Consumer Technologies for Smart Cities

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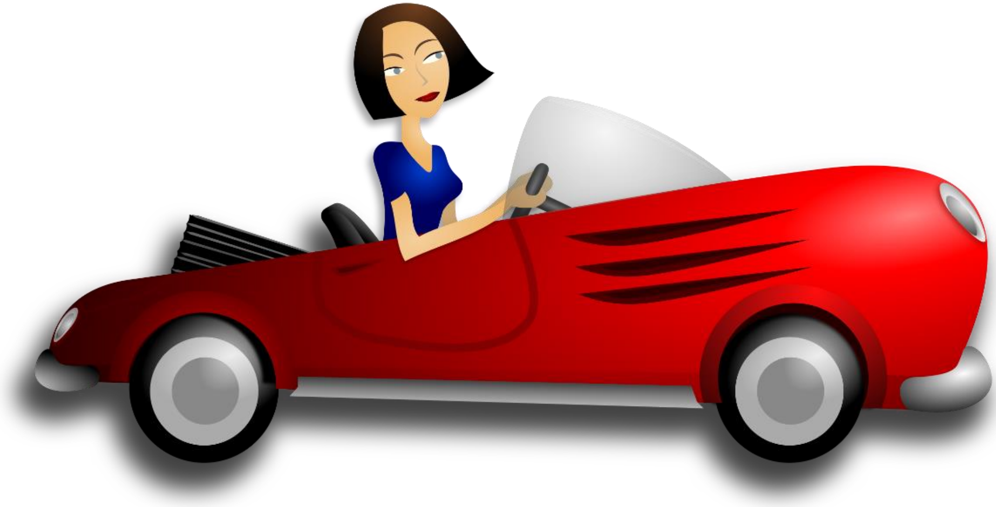
Talk - Outline

- Smarty City Drivers
- Smarty City Components
- Technologies for Smart City
- Challenges and Research on Smarty Cities
- Initiatives on Smarty Cities
- Conclusions and Future Directions

Smart City 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

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

The Problem

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

Source: https://humanitycollege.org

Issues Challenging Sustainability

➢ Pollution

➢ Water crisis

➢ Energy crisis

➢ Traffic

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

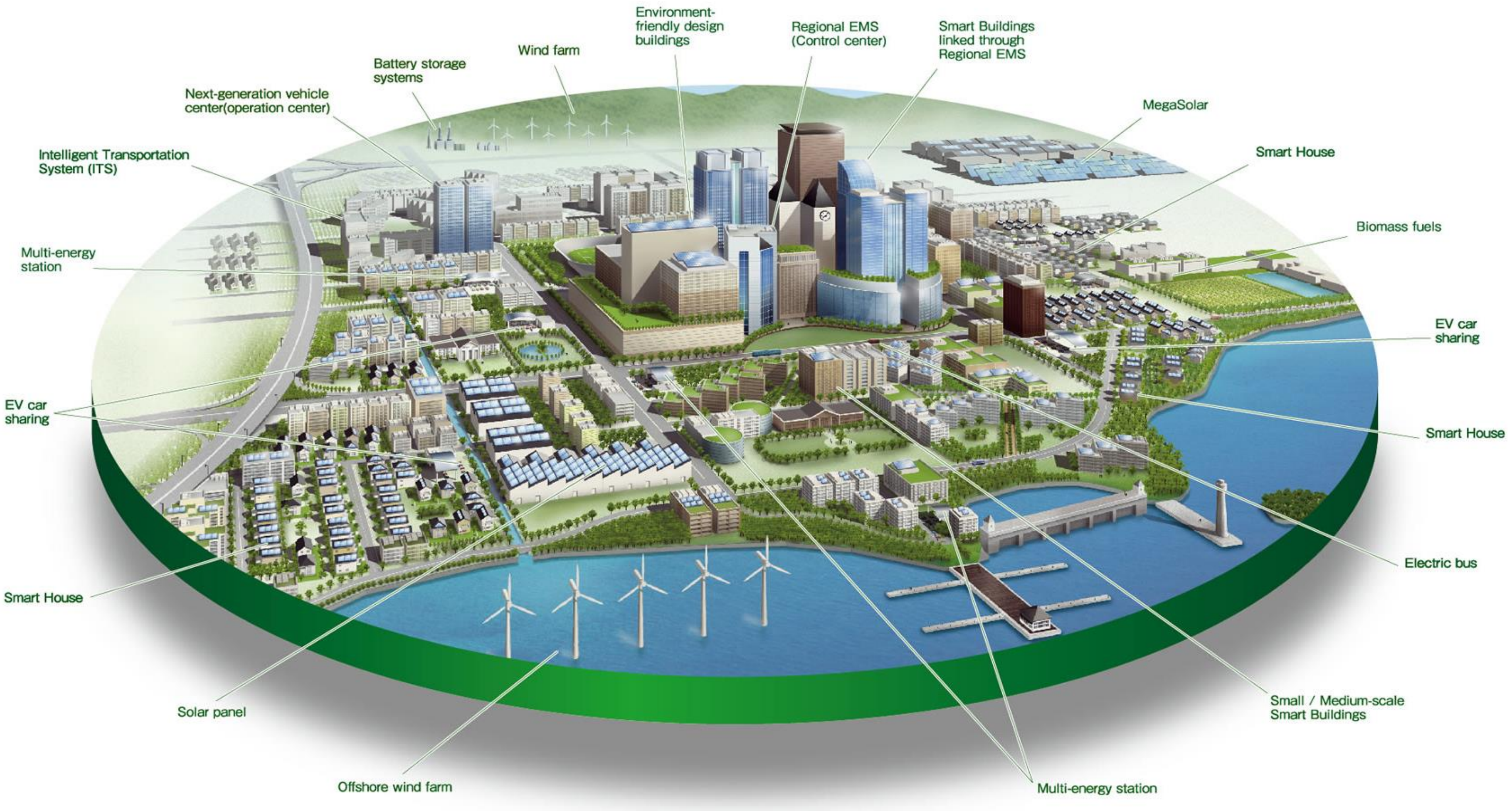
Smart Cities - Formal Definition

- 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: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", IEEE Consumer Electronics Magazine (CEM), Volume 5, Issue 3, July 2016, pp. 60--70.

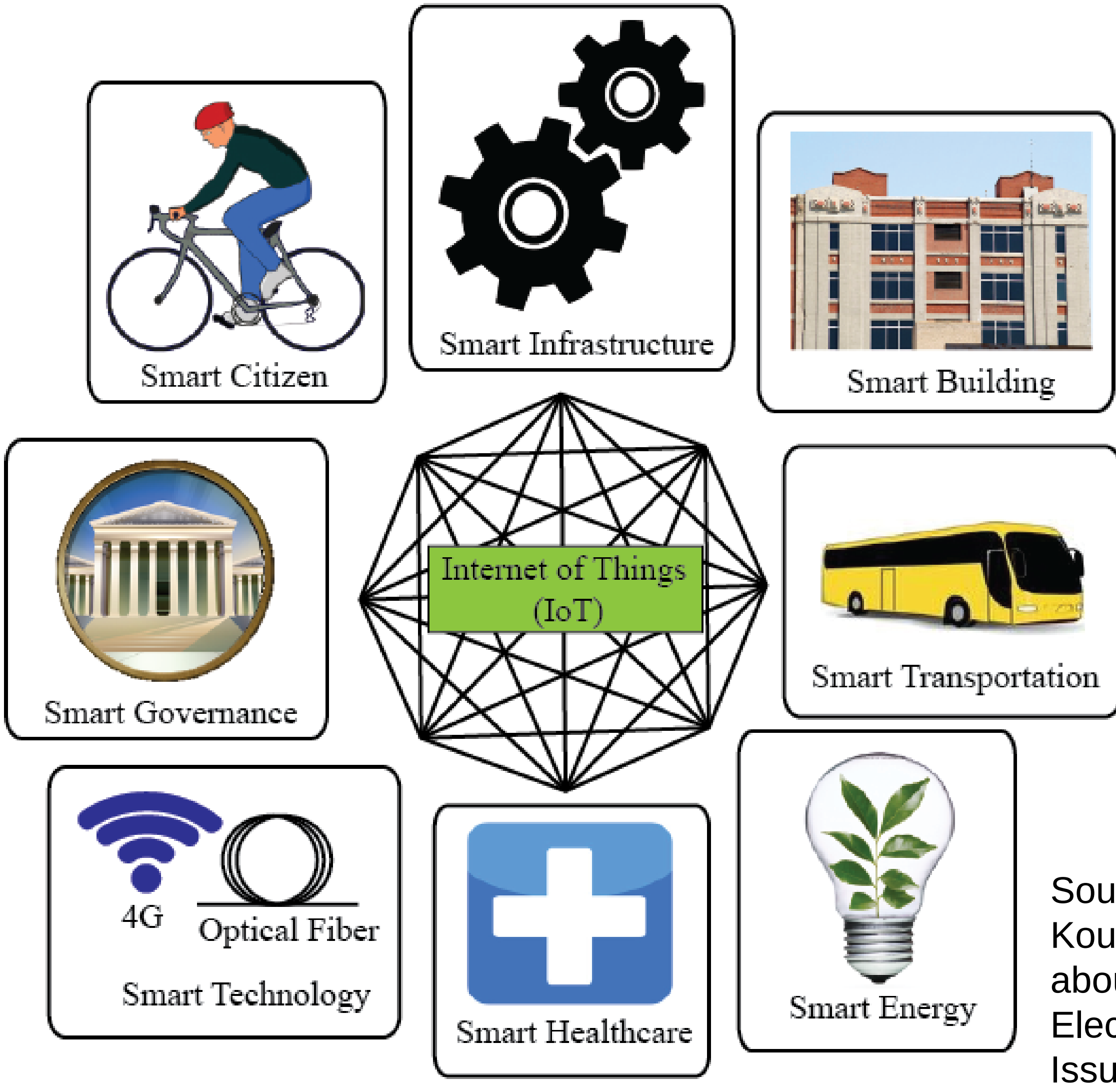
Smart Cities – A Broad View



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

Smart City Components

Smart Cities - Components



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

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, “Everything You wanted to Know about Smart Cities”, IEEE Consumer Electronics Magazine (CEM), Volume 5, Issue 3, July 2016, pp. 60--70.

Smart Healthcare

Healthy Living
- Fitness Tracking
- Disease Prevention
- Food monitoring

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

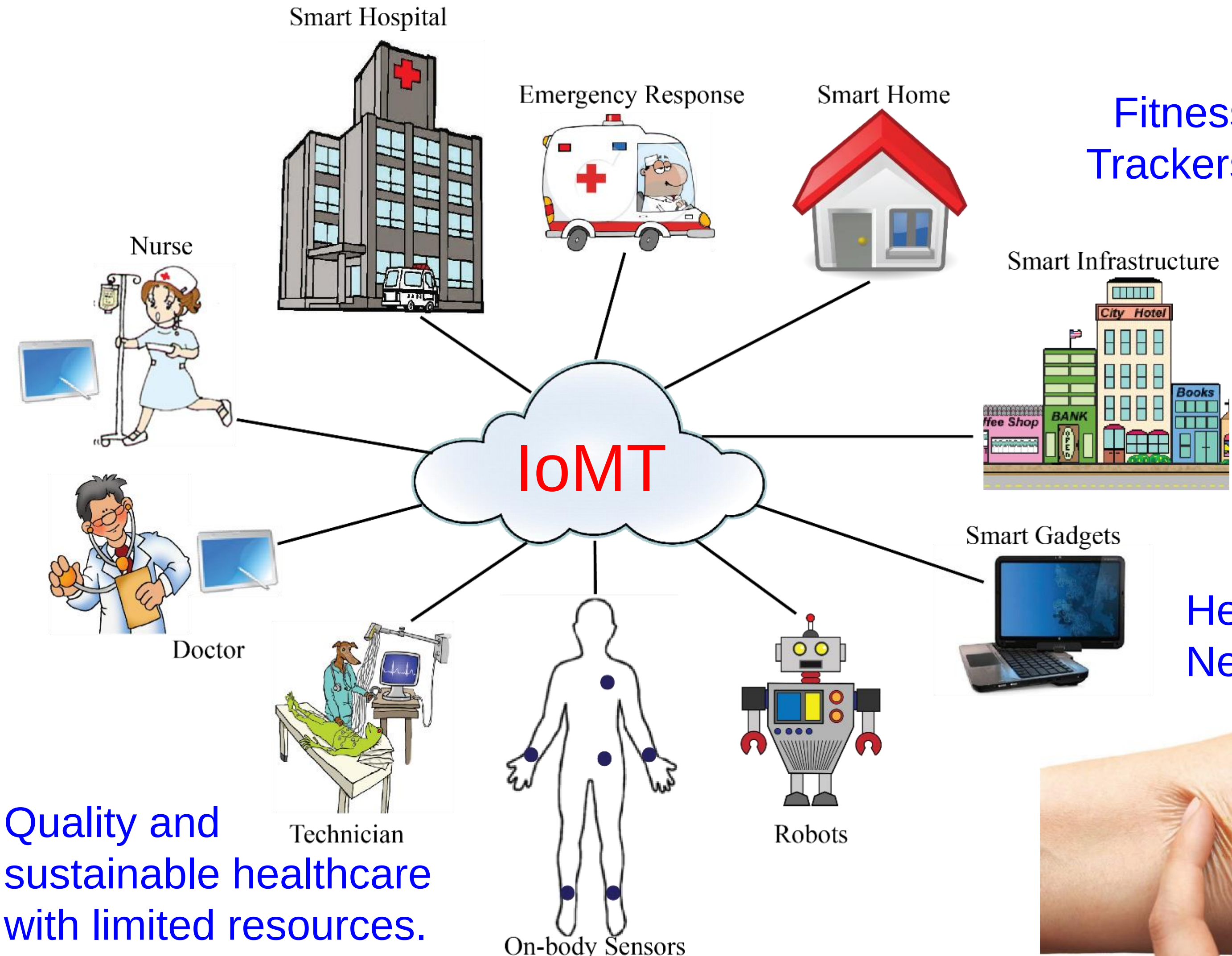
Acute care
- Hospital
- Specialty clinic
- Nursing Home
- Community Hospital

Frost and Sullivan predict smart health-care market value to reach US$348.5 billion by 2025.

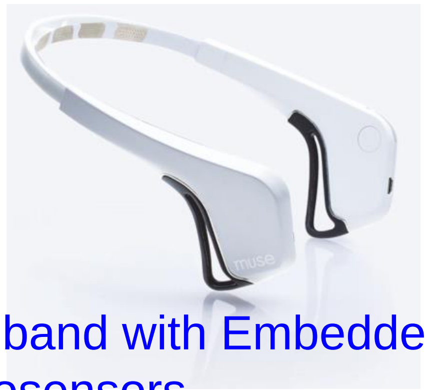
January 2018

Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", IEEE Consumer Electronics Magazine (CEM), Volume 7, Issue 1, January 2018, pp. 18-28.

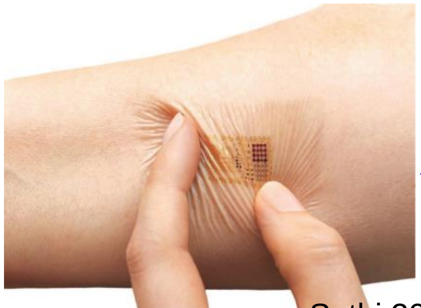
Smart Healthcare



Fitness Trackers



Headband with Embedded Neurosensors



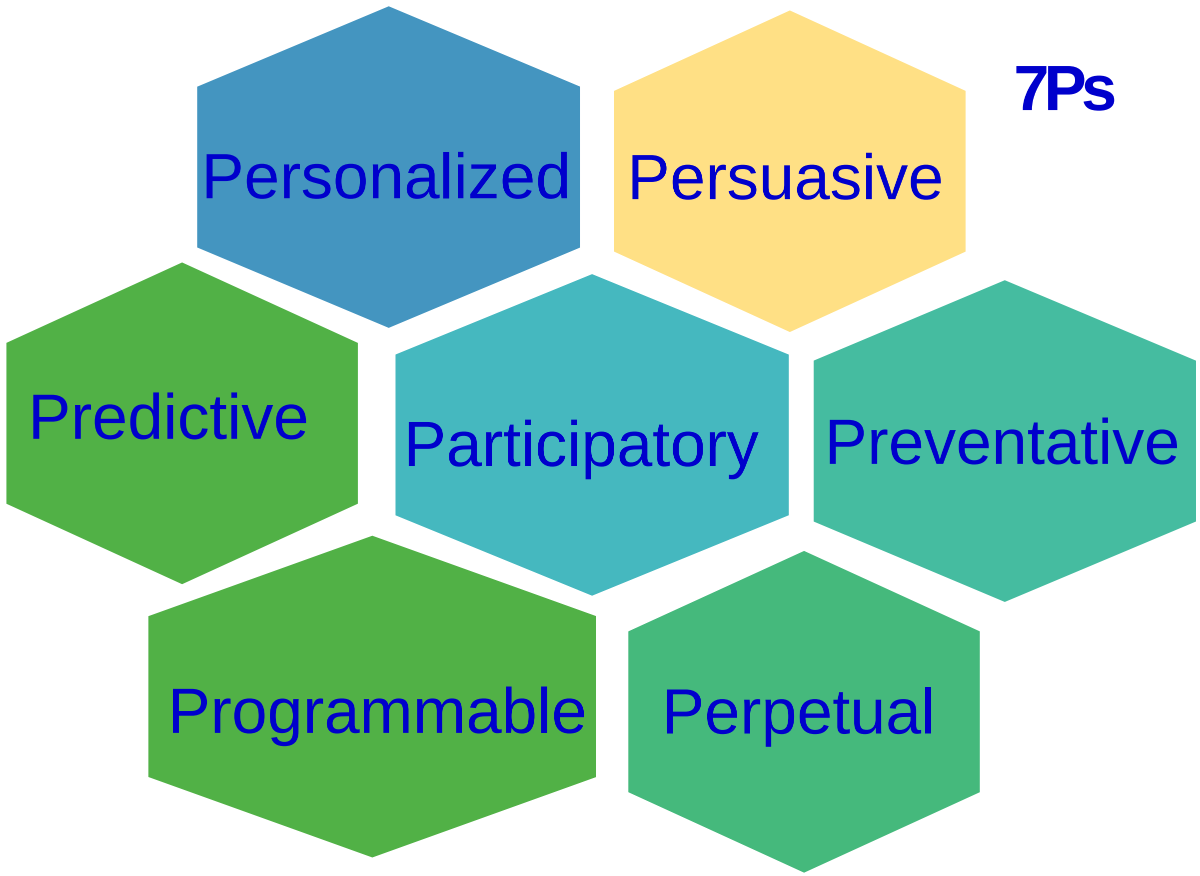
Embedded Skin Patches

Quality and sustainable healthcare with limited resources.

Source: Mohanty 2016, CE Magazine July 2016

Sethi 2017: JECE 2017

Smart Healthcare - Characteristics - 7Ps

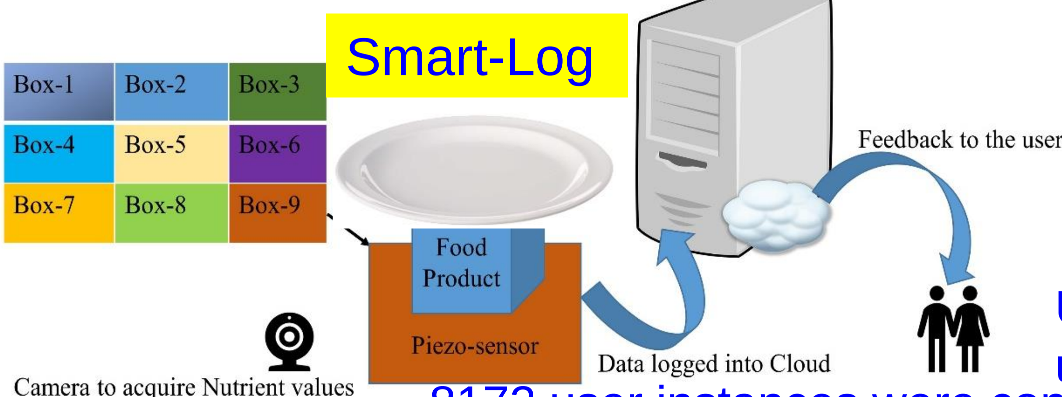


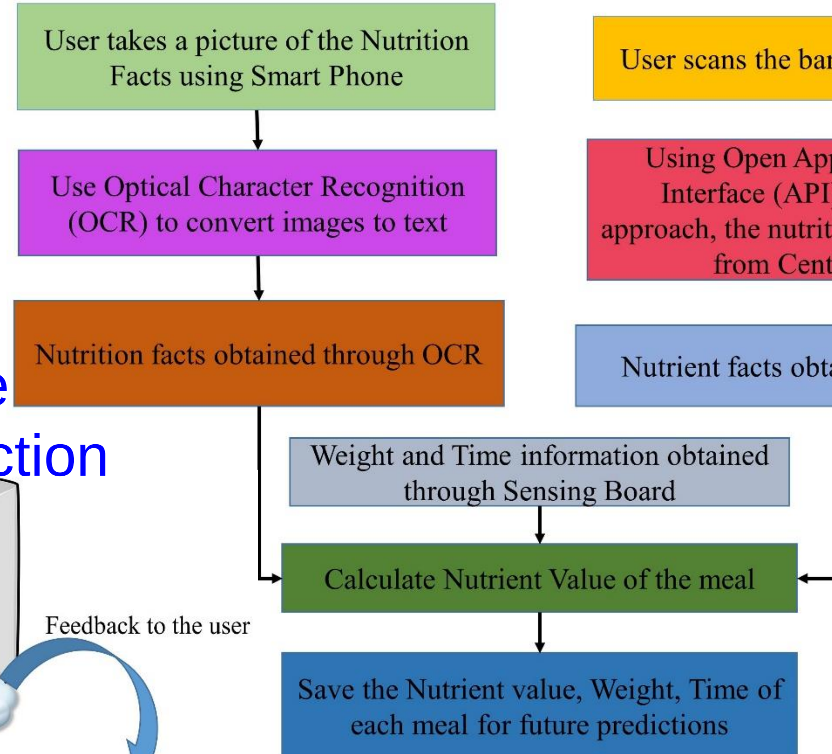
Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y.Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", IEEE Consumer Electronics Magazine, 2019, Accepted.

Smart Healthcare – Diet Monitoring

Automated Food intake Monitoring and Diet Prediction System

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





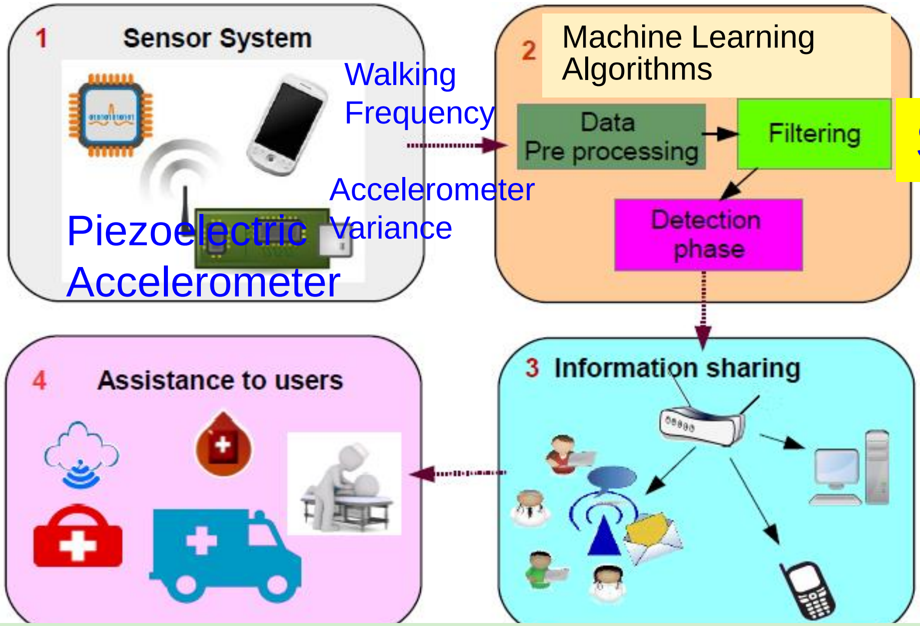
USDA National Nutrient Database used for nutrient values of 8791 items.

8172 user instances were considered

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

Source: P. Sundaravadivel, K. Kesavan, L. Kesavan, S. P. Mohanty, and E. Kougianos, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", IEEE Trans. on Consumer Electronics, Vol 64, No 3, Aug 2018, pp. 390-398.

Smart Healthcare - Activity Monitoring



Automated Physiological Monitoring System

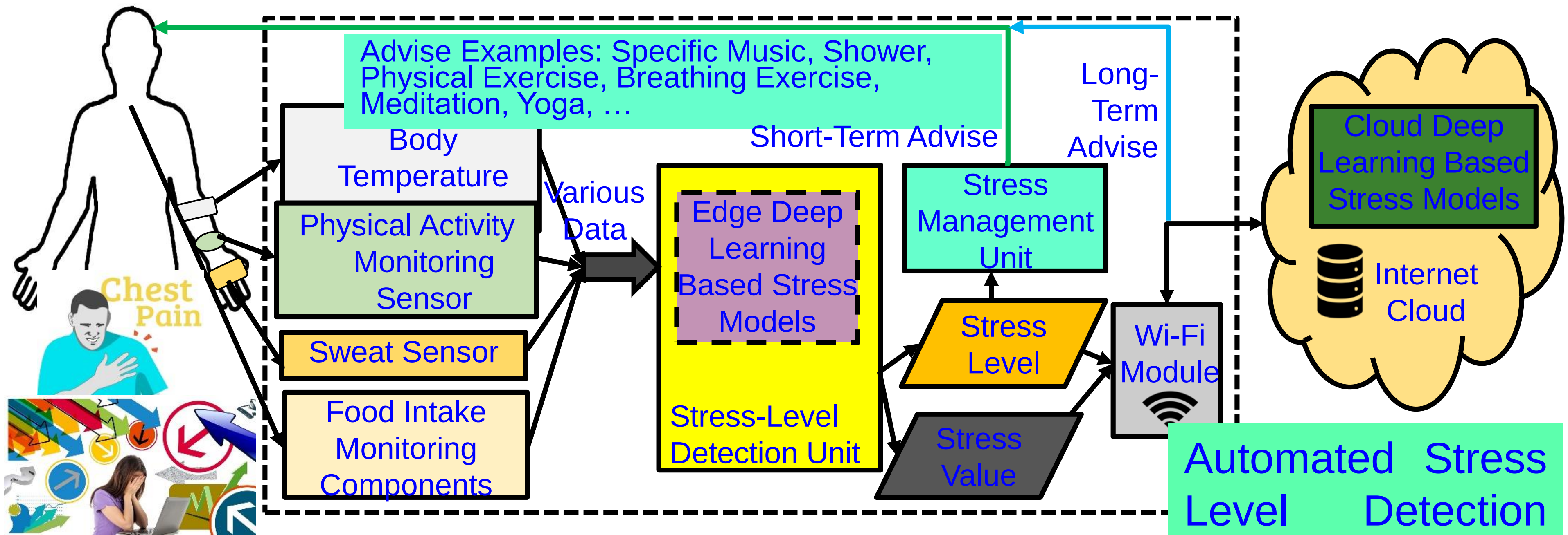
Smart-Walk

10291 Instances Grouped Under 6 Activities - Kaggle

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

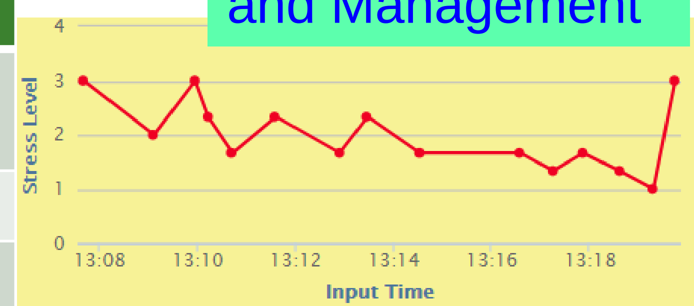
P. Sundaravadivel, S. P. Mohanty, E. Kougianos, V. P. Yanambaka, and M. K. Ganapathiraju, "Smart-Walk: An Intelligent Physiological Monitoring System for Smart Families", in Proc. 36th IEEE International Conf. Consumer Electronics (ICCE), 2018.

Smart Healthcare - Stress Monitoring & Control



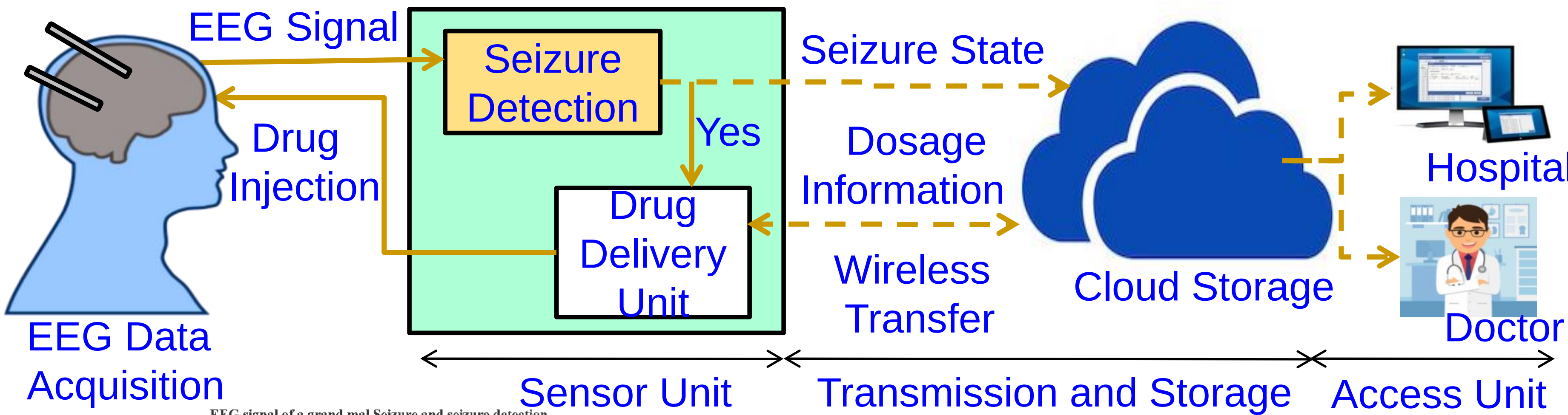
Automated Stress Level Detection and Management

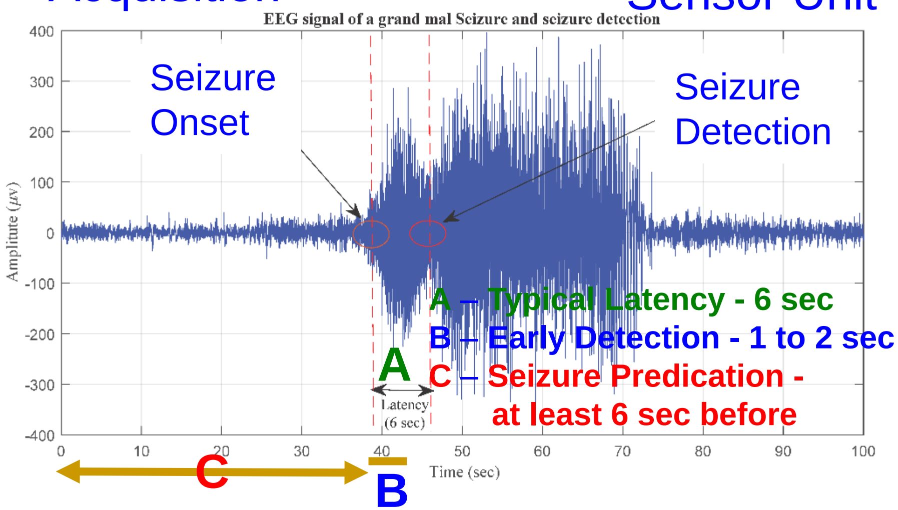
Sensor	Low Stress	Normal Stress	High Stress
Accelerometer (steps/min)	0-75	75-100	101-200
Humidity (RH%)	27-65	66-91	91-120
Temperature ℉	98-100	90-97	80-90



Source: L. Rachakonda, P. Sundaravadivel, S. P. Mohanty, E. Kougianos, and M. Ganapathiraju, “A Smart Sensor in the IoMT for Stress Level Detection”, in Proc. 4th IEEE International Symposium on Smart Electronic Systems (iSES), 2018, pp. 141--145.

Smart Healthcare - Seizure Detection & Control



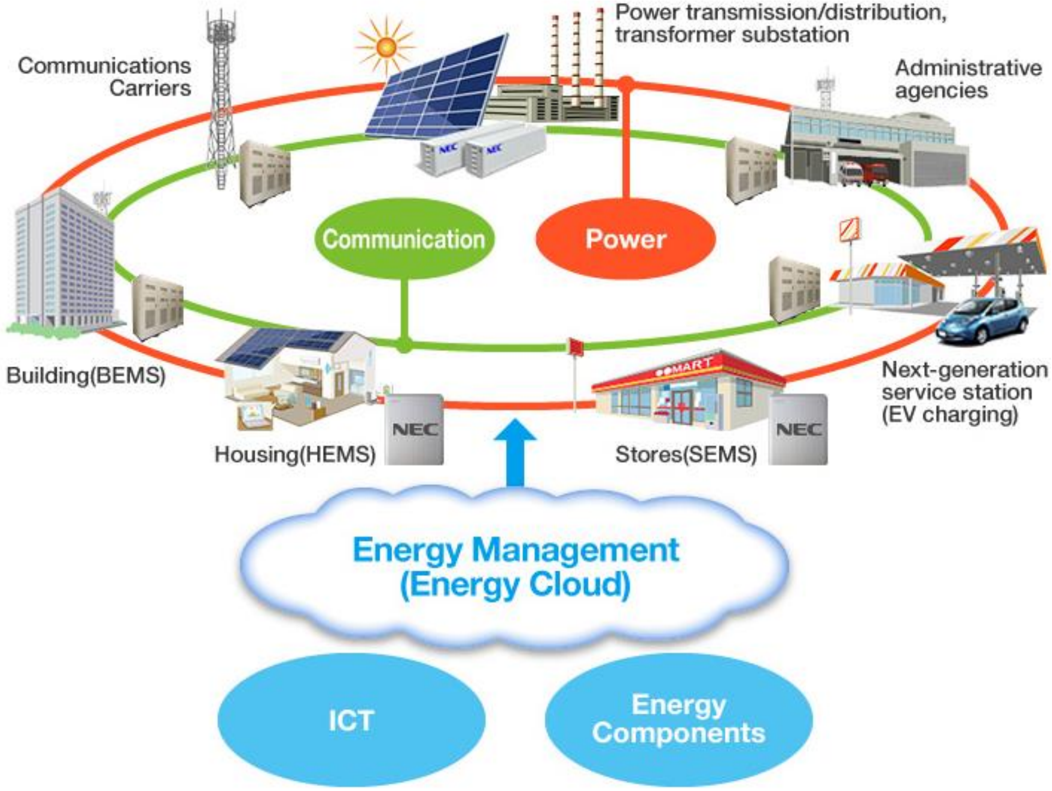


Automated Epileptic Seizure Detection and Control System

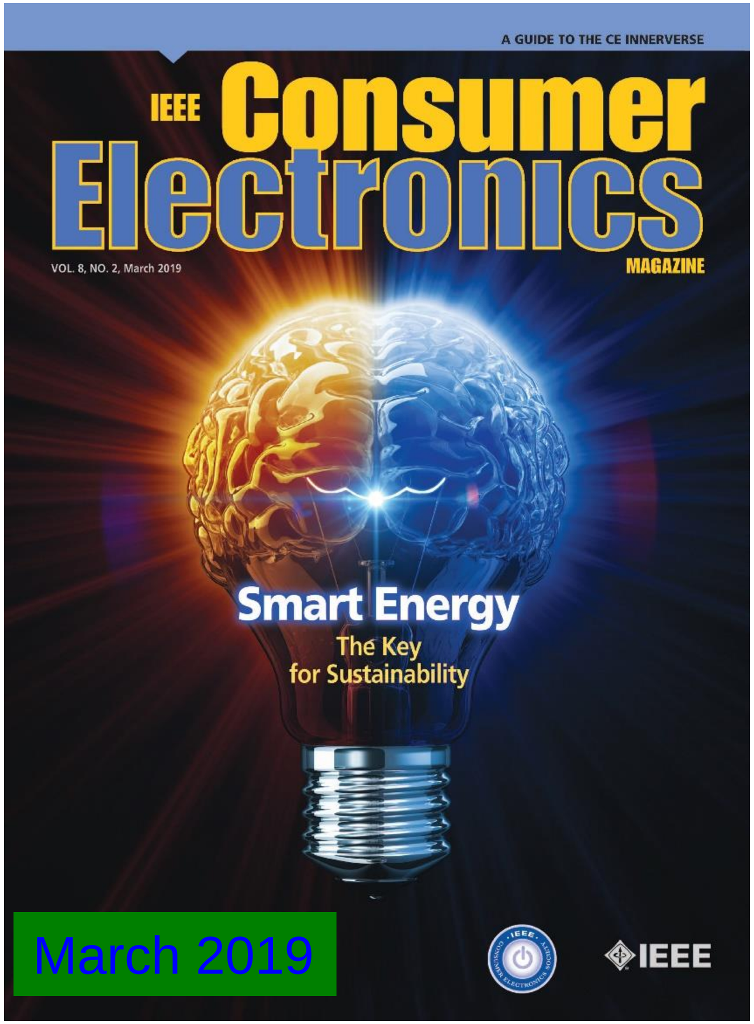
Cloud Vs Edge	Latency	Accuracy
Cloud-IoT based Detection	2.5 sec	98.65%
Edge-IoT based Detection	1.4 sec	98.65%

Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, “Neuro-Detect: A Machine Learning Based Fast and Accurate Seizure Detection System in the IoMT”, *IEEE Transactions on Consumer Electronics (TCE)*, Volume XX, Issue YY, ZZ 2019, pp. Accepted on 16 May 2019, DOI: 10.1109/TCE.2019.2917895 .

Smart Energy



Source: https://www.nec.com/en/global/solutions/energy/index.html



March 2019

Smart Transportation

Driverless Care

Smart Transportation Features:

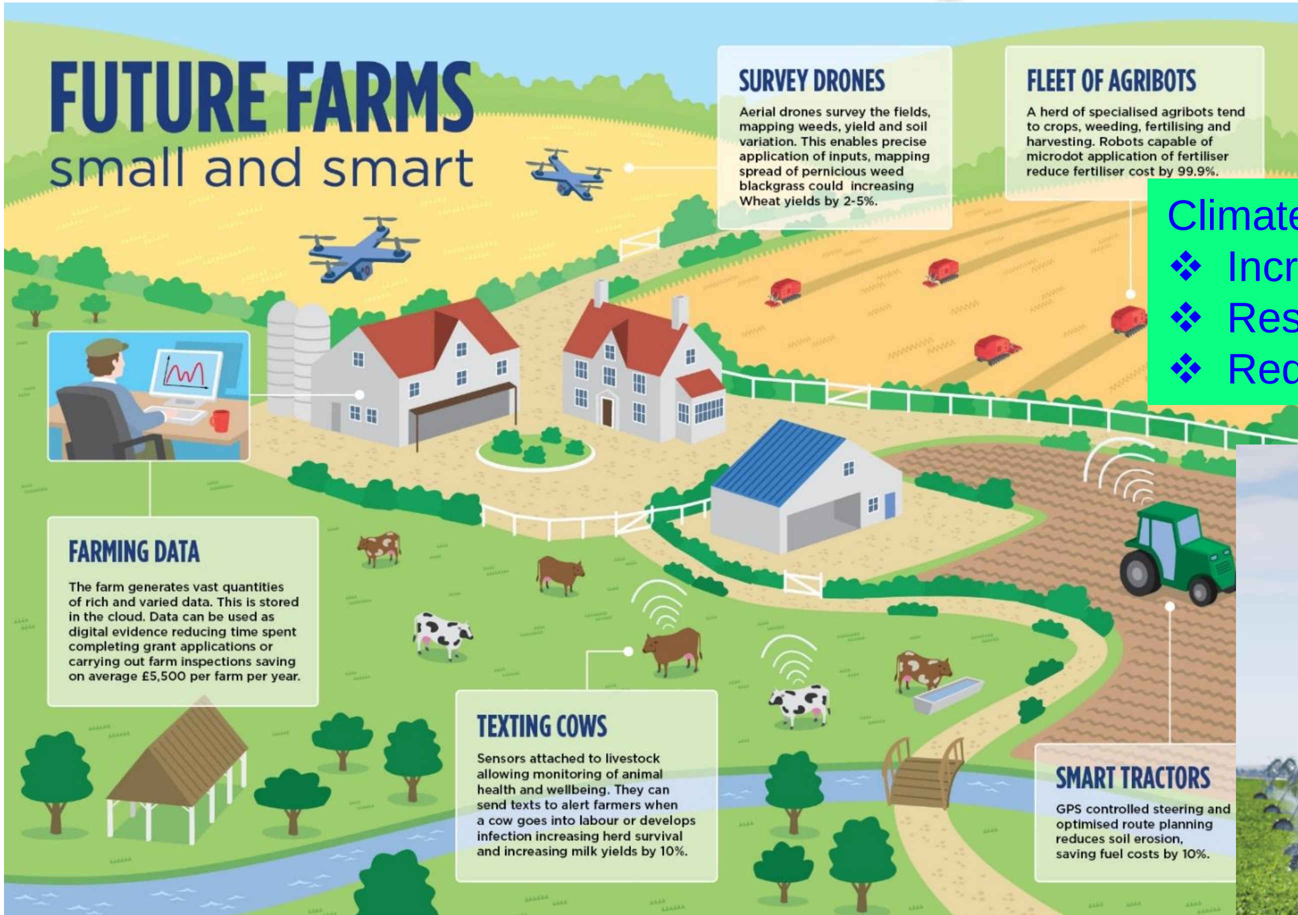
- Autonomous driving
- Effective traffic management
- Real-time vehicle tracking
- Vehicle safety – Automatic brake
- Vehicle-to-Vehicle communication
- Better scheduling of train, aircraft
- Easy payment system

Drone

"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

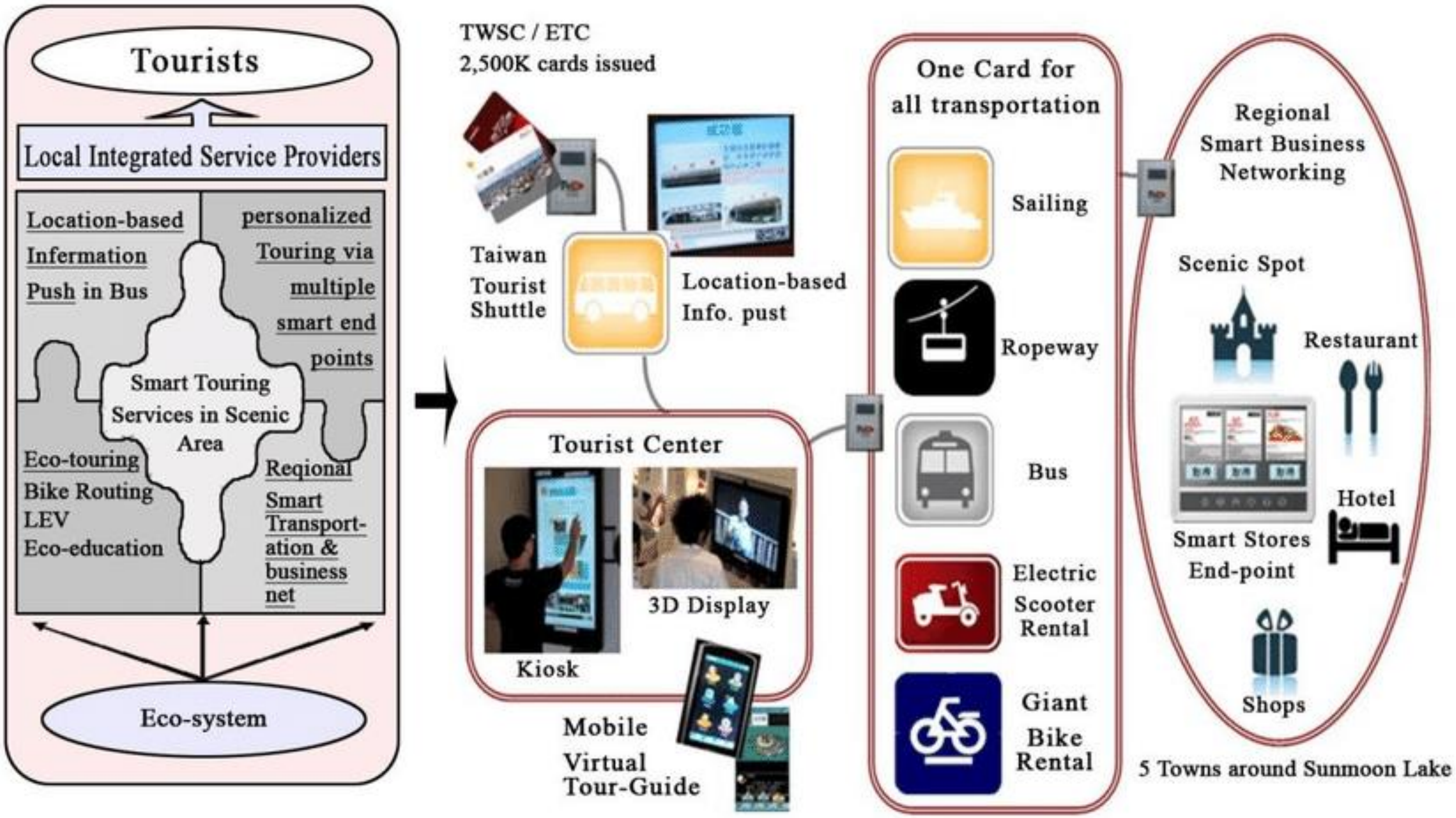
Climate-Smart Agriculture Objectives:
- ❖ Increasing agricultural productivity
- ❖ Resilience to climate change
- ❖ Reducing greenhouse gas

http://www.fao.org

Automatic Irrigation System

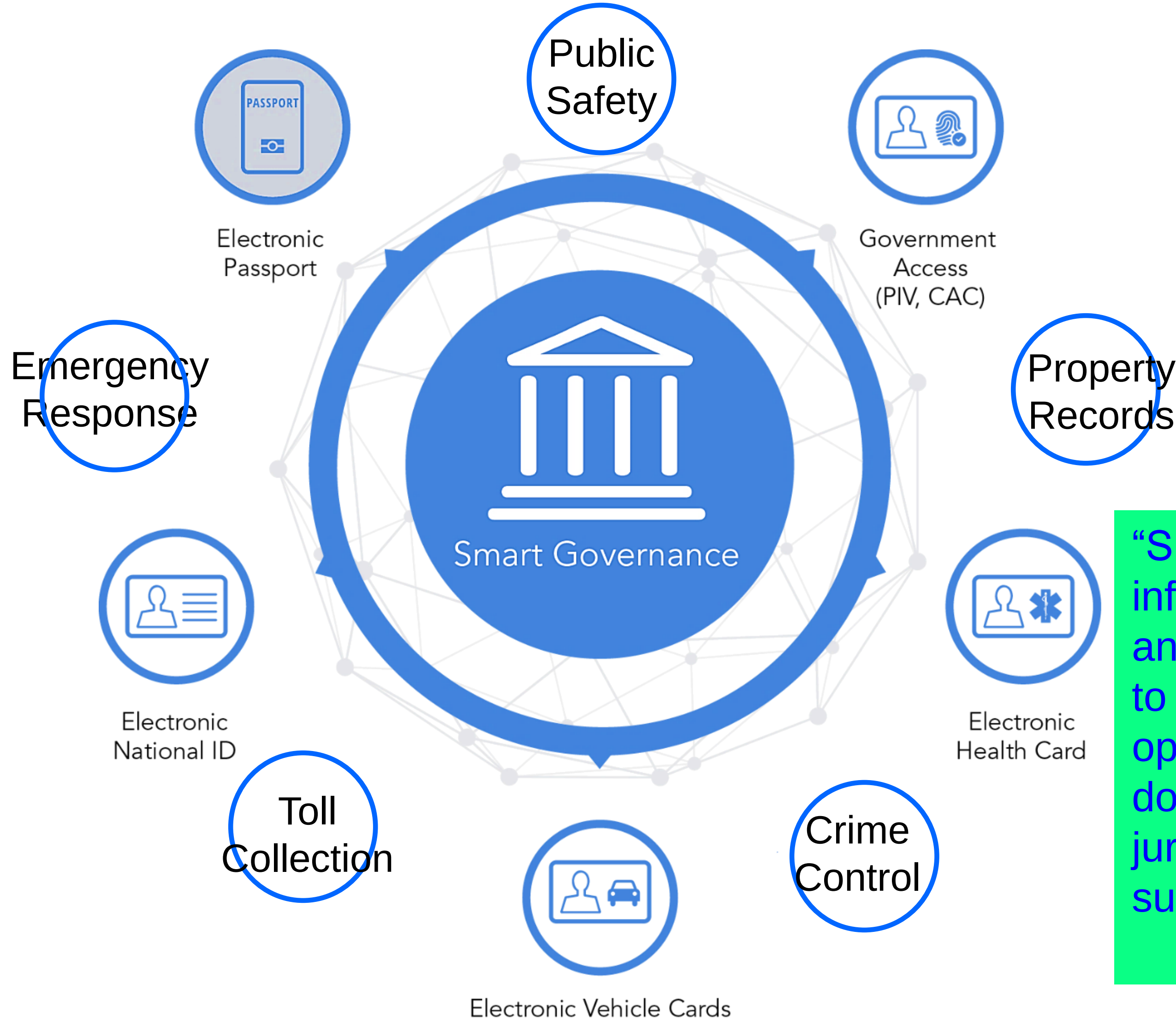
Source: Maurya 2017: CE Magazine July 2017

Smart Tourism



Source: Chih-Kung Lee: https://www.researchgate.net/figure/Concept-of-In-Joy-Life-smart-tourism-8_fig4_269666526

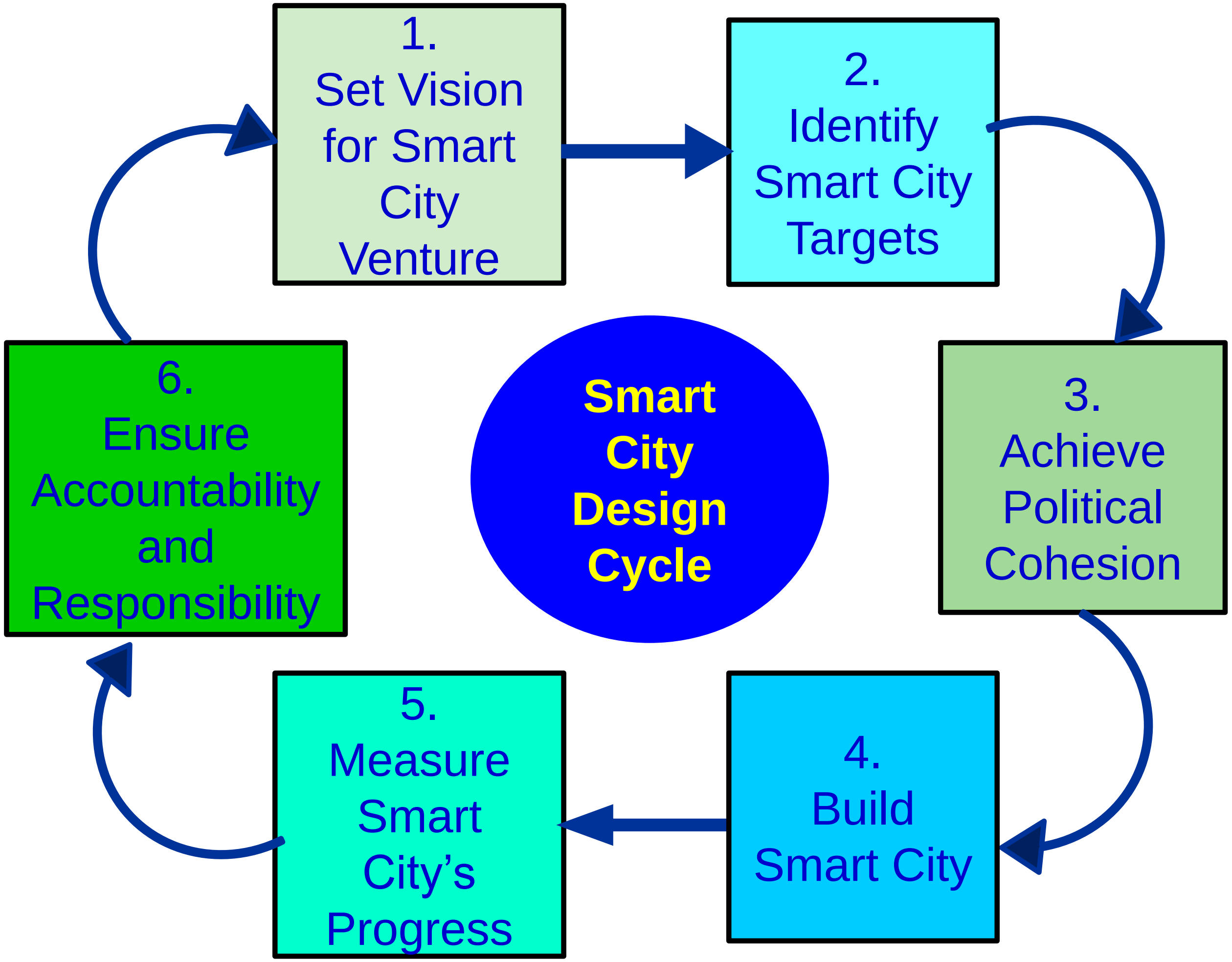
Smart Government



"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

Smart Cities - Design Cycle



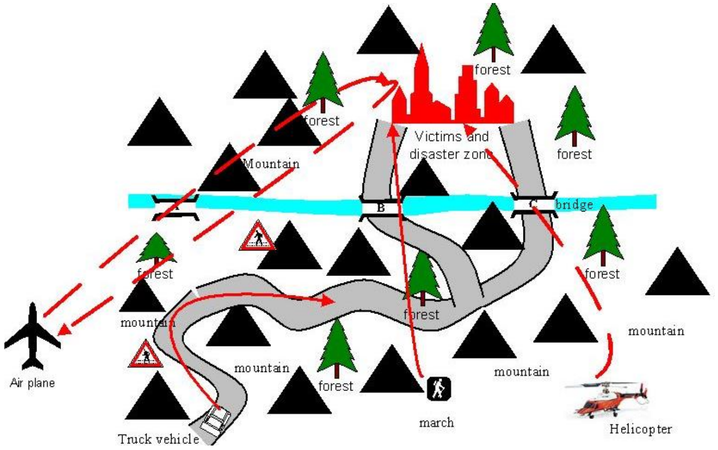
Source: Paolo Gemma 2016, ISC2 2016

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.

UrbanSim

SIMPOP



Smart City - How Many Facilities?

- Number of city facilities required is a function of city population.
- Can be calculated as follows:

$$N_f = N_p\ People \left(\frac{R_p}{Year}\right)\left(\frac{1\ Year}{D\ Days}\right)\left(\frac{1\ Hour}{N_c\ People}\right)\left(\frac{1\ Day}{H\ Hours}\right)$$

where N_f is the number of facilities, N_p is the city population in millions, R_p is the rate per person use in year/week, D is days per year, N_c is the customers per hours, and H is the hours per day.

- For example: How many dental offices might there be for a city population of one million? One Solution:

$$N_f = 10^6\ People \left(\frac{1}{Year}\right)\left(\frac{1\ Year}{300\ Days}\right)\left(\frac{1\ Hour}{5\ People}\right)\left(\frac{1\ Day}{8\ Hours}\right)$$

$$= \left(\frac{10^6}{1.2 \text{ x } 10^4}\right) \simeq 100$$

Source: Adam 2012, X and the city : modeling aspects of urban life

Smart City Technologies

Smart Cities

Smart Cities ←

Regular Cities

+ Information and Communication Technology (ICT)

+ Smart Components

+ Smart Technologies

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, “Everything You wanted to Know about Smart Cities”, IEEE Consumer Electronics Magazine (CEM), Volume 5, Issue 3, July 2016, pp. 60--70.

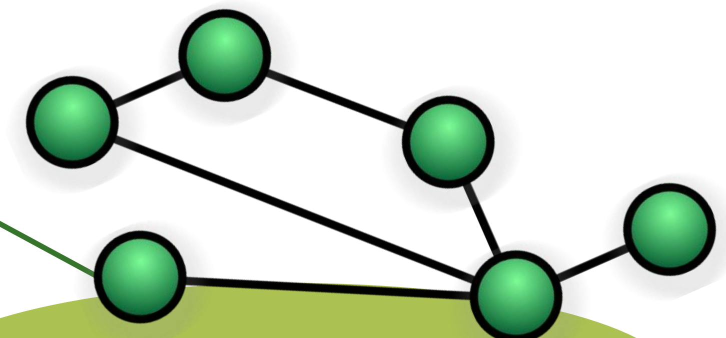
Smart Cities - 3 Is

Instrumentation

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

Smart Cities

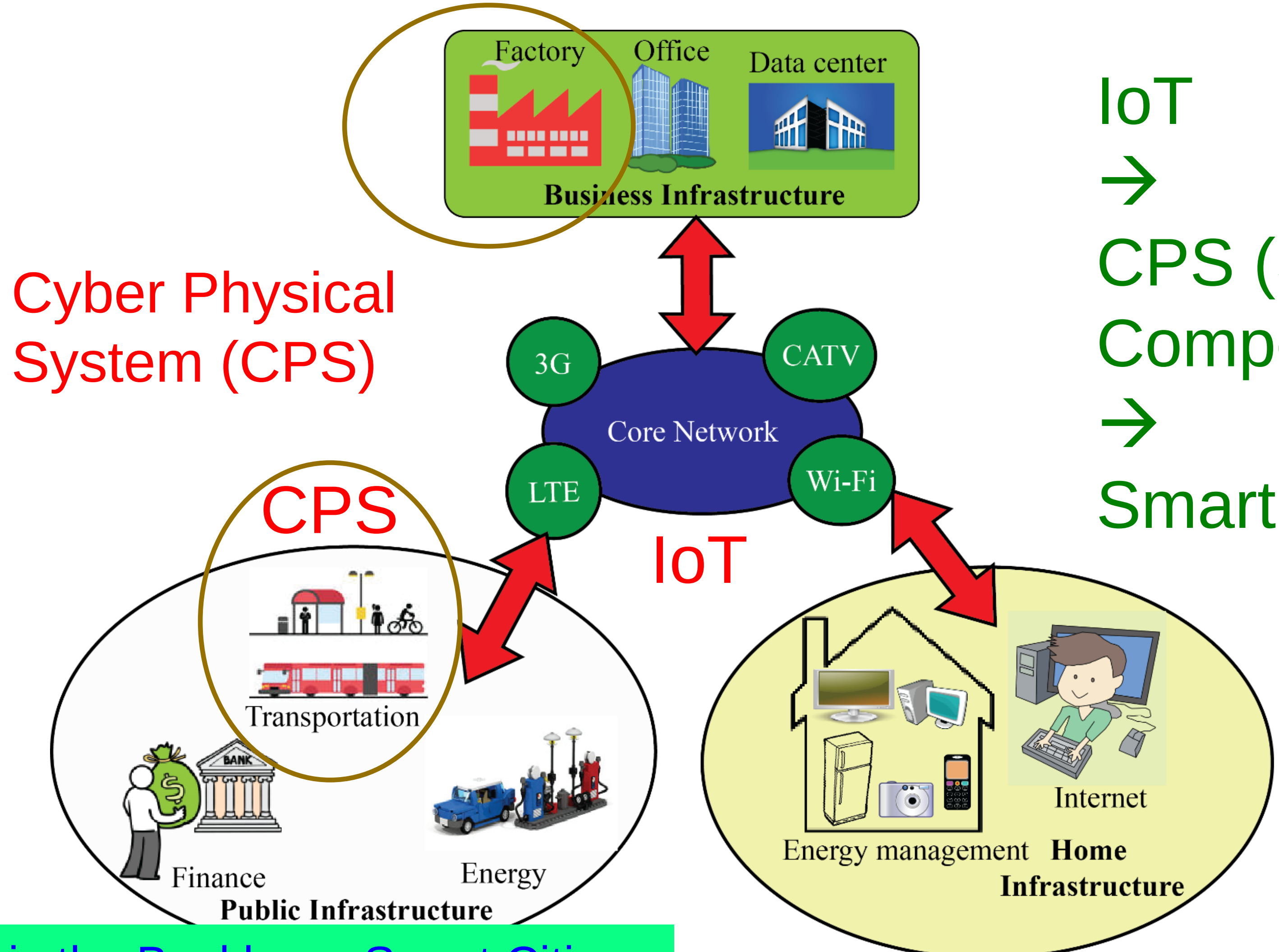
Intelligence



Interconnection

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

IoT → CPS → Smart Cities



IoT
→
CPS (Smart Components)
→
Smart Cities

IoT is the Backbone Smart Cities.

Source: Mohanty 2016, CE Magazine July 2016

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)

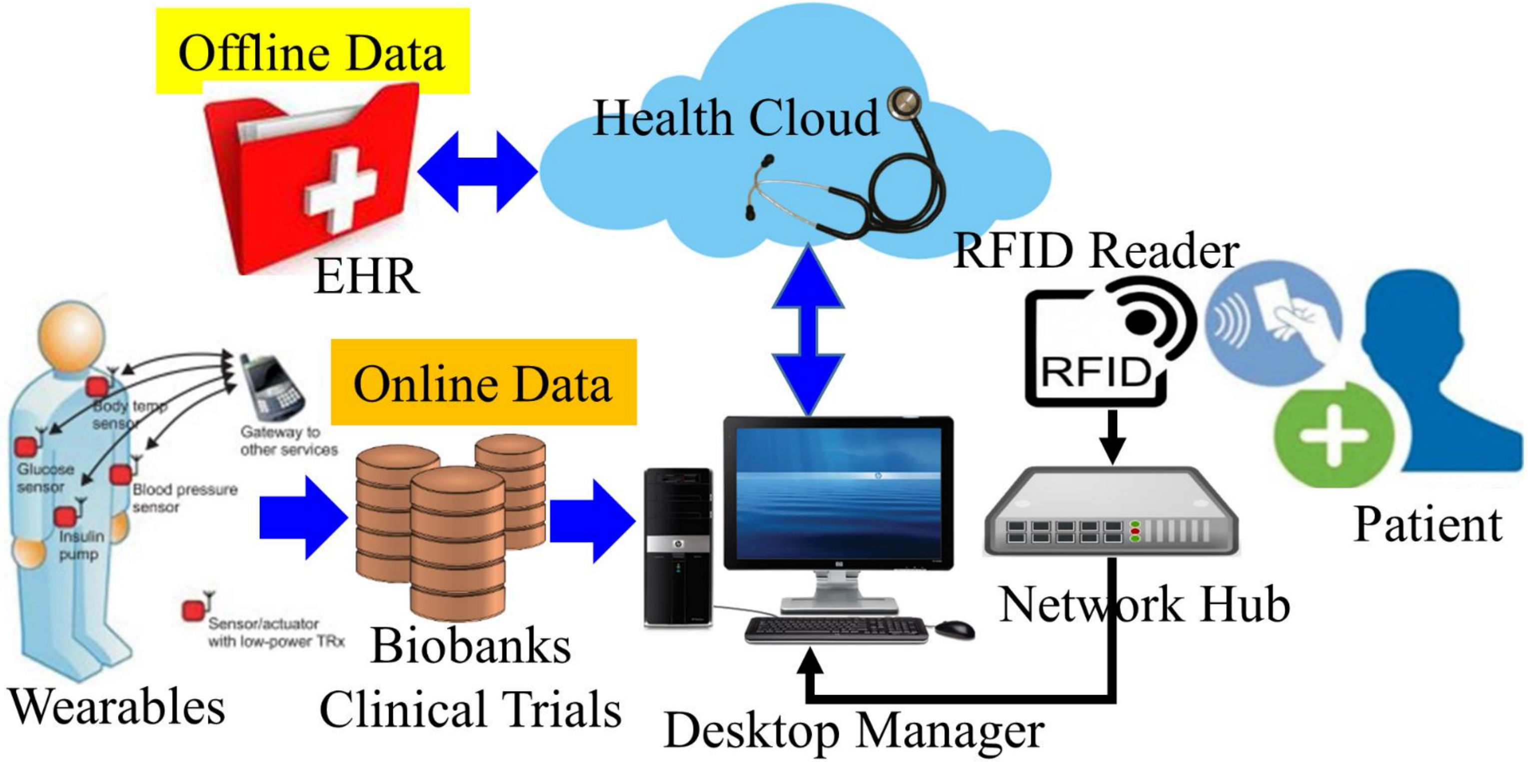
Global Network
Connecting bridge between the local network, cloud services and connected consumer devices

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

Internet of Medical Things (IoMT)



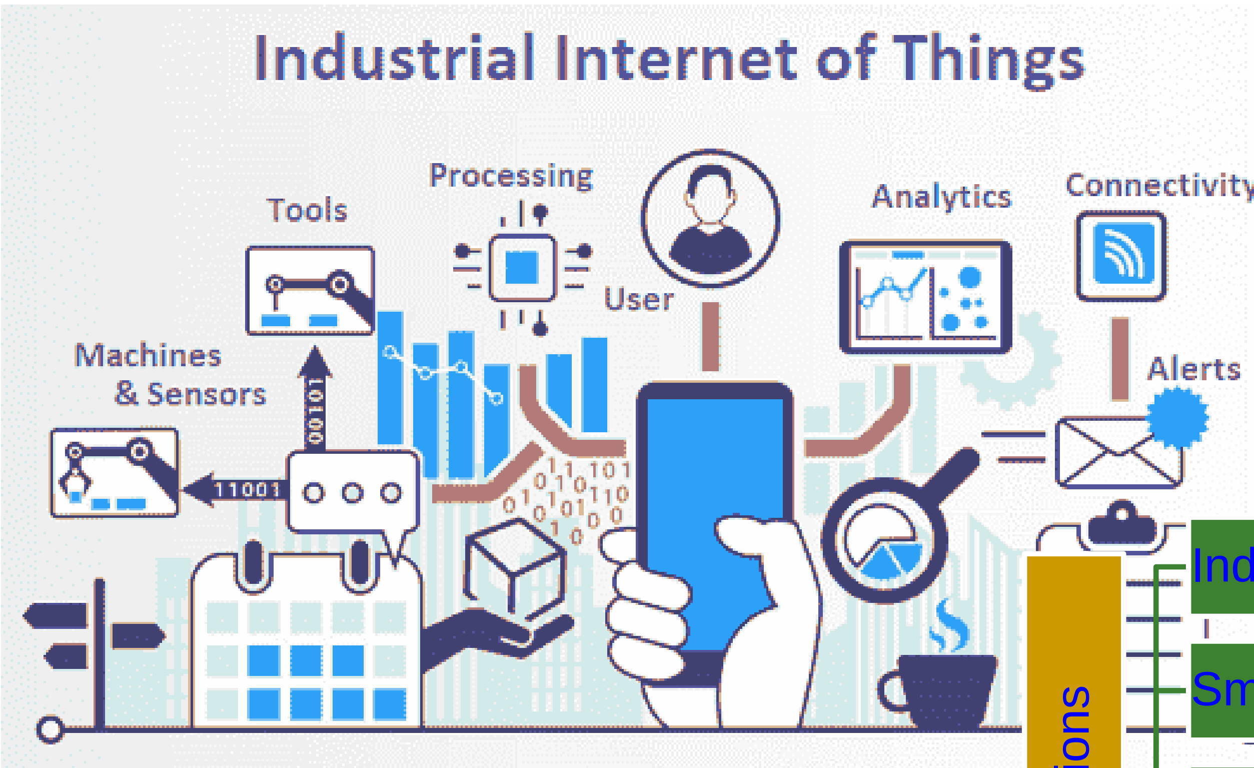
Internet of Health Things (IoHT)

IoMT is a collection of medical devices and applications that connect to healthcare IT systems through Internet.

Source: http://www.icemiller.com/ice-on-fire-insights/publications/the-internet-of-health-things-privacy-and-security/

Source: http://internetofthingsagenda.techtarget.com/definition/IoMT-Internet-of-Medical-Things

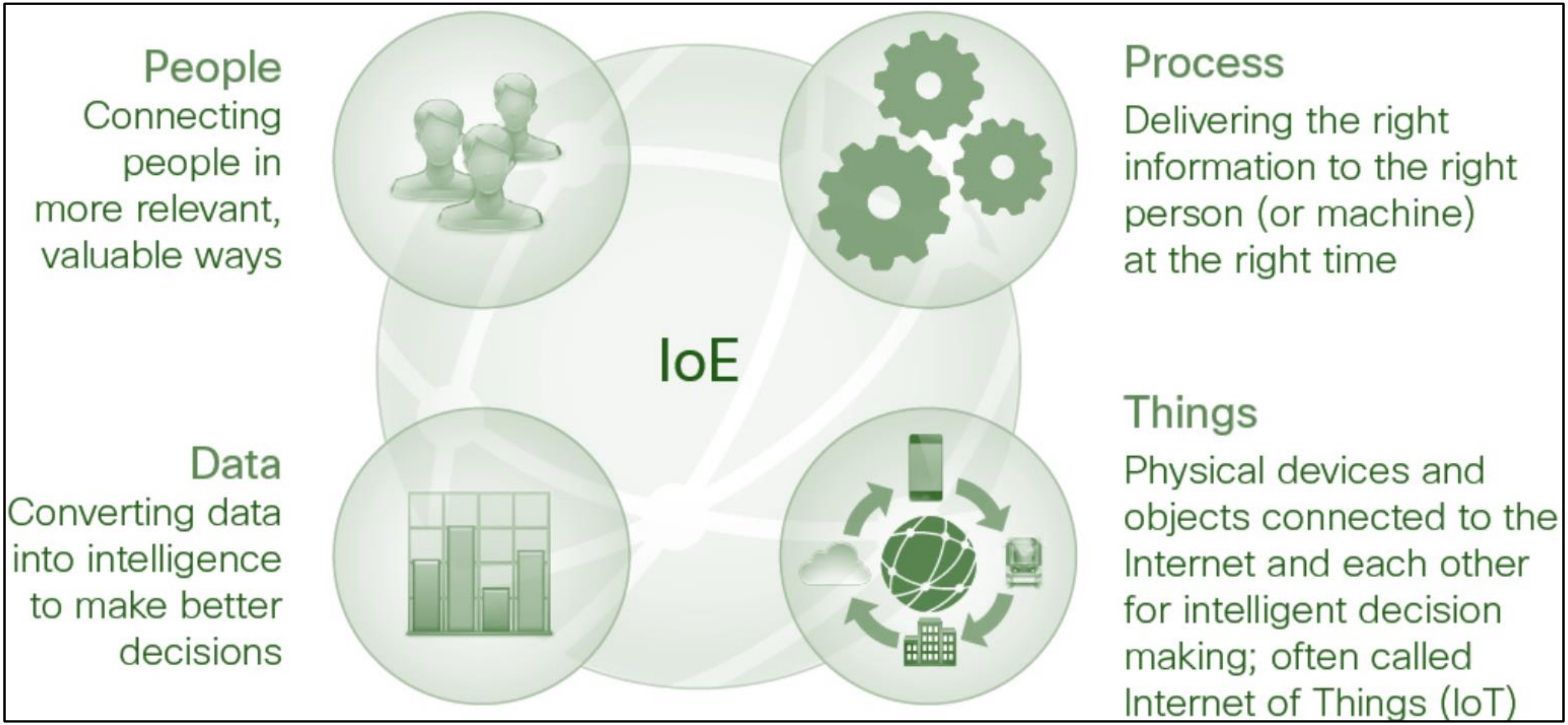
Industrial Internet of Things (IIoT)



Source: https://www.rfpage.com/applications-of-industrial-internet-of-things/

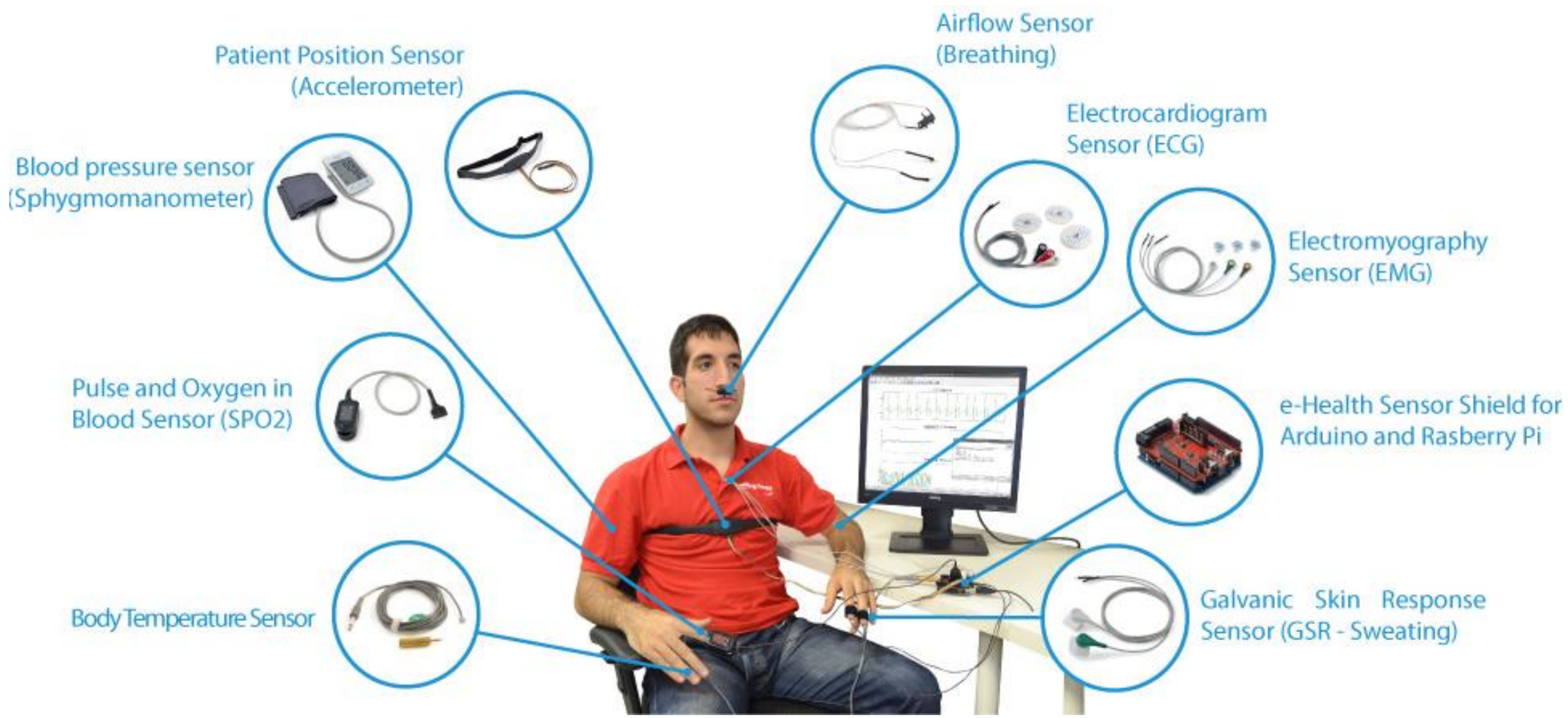
Applications
- Industrial Automation
- Smart Robotics
- Predictive Maintenance
- Integration of Tools / Wearables
- Smart Logistics

Internet of Every Things (IoE)



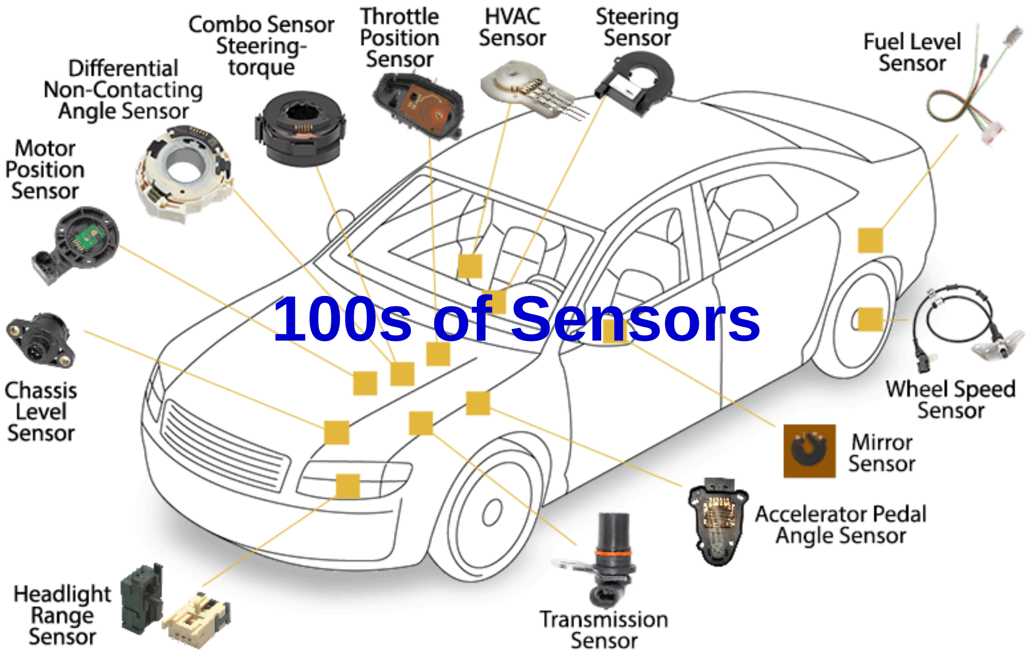
Source: http://iot.ieee.org/images/files/pdf/IEEE_IoT_Towards_Definition_Internet_of_Things_Revision1_27MAY15.pdf

Sensor Technology - Healthcare

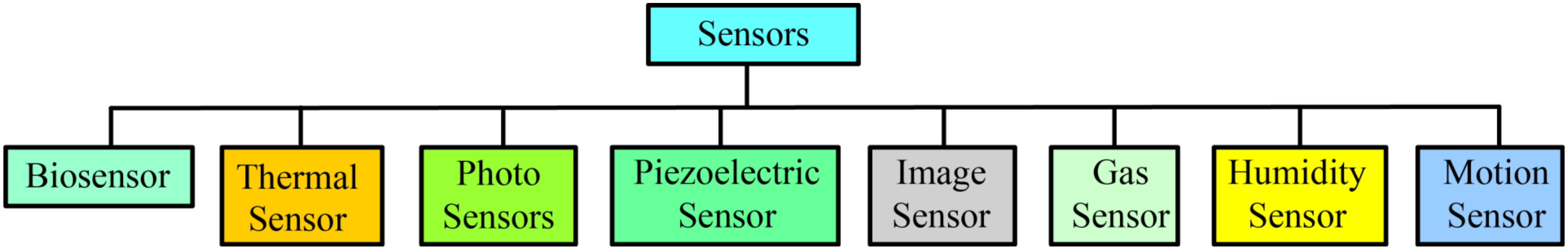


Source: http://www.libelium.com/e-health-low-cost-sensors-for-early-detection-of-childhood-disease-inspire-project-hope/

Sensor Technology – Automobiles



Cheap and Compact Sensor Technology



Source: S. P. Mohanty, Nanoelectronic Mixed-Signal System Design, McGraw-Hill, 2015, ISBN-13: 978-0071825719.

Gas Sensor

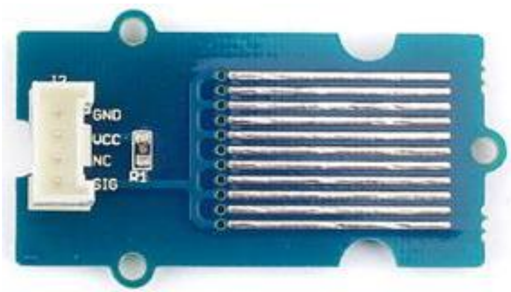
Temperature Sensor

Air Quality Sensor

Humidity and Temperature Sensor

Light Sensor

Barometer Sensor



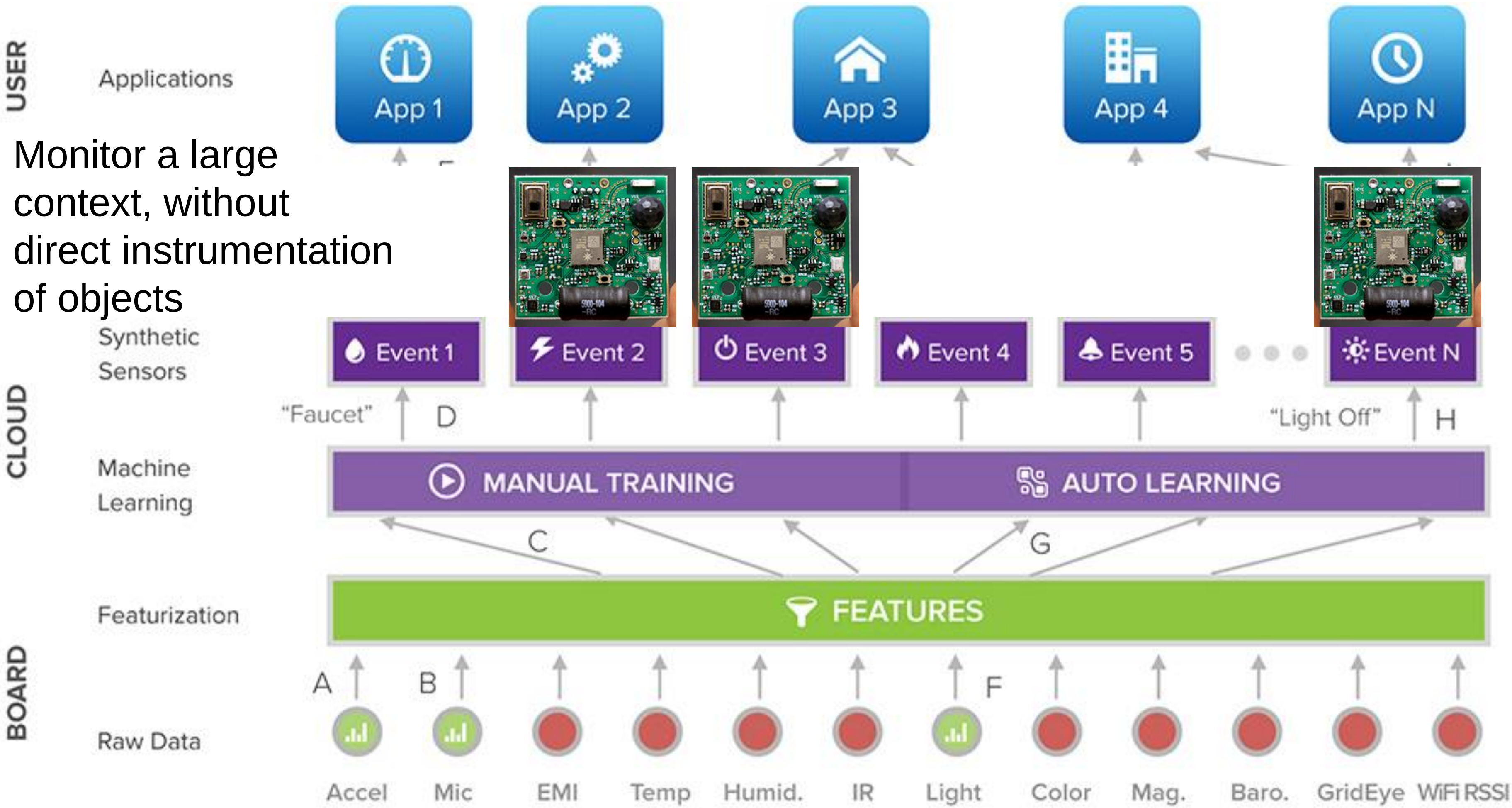
Water Sensor

Dust Sensor

Source: http://wiki.seeed.cc/Sensor/

Smart Sensors - General-Purpose/ Synthetic Sensors

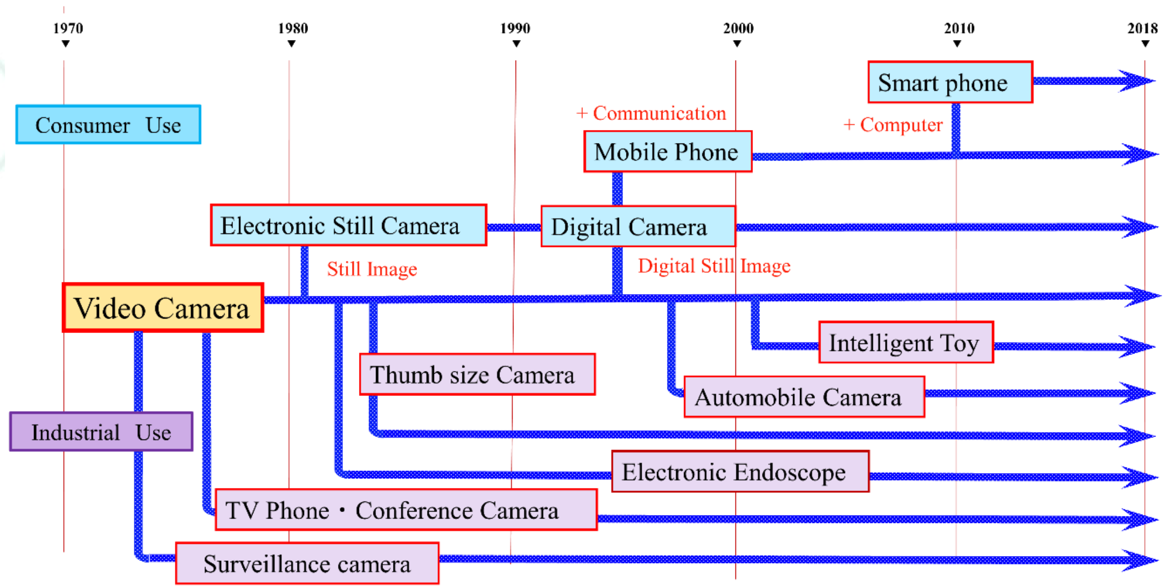
Monitor a large context, without direct instrumentation of objects



Source: Laput 2017, http://www.gierad.com/projects/supersensor/

Cameras are Everywhere

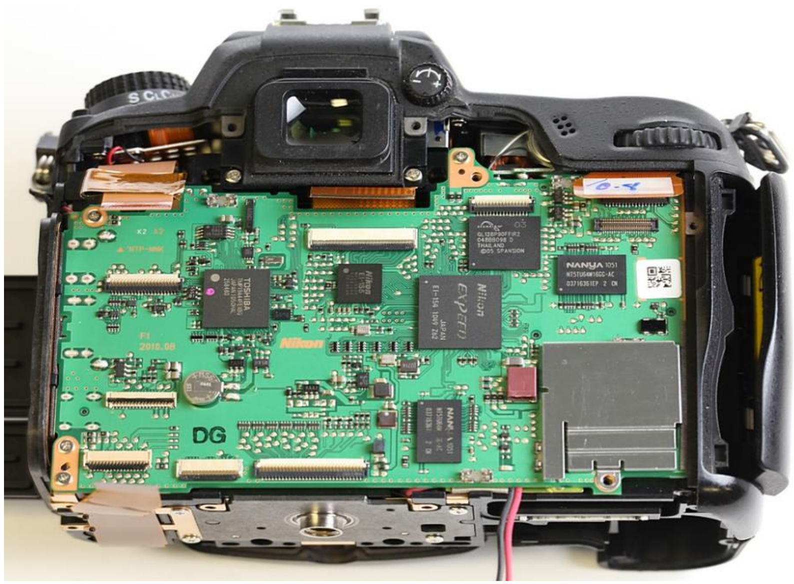
July 2019



CMOS image sensors → Cameras of any size, part of any device, and placed at any location.

Hardware-Technology Scaling has Reduced Cost of Electronics

In 1986: 1.3 megapixels CCD sensor Kodak camera was $13,000.



Digital SLR camera

Source: http://www.lensrentals.com/blog/2012/04/d7000-dissection

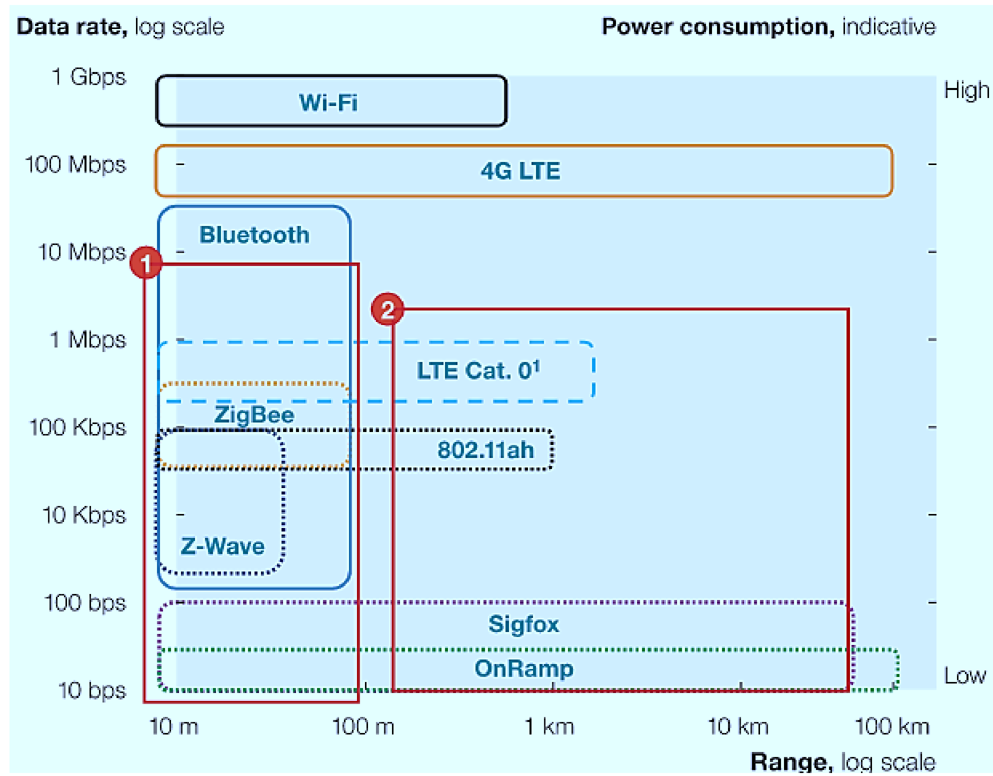
Mirrorless Camera

Source: Mohanty ISCT 2019 Keynote

IoT - Communications Technology

Selected IoT Communications Technology

- Bluetooth Low-Energy (BLE)
- Zigbee
- Z-Wave
- 6LowPAN
- Thread
- WiFi
- Cellular
- NFC
- Sigfox
- Neul
- LoRaWAN



Source: https://www.postscapes.com/internet-of-things-protocols/

Source: https://www.rs-online.com/designspark/eleven-internet-of-things-iot-protocols-you-need-to-know-about

Energy Consumption and Latency in Communications

- IoT with Cloud: Sensor big data goes to cloud for storage and analytics – Consumes significant energy in communications network
- Connected cars require latency of ms to communicate and avoid impending crash:
  - Faster connection
  - Low latency
  - Lower power
- 5G for connected world: Enables all devices to be connected seamlessly.

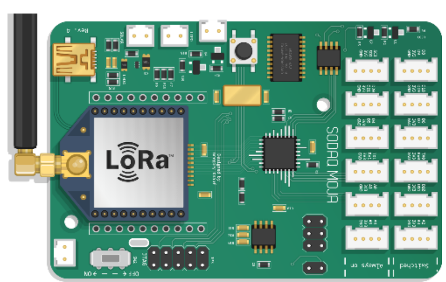
Source: https://www.linkedin.com/pulse/key-technologies-connected-world-cloud-computing-ioe-balakrishnan

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



Visible Light for High-Bandwidth Wireless Communications

- LEDs can switch their light intensity at a rate that is imperceptible to human eye.
- Property can be used for the value added services based on Visible Light Communication (VLC).

High Data Density

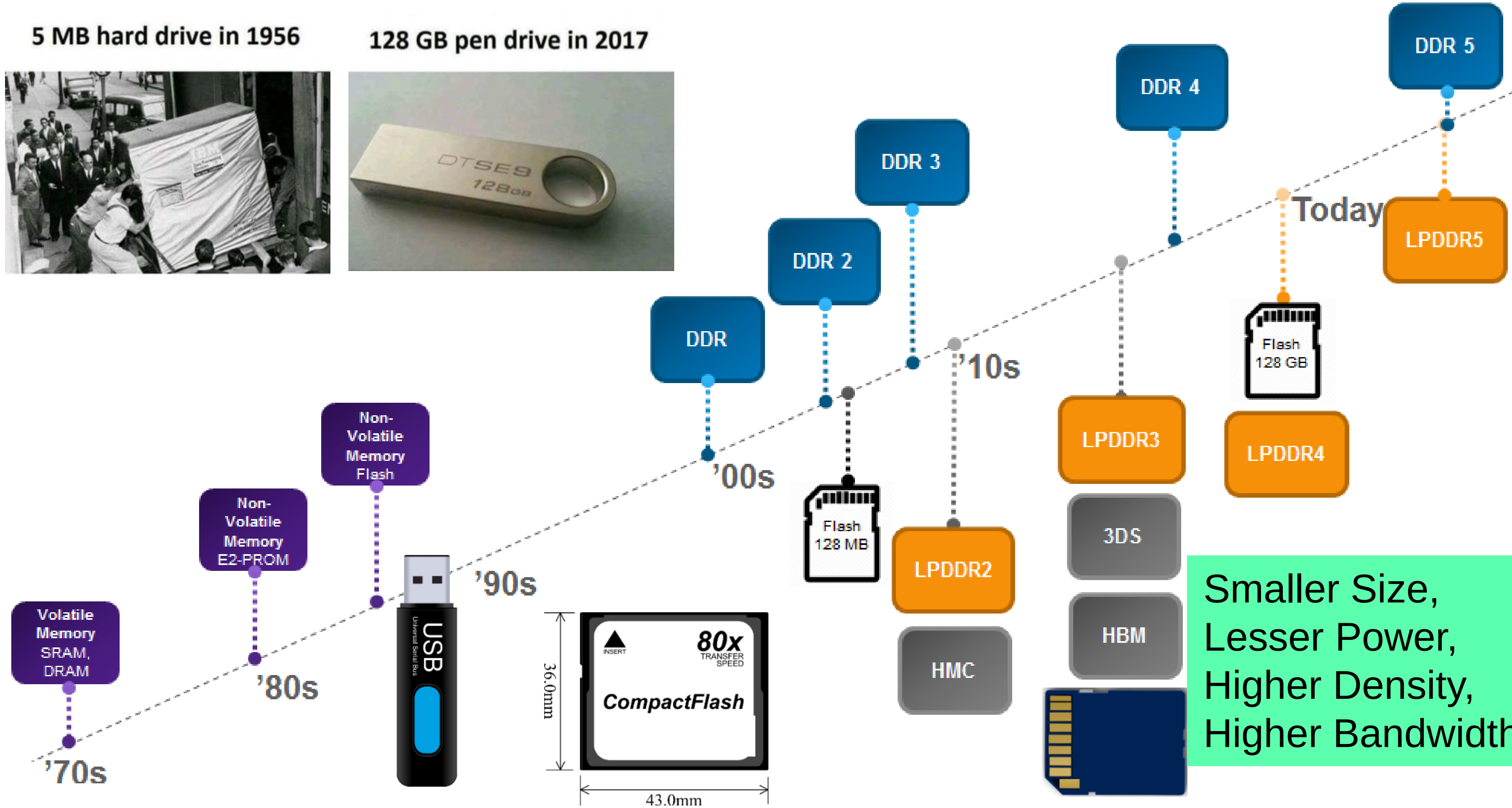
Short Range

Source: VLCS-2014

Source: Ribeiro 2017, CE Magazine October 2017

October 2017

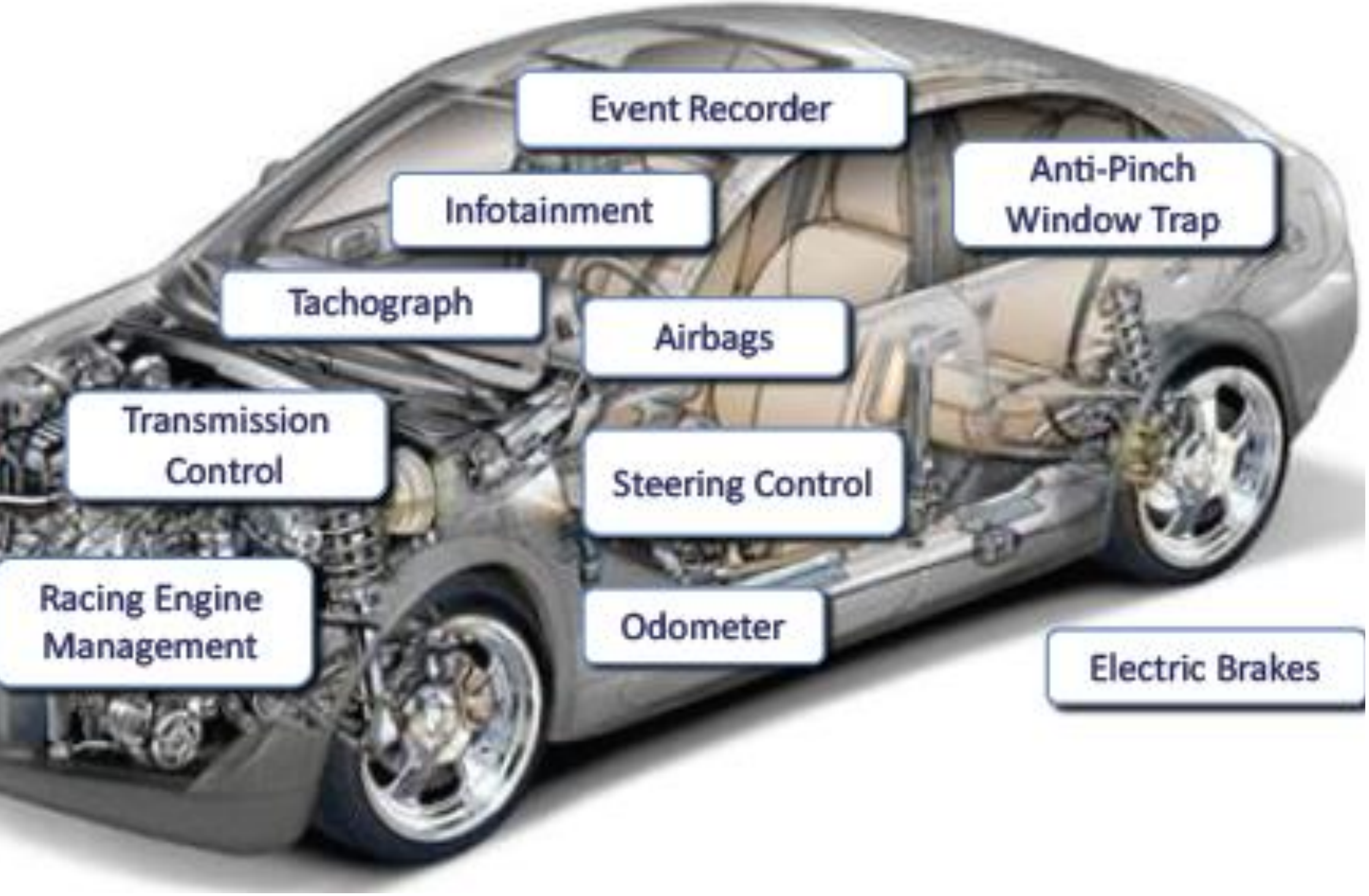
Memory Technology - Cheaper, Larger, Faster, Energy-Efficient



Smaller Size,
Lesser Power,
Higher Density,
Higher Bandwidth

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

Memory Technology – Car Example



Source: Coughlin 2016, CE Magazine October 2016

Blockchain Technology

July 2018

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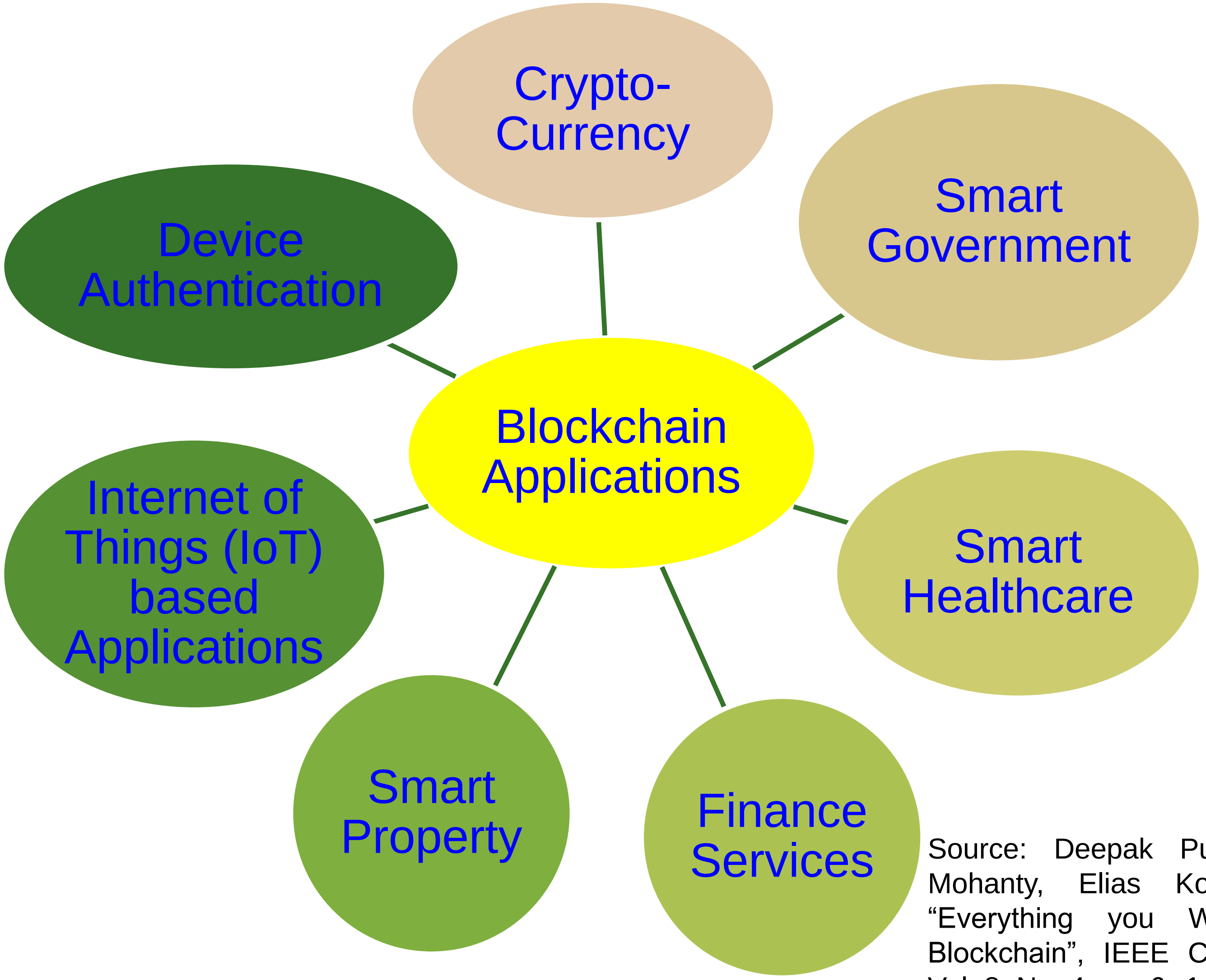
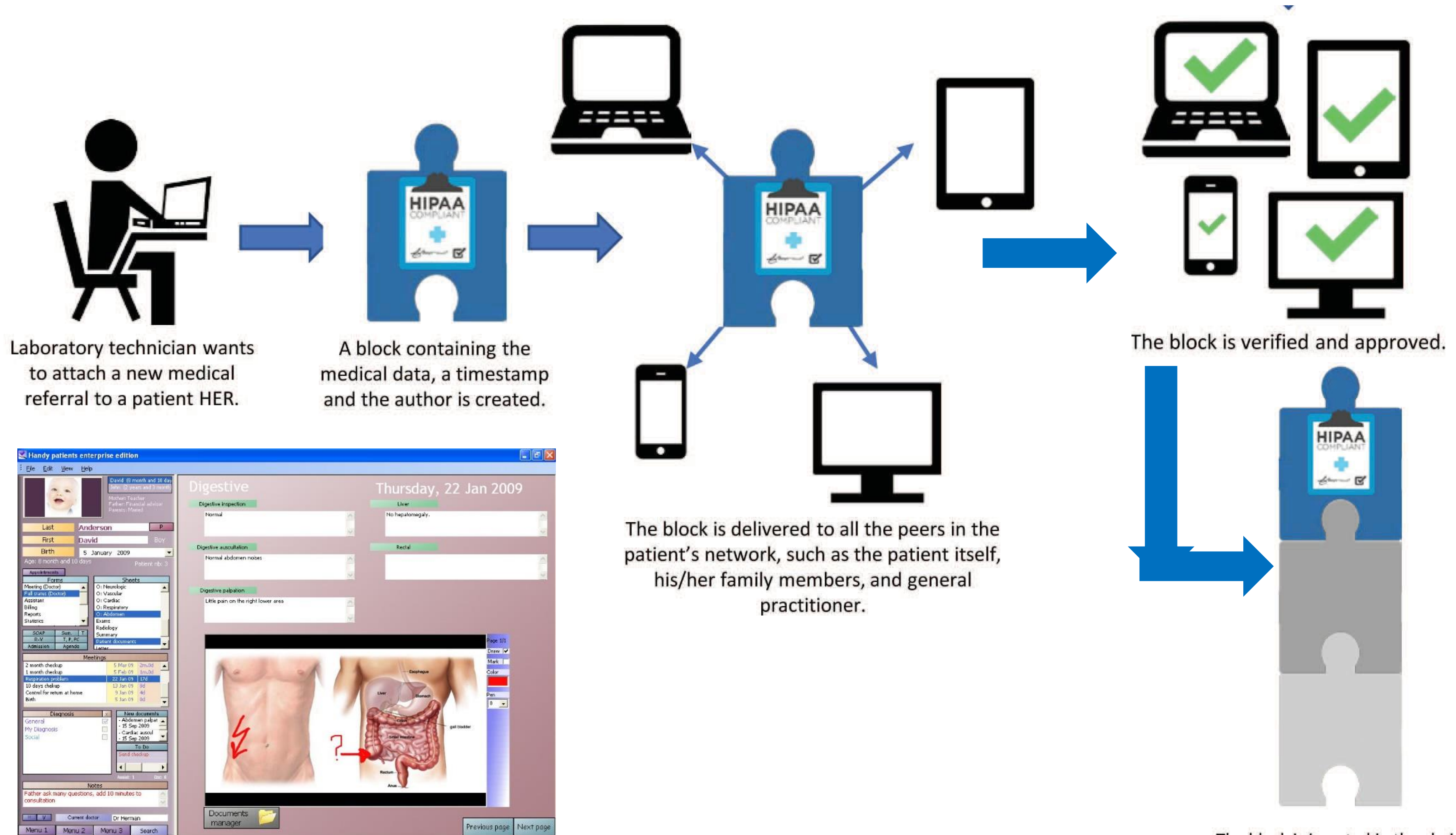
Blockchain Applications



Source: Deepak Puthal, Nisha Malik, Saraju P. Mohanty, Elias Kougianos, and Gautam Das, "Everything you Wanted to Know about the Blockchain", IEEE Consumer Electronics Magazine, Vol. 8, No. 4, pp. 6--14, 2018.

Blockchain in Smart Healthcare



Source: C. Esposito, A. De Santis, G. Tortora, H. Chang and K. R. Choo, "Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy?," IEEE Cloud Computing, vol. 5, no. 1, pp. 31-37, Jan./Feb. 2018.

CE Systems – Diverse Security/ Privacy/ Ownership Requirements

Medical Devices

RFID Chip

Pace maker

Insulin Pump

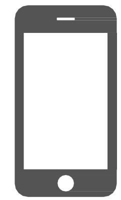
Heart Rate Monitor

Home Devices

Smart Coffee Maker

Smart Thermostat

Personal Devices



Smart Phones/ Tablets

Wearable Devices

Smart Clothing

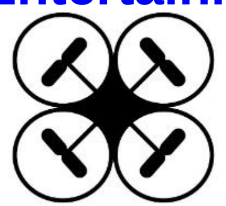
Smart watch

Business Devices

Smart Payment Systems

ATM/Banking Systems

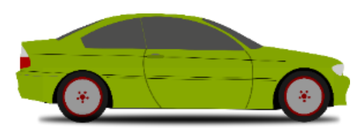
Entertainment Devices



Drones /UAVs

Video Games

Transportation Devices

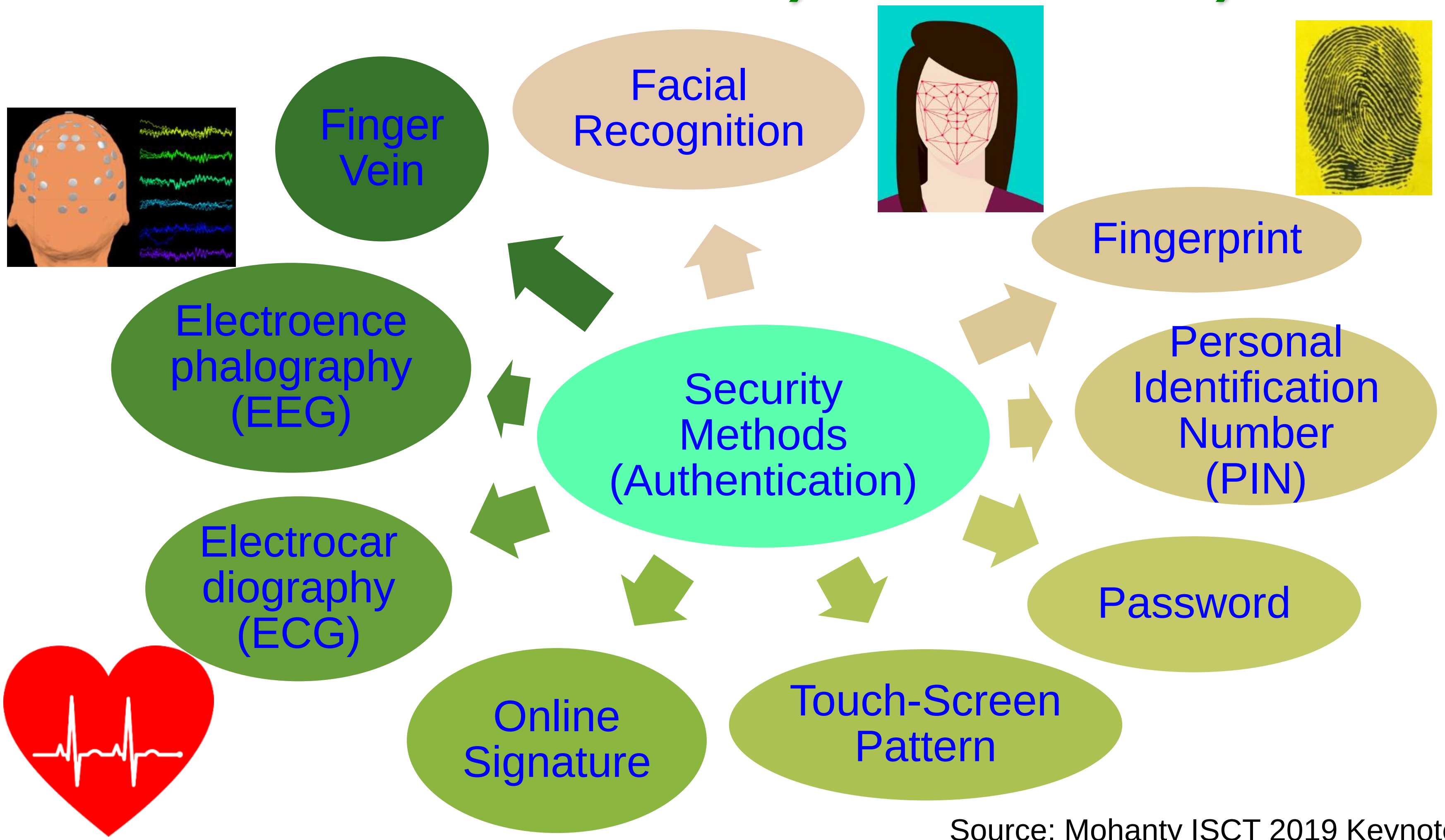


Smart Vehicles/ Autonomous Vehicles

Smart Traffic Controllers

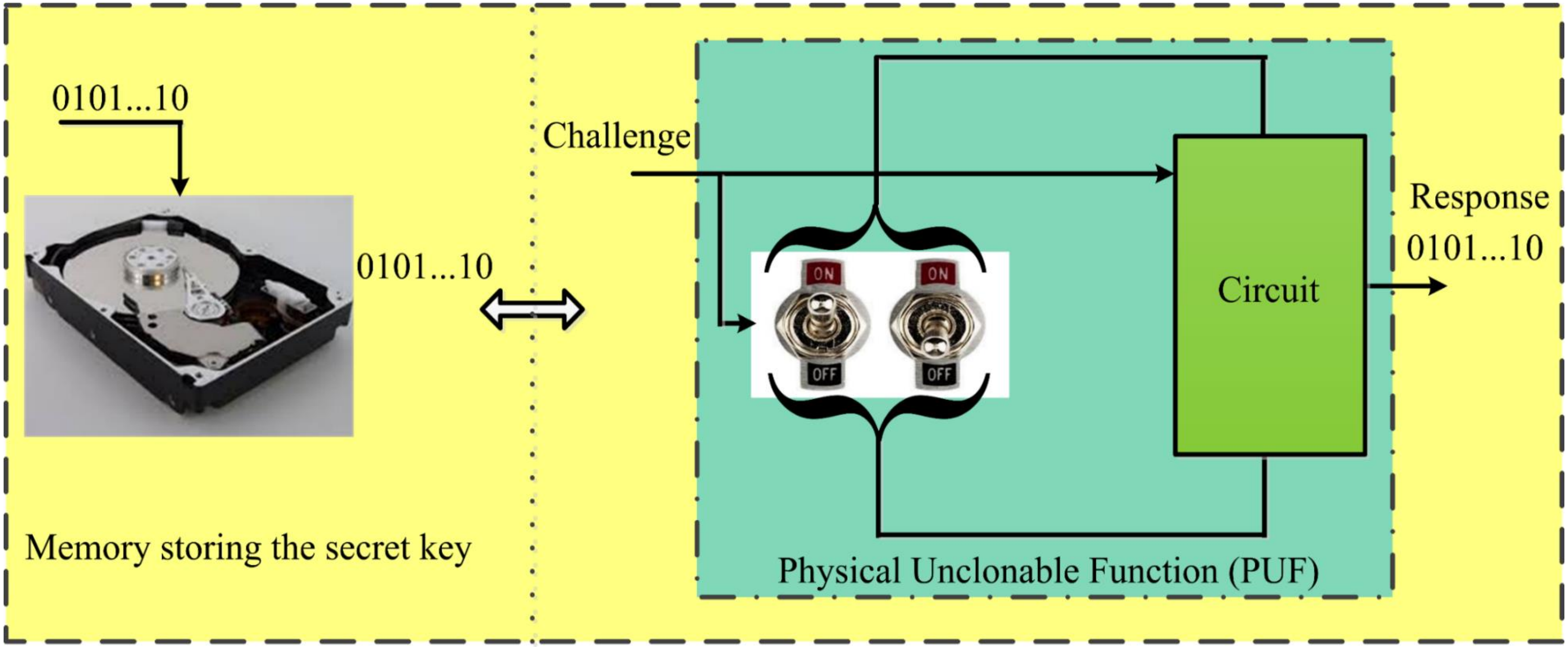
Source: Munir and Mohanty 2019, CE Magazine Jan 2019

Security, Authentication, Access Control – Home, Facilities, ...



Source: Mohanty ISCT 2019 Keynote

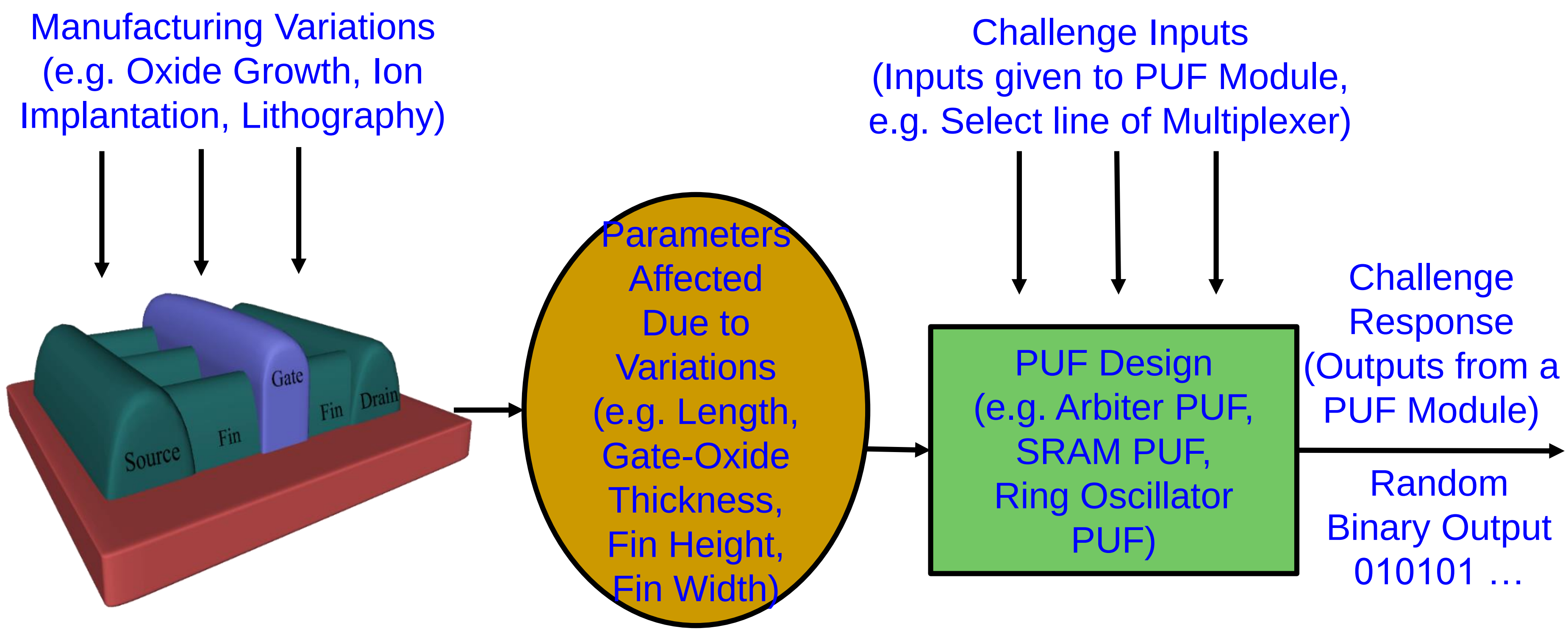
Security Primitives - PUF



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

Source: S. Joshi, S. P. Mohanty, and E. Kougianos, "Everything You Wanted to Know about PUFs", *IEEE Potentials Magazine*, Volume 36, Issue 6, November-December 2017, pp. 38--46.

Physical Unclonable Function (PUF) - Principle



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

Source: V. P. Yanambaka, S. P. Mohanty, and E. Kougianos, “Making Use of Semiconductor Manufacturing Process Variations: FinFET-based Physical Unclonable Functions for Efficient Security Integration in the IoT”, Springer Analog Integrated Circuits and Signal Processing Journal, Volume 93, Issue 3, December 2017, pp. 429--441.

Physical Unclonable Functions (PUFs) - Applications

Random Number Generator

Memory Protection

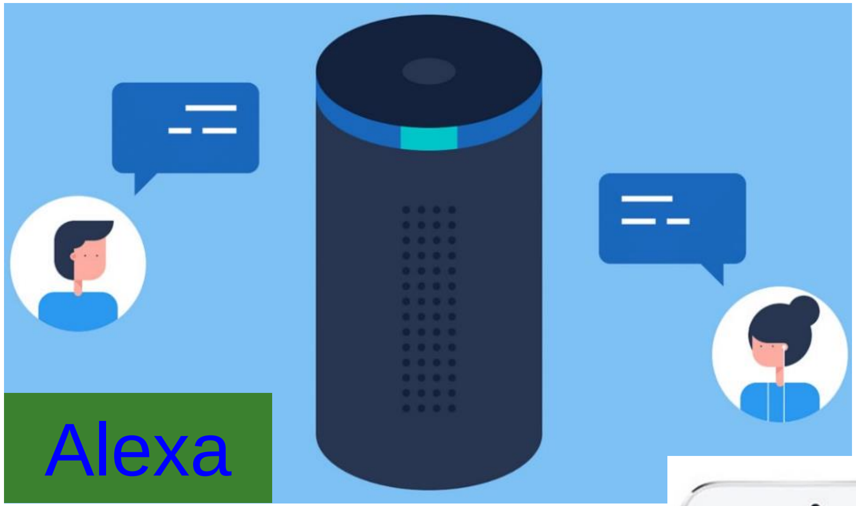
Device Authentication

Software Licensing

Secret Key Generation

Source: S. Joshi, S. P. Mohanty, and E. Kougianos, “Everything You Wanted to Know about PUFs”, IEEE Potentials Magazine, Volume 36, Issue 6, Nov-Dec 2017, pp. 38--46.

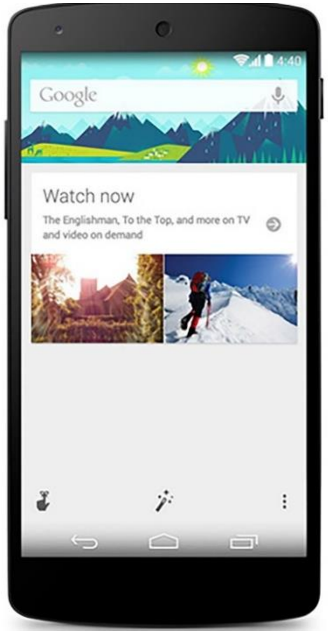
Smart End Devices



Alexa

Apple Siri

Google Now



Windows Cortana

Artificial Intelligence Technology

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

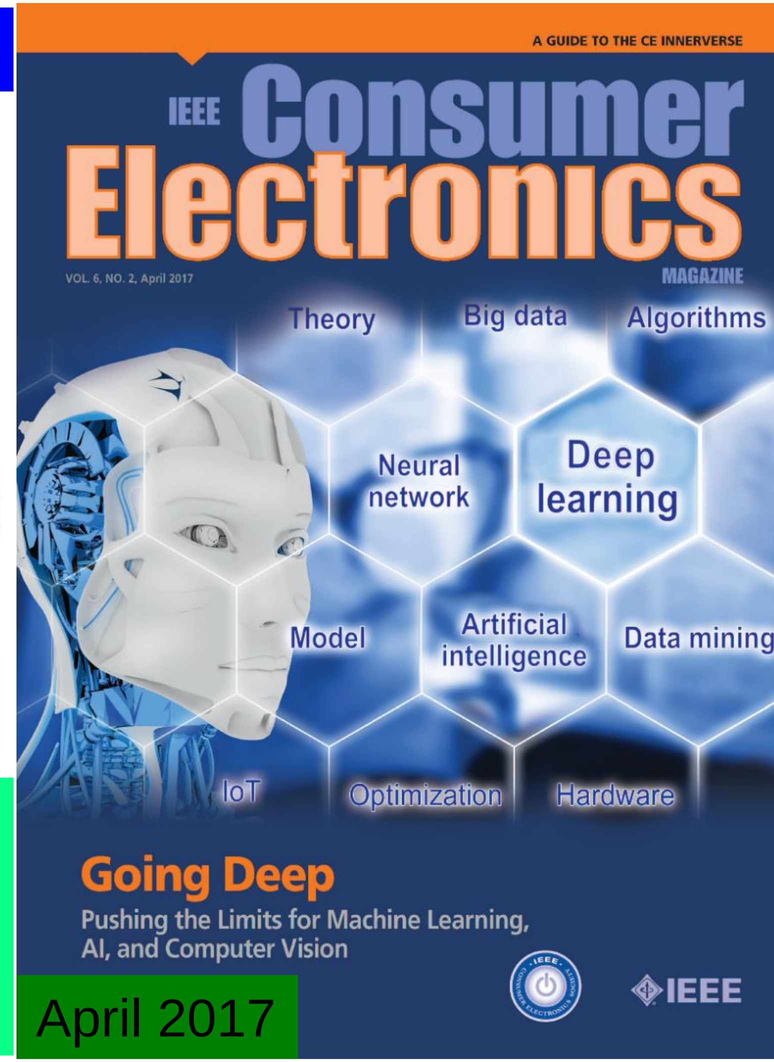
Machine Learning

Deep Learning

Tensor Processing Unit (TPU)

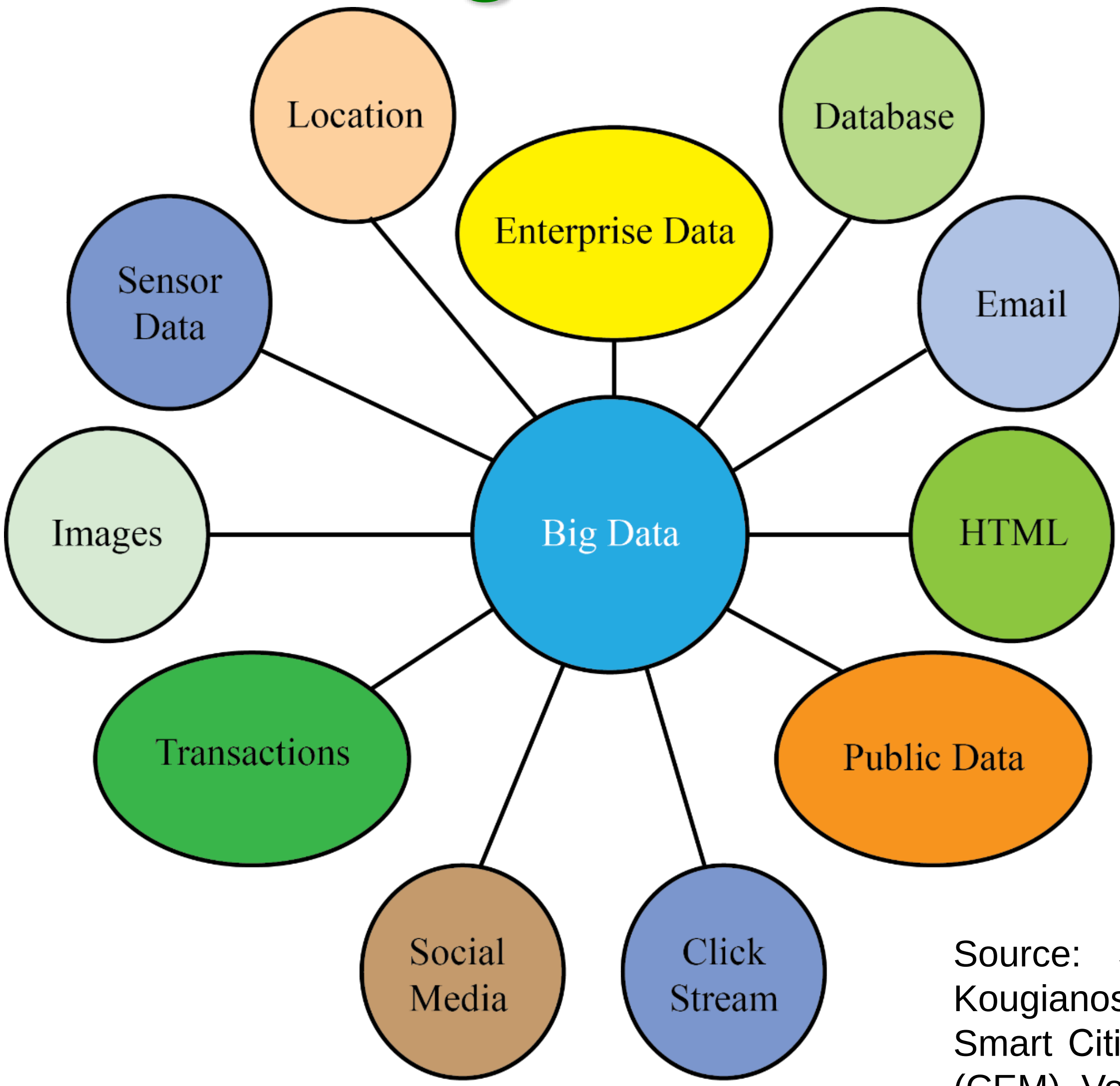
Source: https://fossbytes.com/googles-home-made-ai-processor-is-30x-faster-than-cpus-and-gpus/

Smart City Use:
- Better analytics
- Better decision
- Faster response



April 2017

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: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", IEEE Consumer Electronics Magazine (CEM), Volume 5, Issue 3, July 2016, pp. 60--70.

Data Compression in Smart Cities

Data Compression Techniques based on Data Types

- **Video Data**
  - MPEG-4, H.264
  - H.265 (High Efficiency Video Coding, HEVC)
- **Image Data**
  - JPEG, PNG
  - Better Portable Graphics (BPG)
- **Audio Data**
  - Advanced Audio Coding (AAC)
  - MP3, Dolby AC-4
- **Documents**
  - ZIP, rar, 7z
  - ISO Image
- **Medical Images**
  - JPEG 2000, JPEG-LS
- **Sensor Data**
  - Compressed Sensing, Derivatives of Lempel-Ziv-Welch (LZW)

Source: Mohanty ISCT 2019 Keynote

Efficient Media Compression – Better Portable Graphics (BPG)

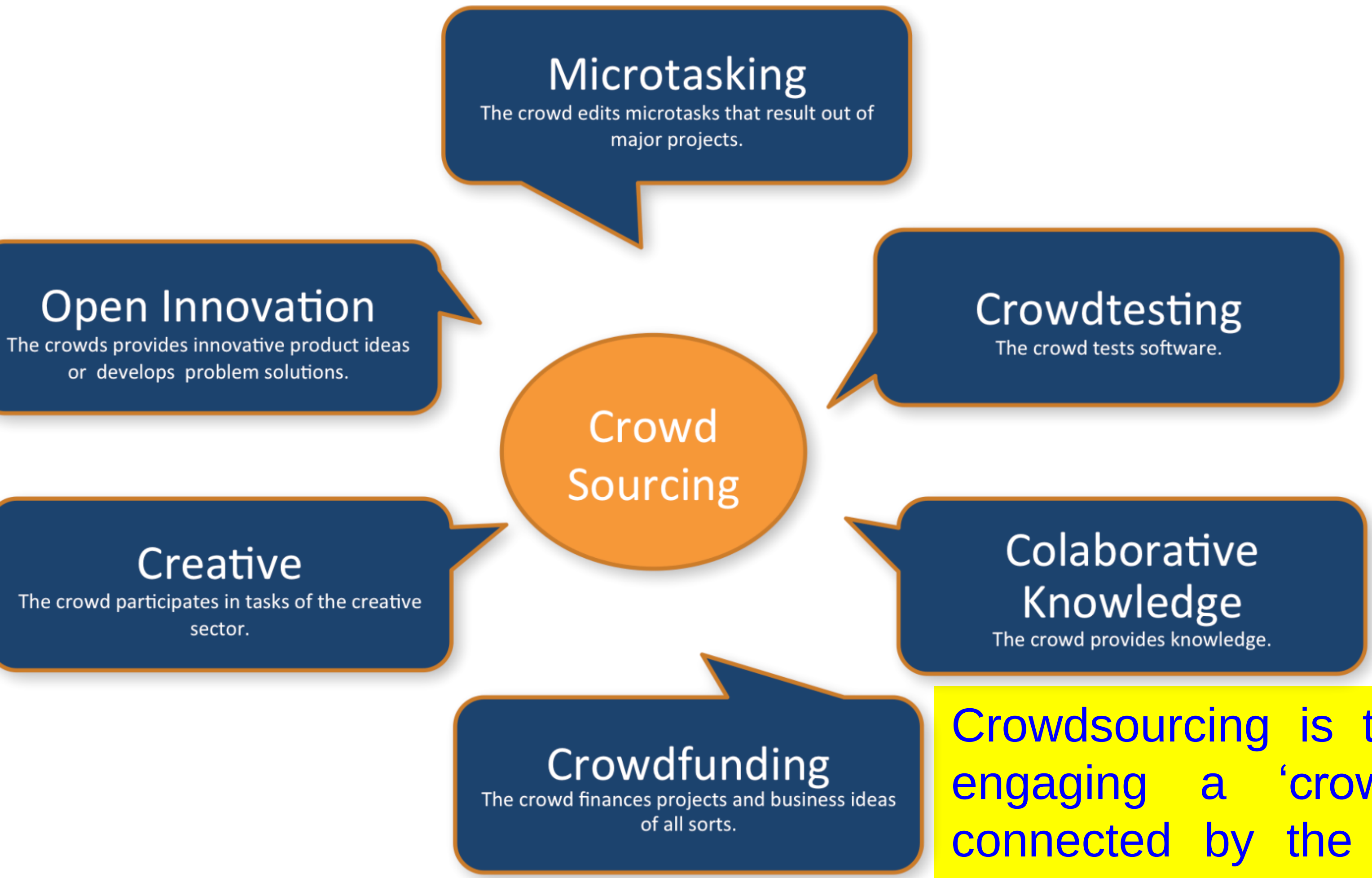
- **BPG compression instead of JPEG?**
- Attributes that differentiate BPG from JPEG and make it an excellent choice include:
  - Meeting modern display requirements: high quality and lower size.
  - BPG compression is based on the High Efficiency Video Coding (HEVC), which is considered a major advance in compression techniques.
  - Supported by most web browsers with a small Javascript decoder.

JPEG Compression

BPG Compression

Source: S. P. Mohanty, E. Kougianos, and P. Guturu, "SBPG: Secure Better Portable Graphics for Trustworthy Media Communications in the IoT (Invited Paper)", IEEE Access Journal, Volume 6, 2018, pp. 5939--5953.

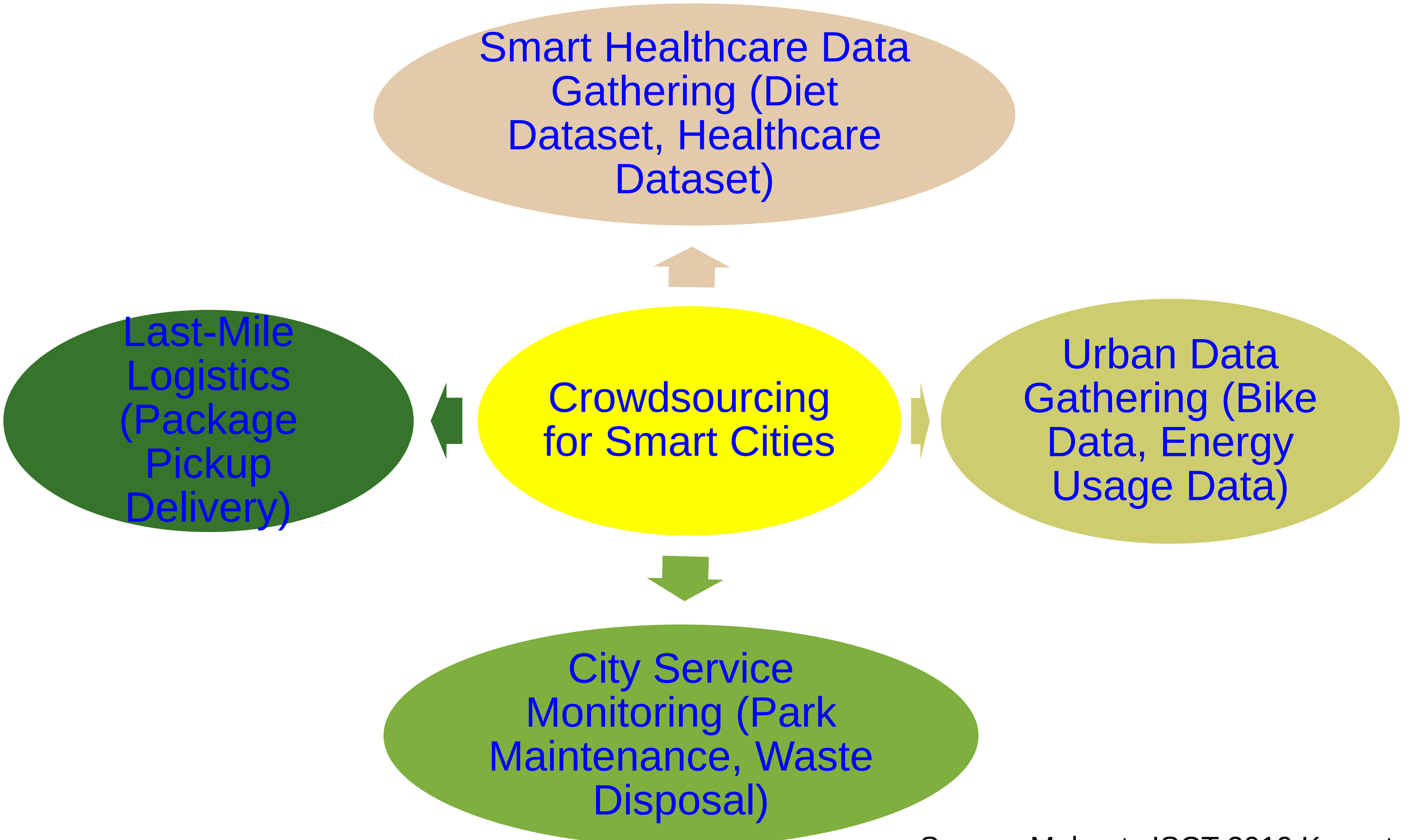
Crowdsourcing



Crowdsourcing is the practice of engaging a ‘crowd’ or group connected by the Internet for a common goal, e.g. data gathering, innovation, and problem solving.

Source: https://www.clickworker.com/about-crowdsourcing/

Crowdsourcing for Smart Cities



Source: Mohanty ISCT 2019 Keynote

Where and How to Compute?

October 2016

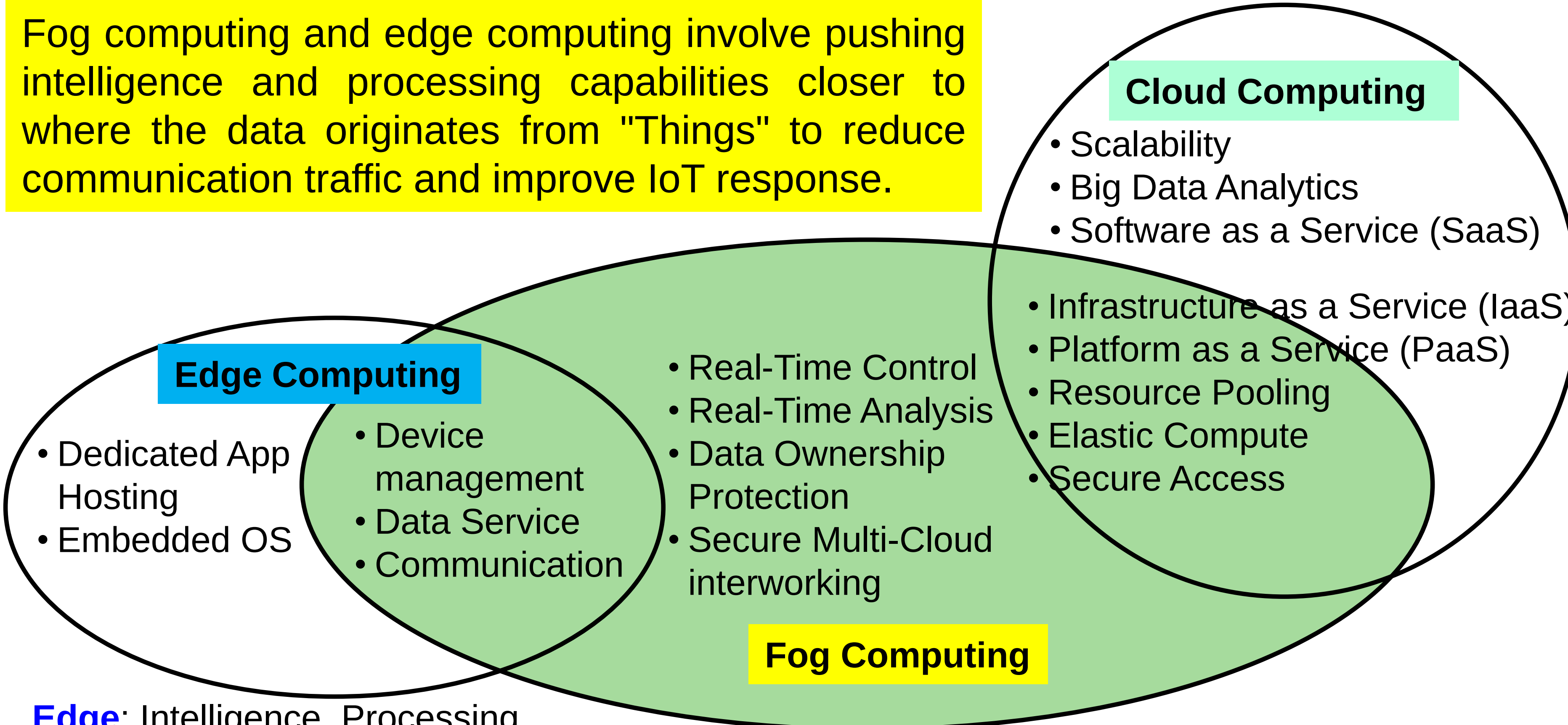
Sensor, Edge, Fog, Cloud?

July 2018

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

Fog Vs Edge Vs Cloud Computing

Fog computing and edge computing involve pushing intelligence and processing capabilities closer to where the data originates from "Things" to reduce communication traffic and improve IoT response.



Edge: Intelligence, Processing, and Communication - Devices like Programmable Automation Controllers (PACs)

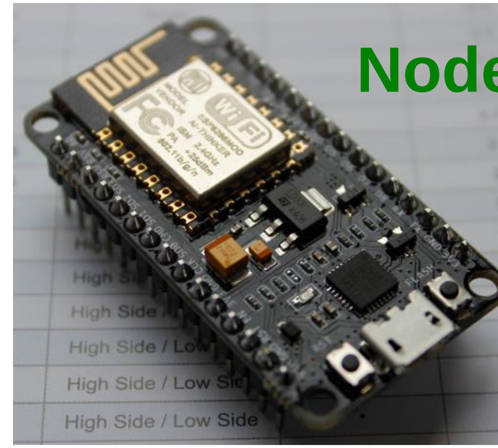
Fog: Intelligence - LAN, Processing - fog node or IoT gateway.

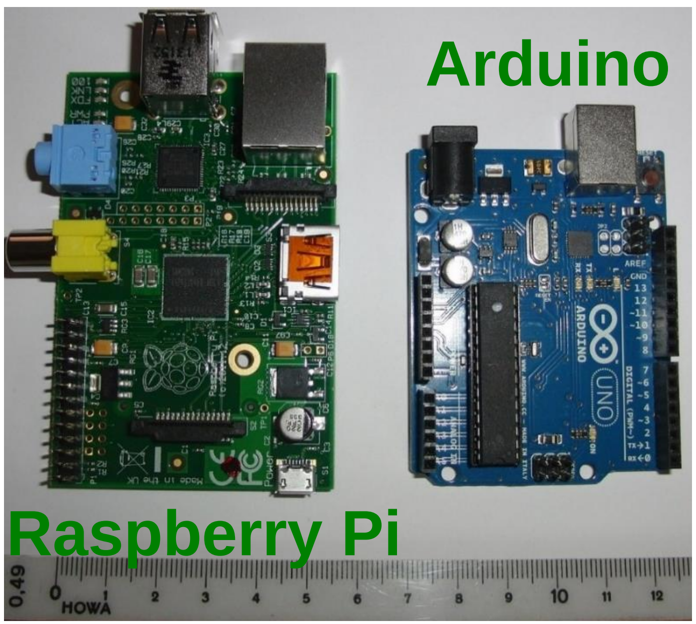
Source: https://www.automationworld.com/fog-computing-vs-edge-computing-whats-difference

Source: https://www.nebbiolo.tech/wp-content/uploads/whitepaper-fog-vs-edge.pdf

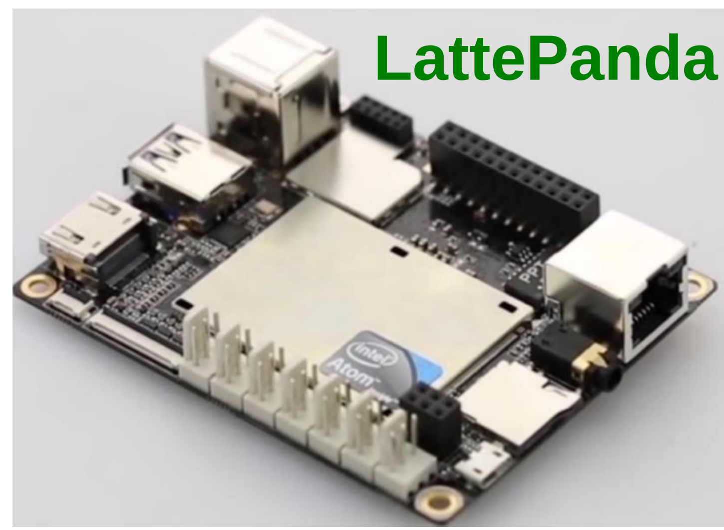
Computing Technology - IoT Platform

Source: https://www.sparkfun.com/products/13678



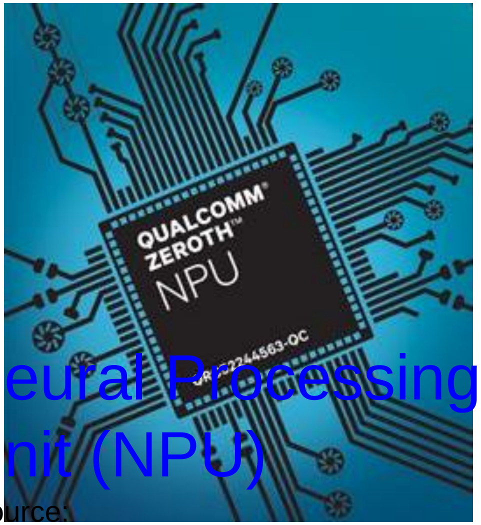


Source: Mohanty ISCT 2019 Keynote



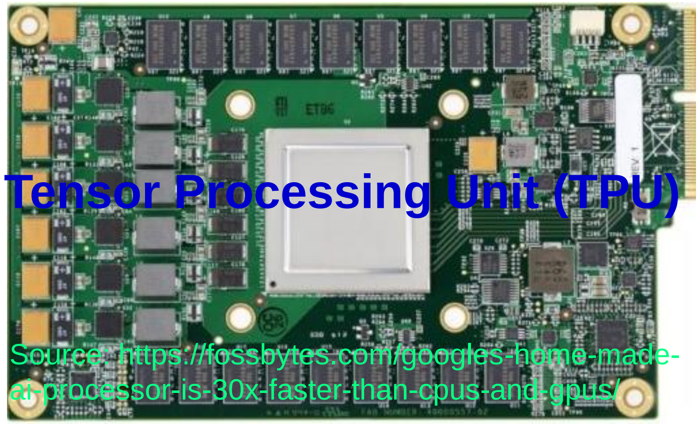
Source: http://www.lattepanda.com

Computing Technology - Current and Emerging



Neural Processing Unit (NPU)

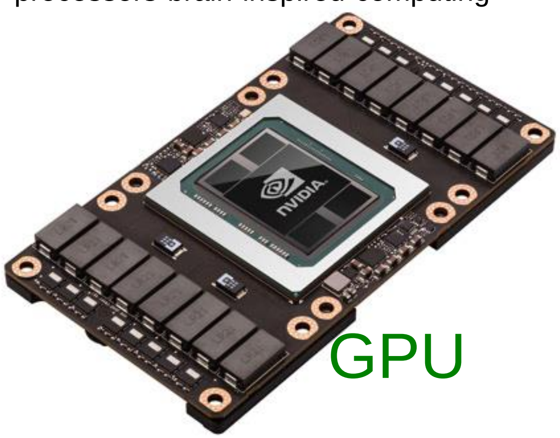
Source: https://www.qualcomm.com/news/onq/2013/10/10/introducing-qualcomm-zeroth-processors-brain-inspired-computing



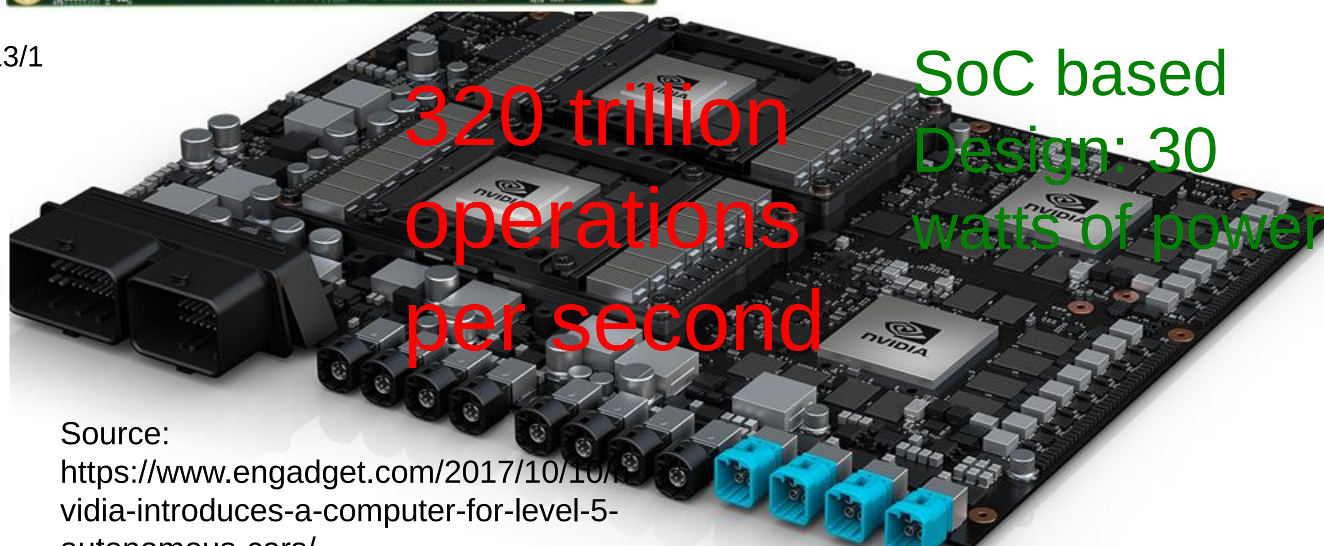
Tensor Processing Unit (TPU)

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

FPGA



GPU



320 trillion operations per second

SoC based Design: 30 watts of power

Source: https://www.engadget.com/2017/10/10/nvidia-introduces-a-computer-for-level-5-autonomous-cars/

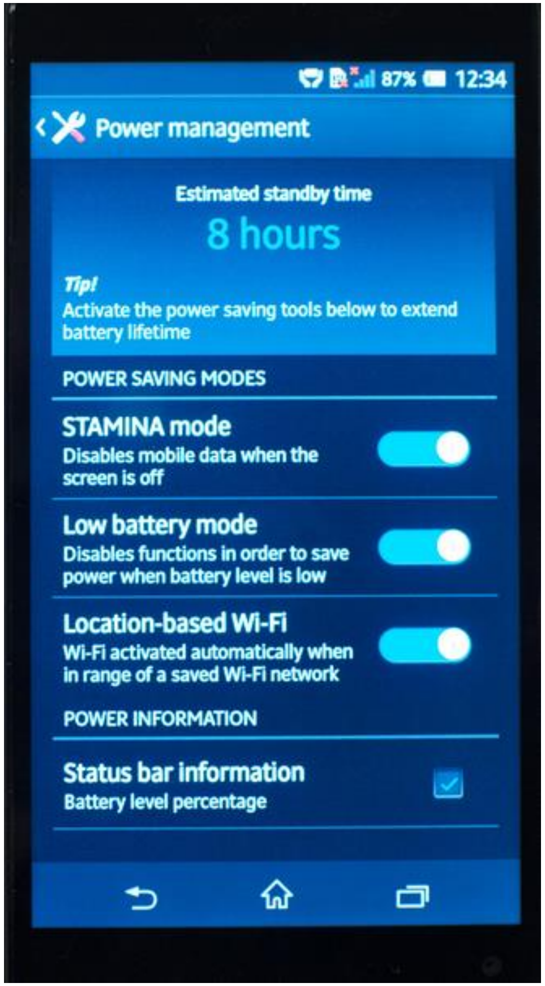
Source: Mohanty ISCT 2019 Keynote

ML Hardware – Cloud and Edge

Product	Cloud or Edge	Chip Type
Nvidia - DGX series	Cloud	GPU
Nvidia - Drive	Edge	GPU
Arm - ML Processor	Edge	CPU
NXP - i.MX processor	Edge	CPU
Xilinx - Zinq	Edge	Hybrid CPU/FPGA
Xilinx - Virtex	Cloud	FPGA
Google - TPU	Cloud	ASIC
Tesla - AI Chip	Edge	Unknown
Intel - Nervana	Cloud	CPU
Intel - Loihi	Cloud	Neuromorphic
Amazon - Echo (custom AI chip)	Edge	Unknown
Apple - A11 processor	Edge	CPU
Nokia - Reefshark	Edge	CPU
Huawei - Kirin 970	Edge	CPU
AMD - Radeon Instinct MI25	Cloud	GPU
IBM - TrueNorth	Cloud	Neuromorphic
IBM - Power9	Cloud	CPU
Alibaba - Ali-NPU	Cloud	Unknown
Qualcomm AI Engine	Edge	CPU
Mediatek - APU	Edge	CPU

Source: Presutto 2018: https://www.academia.edu/37781087/Current_Artificial_Intelligence_Trends_Hardware_and_Software_Accelerators_2018_

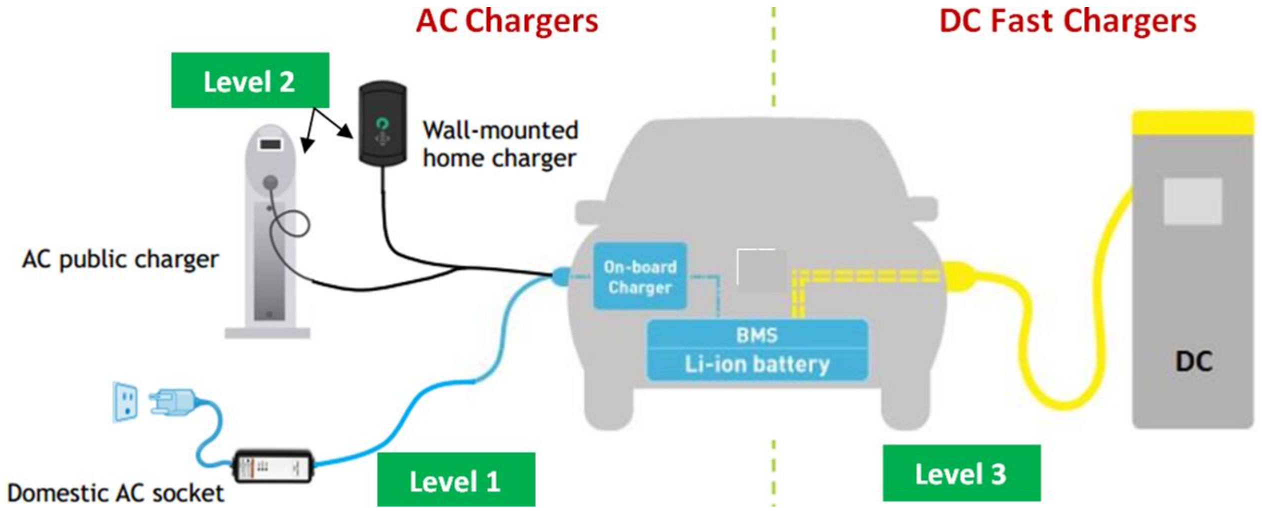
Smart Energy – Smart Consumption



Battery Saver

Smart Home

EV Charging System

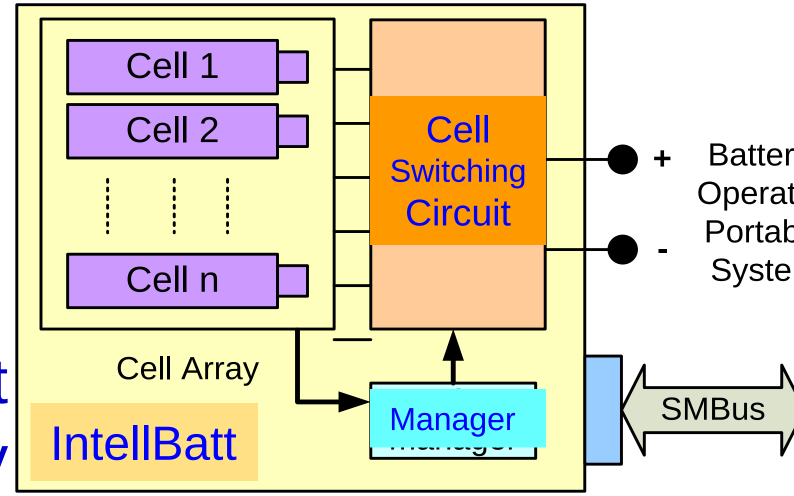


- Design and deployment of Level 2 (AC) and combined charging system
- Design and deployment of hybrid input DC Fast charger
  - (a) with multi-input source and single-output
  - (b) with 5-10 kW output EV charger for E-Rickshaws
  - (c) universal charger design and implementation
- Impact study of storage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

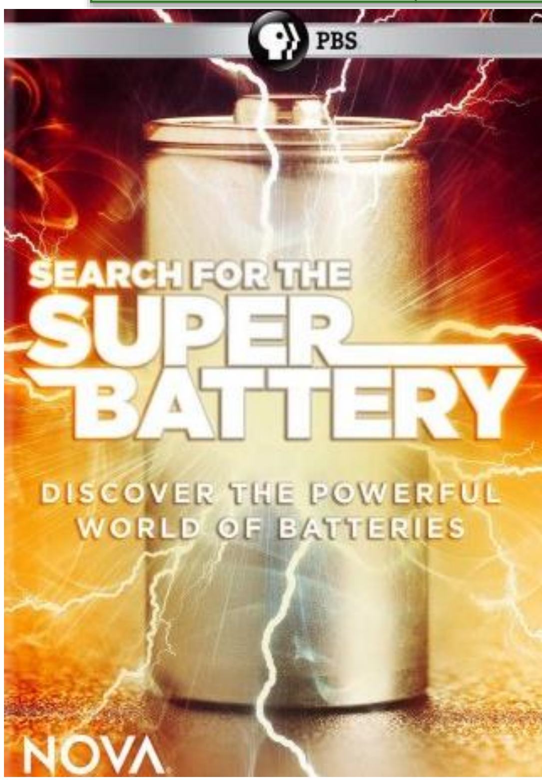
Energy Storage - High Capacity and Efficiency Needed

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



Intelligent Battery

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



Lithium Polymer Battery

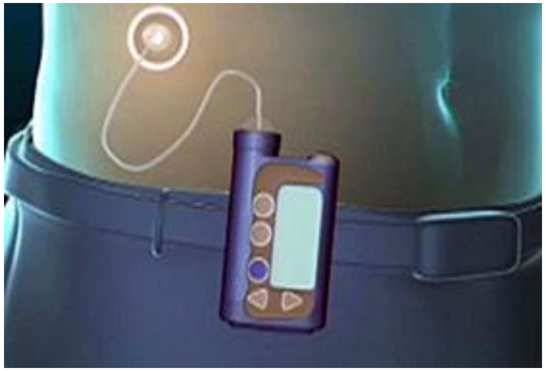
Supercapacitor

Source: Mohanty MAMI 2017 Keynote

Wearable Medical Devices (WMDs)

Fitness Trackers

Headband with Embedded Neurosensors

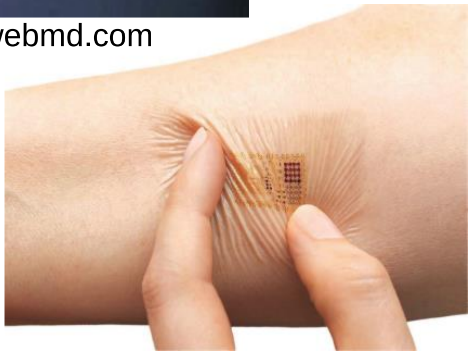


Source: https://www.webmd.com

Insulin Pump

Source: https://www.empatica.com/embrace2/

Medical grade smart watch to detect seizure

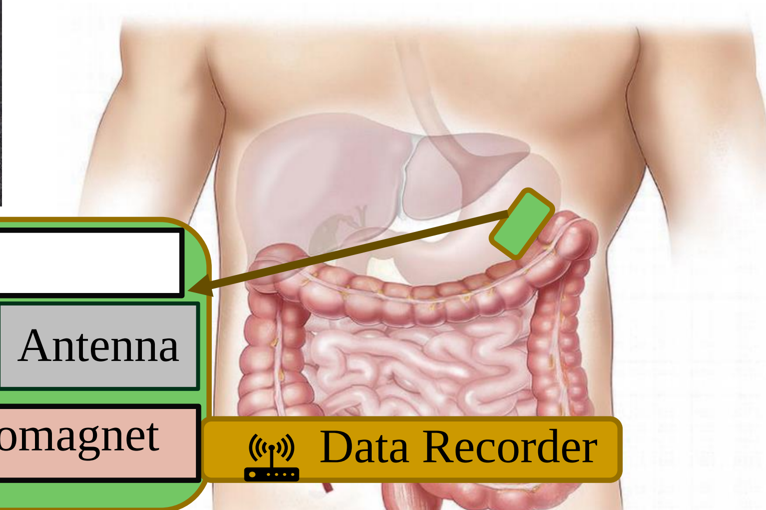


Embedded Skin Patches

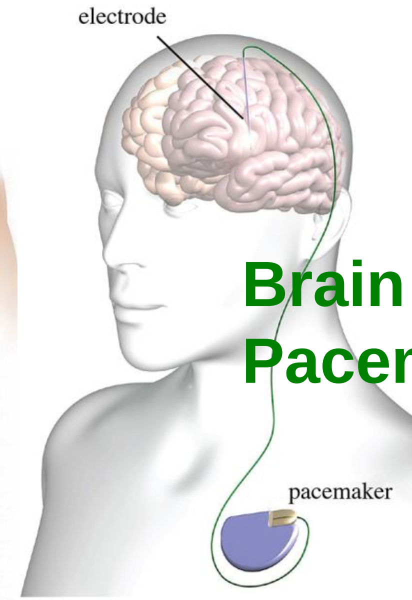
Sethi 2017: JECE 2017

Implantable Medical Devices (IMDs)

Pill Camera



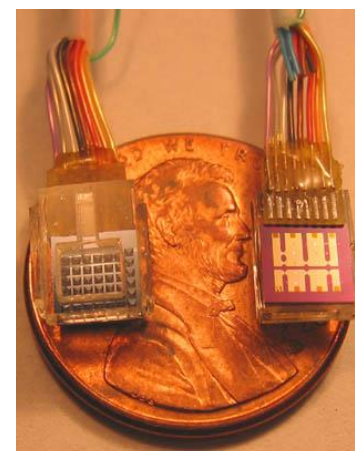
Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", IEEE Consumer Electronics Magazine (CEM), Volume 7, Issue 1, January 2018, pp. 18-28.



Brain Pacemaker

Collectively:
Implantable and Wearable Medical Devices (IWMDs)

Implantable MEMS Device



Source: http://web.mit.edu/cprl/www/research.shtml

Technology for Visually Impaired

Detection Part (Localizes the marker from the other objects)

Visual Marker

Recognition Part (QR code)

Source: C. Lee, P. Chondro, S. Ruan, O. Christen and E. Naroska, "Improving Mobility for the Visually Impaired: A Wearable Indoor Positioning System Based on Visual Markers," IEEE Consumer Electronics Magazine, vol. 7, no. 3, pp. 12-20, May 2018.

May 2018

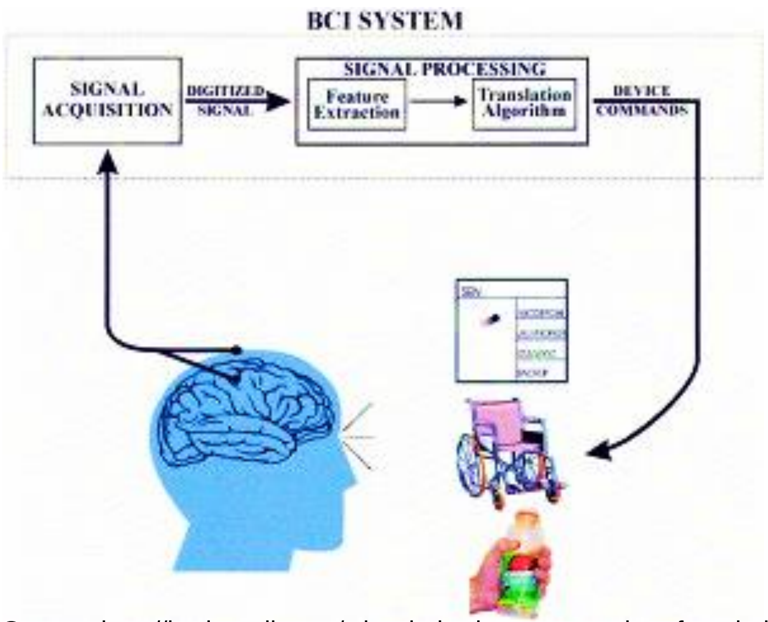
Brain Computer Interface (BCI)

"Currently, people interact with their devices by thumb-typing on their phones. A high-bandwidth interface to the brain would help achieve a symbiosis between human and machine intelligence and could make humans more useful in an AI-driven world."

-- Neuralink - neurotechnology company - Elon Musk.

Sources: http://brainpedia.org/elon-musk-wants-merge-human-brain-ai-launches-neuralink/

BCI - Applications



Source: http://brainpedia.org/what-is-brain-computer-interface-bci/

BCI Allows paralysis patients move a wheelchair

Source: http://brainpedia.org/brain-computer-interface-allows-paralysis-als-patients-type-much-faster/

BCI Allows paralysis patients to Type

- BCI Types
  - Based on Location
    - Non-invasive
    - Semi-invasive
    - Invasive
  - Based on Signal
    - EEG
    - MEG
    - fNIR
    - fMRI

Source: Mohanty ISCT 2019 Keynote

Unmanned Ariel Vehicle (UAV)

Unmanned Arial Vehicles or Remotely Piloted Vehicles is an aircraft without a human pilot on board.

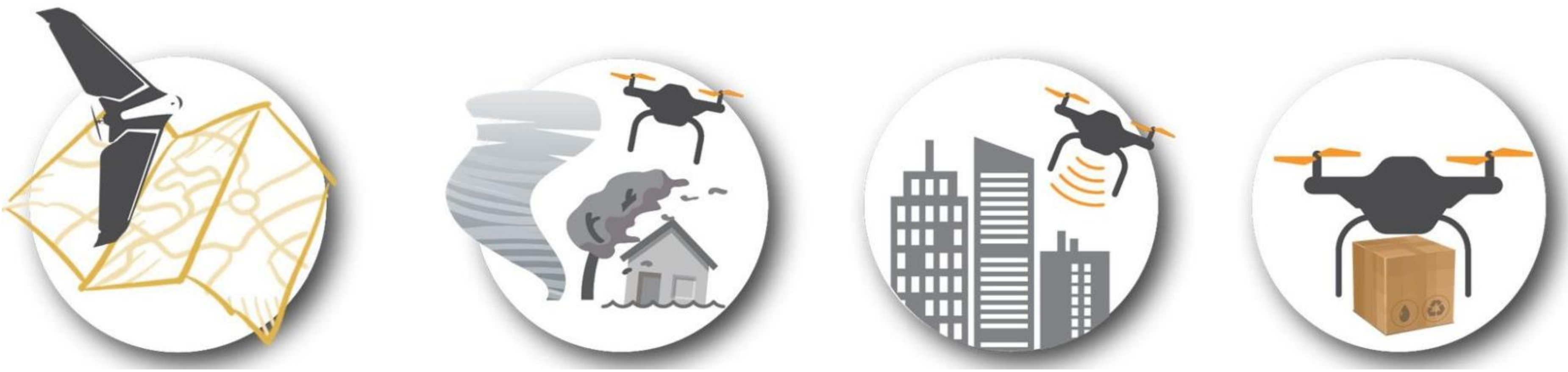
- Unmanned Aerial Vehicle
- Drone - remotely piloted
- Controlled autonomously

First used in Austria for military purposes during 1849.

UAV – Smart City Applications

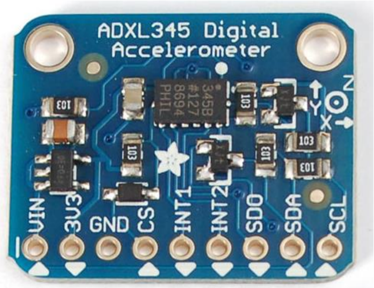
UAV Applications - 4 Categories

Data collection & surveying | Monitoring & Tracking | Temporary Infrastructure | Delivery of Goods



Source: Christos Kyrkou, Stelios Timotheou, Panayiotis Kolios, Theocharis Theocharides, and Christos Panayiotou, "Drones: Augmenting Our Quality of Life" IEEE Potentials Magazine, IEEE Potentials, vol. 38, no. 1, pp. 30-36, Jan.-Feb. 2019.

UAV – CE Components



UAV - Components

- GPS
- Accelerometer
- Barometer
- Compass
- Gyroscope
- Camera
- Communication components
- Thermal sensors
- Light detection and ranging (LIDAR)

Virtual and Augmented Reality Technology

Virtual Reality

Smart City Use:
- Healthcare - Therapy, Surgery
- Tourism - Recreate History
- Entertainment - Movies

January 2017

Augmented Reality

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

Virtual Reality in Healthcare

Source: https://touchstoneresearch.com/tag/applied-vr/

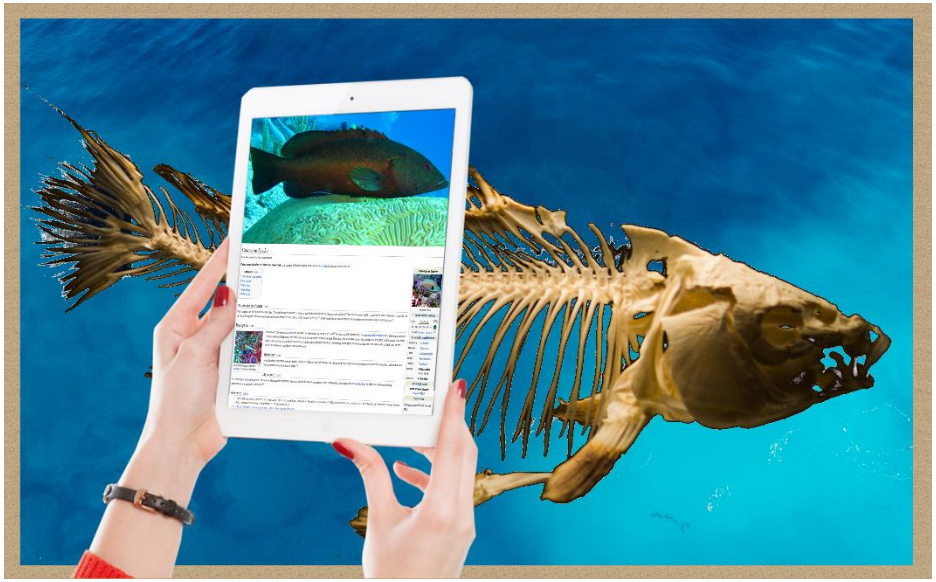
In Surgery

For Therapy

Source: http://medicalfuturist.com/5-ways-medical-vr-is-changing-healthcare/

Source: Mohanty ISCT 2019 Keynote

Virtual and Augmented Reality in Smart Cities Applications



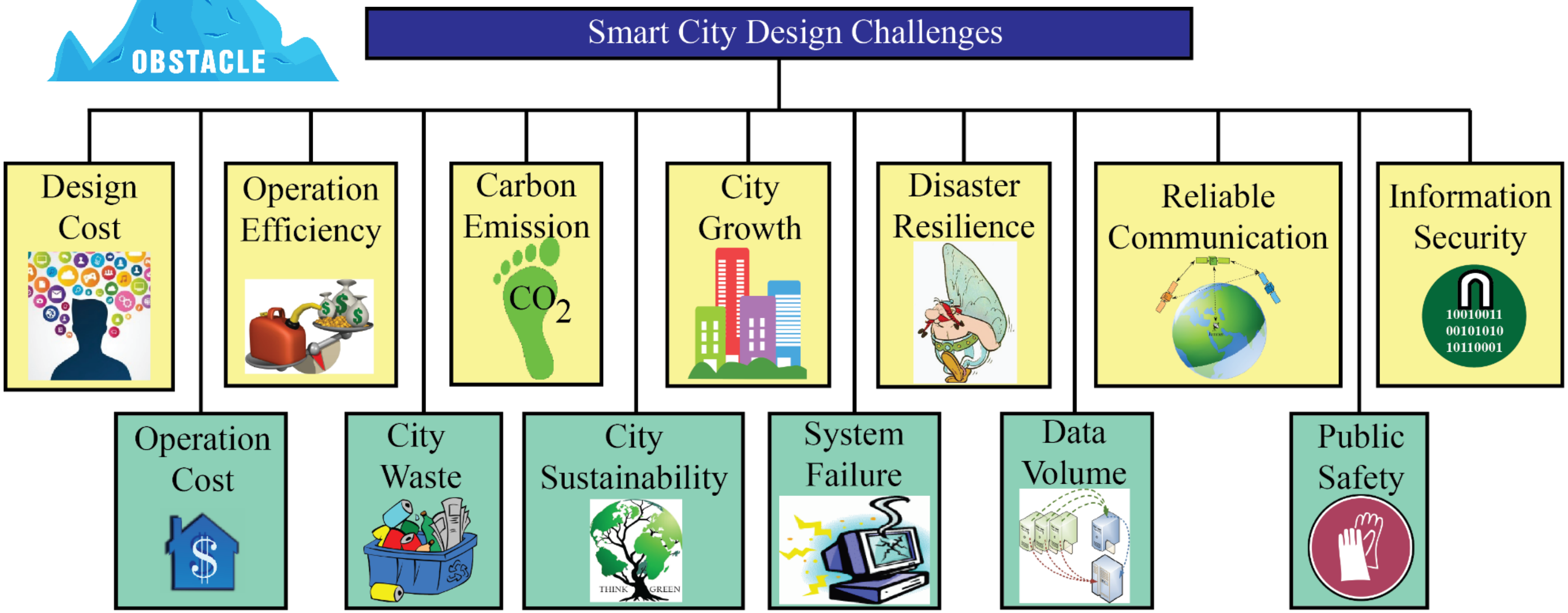
Augmented reality museum in smart tourism.

AR for real-time travel assistance.

Source: N. Shabani, A. Munir and A. Hassan, "E-Marketing via Augmented Reality: A Case Study in the Tourism and Hospitality Industry," IEEE Potentials, vol. 38, no. 1, pp. 43-47, Jan.-Feb. 2019.

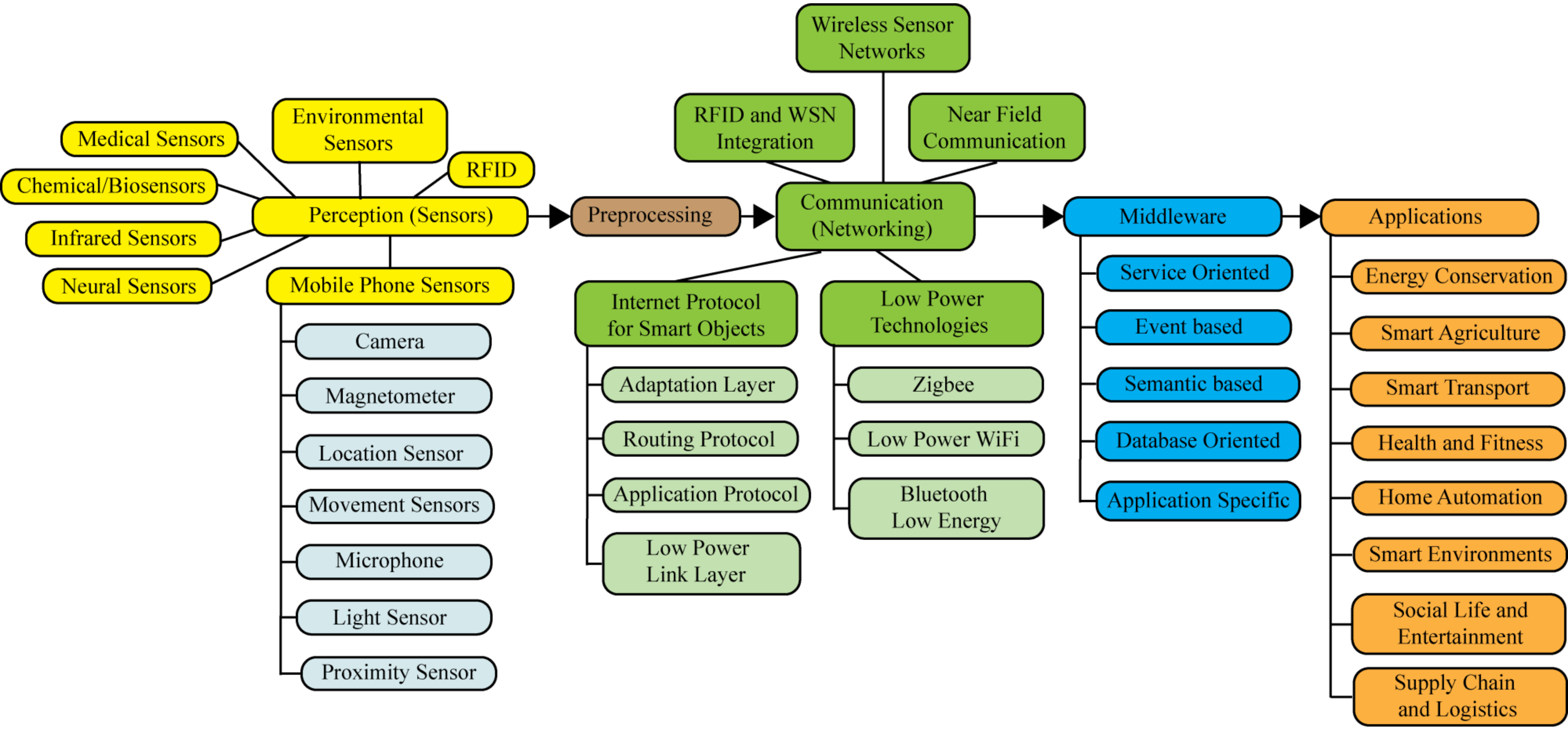
Challenges and Research

Smart City - Selected Design Challenges



Source: S. P. Mohanty, U. Choppali, and E. Kougianos, “Everything You wanted to Know about Smart Cities”, IEEE Consumer Electronics Magazine (CEM), Volume 5, Issue 3, July 2016, pp. 60--70.

Smart City - Multidiscipline Research



Source: Pallavi Sethi and Smruti R. Sarangi Internet of Things: Architectures, Protocols, and Applications, Journal of Electrical and Computer Engineering, Volume 2017, Article ID 9324035, 25 pages.

Design and Operation Cost

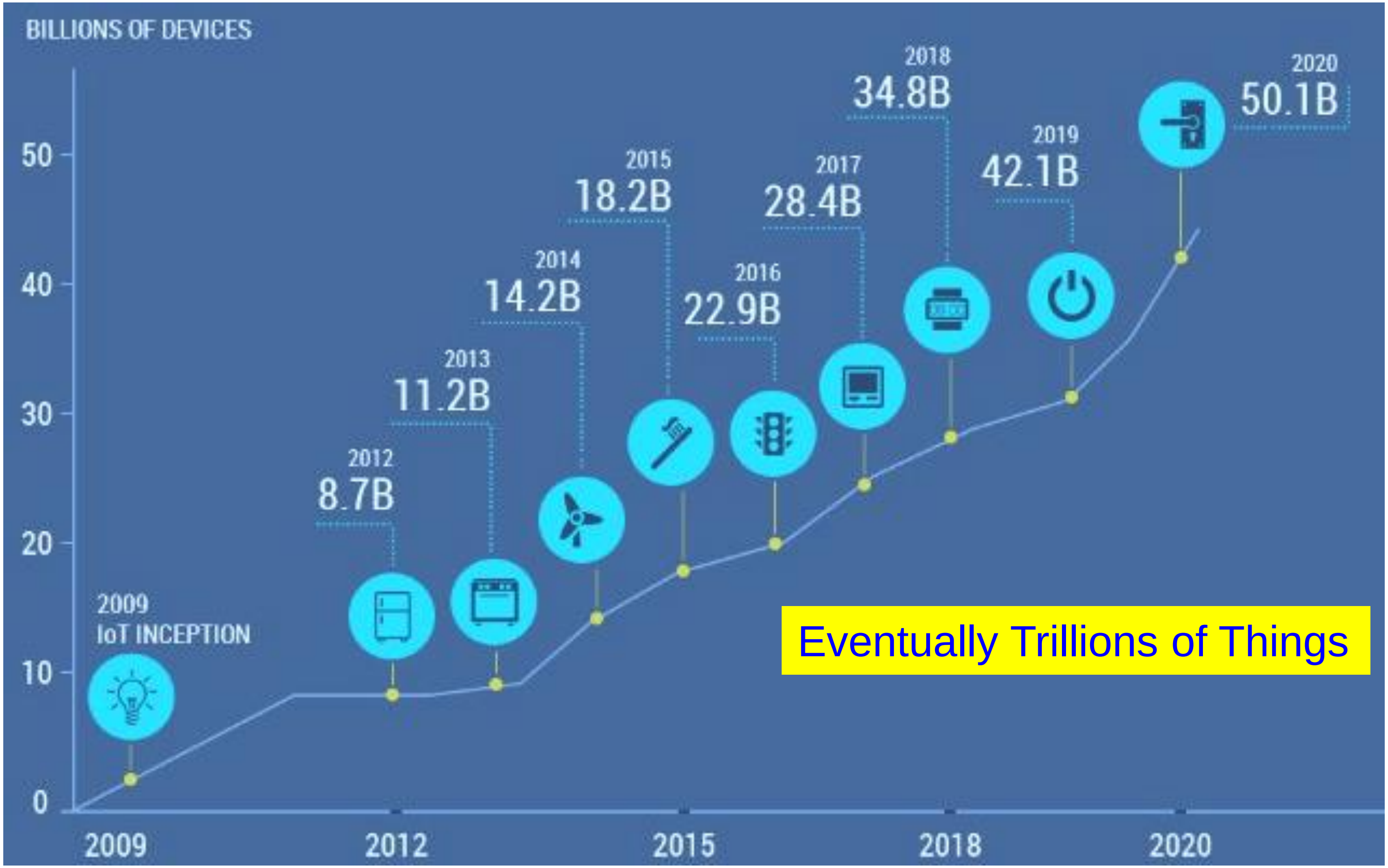
- The design cost is a one-time cost.
- Design cost needs to be small to make a IoT realization possible.
- The operations cost is that required to maintain the IoT.
- A small operations cost will make it easier to operate in the long run with minimal burden on the budget of application in which IoT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

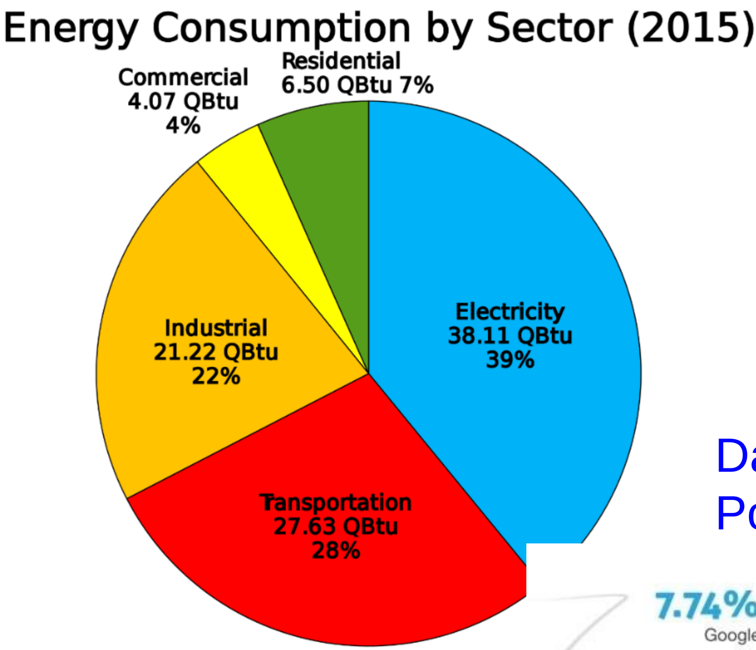
Source: http://www.cnbc.com/2016/10/25/spending-on-smart-cities-around-the-world-could-reach-41-trillion.html

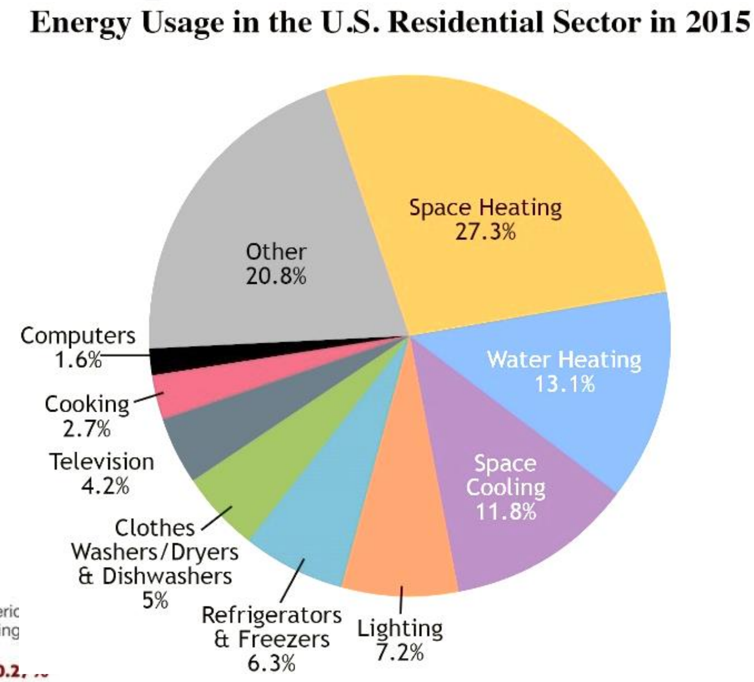
Massive Growth of Sensors/Things



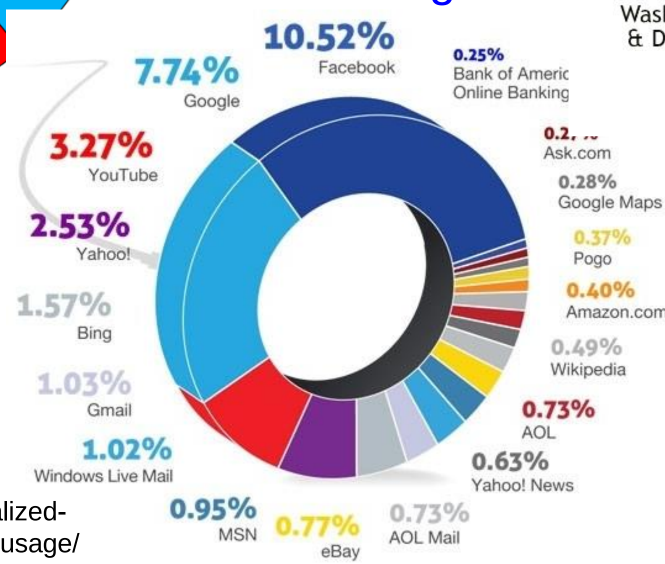
Source: https://www.linkedin.com/pulse/history-iot-industrial-internet-sensors-data-lakes-0-downtime

Energy Consumption





Data Center Power Usage



ENERGY STAR

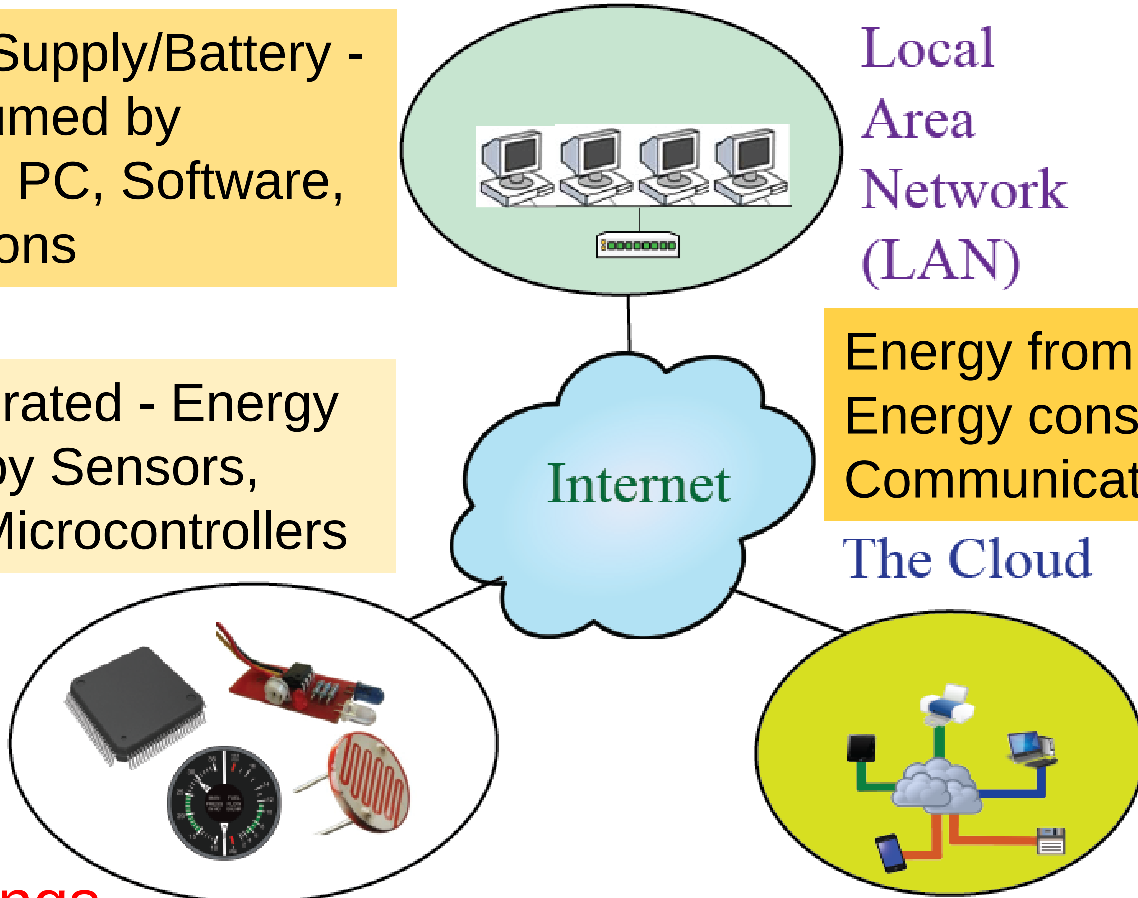
Individual Level:
Imagine how often we charge our portable CE!

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

Battery Operated - Energy consumed by Sensors, Actuators, Microcontrollers



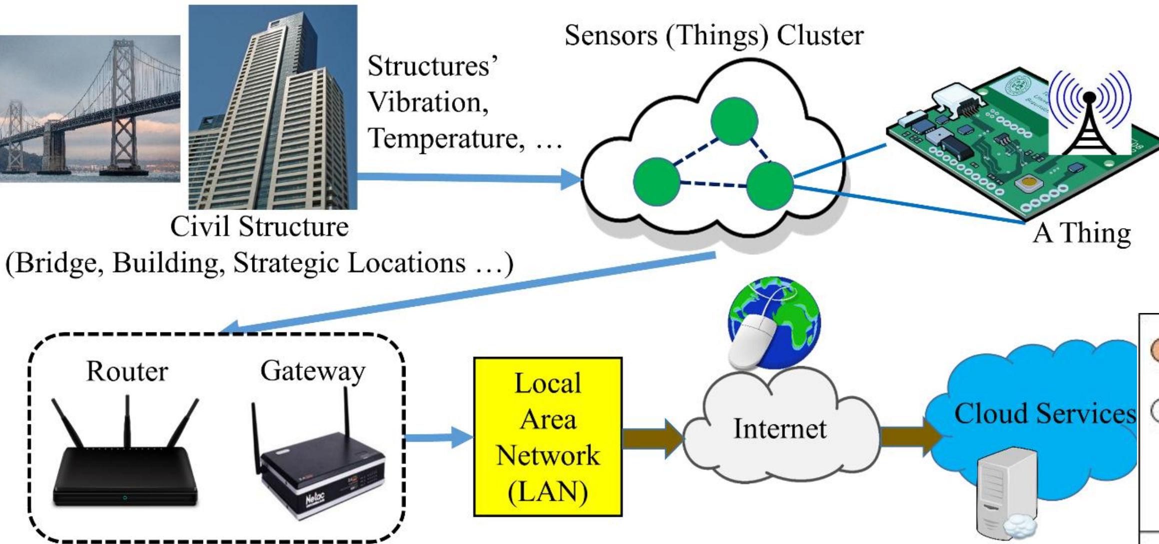
Energy from Supply/Battery - Energy consumed by Communications

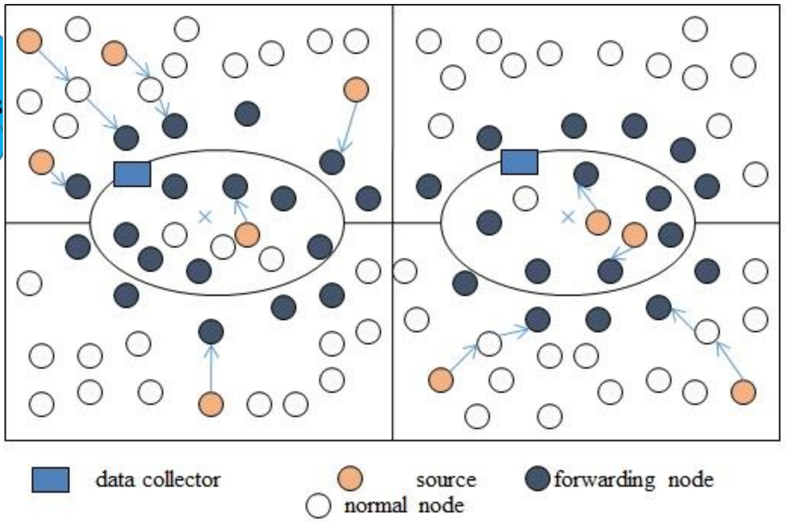
Energy from Supply - Energy consumed in Server, Storage, Software, Communications

Four Main Components of IoT.

Source: Mohanty 2018, iSES 2018 Keynote

Sustainable IoT - Low-Power Sensors and Efficient Routing

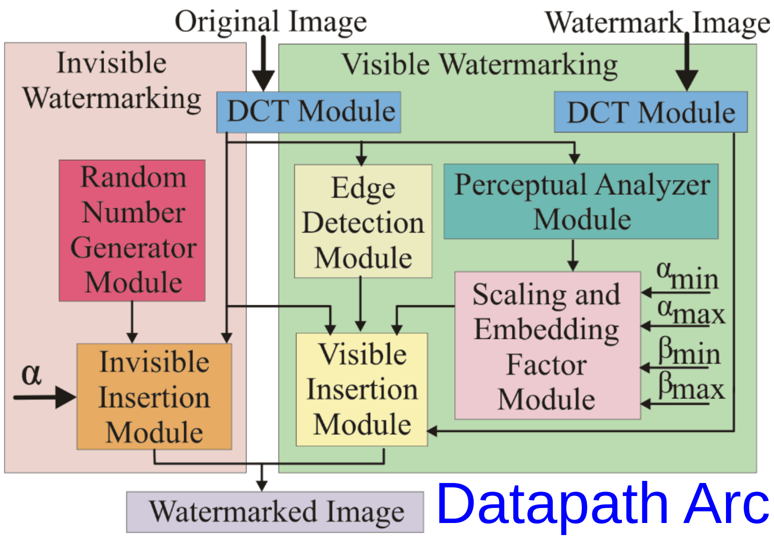




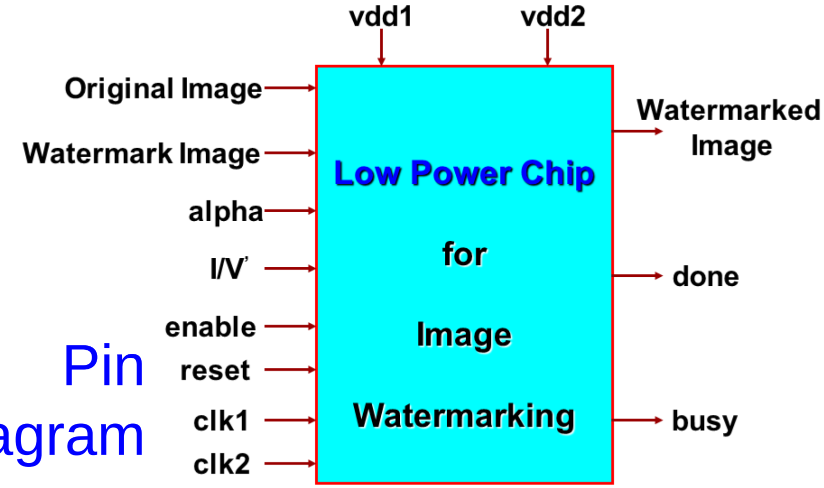
- IoT - sensors near the data collector drain energy faster than other nodes.
- Solution Idea - Mobile sink in which the network is balanced with node energy consumption.
- Solution Need: New data routing to forward data towards base station using mobile data collector, in which two data collectors follow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

Source: S. S. Roy, D. Puthal, S. Sharma, S. P. Mohanty, and A. Y. Zomaya, "Building a Sustainable Internet of Things", *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 2, March 2018, pp. 42--49.

Dual-Voltage Energy Efficient Hardware

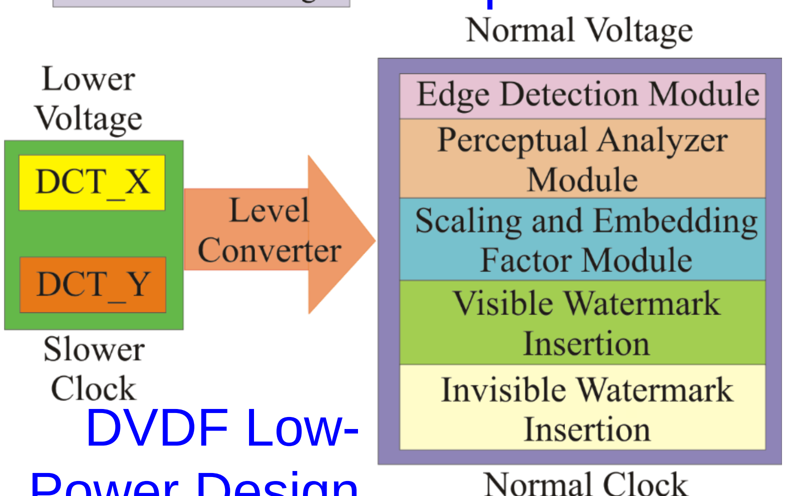


Datapath Architecture



Pin Diagram

Hardware Layout



DVDF Low-Power Design

Physical Design Data

Total Area : 16.2 sq mm

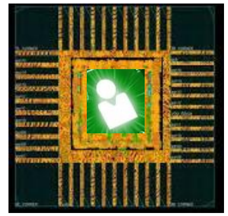
No. of Transistors: 1.4 million

Power Consumption: 0.3 mW

Source: S. P. Mohanty, N. Ranganathan, and K. Balakrishnan, "A Dual Voltage-Frequency VLSI Chip for Image Watermarking in DCT Domain", *IEEE Transactions on Circuits and Systems II (TCAS-II)*, Vol. 53, No. 5, May 2006, pp. 394-398.

Security, Privacy, and IP Rights

Hardware Trojan



Counterfeit Hardware

Source: Mohanty ICIT 2017 Keynote

Security Challenge – Information

Online Banking

…

Credit Card Theft

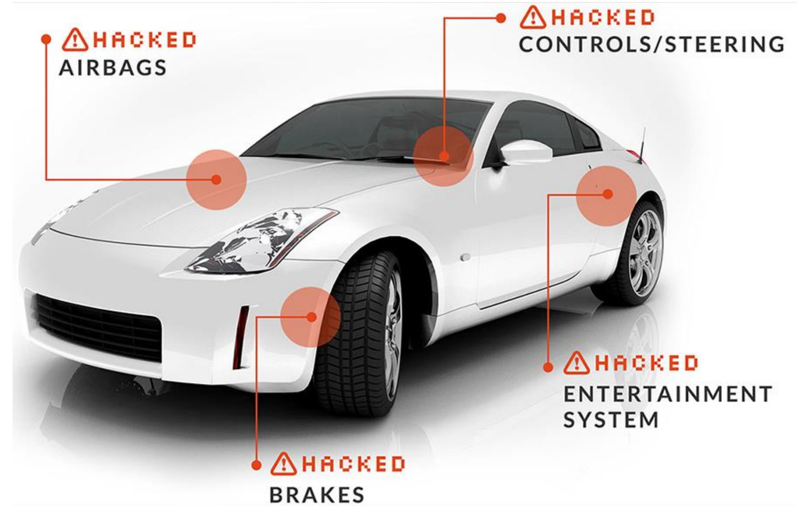
Personal Information

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

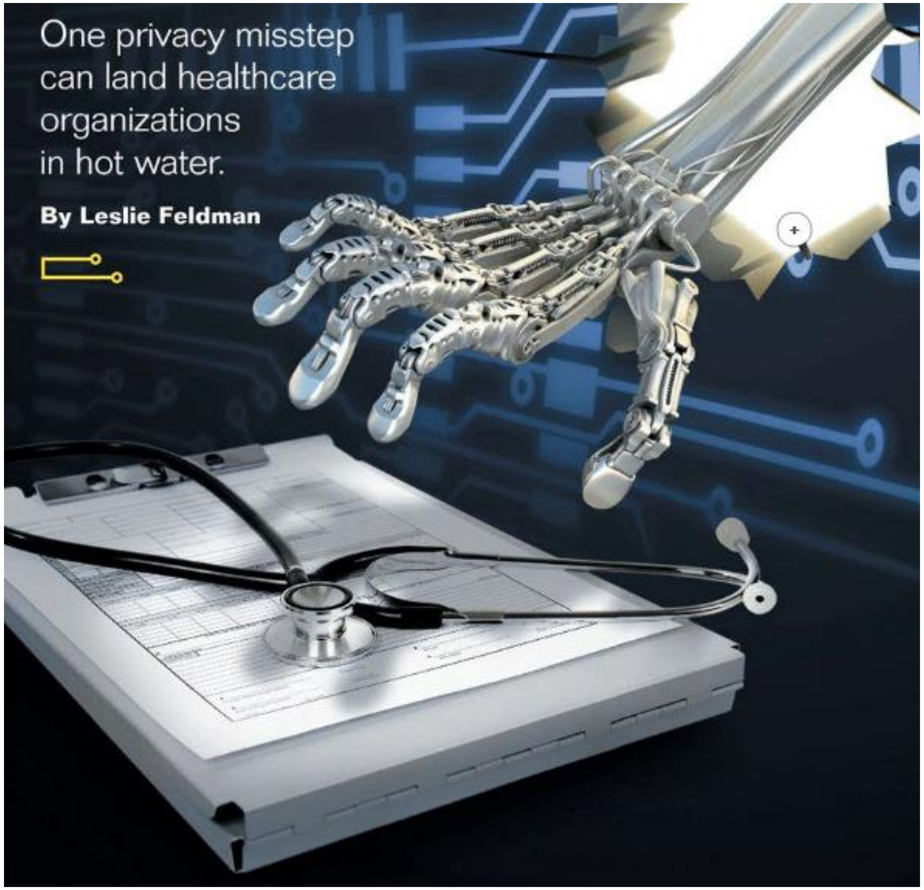


Source: http://money.cnn.com/2014/06/01/technology/security/car-hack/

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

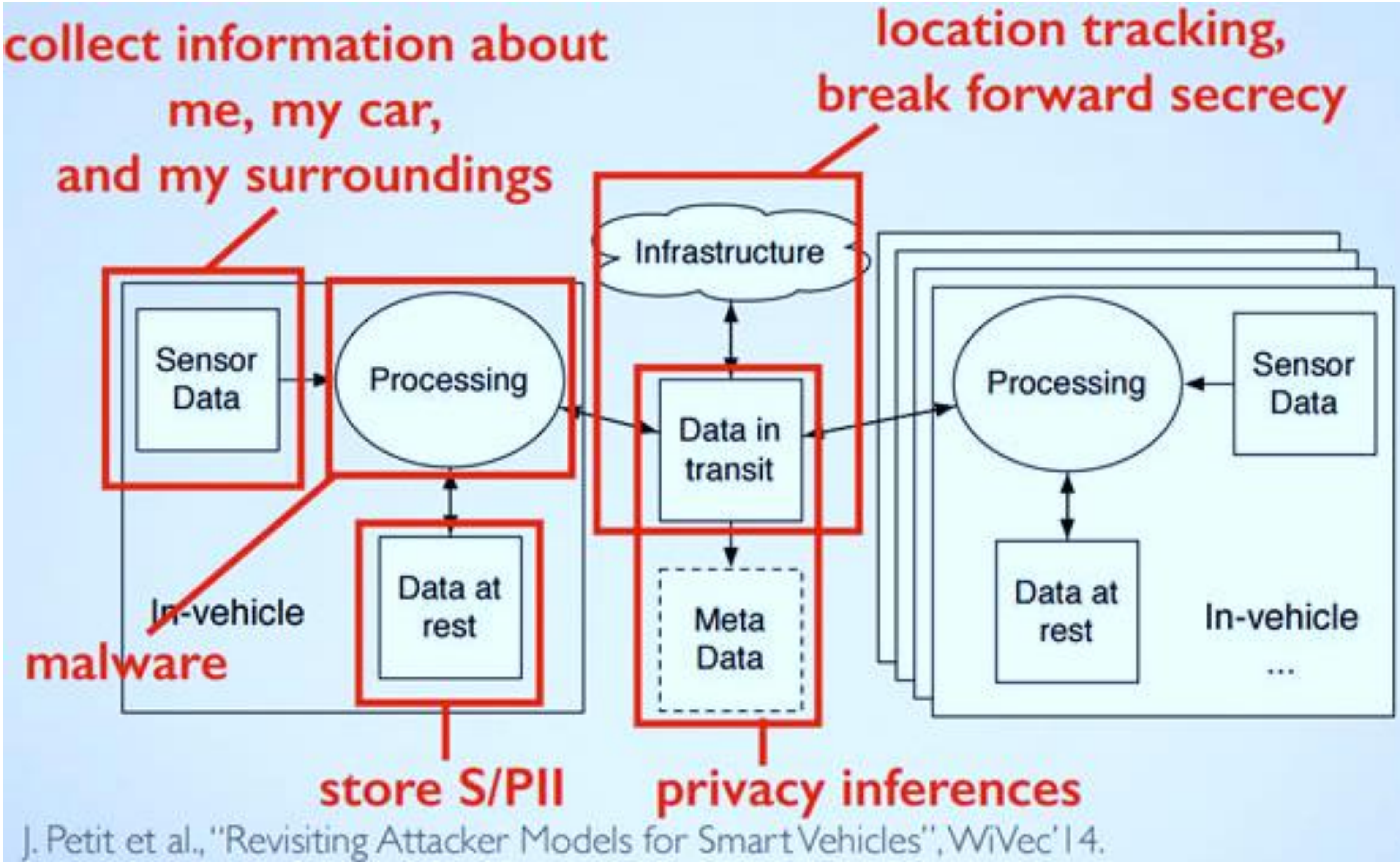
Privacy Challenge - Information

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



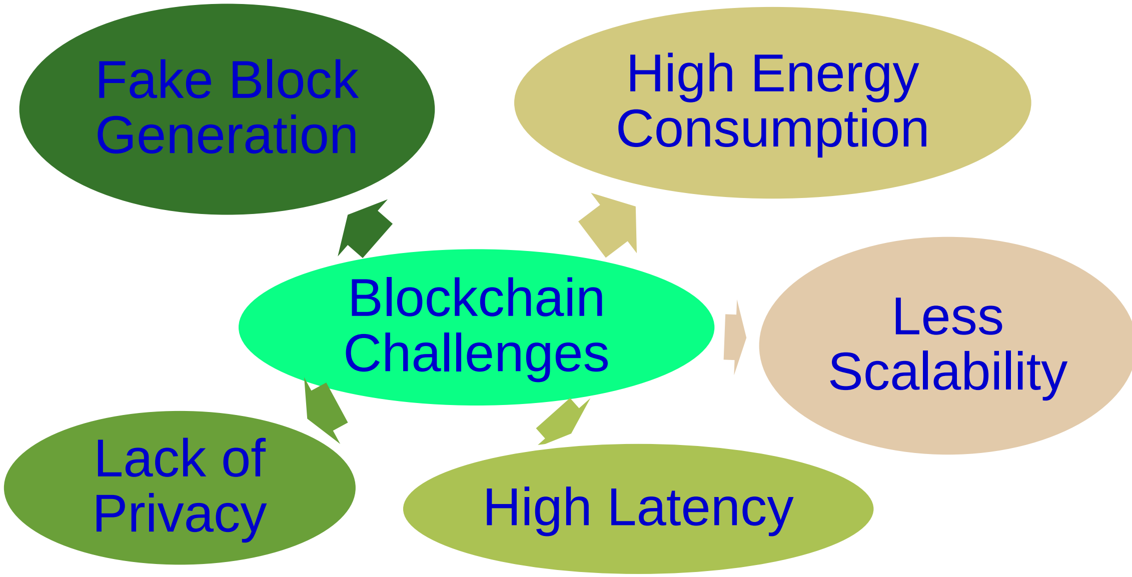
Source: http://www.computerworld.com/article/3005436/cybercrime-hacking/black-hat-europe-it-s-easy-and-costs-only-60-to-hack-self-driving-car-sensors.html

CE Security – Selected Solutions

Analysis of selected approaches to security and privacy issues in CE.			
Category	**Current Approaches**	**Advantages**	**Disadvantages**
Confidentiality	Symmetric key cryptography	Low computation overhead	Key distribution problem
	Asymmetric key cryptography	Good for key distribution	High computation overhead
Integrity	Message authentication codes	Verification of message contents	Additional computation overhead
Availability	Signature-based authentication	Avoids unnecessary signature computations	Requires additional infrastructure and rekeying scheme
Authentication	Physically unclonable functions (PUFs)	High speed	Additional implementation challenges
	Message authentication codes	Verification of sender	Computation overhead
Nonrepudiation	Digital signatures	Link message to sender	Difficult in pseudonymous systems
Identity privacy	Pseudonym	Disguise true identity	Vulnerable to pattern analysis
	Attribute-based credentials	Restrict access to information based on shared secrets	Require shared secrets with all desired services
Information privacy	Differential privacy	Limit privacy exposure of any single data record	True user-level privacy still chal- lenging
	Public-key cryptography	Integratable with hardware	Computationally intensive
Location privacy	Location cloaking	Personalized privacy	Requires additional infrastructure
Usage privacy	Differential privacy	Limit privacy exposure of any single data record	Recurrent/time-series data challenging to keep private

Source: Munir and Mohanty 2019, CE Magazine Jan 2019

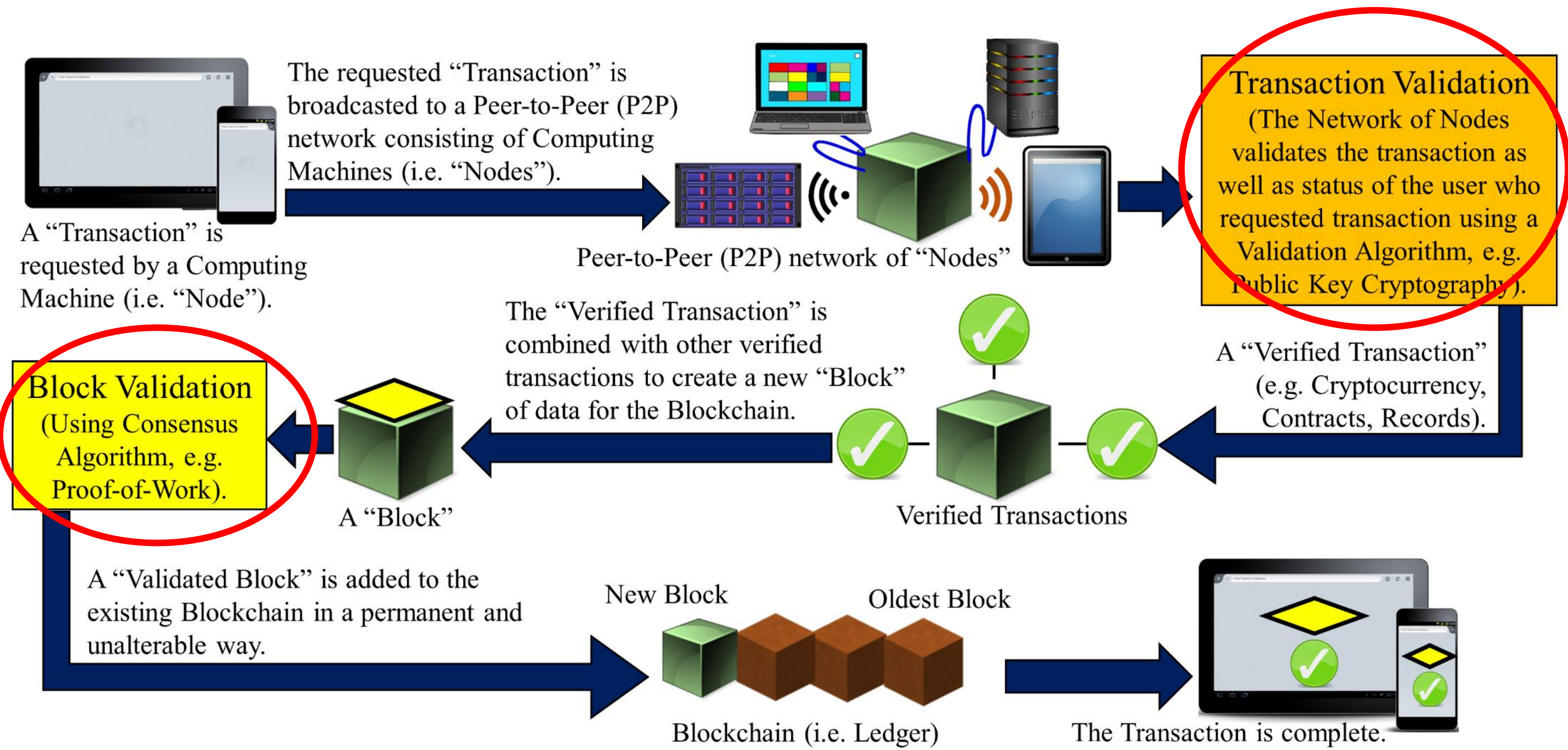
Blockchain - Challenges



- 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.

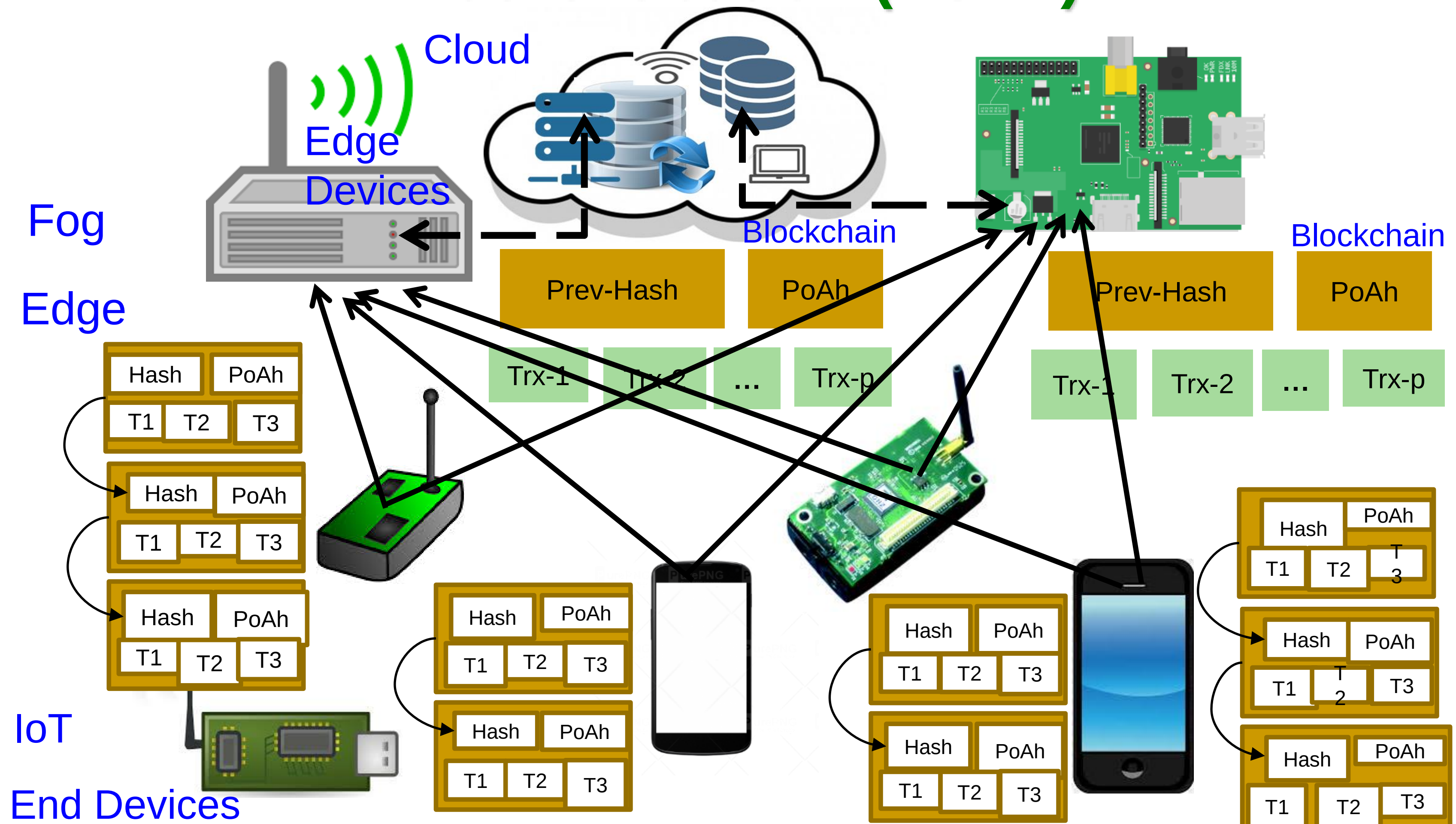
Source: D. Puthal, N. Malik, S. P. Mohanty, E. Kougianos, and G. Das, “Everything you Wanted to Know about the Blockchain”, *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 4, July 2018, pp. 06--14.

Blockchain Technology



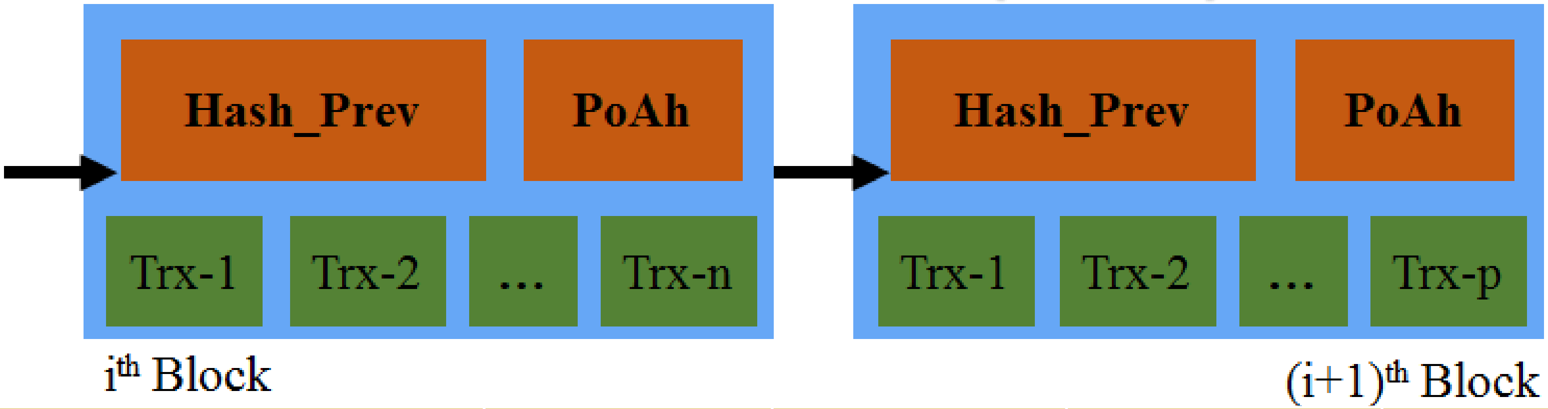
Source: D. Puthal, N. Malik, S. P. Mohanty, E. Kougianos, and G. Das, "Everything you Wanted to Know about the Blockchain", *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 4, July 2018, pp. 06--14.

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



Source: D. Puthal and S. P. Mohanty, "Proof of Authentication: IoT-Friendly Blockchains", *IEEE Potentials Magazine*, Volume 38, Issue 1, January 2019, pp. 26--29.

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**

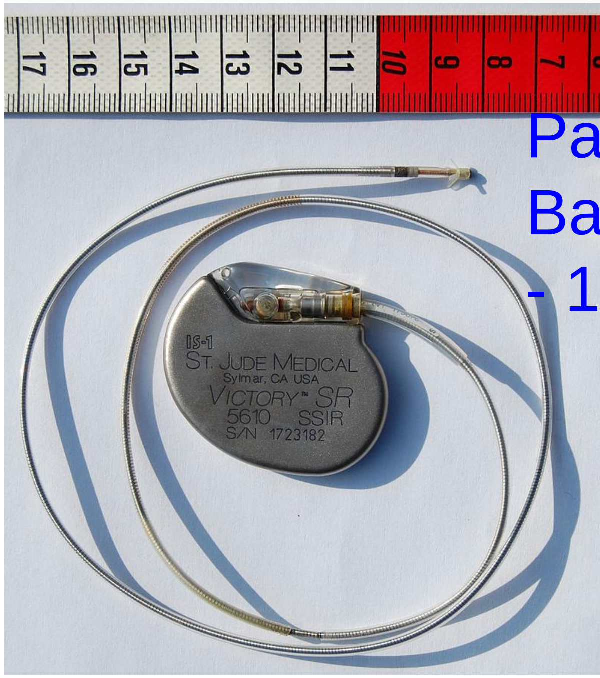
Source: D. Puthal, S. P. Mohanty, P. Nanda, E. Kougianos, and G. Das, "Proof-of-Authentication for Scalable Blockchain in Resource-Constrained Distributed Systems", in Proc. 37th IEEE International Conference on Consumer Electronics (ICCE), 2019.

Implanted Medical Devices - Attacks

- The vulnerabilities affect implantable cardiac devices and the external equipment used to communicate with them.
- The devices emit RF signals that can be detected up to several meters from the body.
- A malicious individual nearby could conceivably hack into the signal to jam it, alter it, or snoop on it.

Source: Emily Waltz, Can "Internet-of-Body" Thwart Cyber Attacks on Implanted Medical Devices?, IEEE Spectrum, 28 Mar 2019, https://spectrum.ieee.org/the-human-os/biomedical/devices/thwart-cyber-attacks-on-implanted-medical-devices.amp.html.

IoMT Security - Energy Constrained



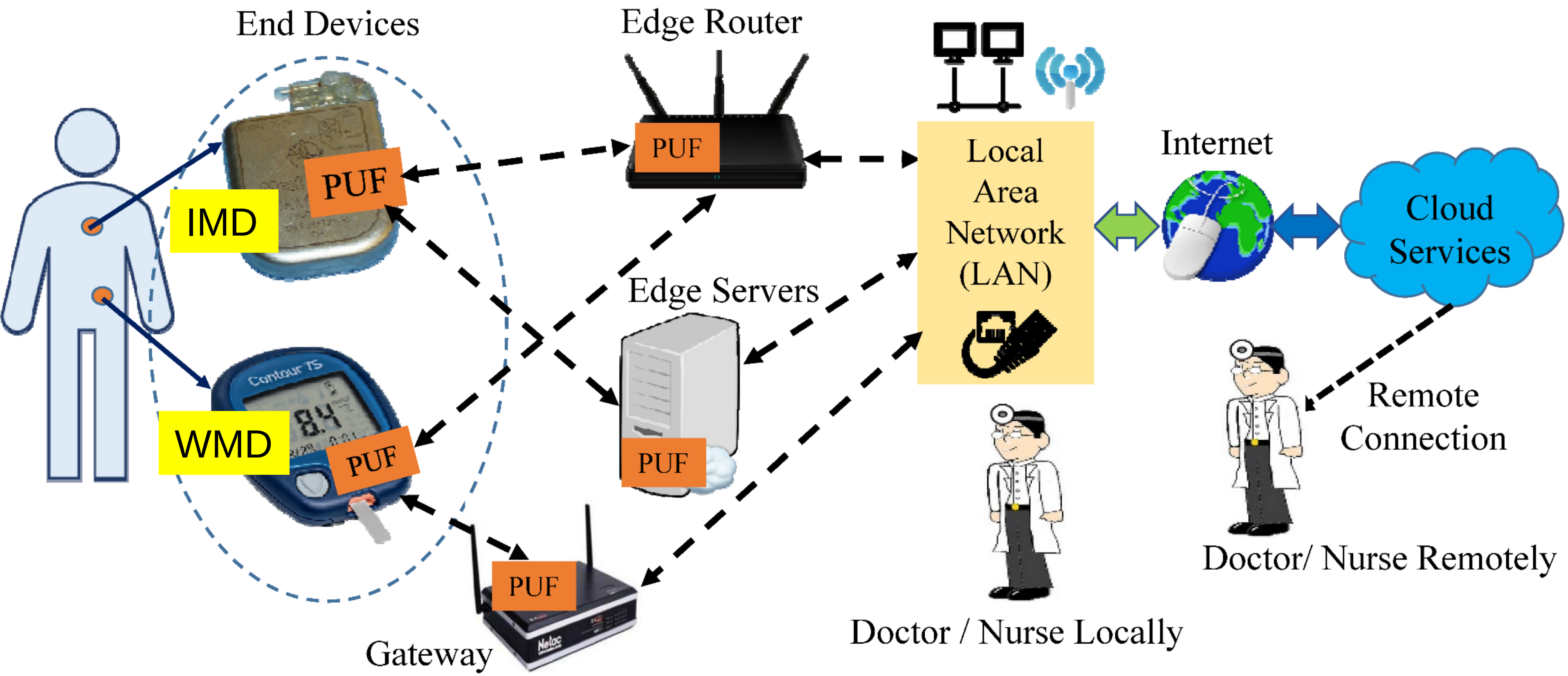
Pacemaker
Battery Life
- 10 years

Neurostimulator
Battery Life
- 8 years

- Implantable Medical Devices (IMDs) have integrated battery to provide energy to all their functions → Limited Battery Life depending on functions
- Higher battery/energy usage → Lower IMD lifetime
- Battery/IMD replacement → Needs surgical risky procedures

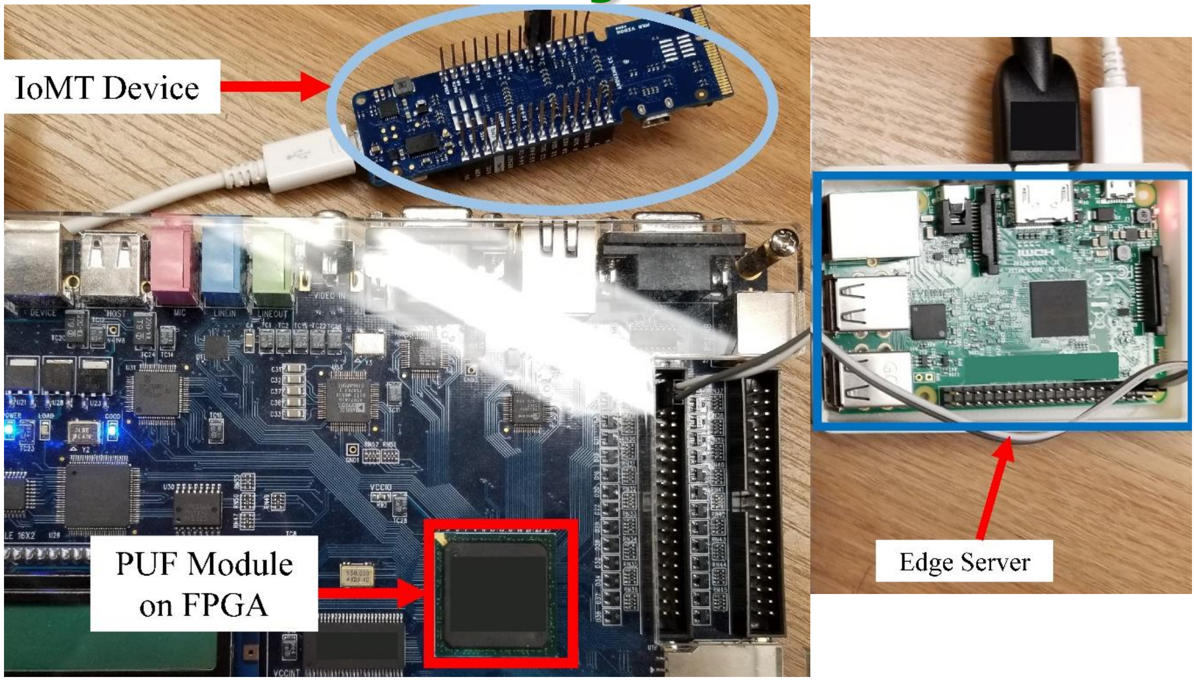
Source: Carmen Camara, PedroPeris-Lopeza, and Juan E.Tapiadora, "ecurity and privacy issues in implantable medical devices: A comprehensive survey", Elsevier Journal of Biomedical Informatics, Volume 55, June 2015, Pages 272-289.

IoMT Security - PUF based Device Authentication



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 XX, Issue YY, ZZ 2019, pp. Accepted on 28 June 2019, DOI: 10.1109/TCE.2019.2926192.

IoMT Security - PUF based Device Authentication



Average Power Overhead – ~ 200 μW

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: 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 XX, Issue YY, ZZ 2019, pp. Accepted on 28 June 2019, DOI: 10.1109/TCE.2019.2926192.

Smart Car Security - Latency Constrained

Protecting Communications
Particularly any Modems for In-vehicle Infotainment (IVI) or in On-board Diagnostics (OBD-II)

Over The Air (OTA) Management
From the Cloud to Each Car

Cars can have 100 Electronic Control Units (ECUs) and 100 million lines of code, each from different vendors – Massive security issues.

Protecting Each Module
Sensors, Actuators, and Anything with an Microcontroller Unit (MCU)

Mitigating Advanced Threats
Analytics in the Car and in the Cloud

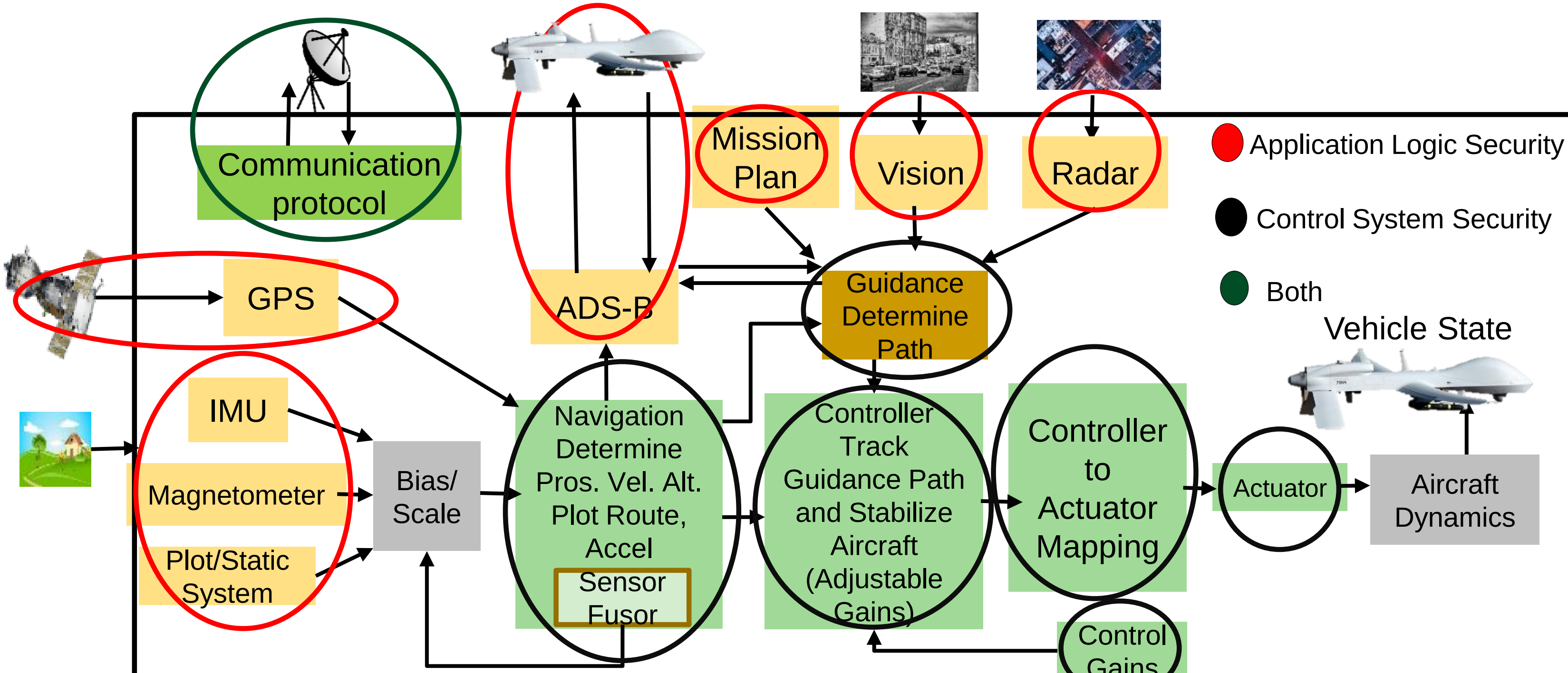
- Connected cars require latency of ms to communicate and avoid impending crash:
  - Faster connection
  - Low latency
  - Energy efficiency

Security Mechanism Affects:
- Latency
- Mileage
- Battery Life

Car Security – Latency Constraints

Source: http://www.symantec.com/content/en/us/enterprise/white_papers/public-building-security-into-cars-20150805.pdf

UAV Security - Energy & Latency Constrained



Source: http://www.secmation.com/control-design/

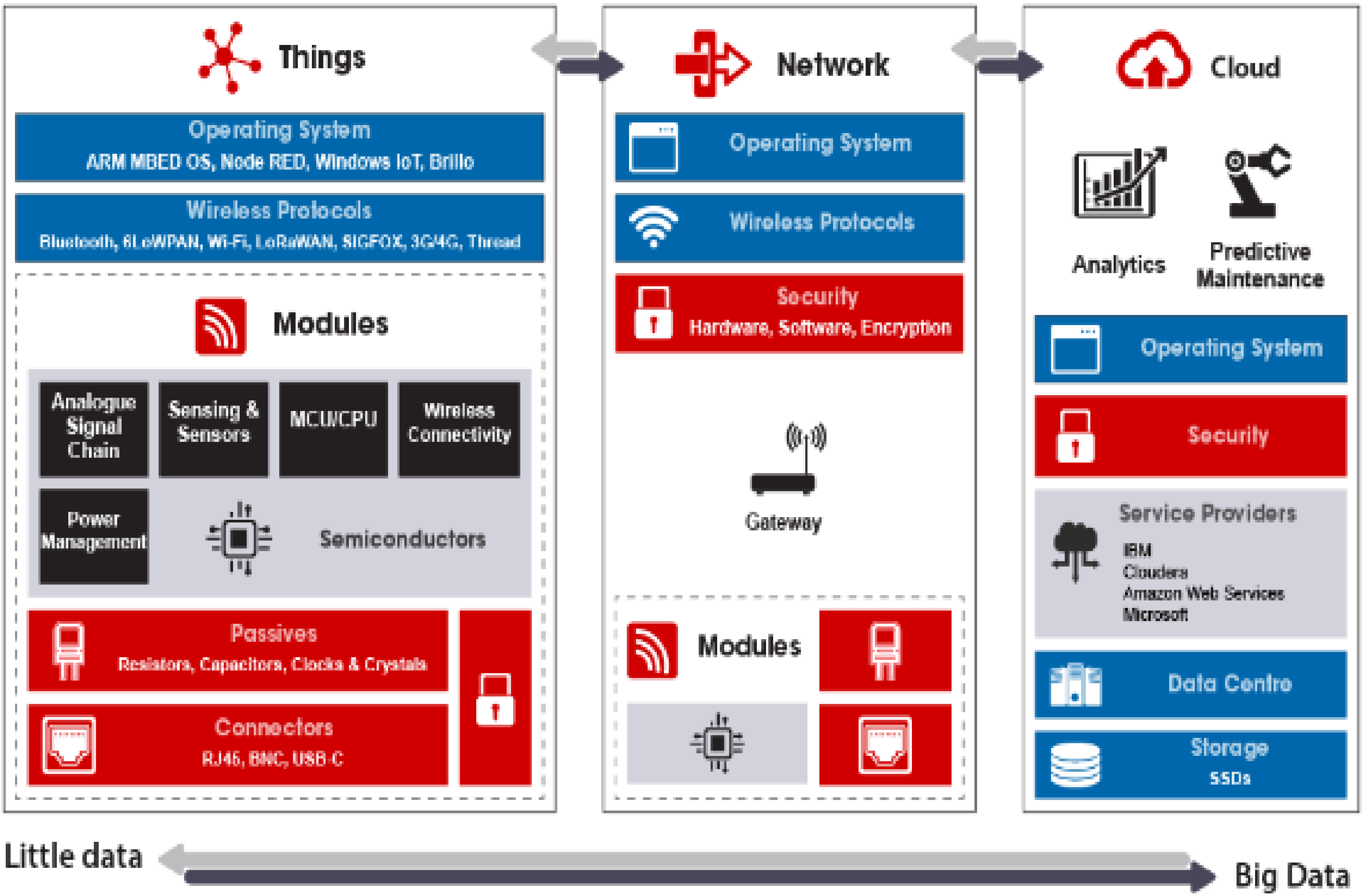
Security Mechanisms Affect:

Battery Life | Latency | Weight | Aerodynamics

UAV Security – Energy and Latency Constraints

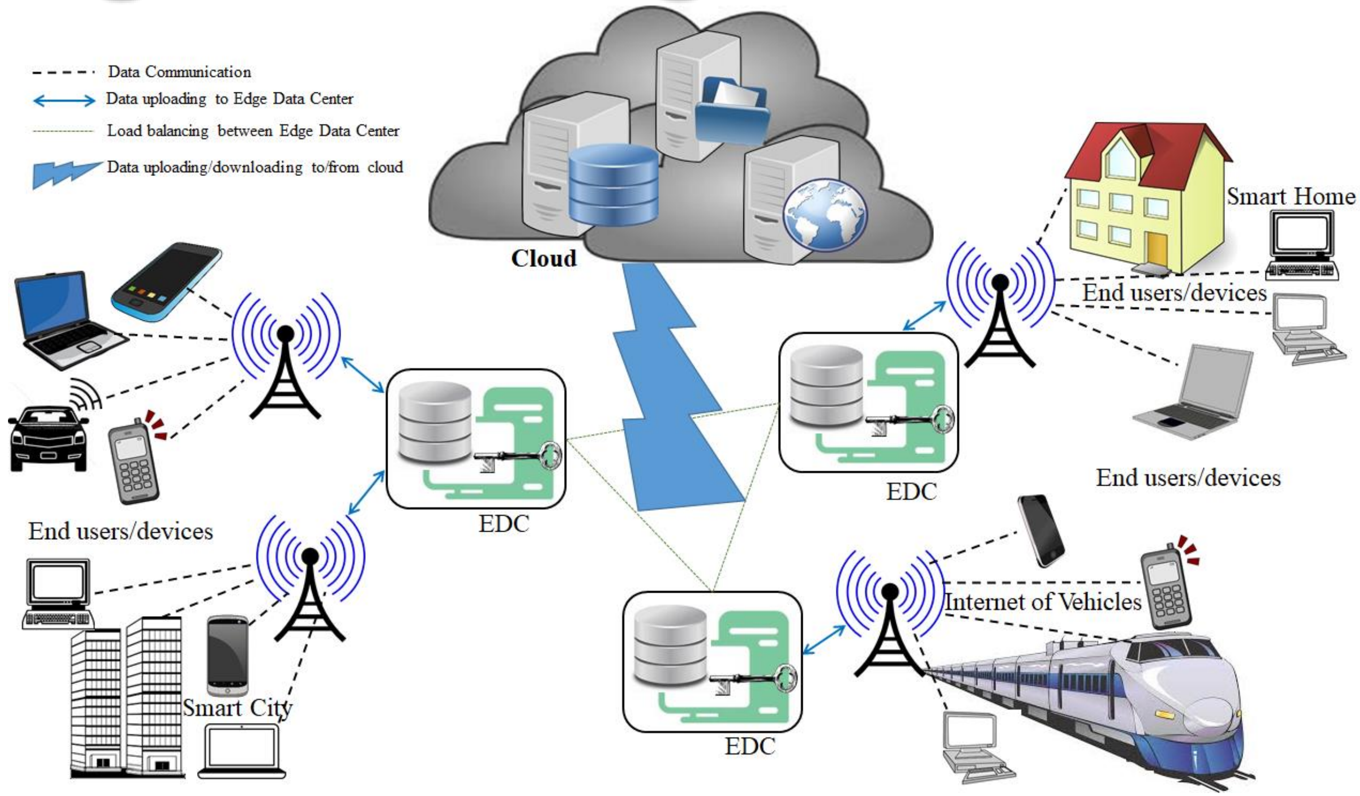
Source: http://politicalblindspot.com/u-s-drone-hacked-and-hijacked-with-ease/

Bigdata in IoT and Smart Cities



Source: M. Elbeheiry, “Internet of Things (IoT) Architecture”, Article, March 12, 2017.

Big Data - Edge Datacenter



End Devices
Sensors, Mobile phone etc.

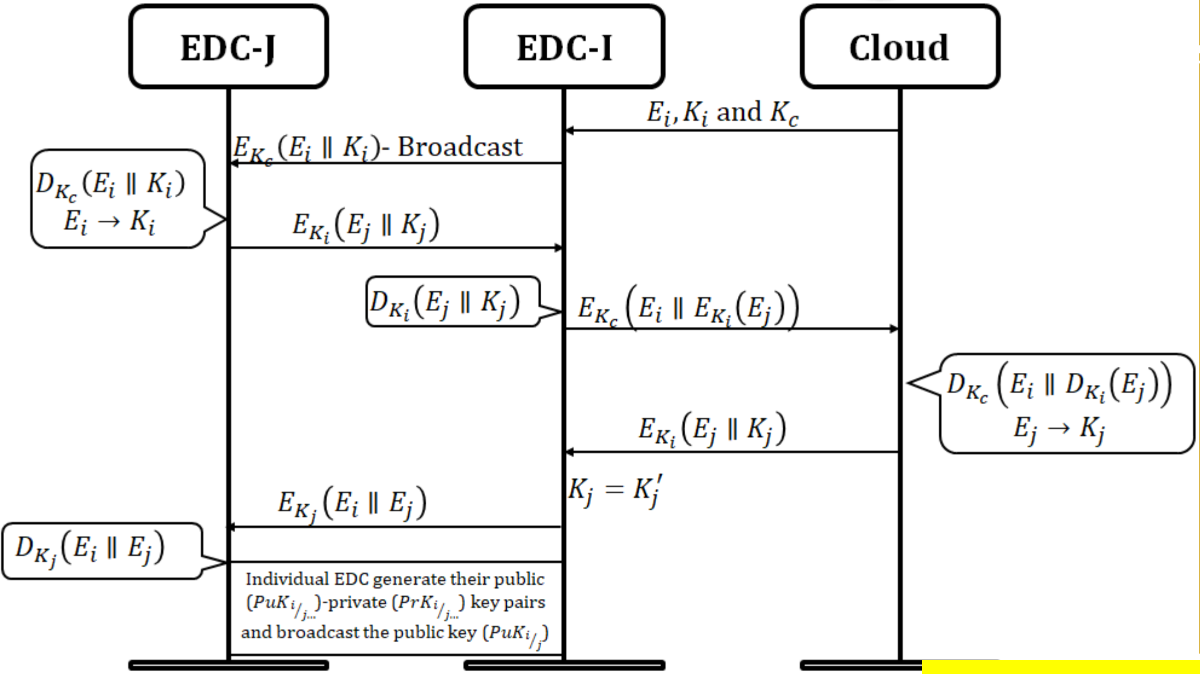
Edge Devices
Router, base stations etc.

Edge Data Center
Data center with limited storage and processing capabilities

Cloud
Data center with enough storage and processing capabilities

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.

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.

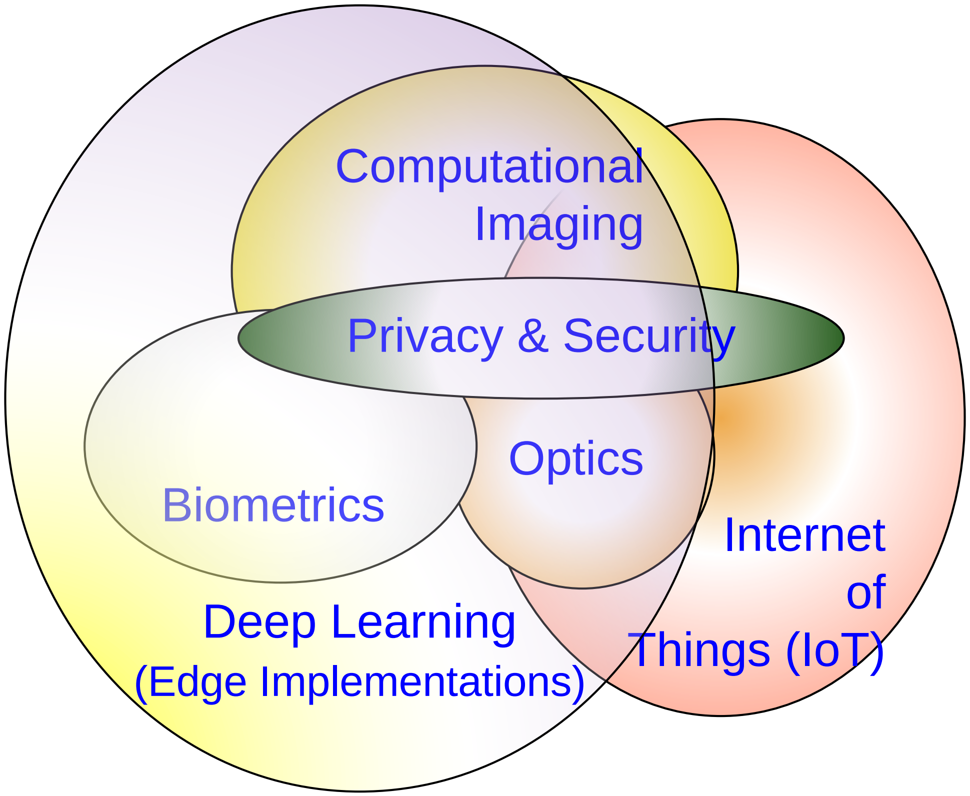
Secure edge datacenter –
- Balances load among the EDCs
- Authenticates EDCs

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

Source: 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.

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.

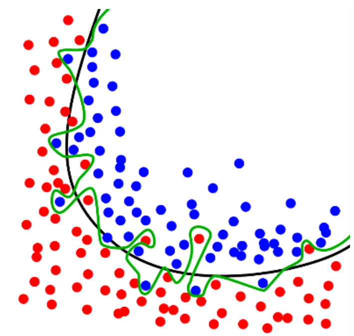


Source: Corcoran Keynote 2018

ML Modeling Issues

Machine Learning Issues

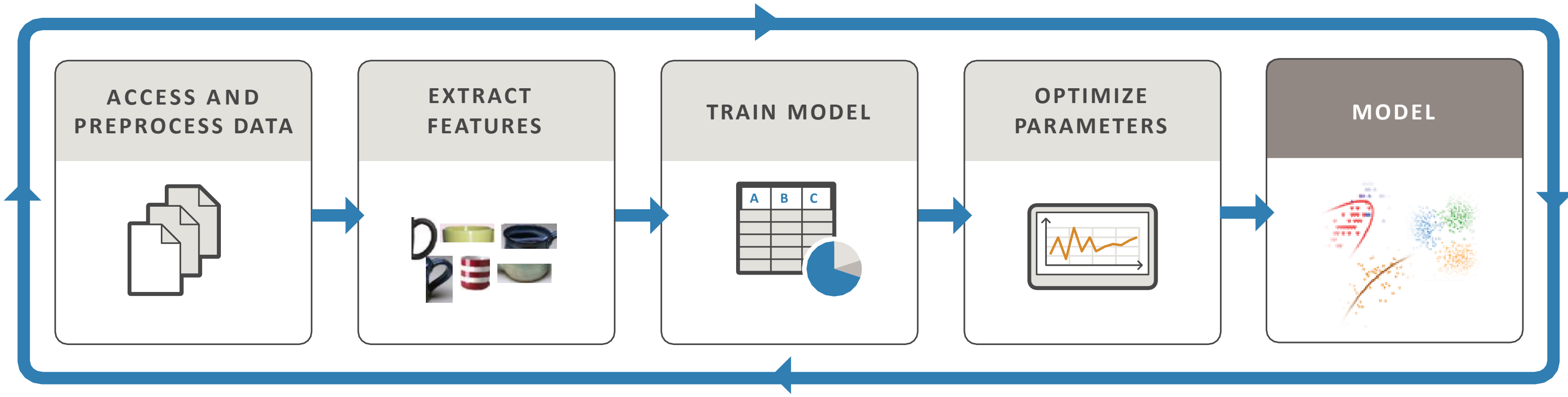
- High Energy Requirements
- High Computational Resource Requirements
- Large Amount of Data Requirements
- Underfitting/Overfitting Issue
- Class Imbalance Issue
- Fake Data Issue



Source: Mohanty ISCT 2019 Keynote

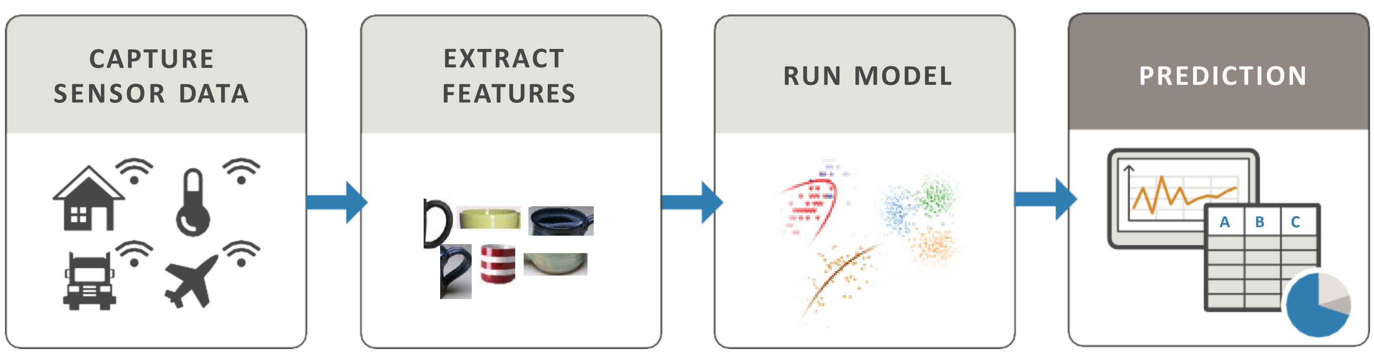
Deep Neural Network (DNN) - Resource and Energy Costs

TRAIN: Iterate until you achieve satisfactory performance.



Needs Significant:
- ➢ Resource
- ➢ Energy

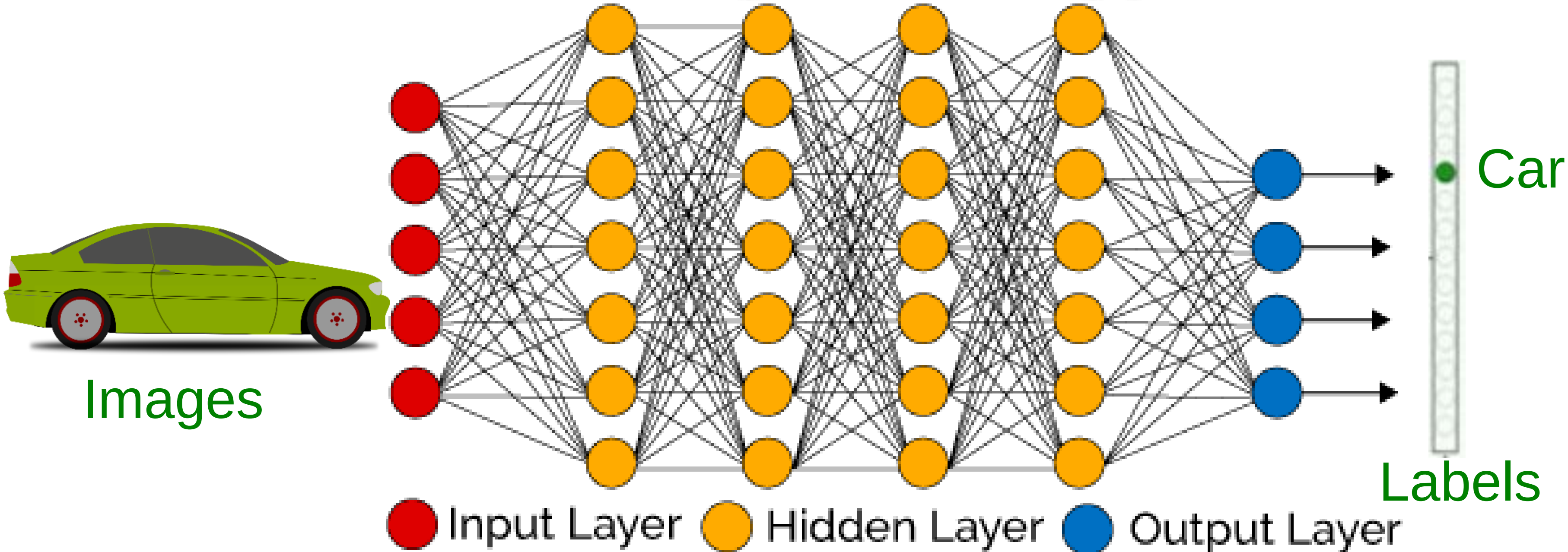
PREDICT: Integrate trained models into applications.



Needs:
- ➢ Resource
- ➢ Energy

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

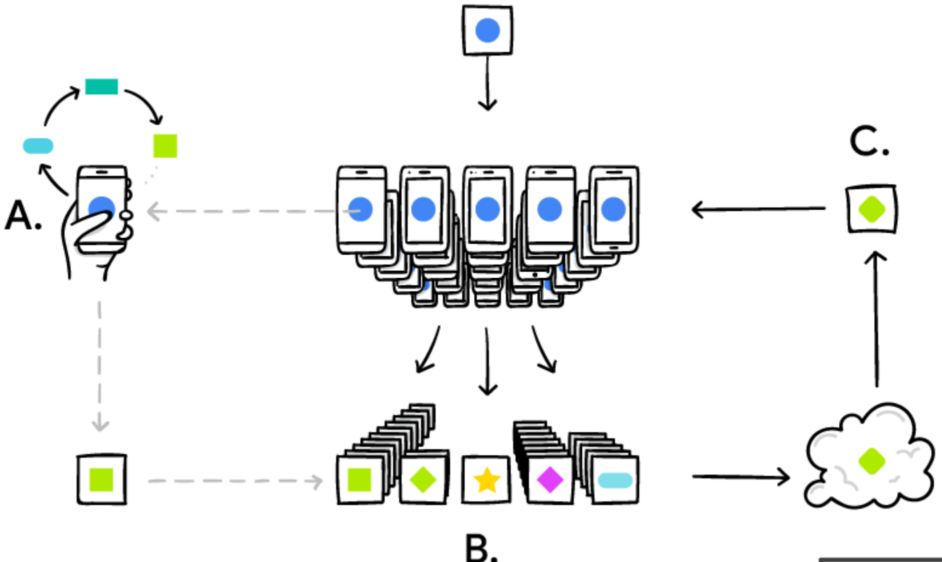
DNN Training - Energy Issue



- DNN considers many training parameters, such as the size, the learning rate, and initial weights.
- High computational resource and time: For sweeping through the parameter space for optimal parameters.
- DNN needs: Multicore processors and batch processing.
- DNN training happens mostly in cloud not at edge or fog.

Source: Mohanty iSES 2018 Keynote

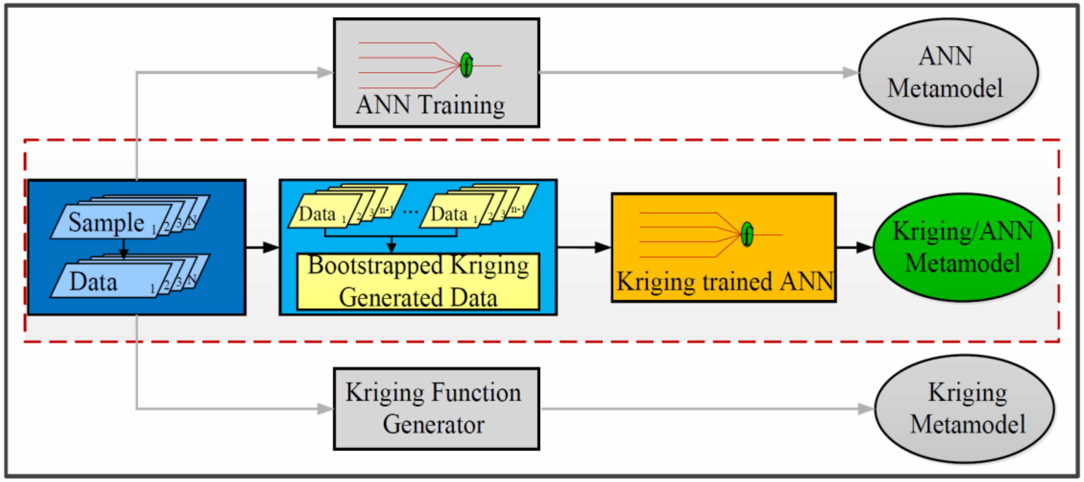
Enhancing DNN Training/Learning



Source: https://ai.googleblog.com/2017/04/federated-learning-collaborative.html

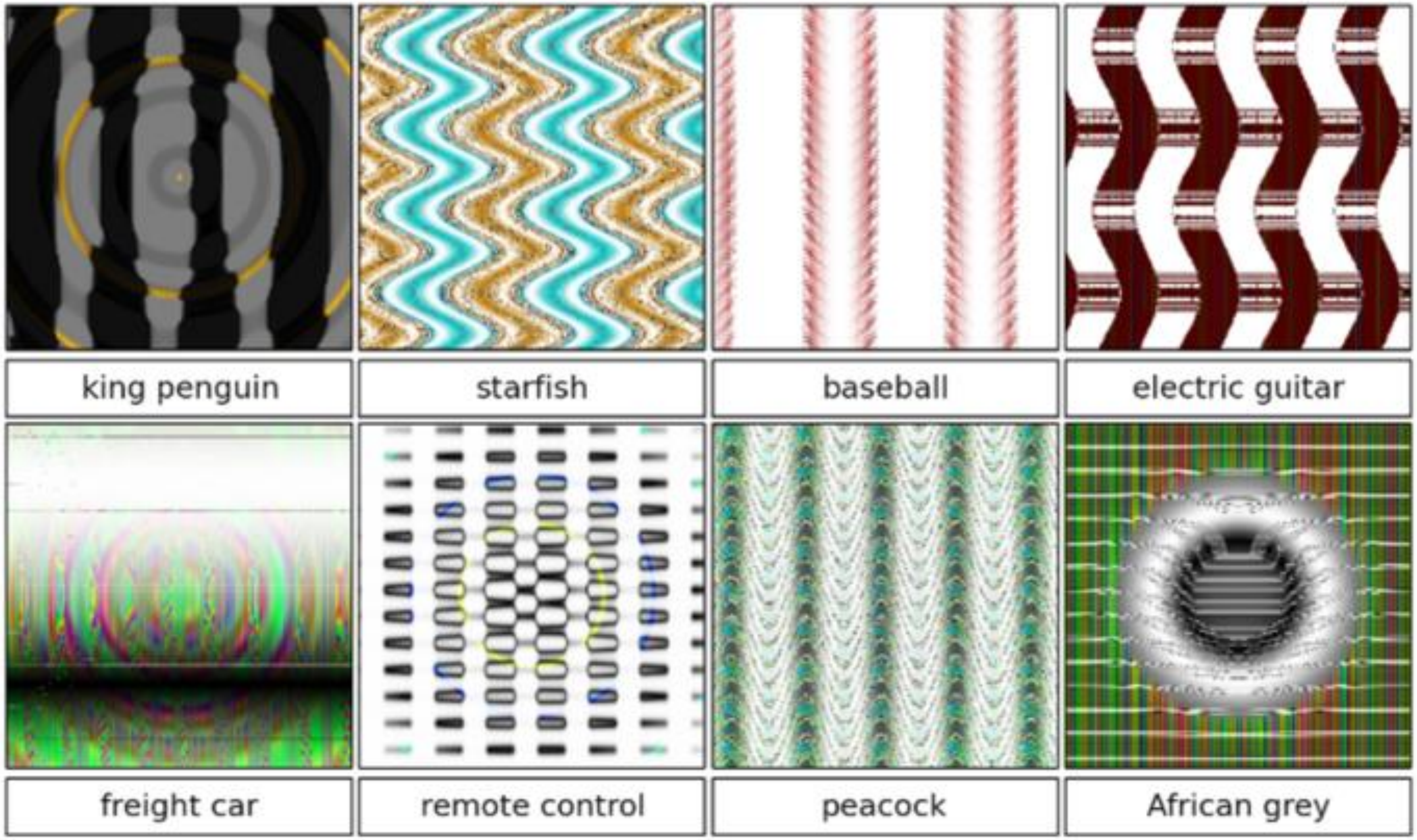
Federated Learning (Google) – A type of Distributed Learning

Hierarchical Learning



Source: O. Okobiah, S. P. Mohanty, and E. Kougianos, "Kriging Bootstrapped Neural Network Training for Fast and Accurate Process Variation Analysis", in Proceedings of the 15th ISQED, 2014, pp. 365--372.

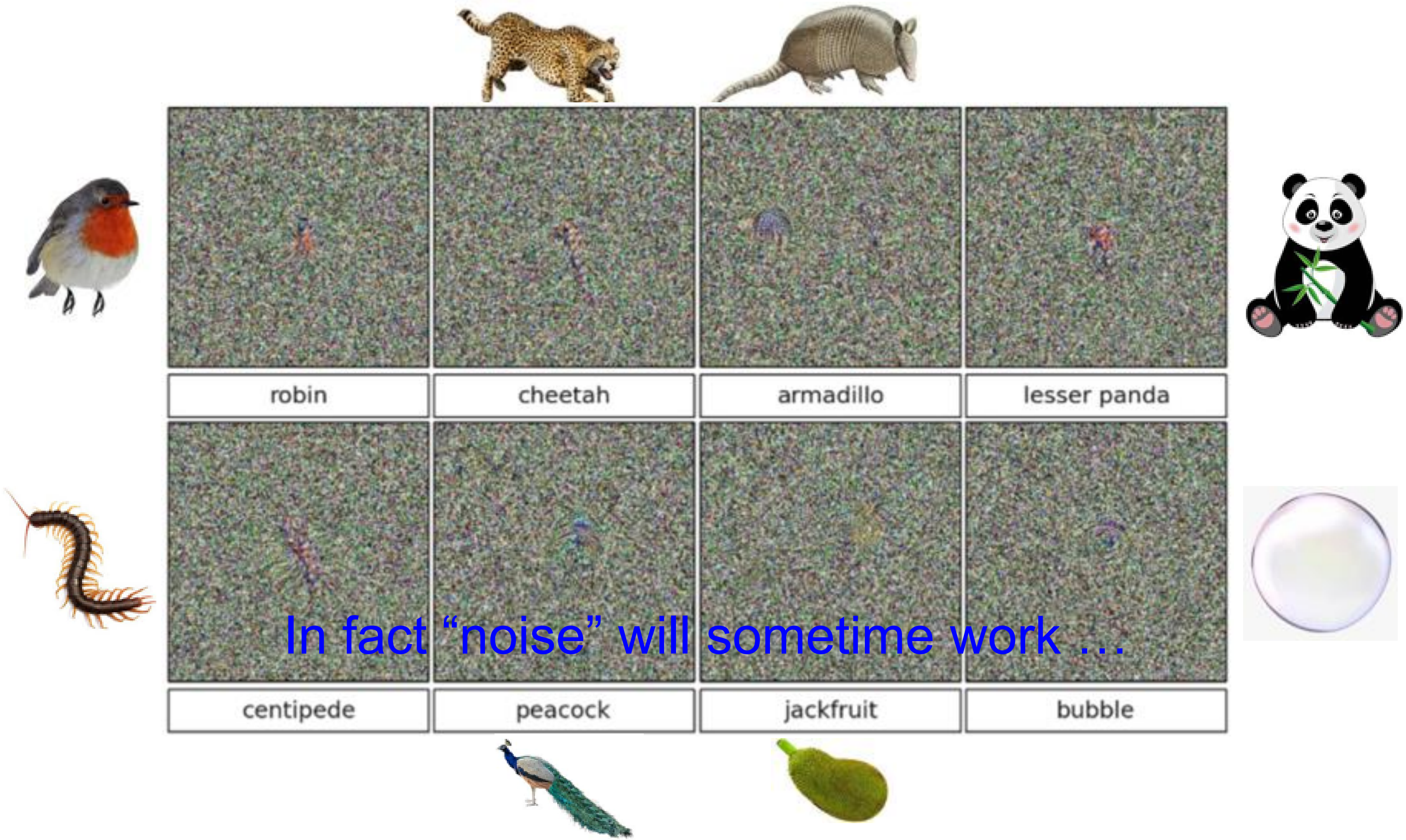
DNNs are not Always Smart



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

Source: A. Nguyen, J. Yosinski and J. Clune, "Deep neural networks are easily fooled: High confidence predictions for unrecognizable images," in Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2015, pp. 427-436.

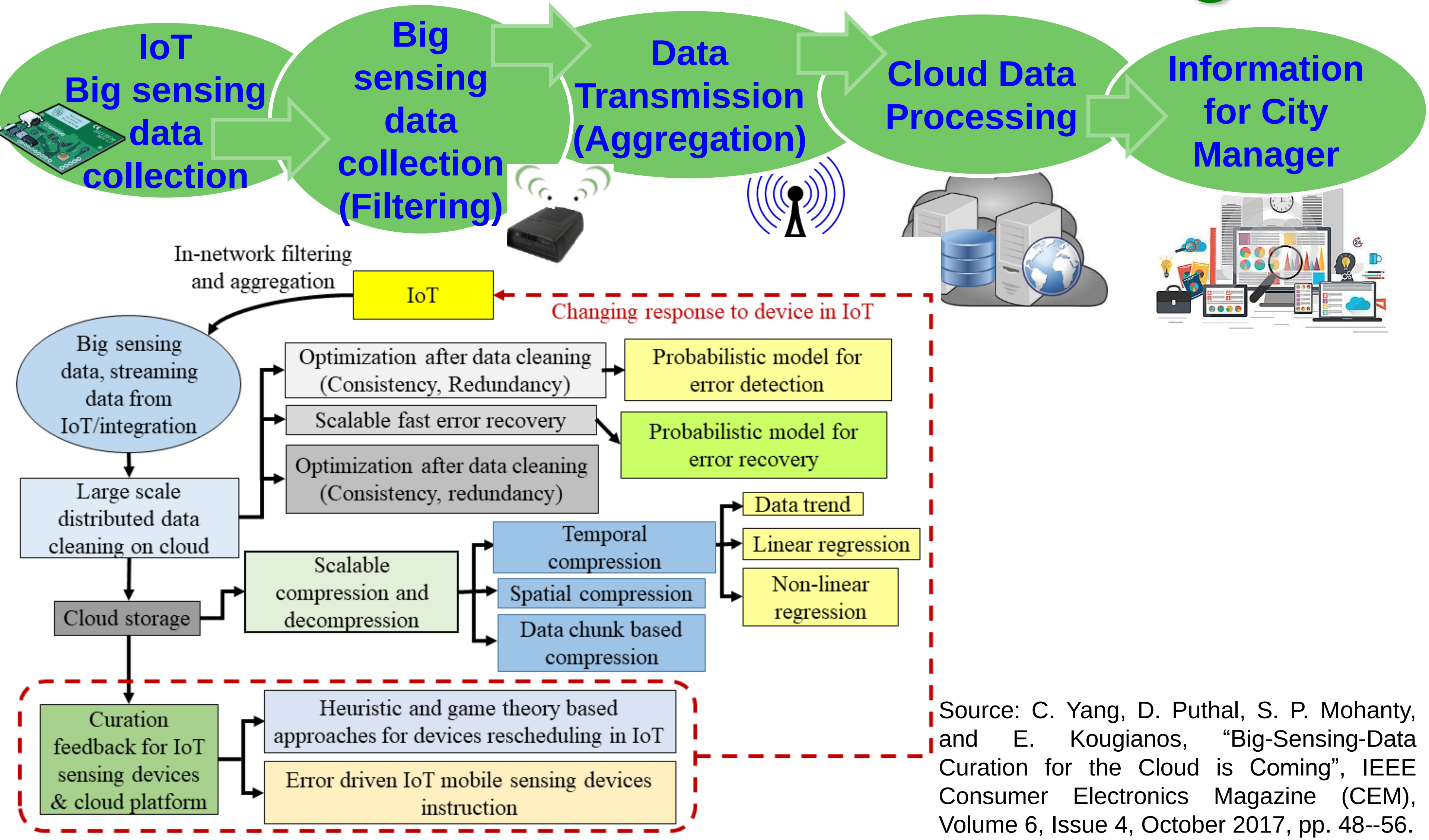
DNNs are not Always Smart



In fact “noise” will sometime work …

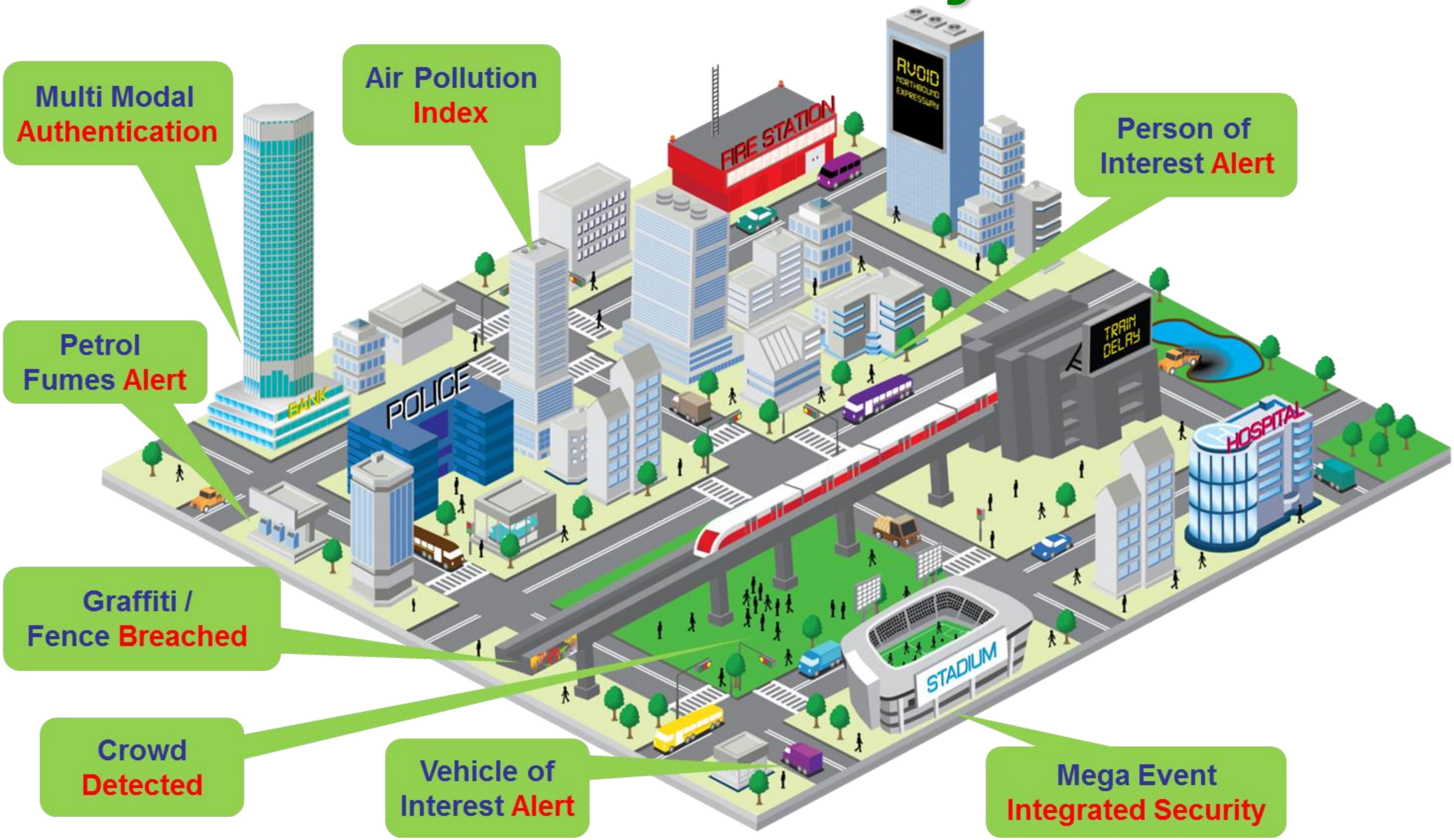
Source: A. Nguyen, J. Yosinski and J. Clune, "Deep neural networks are easily fooled: High confidence predictions for unrecognizable images," in Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2015, pp. 427-436.

Data Curation: Cloud Vs Edge



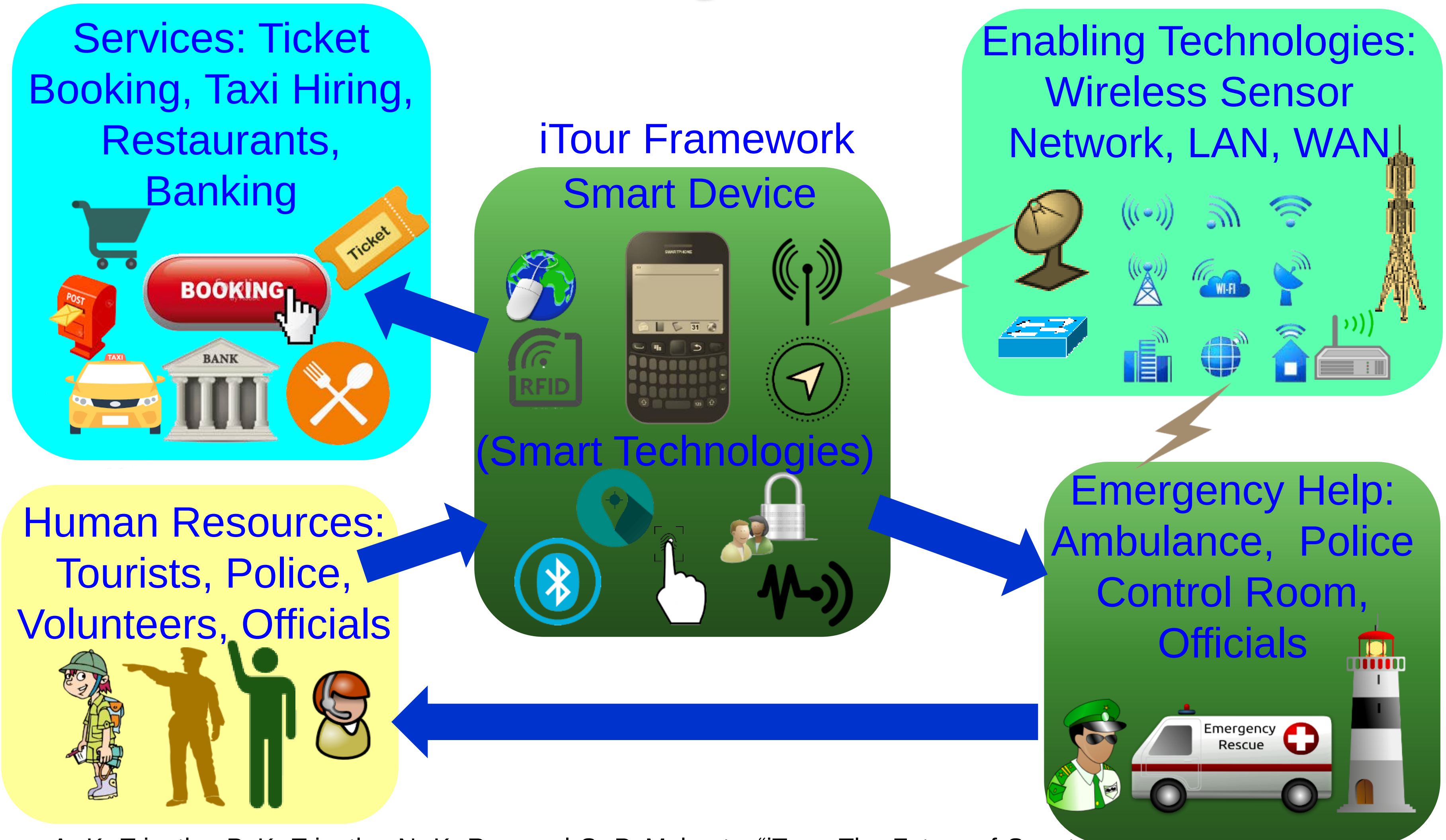
Source: C. Yang, D. Puthal, S. P. Mohanty, and E. Kougianos, "Big-Sensing-Data Curation for the Cloud is Coming", IEEE Consumer Electronics Magazine (CEM), Volume 6, Issue 4, October 2017, pp. 48--56.

Public Safety



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

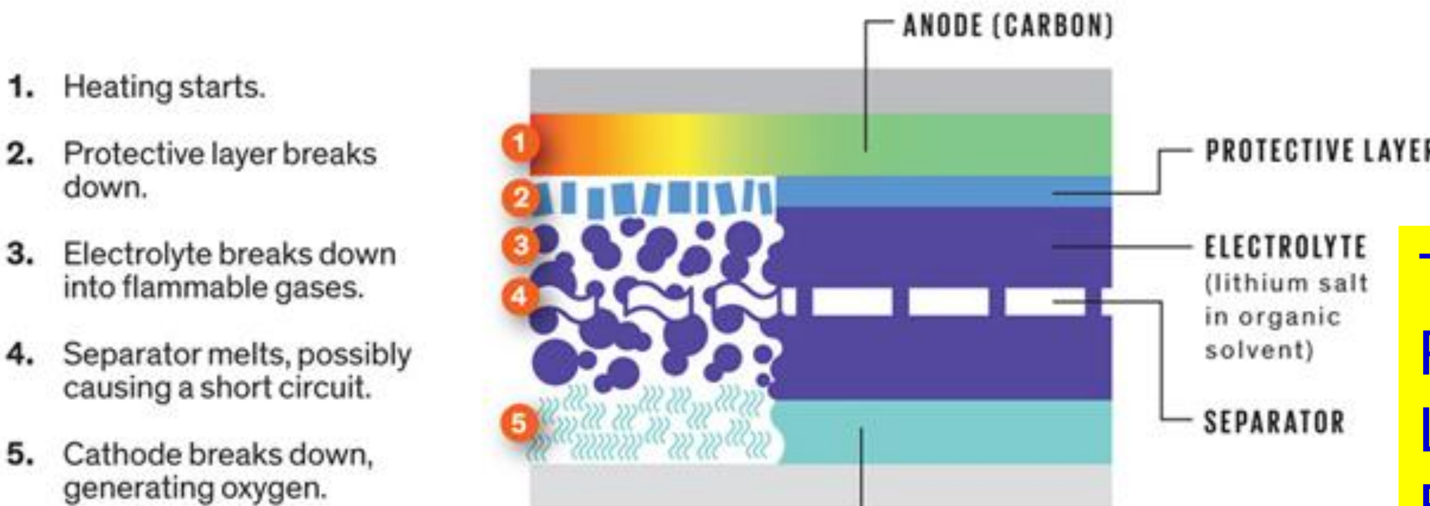
iTour: Safety Framework



Source: A. K. Tripathy, P. K. Tripathy, N. K. Ray, and S. P. Mohanty, "iTour: The Future of Smart Tourism", *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 3, May 2018, pp. 32--37.

Safety of Electronics

Smartphone Battery

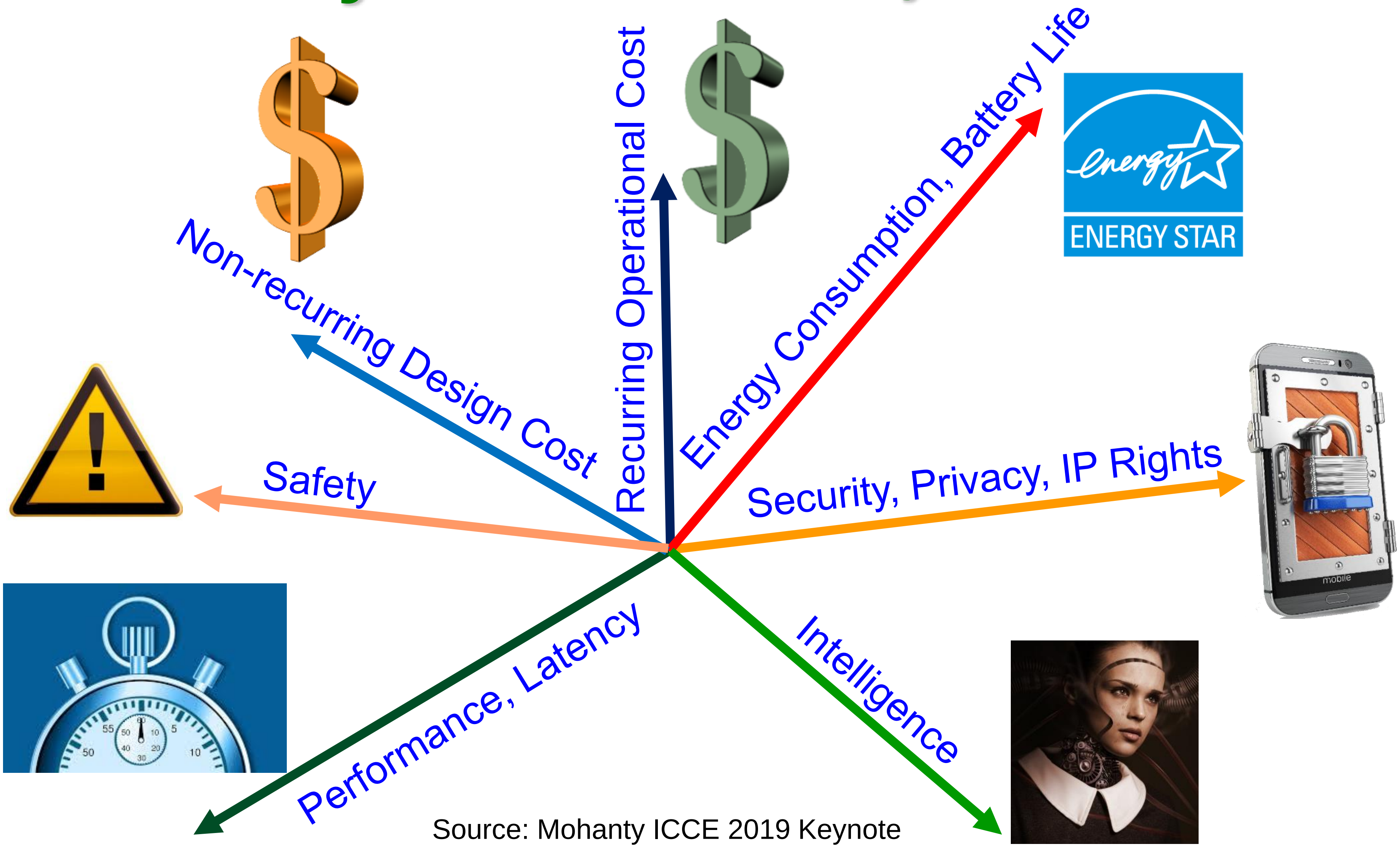


Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

Thermal Runaway in a Lithium-Ion Battery

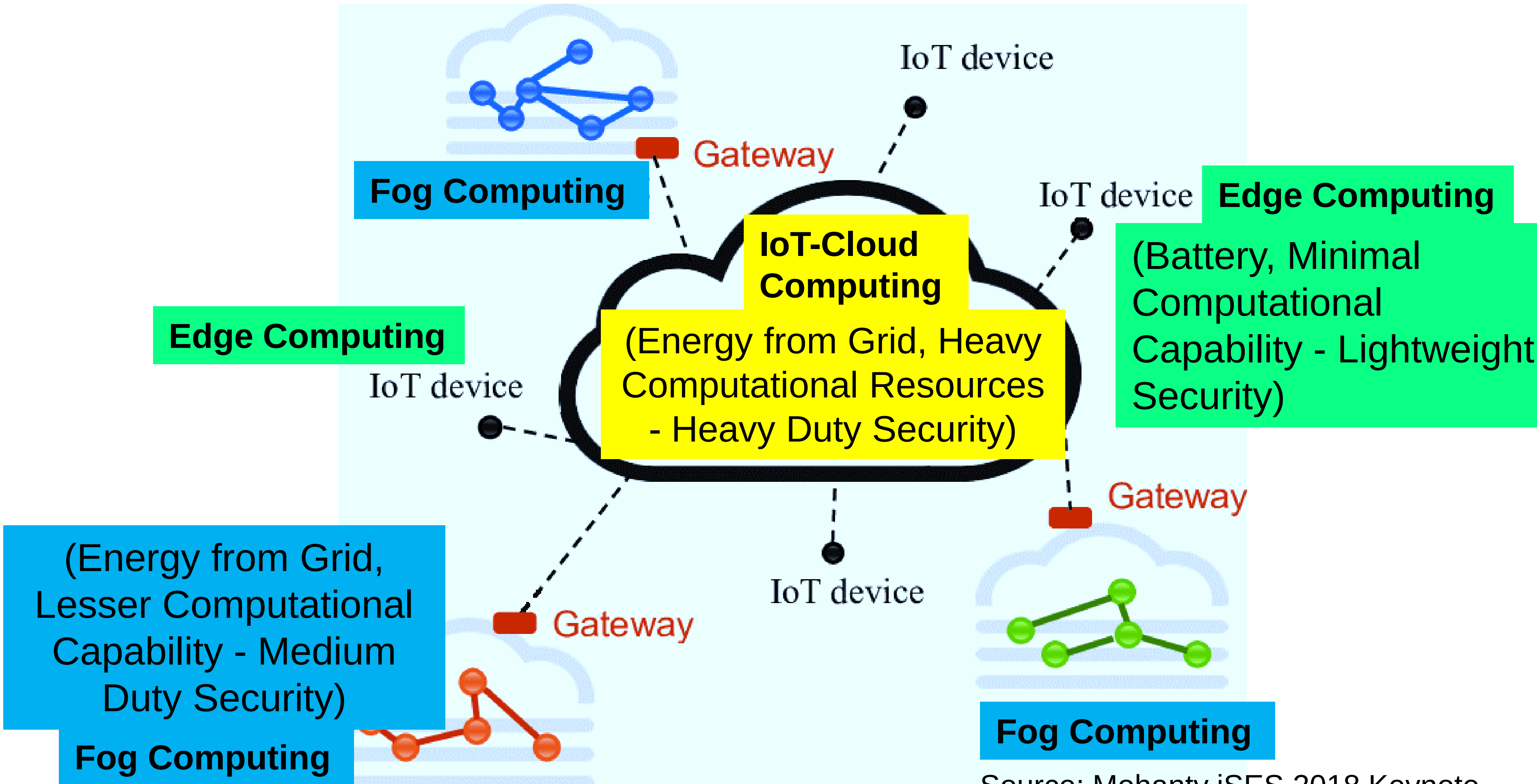
Source: Mohanty ZINC 2018 Keynote

CE/IoT System - Multi-Objective Tradeoffs



Source: Mohanty ICCE 2019 Keynote

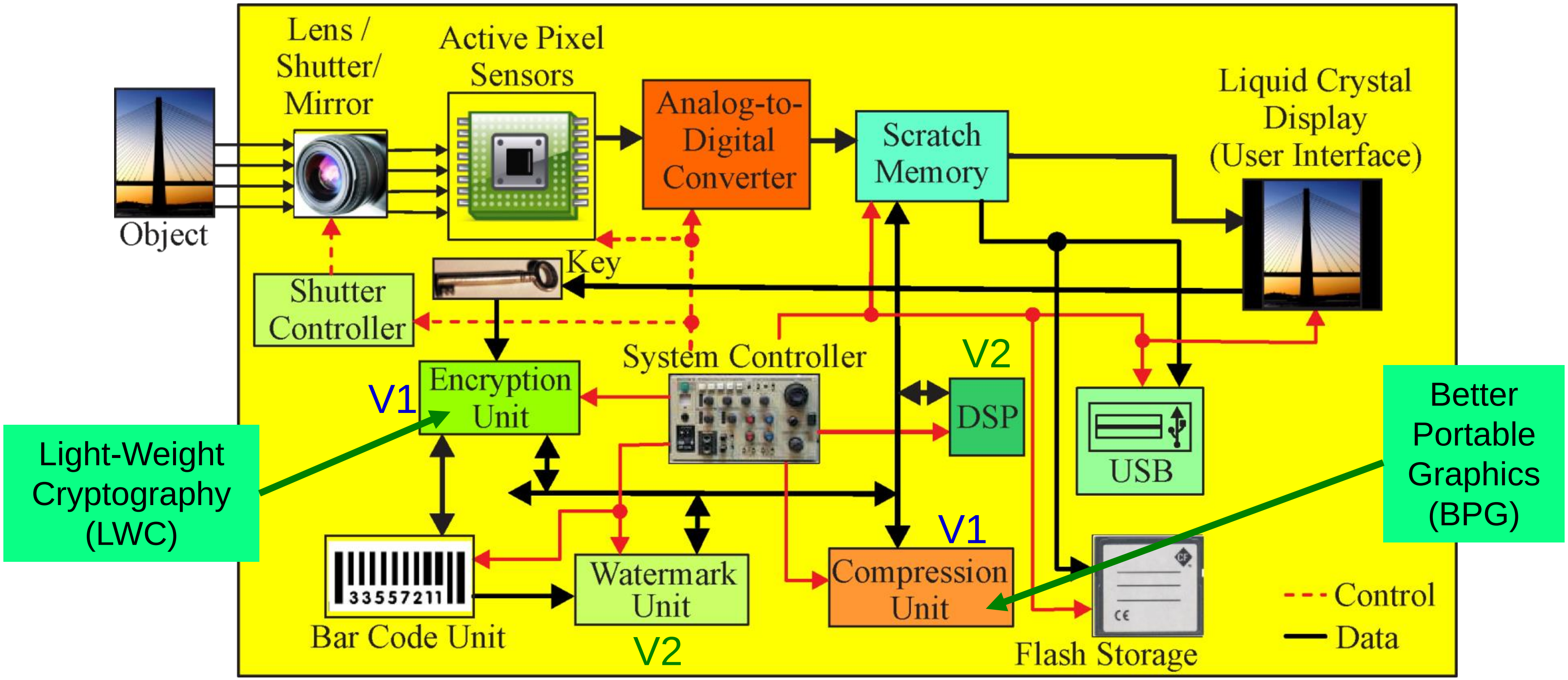
IoT Vs Fog Vs Edge Computing –
Energy, Security, Response Tradeoffs



Source: Mohanty iSES 2018 Keynote

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

ESR-Smart – End-Device Optimization



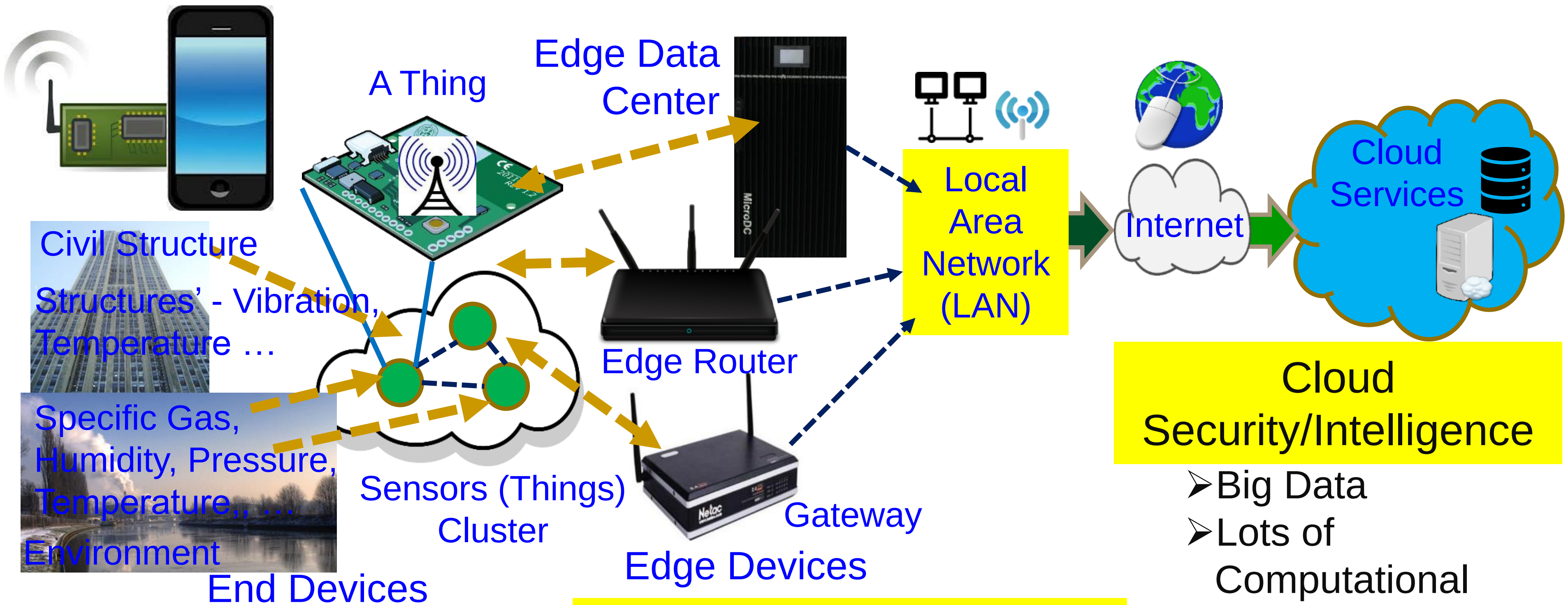
Include additional/alternative hardware/software components and uses DVFS like technology for energy and performance optimization.

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.

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

End, Edge Vs Cloud Security, Intelligence …



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

Source: Mohanty iSES 2018 Keynote

Initiatives

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

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

UN Initiative - United 4 Smart Sustainable Cities (U4SSC)

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

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/

Conclusions

Conclusions

- Smart cities is not a technological trend, rather it is a necessity.
- Consumer Technologies are building blocks of smart cities.
- 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

- Energy-efficiency at various levels of smart city: sensor, edge, communications, cloud
- System and Data Security methods
- System and Data Privacy methods
- Big data processing at: Edge, Cloud
- ML training time and resource requirement reduction
- Energy, Security, Response (ESR) tradeoffs at various levels of smart city

What is Smart?

- Ability to take decisions based on the data, circumstances, situations?

Intelligence Quotient (IQ) ?

- If Smart Electronics means Intelligence then can we measure its IQ?

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.