Internet of Things (IoT) - The State-of-Art

Faculty Development Program

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More Info: http://www.smohanty.org

Talk - Outline

- Motivations for IoT
- Selected Components of IoT
- Selected Applications of IoT
- Driving Technologies of IoT
- Challenges and Research in IoT
- IoT Design Flow
- Tools and Solutions for IoT
- Related Buzzwords of IoT
- Conclusions and Future Directions

Smart Cities - A Solution

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

"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

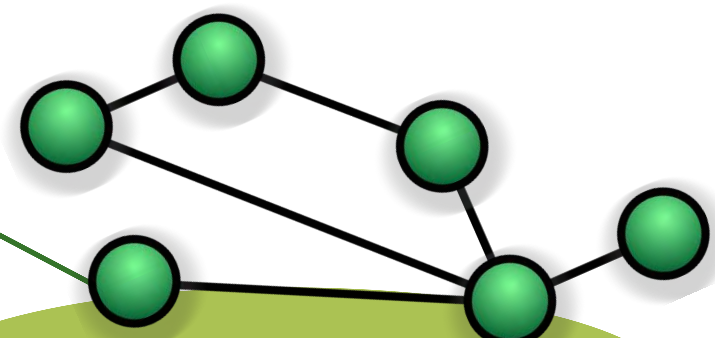
July 2016

Smart Cities - 3 Is

Instrumentation

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

Smart Cities

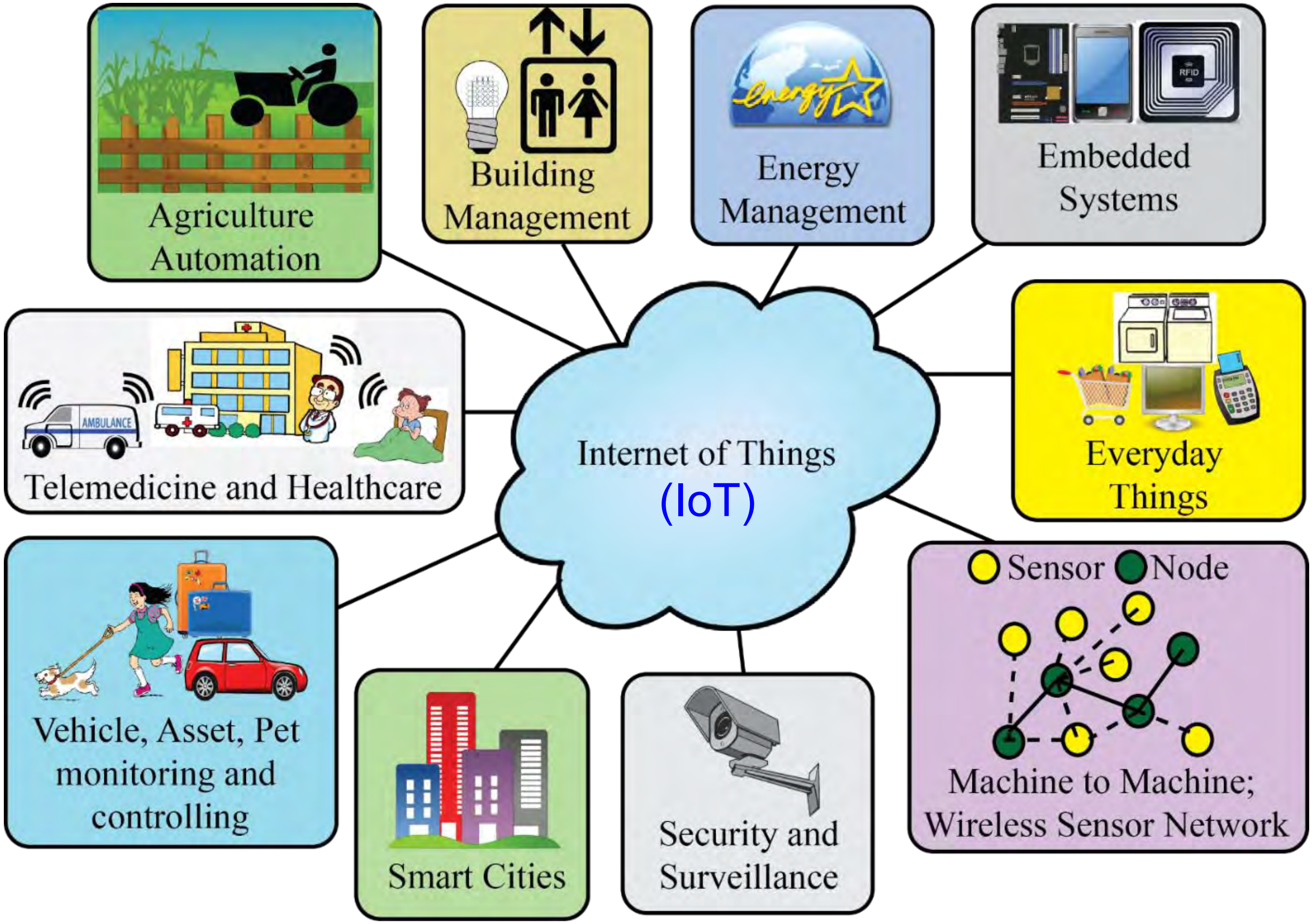


Intelligence

Interconnection

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

IoT is the Backbone Smart Cities



Source: Mohanty 2016, CE Magazine July 2016

Internet of Things (IoT) - History

Source: http://events.linuxfoundation.org/sites/events/files/slides/Design%20-%20End-to-End%20%20IoT%20Solution%20-%20Shivakumar%20Mathapathi.pdf

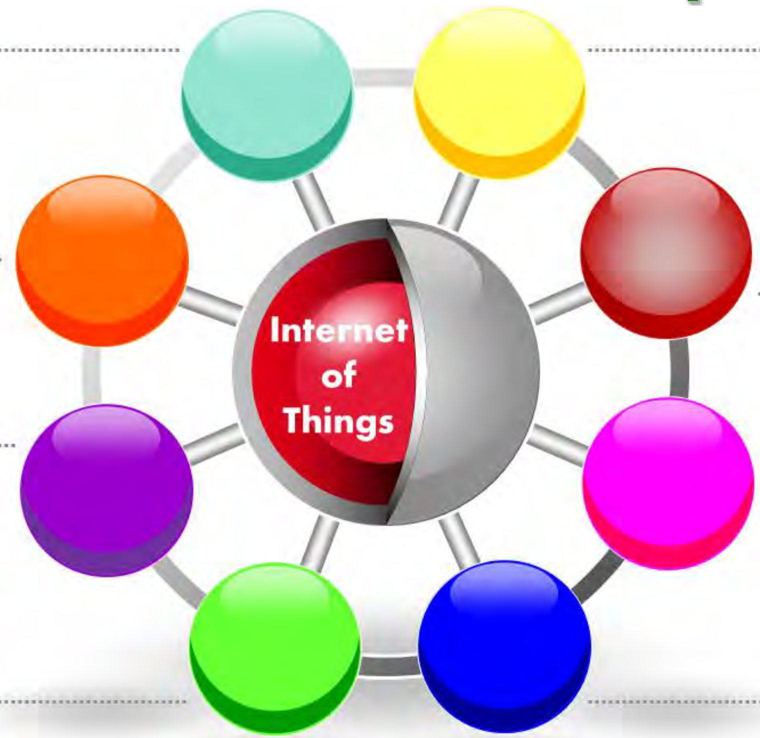
IoT – Definition - IoT European Research Cluster (IERC)

A *dynamic global network infrastructure*

with *self configuring capabilities*

based on *standard and interoperable communication protocols*

where *physical and virtual "things"*



have *identities, physical attributes, and virtual personalities*

and

use *intelligent interfaces*,

and are *seamlessly integrated*

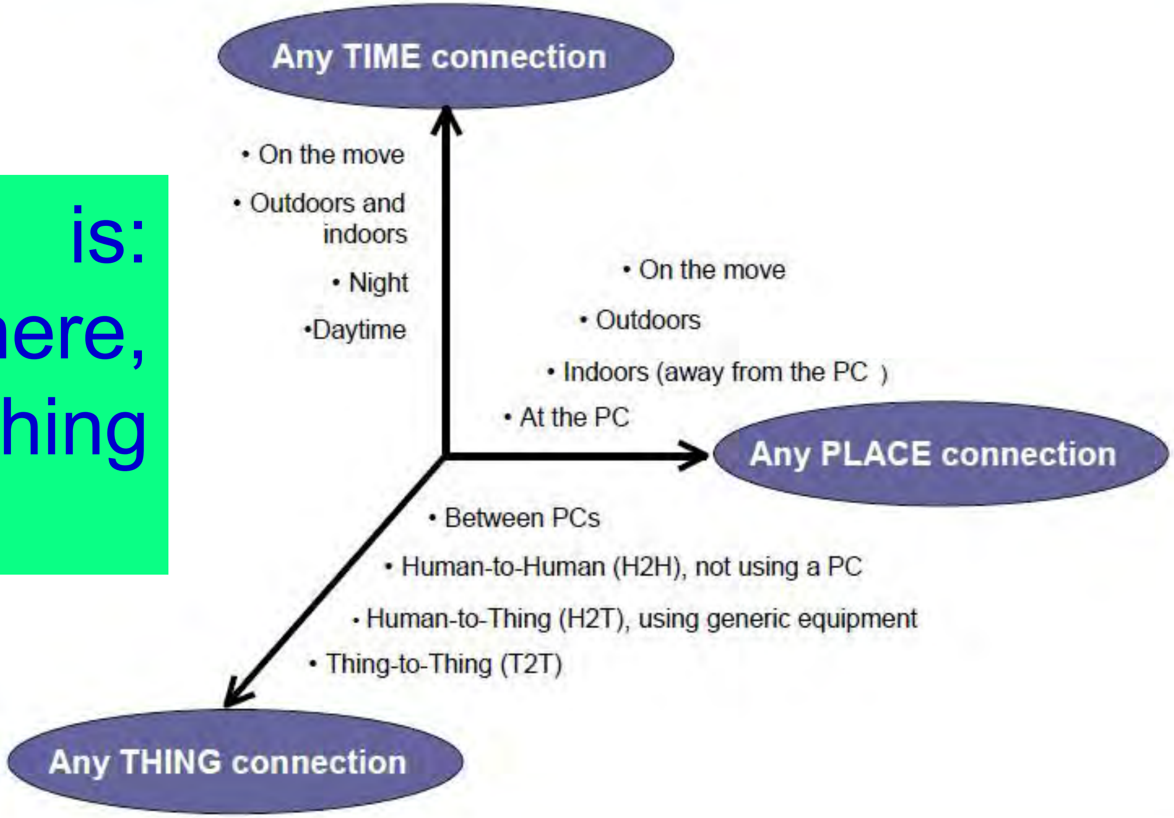
into *the information network.*

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

IEEE also provides a formal, comprehensive definition of IoT.

IoT – Definition - International Telecommunication Union (ITU)

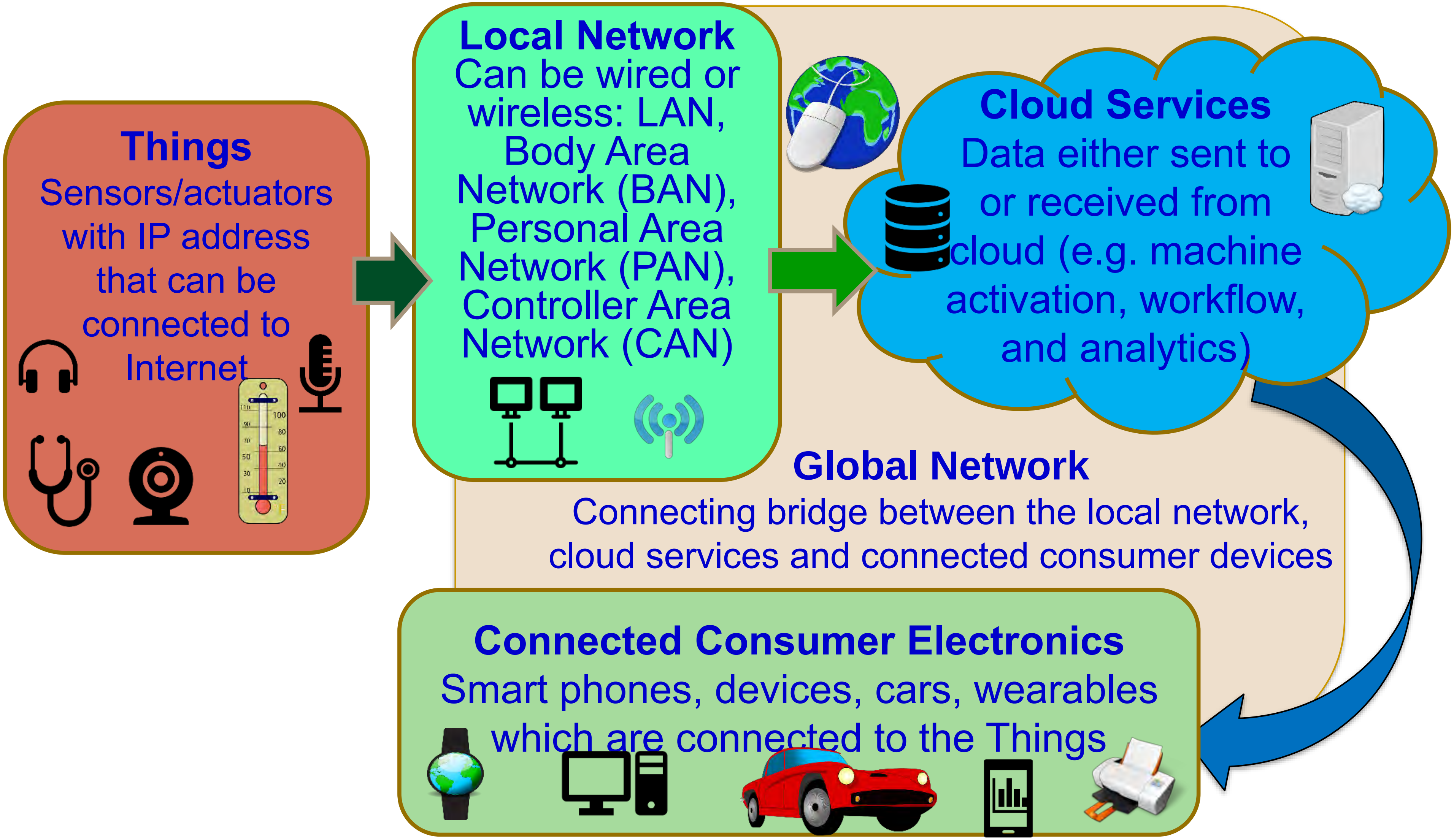
A network that is: "Available anywhere, anytime, by anything and anyone."



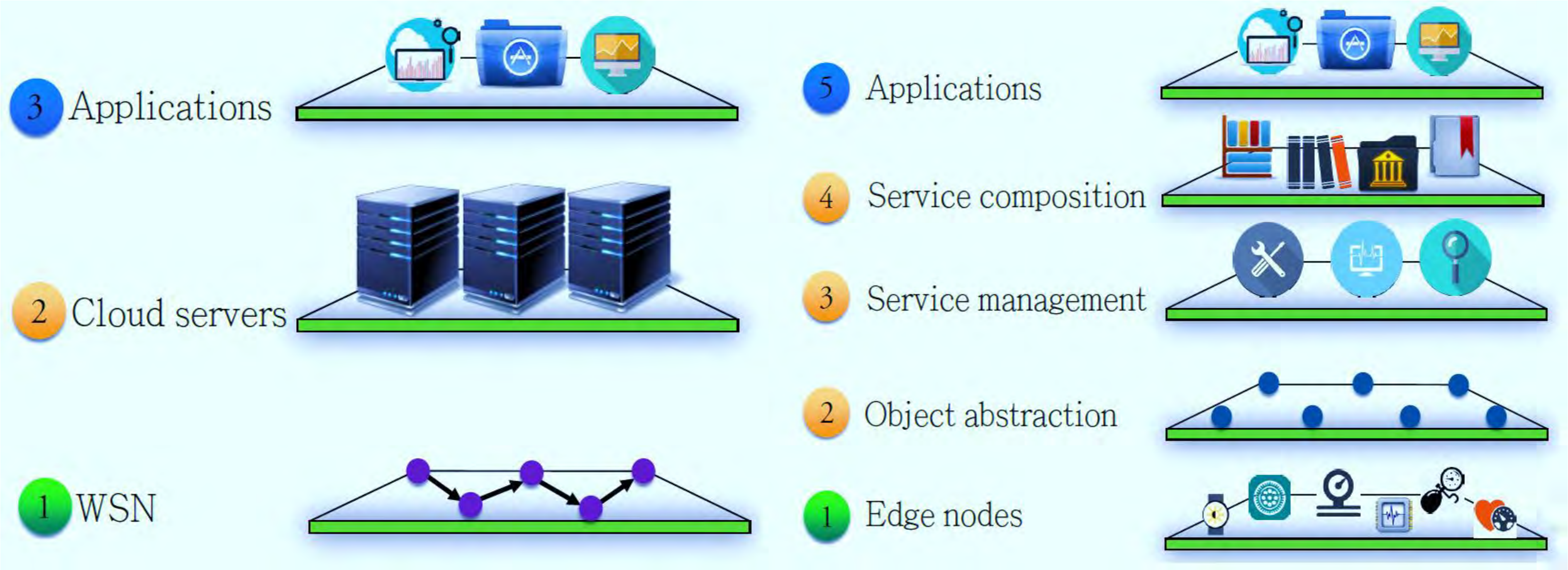
Source: http://iot.ieee.org/images/files/pdf/IEEE_IoT_Towards_Definition_Internet_of_Things_Revision1_27MAY15.pdf

Components

Internet of Things (IoT) – Concept



IoT Architecture - 3 & 5 Level Model

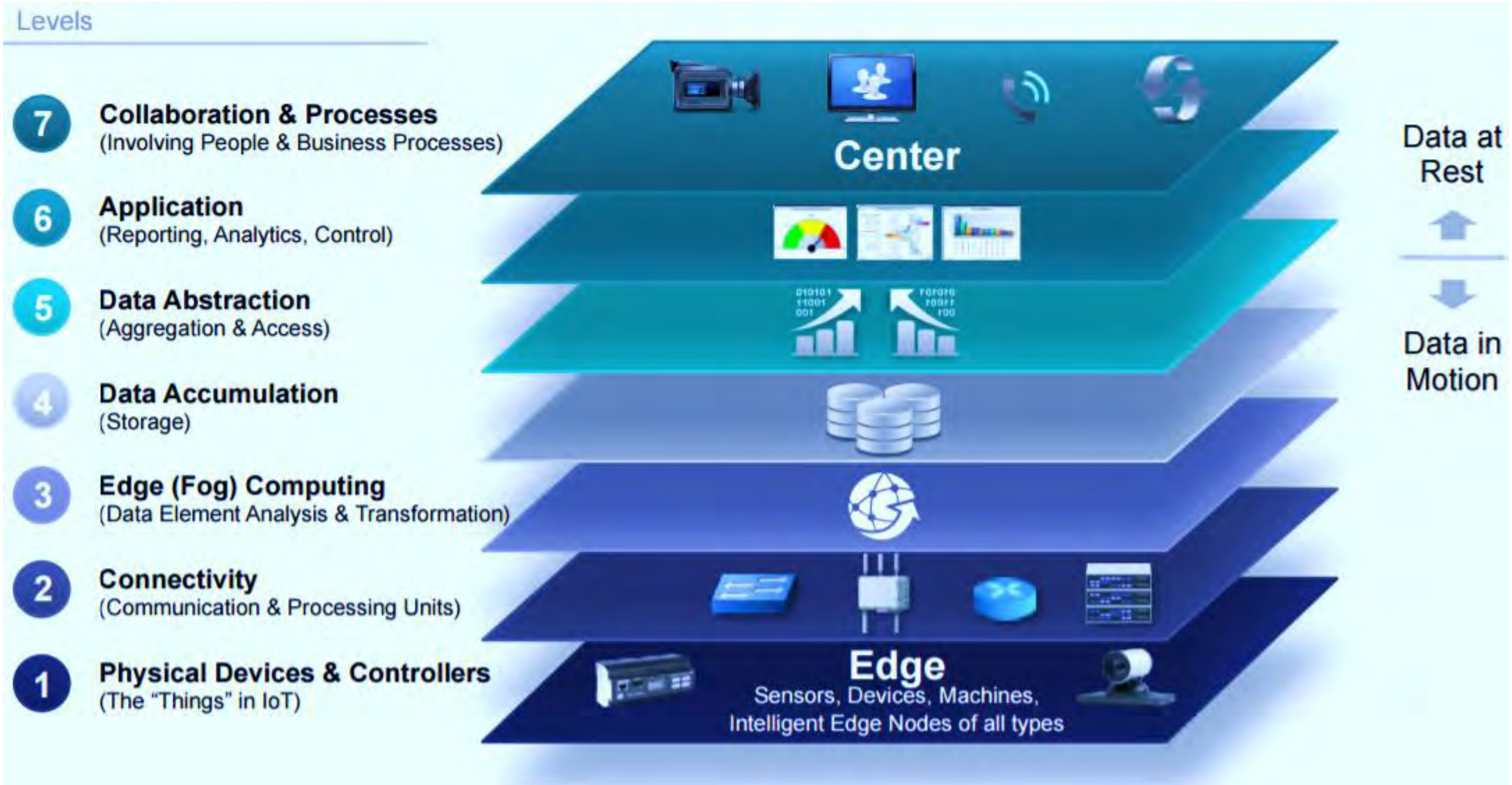


Three Level Model

Five Level Model

Source: Nia 2017, IEEE TETC 2017

IoT Architecture - 7 Level Model

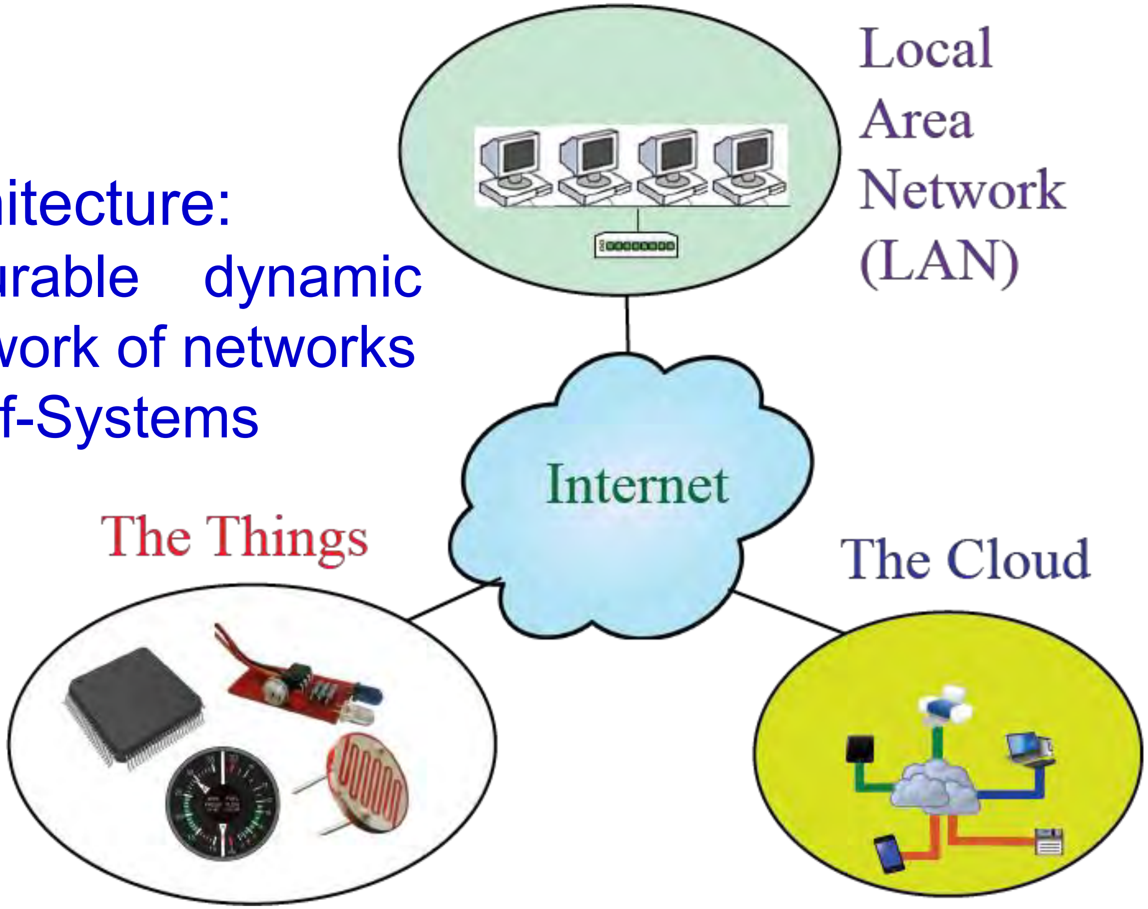


Source: http://cdn.iotwf.com/resources/71/IoT_Reference_Model_White_Paper_June_4_2014.pdf

IoT - Architecture

Overall architecture:

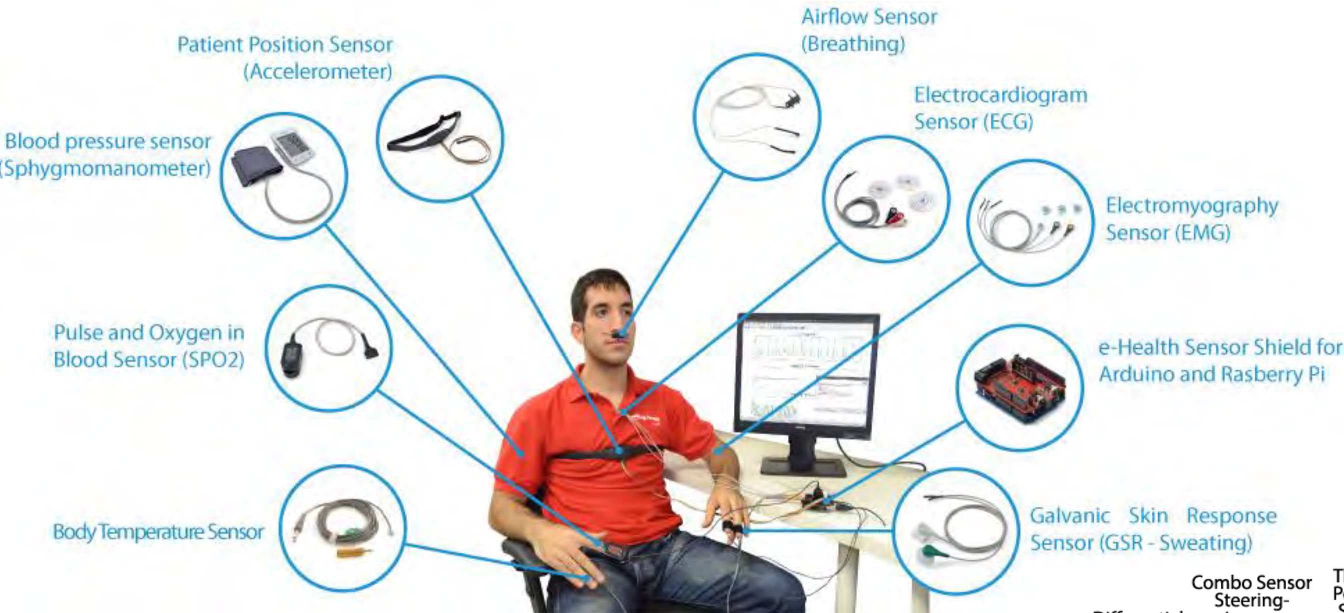
- A configurable dynamic global network of networks
- Systems-of-Systems



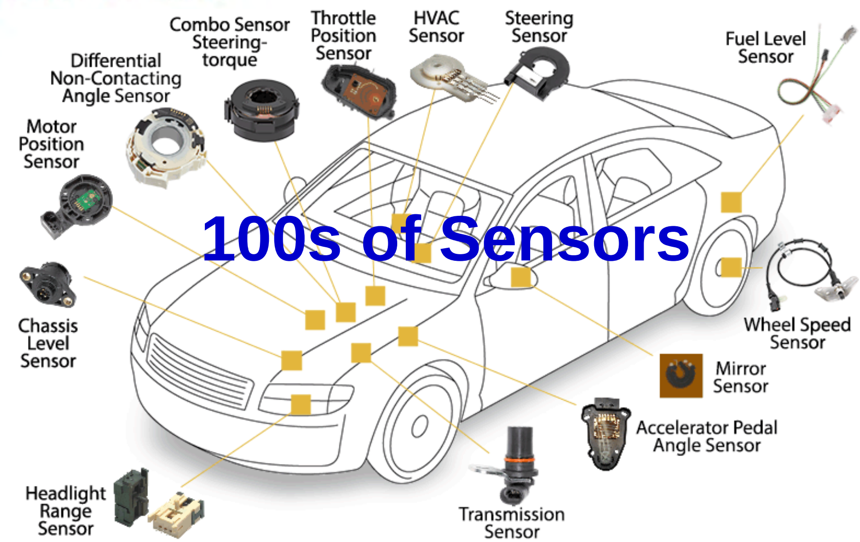
Four Main Components of IoT.

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

IoT – Sensors



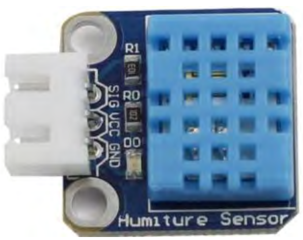
Source: http://www.libelium.com/e-health-low-cost-sensors-for-early-detection-of-childhood-disease-inspire-project-hope/

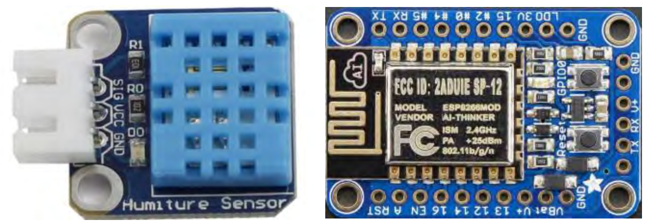


100s of Sensors

IoT – Things

Sensor





Thing

Sensors + Device with its own IP address → Things

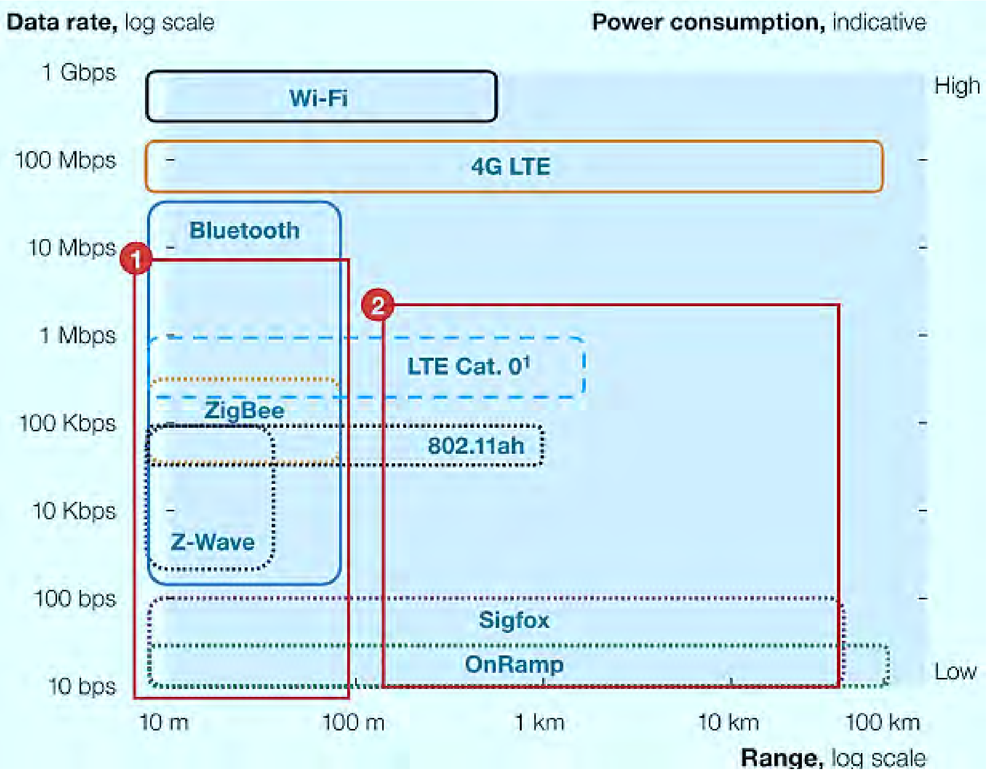
IP Address for Internet Connection

The "Things" refer to any physical object with a device that has its own IP address and can connect and send/receive data via network.

IoT - Communications

Selected IoT Communications Technology

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

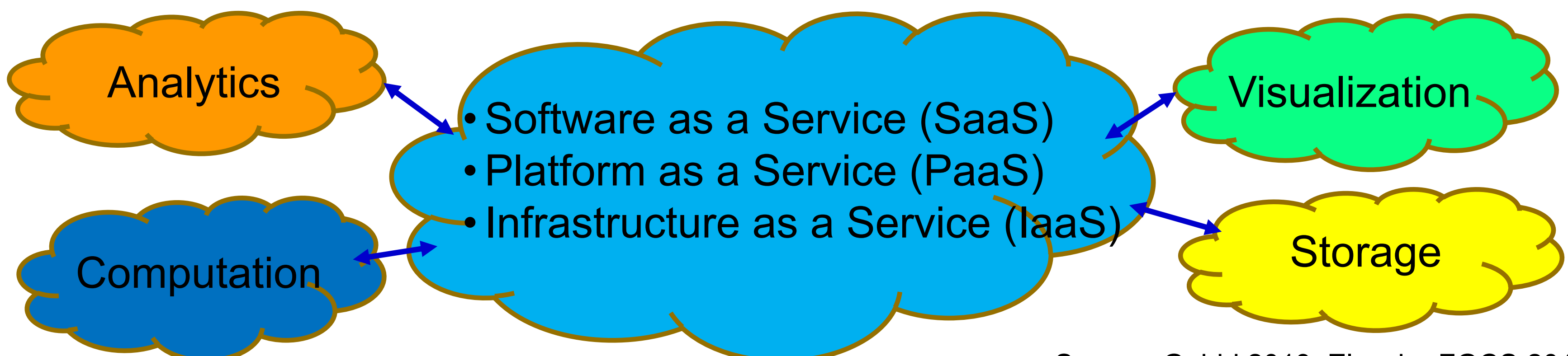


Source: https://www.postscapes.com/internet-of-things-protocols/

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

IoT - Cloud

Source: https://www.livewireindia.com/cloud_computing_training.php



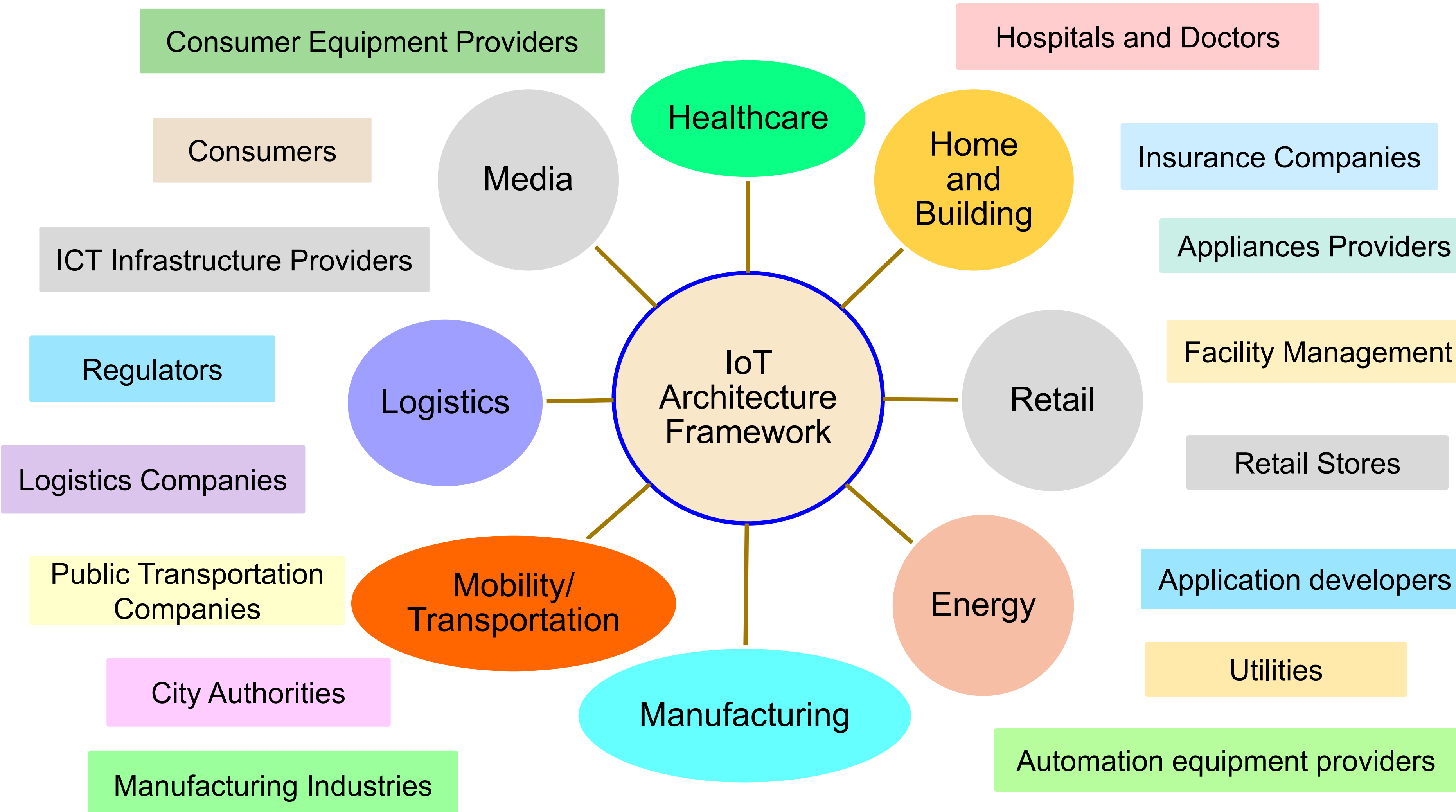
Source: Gubbi 2013, Elsevier FGCS 2013

IoT - Elements

- Sensors
- Application-Specific Hardware
- General-Purpose Hardware
- Firmware
- Operating System
- Middleware
- Software

IoT - Applications

IoT - Markets and Stakeholders

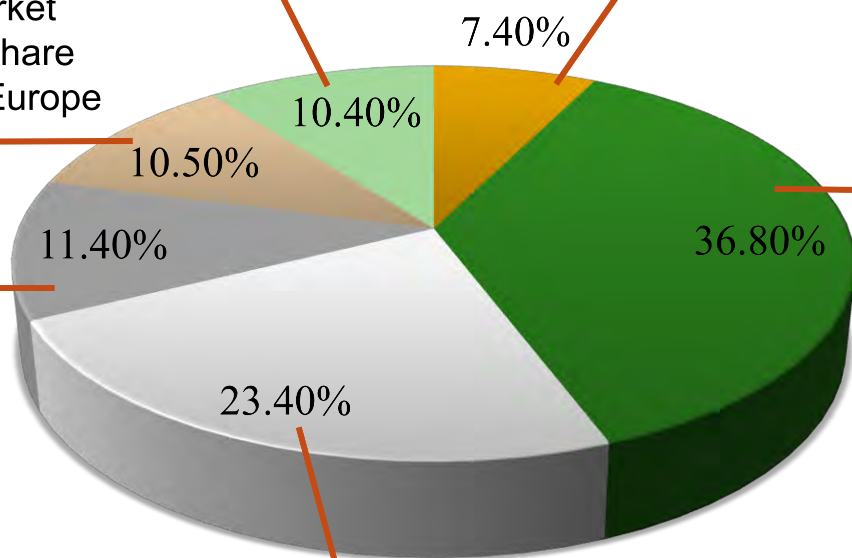


Source: http://iot.ieee.org/images/files/pdf/IEEE_IoT_Towards_Definition_Internet_of_Things_Revision1_27MAY15.pdf

Smart City Market Segments – by 2025

5 Smart Healthcare
Market Value: $348.5Billion
CAGR: 8.8% (2012-2025)
North America to dominate Smart Healthcare market with more than 50% share by 2025 followed by Europe

6 Smart Building
Market Value: $248.65Billion
CAGR: 4.1% (2012-2025)
China and India are fastest growing markets followed by Japan and Korea



4 Smart Transportation
Market Value: $351.13Billion
CAGR: 19.6% (2012-2025)
Market growth in Latin America, Middle East, Africa, CIS + Eastern Europe

1 Smart Governance and Smart Security
Market Value: $1230.26 Billion
CAGR: 11.6% (2012-2025)
More Projects coming up in North America, Middle East and European regions

3 Smart Infrastructure
Market Value: $381.53 Billion
CAGR: 12.0% (2012-2025)
Highest growth in North America and Asia

2 Smart Energy
Market Value: $781.66 Billion
CAGR: 28.7% (2012-2025)
Highest growth in North America

Source: Frost & Sullivan analysis.

Source: https://www.slideshare.net/IoTTunisia/farouk-kamoun-smart-cities-innovative-applications-iot-tunisia-2016

Smart Healthcare

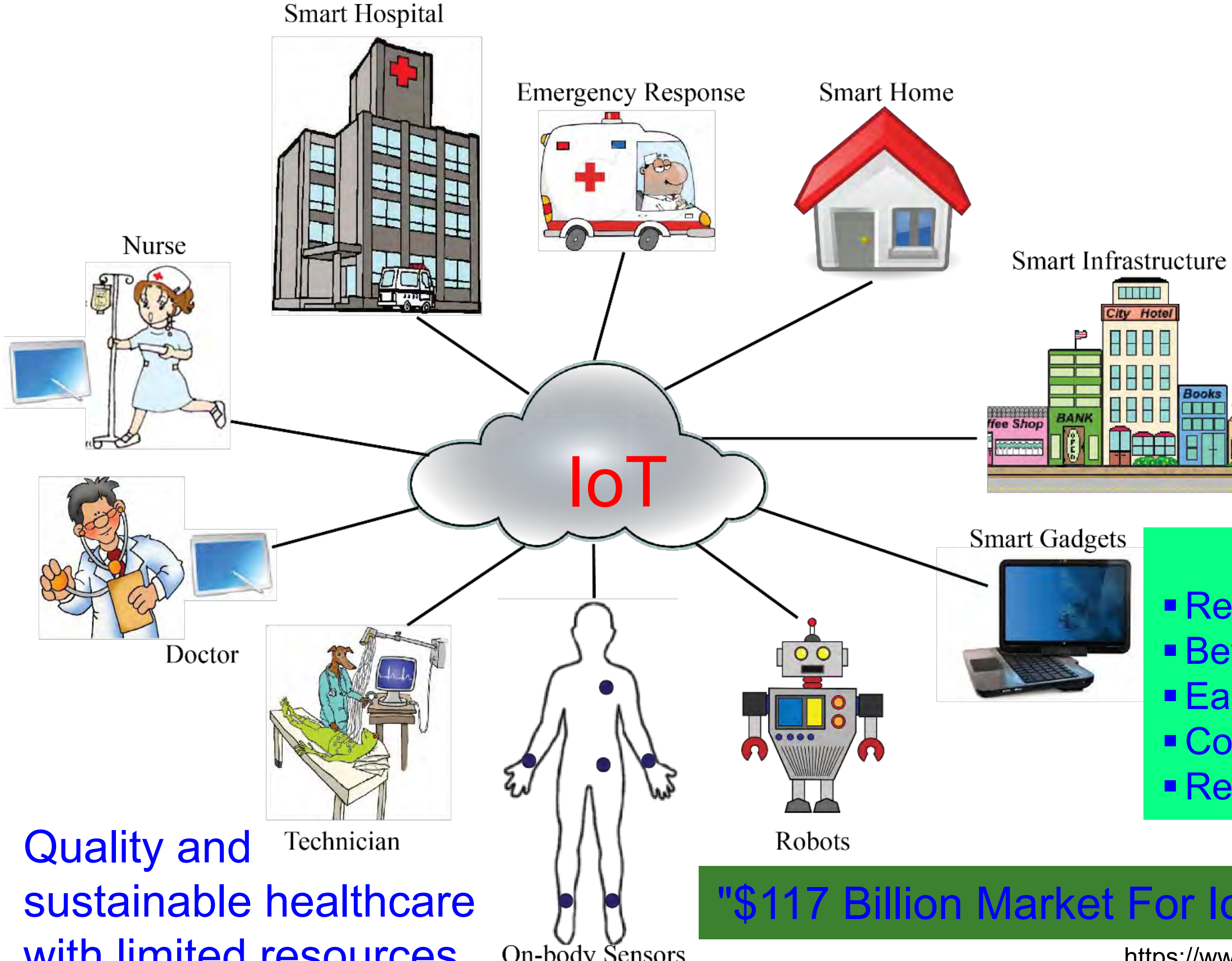
Healthy Living
- Fitness Tracking
- Disease Prevention
- Food monitoring

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

IoT in Smart Healthcare



Fitness Trackers

IoT Role Includes:
- Real-time monitoring
- Better emergency response
- Easy access of patient data
- Connectivity among stake holders
- Remote access to healthcare

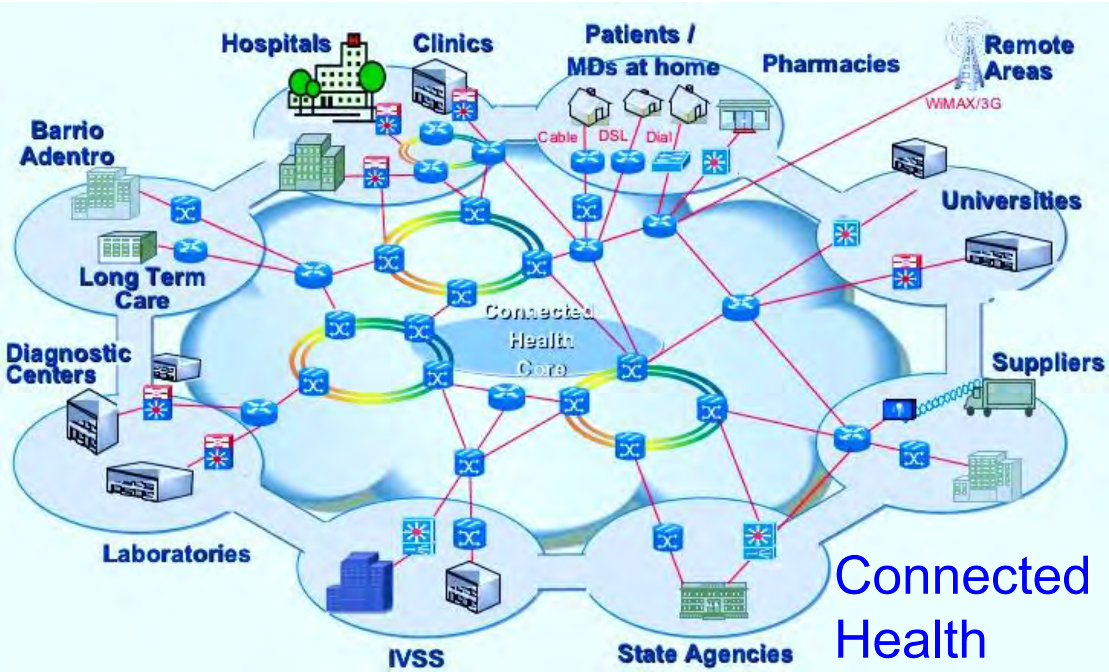
"$117 Billion Market For IoT in Healthcare By 2020."

https://www.forbes.com/sites/tjmccue/2015/04/22/117-billion-market-for-internet-of-things-in-healthcare-by-2020/

Quality and sustainable healthcare with limited resources, anywhere, anytime.

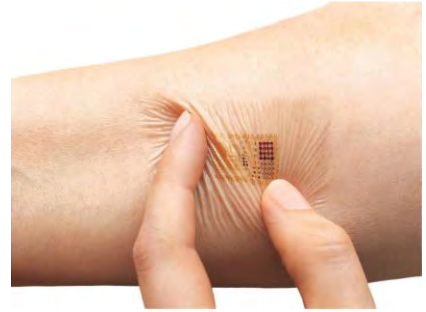
Source: Mohanty 2016, CE Magazine July 2016

IoT in Smart Healthcare



Connected Health

Source: https://www.slideshare.net/tibisay_hernandez/connected-health-venfinal



Embedded Skin Patches

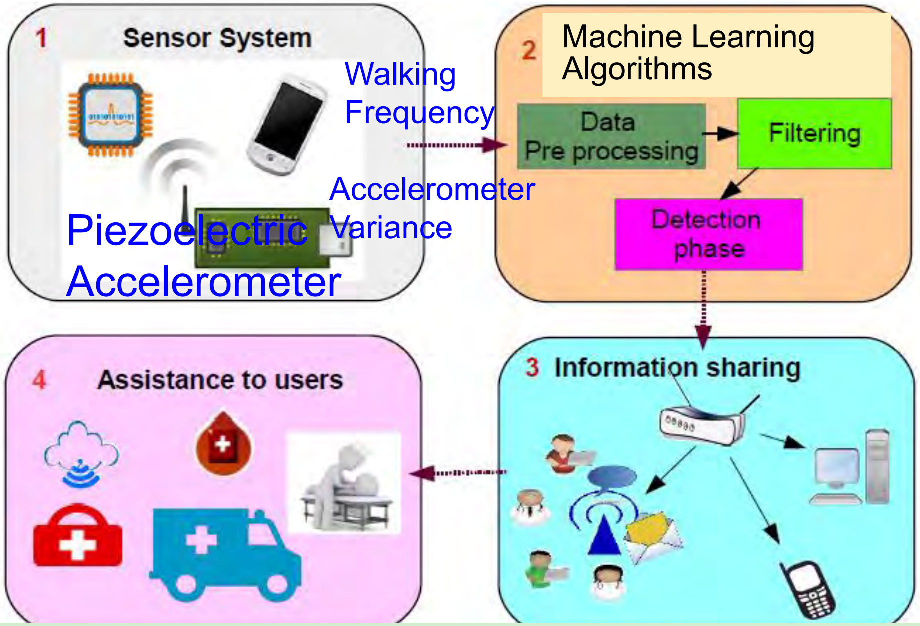
Source: Sethi 2017, JECE 2017

Virtual Reality in Healthcare

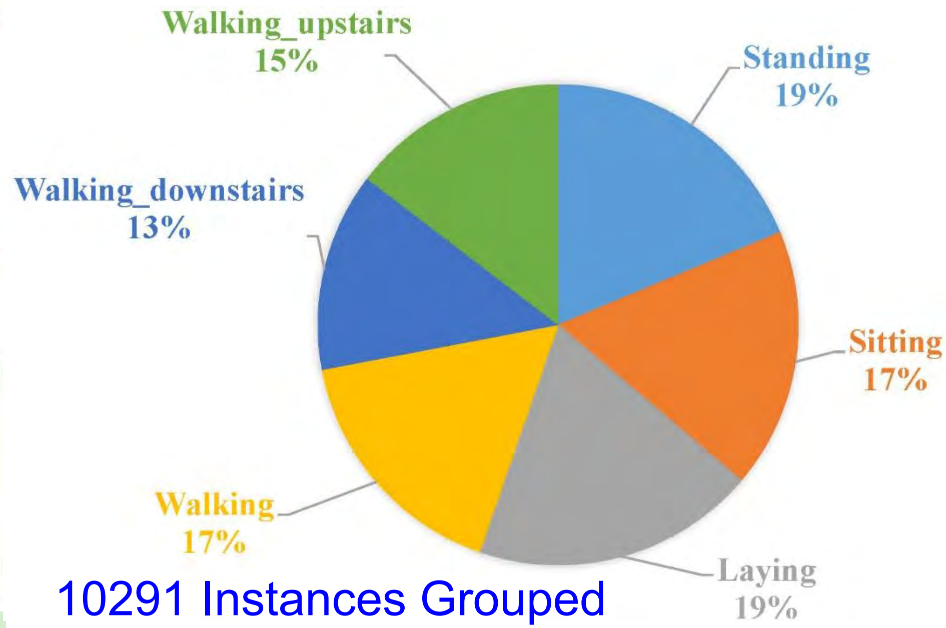
Source: http://medicalfuturist.com/5-ways-medical-vr-is-changing-healthcare/
https://touchstoneresearch.com/tag/applied-vr/

Headband with Embedded Neurosensors

Smart Healthcare - Smart-Walk



Automated Physiological Monitoring System



10291 Instances Grouped Under 6 Activities - Kaggle

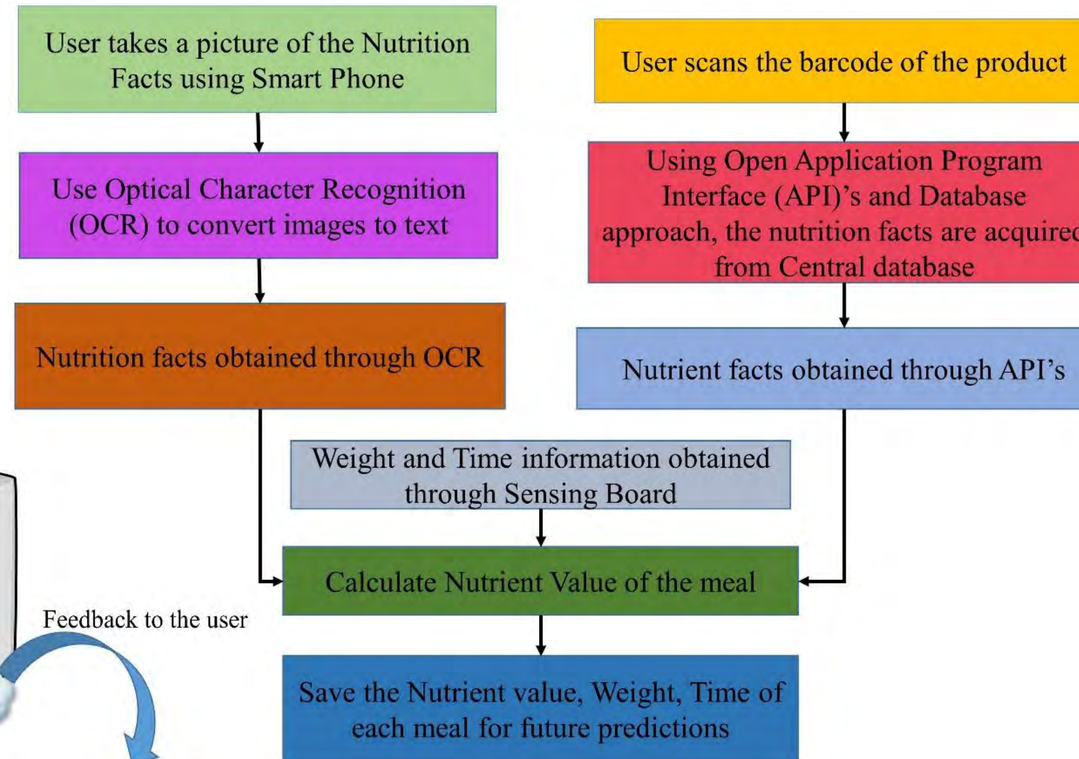
Research Works	Method	Features considered	Activities	Accuracy (%)
This Work	Adaptive algorithm based on feature extraction (WEKA)	Step detection and Step length estimation	Walking, sitting, standing, etc.	97.9

Source: Mohanty ICCE 2018

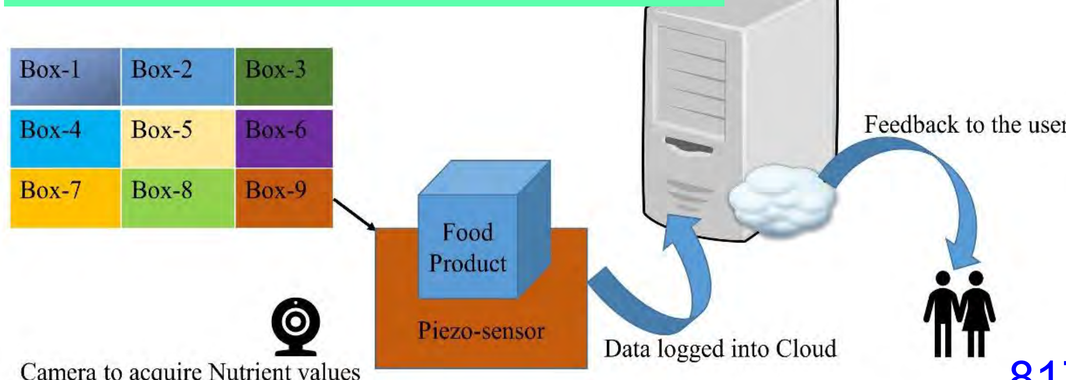
Smart Healthcare - Smart-Log

- Smart Sensor Board
- Data Acquisition
- Future Meal Predictions

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



Automated Food Monitoring System

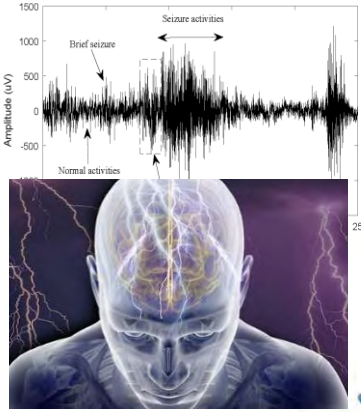


8172 user instances were considered

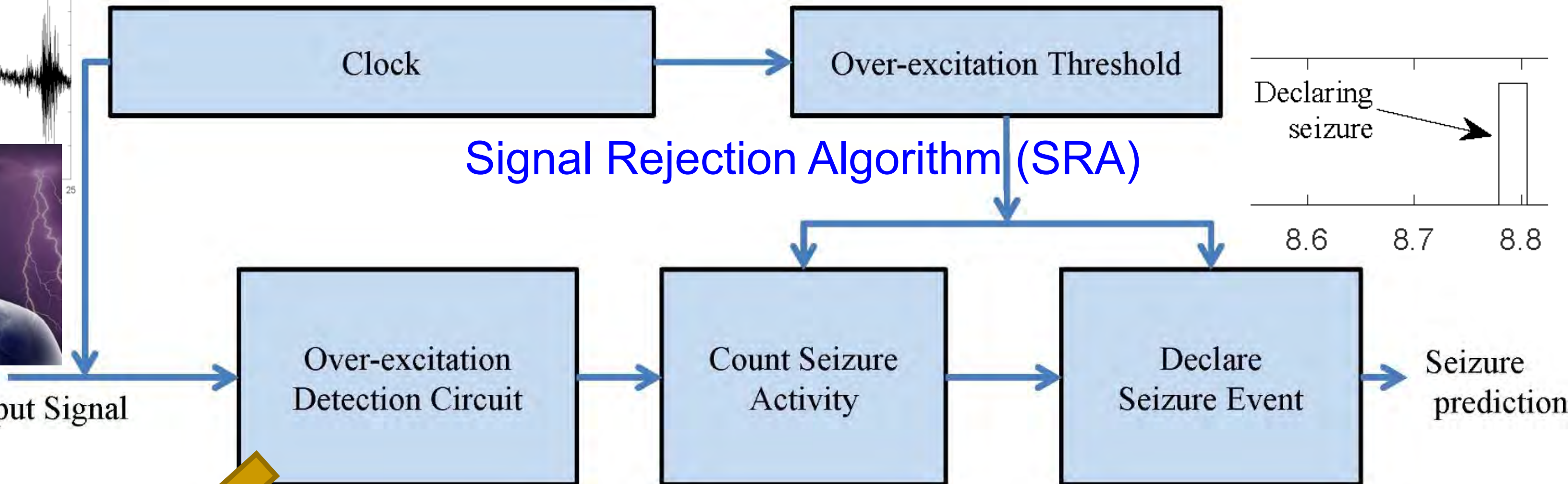
Research Works	Food Recognition Method	Efficiency (%)
This Work	Mapping nutrition facts to a database	98.4

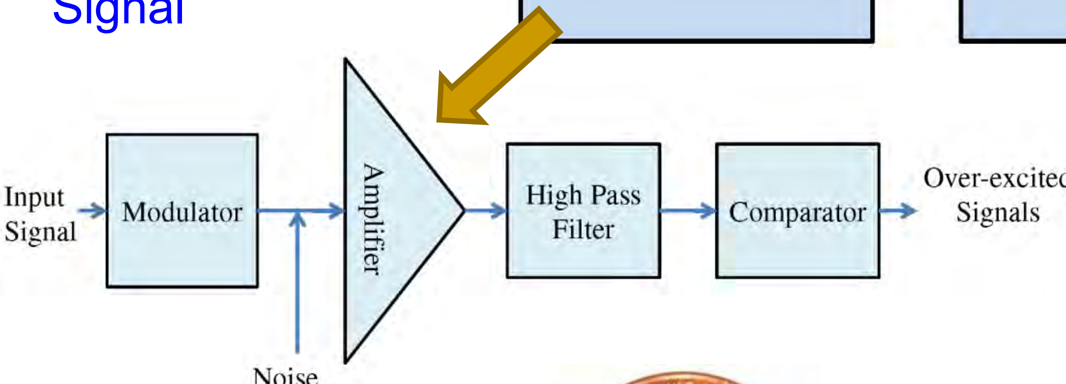
Source: Mohanty ICCE 2018

Smart Healthcare – Efficient Epileptic Seizure Detector

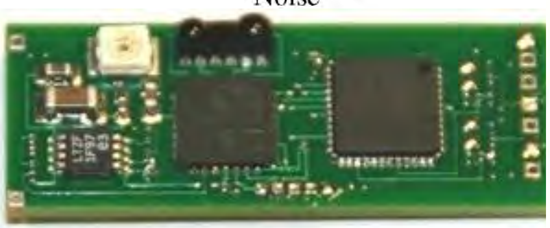


EEG Signal





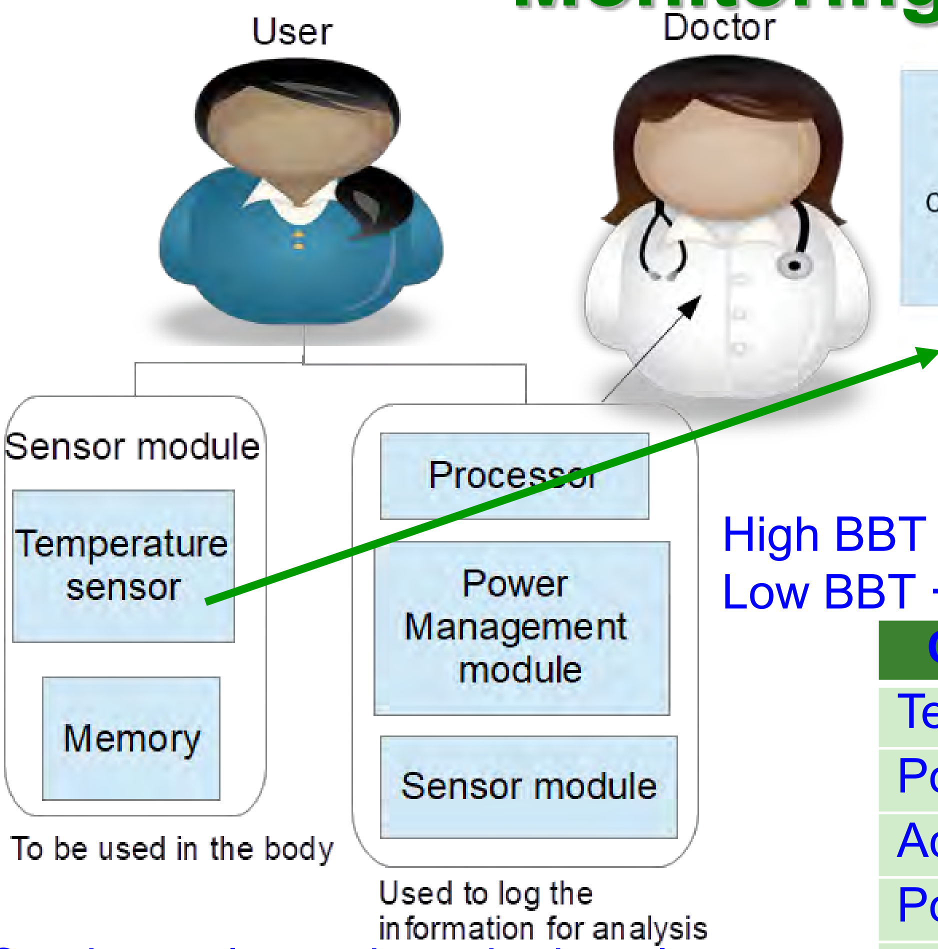
Parameter	Value
Seizure Frequency (Minimum)	5 Hz
Seizure Frequency (Minimum)	25 HZ
Voltage Level Detector (Avg. Lower Threshold)	210 mV
Voltage Level Detector (Avg. Upper Threshold)	380 mV
Total power consumption	6.18 μW

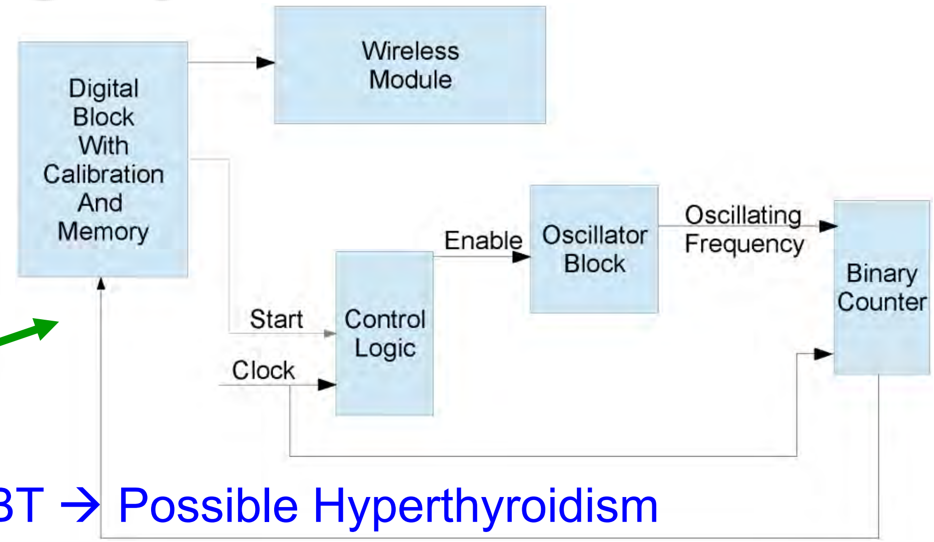


Source: Zaveri, Yale University

Source: Mohanty ICCE 2018

Smart Healthcare - Thyroid Monitoring System





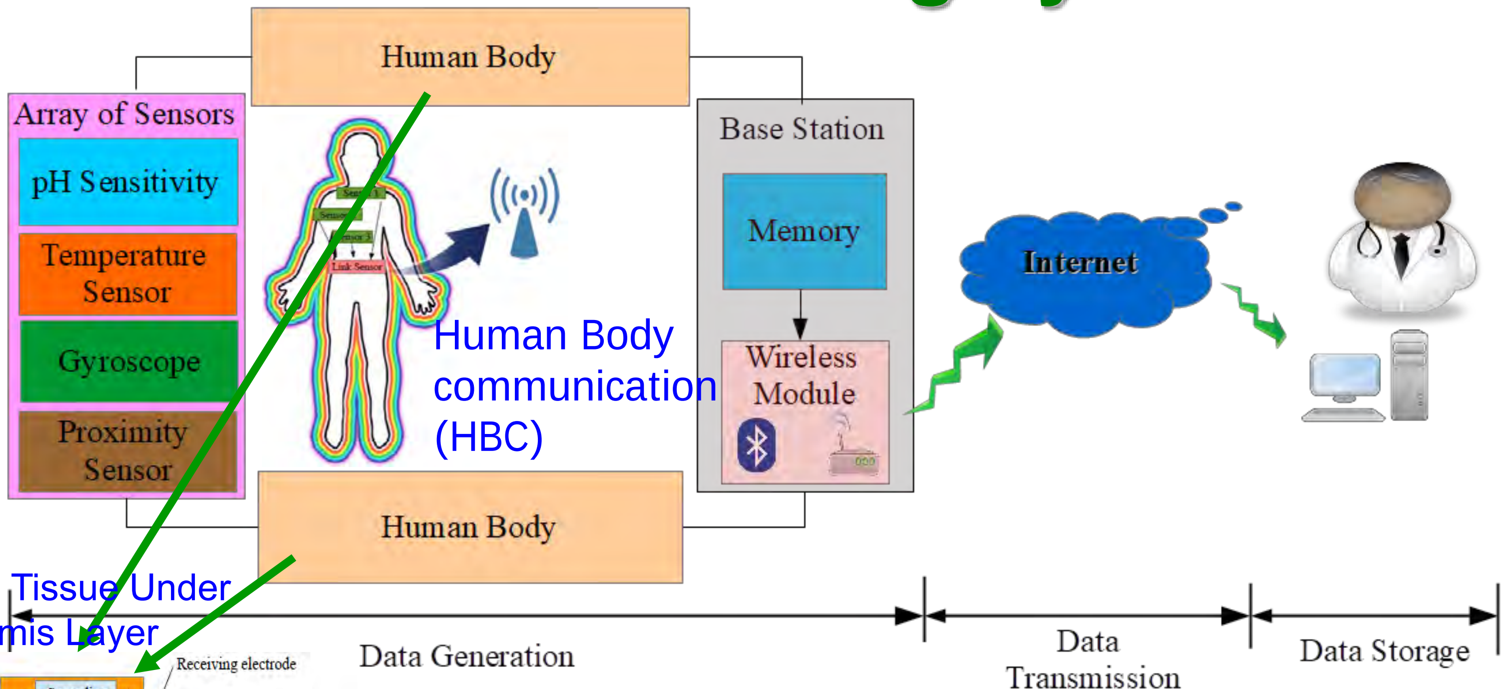
High BBT → Possible Hyperthyroidism
Low BBT → Possible Hypothyroidism

Characteristics	Values
Temperature range	25˚C to 40˚C
Power Supply	4 V
Accuracy	± 0.1˚C
Power dissipation	28.5 µW
Frequency range	42.906 – 43.5 MHz

Continuously monitors the basal body temperature (BBT)

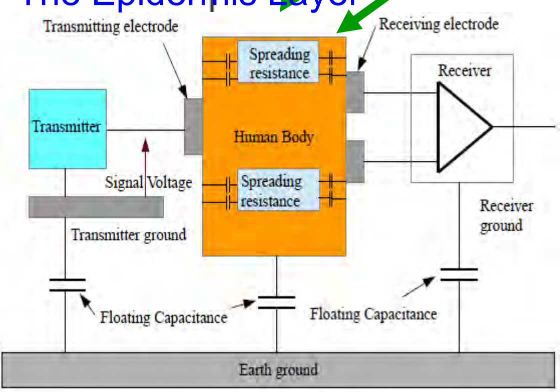
Source: Mohanty EuroSimE 2016

Smart Healthcare – Ambulatory Health Monitoring System



Human Body communication (HBC)

Conductive Tissue Under The Epidermis Layer



Characteristics	Values
Communication Environment	Intra Body Communication
BCC Coupling method	Capacitively coupled
Frequency range of operation	1 – 100 MHz
Power consumption	3.14 mW (31% less)

Source: Mohanty iNIS 2016

IoT in Smart Transportation

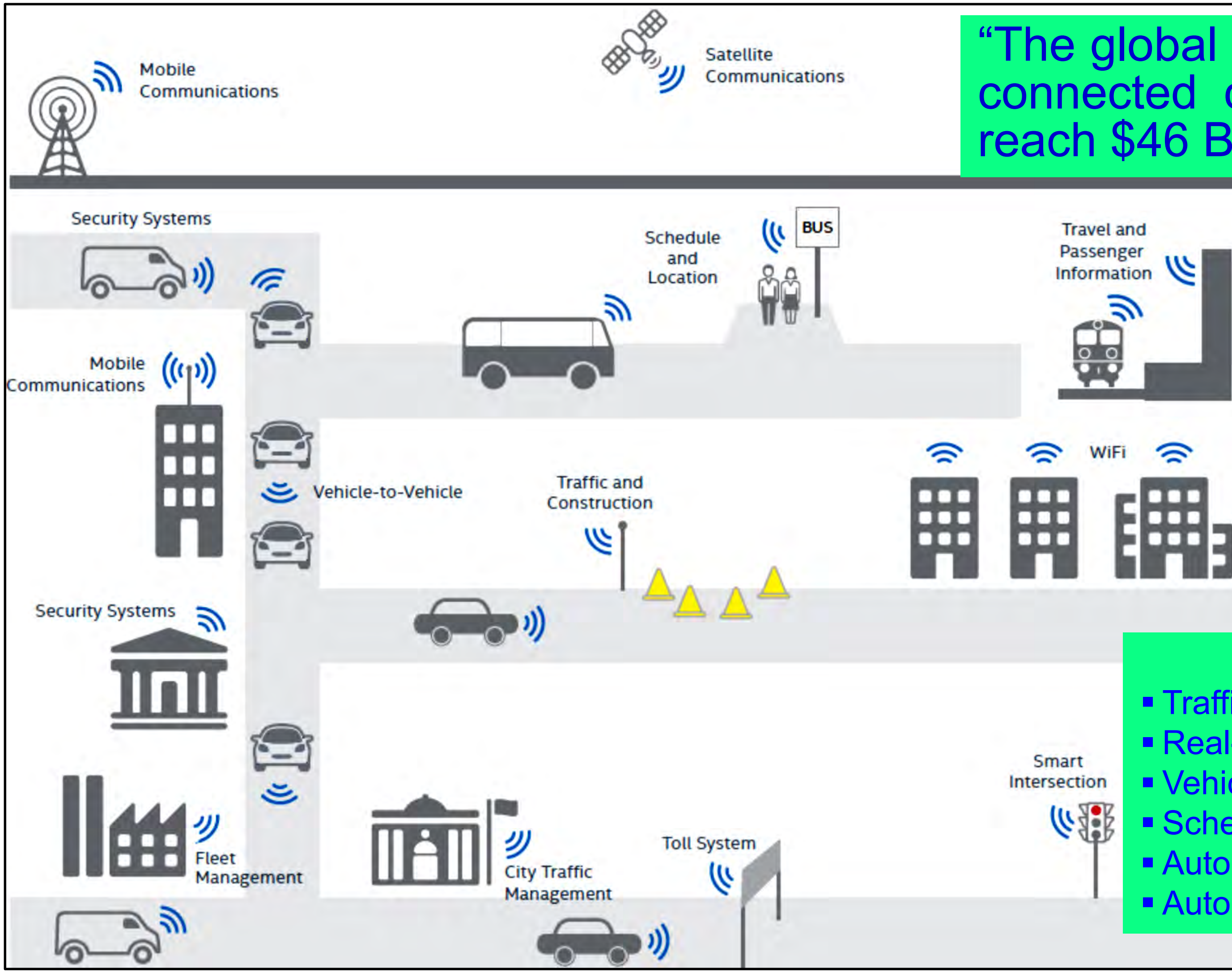
Source: Mohanty 2016, CE Magazine July 2016

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

Smart Transportation Features:

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

IoT in Smart Transportation



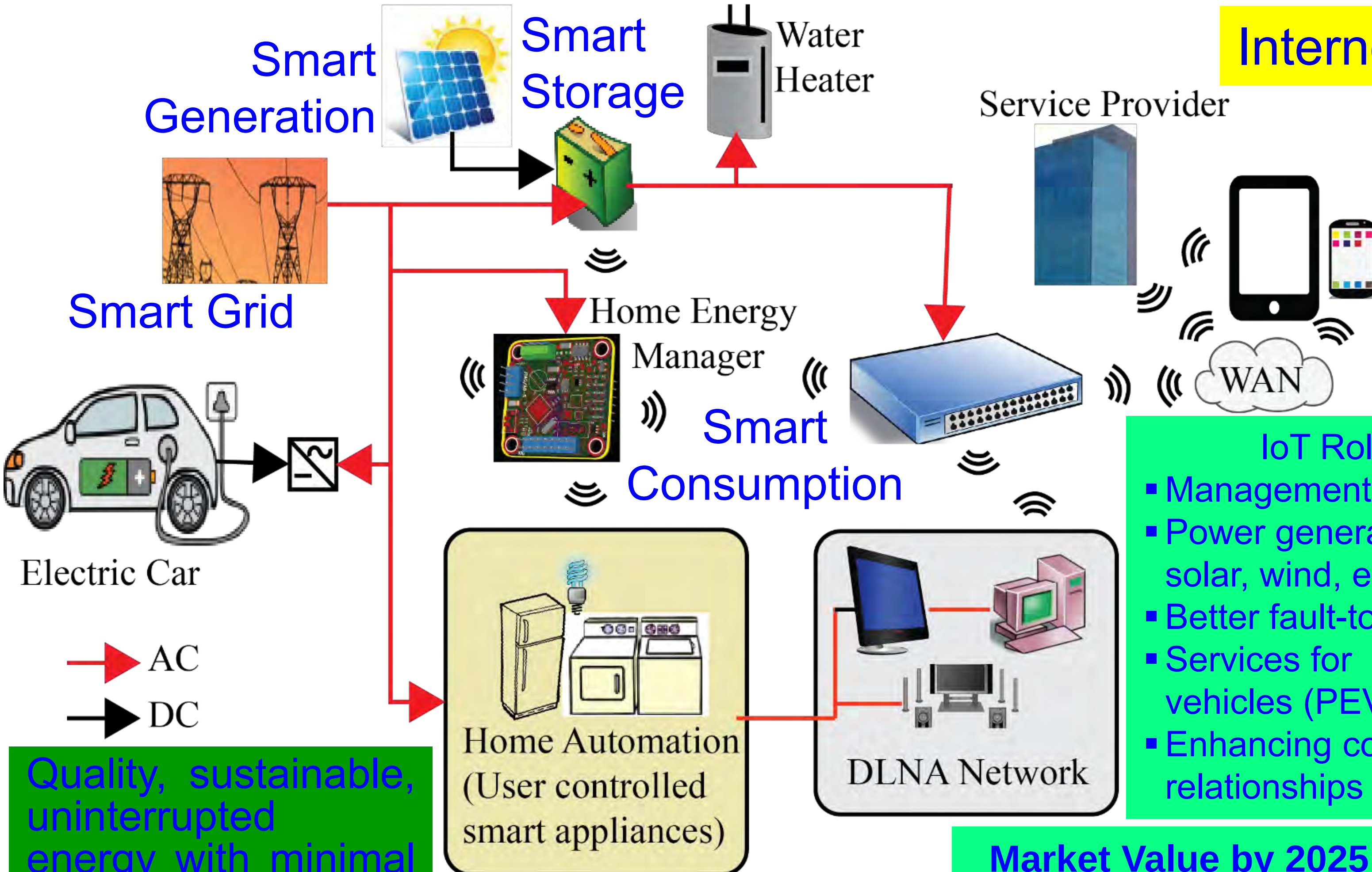
"The global market of IoT based connected cars is expected to reach $46 Billion by 2020."

Source: Datta 2017, CE Magazine Oct 2017

IoT Role Includes:
- Traffic management
- Real-time vehicle tracking
- Vehicle-to-Vehicle communication
- Scheduling of train, aircraft
- Automatic payment/ticket system
- Automatic toll collection

Source: https://www.mcafee.com/us/resources/white-papers/wp-automotive-security.pdf

IoT in Smart Energy



Internet of Energy

IoT Role Includes:

- 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

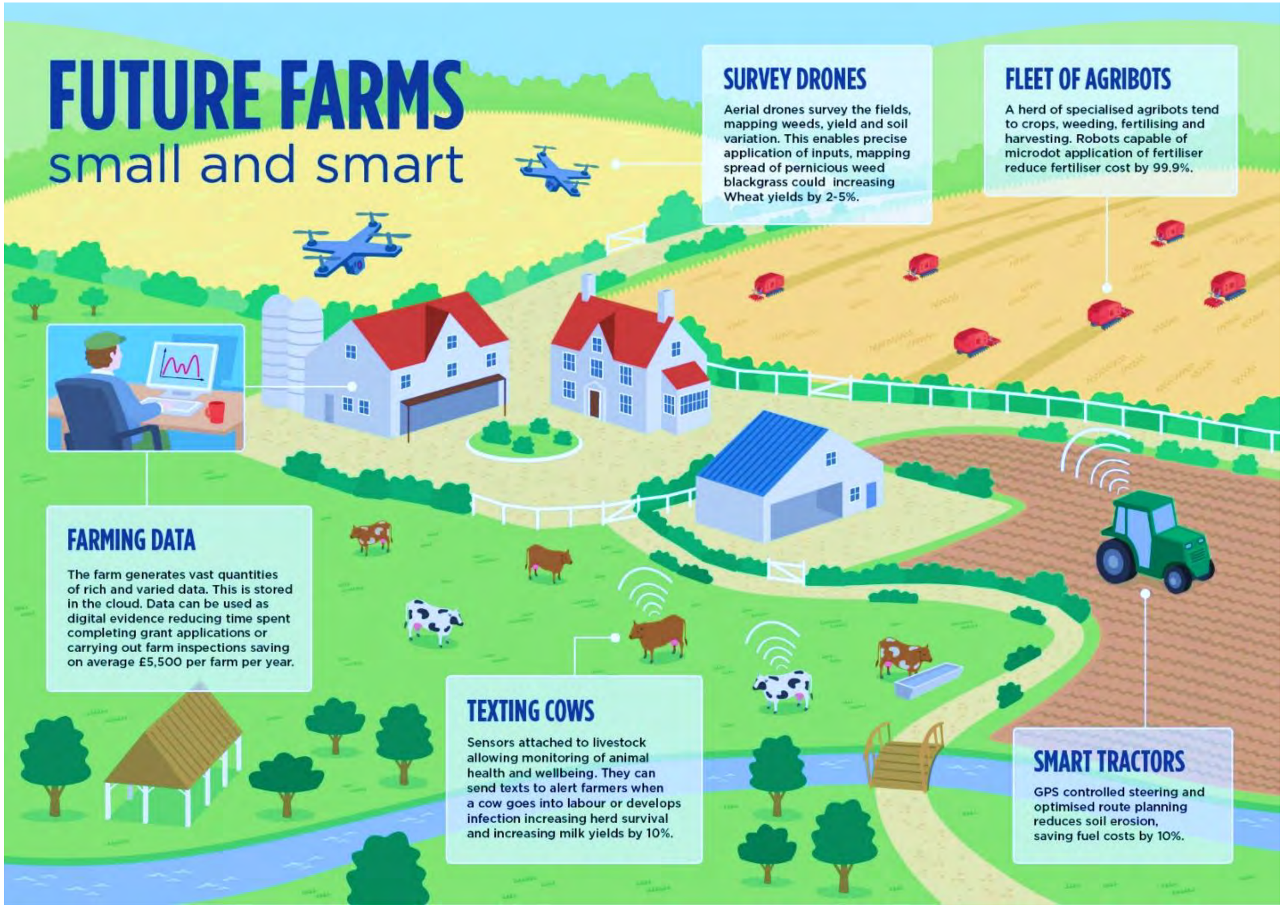
Quality, sustainable, uninterrupted energy with minimal carbon footprint.

Market Value by 2025: $781.66 Billion

Source: Frost & Sullivan

Source: Mohanty 2016, CE Magazine July 2016

IoT in 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

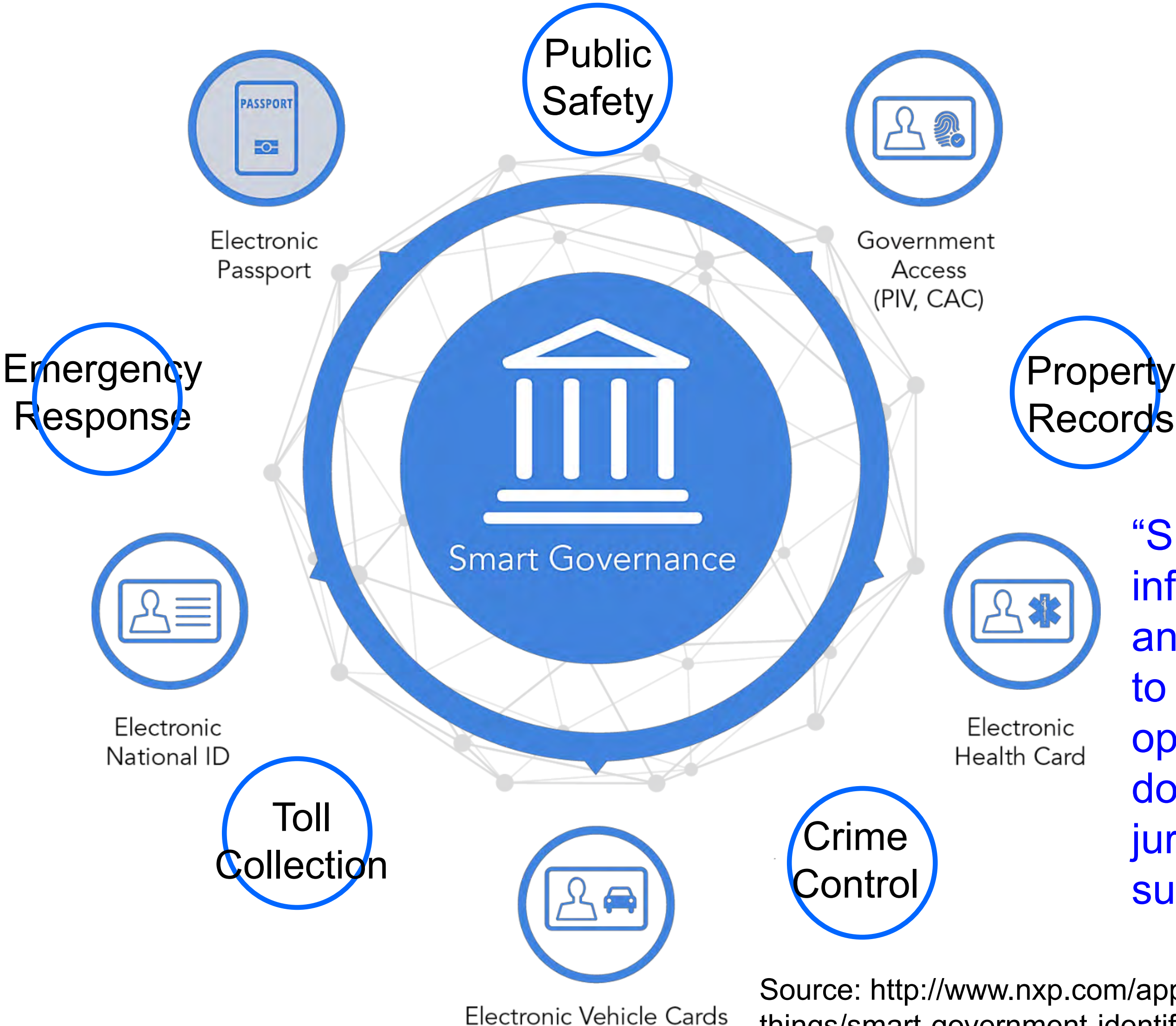
Automatic Irrigation System

Source: Maurya 2017, CE Magazine July 2017

Smart Agriculture/Farming Market Worth $18.21 Billion By 2025

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

IoT in 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

IoT in Smart Structure

Smart Building

Source: http://www.exchangecommunications.co.uk/products/smart-building-and-cities/smart-buildings.php

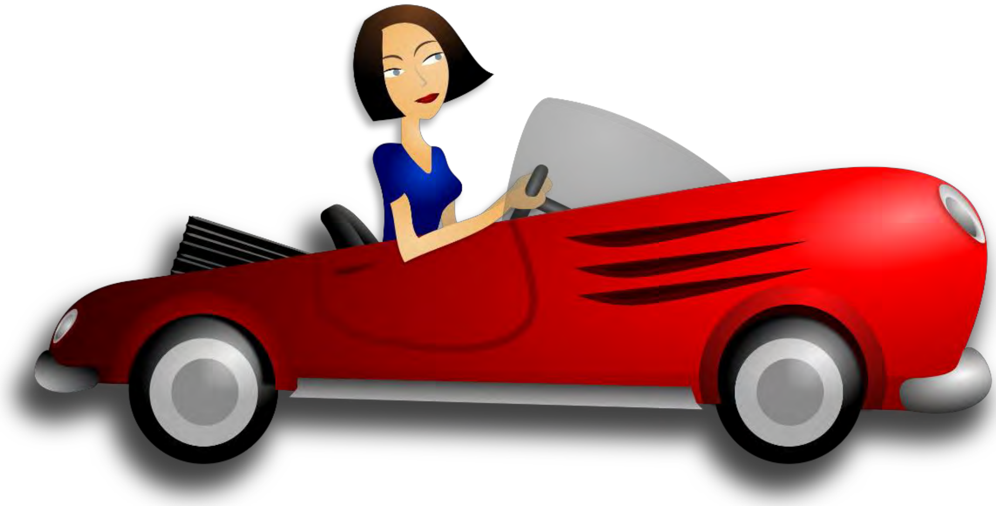
Smart Structure

Source: https://www.slideshare.net/RajivDinesh2/lelantosstructuralhealthmonitoringbrochure

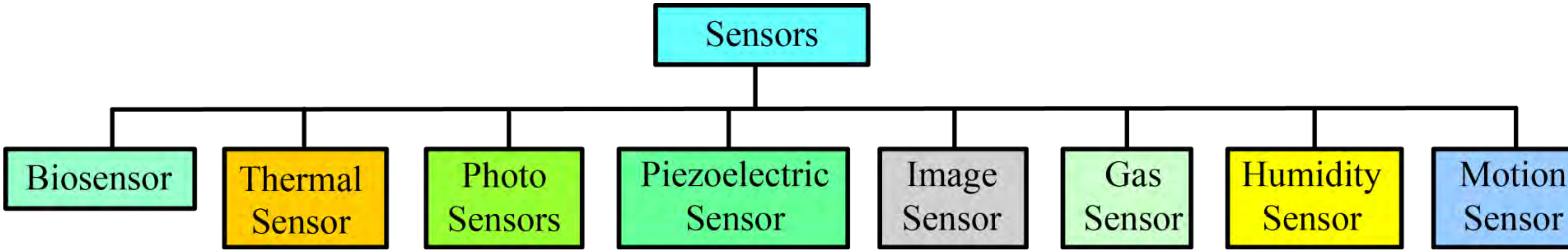
IoT in Smart Home

Source: https://community.cadence.com/cadence_blogs_8/b/ip/archive/2014/08/28/iot-applications-wrestling-with-energy_2c00_-cost-and-time-to-market-considerations

Driving Technologies



Cheap and Compact Sensor Technology



Source: Mohanty 2015, McGraw-Hill 2015

Gas Sensor

Temperature Sensor

Air Quality Sensor

Humidity and Temperature Sensor

Light Sensor

Barometer Sensor

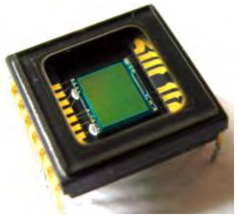
Water Sensor

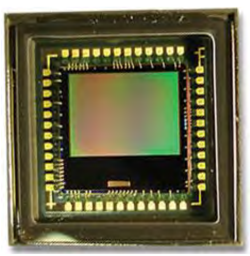
Dust Sensor

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

Better Imaging Sensor Technology

- Image Sensors
  - Charged Couple Device (CCD) Sensor
  - Complementary Metal Oxide Semiconductor (CMOS) Sensors
    - Passive Pixel Sensor (PPS)
    - Active Pixel Sensor (APS)
      - Based on Sensing Element
        - Photodiode-Type APS
        - Photogate-Type APS
      - Based on Operation Mode
        - Linear-Mode APS
        - Logarithmic-Mode APS
    - Digital Pixel Sensor (DPS)



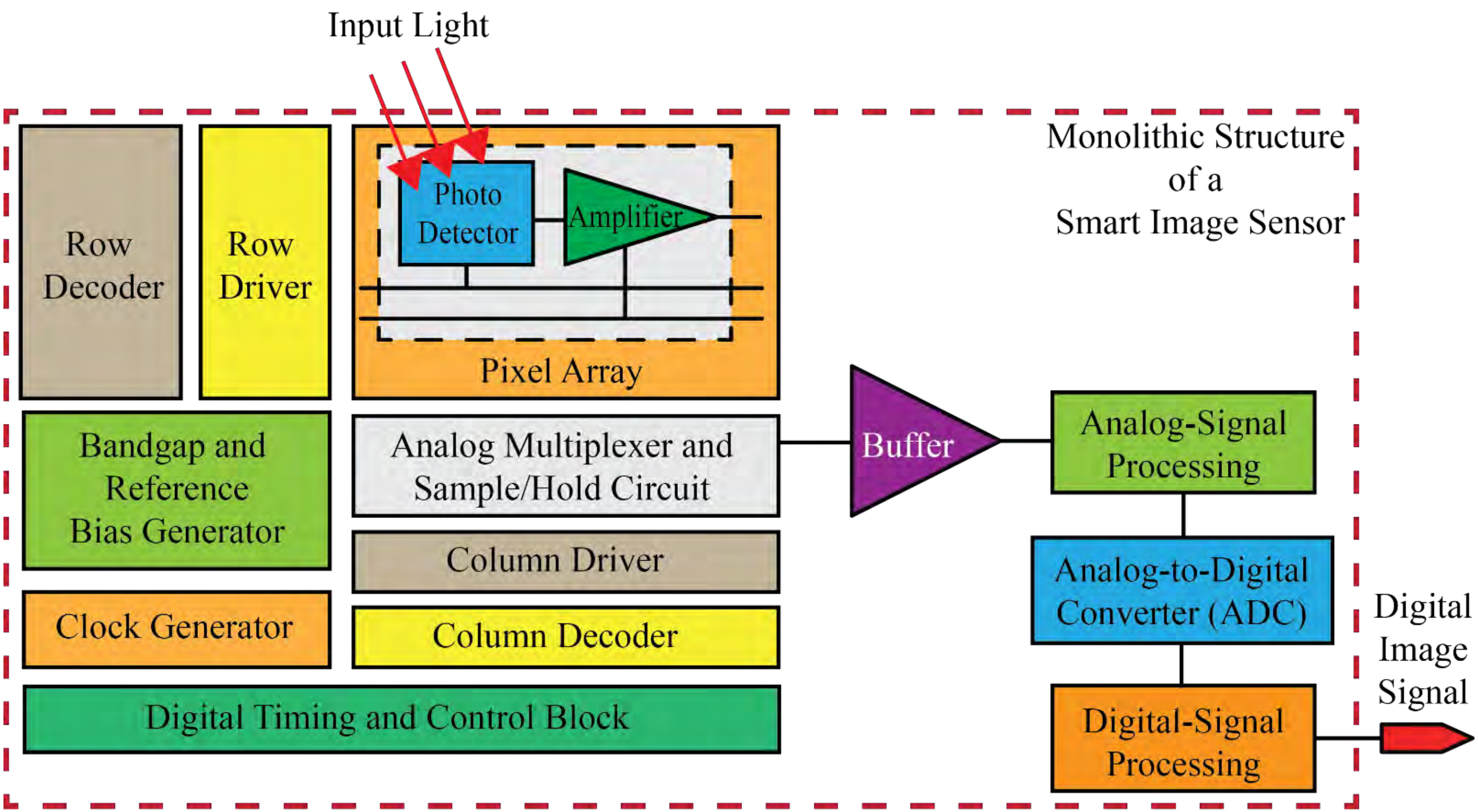


"The global CMOS image sensor market is likely to be worth $10.17 billion by 2020."

Source: Mohanty 2015, McGraw-Hill 2015

Source: http://www.grandviewresearch.com/press-release/global-cmos-image-sensors-market

Smart Image Sensor



Source: Mohanty 2015, McGraw-Hill 2015

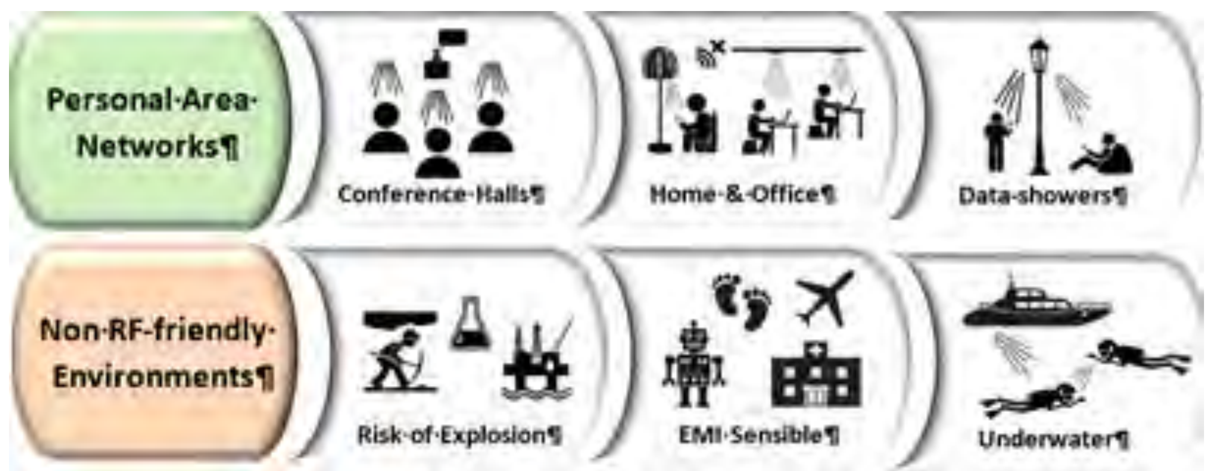
Variety of Communications Technology

Visible Light Communications (VLC)

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

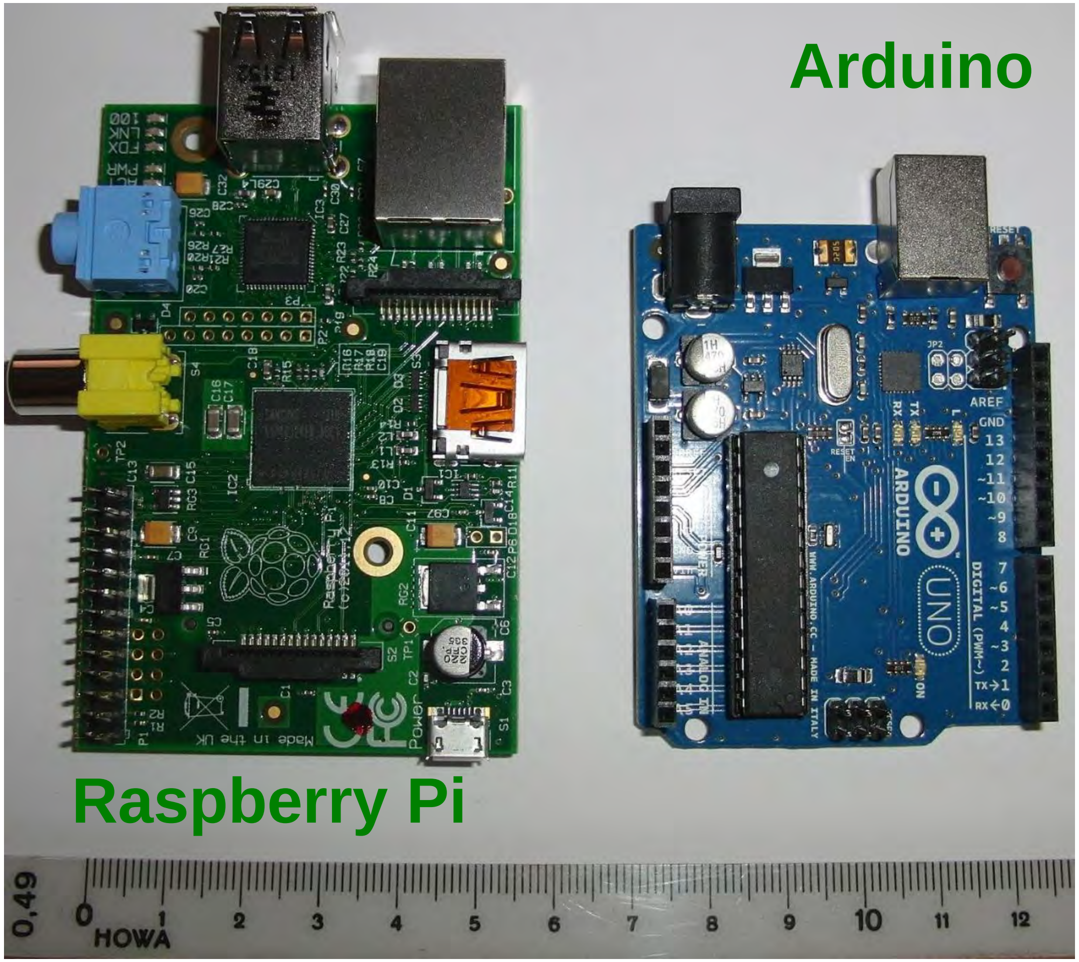
Characteristic	LiFi	WiFi
Bandwidth	Huge	Limited
Requires Line of Sight	Yes	No
EMI + Hazard Concerns	Low	High
Susceptibility to Eavesdropping	Low	High
Range	Short	Medium
Data Density	High	Limited

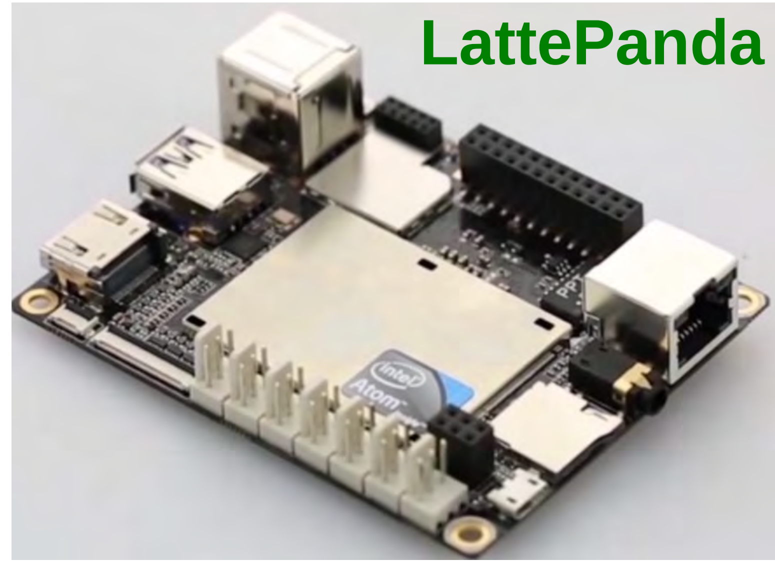
Source: VLCS-2014



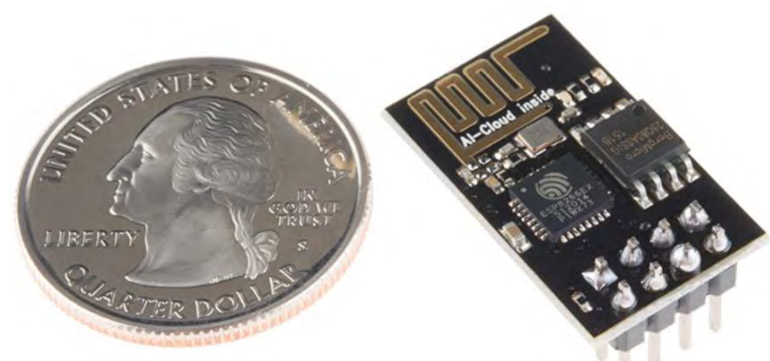
Source: Ribeiro 2017, CE Magazine October 2017

Cheap Computing Technology





Source: http://www.lattepanda.com



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

Efficient Media Compression – Better Portable Graphics (BPG)

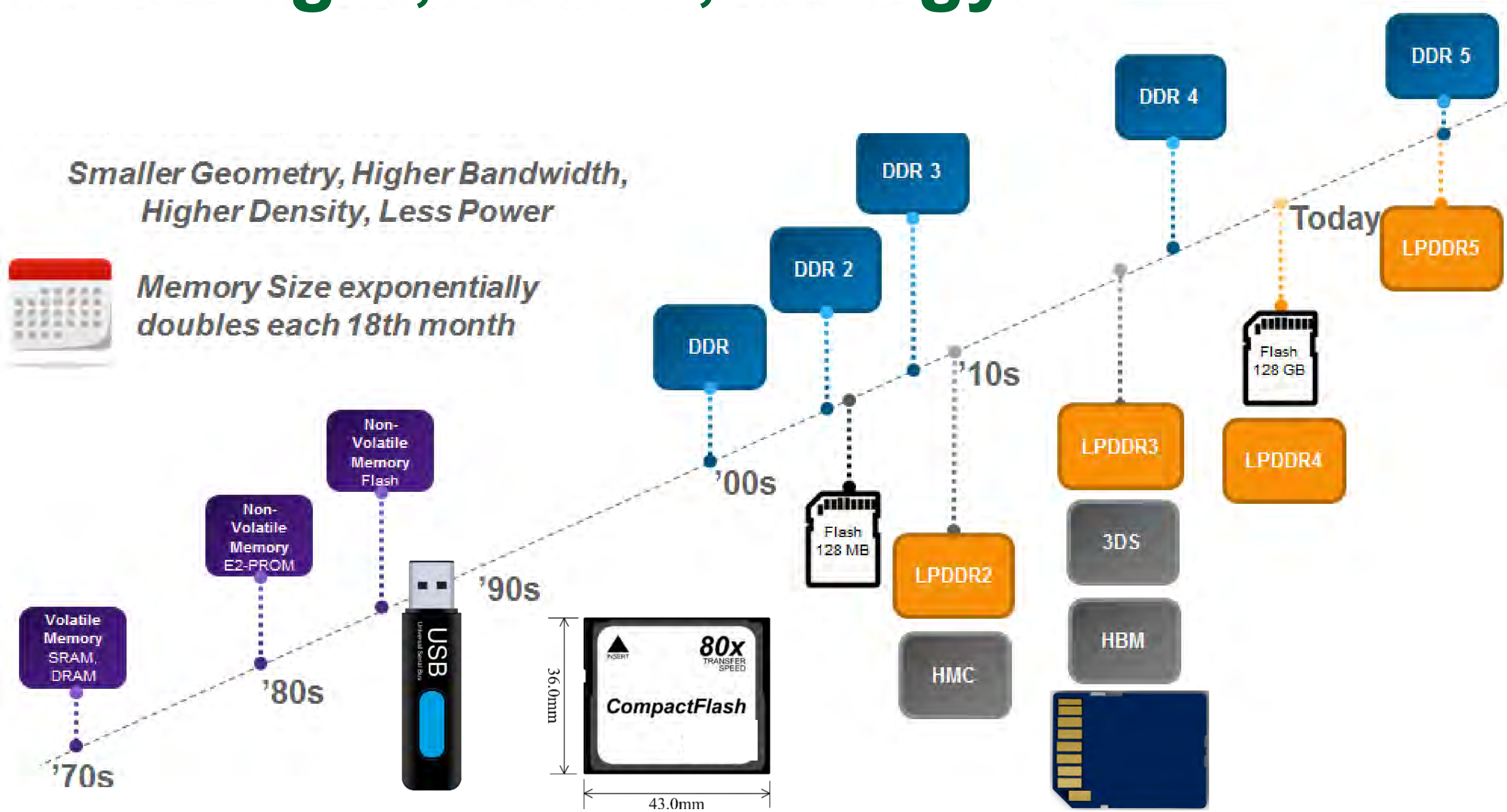
- **BPG compression instead of JPEG?**
- Attributes that differentiate BPG from JPEG and make it an excellent choice include:
  - Meeting modern display requirements: high quality and lower size.
  - BPG compression is based on the High Efficiency Video Coding (HEVC), which is considered a major advance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

JPEG Compression

BPG Compression

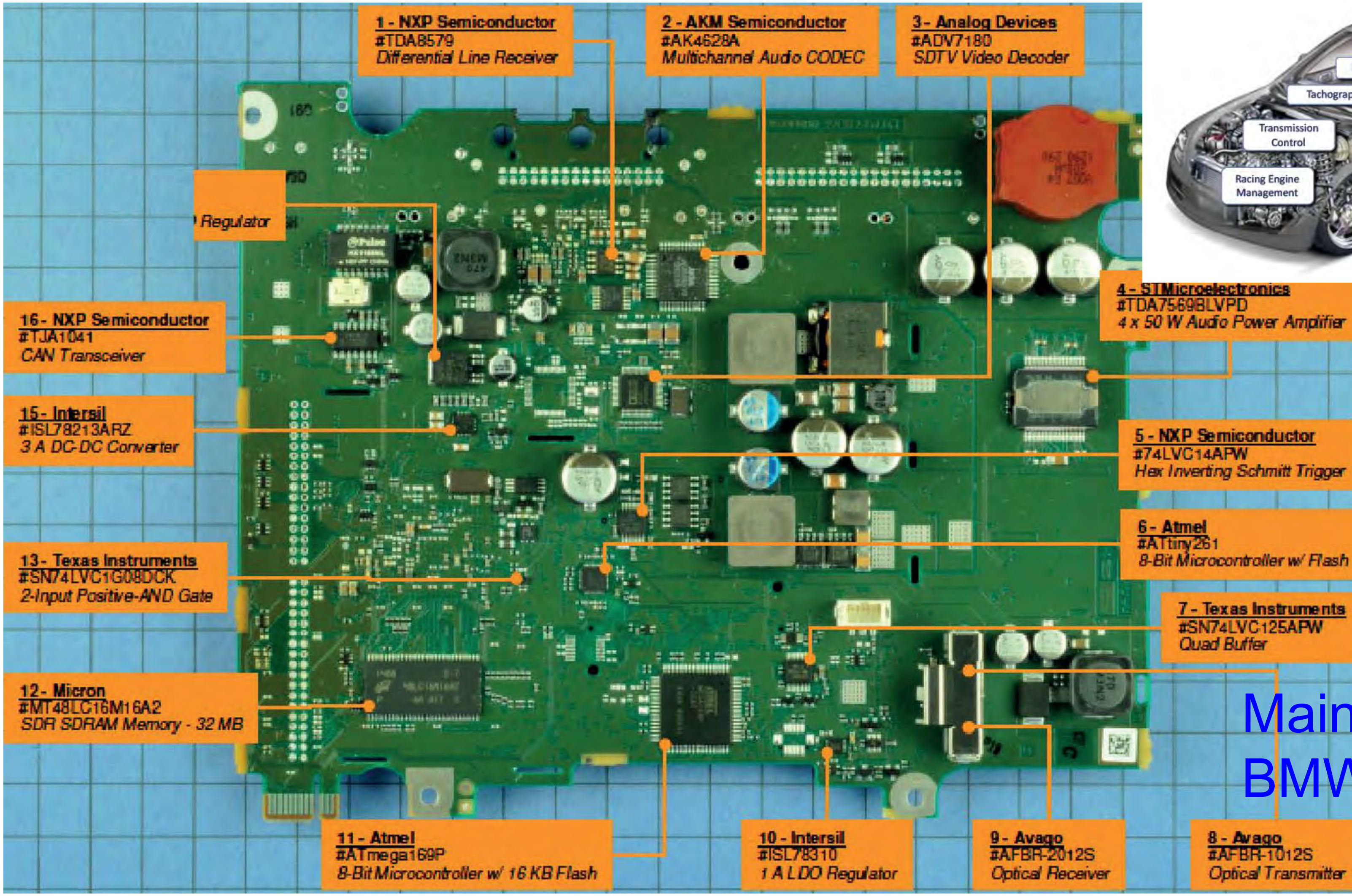
Source: Mohanty 2016, IEEE Access 2016

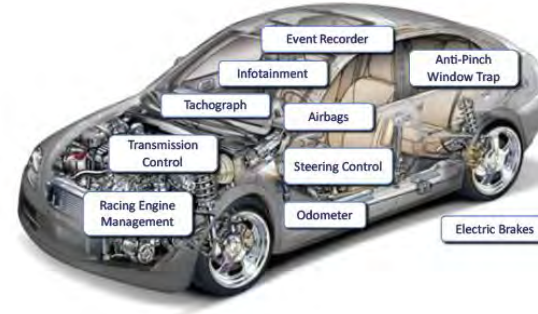
Memory Technology: Cheaper, Larger, Faster, Energy-Efficient



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

Memory Technology – Car Example





Main Board of BMW HBB125.

Source: Coughlin 2016, CE Magazine October 2016

Variety of Computer Memory

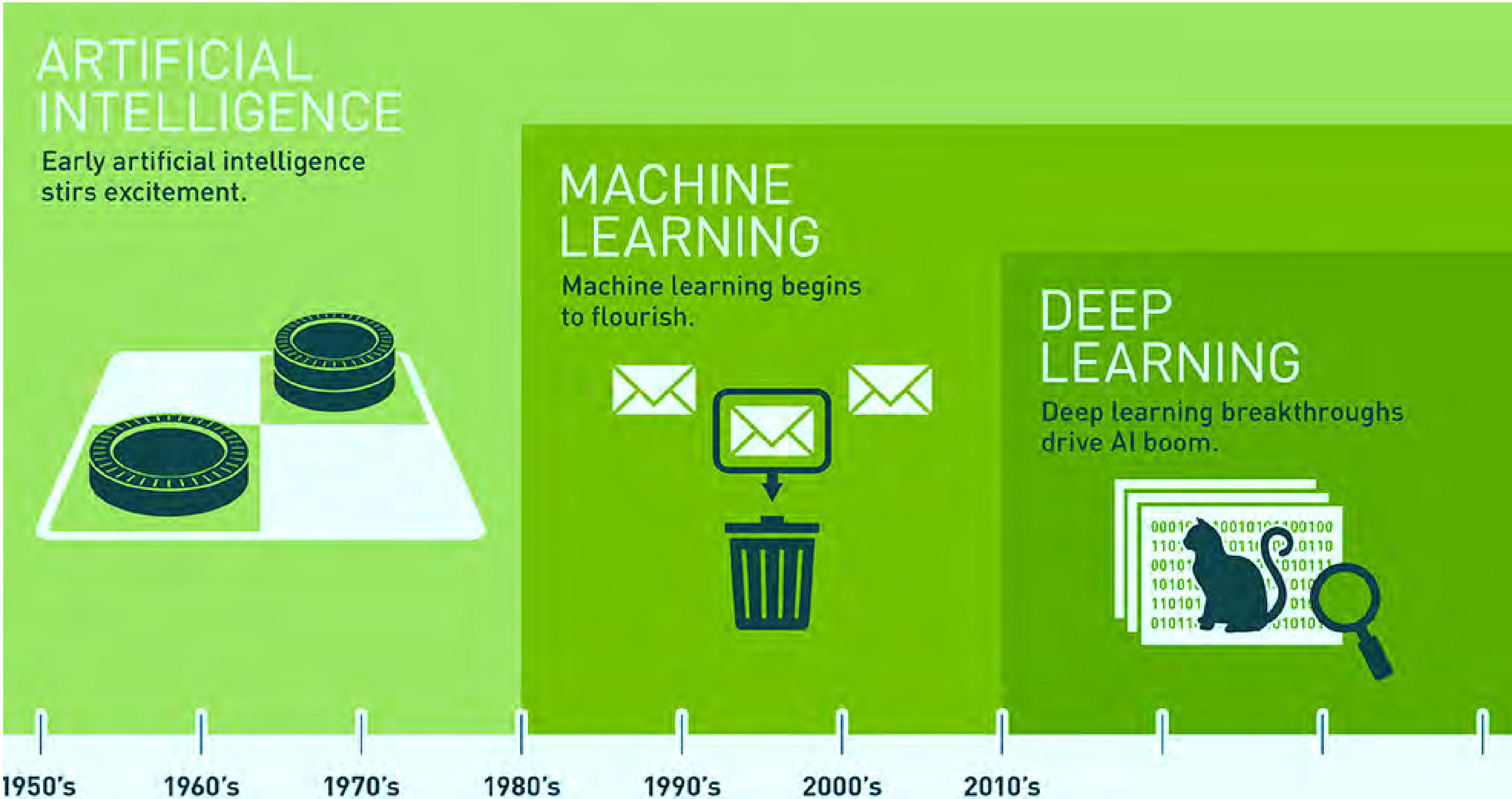
- Computer Memory
  - Based on Storage Capability
    - Volatile
      - Static RAM (SRAM)
      - Dynamic RAM (DRAM)
      - Twin Transistor RAM (TTRAM)
      - Zero-Capacitor RAM (ZRAM)
      - Thyristor RAM (TRAM)
    - Nonvolatile
      - Read-Only Memory (e.g. Programmable ROM (PROM), Erasable PROM (EPROM), Electrically Erasable PROM (EEPROM)
      - Magnetic Storage Hard Disk Drive (HDD)
      - Non-Volatile RAM (NVRAM) (e.g Flash Memory)
      - Resistive RAM (RRAM or ReRAM)
      - Magnetic or Magnetoresistive RAM (MRAM)
      - Phase-Change RAM (PRAM, PCRAM)
      - Conductive Metal Oxide (CMOX) Memory
  - Based on Access
    - Random-Access Memory (RAM)
    - Serial Access Memory (e.g. Shift Registers, Queues)
    - Content Addressable Memory (CAM)

Source: Mohanty 2015, McGraw-Hill 2015

The flash memory market is expected to be worth $37.6 worldwide by 2020.

Source: https://www.statista.com/statistics/553556/worldwide-flash-memory-market-size/

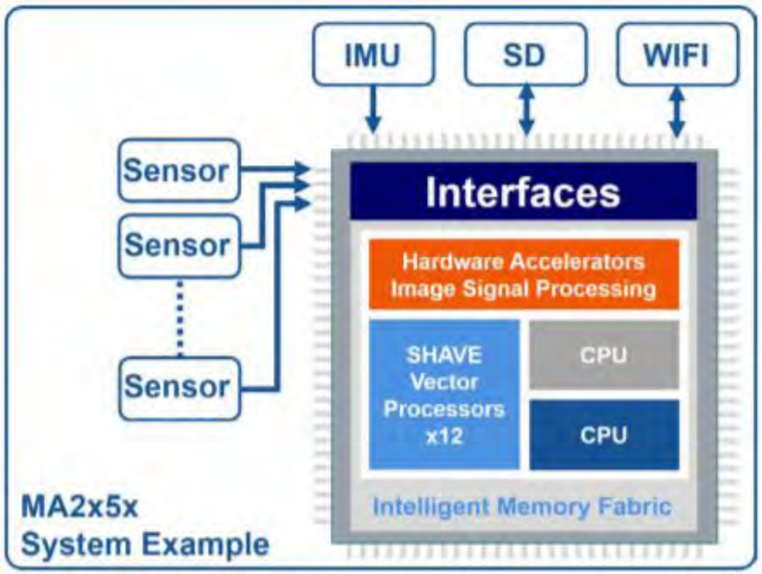
AI, Machine Learning, and Deep Learning



Source: https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

Vision Processing Unit (VPU)

- ➢ High-Performance Machine Vision Processing
- ➢ Deep Neural Network-based Classification
- ➢ Pose Estimation
- ➢ 3D Depth Estimation
- ➢ Visual Inertial Odometry (Navigation)
- ➢ Gesture/Eye Tracking and Recognition



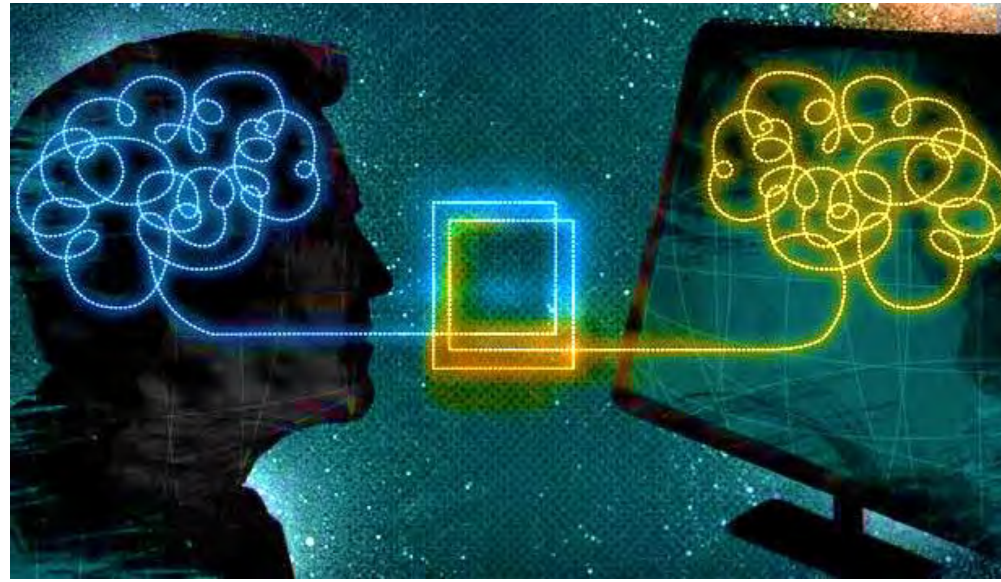
Vision Processing Unit (VPU)

Source: https://www.movidius.com/solutions/vision-processing-unit

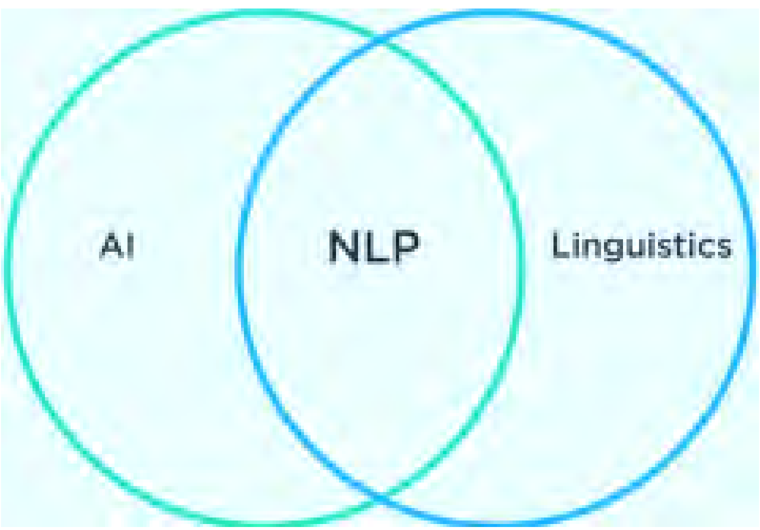
- ❑ Video Processing Unit → Video encoding and decoding
- ❑ Graphics Processing Unit (GPU) → Rasterization and Texture Mapping
- ❑ Vision Processing Unit (VPU) → Machine vision algorithms (e.g. Convolutional Neural Network (CNN)

Natural Language Processing (NLP)

- NLP is the computer method to analyze, understand, and derive meaning from human language.
- Enables user to address computers as if they are communicating with a person.



Source: https://www.linkedin.com/pulse/natural-language-processing-2016-global-market-forecasts-rane



Source: http://blog.algorithmia.com/introduction-natural-language-processing-nlp/

Selected NLP Applications

- Machine Translation
- Information Retrieval
- Text Categorization
- Big Data

Cognitive Computing

The Tabulating Era (1900s – 1940s) | The Programming Era (1950s– present) | The Cognitive Era (2011 –)

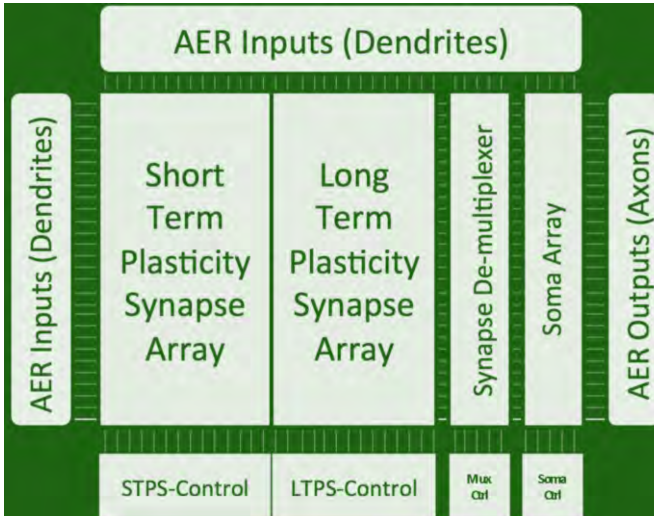
Cognitive Computing: Not just "right" or "wrong" anymore but "probably".

- Systems that learn at scale, reason with purpose and interact with humans naturally.
- Learn and reason from their interactions with humans and from their experiences with their environment; not programmed.

Usage:
- AI applications
- Expert systems
- Natural language processing
- Robotics
- Virtual reality

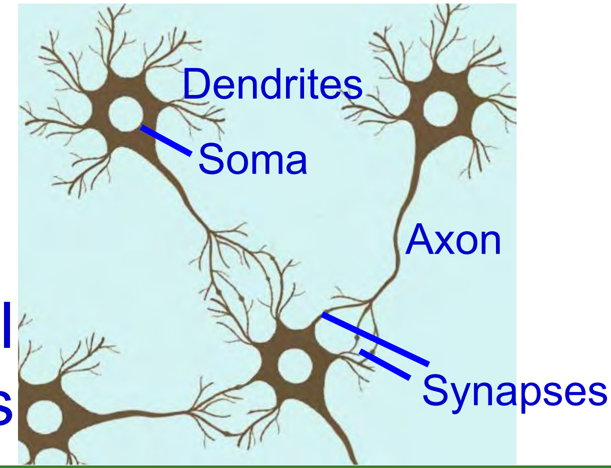
Source: http://www.research.ibm.com/software/IBMResearch/multimedia/Computing_Cognition_WhitePaper.pdf

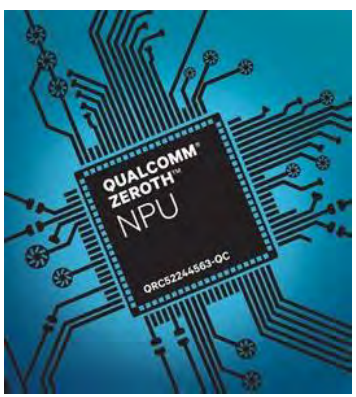
Neuromorphic Computing or Brain-Inspired Computing



Neuromorphic Architecture

Neuronal Circuits





Processing Powers MIT Technical Review

Types of Chips	Functions	Applications
Traditional Chips (von Neumann Architecture)	Reliably make precision calculations	Any numerical problem, Complex problems require more amount of energy
Neuromorphic Chips	Detect and Predict Patterns in complex data using minimal energy	Applications with significant visual/ auditory data requiring a system to adjust its behavior as it interacts with the world

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

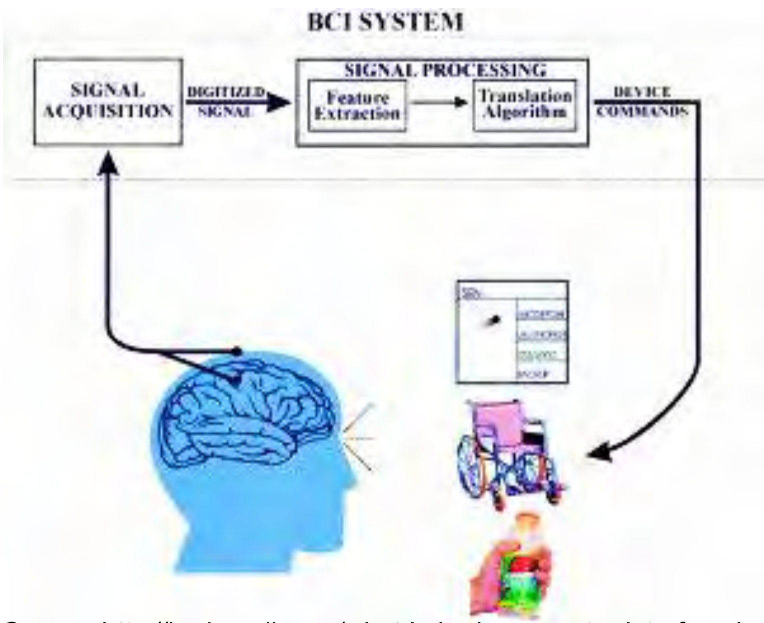
Neuromorphic Computing or Brain-Inspired Computing

Application 1: Integrate into assistive glasses for visually impaired people for navigating through complex environments, even without the need for a WiFi connection.

Application 2: Neuromorphic-based, solar-powered "sensor leaves" equipped with sensors for sight, smell or sound can help to monitor natural disasters.

Source: https://blogs.scientificamerican.com/observations/brain-inspired-computing-reaches-a-new-milestone/

Brain Computer Interface (BCI)



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

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

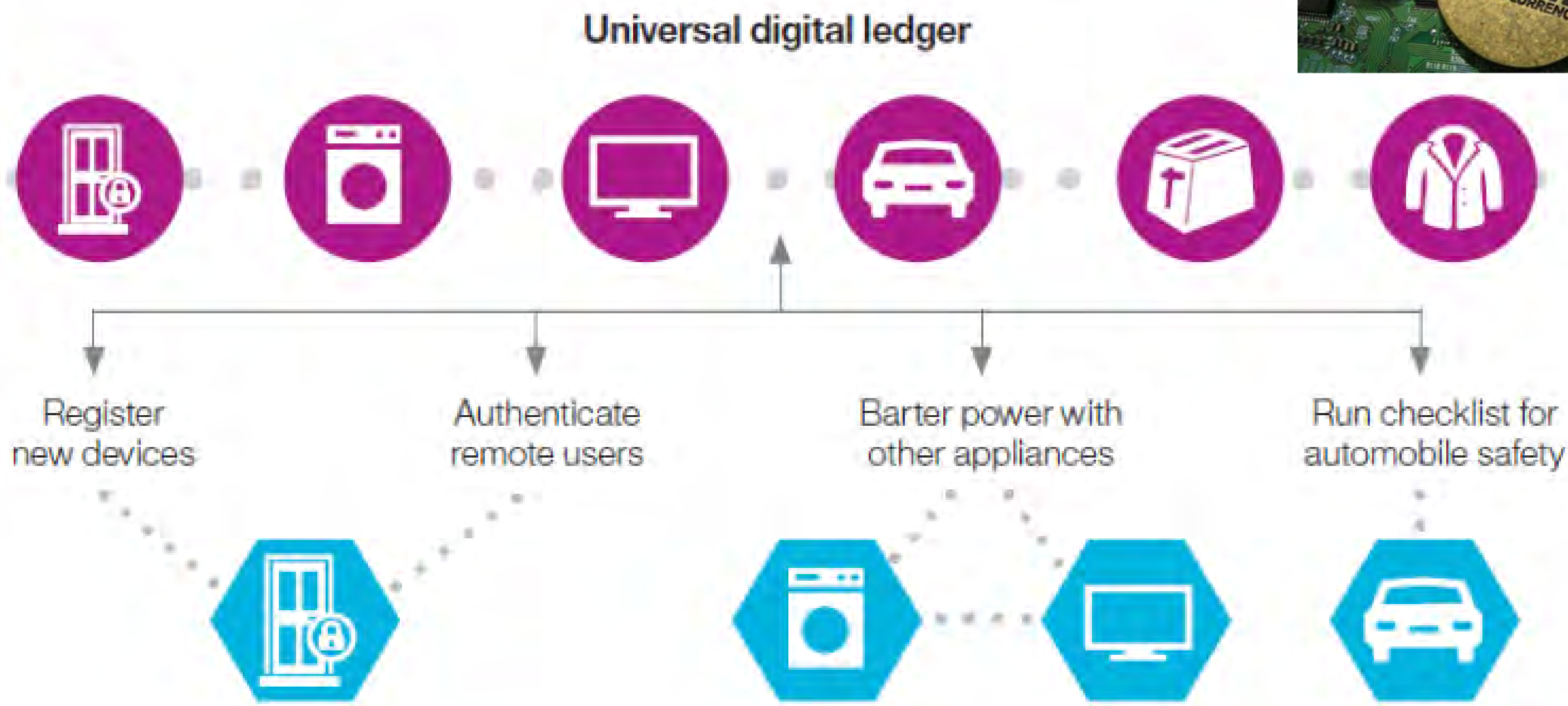
Brain-Computer Interface Allows paralysis patients to Type Faster

"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/

Blockchain Technology



- Think of it as cloud based peer to peer ledger.
- A Blockchain is a cloud based database shared by every participant in a system.
- The Blockchain contains the complete transaction or other record keeping.

Source: https://www.linkedin.com/pulse/securing-internet-things-iot-blockchain-ahmed-banafa
Refer: Puthal, Mohanty 2018, CE Magazine March 2018

Natural User Interface (NUI)

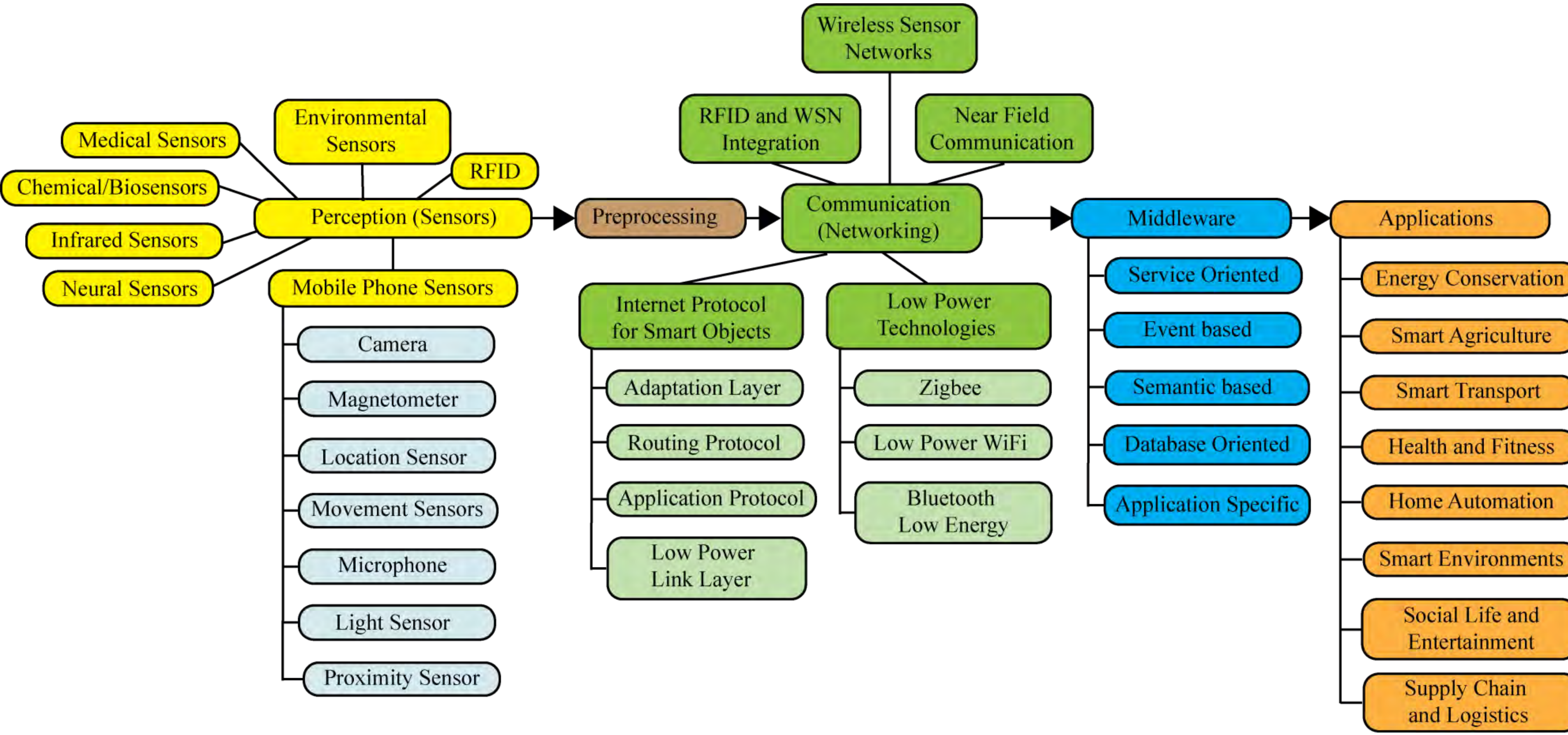
NUI : User interfaces where the interaction is direct and consistent with our “natural” behavior.

Microsoft Kinect

Source: https://www.interaction-design.org/literature/article/natural-user-interfaces-what-are-they-and-how-do-you-design-user-interfaces-that-feel-natural

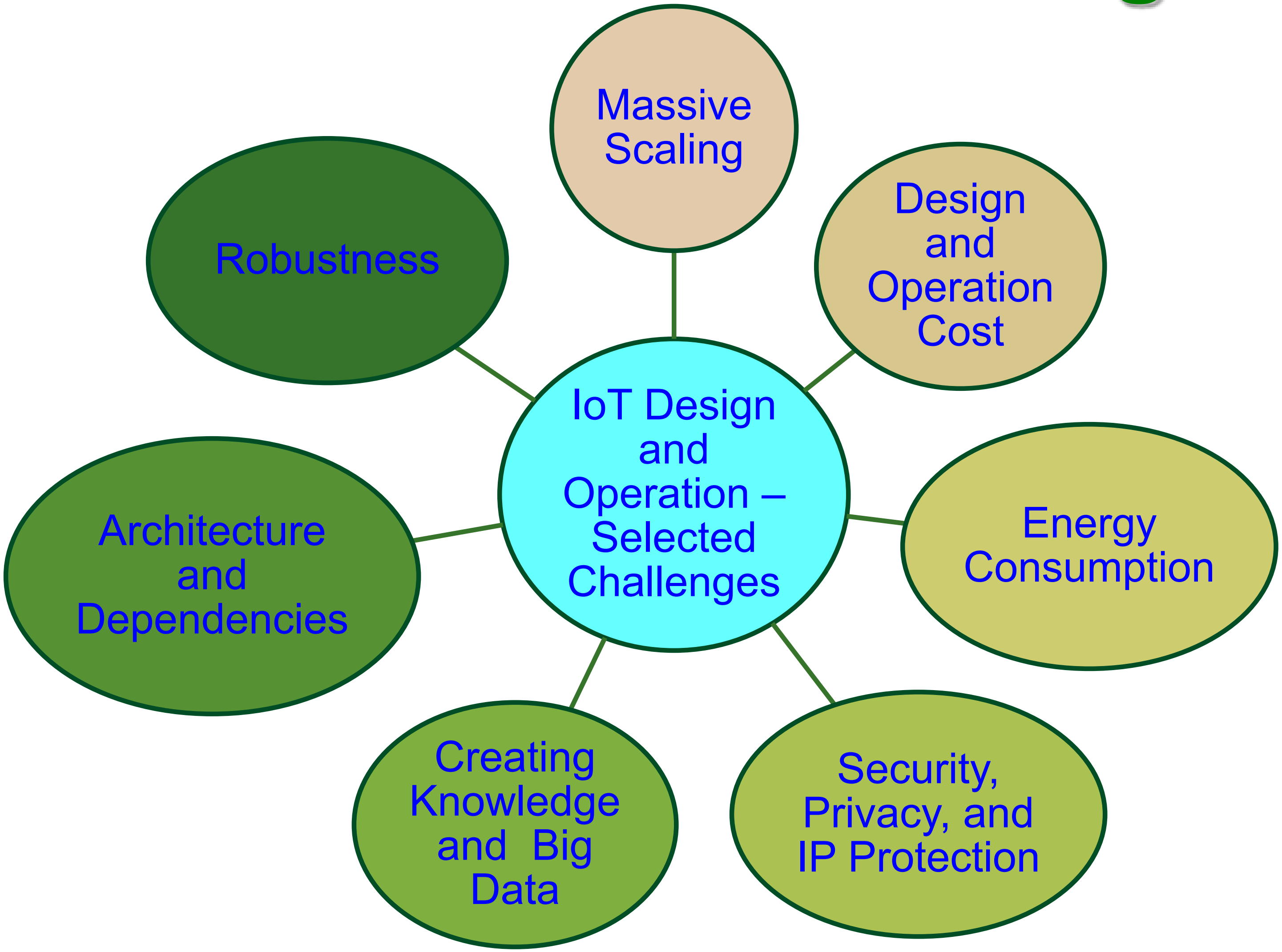
Challenges and Research

IoT – Multidiscipline Research



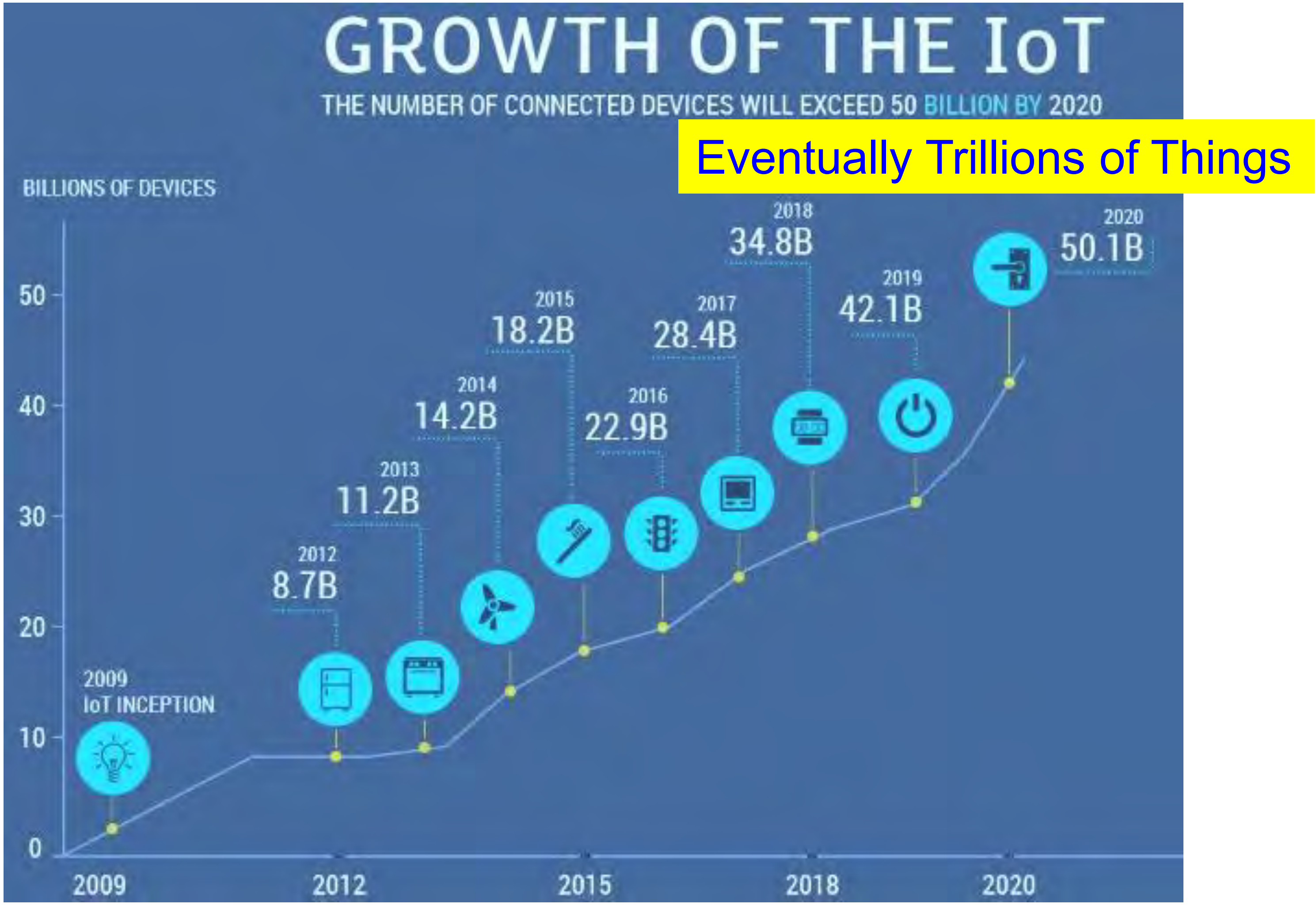
Source: Sethi 2017, JECE 2017

IoT – Selected Challenges



Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

Massive Scaling



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

High 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

Communication Latency and Energy Consumption

- Connected cars require latency of ms to communicate and avoid impending crash.
  - Faster connection
  - Low latency
  - Lower power
- 5G for connected world: This enables all devices to be connected seamlessly.
- How about 5G, WiFi working together more effectively?

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

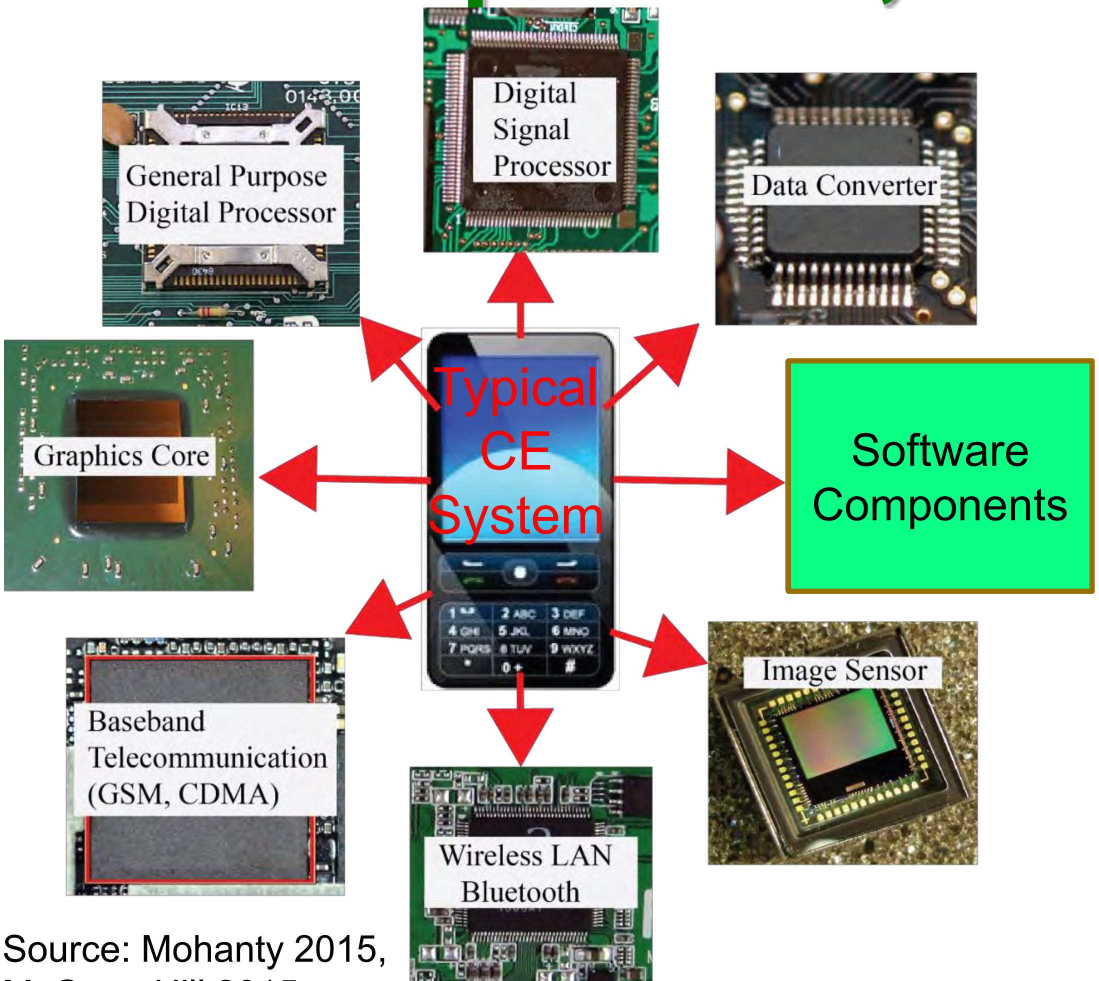
Impact of High Energy Consumption

Source: Mohanty 2015, McGraw-Hill 2015

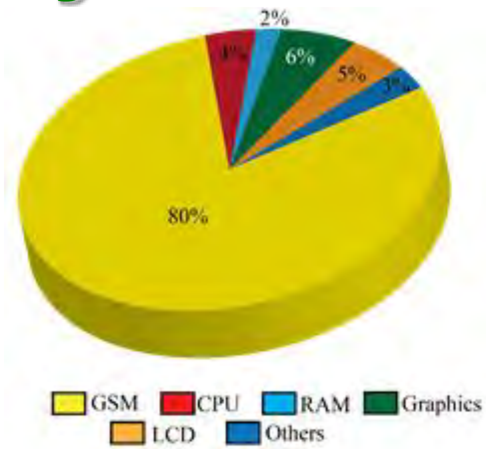
- Great idea: Smartwatch with functioning like smartphone.
- Big Problem: Battery life of one time charging is only 1 day.

Source: Mohanty 2013, CARE 2013 Keynote

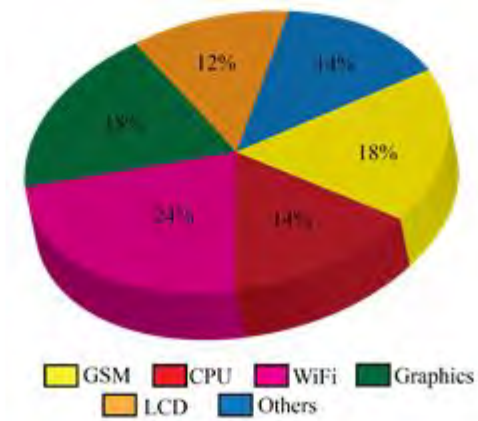
Energy Consumption of Sensors, Components, and Systems



Source: Mohanty 2015, McGraw-Hill 2015



During GSM Communications

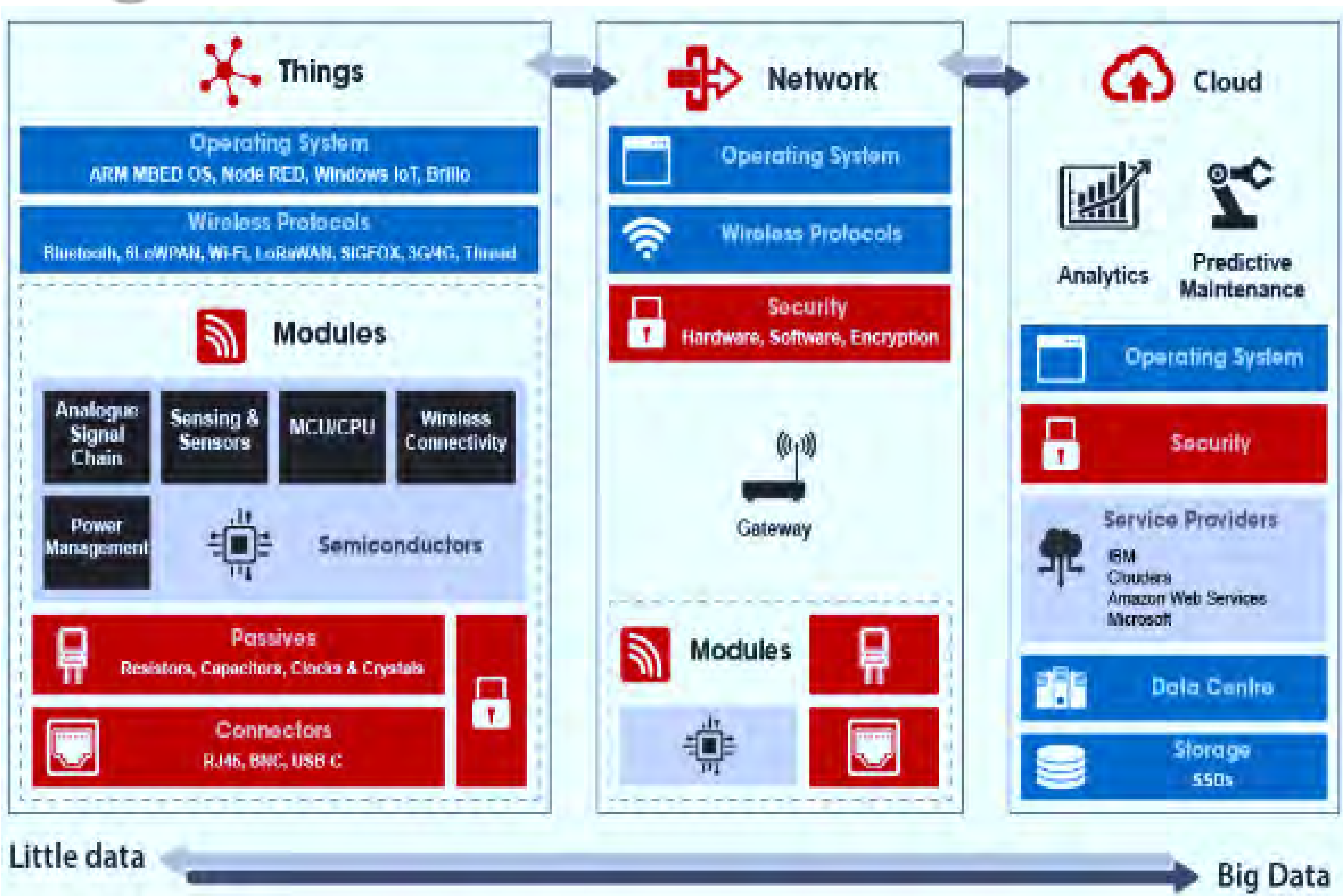


During WiFi Communications

Data is Most Valuable

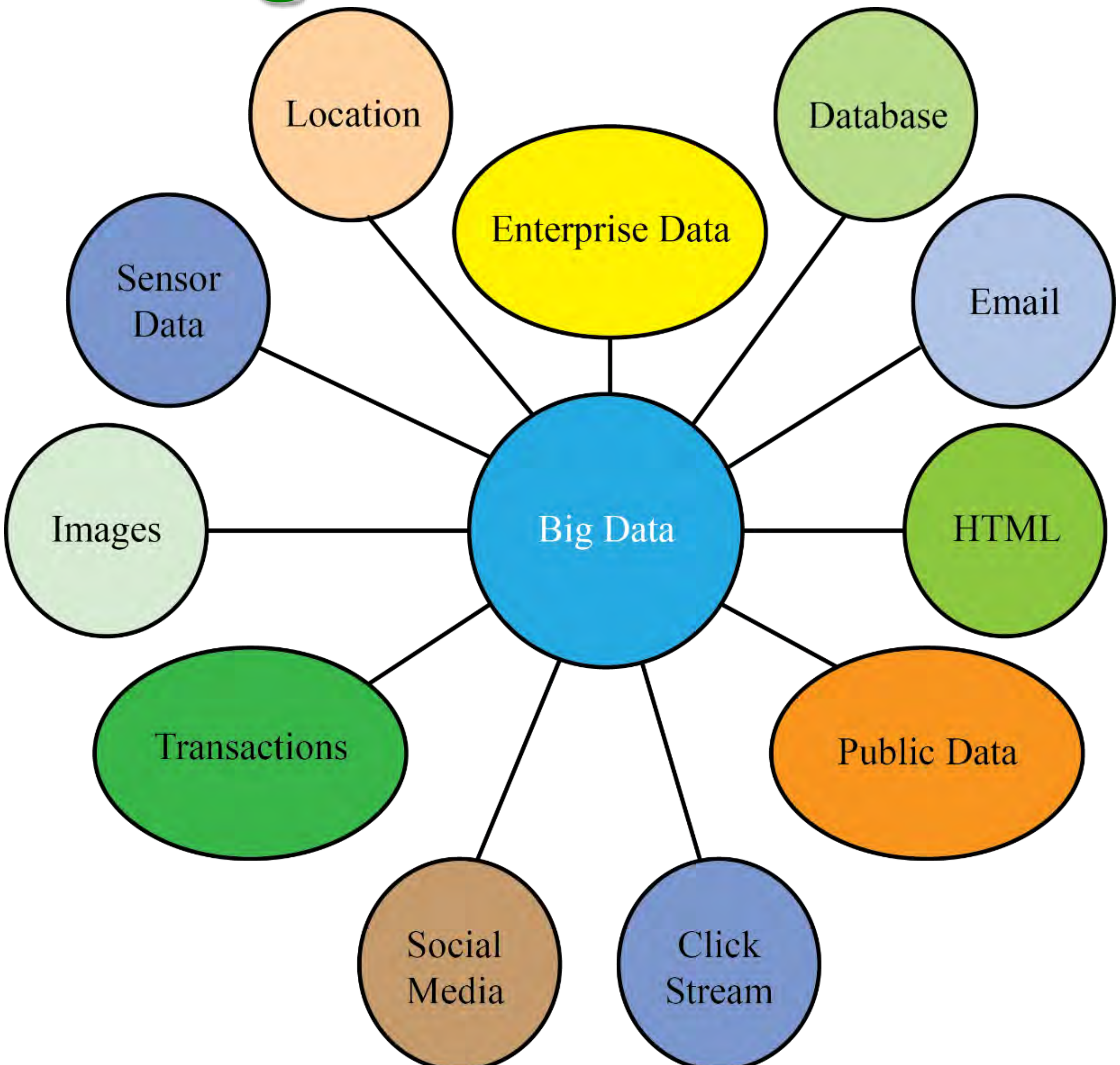
Source: http://www.economist.com/news/leaders/21721656-data-economy-demands-new-approach-antitrust-rules-worlds-most-valuable-resource

Bigdata in IoT and Smart Cities



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

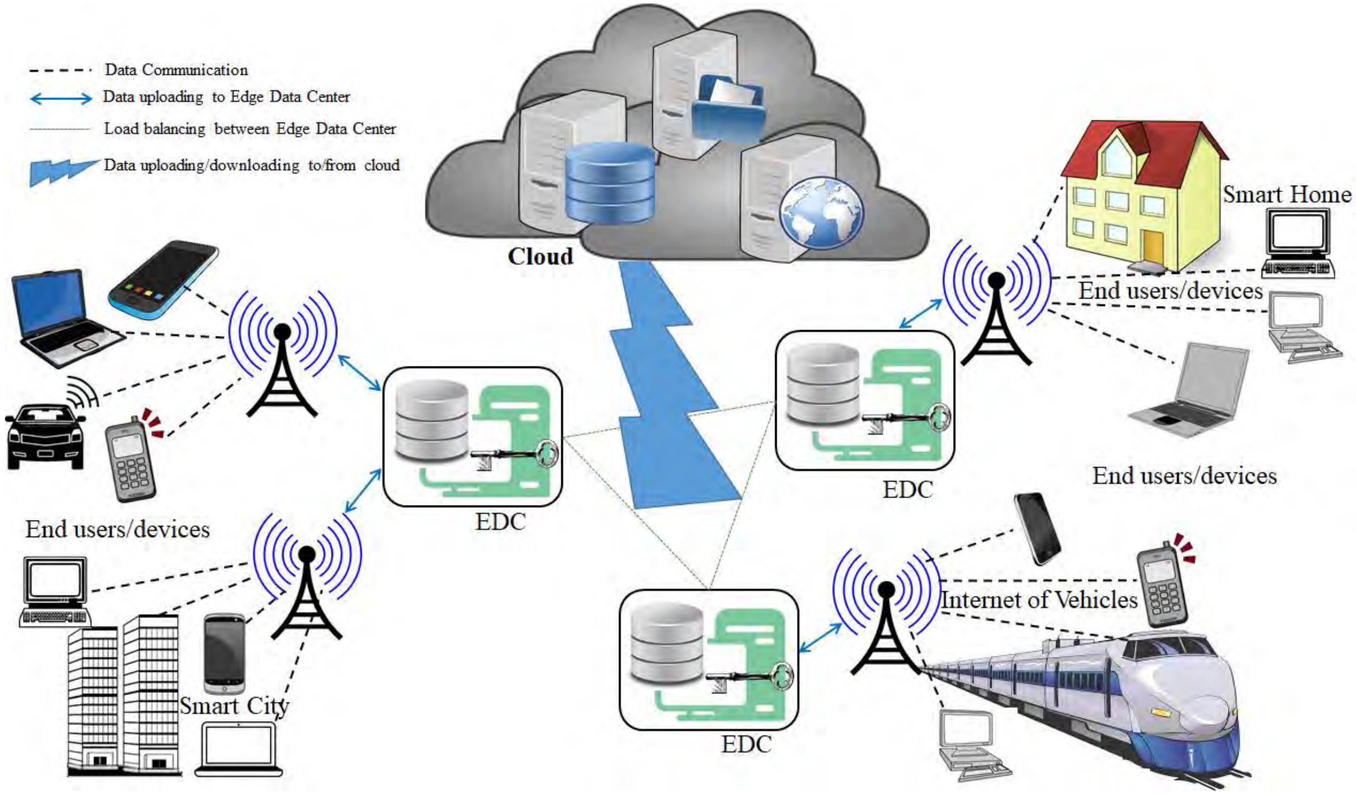
Bigdata in IoT and Smart Cities

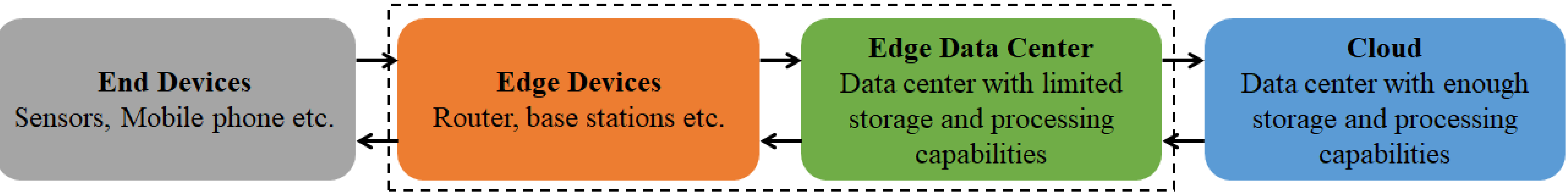


Sensors, social networks, web pages, image and video applications, and mobile devices generate more than 2.5 quintillion bytes data per day.

Source: Mohanty 2016, CE Magazine July 2016

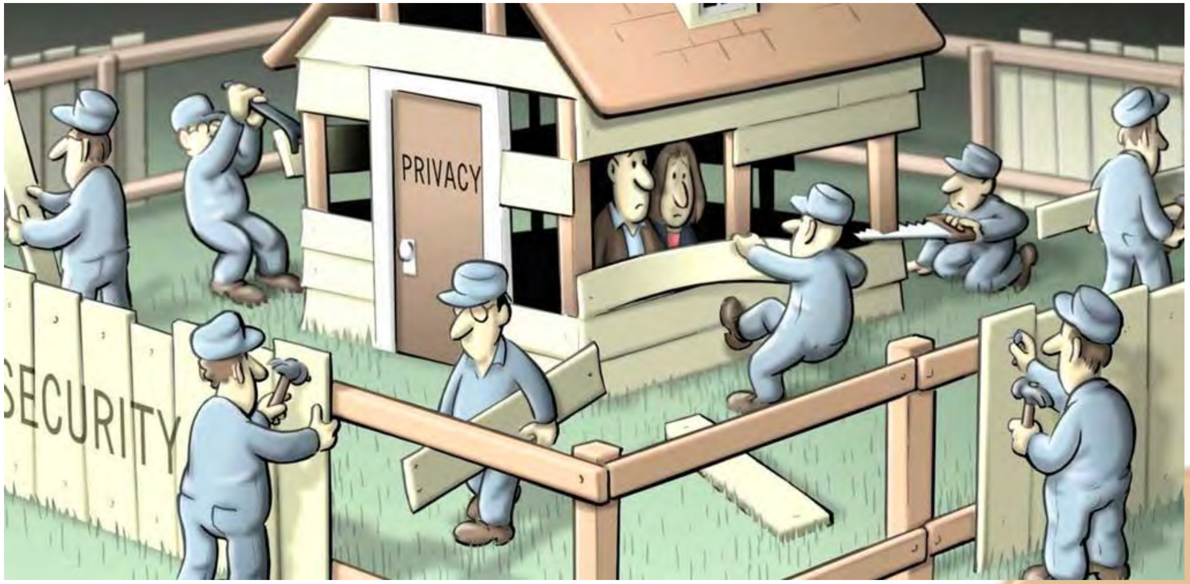
Big Data - Edge Datacenter

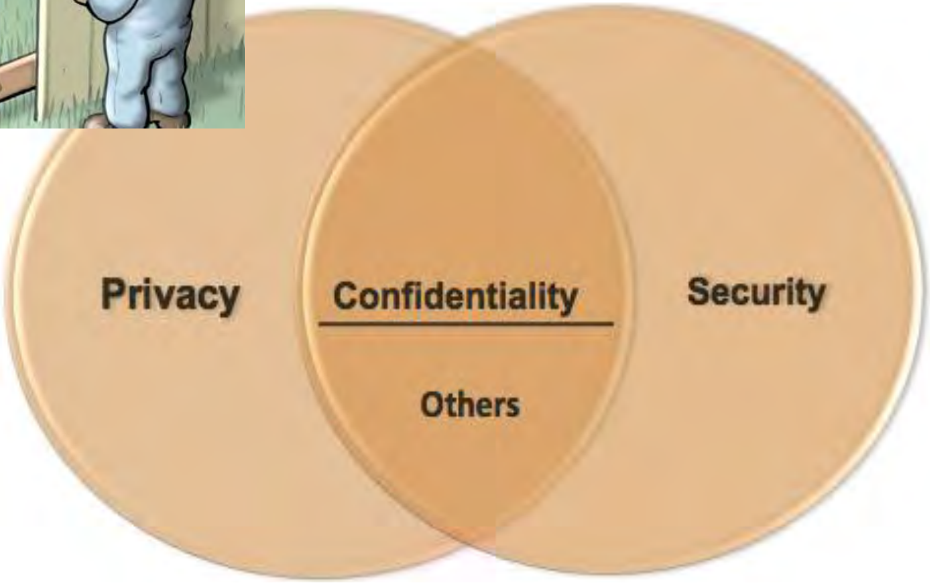




Source: Puthal, Mohanty 2018, IEEE Comm. Magazine May 2018

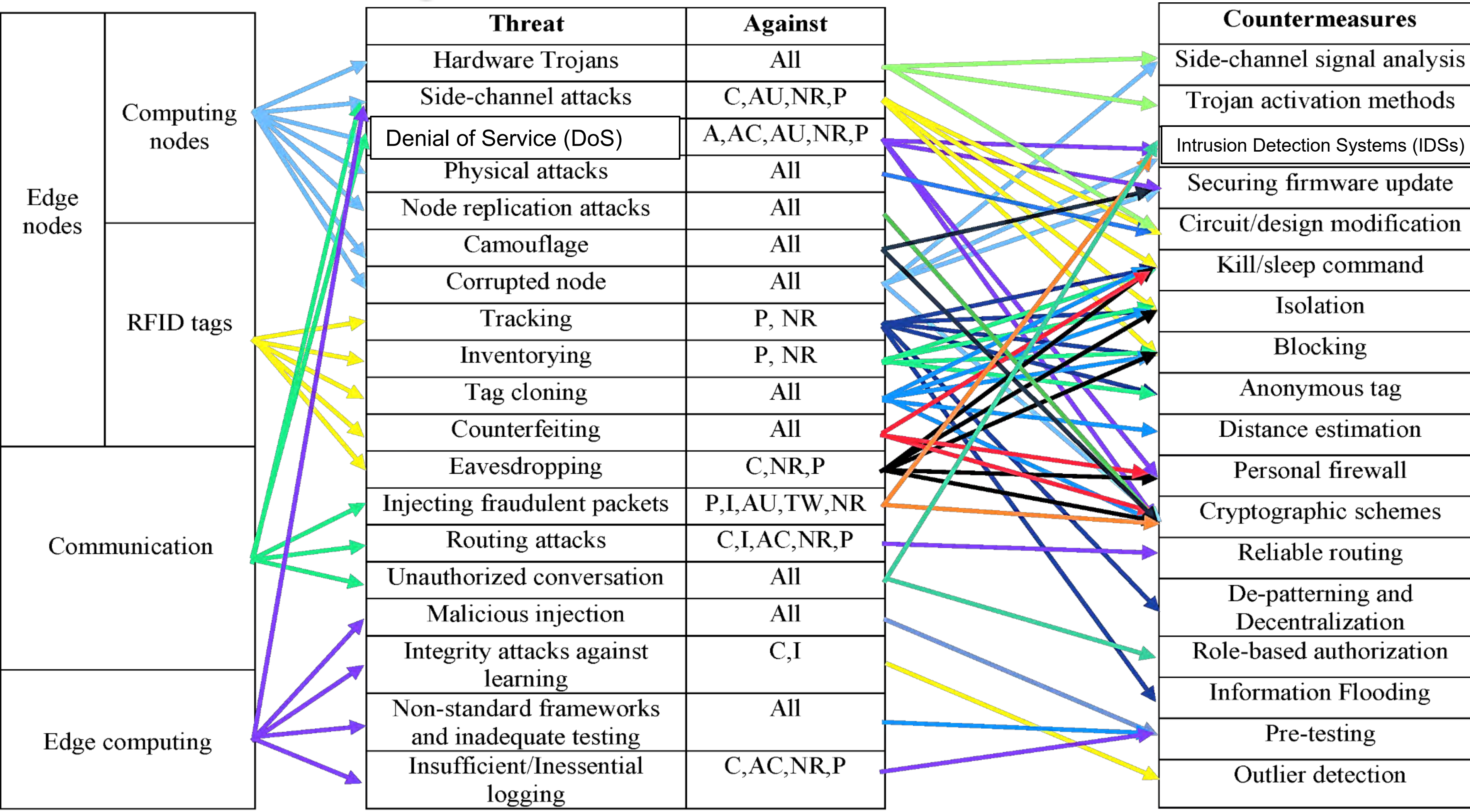
Security, Privacy, IP Rights





Source: https://blogs.deusto.es/master-informatica/privacidad-vs-seguridad/

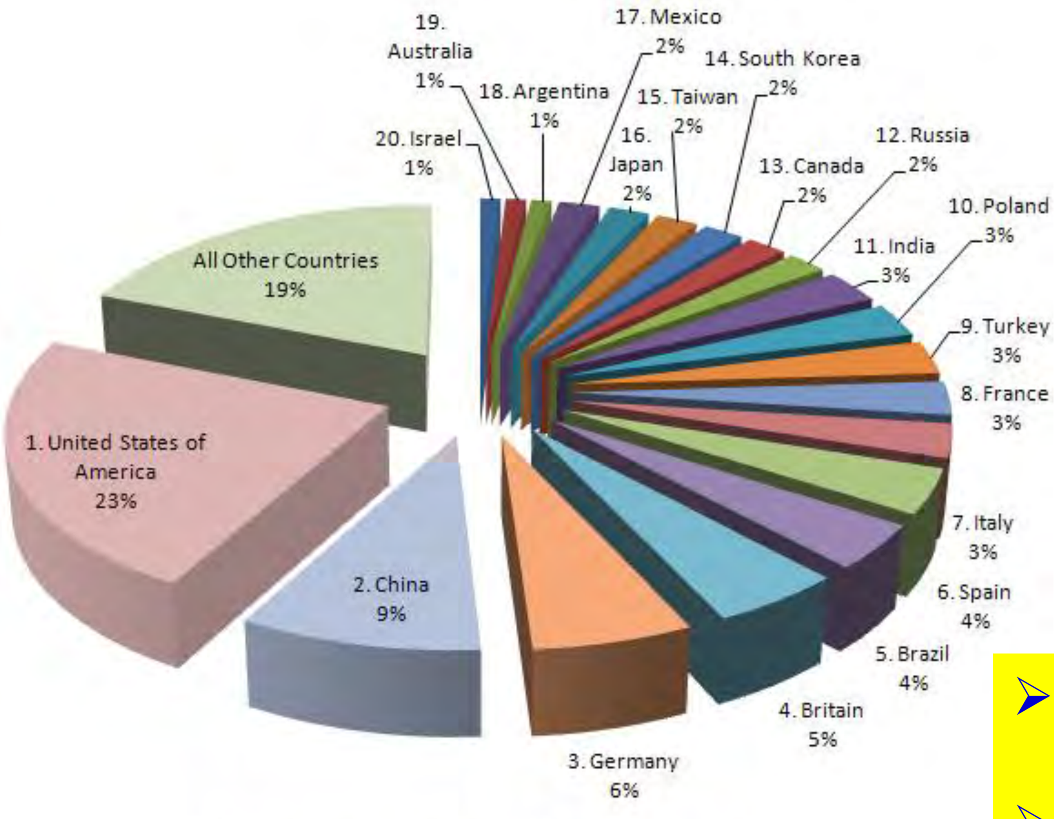
IoT Security - Attacks and Countermeasures



C- Confidentiality, I – Integrity, A - Availability, AC – Accountability, AU – Auditability, TW – Trustworthiness, NR - Non-repudiation, P - Privacy

Source: Nia 2017,IEEE TETC 2017

Security - Information, System



Cybercrime: Top 20 Countries

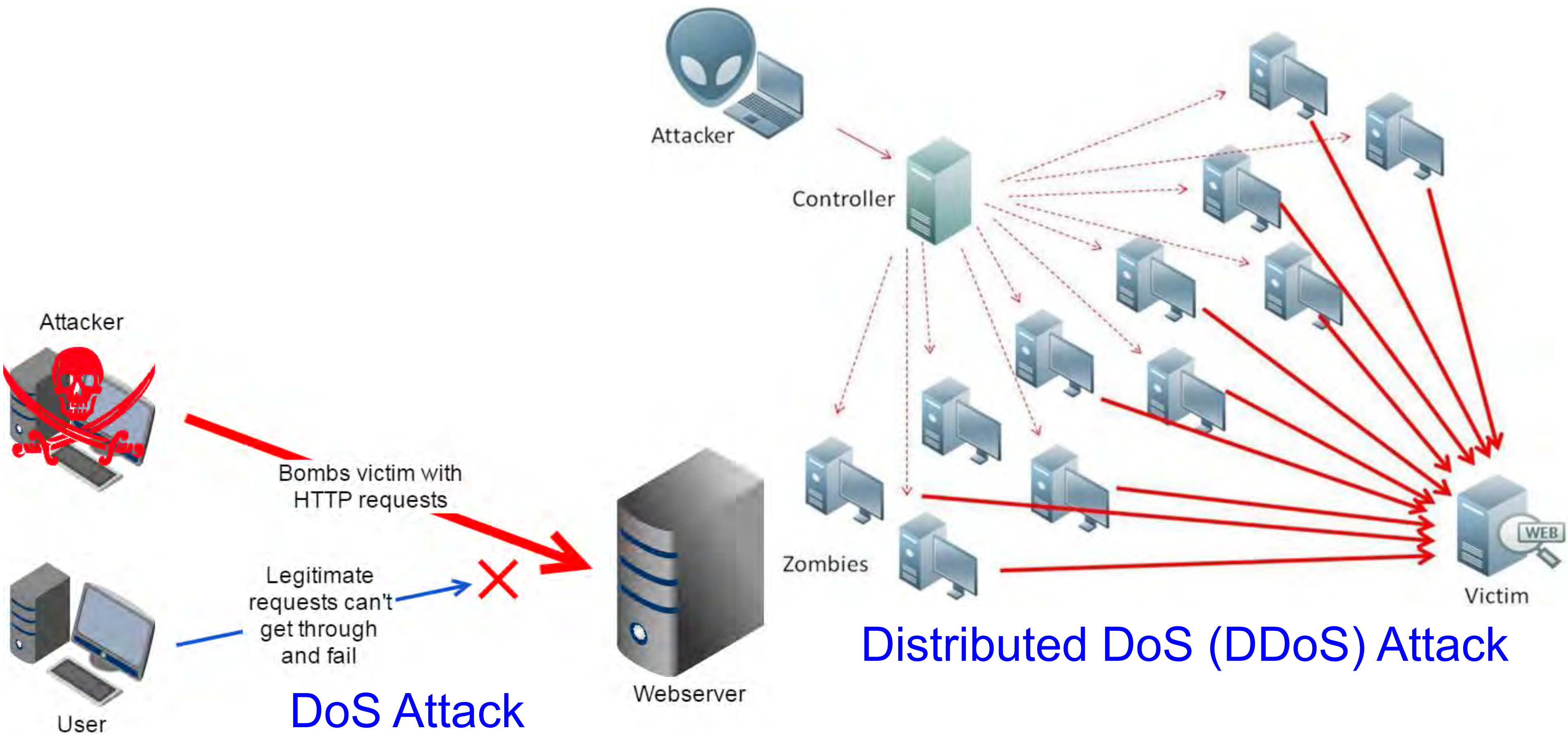
Source: https://www.enigmasoftware.com/top-20-countries-the-most-cybercrime/

- Cybercrime damage costs to hit $6 trillion annually by 2021
- Cybersecurity spending to exceed $1 trillion from 2017 to 2021

Source: http://www.csoonline.com/article/3153707/security/top-5-cybersecurity-facts-figures-and-statistics-for-2017.html

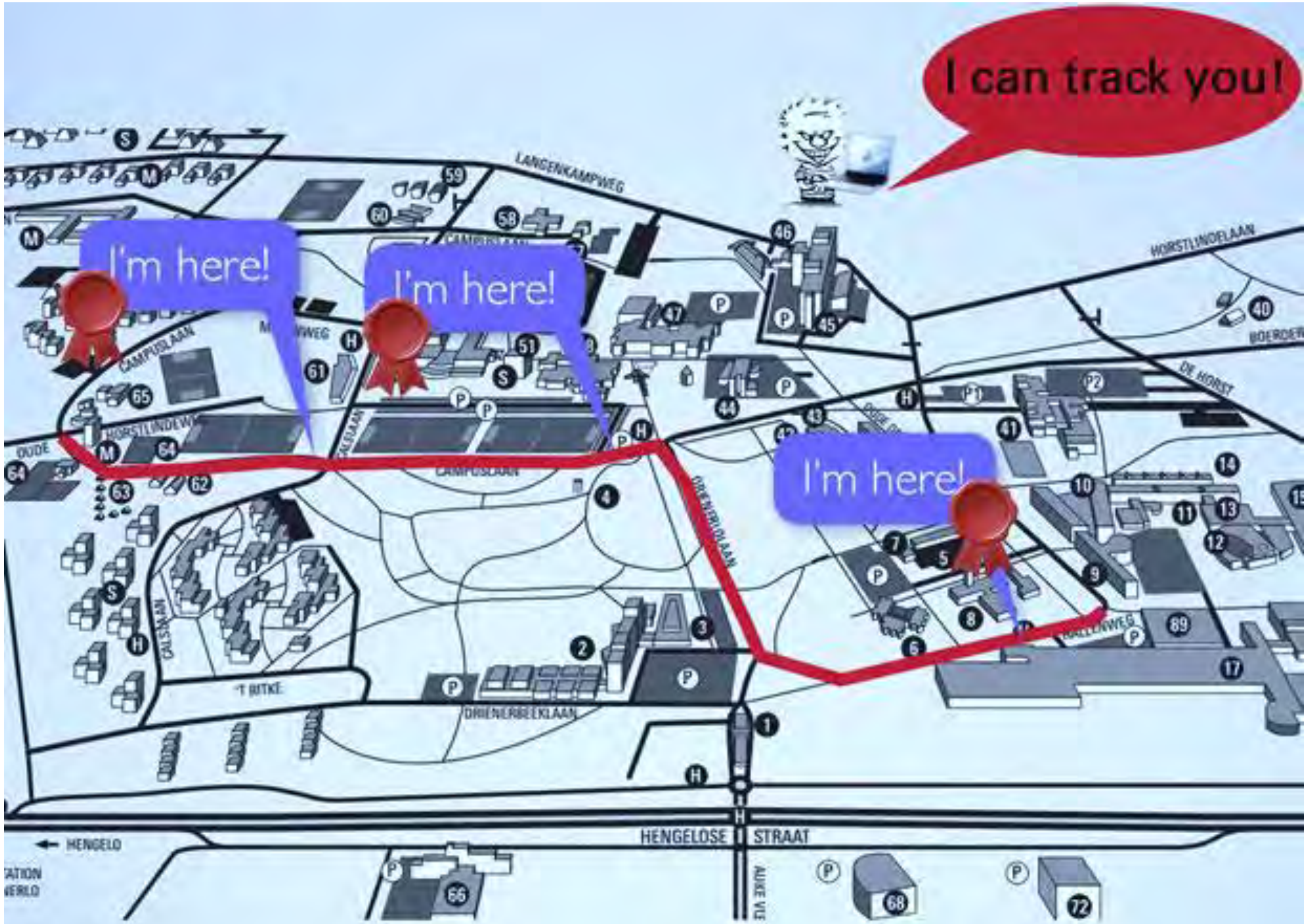
Security in Communications Technology

Denial-of-Service (DoS) Attacks



Source: https://bogner.sh/2015/05/analysing-a-denial-of-service-attack-tool/

Autonomous Car – Privacy Venerability



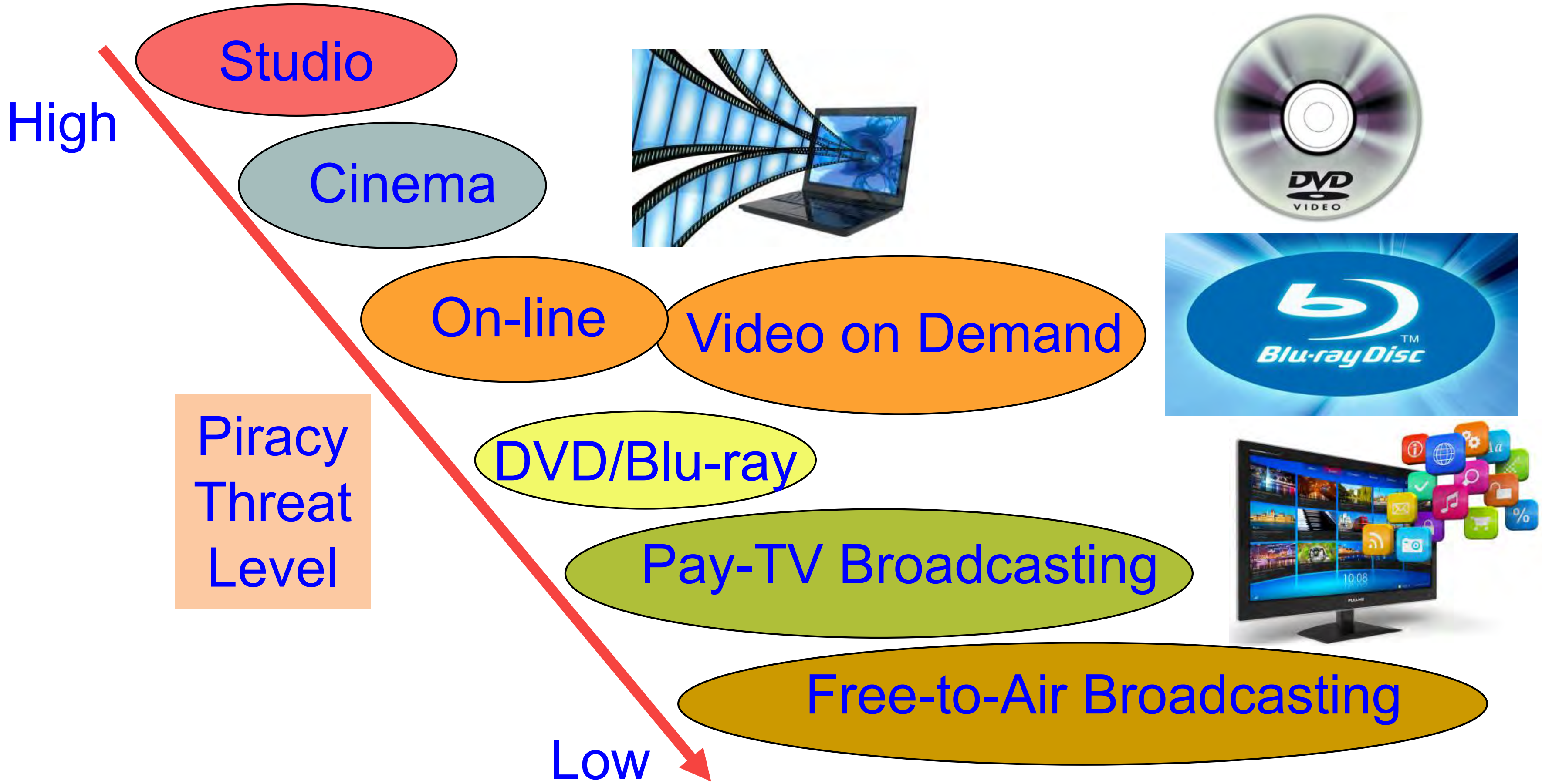
Source: http://www.computerworld.com/article/3005436/cybercrime-hacking/black-hat-europe-it-s-easy-and-costs-only-60-to-hack-self-driving-car-sensors.html

Smart Healthcare - Security and Privacy Issue

Selected Smart Healthcare Security/Privacy Challenges

- Data Eavesdropping
- Data Confidentiality
- Data Privacy
- Location Privacy
- Identity Threats
- Access Control
- Unique Identification
- Data Integrity

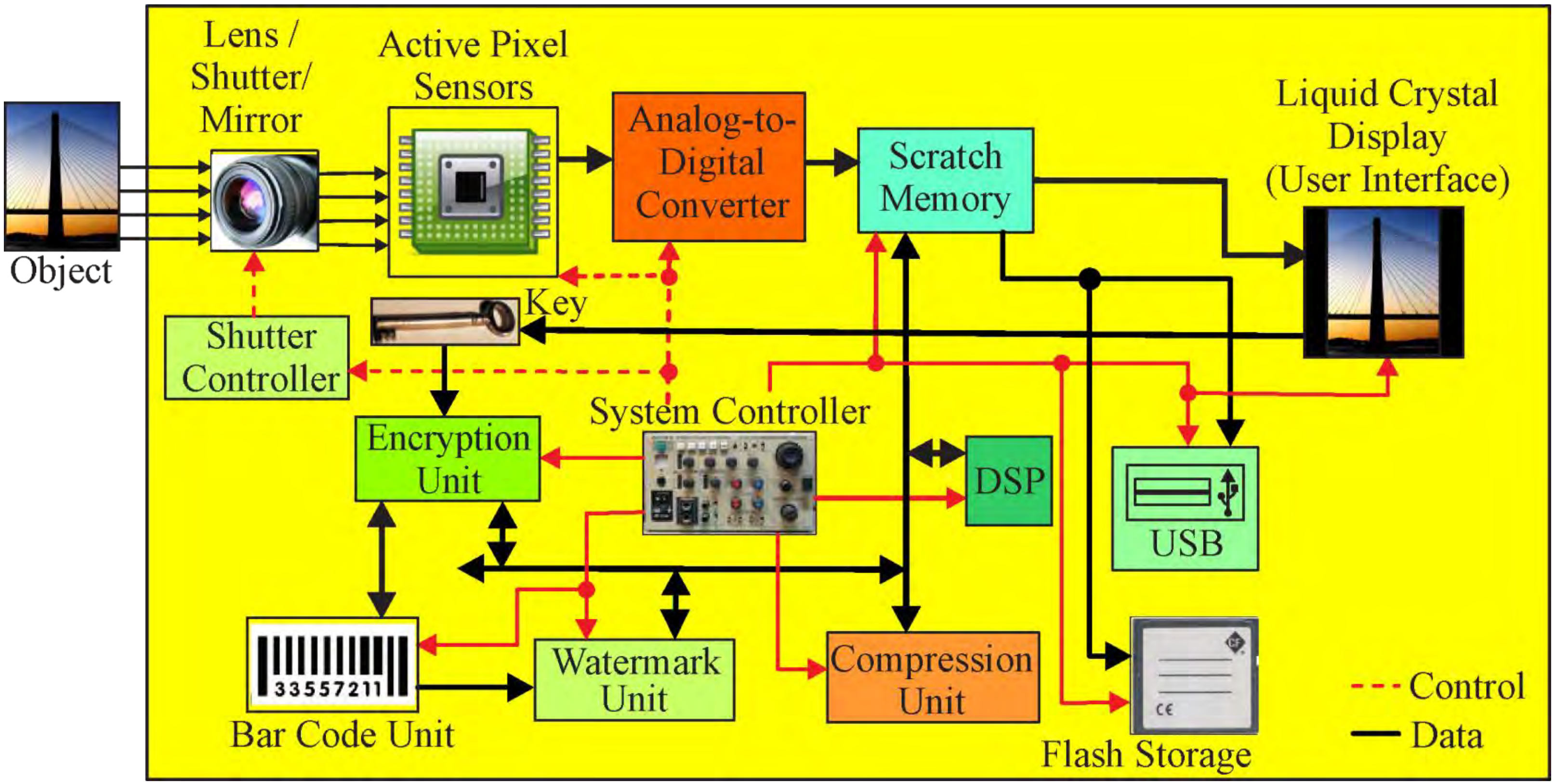
Multimedia Piracy – Movie/Video



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

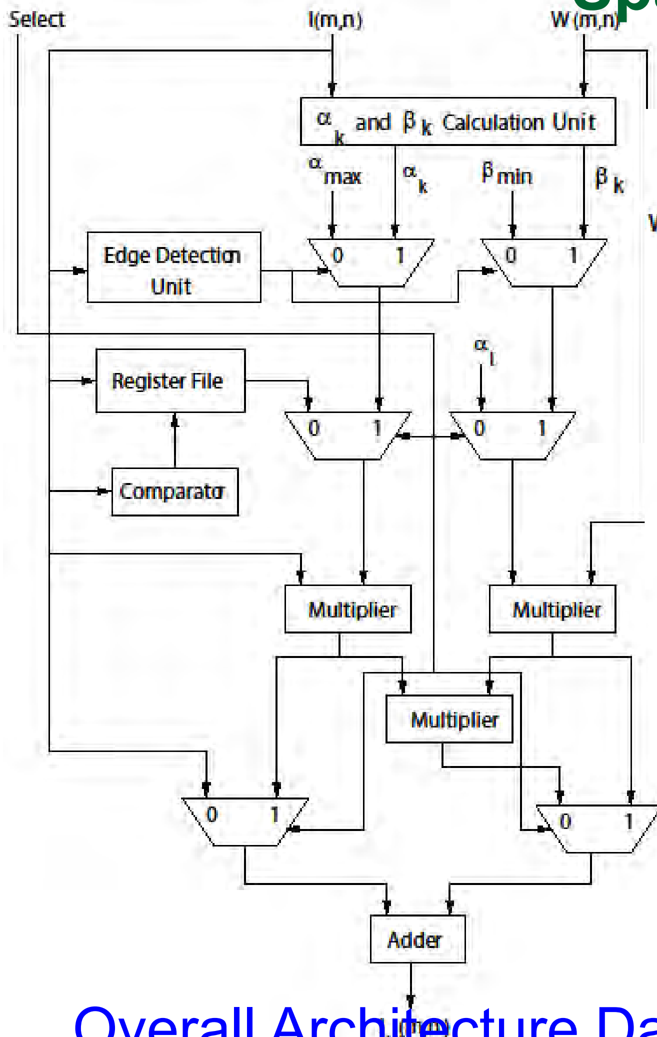
Source: http://www.ipi.org/ipi_issues/detail/illegal-streaming-is-dominating-online-piracy

A DRM Hardware Integrated CE System – Secure Digital Camera (SDC) Example

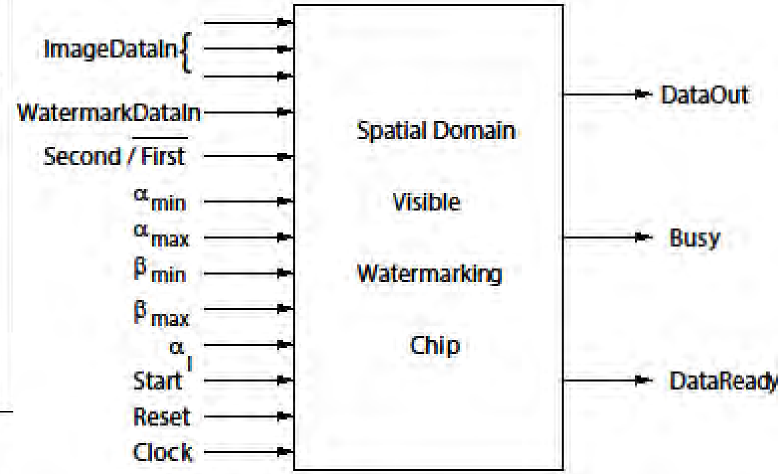


Source: Mohanty 2017, CE Magazine July 2017; Mohanty 2009, JSA Oct 2009

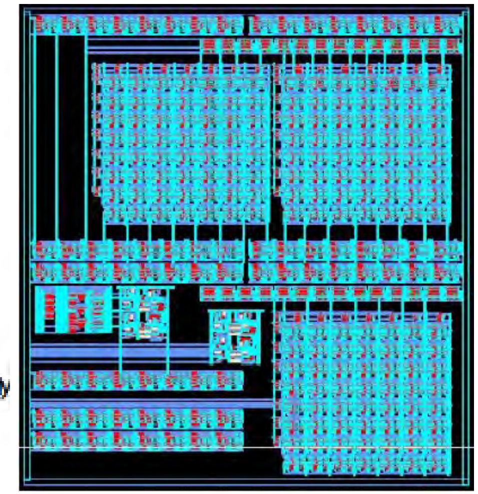
Copyright Protection Hardwares – Spatial Domain Watermarking



Overall Architecture Datapath



Chip Pin Diagram



Hardware Layout

Physical Design Data

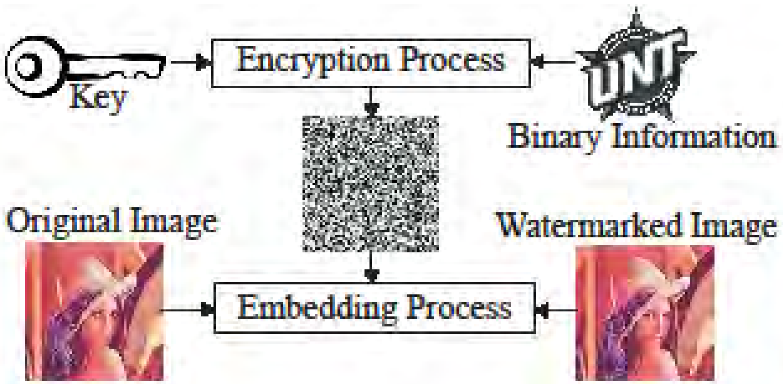
Total Area : 9.65 sq mm

No. of Gates: 28469

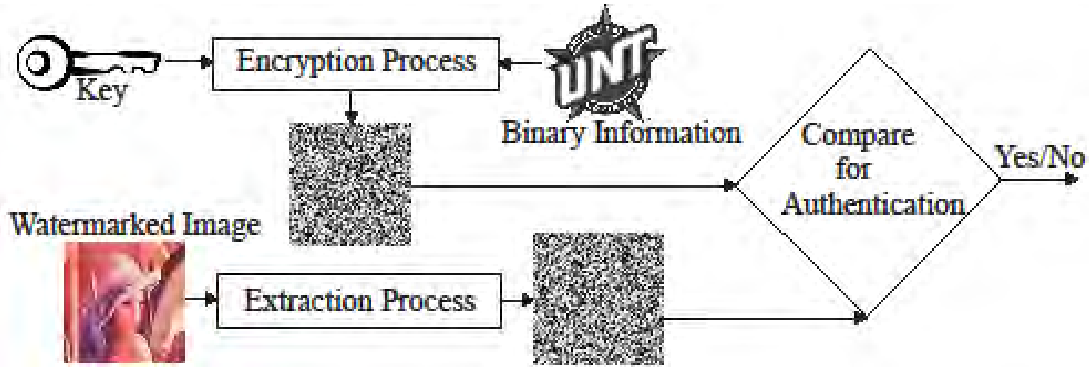
Power consumption: 6.92 mW

Source: Mohanty 2005, TVLSI Aug 2005

DRM Hardwares – CyptMark: Encryption + Watermarking

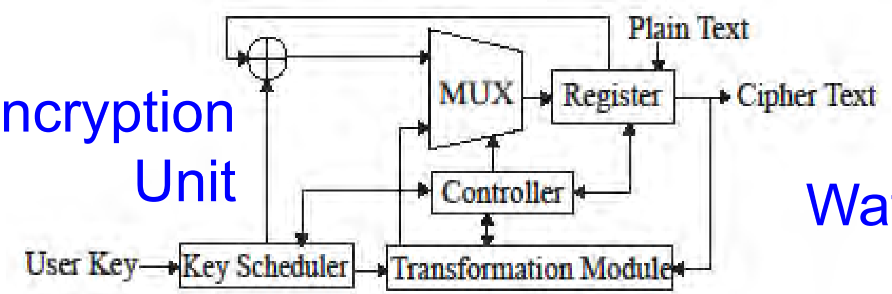


CryptMark: Embedding

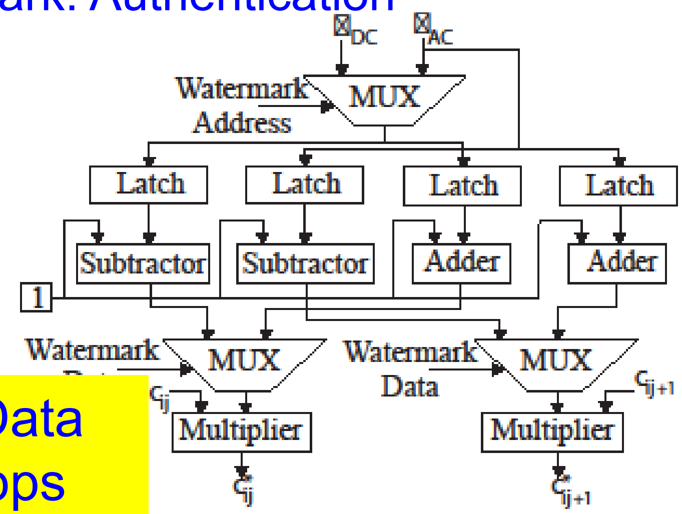


CryptMark: Authentication

Encryption Unit



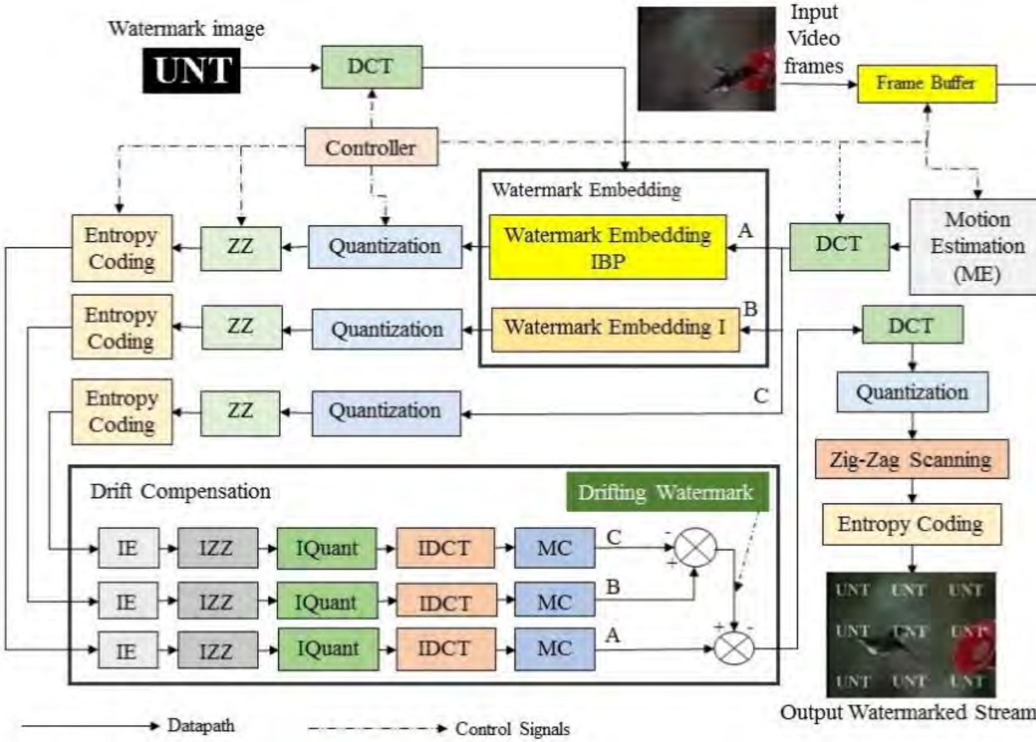
Watermarking Unit



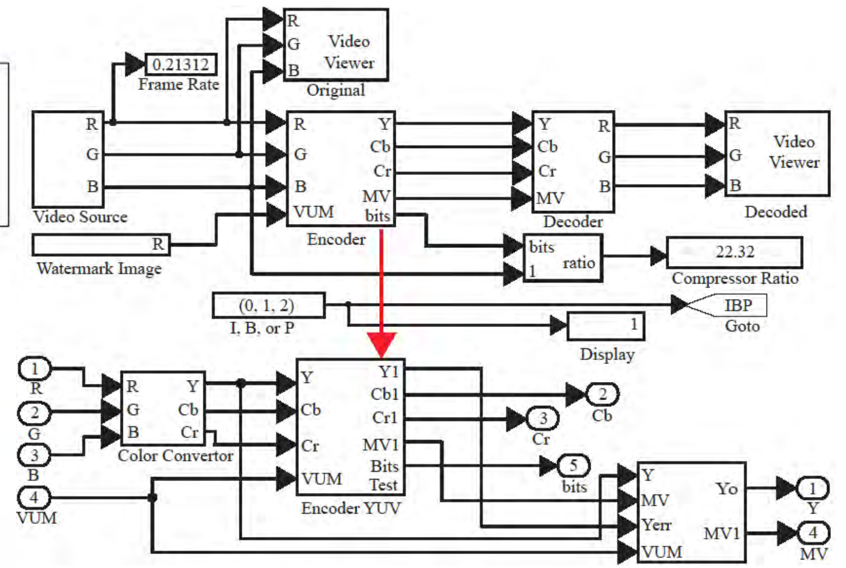
FPGA Prototyping Data
Throughput: 2.48 Gbps
Power Dissipation: 39.8 mW

FPGA Prototyping Data
hroughput: 544.2 Mbps
ower Dissipation: 3.7 mW

Copyright Protection Hardware –
MPEG-4 Video Watermarking



Video Watermarking Architecture Datapath



Video Watermarking Architecture: Simulink Model

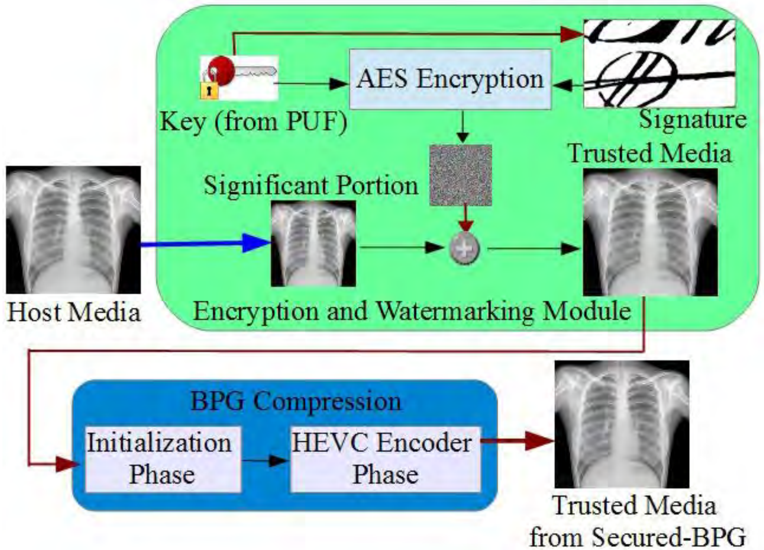
FPGA Prototyping

Throughput: 44 frames/sec

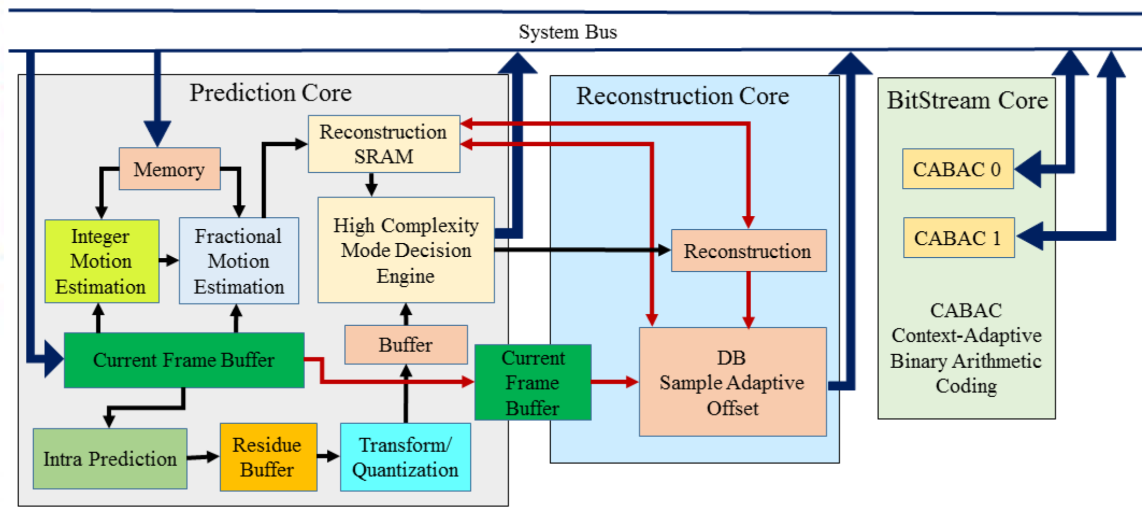
Logic Elements in FPGA Prototyping : 28322

Source: Mohanty 2011, JSS May 2011

DRM Hardware - Secure Better Portable Graphics (SBPG)



Idea of Secure BPG (SBPG)

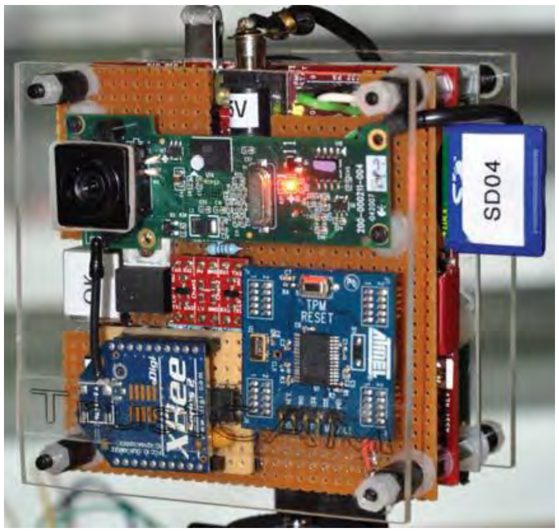


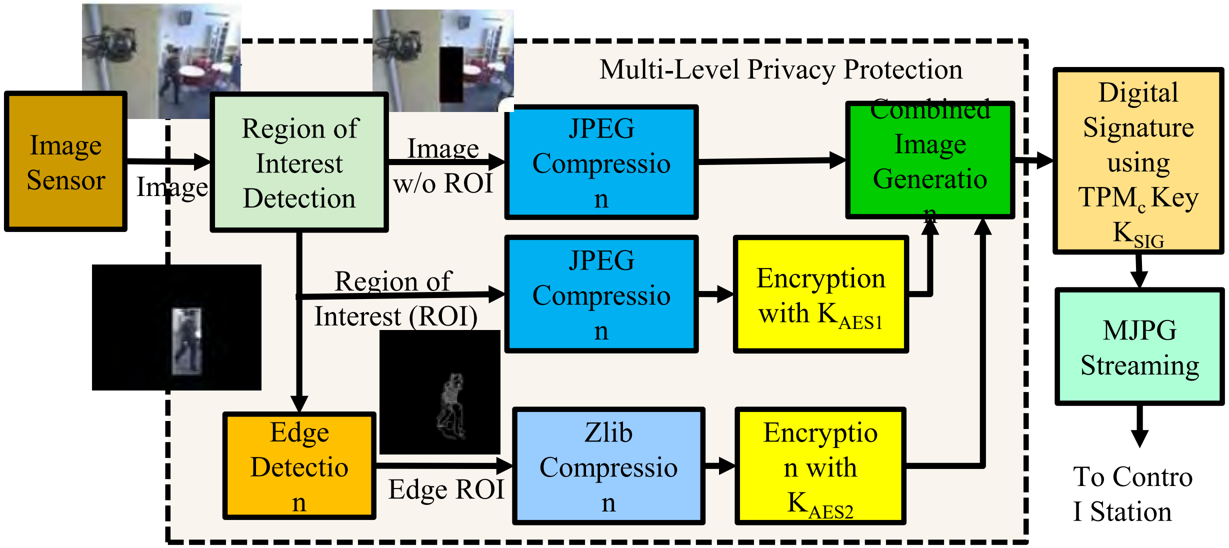
High-Efficiency Video Coding Architecture

Simulink Prototyping
Throughput: 44 frames/sec
Power Dissipation: 8 nW

Source: Mohanty 2018, IEEE Access 2018
Source: Mohanty 2016, ISVLSI 2016 and EuroSimE 2016

TrustCAM - Security and Privacy





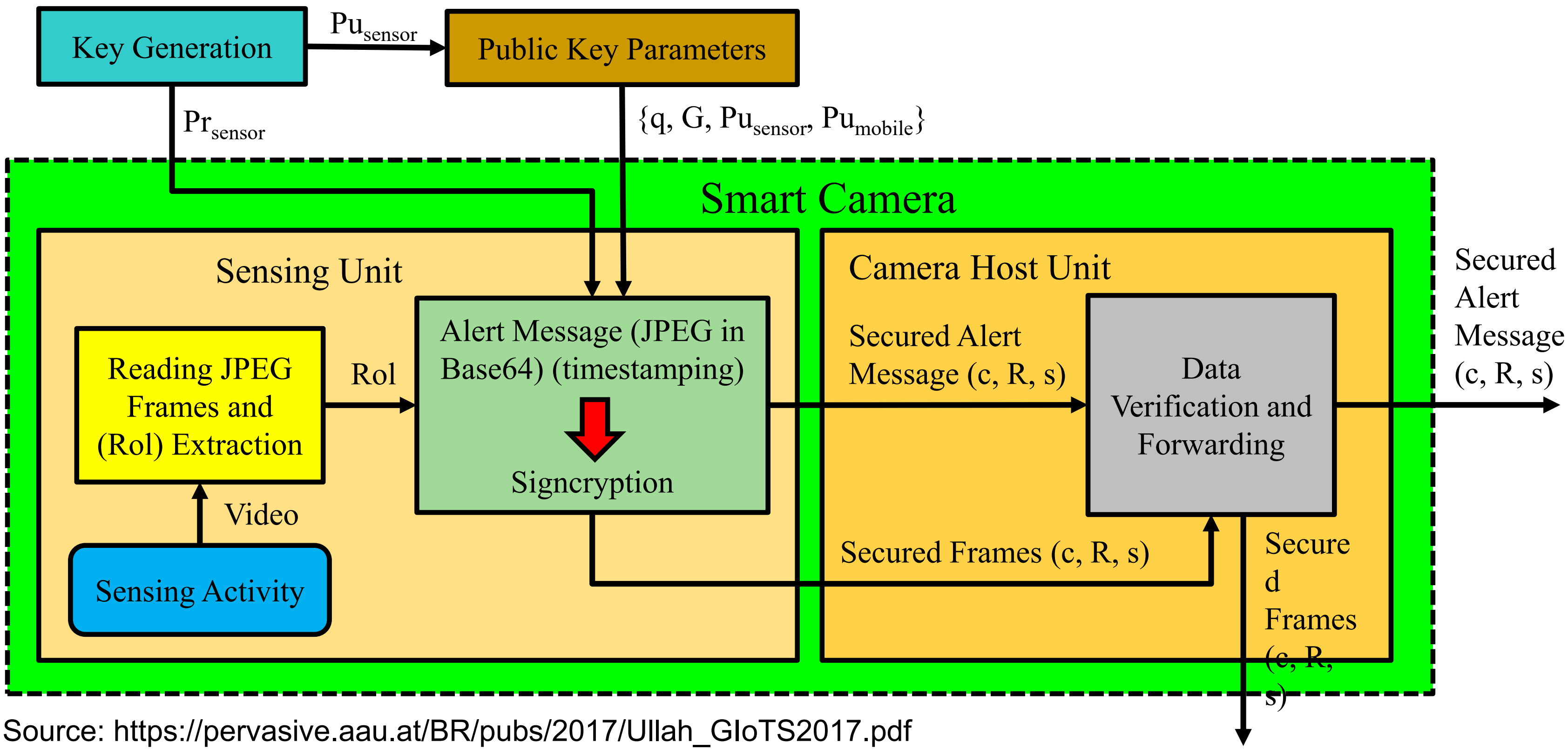
For integrity protection, authenticity and confidentiality of image data.

- Identifies sensitive image regions.
- Protects privacy sensitive image regions.
- A Trusted Platform Module (TPM) chip provides a set of security primitives.

Source: https://pervasive.aau.at/BR/pubs/2010/Winkler_AVSS2010.pdf

Smart Cameras with Signcryption

- Signcryption is a resource-efficient technique which implements signature and encryption in a single step for lower computational and communications overhead.



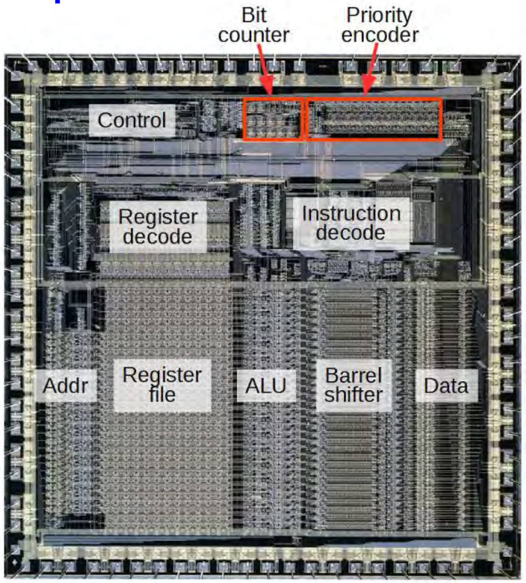
Source: https://pervasive.aau.at/BR/pubs/2017/Ullah_GIoTS2017.pdf

Hardware Reverse Engineering

Source: http://legacy.lincolninteractive.org/html/CES%20Introduction%20to%20Engineering/Unit%203/u3l7.html

CE System disassembly
Subsystem identification, modification

Chip-Level Modification

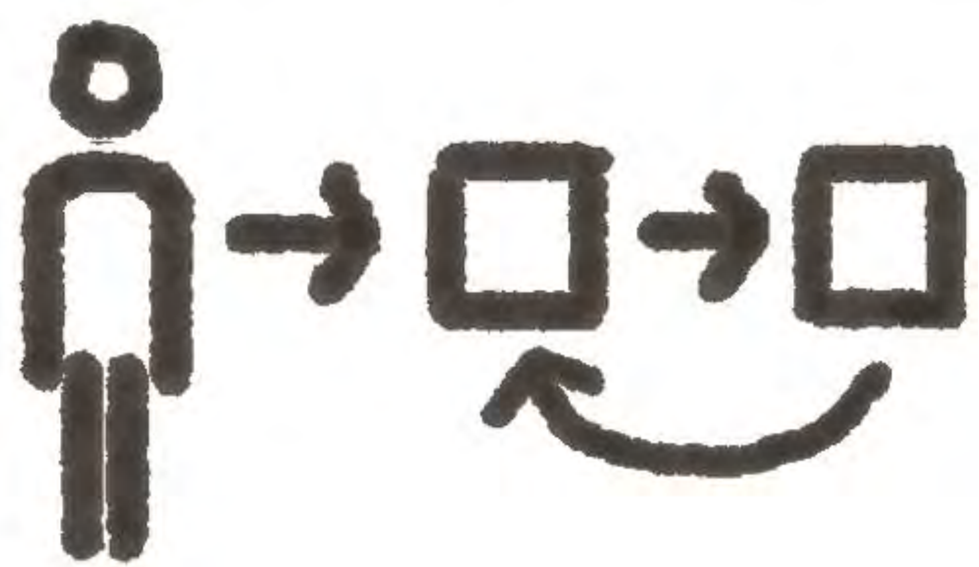


Source: http://pic-microcontroller.com/counting-bits-hardware-reverse-engineering-silicon-arm1-processor/

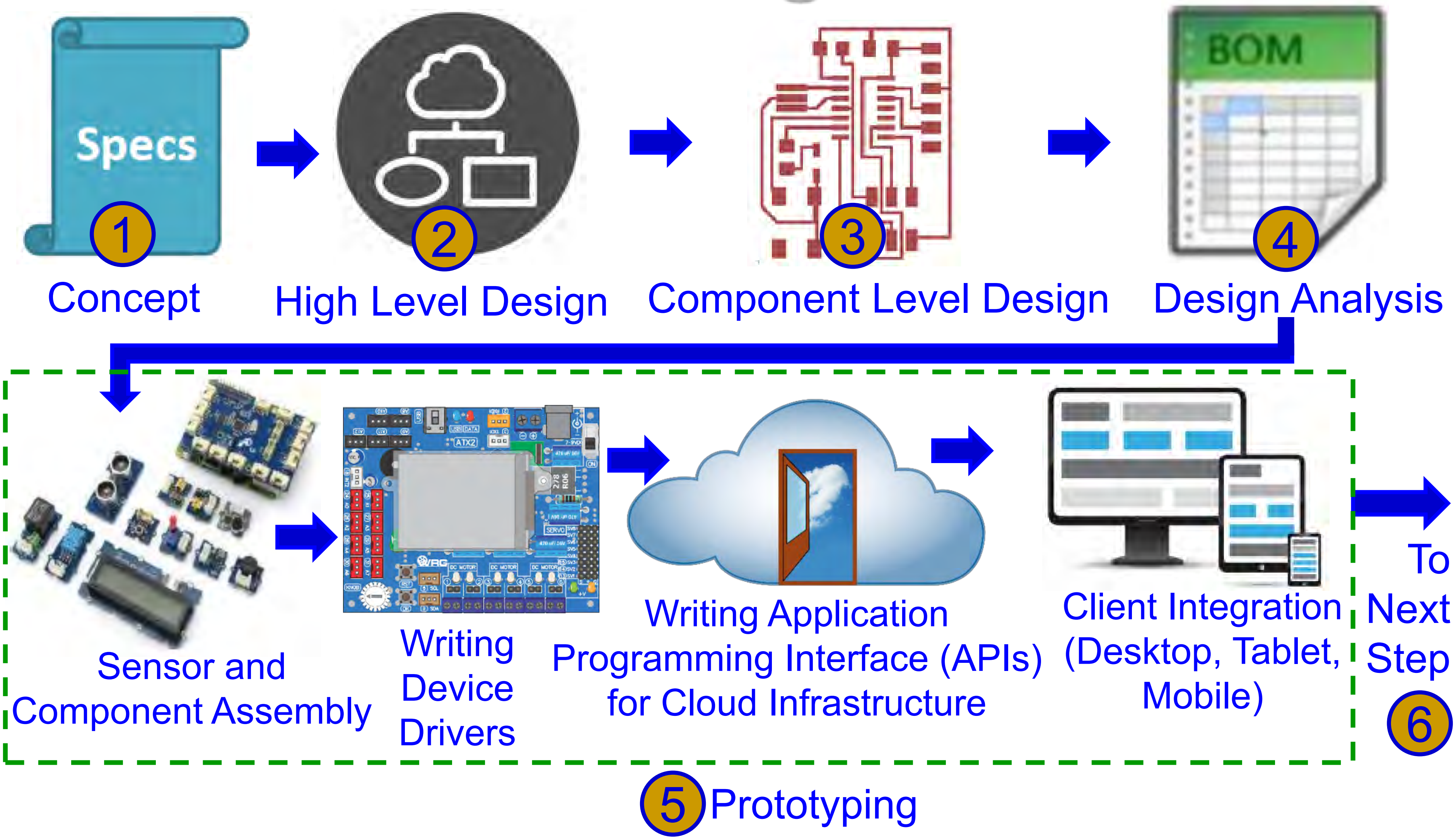
Source: https://www.slideshare.net/SOURCEConference/slicing-into-apple-iphone-reverse-engineering

Source: http://grandideastudio.com/wp-content/uploads/current_state_of_hh_slides.pdf

Design Flow



IoT – Design Flow



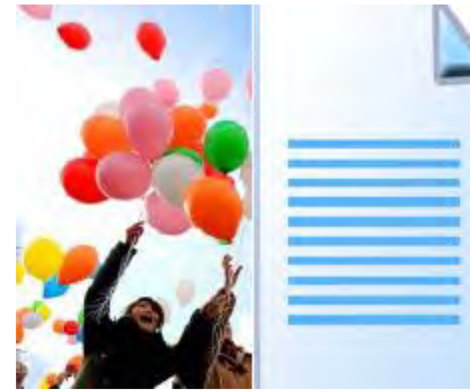
Source: http://events.linuxfoundation.org/sites/events/files/slides/Design%20-%20End-to-End%20%20IoT%20Solution%20-%20Shivakumar%20Mathapathi.pdf

IoT – Design Flow

6 Field Testing

7 Release of Beta Version

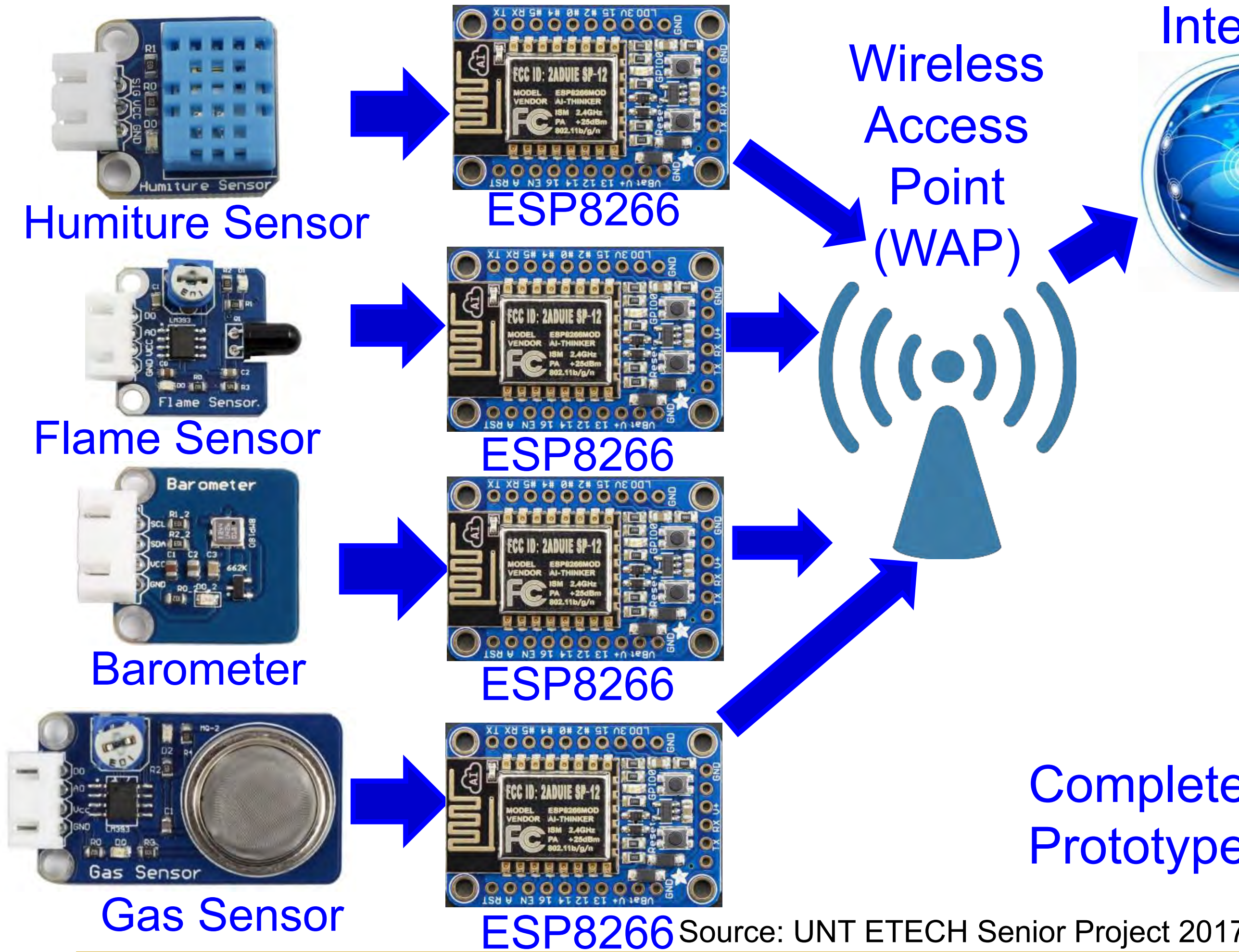
8 Production

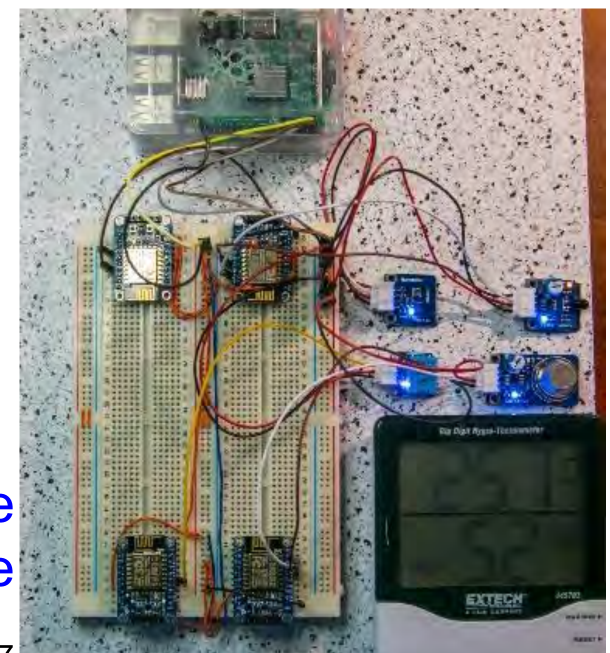


9 Release and Documentation

Source: http://events.linuxfoundation.org/sites/events/files/slides/Design%20-%20End-to-End%20%20IoT%20Solution%20-%20Shivakumar%20Mathapathi.pdf

IoT Design – Case Study – Indoor Air Quality Monitoring





Source: UNT ETECH Senior Project 2017

Hardware for IoT

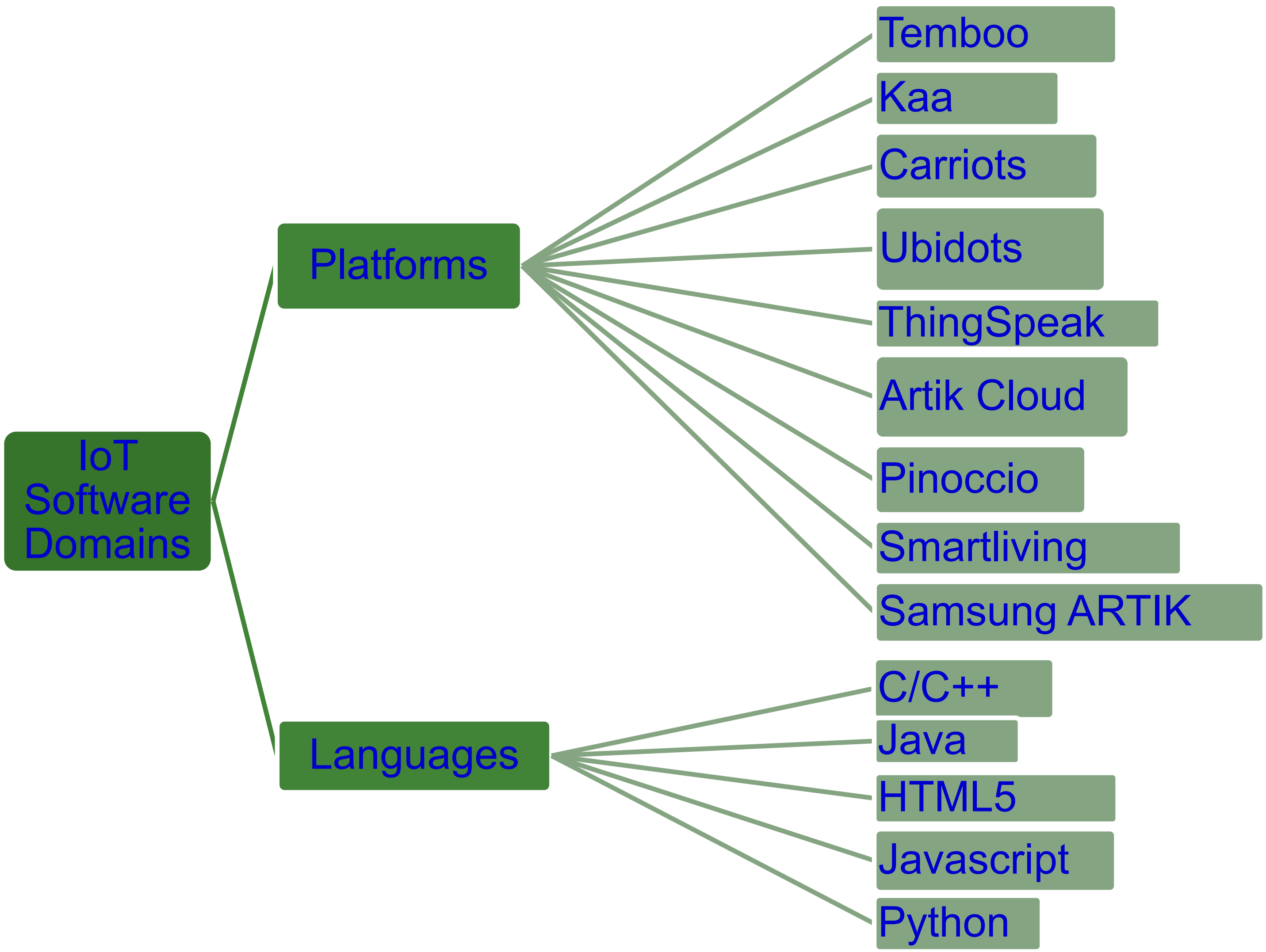
IoT Hardware Domains

- Embedded Systems and Boards (e.g. Arduino Yun, Raspberry Pi, BeagleBone, Samsung ARTIK)
- Wearable Devices and Gadgets (e.g. Samsung Gear 2, FitBit Flex, FLORA, iWallet)

Features	Processor/Microcontroller	Graphics Processing Unit	Clock Speed	Size	Memory	RAM	Supply Voltage	Listed Price
SparkFun Blynk Board	Tensilica L106 32-b	No	26 MHz	51 mm x 42 mm	4 MB	128 KB	5 V via micro-USB/ Li-Po connector and charging circuit	US$29.95
Arduino Yun	ATmega32u4 and Atheros AR9331 (for Linux)	No	16 MHz and 400 MHz	73 mm x 53 mm	32 KB and 16 MB + micro-SD	64 MB DDR2	5 V via micro-USB	US$58
Raspberry Pi 3	Broadcom BCM2837 and ARM Cortex-A53 64-b Quad Core	VideoCore IV @ 300/400 MHz	1.2 GHz	85 mm x 56 mm	Micro-SD	1 GB LPDDR2	5 V via micro-USB	US$35
cloudBit	Freescale i.MX233 (ARM926EJ-S core)	No	454 MHz	55 mm x 19 mm	Micro-SD slot with 4-GB micro-SD	64 MB	5 V via micro-USB	US$59.95
Photon	STM32F205 120Mhz ARM Cortex M3	No	120 MHz	36.5 mm x 20.3 mm	1 MB	128 KB	5 V via micro-USB	US$19
BeagleBone Black	AM335x ARM Cortex-A8	PowerVR SGX530	1 GHz	86 mm x 56 mm	4 GB 8-b eMMC, micro-SD	512 MB DDR3	5 V via mini-USB	US$49
Pinoccio	ATmega256RFR2	No	16 MHz	70 mm x 25 mm	256 KB	32 KB	5 V via micro-USB/ Li-Po connector and charging circuit	US$109
UDOO	Freescale i.MX 6 ARM Cortex-A9 and Atmel SAM3X8E ARM Cortex-M3	Vivante GC 2000 for 3-D + GC 355 for 2-D (vector graphics) + GC 320 for 2-D	1 GHz	110 mm x 85 mm	Micro-SD	1 GB DDR3	12 V	US$135
Samsung Artik 10	ARM A15x4 and A7x4	Mali-T628 MP6 core	1.3 GHz and 1.0 GHz	39 mm x 29 mm	16 GB	2 GB LPDDR3	3.4–5 V	US$100

Source: Singh 2017, CE Magazine, April 2017

Software for IoT



Source: Singh 2017, CE Magazine, April 2017

Tools and Solutions

IoT - Design & Simulation Challenges

- Traditional controllers and processors do not meet IoT requirements, such as multiple sensor, communication protocol, and security requirements.
- Existing tools are not enough to meet challenges such as time-to-market, complexity, cost of IoT.
- Can a framework be developed for simulation, verification, and optimization:
  - of individual (multidiscipline) “Things”
  - of IoT Components
  - of IoT Architecture

IoT Simulators

Selected IoT Simulators

- Bevywise IoT Simulator
- CupCarbon
- IoTIFY
- Meshify
- Node-RED
- NetSim
- SimpleIoTSimulator

IoT Simulator - CUPCARBON

- **About**
  - CUPCARBON is a smart city and Internet of Things Wireless sensor network simulator (SCI-WSN)
- **Objective**
  - Design, Visualize, Debug
  - Validate distributed algorithms
  - Create environmental scenarios

Source: http://www.cupcarbon.com/

- **Environments**
  - Design of mobility scenarios and the generation of natural events such as fires and gas as well as the simulation of mobiles such as vehicles and flying objects (e.g. UAVs, insects, etc.).
  - A discrete event simulation of WSNs which takes into account the scenario designed on the basis of the first environment.

IoT Simulators - Node-RED

- **About**:
  - Node-RED is a flow-based IoT Simulator.
  - It is a programming tool for wiring together hardware devices, APIs and online services in new ways.
  - The light-weight runtime is built on Node.js, taking full advantage of its event-driven, non-blocking model.
- **Editor**:
  - Browser-based editor.
  - The flows created in Node-RED are stored using JSON which can be easily imported and exported for sharing with others.
- **Advantages**:
  - Available for smaller computing devices such as Raspberry Pi.
  - It takes moments to create cloud applications that combine services from across the platform.

IoT Simulators - Meshify

- About:
  - Meshify offers industrial IoT solutions. It helps to monitor, analyze, control, & track your devices.
  - It was founded in 2011 with the goal of making IoT more accessible.
- Services:
  - Hardware Selection & Implementation
  - UI/UX Design & development
  - Seasoned Integrations Team
  - End-to-end Architecture design
  - Professional Project Management

IoT Simulators – Observations

- IoT does not have a one-size-fits-all solution.
- IoT solutions often require pulling together different device APIs and online services in new and interesting ways.
- It is a multi-disciplinary domain and everyone cannot master everything.
- Tools that make it easier for developers at all levels, are always in demand.

Model based Simulation?

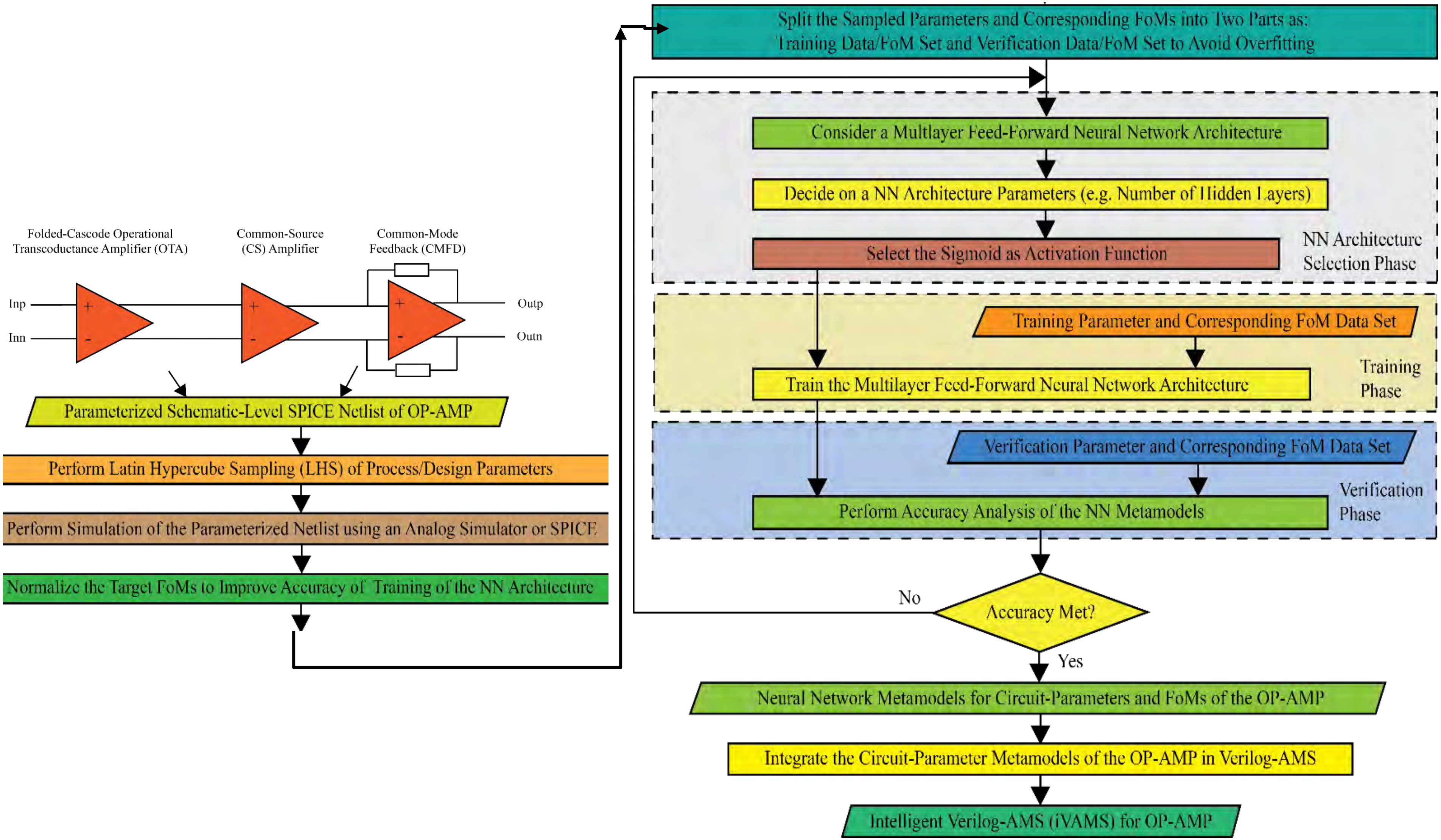
- "Model of a model" -- Metamodels are mathematical function (s) used to represent computer simulation models – e.g. polynomial functions, DOE predictive functions, neural networks, and Kriging interpolation:

$$\hat{F}(x_n) = F(x_n) + \varepsilon \approx F(x_n)$$

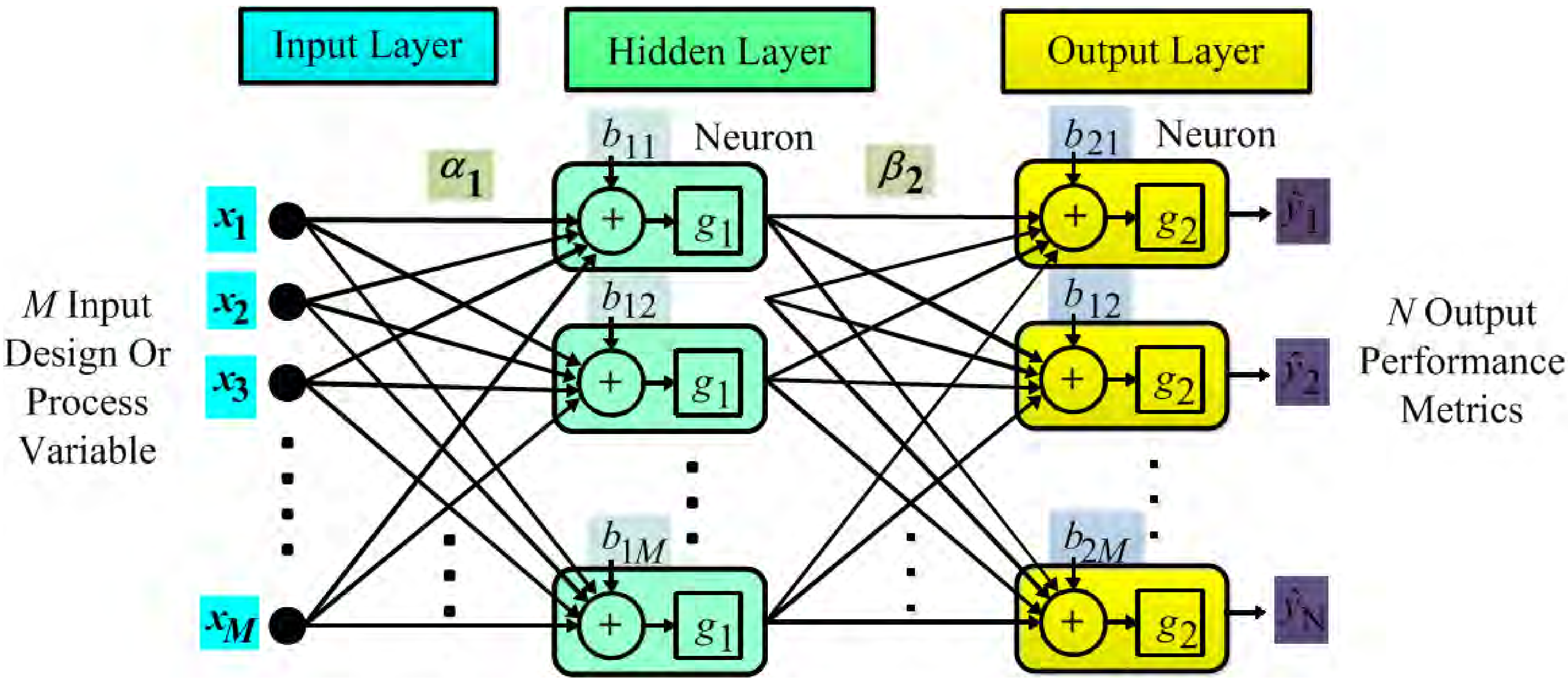
Selected Models

- Polynomial
- Kriging Methods
- ANN
- CNN
- DNN

iVAMS - ANN Model Generation

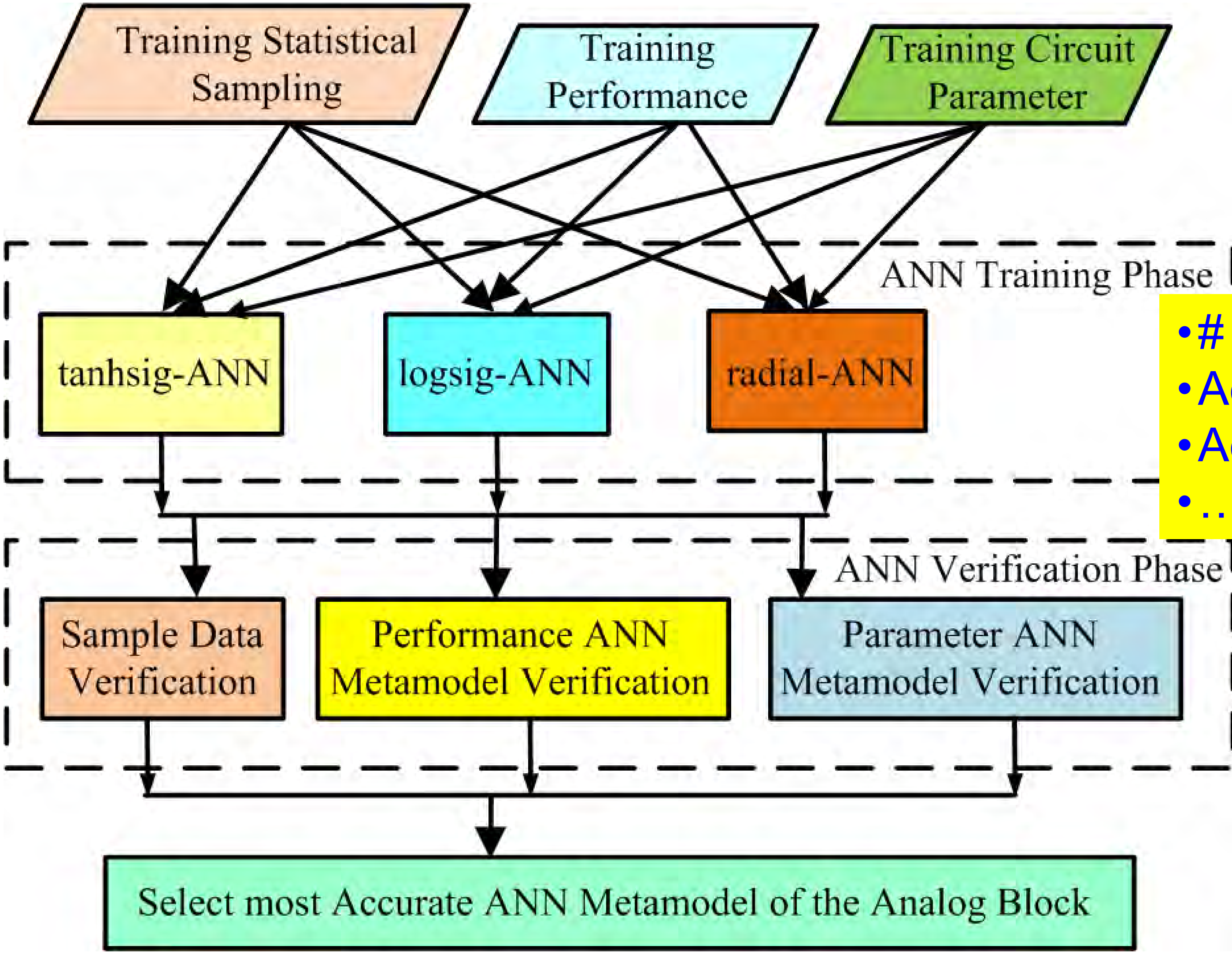


iVAMS - ANN Model



ANN? CNN? DNN?

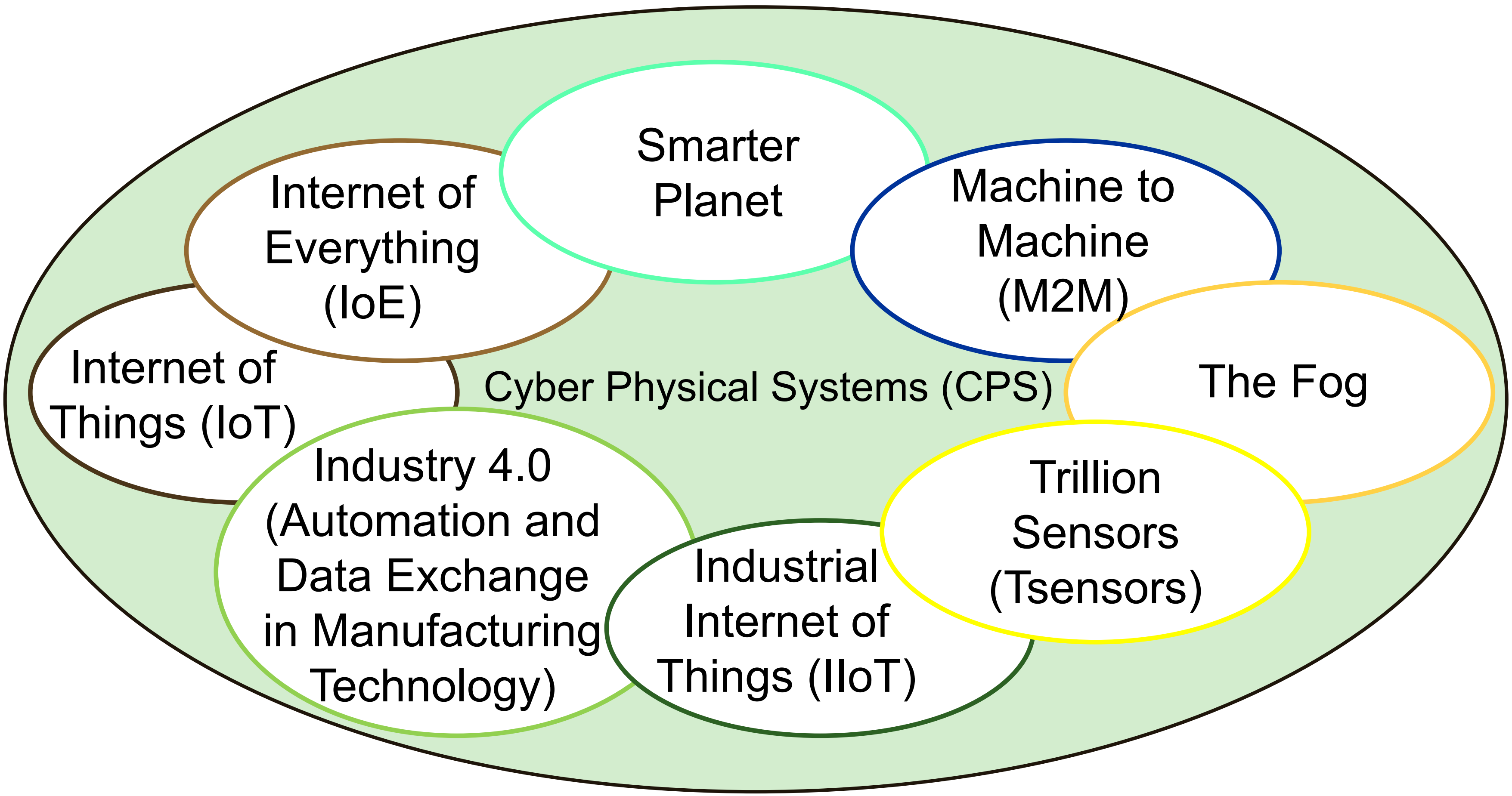
iVAMS - ANN Model



- # of Layers?
- Activation Function?
- Accuracy metrics?
- …

Related Buzzwords

Some related Buzzwords



Source: Sangiovanni-Vincentelli 2016, ISC2 2016

IoT Vs Sensor Networks

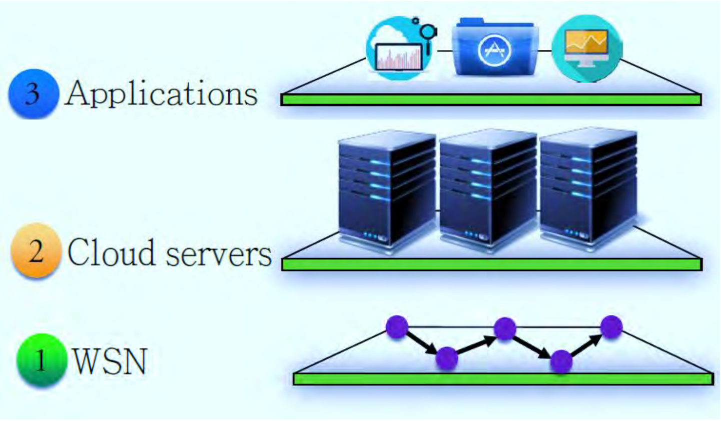
Wireless Sensor Networks (WSN)

- WSN is like the eyes and ears of the IoT.
- Anetwork of small wireless electronic nodes which consists of different sensors.
- The purpose is to collect data from the environment.

IoT adds value to data!

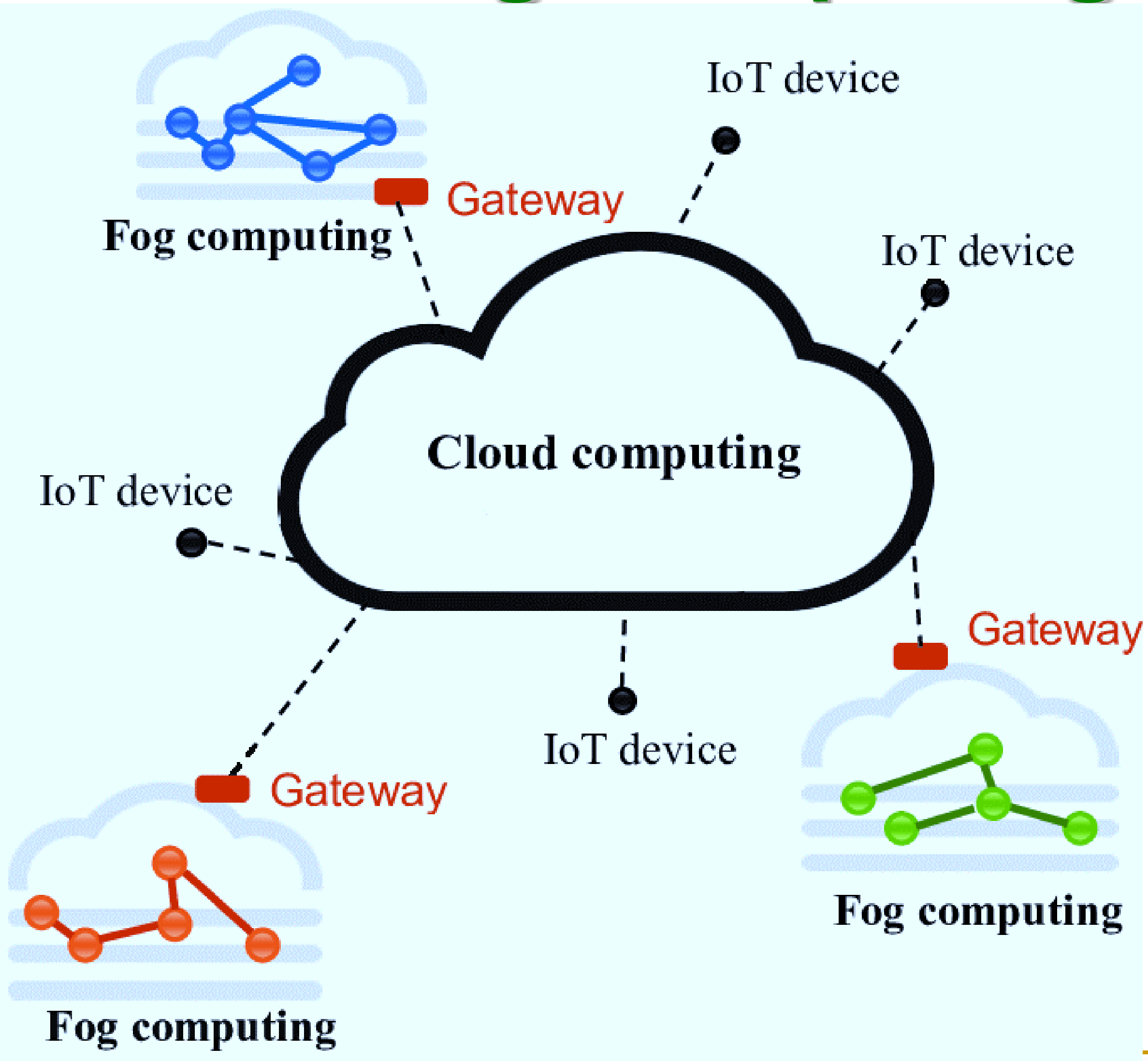
IoT

- IoT in a broad sense is like a brain.
- Store both real world data and can also be used to monitor the real world parameters and give meaningful interpretation.



Source: Nia 2017, IEEE TETC 2017

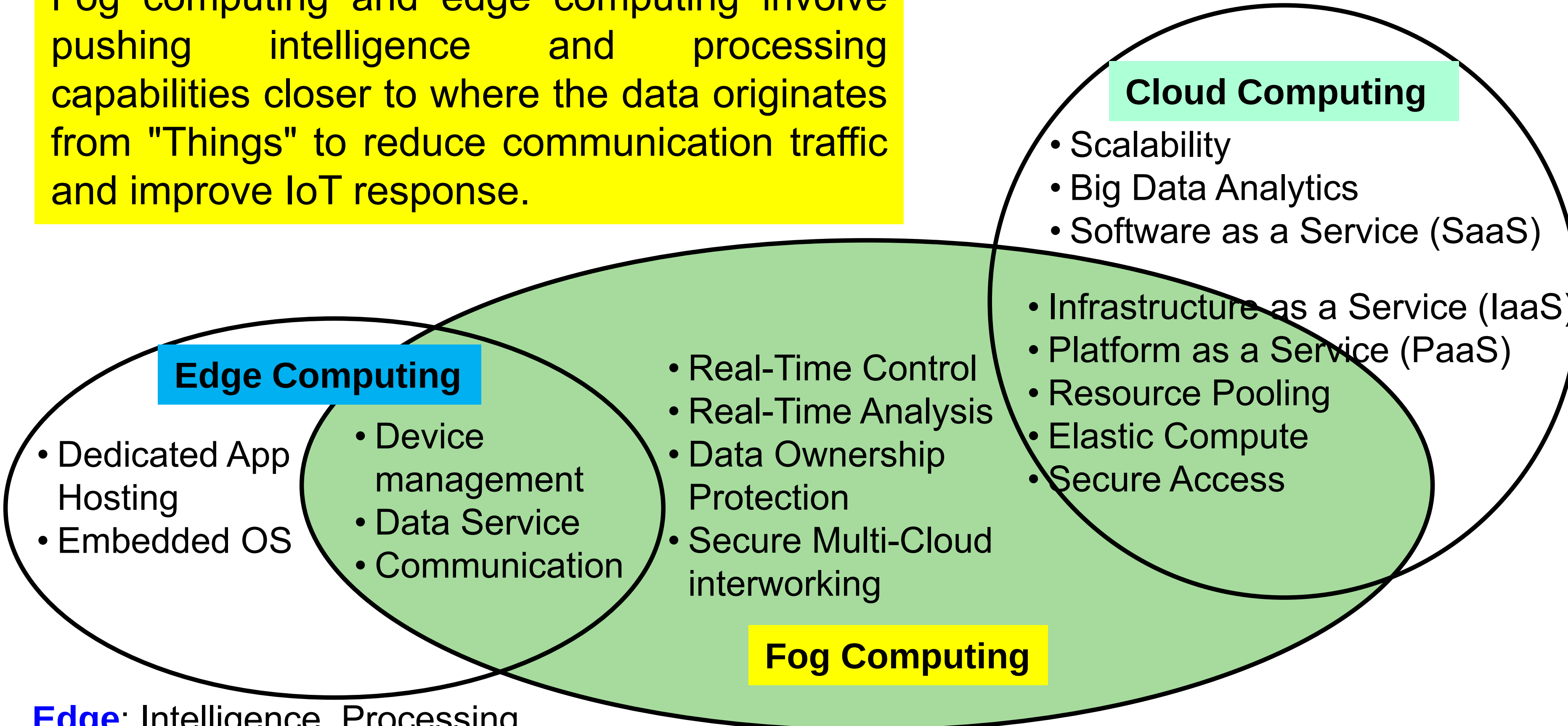
IoT Vs Fog Computing



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

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.



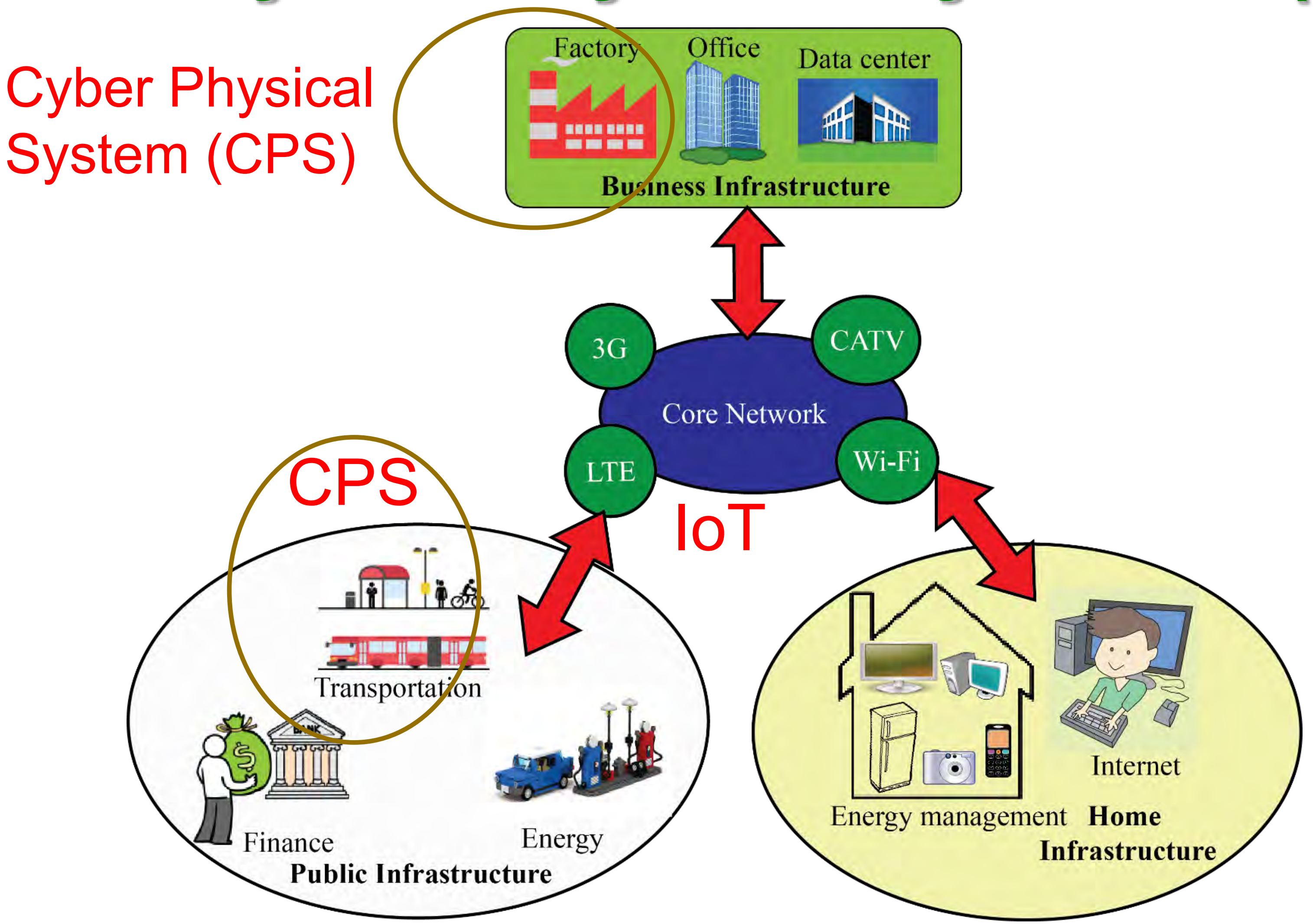
Edge: Intelligence, Processing, and Communication - Devices like Programmable Automation Controllers (PACs)

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

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

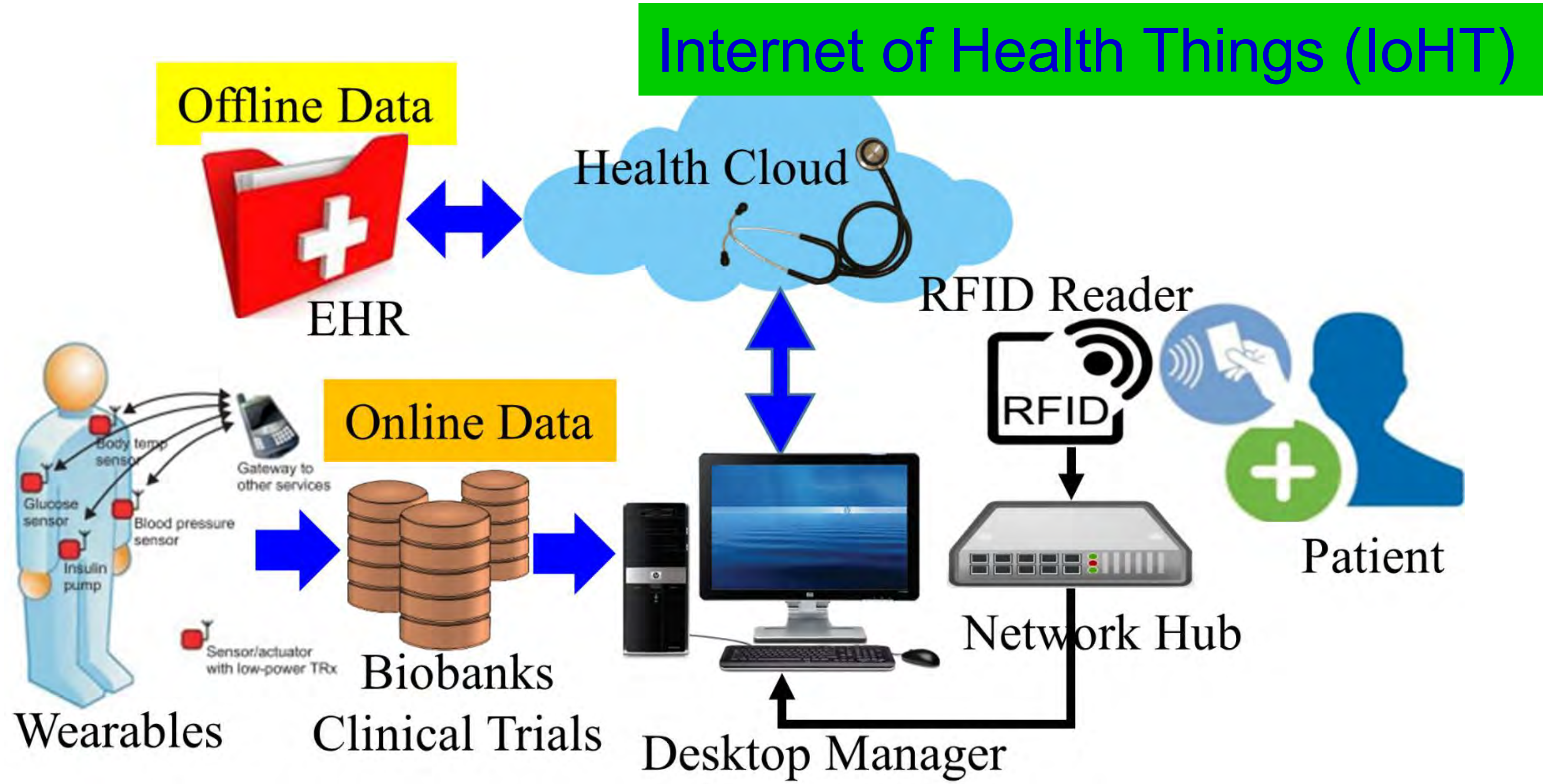
Source: https://www.nebbiolo.tech/wp-content/uploads/whitepaper-fog-vs-edge.pdf

IoT Vs Cyber Physical Systems (CPS)



Source: Mohanty 2016, CE Magazine July 2016

Internet of MedicalThings (IoMT)

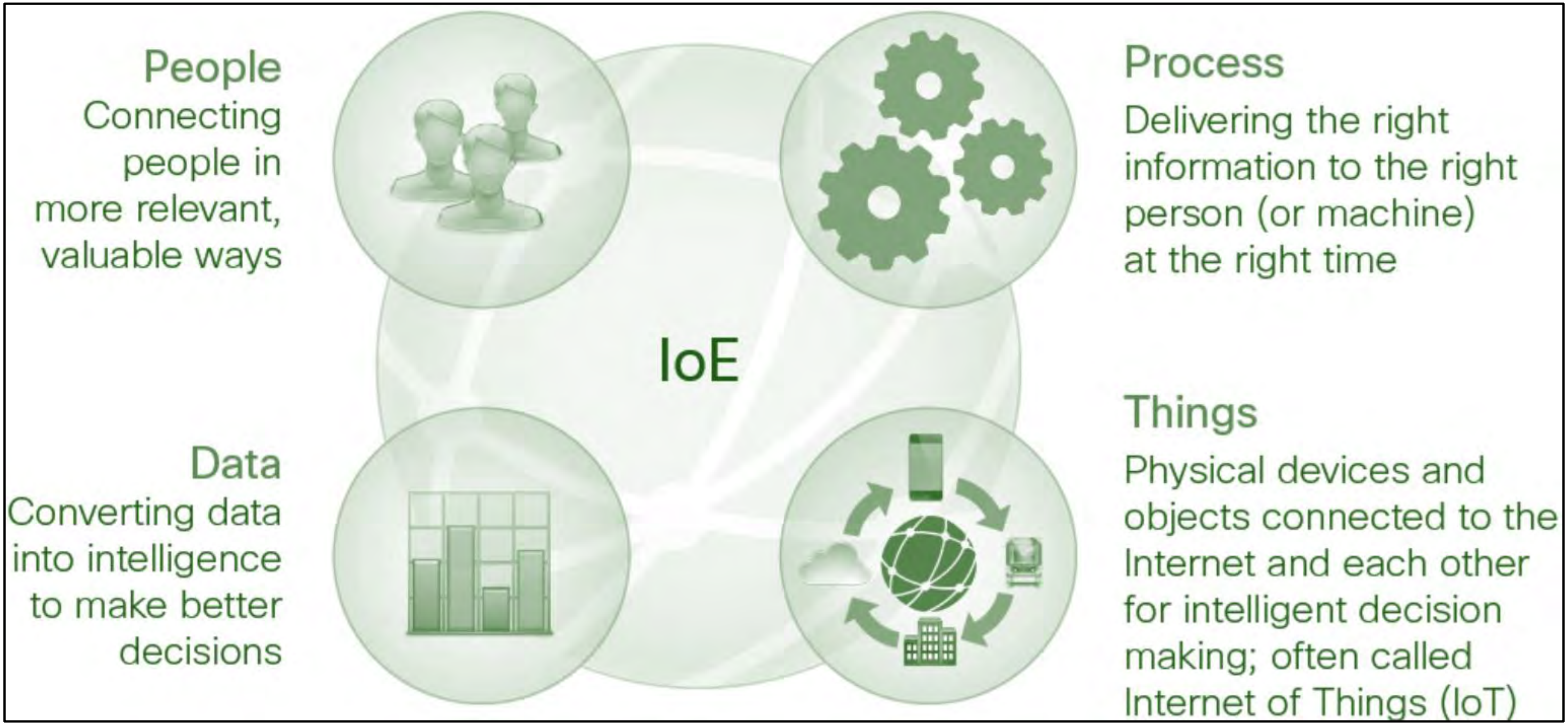


IoMT is a collection of medical devices and applications that connect to healthcare IT systems through Internet.

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

Internet of Every Things (IoE)



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

Conclusions

Conclusions

- IoT has following components: Things, LAN, Cloud, Internet.
- IoT is backbone of smart cities.
- Scalability, Cost, Energy-consumption, Security are some important challenges of IoT.
- Security, Privacy, and Ownership Rights are critical for trustworthy IoT design.
- Physical Unclonable Functions (PUF) emerging as a good security solution.
- Coordination among the various researchers and design engineers is a challenge as IoT is multidisciplinary.

Future Directions

- Energy-Efficient "Thing" design is needed.
- Security and Privacy of Information need more research.
- Security of the CE systems (e.g. UAV, Smart Cars) needs research.
- Safer and efficient battery need research.
- IoT automatic design tool needs research.
- Some IoT simulators exist, but more needed for efficient, accurate, scalable, multi-discipline simulations.

Population Trend – Urban Migration

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

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

Source: http://www.urbangateway.org

Human Migration Problem

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

Source: https://humanitycollege.org

Can Any Smartness/Intelligence Solve?

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

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IEEE

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IEEE Consumer Electronics Magazine

The IEEE Consumer Electronics Magazine (CEM) is the flagship award-winning magazine of the consumer electronics (CE) society of IEEE. From 2018, the magazine is published on a bimonthly basis and features a range of topical content on state-of-art consumer electronics systems, services and devices, and associated technologies.

The CEM won an Apex Grand Award for excellence in writing in 2013. The CEM is the winner in the Regional 2016 STC Technical Communication Awards - Award of Excellence! The CEM is indexed in Clarivate Analytics (formerly IP Science of Thomson Reuters). The 2017 impact factor of CEM is 1.434.

Aim and Scope

- Consumer electronics magazine covers the areas or topics that are related to "consumer electronics".
- Articles should be broadly scoped – typically review and tutorial articles are well fit for a magazine flavor.
- Technical articles may be suitable but these should be of general interest to an engineering audience and of broader scope than archival technical papers.
- Topics of interest to consumer electronics: Video technology, Audio technology, White goods, Home care products, Mobile communications, Gaming, Air care products, Home medical devices, Fitness devices, Home automation and networking devices, Consumer solar technology, Home theater, Digital imaging, In-vehicle technology, Wireless technology, Cable and satellite technology, Home security, Domestic lighting, Human interface, Artificial intelligence, Home computing, Video Technology, Consumer storage technology. Studies or opinion pieces on the societal impacts of consumer electronics are also welcome.

Have questions on submissions or ideas for special issues, contact EiC at: saraju.mohanty@unt.edu

Submission Instructions

Submission should follow IEEE standard template and should consist of the following:

I. A manuscript of maximum 6-page length: A pdf of the complete manuscript layout with figures, tables placed within the text, and

II. Source files: Text should be provided separately from photos and graphics and may be in Word or LaTeX format.

- High resolution original photos and graphics are required for the final submission.
- The graphics may be provided in a PowerPoint slide deck, with one figure/graphic per slide.
- An IEEE copyright form will be required. The manuscripts need to be submitted online at the URL: http://mc.manuscriptcentral.com/cemag

More Information at: http://cesoc.ieee.org/publications/ce-magazine.html

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Technical Scope Various aspects of VLSI design including design of system-level, logic-level, and circuit-level, and semiconductor processes

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