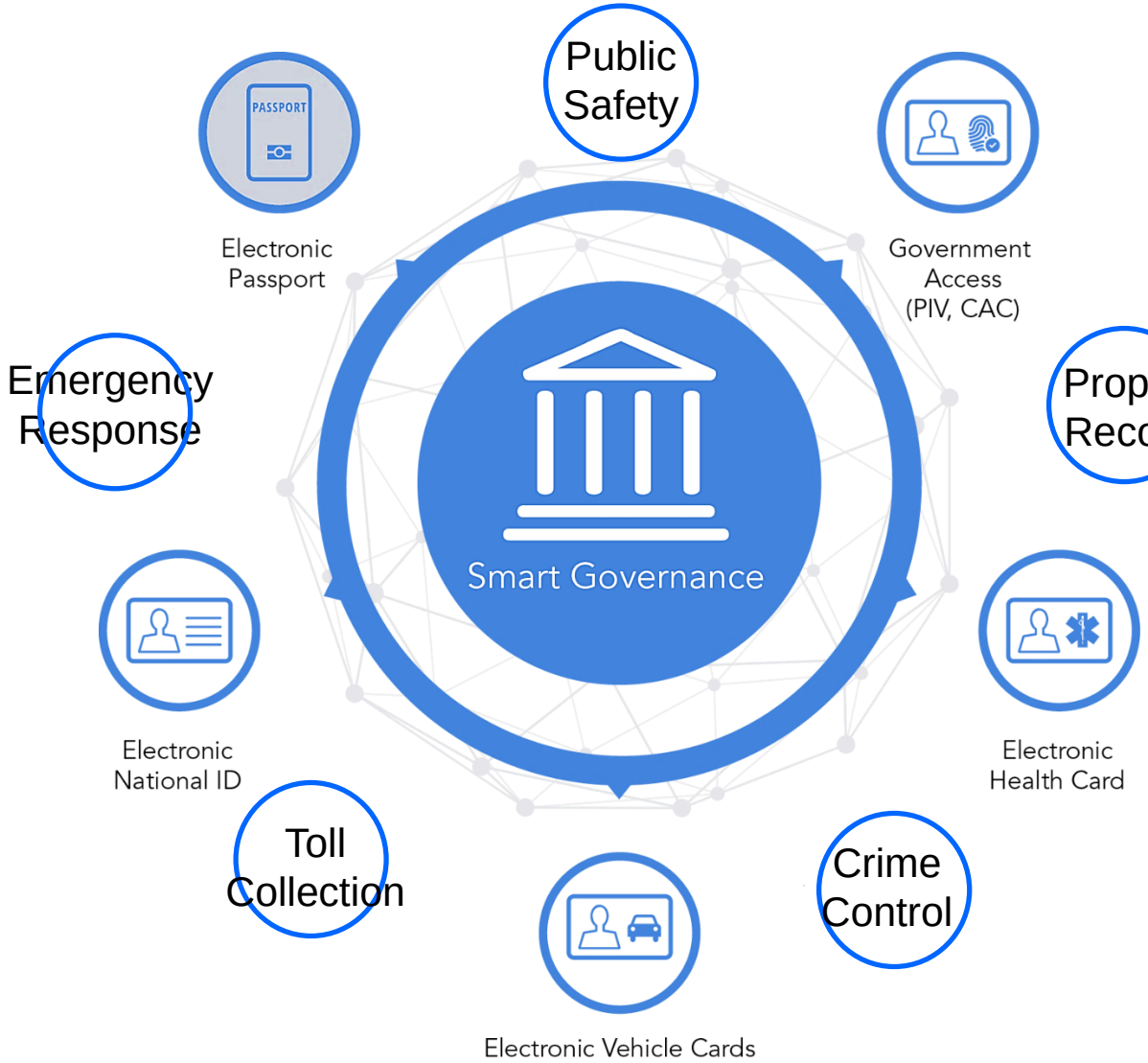
- Increasing agricultural productivity
- Resilience to climate change
- Reducing greenhouse gas

http://www.fao.org

Automatic Irrigation System

Source: Maurya 2017: CE Magazine July 2017

Smart Government



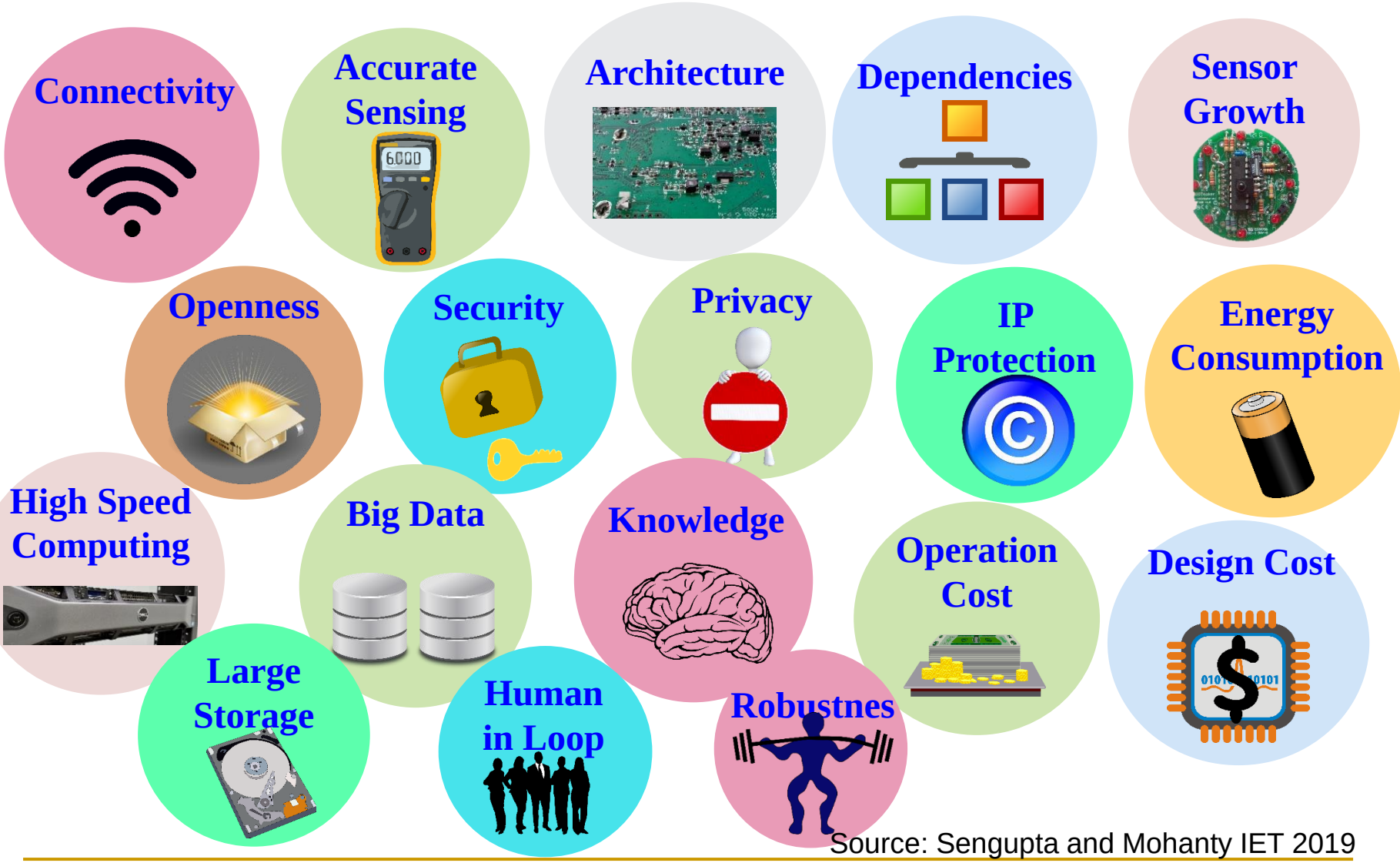
"Smart government integrates information, communication and operational technologies to planning, management and operations across multiple domains, process areas and jurisdictions to generate sustainable public value."

-- http://www.gartner.com

Source: http://www.nxp.com/applications/internet-of-things/secure-things/smart-government-identification:SMART-GOVERNANCE

Challenges and Research

CE/IoT – Selected Challenges



Source: Sengupta and Mohanty IET 2019

Design and Operation Cost

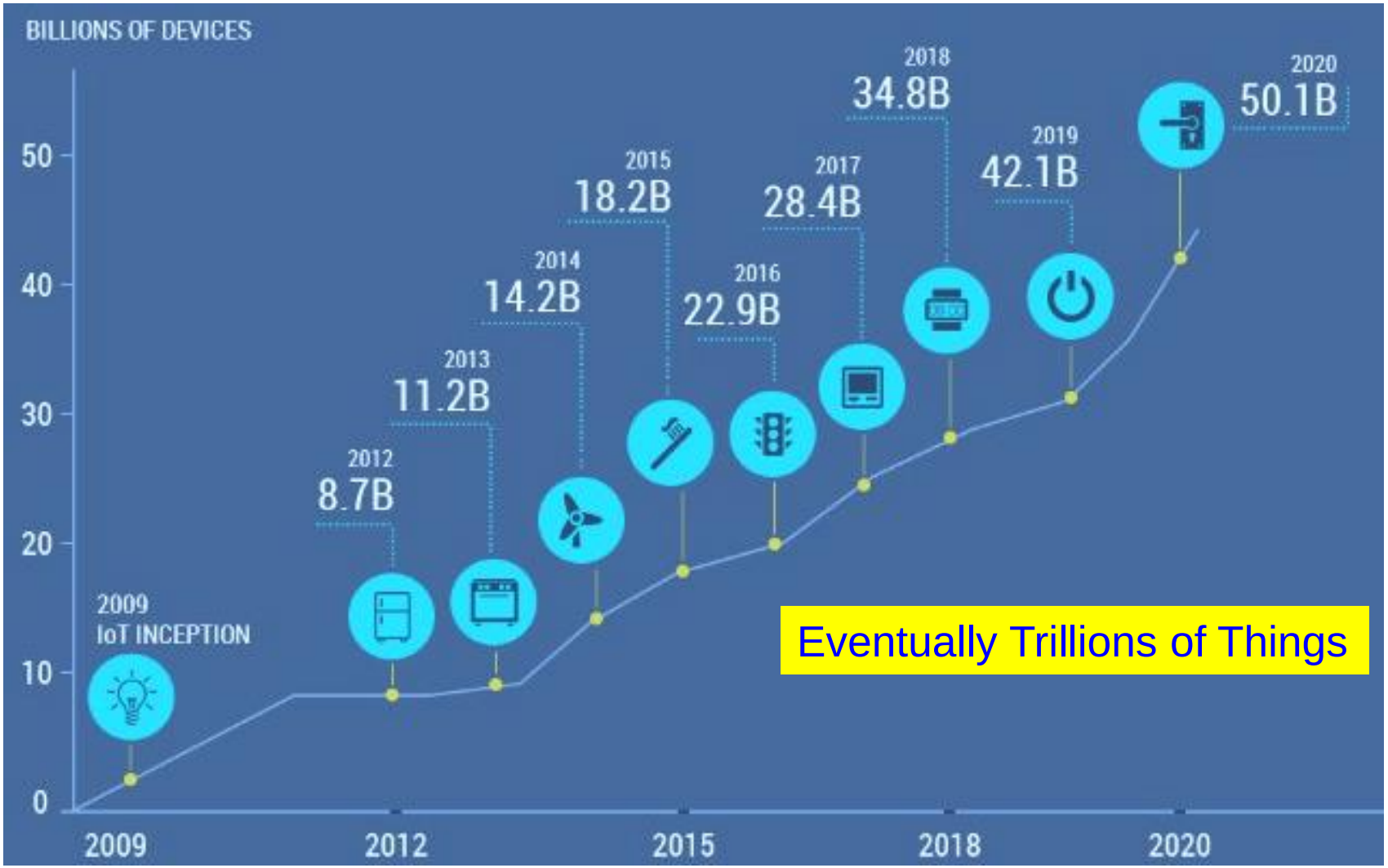
- The design cost is a one-time cost.
- Design cost needs to be small to make a IoT realization possible.
  - The operations cost is that required to maintain the IoT.
  - A small operations cost will make it easier to operate in the long run with minimal burden on the budget of application in which IoT is deployed.

Source: http://www.industrialisation-produits-electroniques.fr

"Cities around the world could spend as much as $41 trillion on smart tech over the next 20 years."

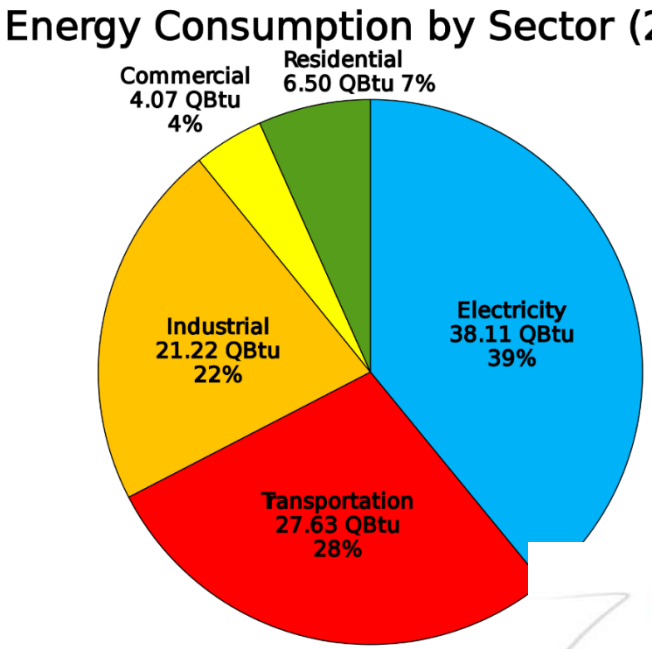
Source: http://www.cnbc.com/2016/10/25/spending-on-smart-cities-around-the-world-could-reach-41-trillion.html

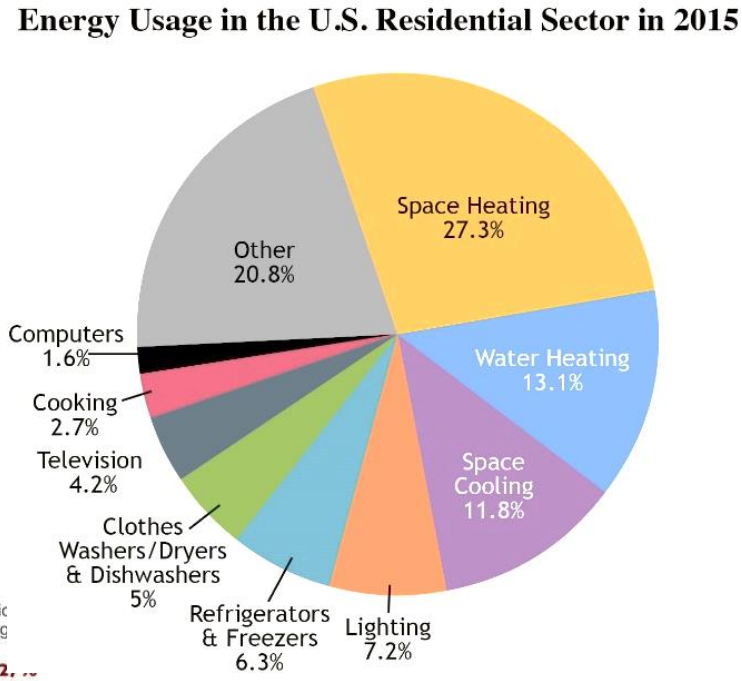
Massive Growth of Sensors/Things



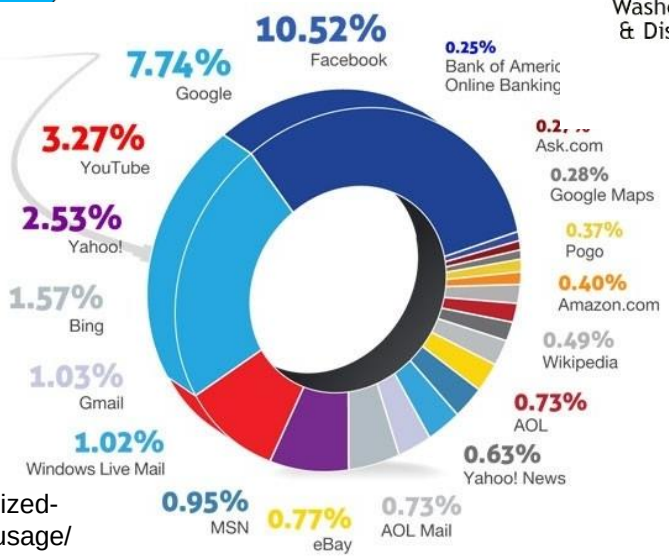
Source: https://www.linkedin.com/pulse/history-iot-industrial-internet-sensors-data-lakes-0-downtime

Energy Consumption





Data Center Power Usage

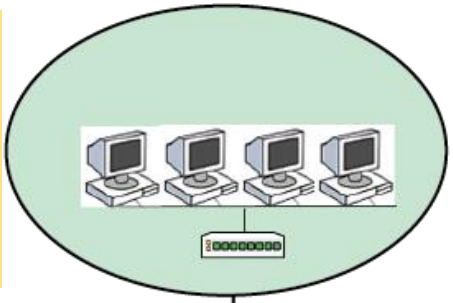


Individual Level: Imagine how often we charge our portable CE!

Source: https://www.engadget.com/2011/04/26/visualized-ring-around-the-world-of-data-center-power-usage/

Energy Consumption Challenge in IoT

Energy from Supply/Battery - Energy consumed by Workstations, PC, Software, Communications



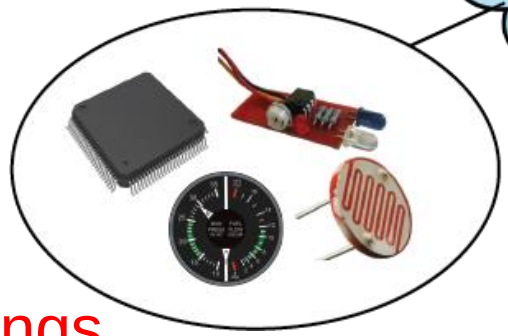
Local Area Network (LAN)

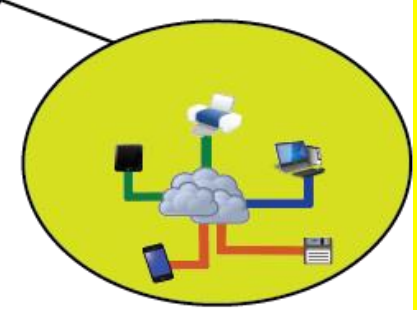
Energy from Supply/Battery - Energy consumed by Communications

Battery Operated - Energy consumed by Sensors, Actuators, Microcontrollers

Internet

The Cloud





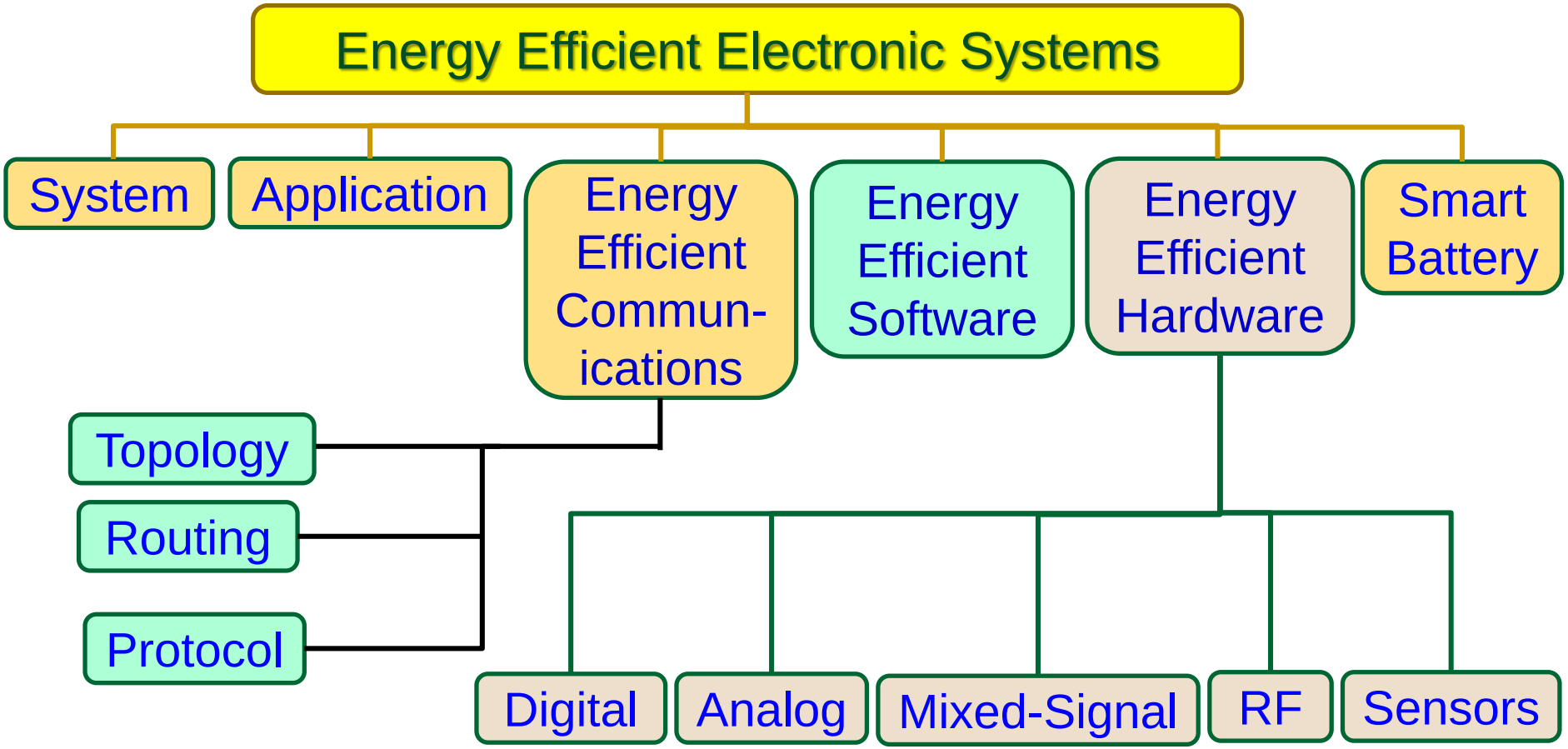
Energy from Supply - Energy consumed in Server, Storage, Software, Communications

The Things

Four Main Components of IoT.

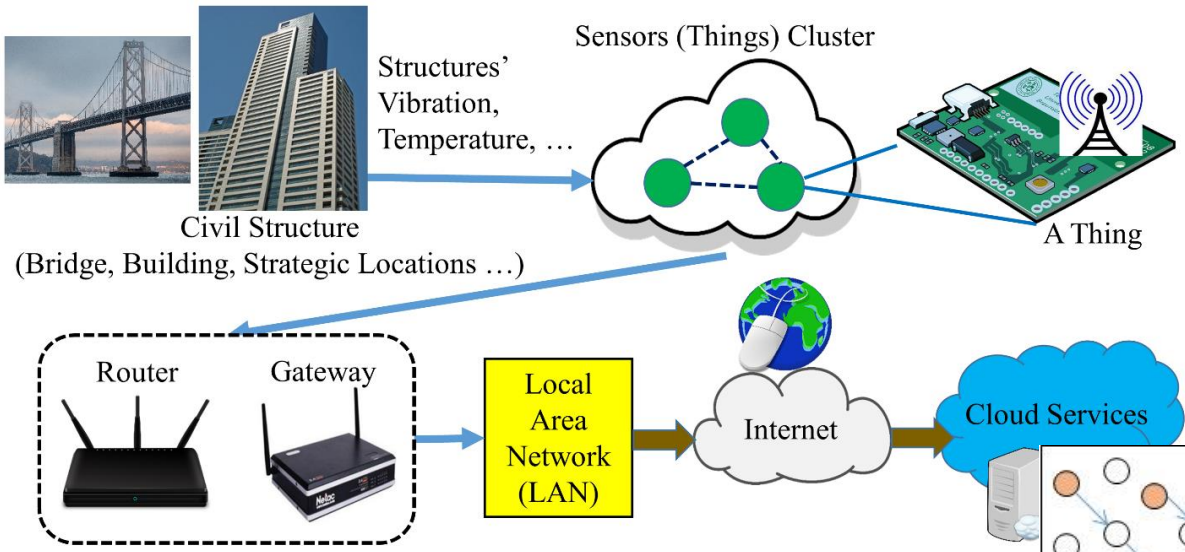
Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

Energy Efficient Electronics: Possible Solution Fronts

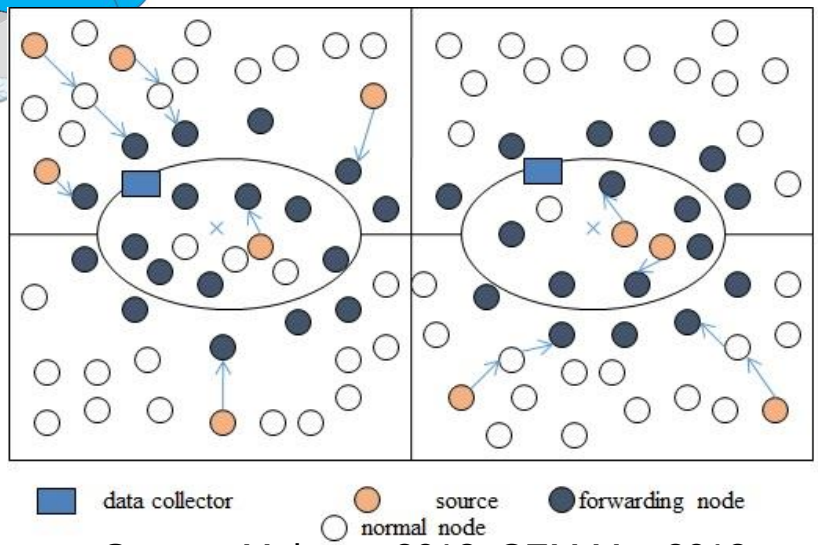


Source: Mohanty ZINC 2018 Keynote

Sustainable IoT – Low-Power Sensors and Efficient Routing

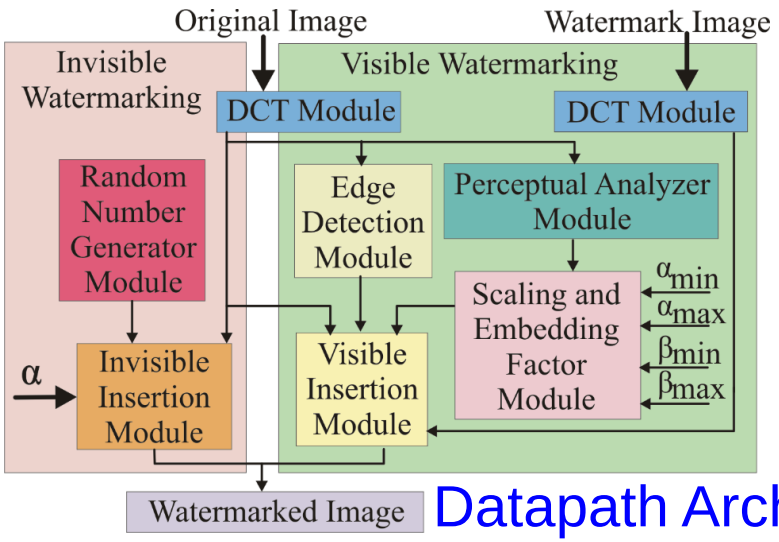


- IoT - sensors near the data collector drain energy faster than other nodes.
- Solution Idea - Mobile sink in which the network is balanced with node energy consumption.
- Solution Need: New data routing to forward data towards base station using mobile data collector, in which two data collectors follow a predefined path.

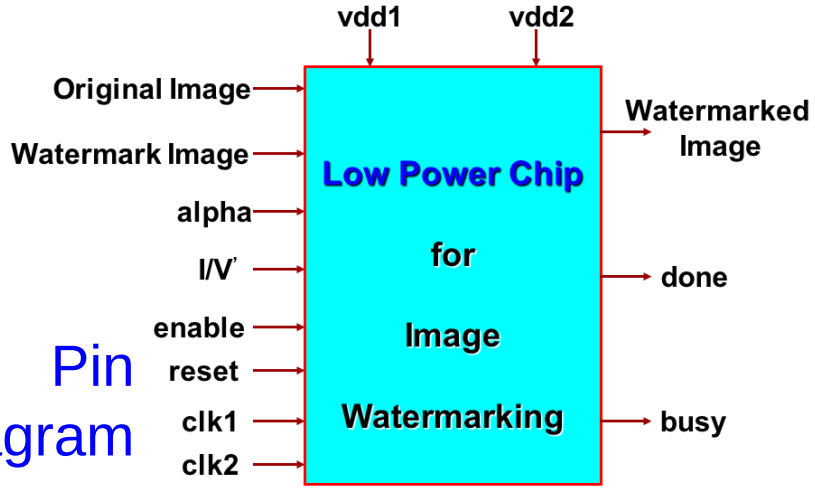


Source: Mohanty 2018, CEM Mar 2018

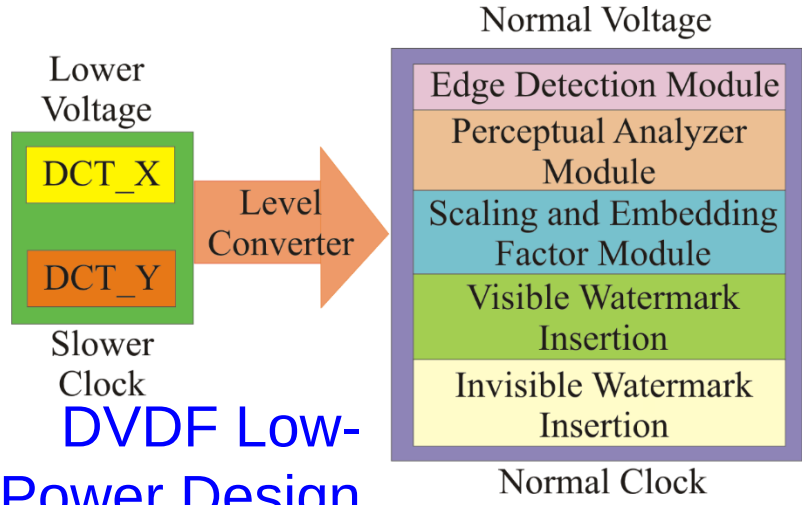
Dual-Voltage/Frequency Based Hardware



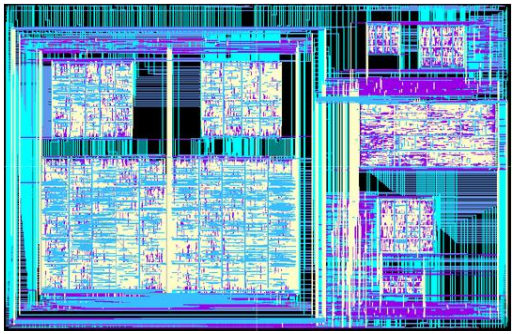
Datapath Architecture



Pin Diagram



DVDF Low-Power Design



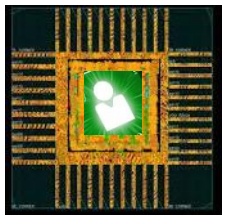
Hardware Layout

Physical Design Data
Total Area : 16.2 sq mm
No. of Transistors: 1.4 million
Power Consumption: 0.3 mW

Source: Mohanty 2006, TCASII May 2006

Security, Privacy, and IP Rights

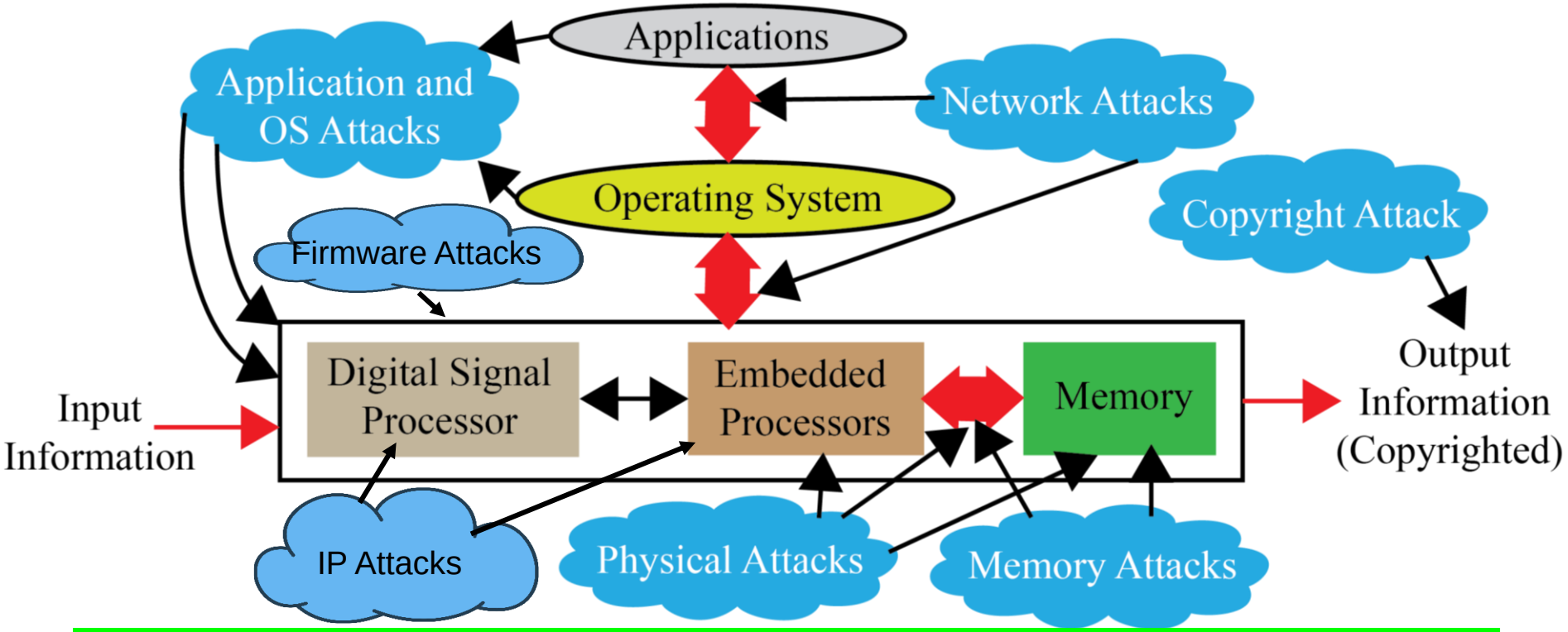
Hardware Trojan



Counterfeit Hardware

Source: Mohanty ICIT 2017 Keynote

Selected Attacks on a CE System – Security, Privacy, IP Rights



Diverse forms of Attacks, following are not the same: System Security, Information Security, Information Privacy, System Trustworthiness, Hardware IP protection, Information Copyright Protection.

Source: Mohanty ZINC 2018 Keynote

Security Challenge – Information

Online Banking

...

Credit Card Theft

Hacked: Linkedin, Tumbler, & Myspace

LinkedIn tumblr. myspace

Who did it: A hacker going by the name Peace.

What was done: 500 million passwords were stolen.

Details: Peace had the following for sale on a Dark Web Store:

- 167 million Linkedin passwords
- 360 million Myspace passwords
- 68 million Tumbler passwords
- 100 million VK.com passwords
- 71 million Twitter passwords

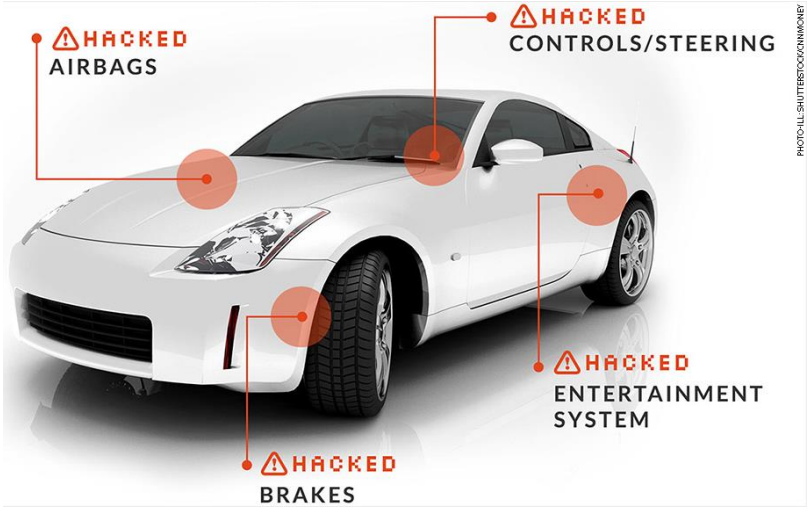
Personal Information

Credit Card/Unauthorized Shopping

Security Challenge - System …

Power Grid Attack

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

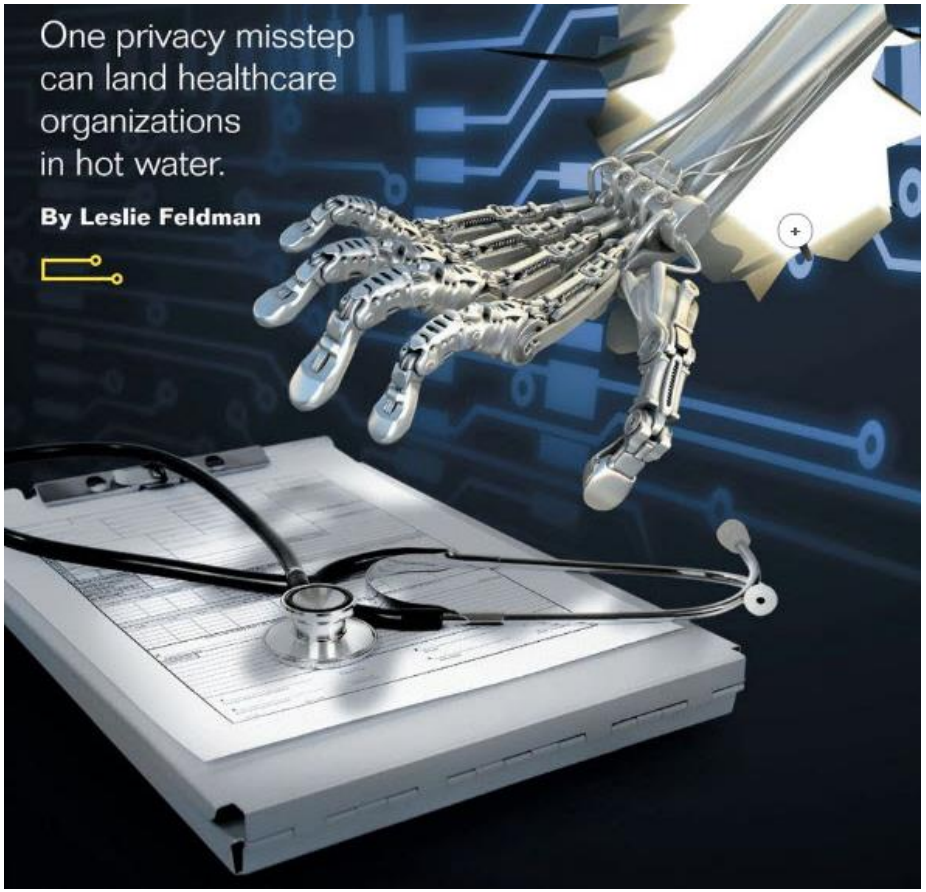


Source: http://money.cnn.com/2014/06/01/technology/security/car-hack/

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

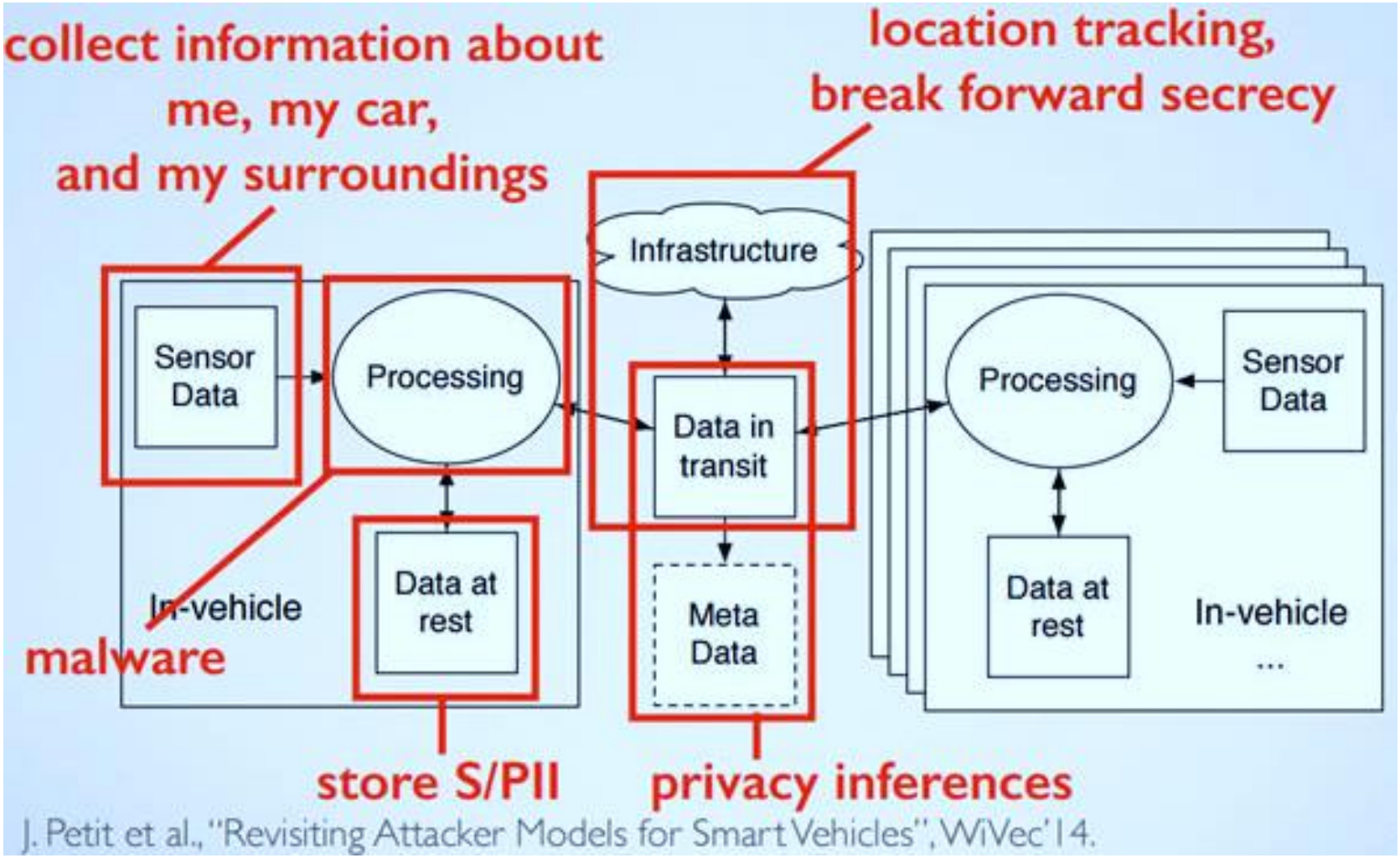
Privacy Challenge - Information

Source: http://ciphercloud.com/three-ways-pursue-cloud-data-privacy-medical-records/



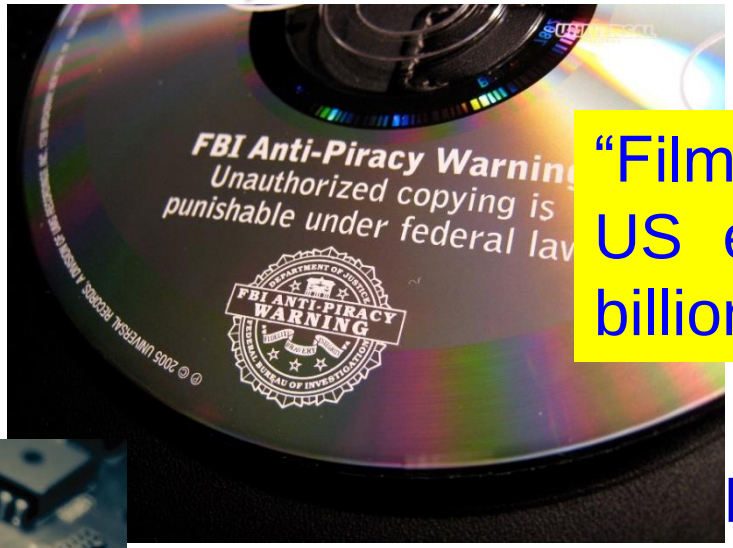
Source: http://blog.veriphyr.com/2012/06/electronic-medical-records-security-and.html

Privacy Challenge – System, Smart Car



Source: http://www.computerworld.com/article/3005436/cybercrime-hacking/black-hat-europe-it-s-easy-and-costs-only-60-to-hack-self-driving-car-sensors.html

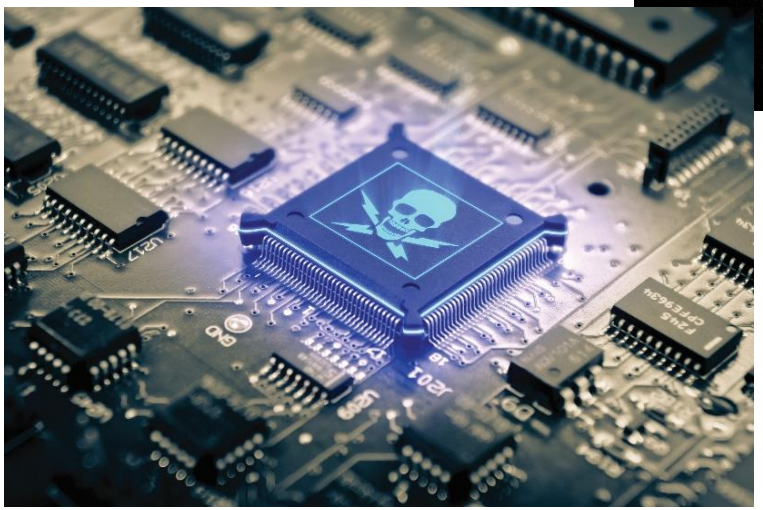
Ownership - Media, Hardware, Software



"Film piracy cost the US economy $20.5 billion annually."

Media Piracy

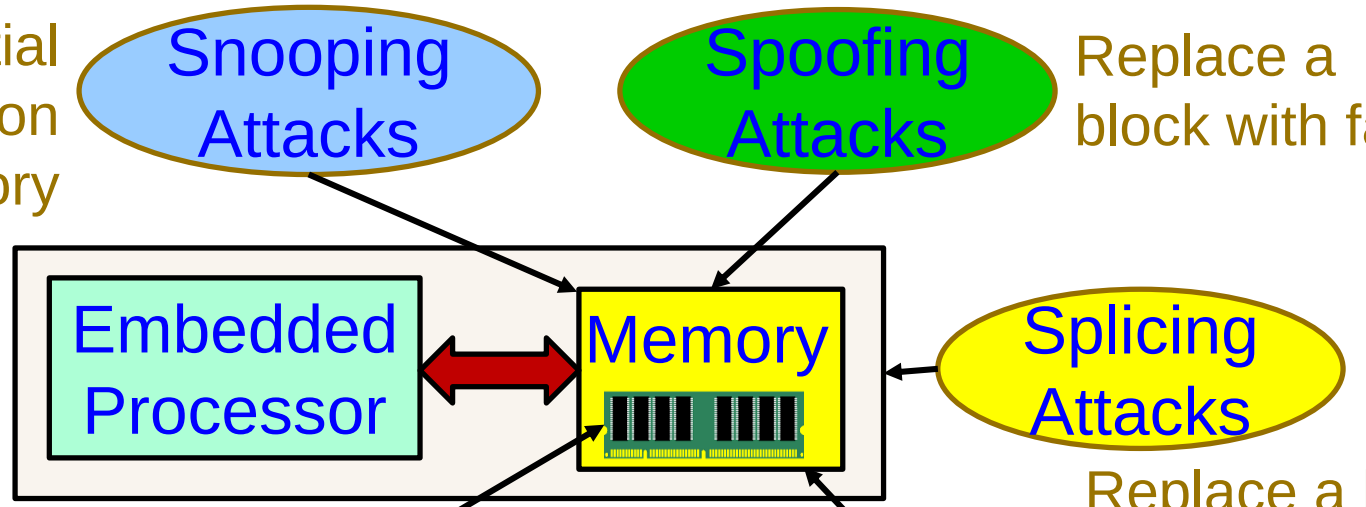
Hardware Piracy → Counterfeit Hardware



Top counterfeits could have impact of $300B on the semiconductor market.

Software Piracy

Memory Attacks



Read confidential information in memory

Snooping Attacks

Spoofing Attacks

Replace a block with fake

Splicing Attacks

Replace a block with a block from another location

Physical access memory to retrieve encryption keys

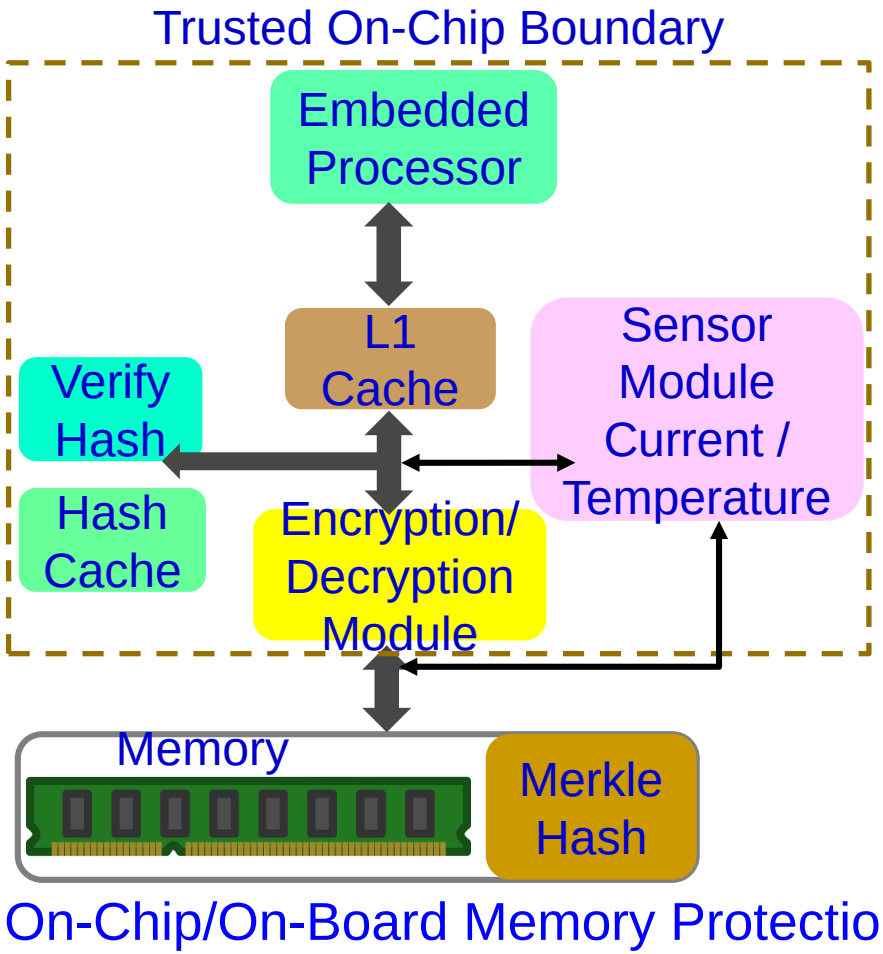
Cold Boot Attacks

Replay Attacks

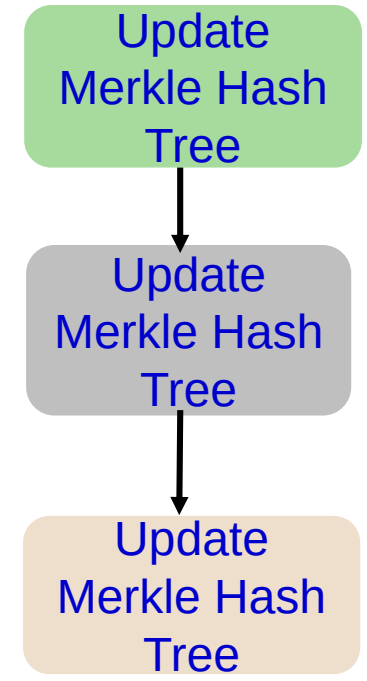
The value of a block at a given address at one time is written at exactly the same address at a different times; Hardest attack.

Source: Mohanty 2013, Springer CSSP Dec 2013

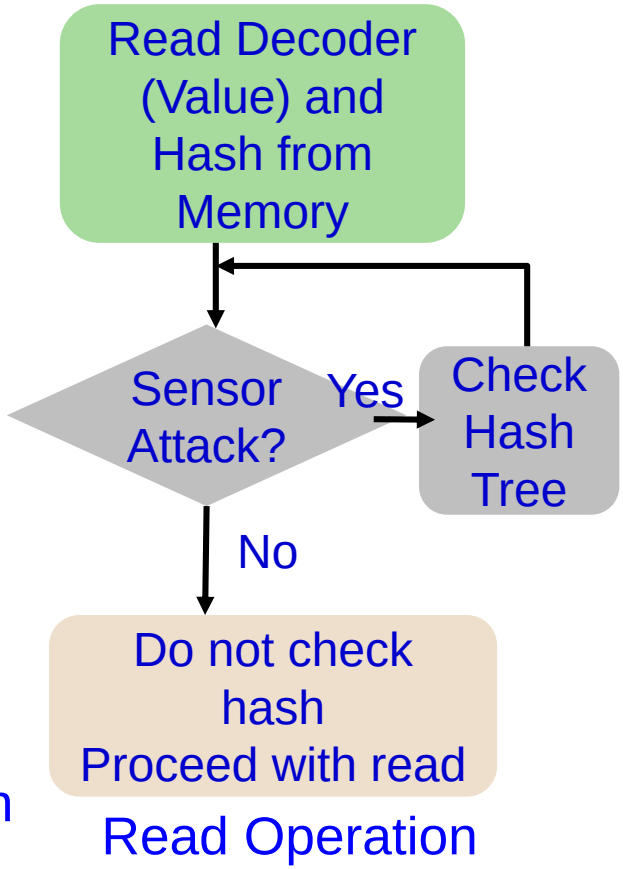
Embedded Memory Security/Protection



On-Chip/On-Board Memory Protection



Write Operation

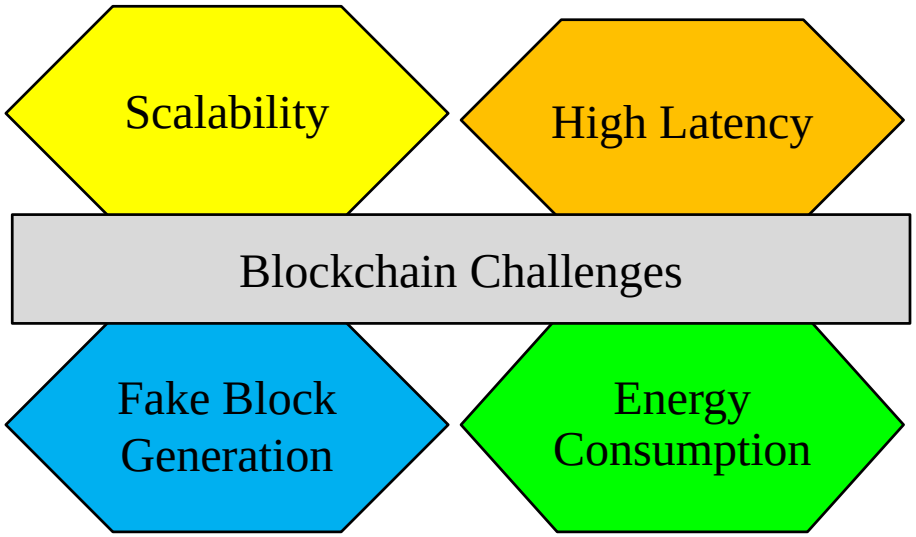


Read Operation

Some performance penalty due to increase in latency!

Source: Mohanty 2013, Springer CSSP Aug 2013

Blockchain – Energy Issue

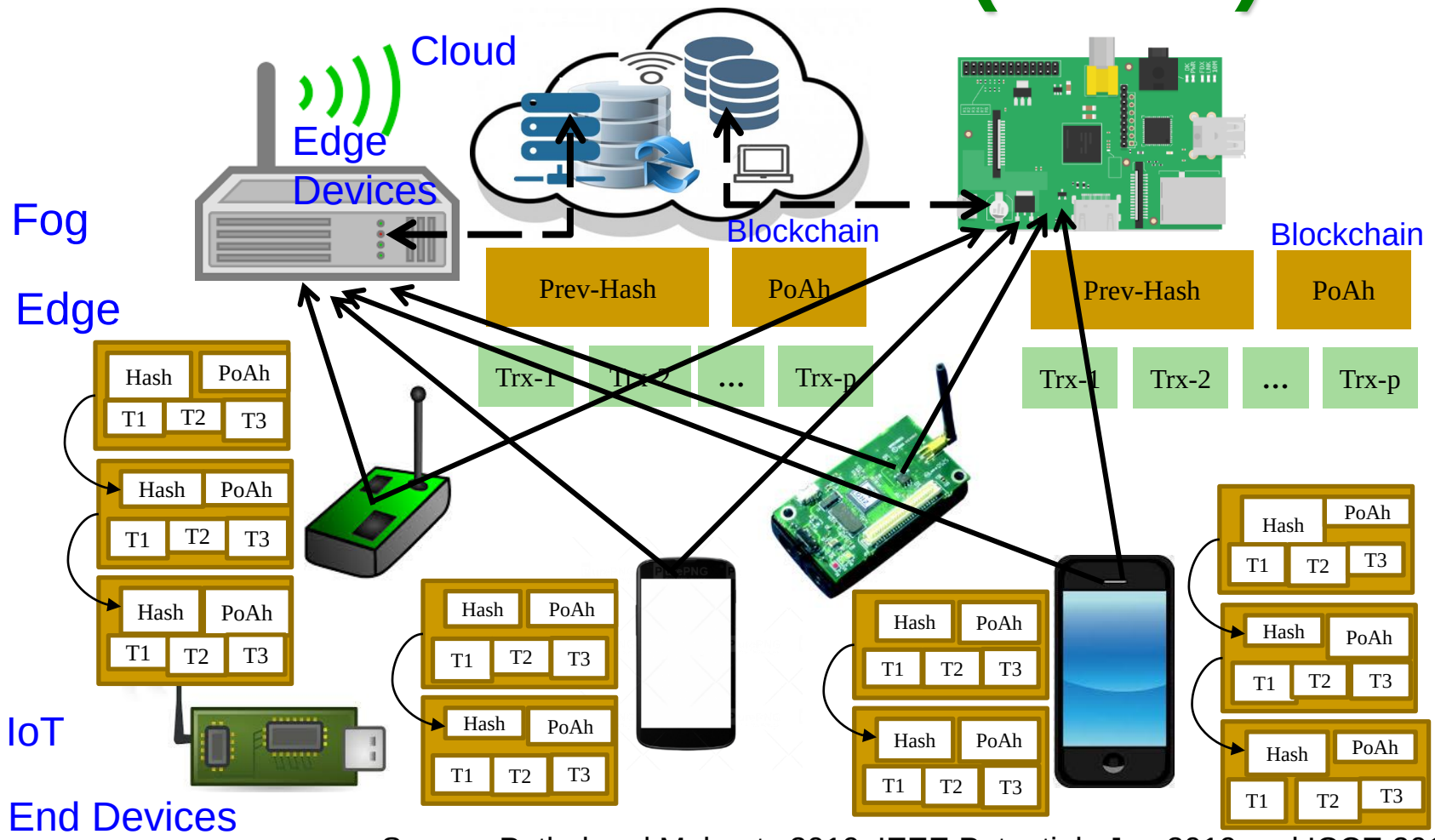


Source: Puthal, Mohanty 2018, CE Magazine July 2018

- Energy for mining of 1 bitcoin → 2 years consumption of a US household.
- Energy consumption for each bitcoin transaction → 80,000X of energy consumption of a credit card processing.

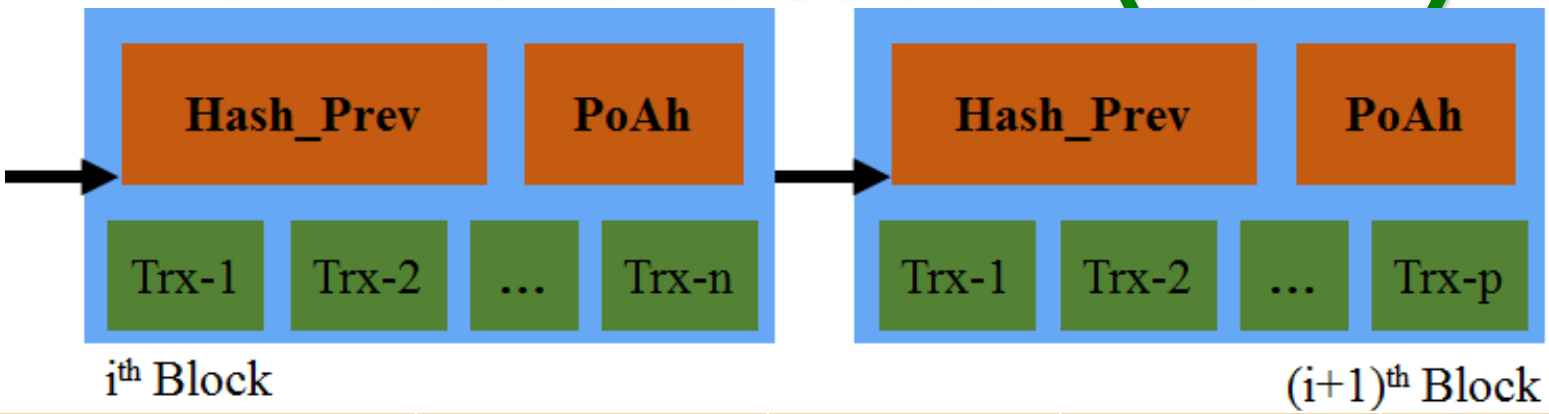
Source: N. Popper, "There is Nothing Virtual About Bitcoin's Energy Appetite", The New York Times, 21st Jan 2018, https://www.nytimes.com/2018/01/21/technology/bitcoin-mining-energy-consumption.html.

IoT Friendly Blockchain – Proof-of-Authentication (PoAh)



Source: Puthal and Mohanty 2019, IEEE Potentials Jan 2019 and ICCE 2019

IoT Friendly Blockchain – Proof-of-Authentication (PoAh)



	Proof-of-Work (PoW)	Proof-of-Stake (PoS)	Proof-of-Activity (PoA)	Proof-of-Authentication (PoAh)
Energy consumption	High	High	High	Low
Computation requirements	High	High	High	Low
Latency	High	High	High	Low
Search space	High	Low	NA	NA

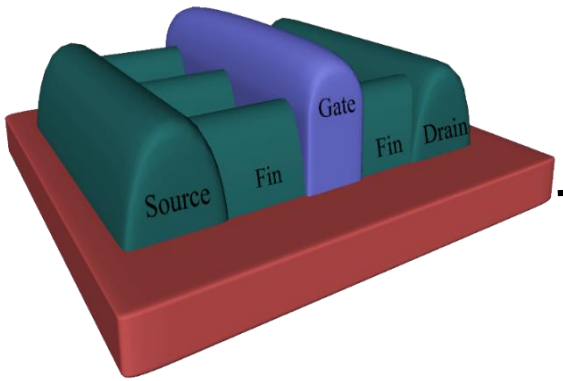
PoW - 10 min in cloud	**PoAh - 3 sec in Rasperry Pi**	**PoAh - 200X faster than PoW**

Source: Puthal and Mohanty 2019, IEEE Potentials Jan 2019 and ICCE 2019

Physical Unclonable Function (PUF) - Principle

Manufacturing Variations (e.g. Oxide Growth, Ion Implantation, Lithography)

Challenge Inputs (Inputs given to PUF Module, e.g. Select line of Multiplexer)



Parameters Affected Due to Variations (e.g. Length, Gate-Oxide Thickness, Fin Height, Fin Width)

PUF Design (e.g. Arbiter PUF, SRAM PUF, Ring Oscillator PUF)

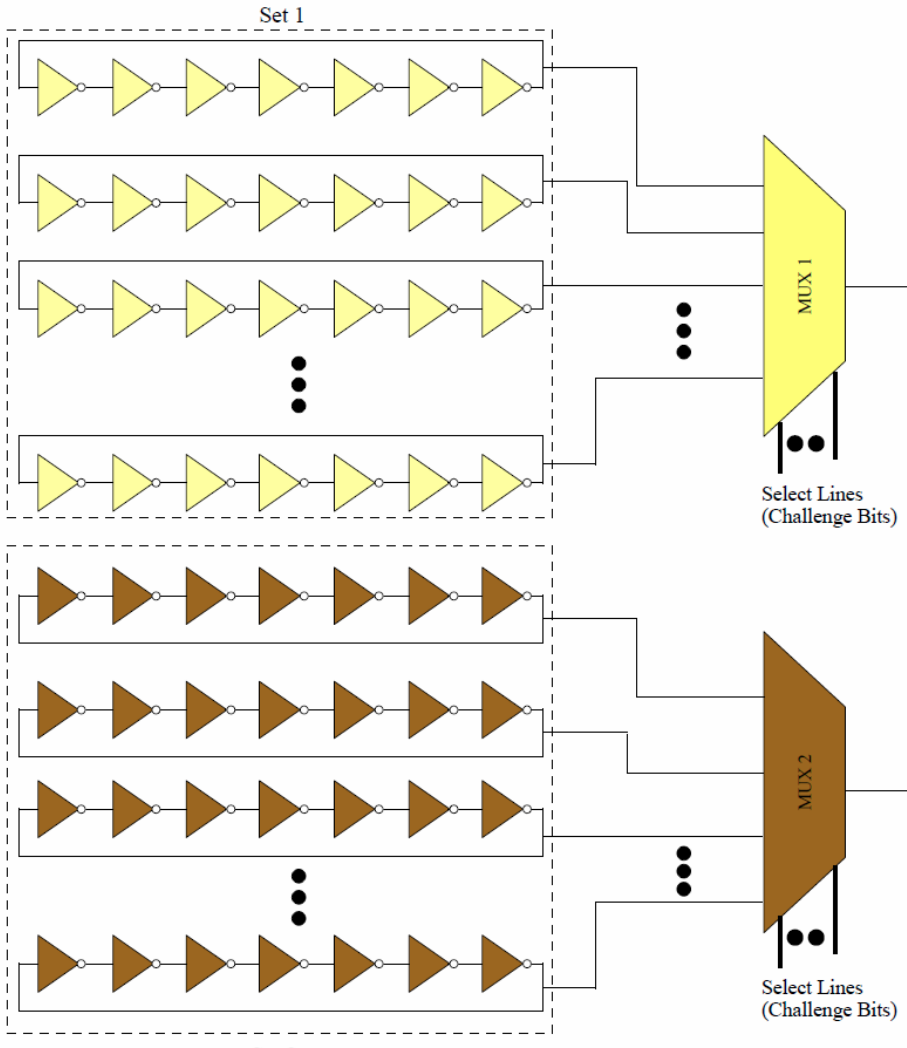
Challenge Response (Outputs from a PUF Module)

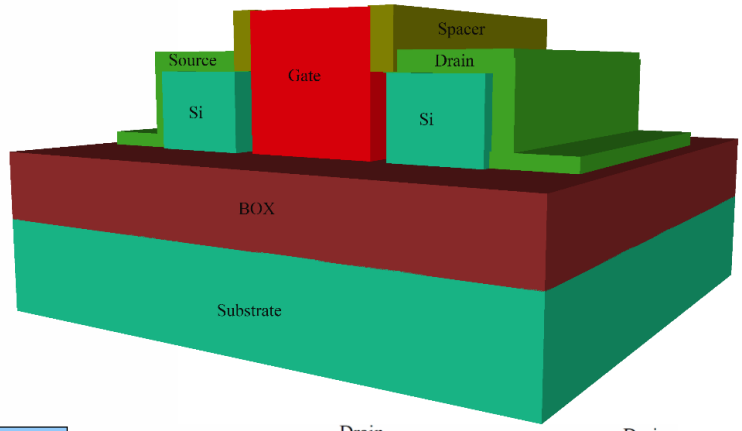
Random Binary Output 010101 …

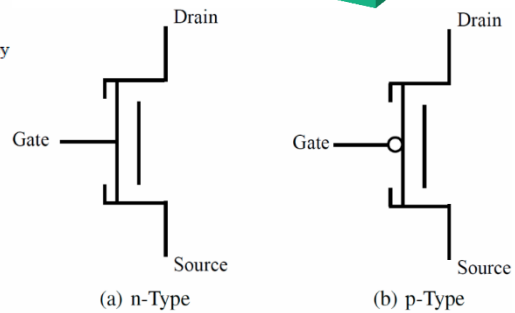
Silicon manufacturing process variations are turned into a feature rather than a problem.

Source: Mohanty 2017, Springer ALOG 2017

Power Optimized Hybrid Oscillator Arbiter PUF





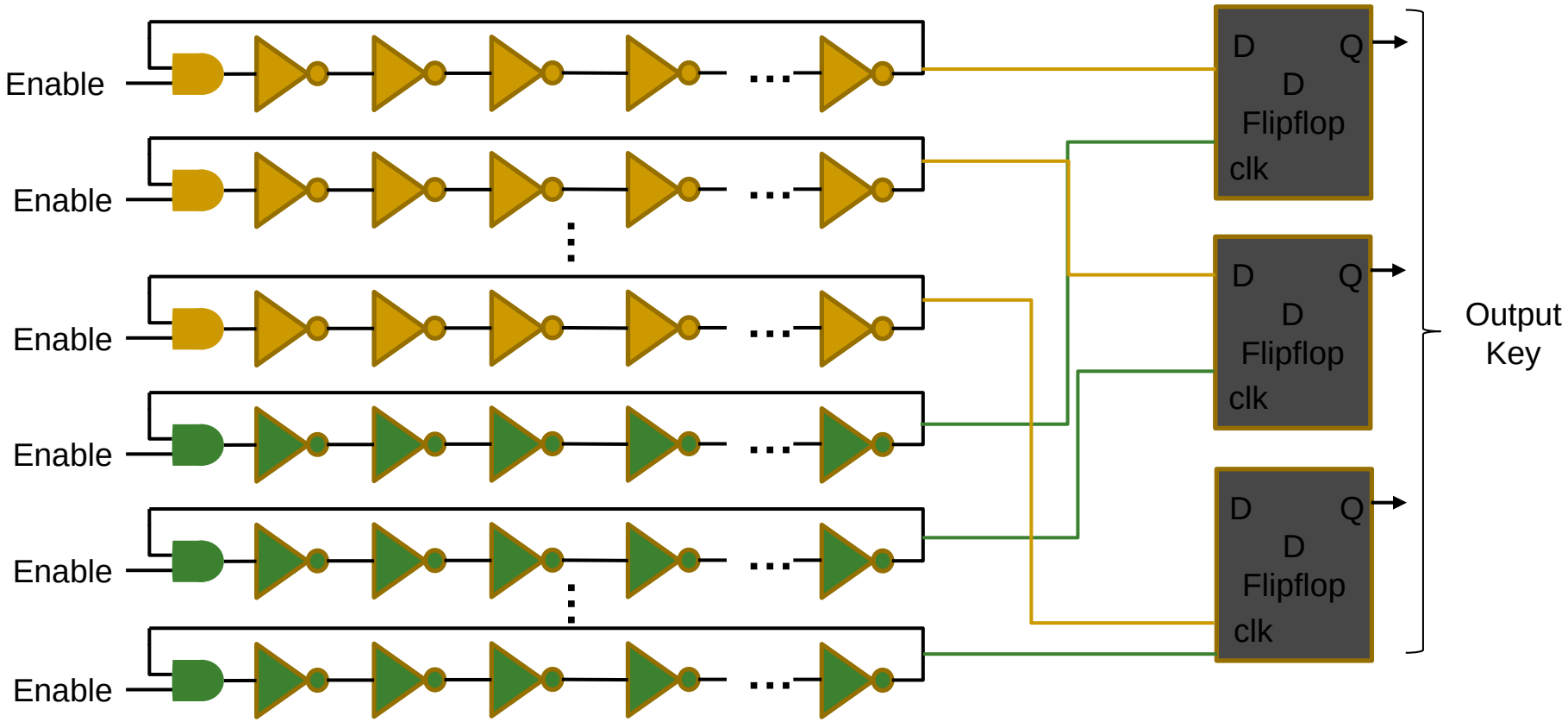


Characteristics	FinFET Technology	DLFET Technology
Average Power	219.34 μW	121.3 μW
Hamming Distance	49.3 %	48 %
Time to generate key	150 ns	150 ns

Source: Mohanty 2018, TSM May 2018

Source: Mohanty 2017, Springer ALOG 2017

Speed Optimized Hybrid Oscillator Arbiter PUF

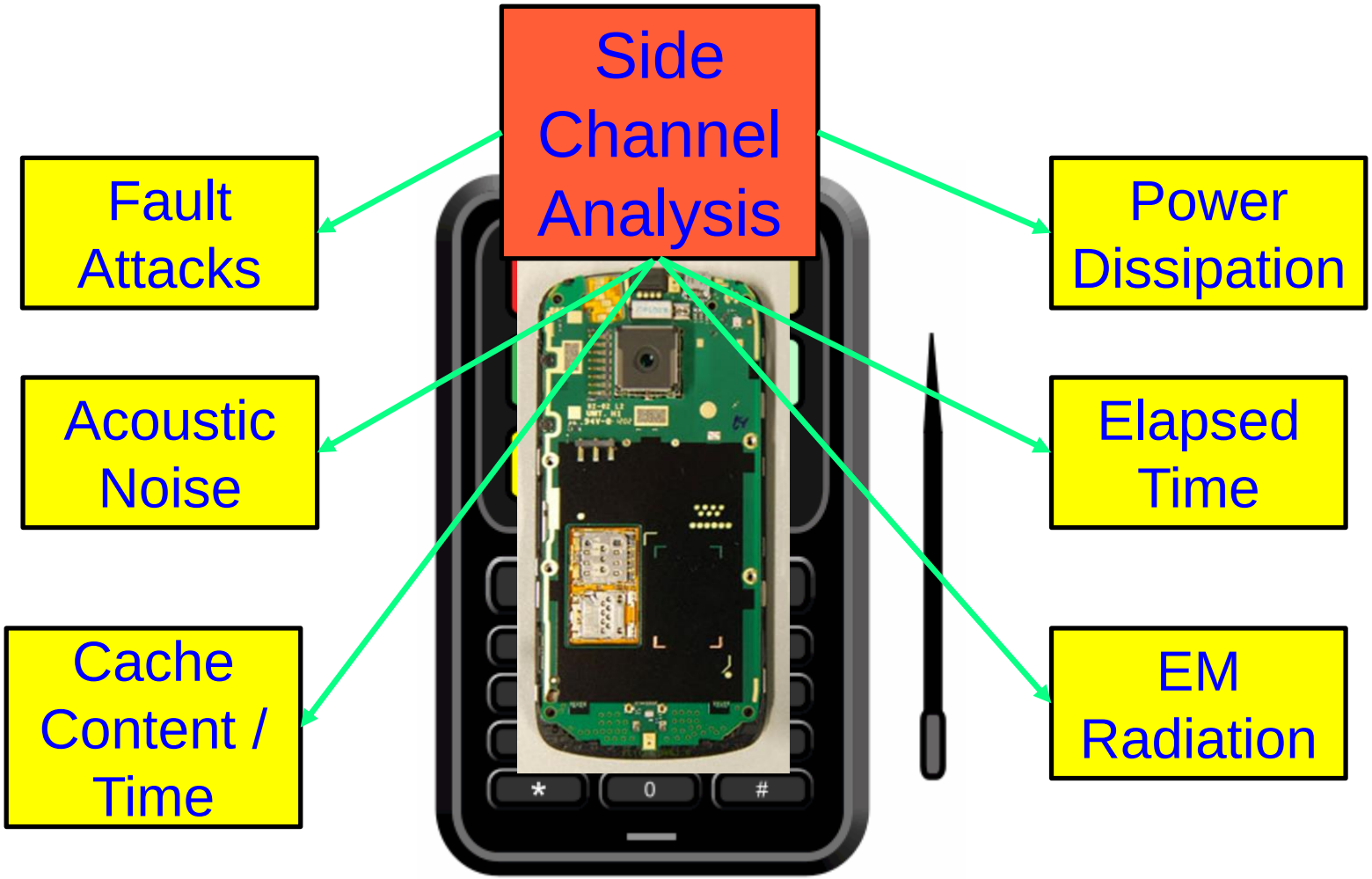


Characteristics	FinFET Technology	DLFET Technology
Average Power	250.15 mW	151 μW
Hamming Distance	49.6 %	50 %
Time to generate key	50 ns	50 ns

Source: Mohanty 2018, TSM May 2018

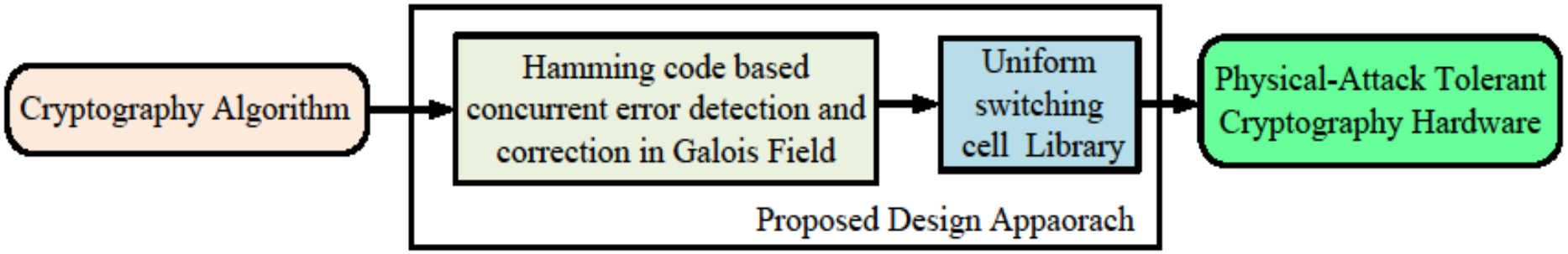
Source: Mohanty 2017, Springer ALOG 2017

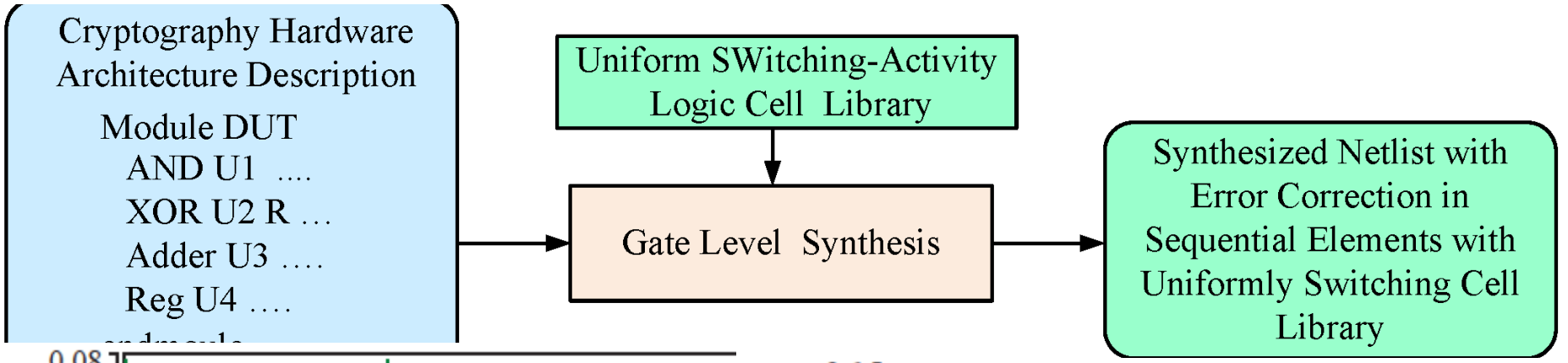
Side Channel Analysis Attacks

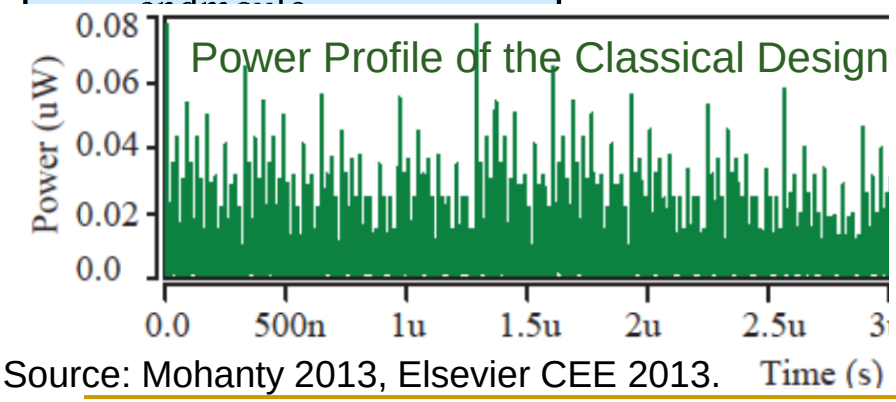


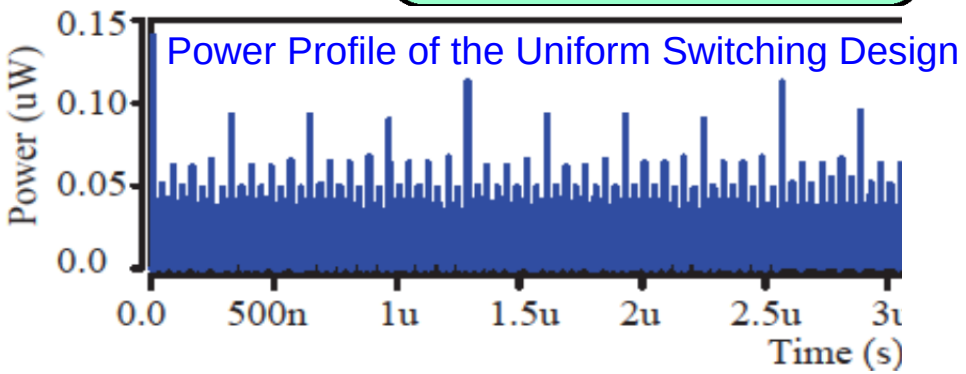
Source: Parameswaran Keynote iNIS-2017

DPA Resilience Hardware: Synthesis









Source: Mohanty 2013, Elsevier CEE 2013.

Trojan Secure Digital Hardware Synthesis

Architecture Module Library Comprising of Modules Info from Different Vendors

Datapath Resource configuration (R_n)

Vendor Allocation Type (A_v)

Unrolling Factor (U)

Trojan Detection Block

Dual Modular Redundant (DMR) Scheduling

Modified Allocation in DMR based on Distinct Vendor Rule

PSO-Driven Exploration for Optimizing Independent Factors Simultaneously

Optimizing Datapath Configuration

Optimizing Vendor Allocation Type

Optimizing Unrolling Factor

Binding

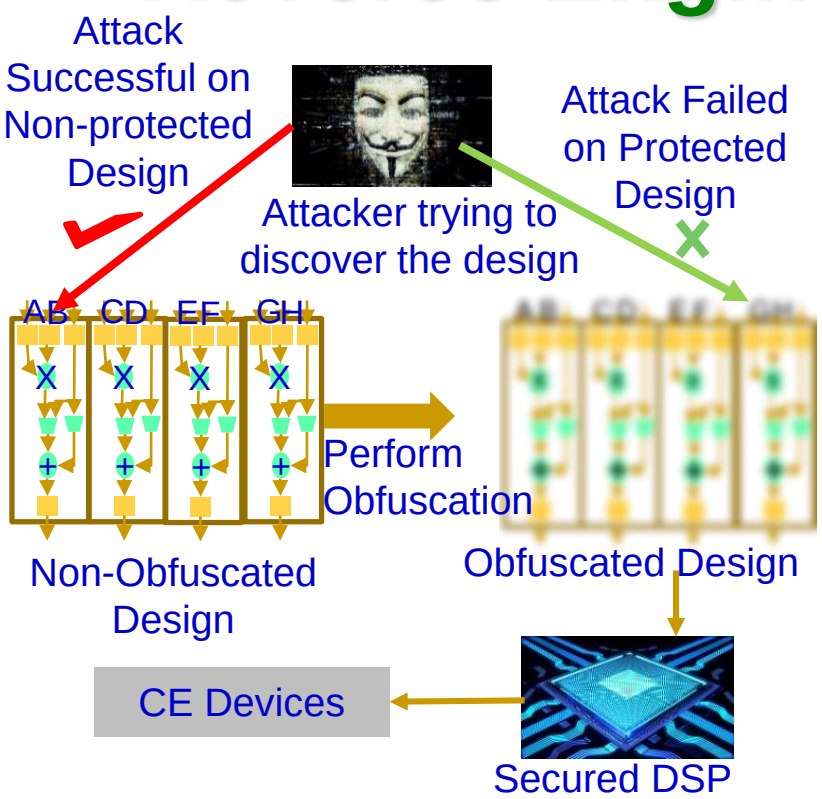
Cost Evaluation

Provide backdoor to adversary. Chip fails during critical needs.

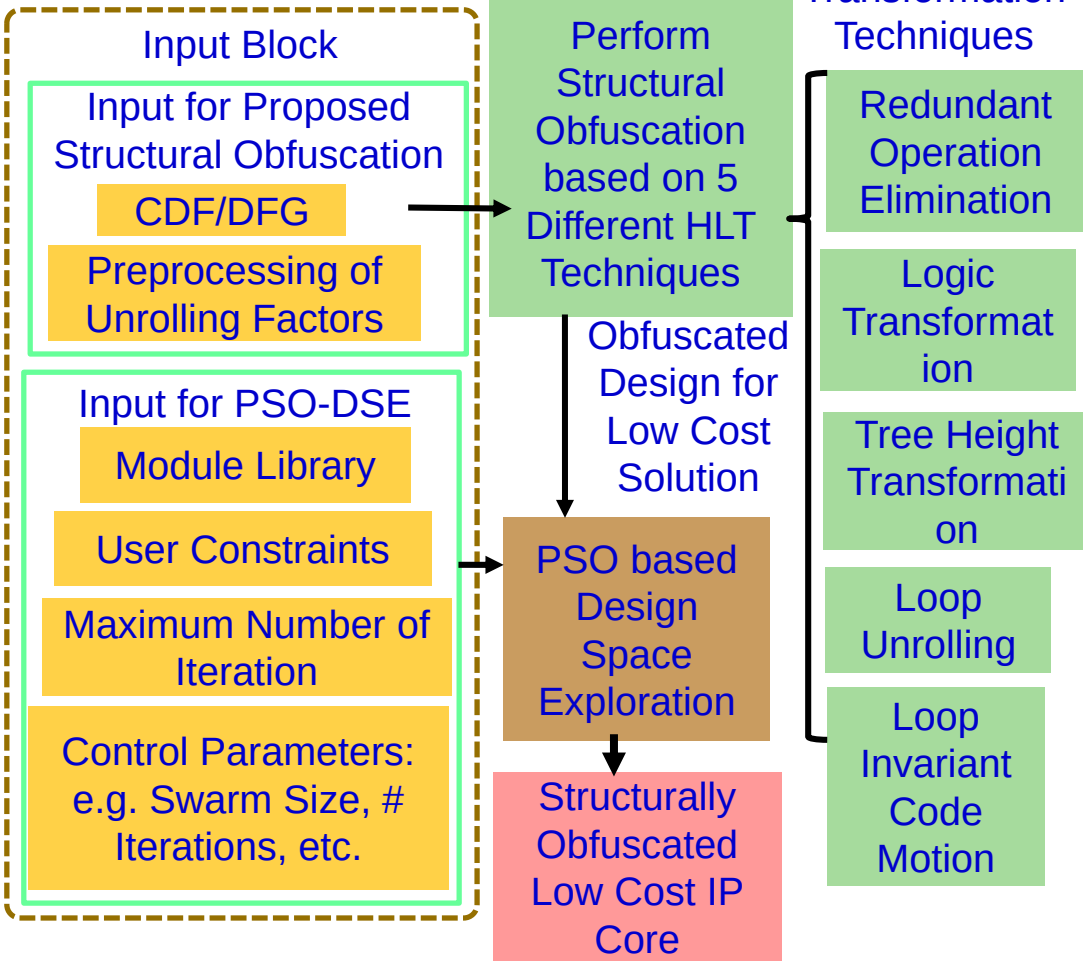
Low Cost Trojan Secured Datapath

Source: Sengupta, Mohanty 2017: TCAD April 2017

Digital Hardware Synthesis to Prevent Reverse Engineering - Obfuscation

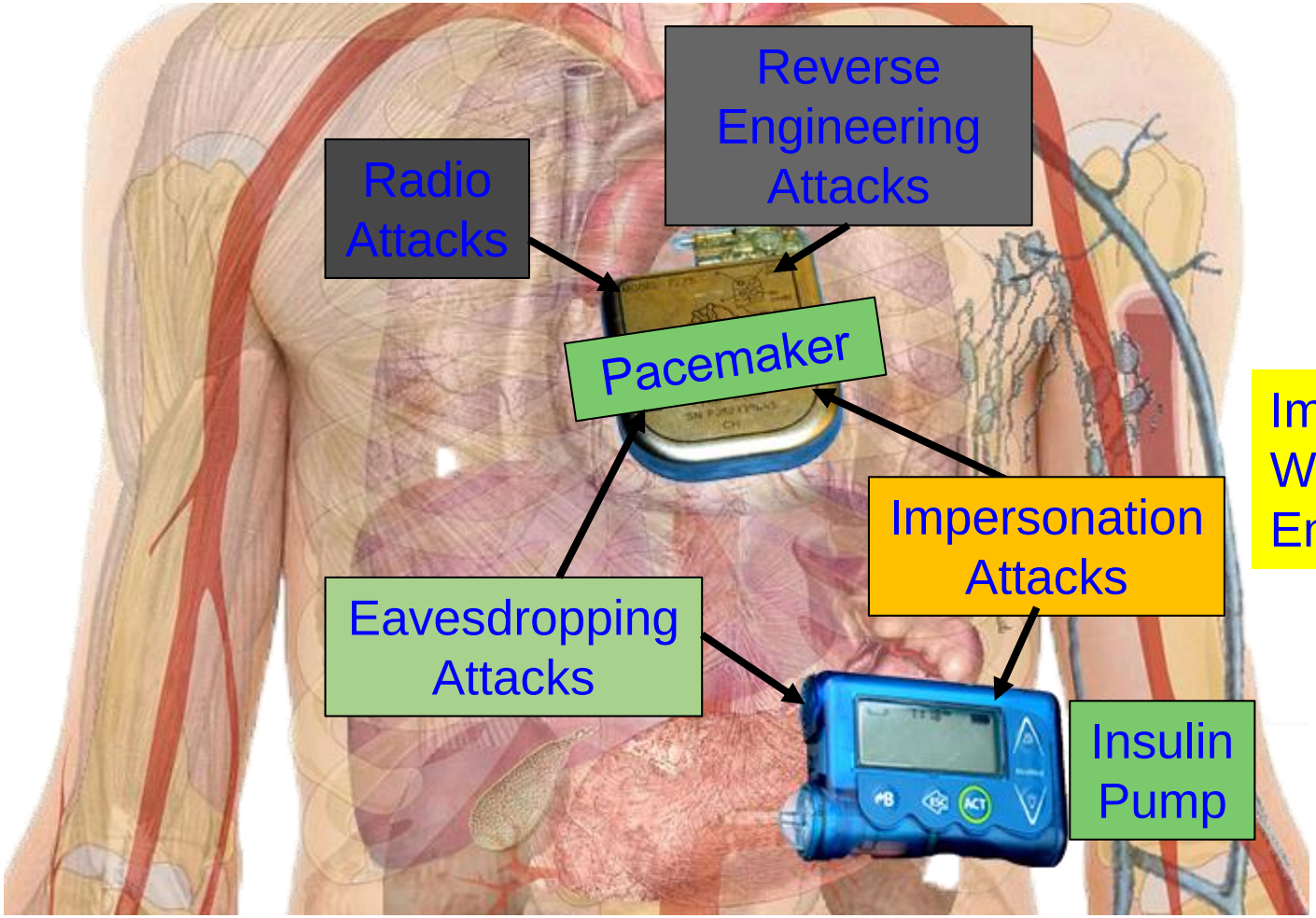


Obfuscation – Intentional modification of the description or the structure of electronic hardware to conceal its functionality for making reverse-engineering difficult.



Source: Sengupta, Mohanty 2017, TCE November 2017

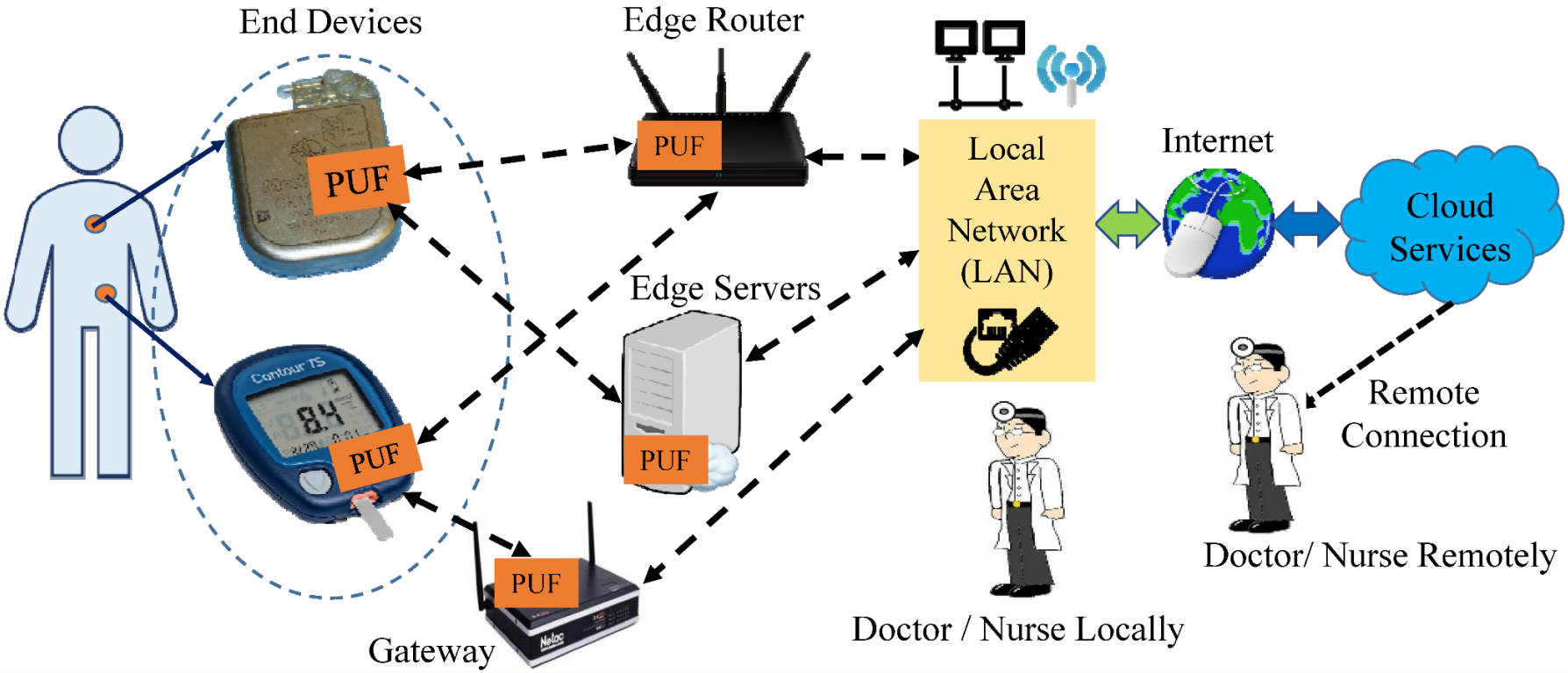
Security Measures in Smart Devices – Smart Healthcare



Implantable / Wearable Security – Energy Constraints

Source: Mohanty 2019, IEEE TCE Under Preparation

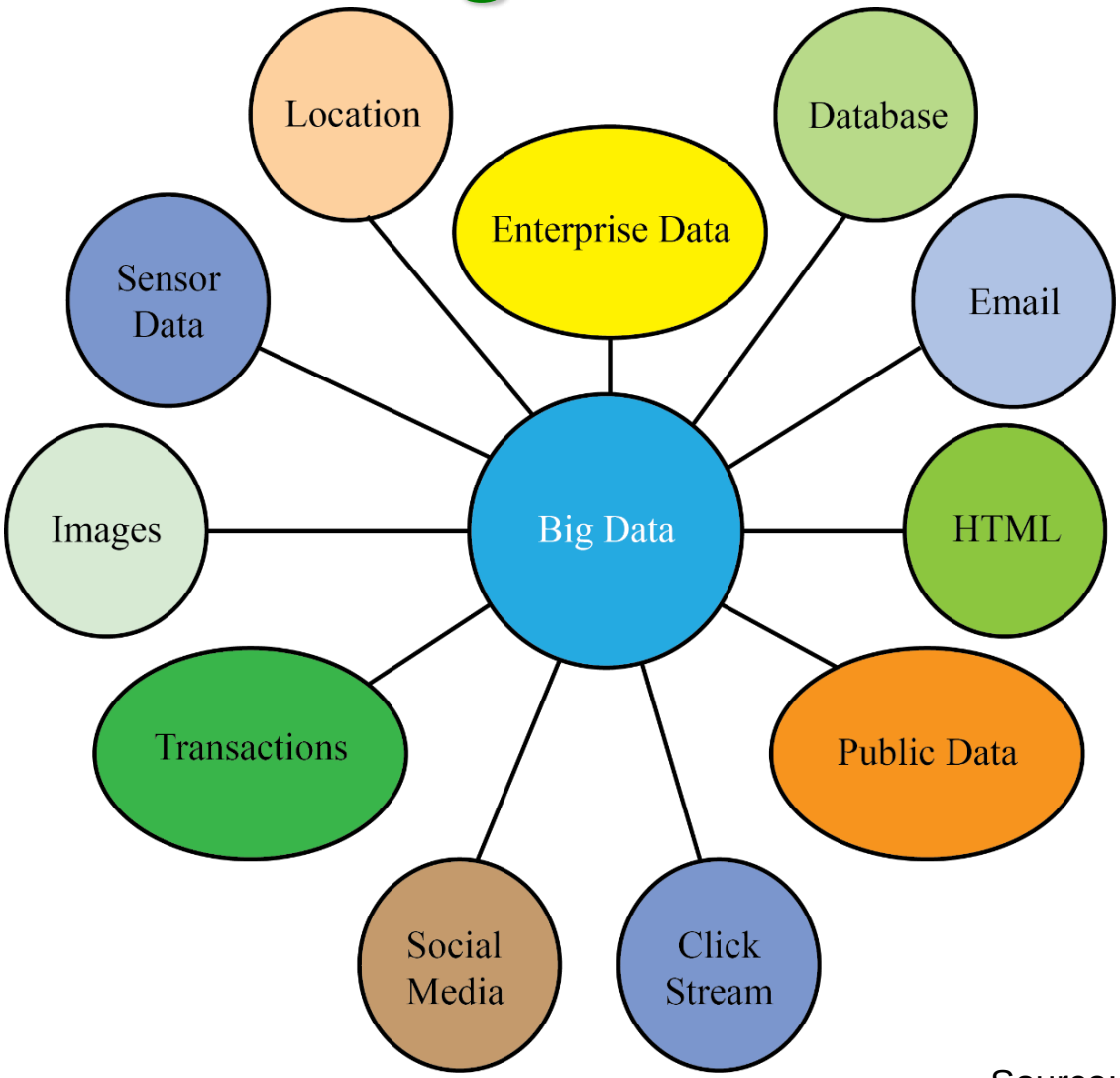
IoMT Security – A PUF a Device Authentication



Proposed Approach Characteristics	Value (in a FPGA / Raspberry Pi platform)
Time to Generate the Key at Server	800 ms
Time to Generate the Key at IoMT Device	800 ms
Time to Authenticate the Device	1.2 sec - 1.5 sec

Source: Mohanty 2019, IEEE TCE Under Preparation

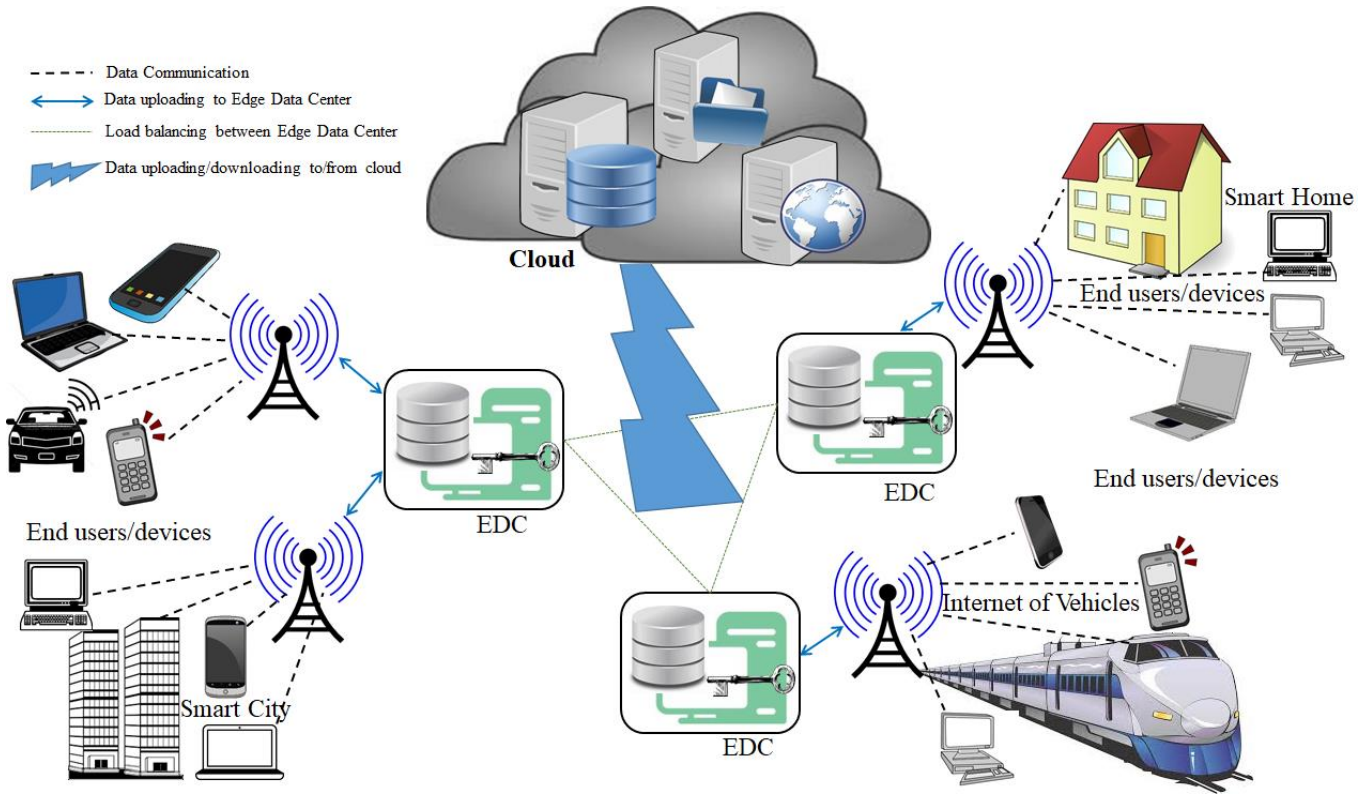
Bigdata in Smart Cities

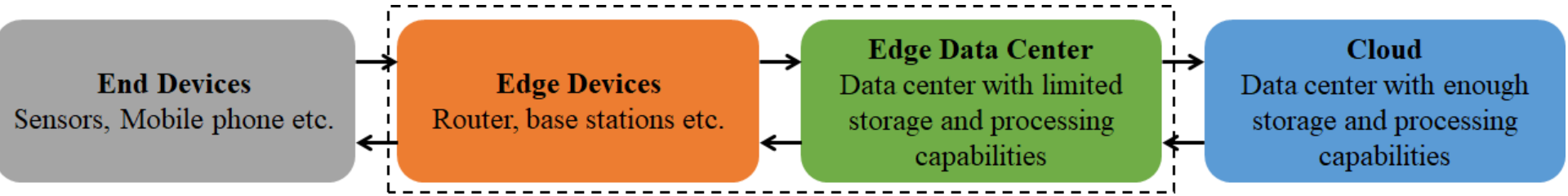


Sensors, social networks, web pages, image and video applications, and mobile devices generate more than 2.5 quintillion bytes data per day.

Source: Mohanty 2016, CE Magazine July 2016

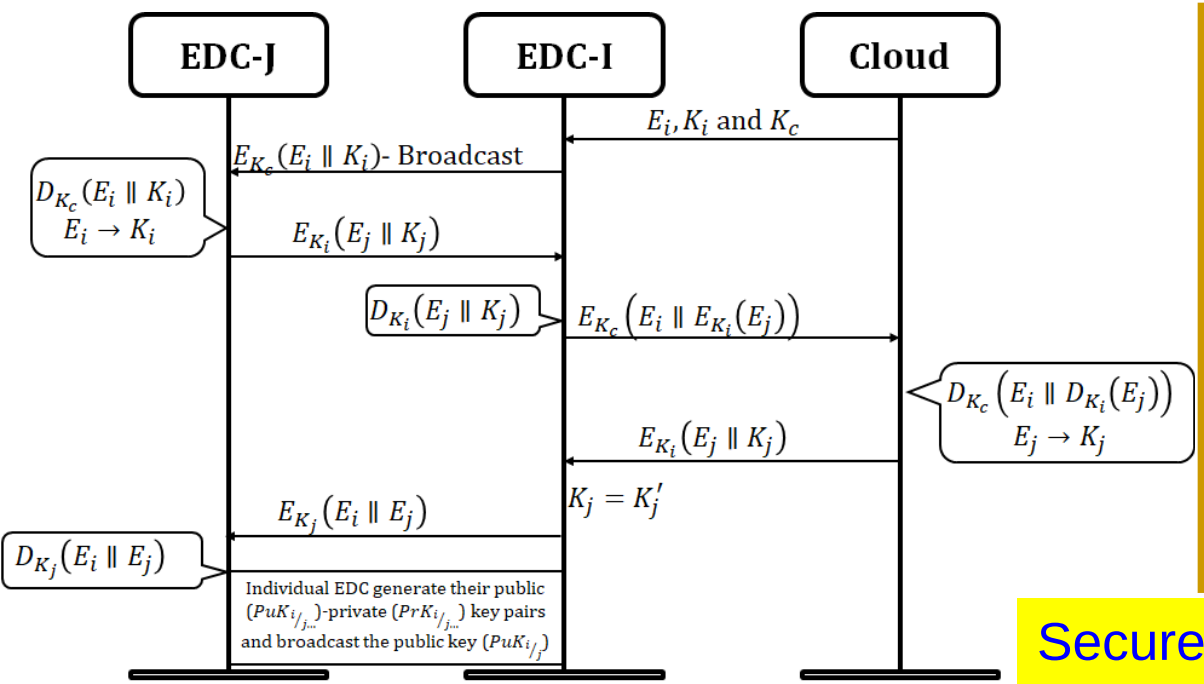
Big Data - Edge Datacenter





Source: Puthal, Mohanty 2018, IEEE Comm. Magazine May 2018

Secure Edge Datacenter



Algorithm 1: Load Balancing Technique

1. If (EDC-I is overloaded)
2. EDC-I broadcast (E_i, L_i)
3. EDC-J (neighbor EDC) verifies:
4. If (E_i is in database) & ($p \leq 0.6 \& L_i << (n-m)$)
5. Response $E_{Kpu_i}(E_j||K_j||p)$
6. EDC-I perform $D_{Kpr_i}(E_j||K_j||p)$
7. $k_j' \leftarrow E_j$
8. If ($k_j' = k_j$)
9. EDC-I select EDC-J for load balancing.

Secure edge datacenter –

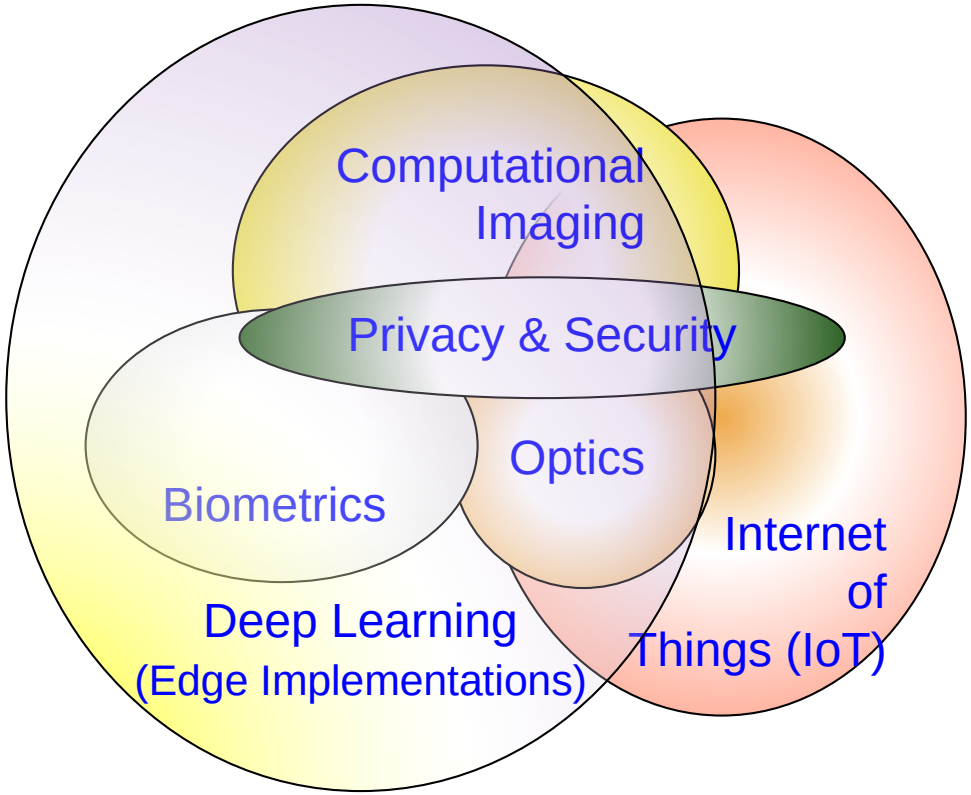
- Balances load among the EDCs
- Authenticates EDCs

Response time of the destination EDC has reduced by 20-30 % using the proposed allocation approach.

Source: Puthal, Mohanty: IEEE Communications Magazine May 2018

Bigdata → Intelligence – Deep Learning is the Key

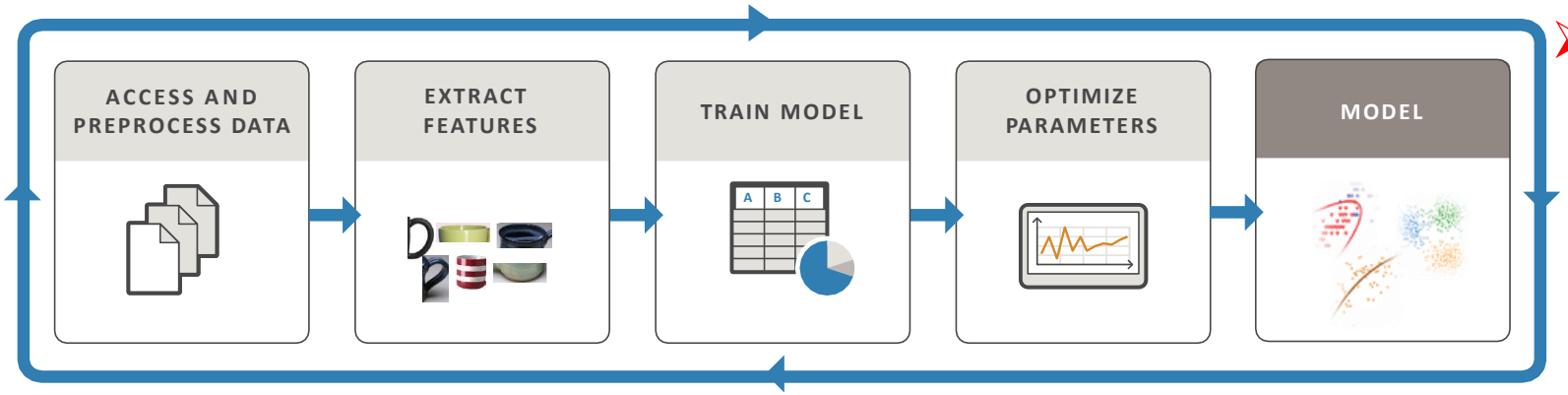
- "DL at the Edge" overlaps all of these research areas.
- New Foundation Technologies, enhance data curation, improved AI, and Networks accuracy.



Source: Corcoran Keynote 2018

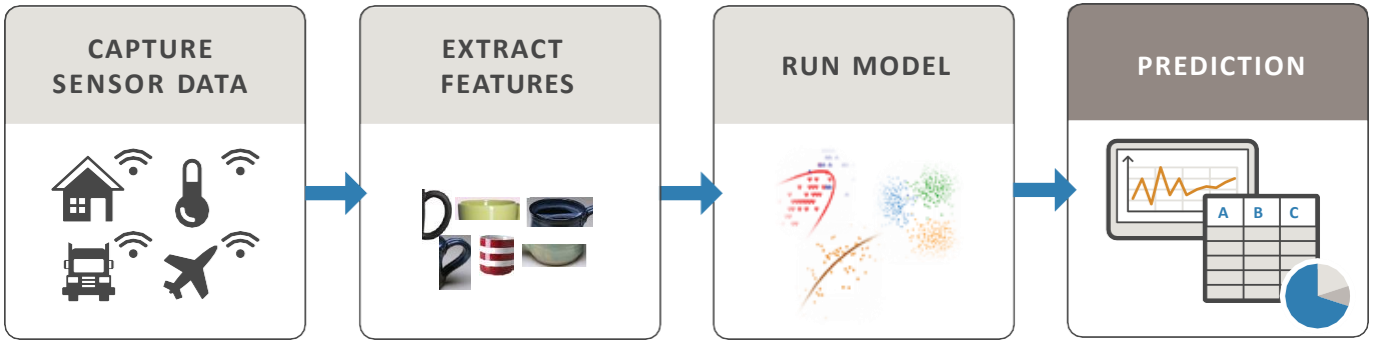
Deep Neural Network (DNN) - Resource and Energy Costs

TRAIN: Iterate until you achieve satisfactory performance.



Needs Significant:
- Resource
- Energy

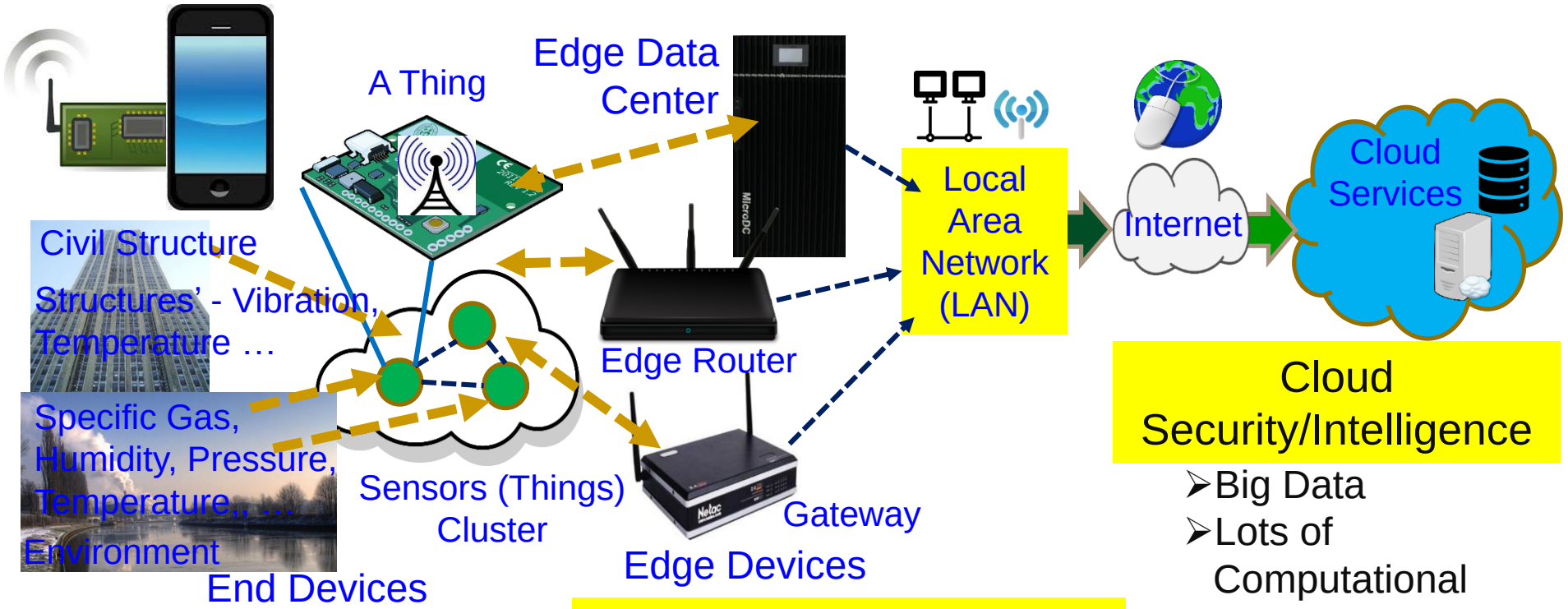
PREDICT: Integrate trained models into applications.



Needs:
- Resource
- Energy

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

End, Edge Vs Cloud Security, Intelligence …



End Security/Intelligence

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

Edge Security/Intelligence

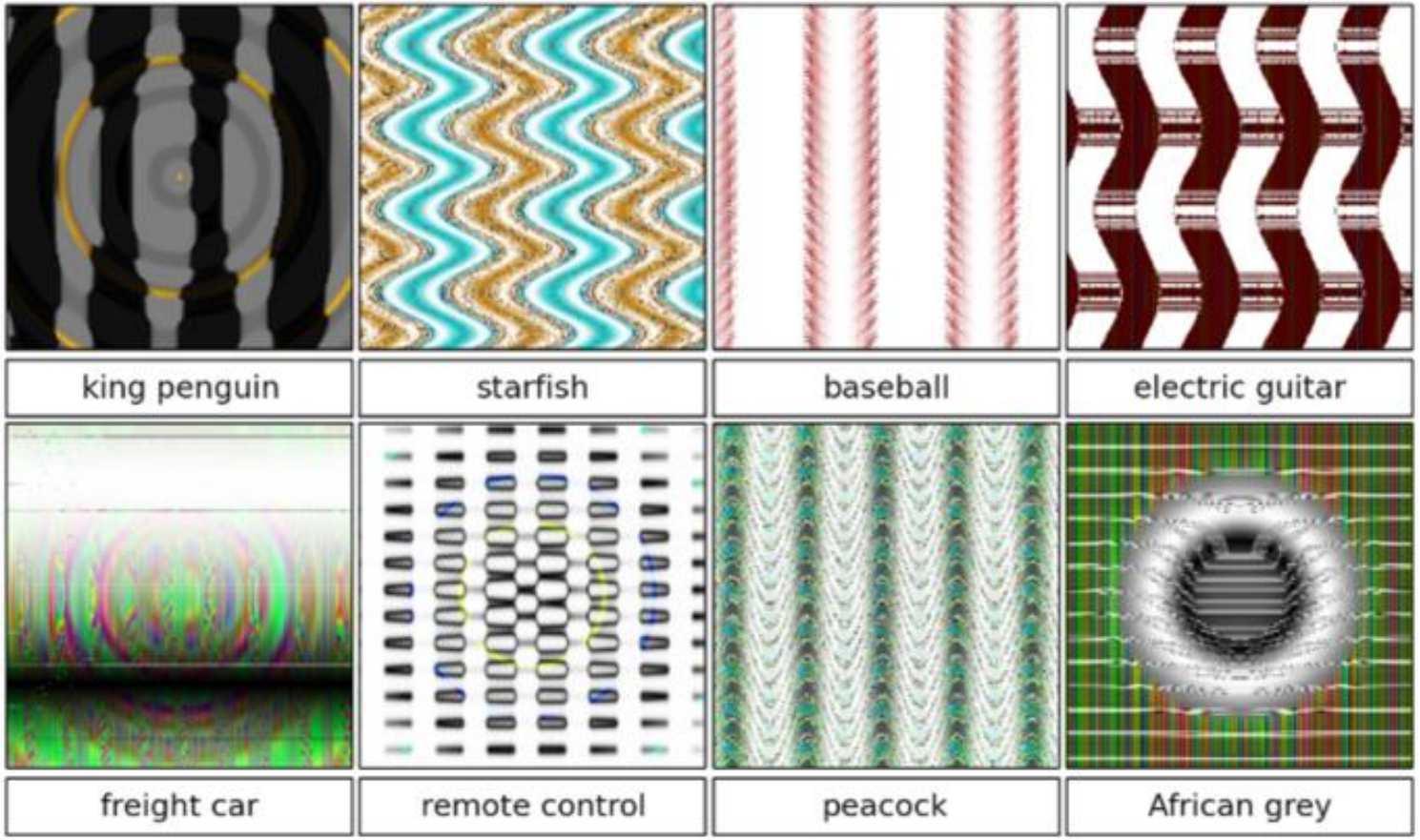
- Less Data
- Less Computational Resource
- Less Accurate Data Analytics
- Rapid Response

Cloud Security/Intelligence

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

Source: Mohanty iSES Keynote 2018

DNNs are not Always Smart

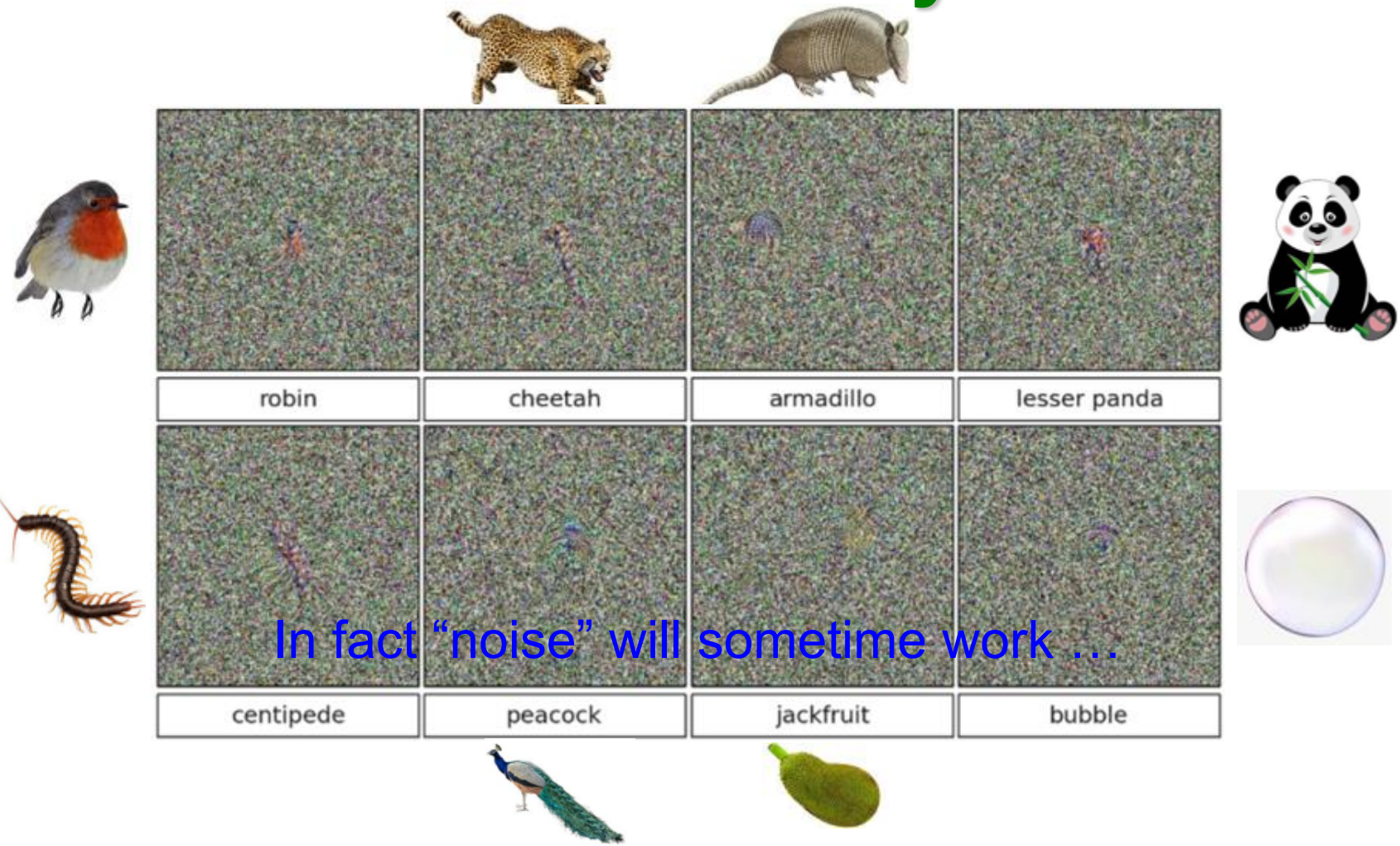


DNNs can be fooled by certain “learned” (Adversarial) patterns …

Source: Nguyen, et al. 2014 - Deep Neural Networks are Easily Fooled: High Confidence Predictions for Unrecognizable Images

Source: Corcoran Keynote 2018

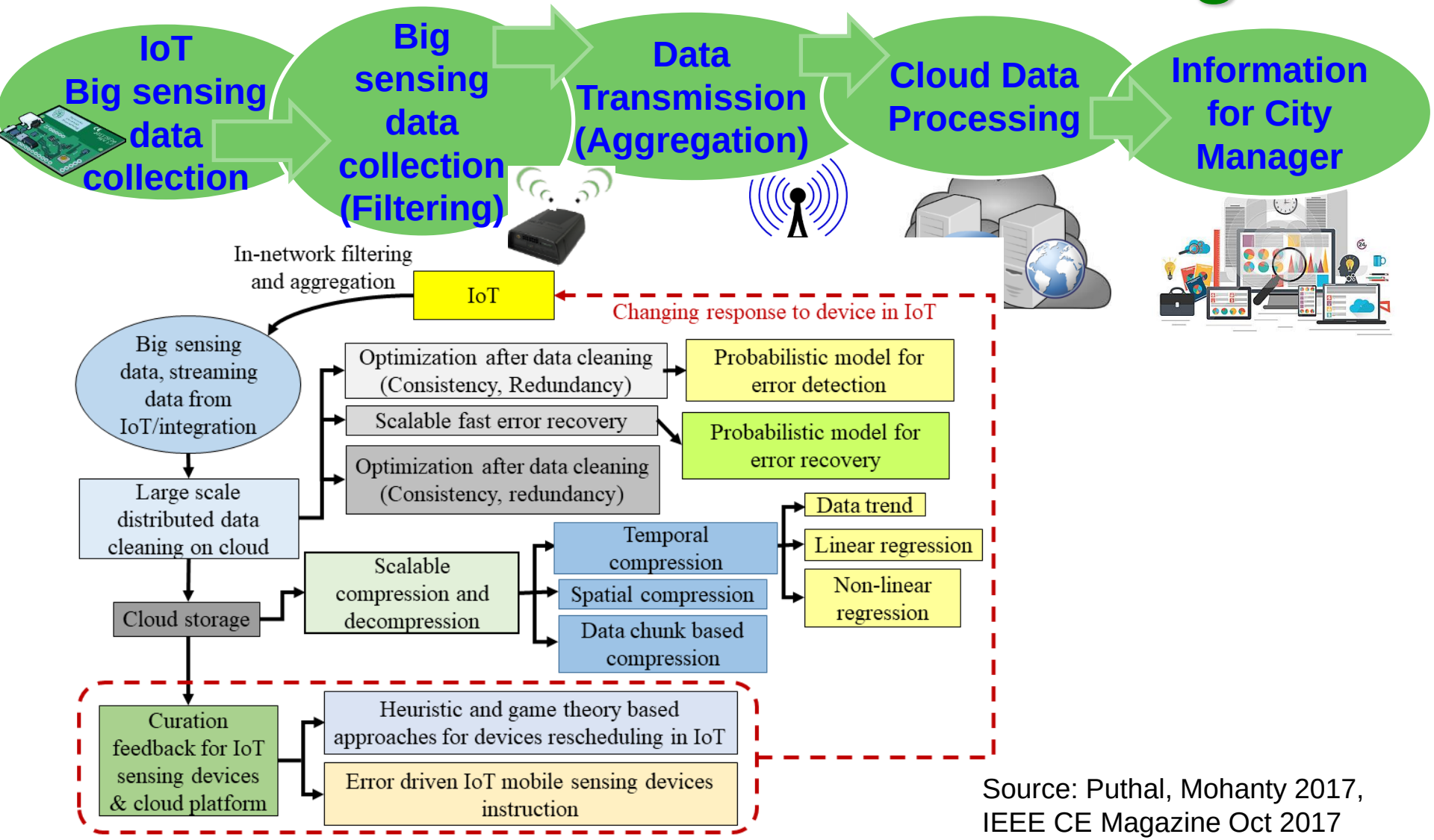
DNNs are not Always Smart



Source: Nguyen, et al. 2014 - Deep Neural Networks are Easily Fooled: High Confidence Predictions for Unrecognizable Images

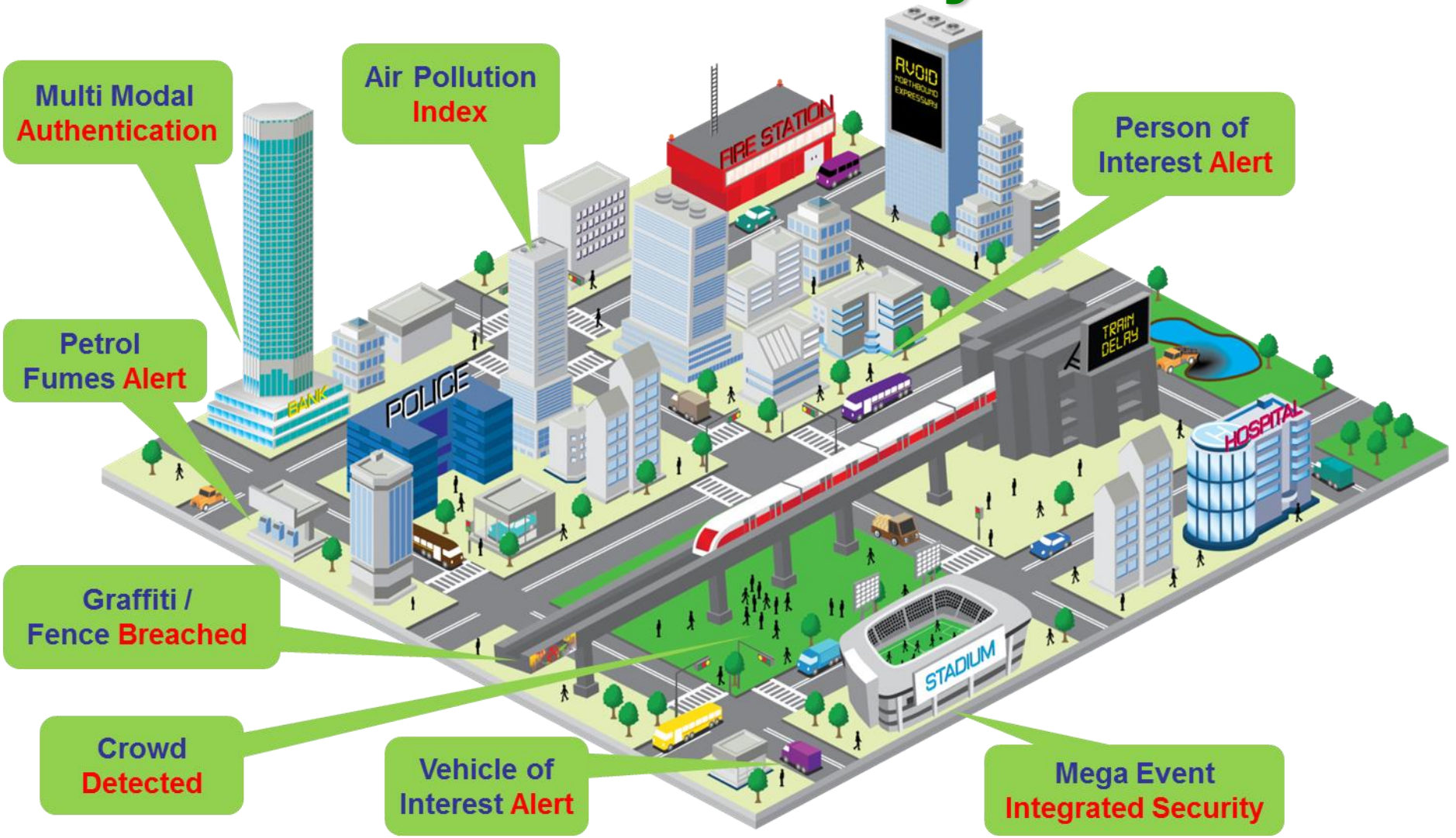
Source: Corcoran Keynote 2018

Data Curation: Cloud Vs Edge



Source: Puthal, Mohanty 2017, IEEE CE Magazine Oct 2017

Public Safety



Source: http://www.nec.com/en/global/solutions/safety/Inter-Agency/index.html

iTour: Safety Framework

Services: Ticket Booking, Taxi Hiring, Restaurants, Banking

iTour Framework

Smart Device

(Smart Technologies)

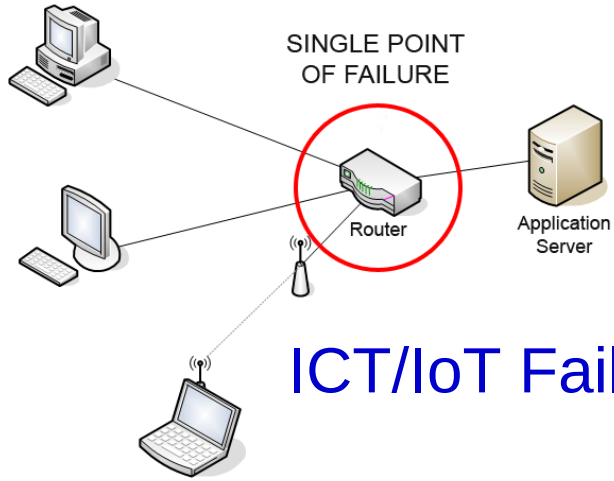
Enabling Technologies: Wireless Sensor Network, LAN, WAN

Human Resources: Tourists, Police, Volunteers, Officials

Emergency Help: Ambulance, Police Control Room, Officials

Source: Ray and Mohanty 2018: "iTour: The Future of Smart Tourism", *IEEE CE Magazine*, May 2018.

Failure Tolerance and Resilience



ICT/IoT Failure

Electromagnetic Pulse (EMP) Attack

- An electromagnetic pulse (EMP) is the electric wave produced by nuclear blasts which can knocking out electronics and the electrical grid as far as 1,000 miles away.
- The disruption could cause catastrophic damage and loss of life if power is not restored or backed up quickly.

Source: http://bwcentral.org/2016/06/an-electromagnetic-pulse-emp-nuclear-attack-may-end-modern-life-in-america-overnight/

CE/IoT System - Multi-Objective Tradeoffs

Non-recurring Design Cost

Recurring Operational Cost

Energy Consumption, Battery Life

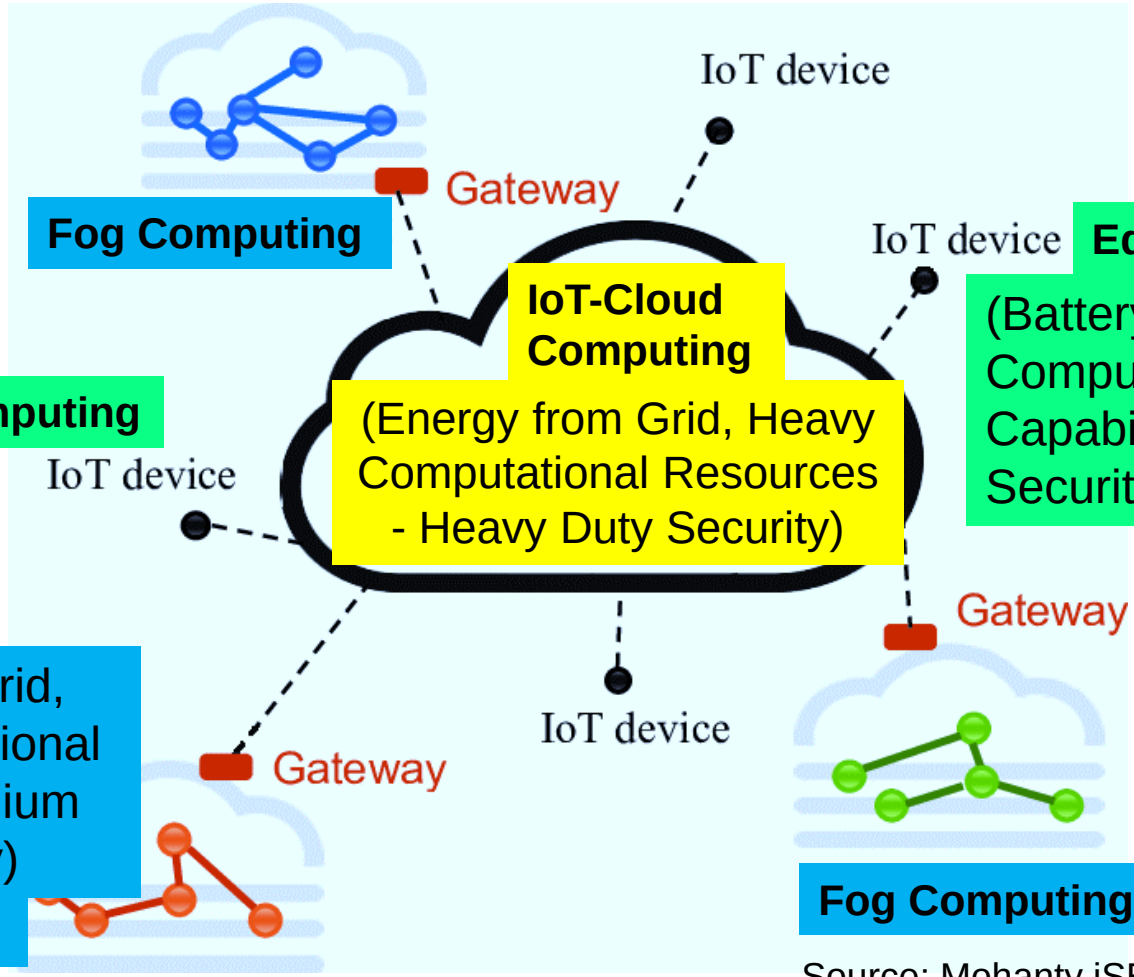
ENERGY STAR

Security, Privacy, IP Rights

Performance, Latency

Intelligence

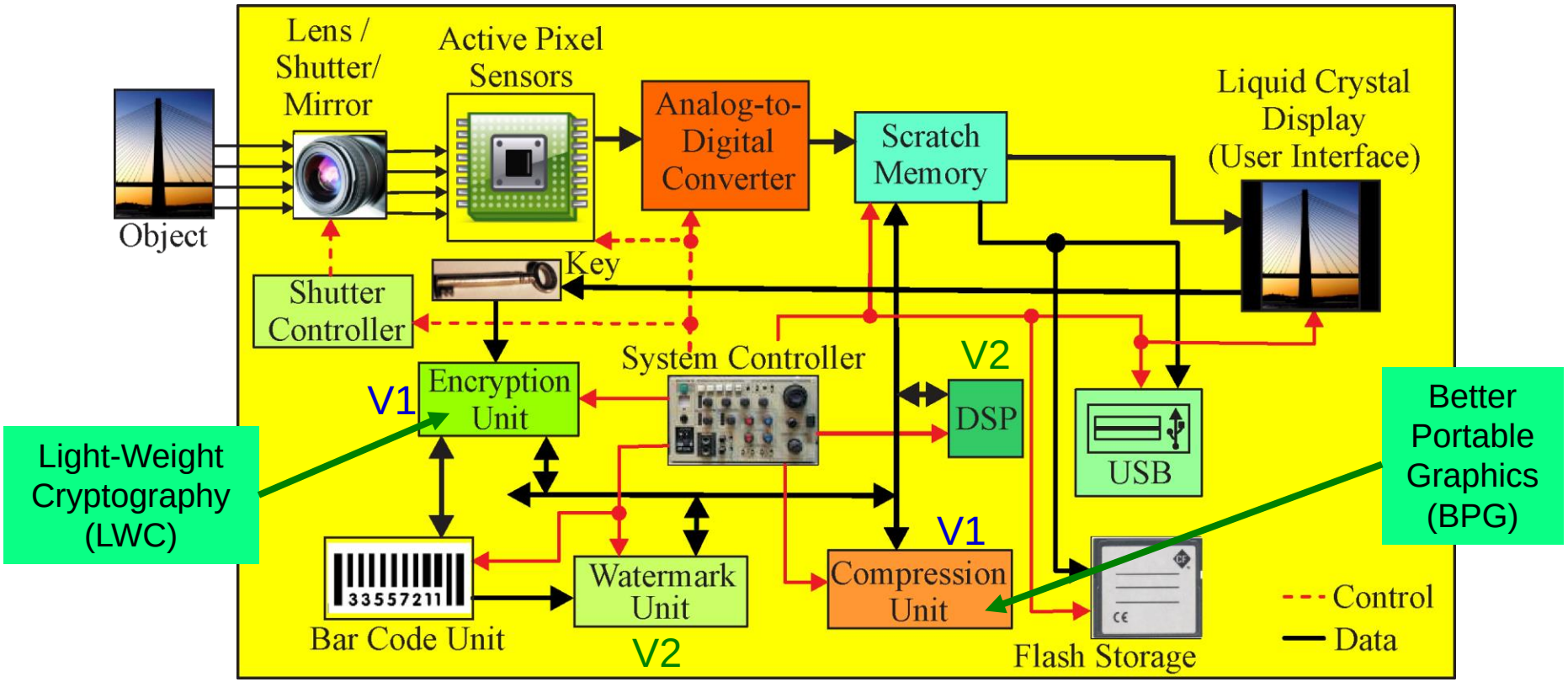
IoT Vs Fog Vs Edge Computing – Energy, Security, Response Tradeoffs



Source: Mohanty iSES Keynote 2018

Source: https://www.researchgate.net/figure/311918306_fig1_Fig-1-High-level-architecture-of-Fog-and-Cloud-computing

ESR-Smart – End-Device Optimization

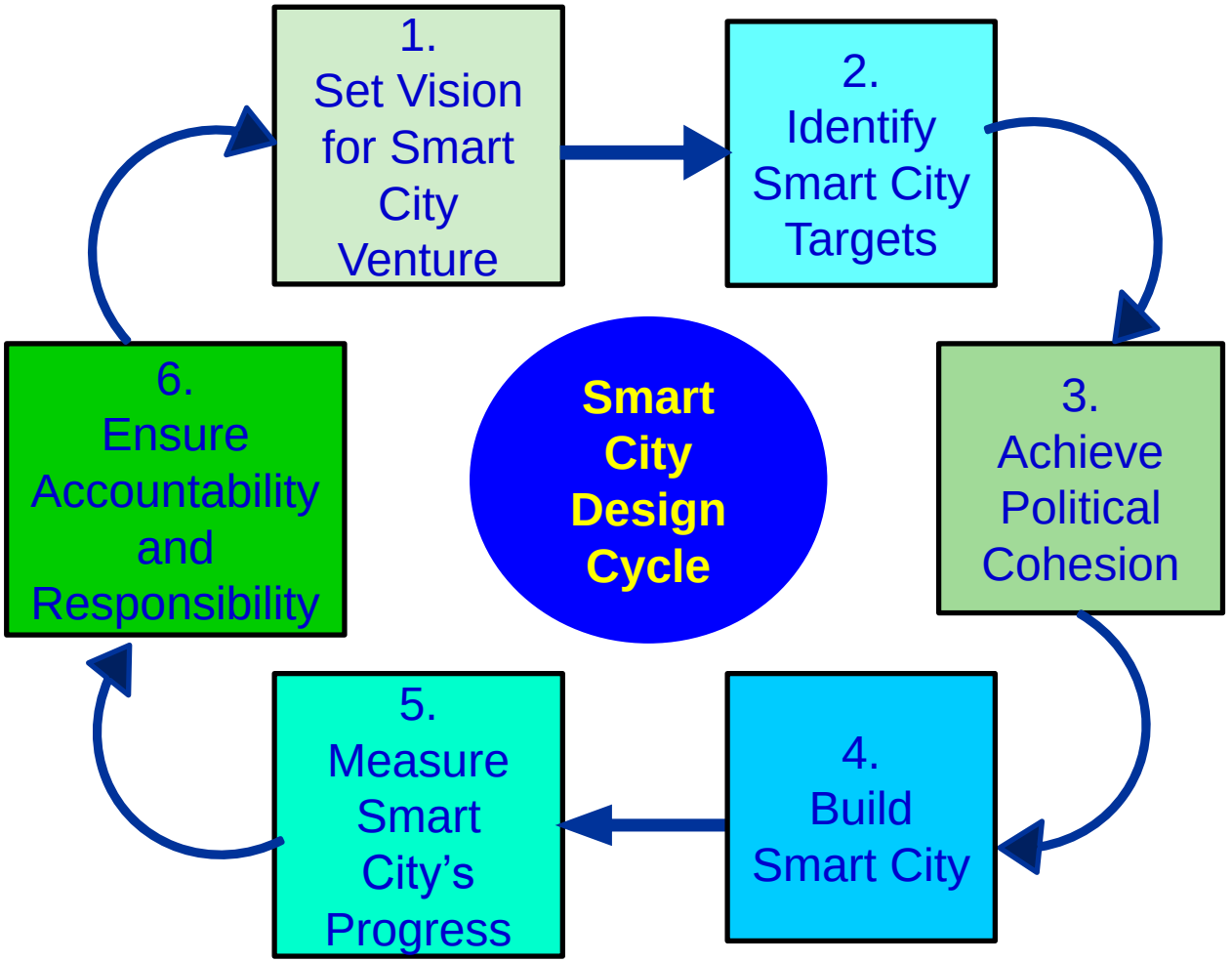


Include additional/alternative hardware/software components and uses DVFS like technology for energy and performance optimization.

Source: Mohanty 2006, TCAS-II May 2006; Mohanty 2009, JSA Oct 2009; Mohanty 2016, Access 2016

Design and Operation

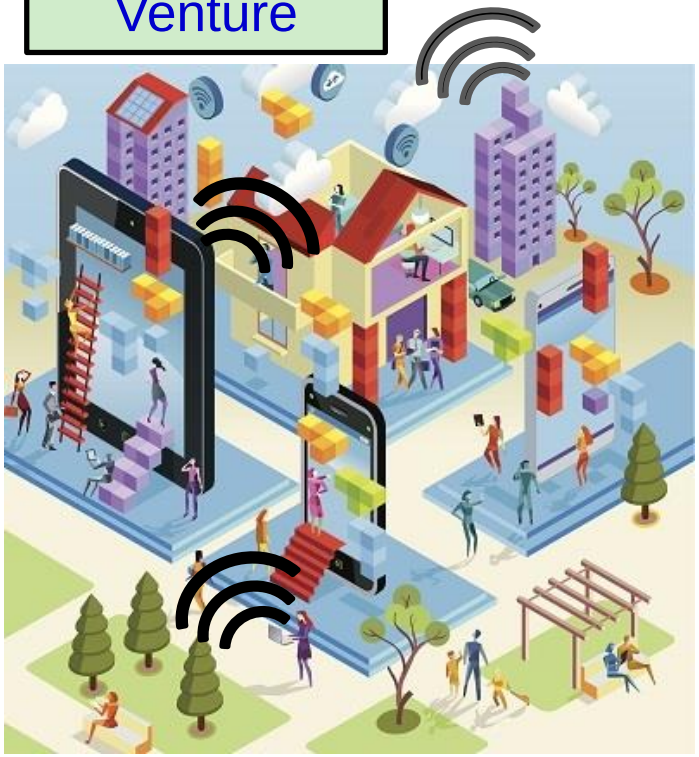
Smart Cities - Design Cycle



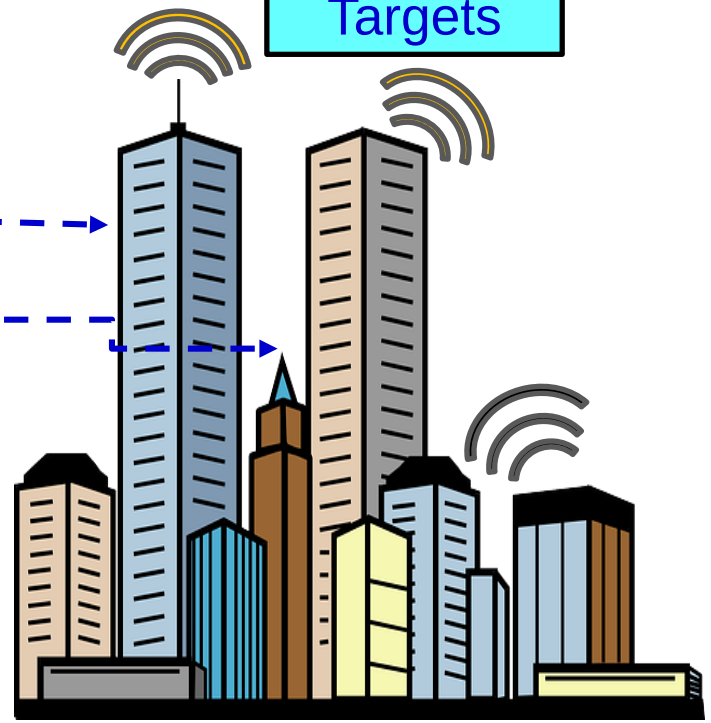
Source: Paolo Gemma 2016, ISC2 2016

Smart City Design – Vision and Target

1.
Set Vision for Smart City Venture



2.
Identify Smart City Targets



Source: Paolo Gemma 2016, ISC2 2016

Smart City Design - Stakeholders

3. Achieve Political Cohesion

4. Build Smart City

Academia, Research Organizations and Specialized Bodies

International, Regional and Multilateral Organizations

ICT Companies

City Service Companies

Utility Providers

Urban Planners

Municipalities, City Council and City Administration

Standardization Bodies

National and Regional Governments

Citizens and Citizen Organizations

Non-Governmental Organization (NGO)

Industry Associations

Source: Paolo Gemma 2016, ISC2 2016

Smart City Design - Sustainable Developmental Goals

5. Measure City's Progress

Dimensions of Key Performance Indicators (KPIs)

Environment	Society and Culture	Economy
• Air quality • Water • Noise • Biodiversity • Energy • Environmental quality	• Education • Health • Safety • Housing • Culture • Social inclusion	• Innovation • Employment • Trade • Productivity • Physical infrastructure • ICT infrastructure and Access/Usage • Public Sector

Source: Paolo Gemma 2016, ISC2 2016

Smart City Design – Building Trust

6. Ensure Accountability and Responsibility

Citizen-Centric

Smart Tools

Data-Driven Decision

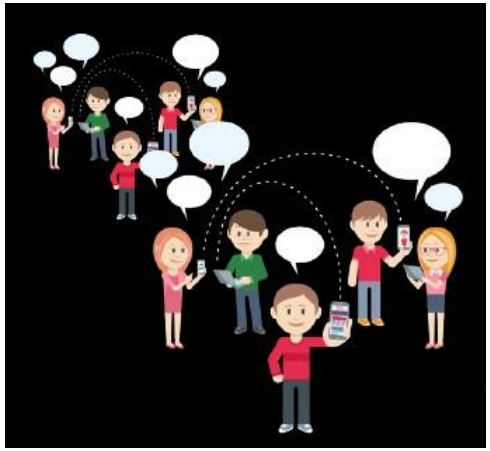
Cost Effective

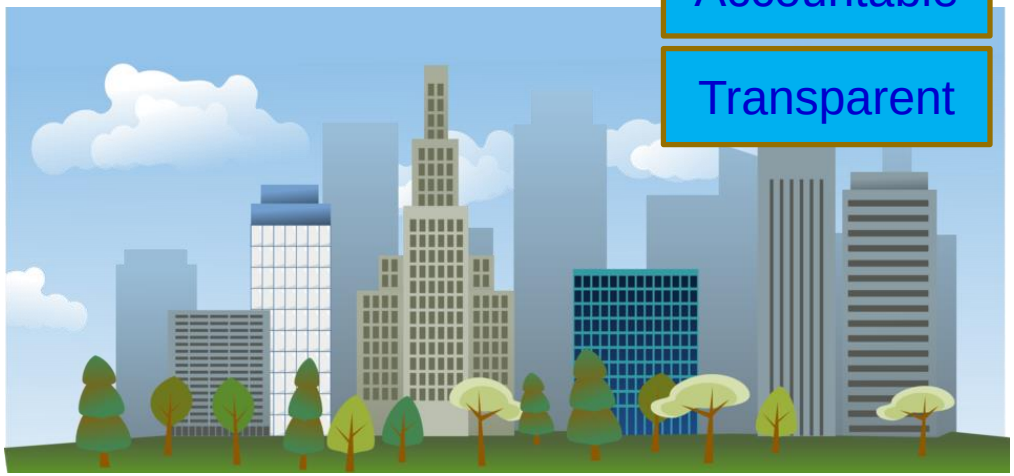
Collaborative

Responsive

Accountable

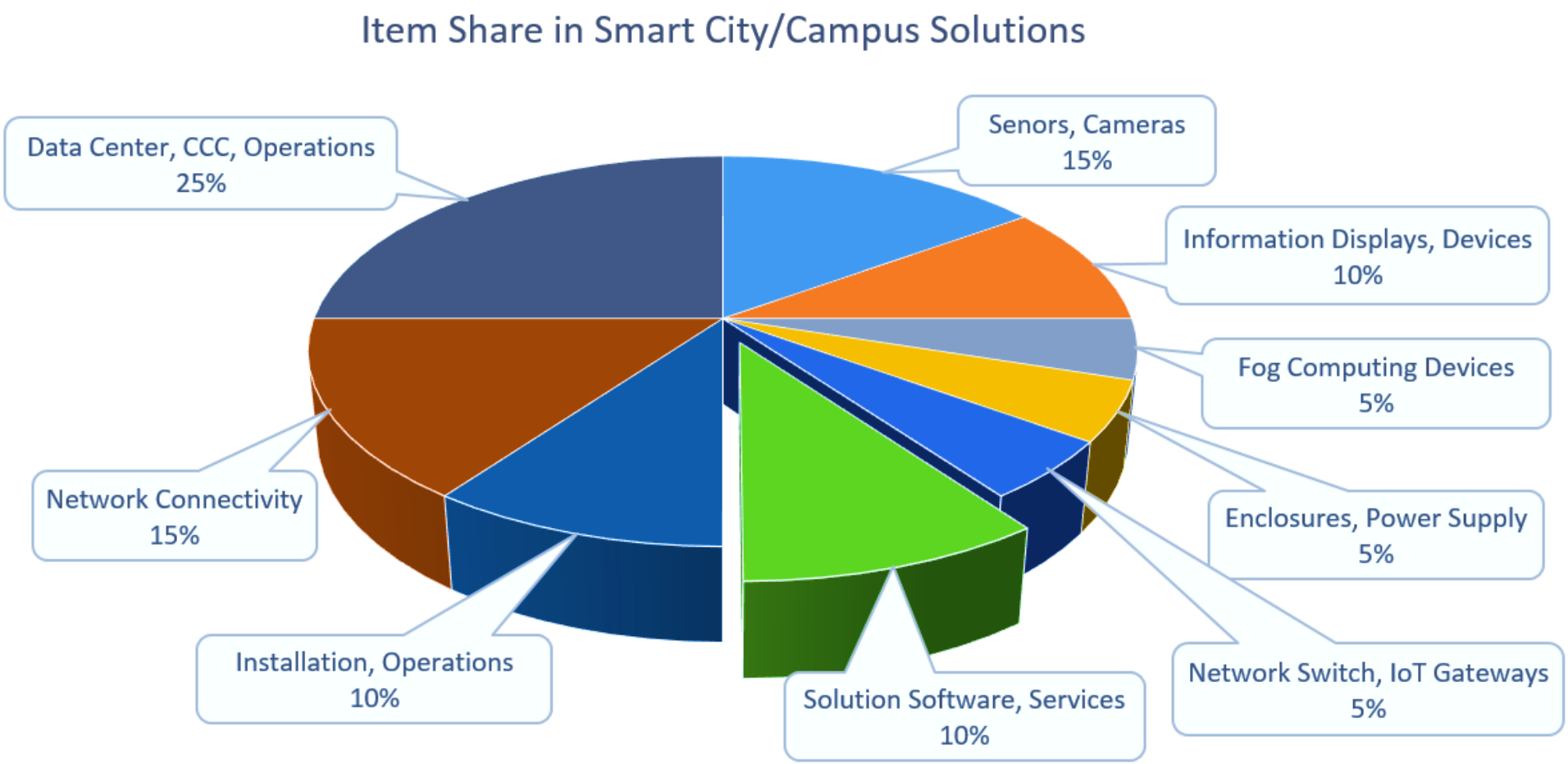
Transparent





Source: Paolo Gemma 2016, ISC2 2016

Smart City Design - Verticals

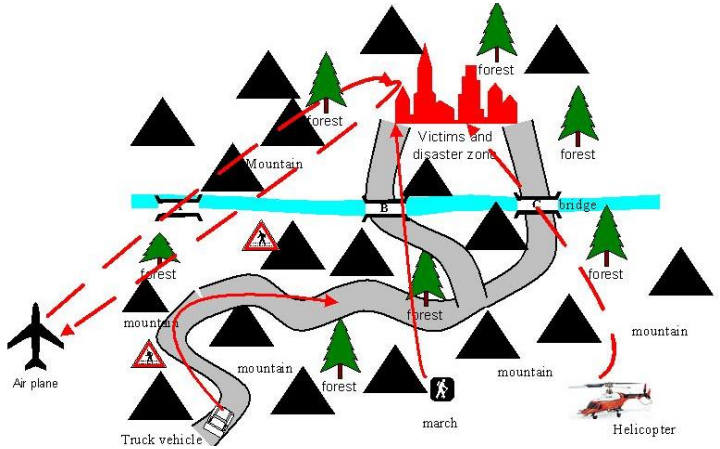


Source: https://www.linkedin.com/pulse/smart-citiescampus-what-could-your-share-suresh-kumar-kk

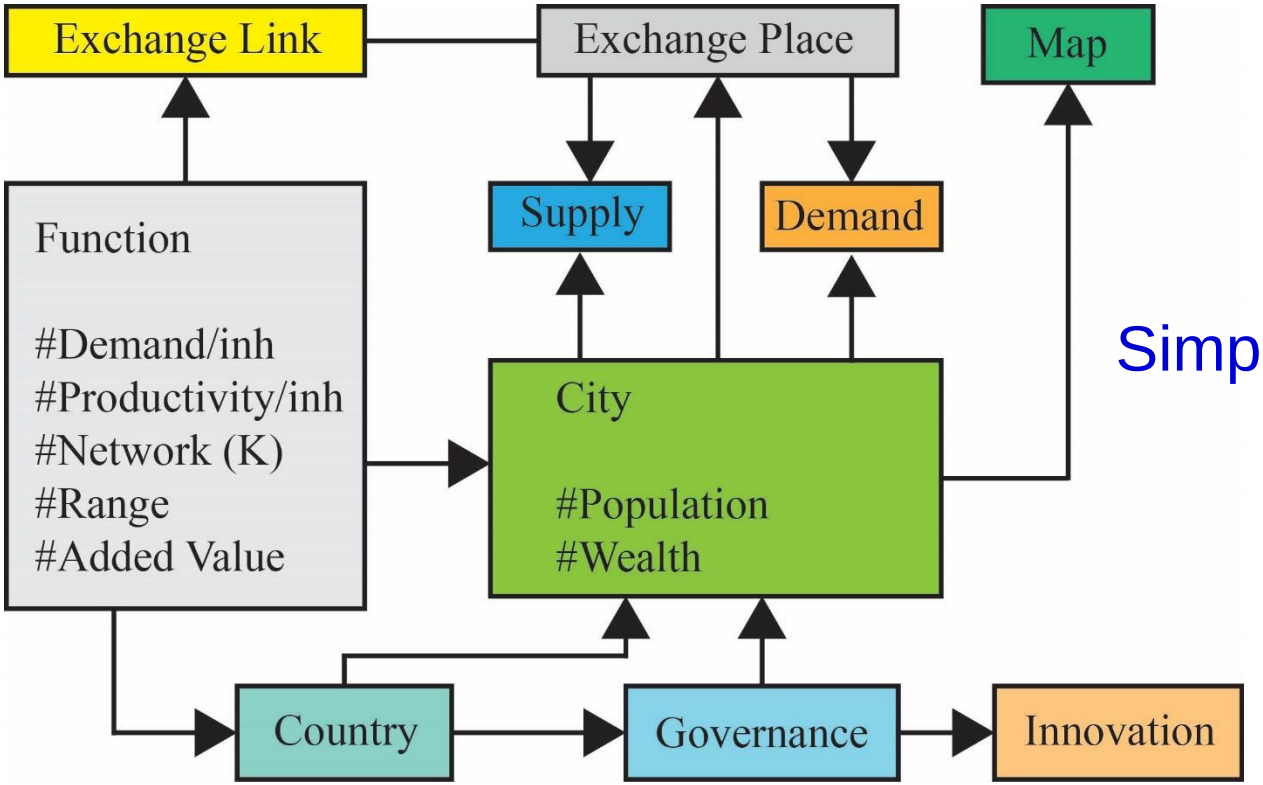
Tools and Solutions

Smart Cities Simulator

- Simulator is needed to verify and characterize a smart city component (or a cyber physical system (CPS)), before deployment.
- Smart city is too large, complex, and diverse.
- For different components of smart cities, different simulator may be needed.



Smart Cities Simulator - Simpop

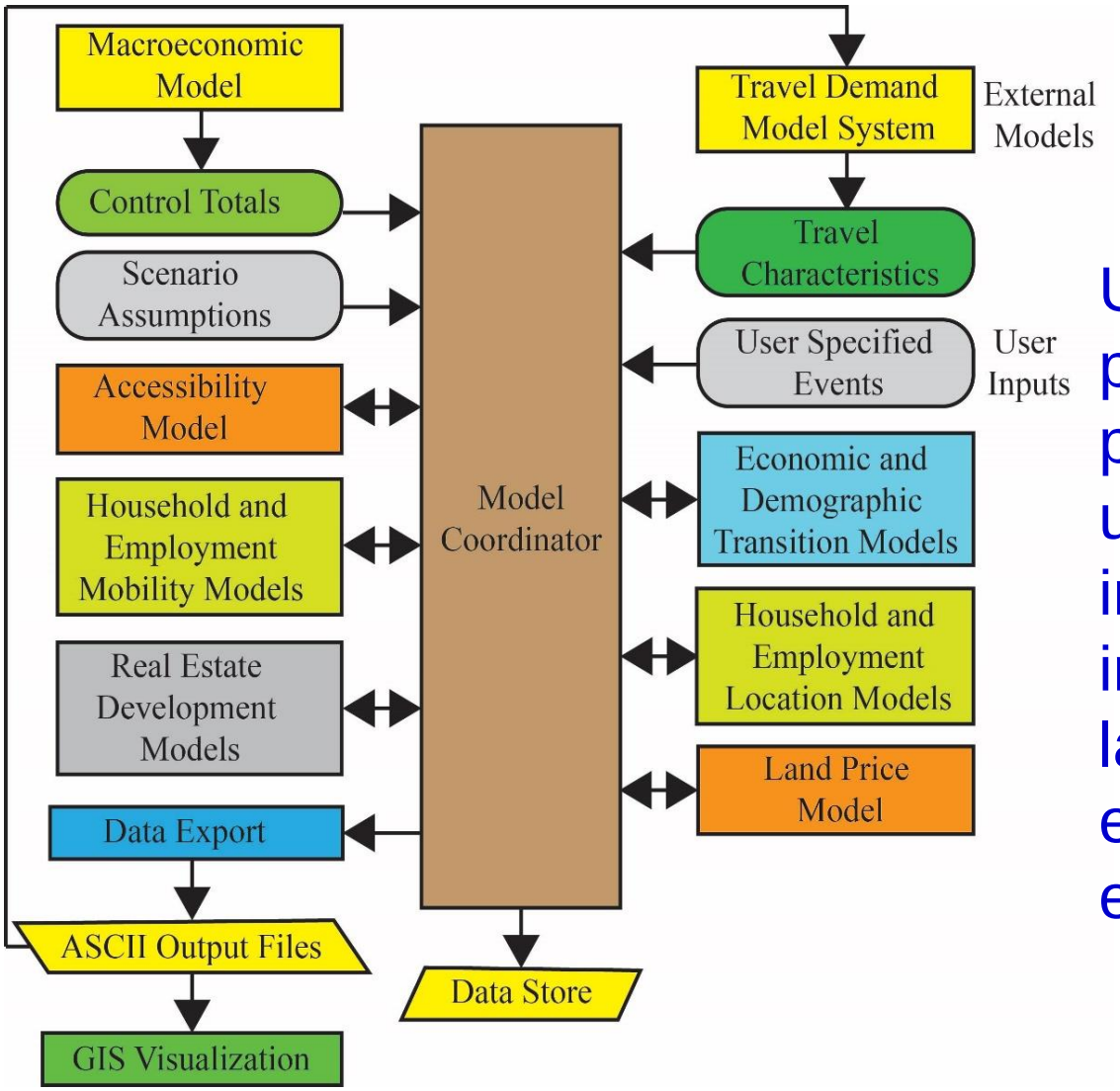


Simpop2

- SIMPOP is a geosimulation tool for exploring smart cities.
- Common features in the genesis and long-term evolution of cities help in understanding and predicting their future dynamics.

Source: http://www.simpop.parisgeo.cnrs.fr/models/simpop2

Smart Cities Simulator - UrbanSim



UrbanSim is a simulation platform for supporting planning and analysis of urban development, incorporating the interactions between land use, transportation, economy, and environment.

Source: http://www.urbansim.com/home

Standards

Standards - Why

- To determine entry points for investment in city markets and make informed decisions through data analysis
- To benchmark investments and monitor progress
- To evaluate the “impact” of infrastructure projects on the sustainability and efficiency of the city
- To build smart and sustainable cities
- To evaluate the investment in comparative perspective across cities nationally and globally
- To strengthen the effectiveness of city governance

Source: https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2015/SSC/S6-MrDWelsh_MrFDadaglio.pdf

Standards - What

- International Organization for Standards (ISO) initiatives.
- International Telecommunication Union (ITU), United Nations specialized agency on ICT has been working.
- International Electrotechnical Commission (IEC) has initiatives.
- IEEE has been developing standards for smart cities for its different components including smart grids, IoT, eHealth, and intelligent transportation systems (ITS).
- Selected indicators: economy, education, energy, and environment.

Standards - ISO 37120

- ISO 37120 defines 100 city performance indicators which include 46 core and 54 supporting indicators.
- 2 Core Indicators for Transportation:
  - Kilometers of high capacity public transportation per 100,000 population
  - Annual number of public transport trips per capita
- 2 Core Indicators for Economy:
  - City's unemployment rate
  - Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties
- 2 Core Indicators for Energy:
  - Total electrical energy use per capita (kWh / year)
  - Average number of electrical interruptions per customer per year

Source: http://smartcitiescouncil.com/article/dissecting-iso-37120-why-new-smart-city-standard-good-news-cities

Standards - IEEE

- Standards activities are underway:
  - Smart Grid
  - Cloud Computing
  - Internet of Things (IoT)
  - Intelligent Transportation
  - eHealth

Source: http://standards.ieee.org/develop/msp/smartcities.pdf

Initiatives

Top Smart Cities Using 4 KPIs in 2018

	Mobility	Health	Safety	Productivity
1	Singapore	Singapore	Singapore	Singapore
2	San Francisco	Seoul	New York	London
3	London	London	Chicago	Chicago
4	New York	Tokyo	Seoul	San Francisco
5	Barcelona	Berlin	Dubai	Berlin
6	Berlin	New York	Tokyo	New York
7	Chicago	San Francisco	London	Barcelona
8	Portland	Melbourne	San Francisco	Melbourne
9	Tokyo	Barcelona	Rio de Janeiro	Seoul
10	Melbourne	Chicago	Nice	Dubai
11	San Diego	Portland	San Diego	San Diego
12	Seoul	Dubai	Melbourne	Nice
13	Nice	Nice	Bhubaneswar	Portland
14	Dubai	San Diego	Barcelona	Tokyo
15	Mexico City	Wuxi	Berlin	Wuxi
16	Wuxi	Mexico City	Portland	Mexico City
17	Rio de Janeiro	Yinchuan	Mexico City	Rio de Janeiro
18	Yinchuan	Hangzhou	Wuxi	Yinchuan
19	Hangzhou	Rio de Janeiro	Yinchuan	Hangzhou
20	Bhubaneswar	Bhubaneswar	Hangzhou	Bhubaneswar

Source: https://newsroom.intel.com/wp-content/uploads/sites/11/2018/03/smart-cities-whats-in-it-for-citizens.pdf

Smart Cities - Case Study - Barcelona

Source: http://www.ioti.com/smart-cities/world-s-5-smartest-cities

- Sensors monitor traffic levels, road pollution, crowds
- Sensors monitor the weather
- Sensors measure rainfall & analyze irrigation levels in the ground
- LED lighting arrangements

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-

Smart Cities - Case Study - San Francisco

Source: http://www.ioti.com/smart-cities/world-s-5-smartest-cities

- LEED-certified buildings than any other in the United States and a connected city initiative
- Smart transportation: Smart parking, Contactless payments
- LED lighting arrangements.

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-

Smart Cities - Case Study - Singapore

- Smart transport with traffic lights/management, smart parking
- Visible Light Communication (VLC) or LiFi for indoor positioning in malls
- Smart waste management.

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-

IEEE Smart Cities

- IEEE Technical Community created: http://smartcities.ieee.org
- The IEEE International Smart Cities Conference (ISC2) is the flagship event of the IEEE Smart Cities Initiative.
- IEEE Smart Cities initiative: IEEE Core Smart Cities program recognizes/helps cities which establish and invest both human/financial capital into smart city plans.
- Current IEEE Core Smart Cities: Casablanca, Morocco; Guadalajara, Mexico; Kansas City, USA; Trento, Italy; and Wuxi, China.
- IEEE Affiliated Smart Cities program: Allow more cities to participate in and enjoy benefits of the IEEE Smart Cities program and network.

Source: http://smartcities.ieee.org/

UN Initiative - United 4 Smart Sustainable Cities (U4SSC)

U4SSC is a global platform for smart city stakeholders which advocates for public policy to encourage the use of ICTs to facilitate the transition to smart sustainable cities.

WG 01 – Setting the Framework
- Urban Planning
- Policy, Standards and Regulation
- Key Performance Indicators

WG 02 – Connecting Cities and
- Smart Living
- Smart Mobility
- Smart Environment

WG 03 – Enhancing Innovation and Participation
- Smart Governance
- Smart People
- Smart Economy

Source: http://wftp3.itu.int/pub/epub_shared/TSB/2016-ITUT-SSC-Brochure/en/index.html Source: Paolo Gemma 2016, ISC2 2016

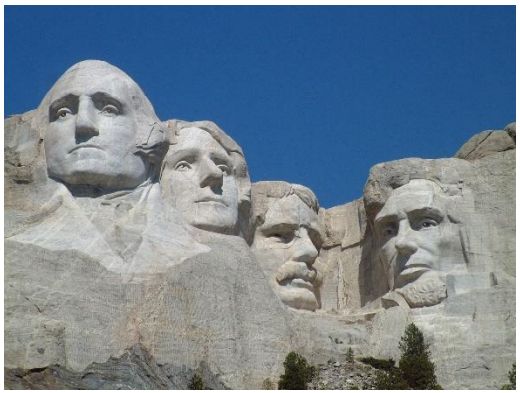
Smart Cities Council

- The Smart Cities Council is a network of leading companies advised by top universities, laboratories and standards bodies.
- Help cities become smarter through a combination of advocacy and action:
  - Readiness Guides
  - Financing templates and case studies
  - Policy frameworks and case studies
  - Visibility campaigns
  - Regional networking events

Source: http://smartcitiescouncil.com/

USA - National Science Foundation (NSF)

- Smart and Connected Communities (S&CC)
- Smart and Connected Health (SCH)
- Smart and Autonomous Systems (S&AS)



Source: https://www.nsf.gov

US Department of Transportation

- The USDOT encouraged cities to put ideas to answer the questions raised in Beyond Traffic 2045: Trends and Choices
  - How will we move things?
  - How will we move?
  - How will we adapt?
  - How will we move better?
  - How will we align decisions and dollars?

Source: https://www.transportation.gov/smartcity

US Ignite

- US Ignite is accelerating the smart city movement
  - and creating value for an entire ecosystem
  - by guiding communities into the connected future, creating a path for private sector growth, and advancing technology research that's at the heart of smart city development.

Source: https://www.us-ignite.org/

Conclusions

Conclusions

- Smart cities is not a technological trend, rather it is a necessity.
- Smart cities technology is an ongoing R & D.
- Multi-Front research on smart cities from academia and industries are in full swing.
- Smart cities still need significant maturity for effective design and operation.
- R & D seems to be in right direction.

Future Research

- Accurate and scalable smart city simulator
- Energy-efficient, accurate sensors
- Security
- Privacy
- IP or content protection
- Energy efficiency
- Big data processing
- Efficient, Safer Battery
- Larger, cheaper, faster memory

Can Any Smartness/Intelligence Solve?

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

Thank You !!!

Slides Available at: http://www.smohanty.org

Hardwares are the drivers of the civilization, even softwares need them.