# Internet of Things (IoT) - Demystified

## Keynote – ICIT 2017
## 22nd Dec 2017

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# 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

# 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

# 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

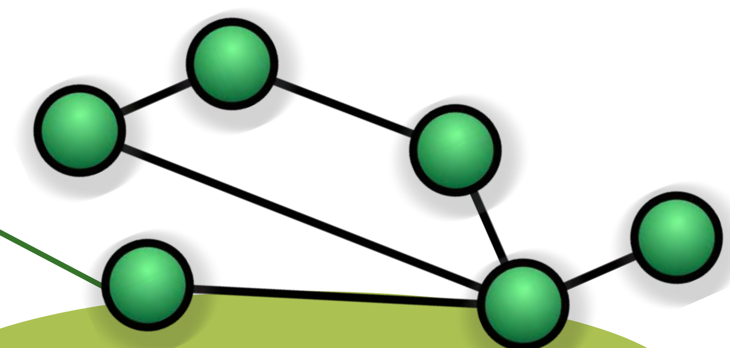
# Smart Cities - 3 Is


Instrumentation

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

Smart Cities

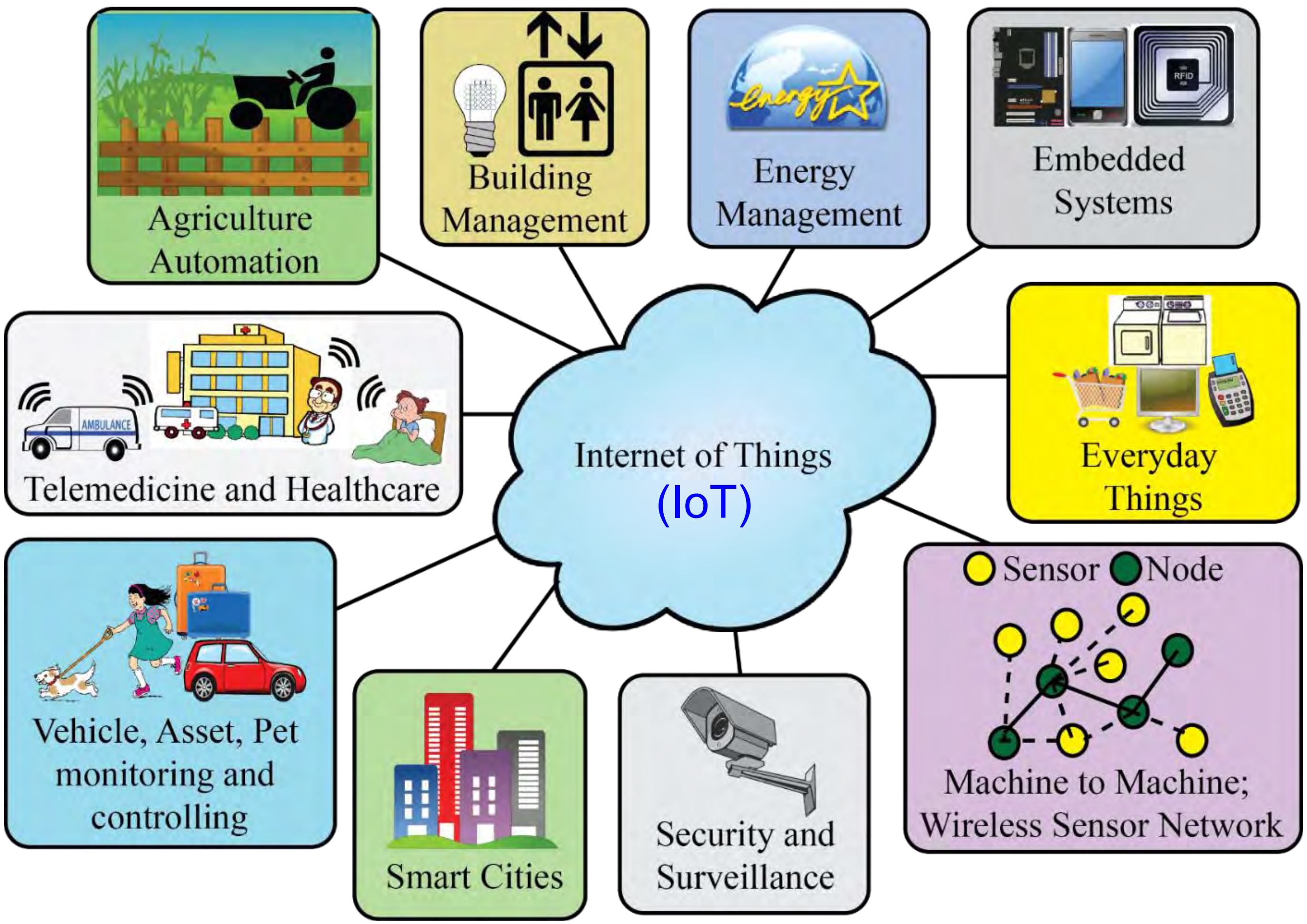
Intelligence



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

# Components

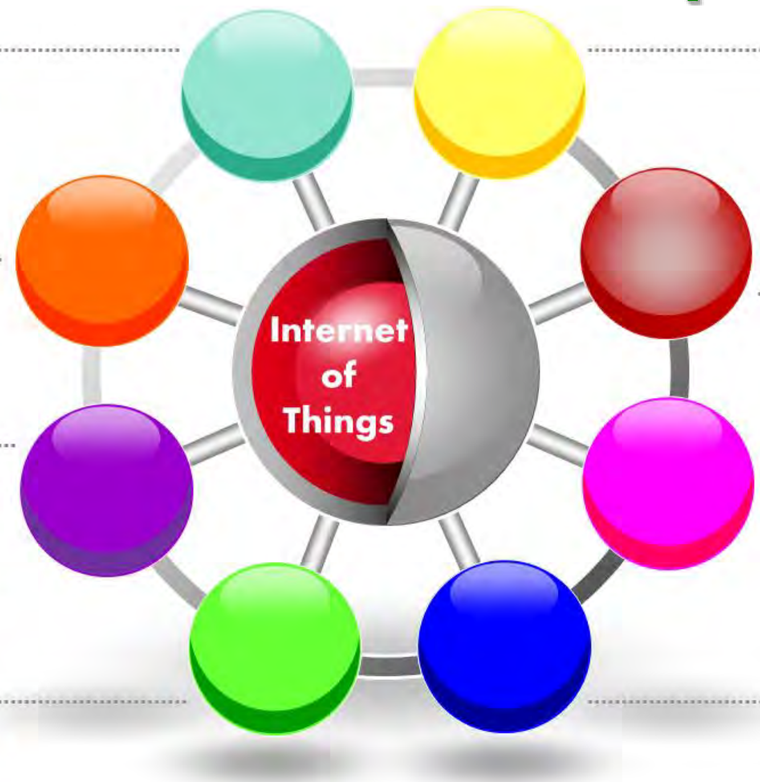
# IoT – Definition - IoT European Research Cluster (IERC)

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***

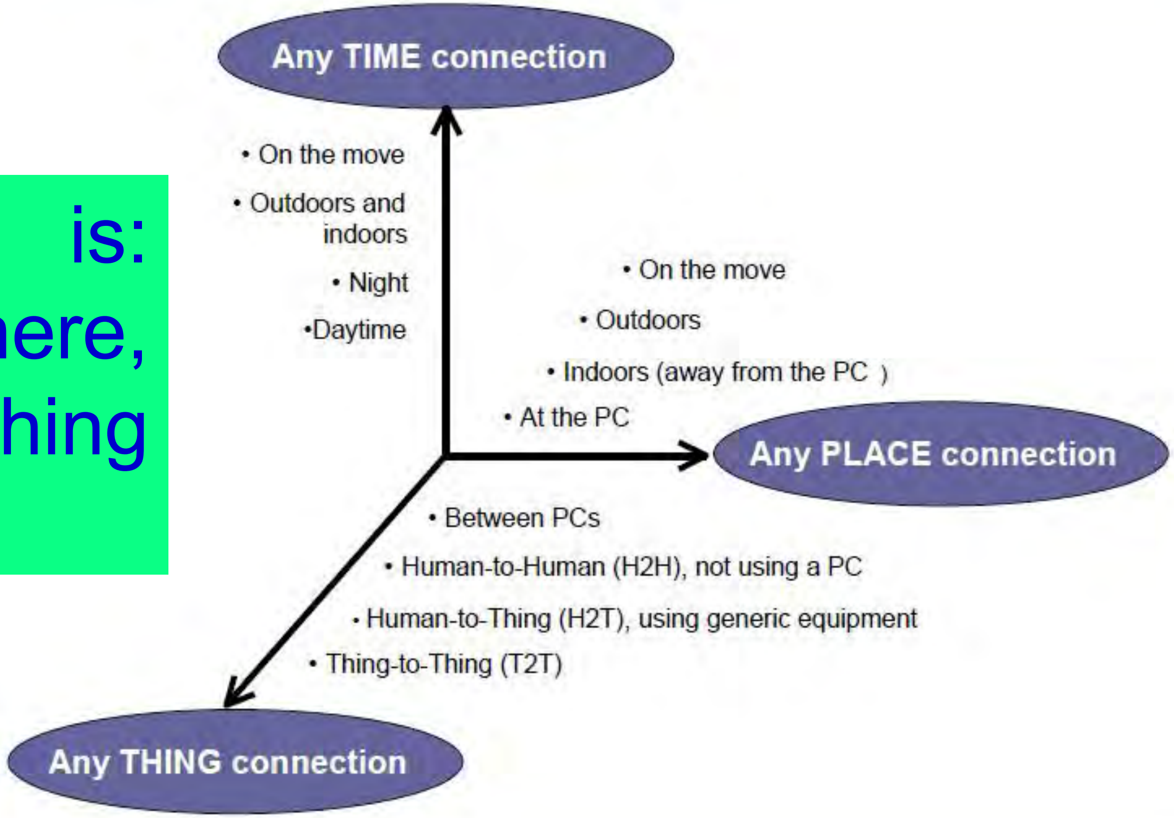
into ***the information network.***

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

# Internet of Things (IoT) – Concept

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

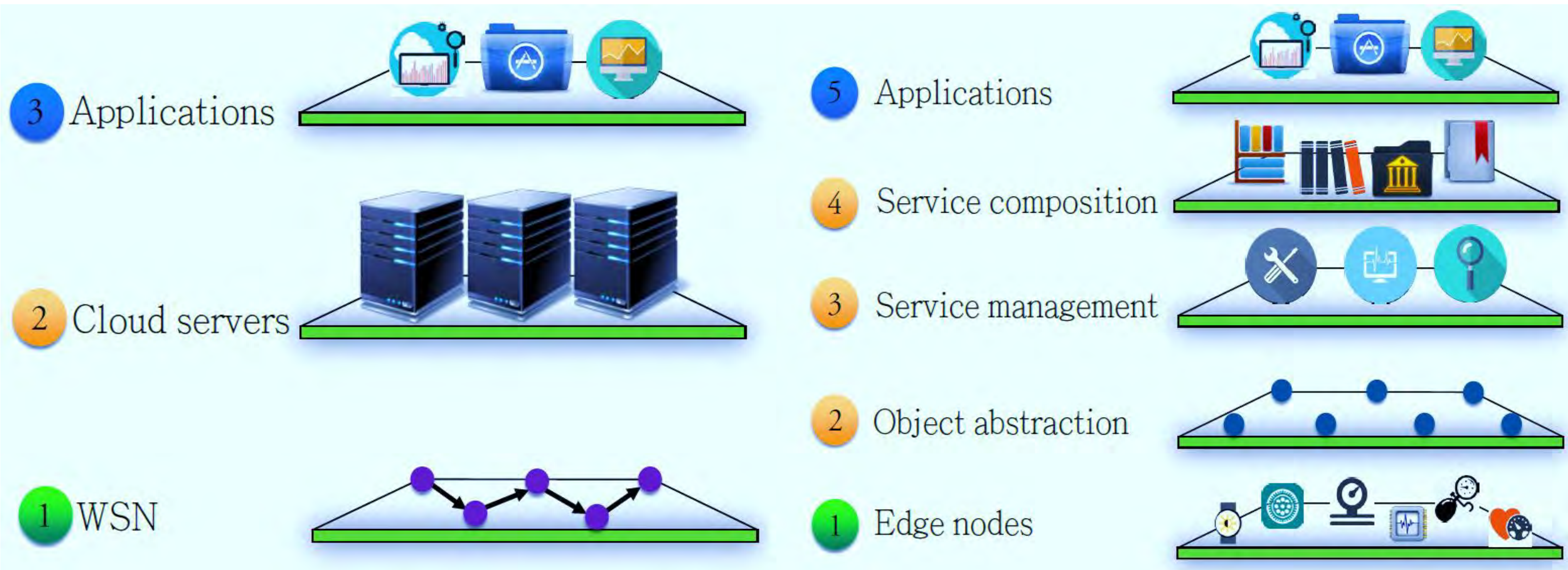
**Local Network**
Can be wired or wireless: LAN, Body Area Network (BAN), Personal Area Network (PAN), Controller Area Network (CAN)

**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

# IoT Architecture - 3 & 5 Level Model

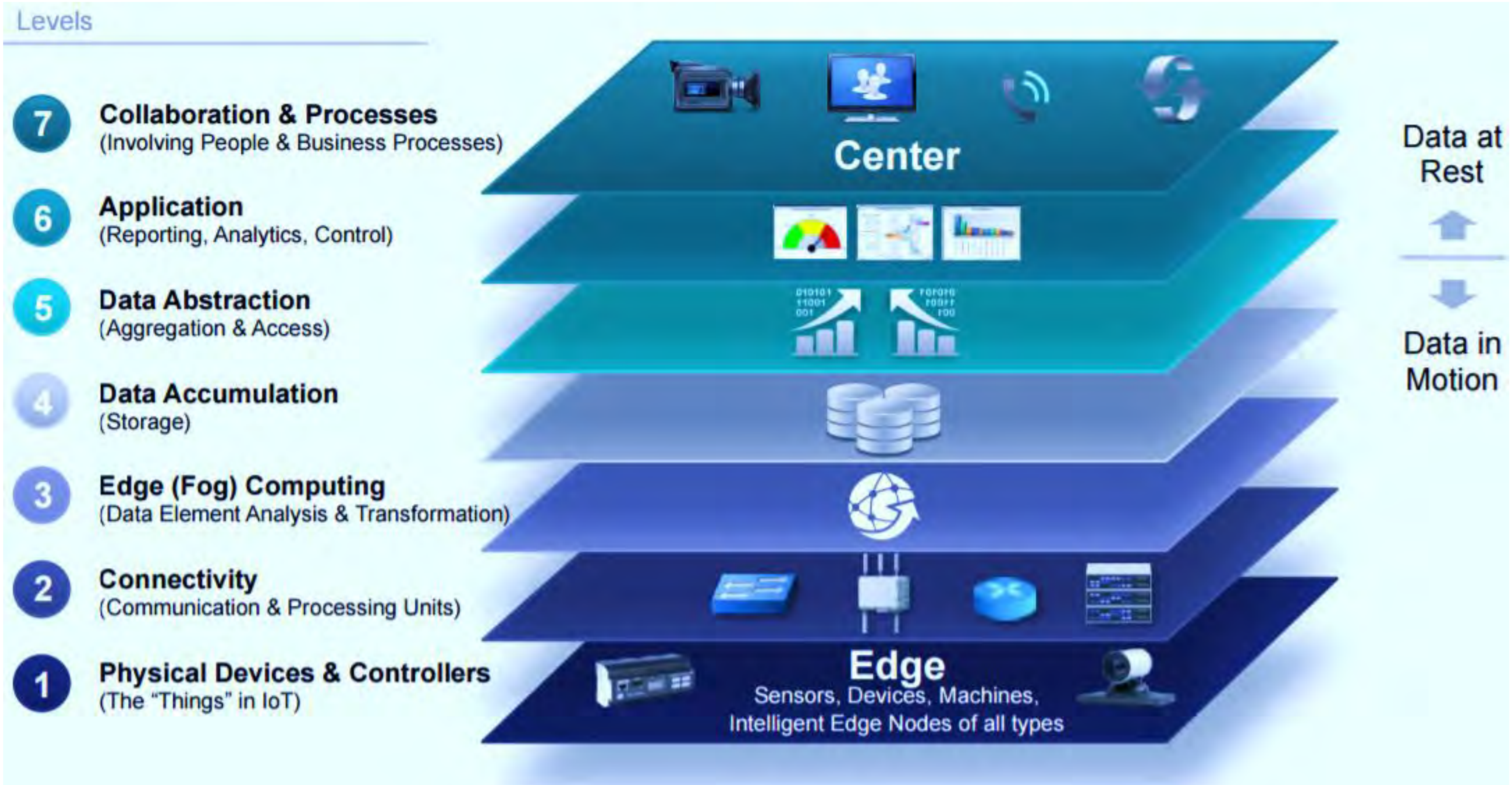



Three Level Model

Five Level Model

Source: Nia 2017, IEEE TETC 2017

# IoT Architecture - 7 Level Model

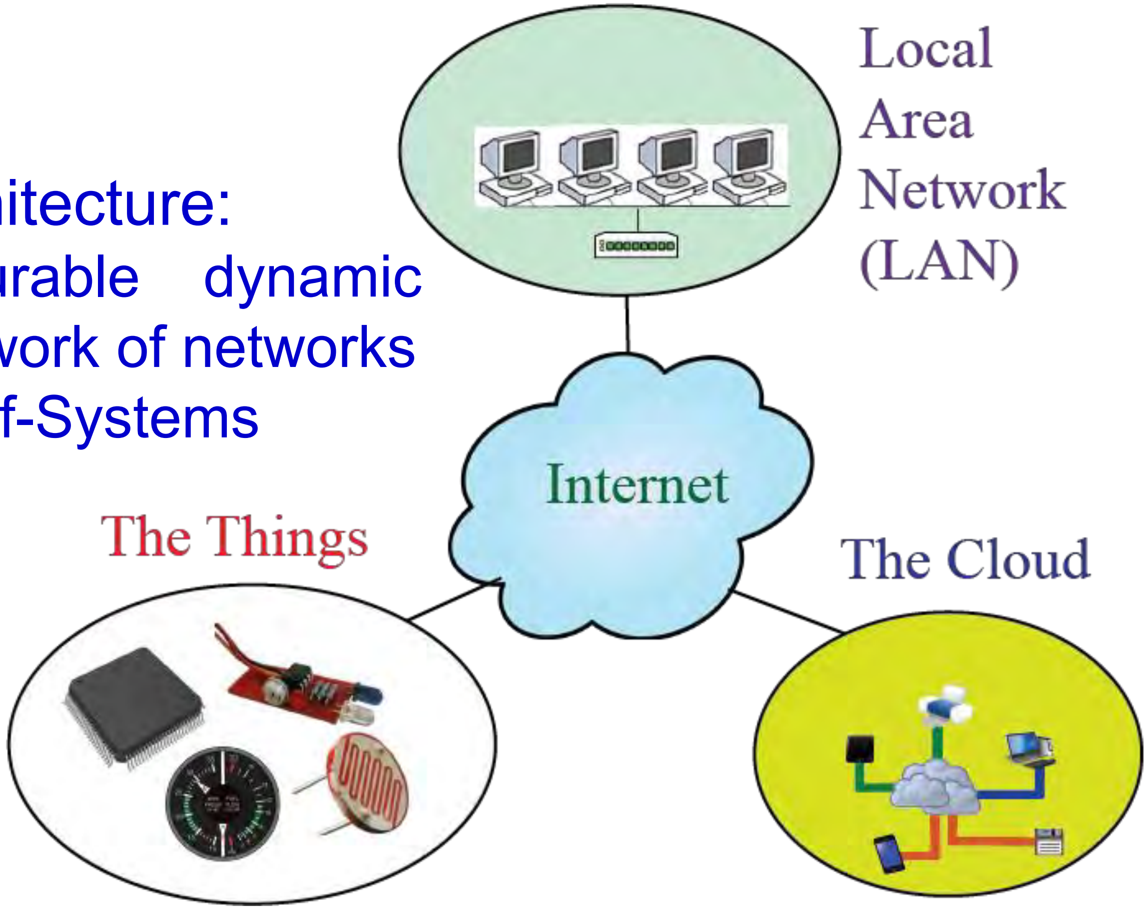



Source: http://cdn.iotwf.com/resources/71/IoT_Reference_Model_White_Paper_June_4_2014.pdf

# IoT - Architecture

Overall architecture:

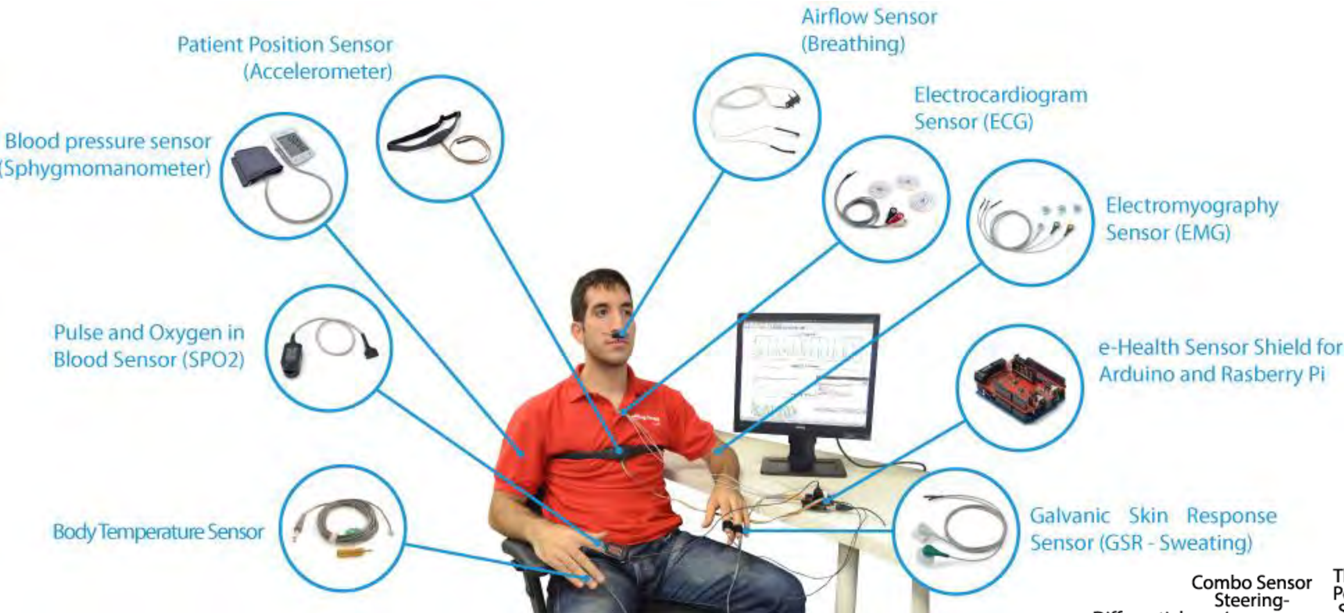
- ❖ A configurable dynamic global network of networks
- ❖ Systems-of-Systems



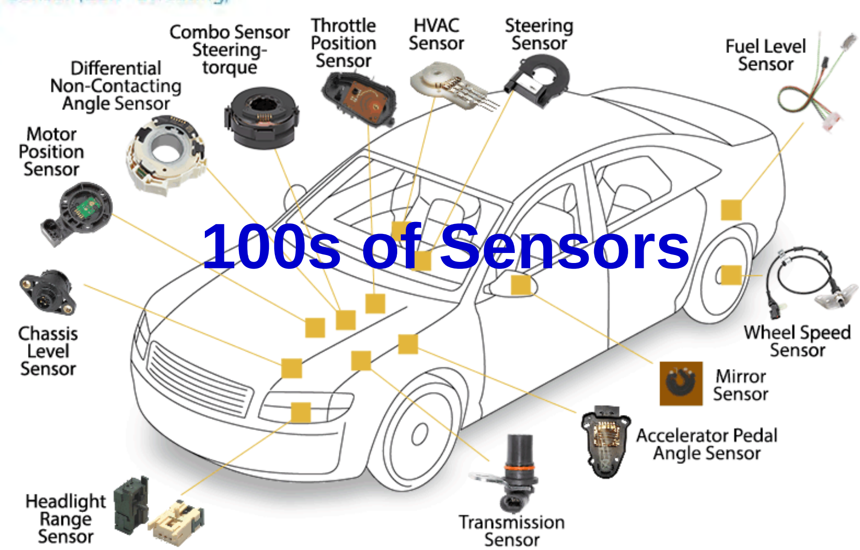

Four Main Components of IoT.

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

# IoT – Sensors

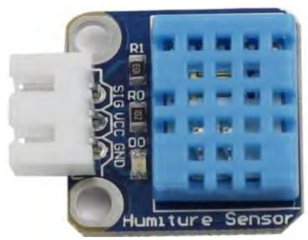


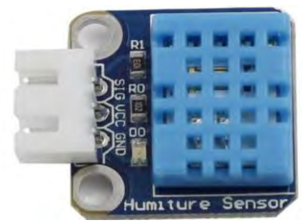

Source: http://www.libelium.com/e-health-low-cost-sensors-for-early-detection-of-childhood-disease-inspire-project-hope/



# IoT – Things

Sensor





Thing


Sensors + Device with its own IP address → Things

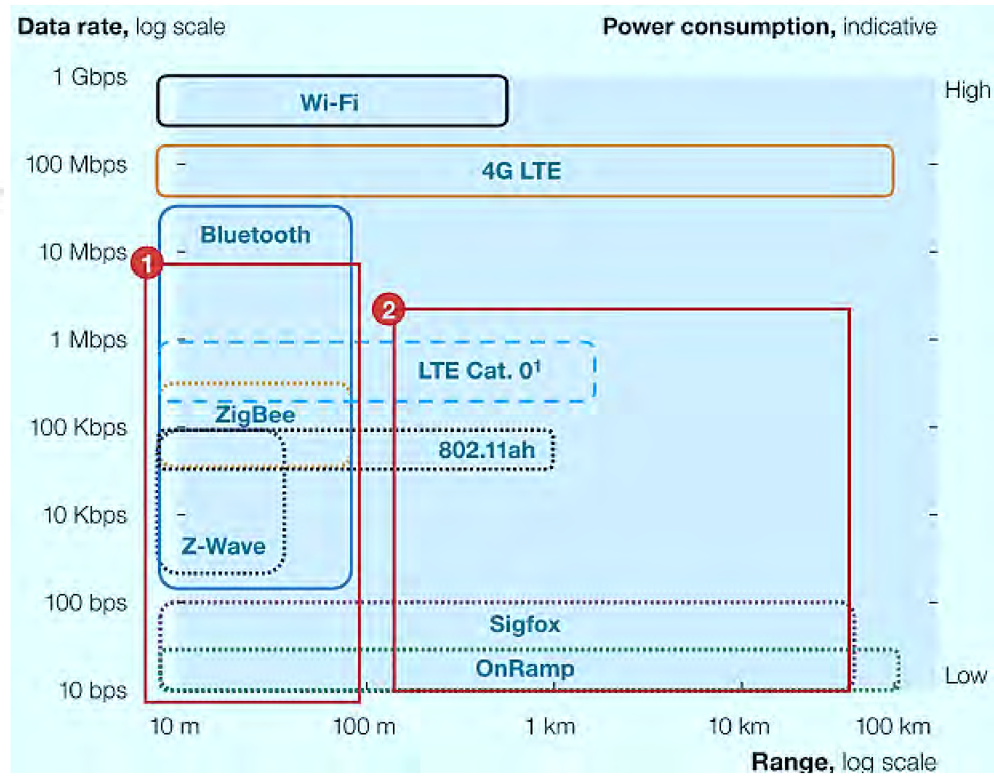
IP Address for Internet Connection

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

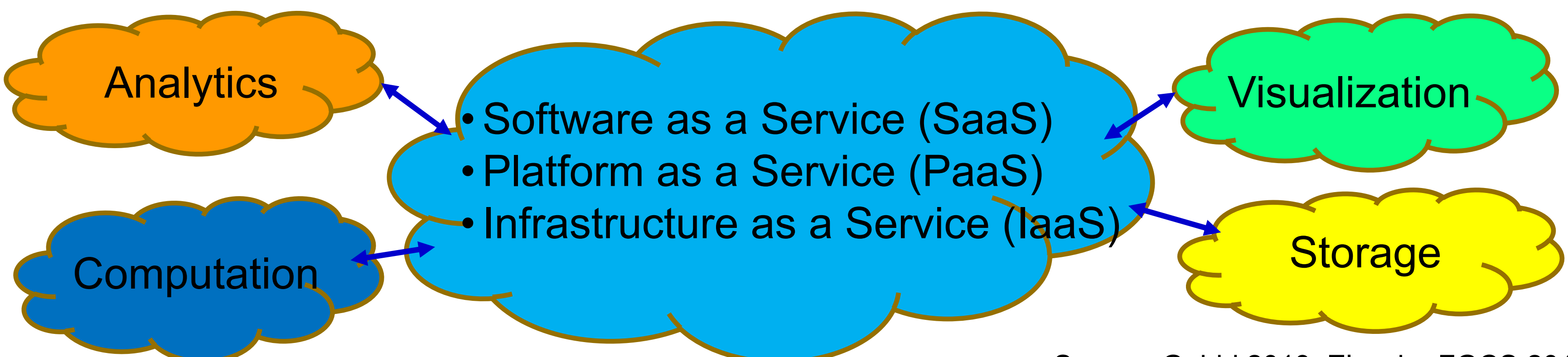



Source: https://www.postscapes.com/internet-of-things-protocols/

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

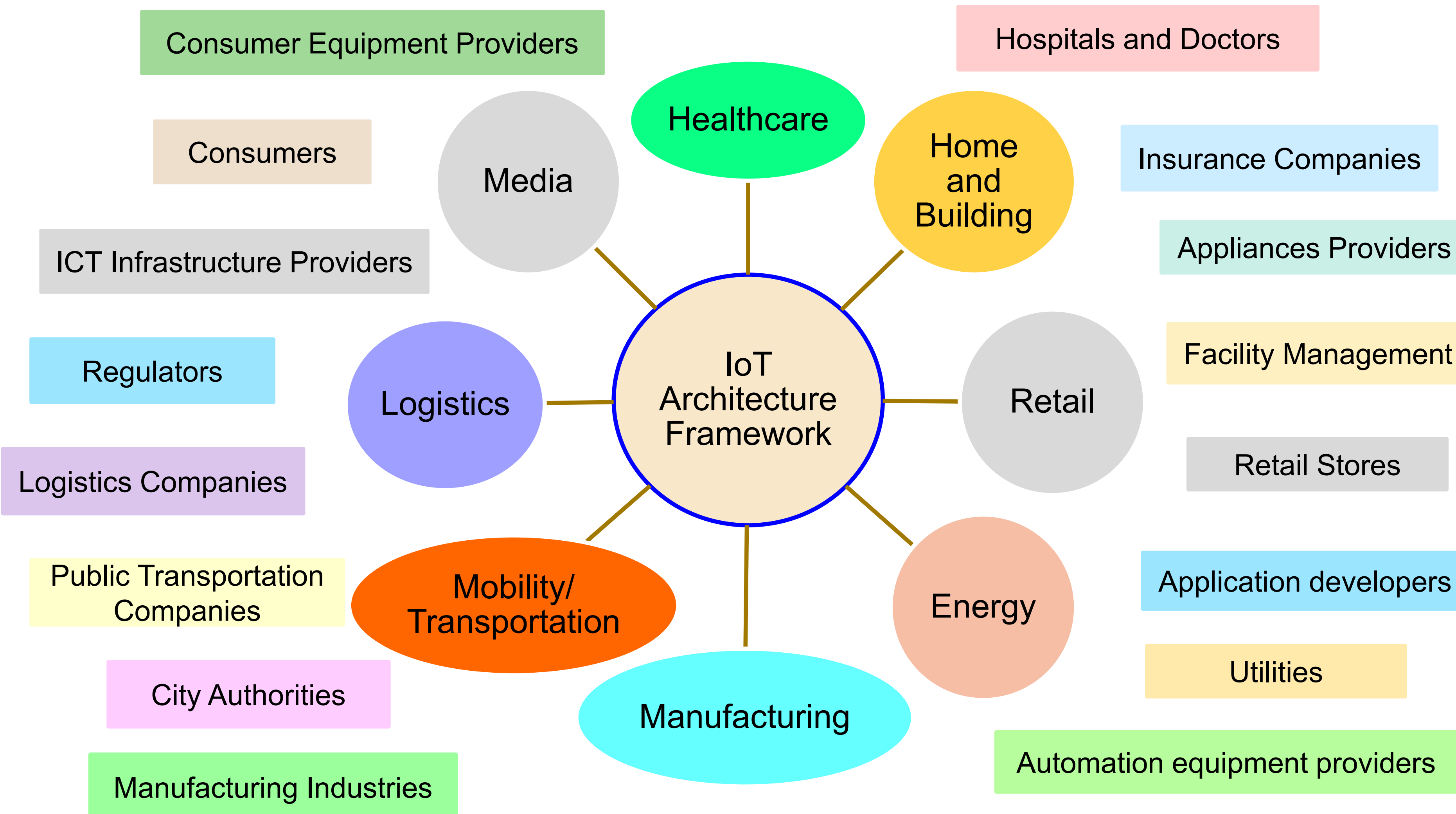



Source: Gubbi 2013, Elsevier FGCS 2013

# IoT - Applications

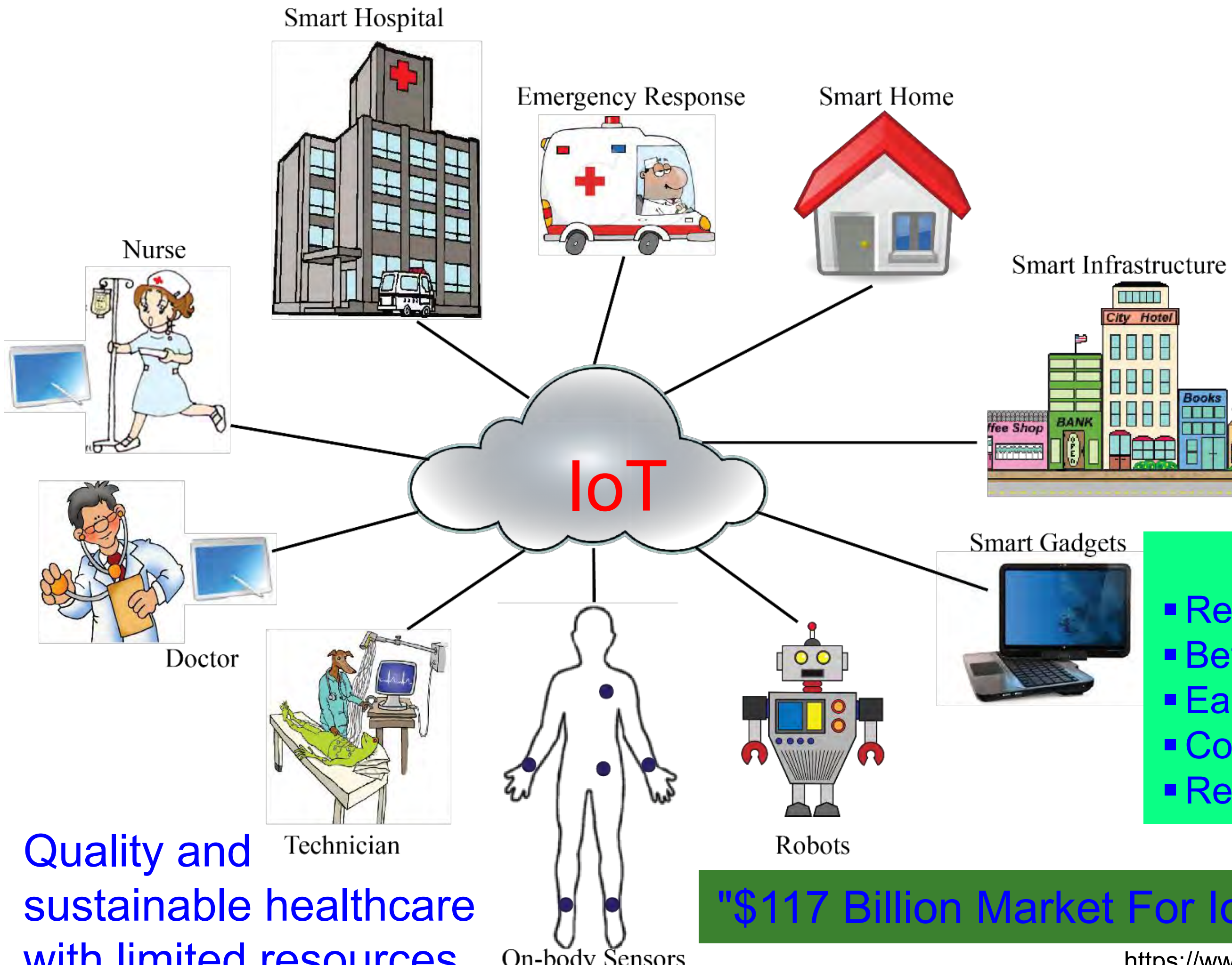

Smart Electronic Systems Laboratory (SESL)

# IoT - Markets and Stakeholders




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

# 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

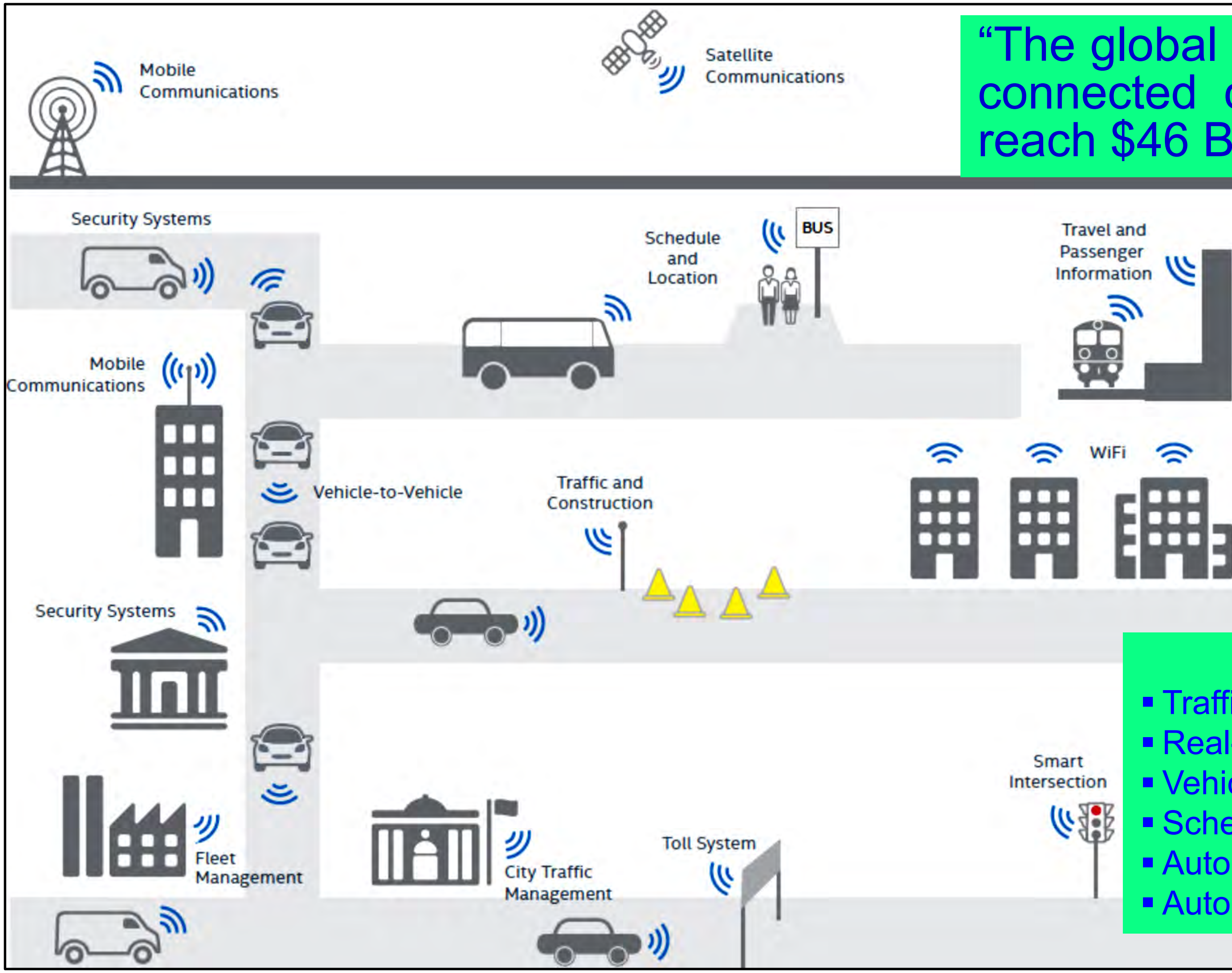
Quality and sustainable healthcare with limited resources, anywhere, anytime.

"$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/

Source: Mohanty 2016, CE Magazine July 2016

# IoT in Smart Transportation




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

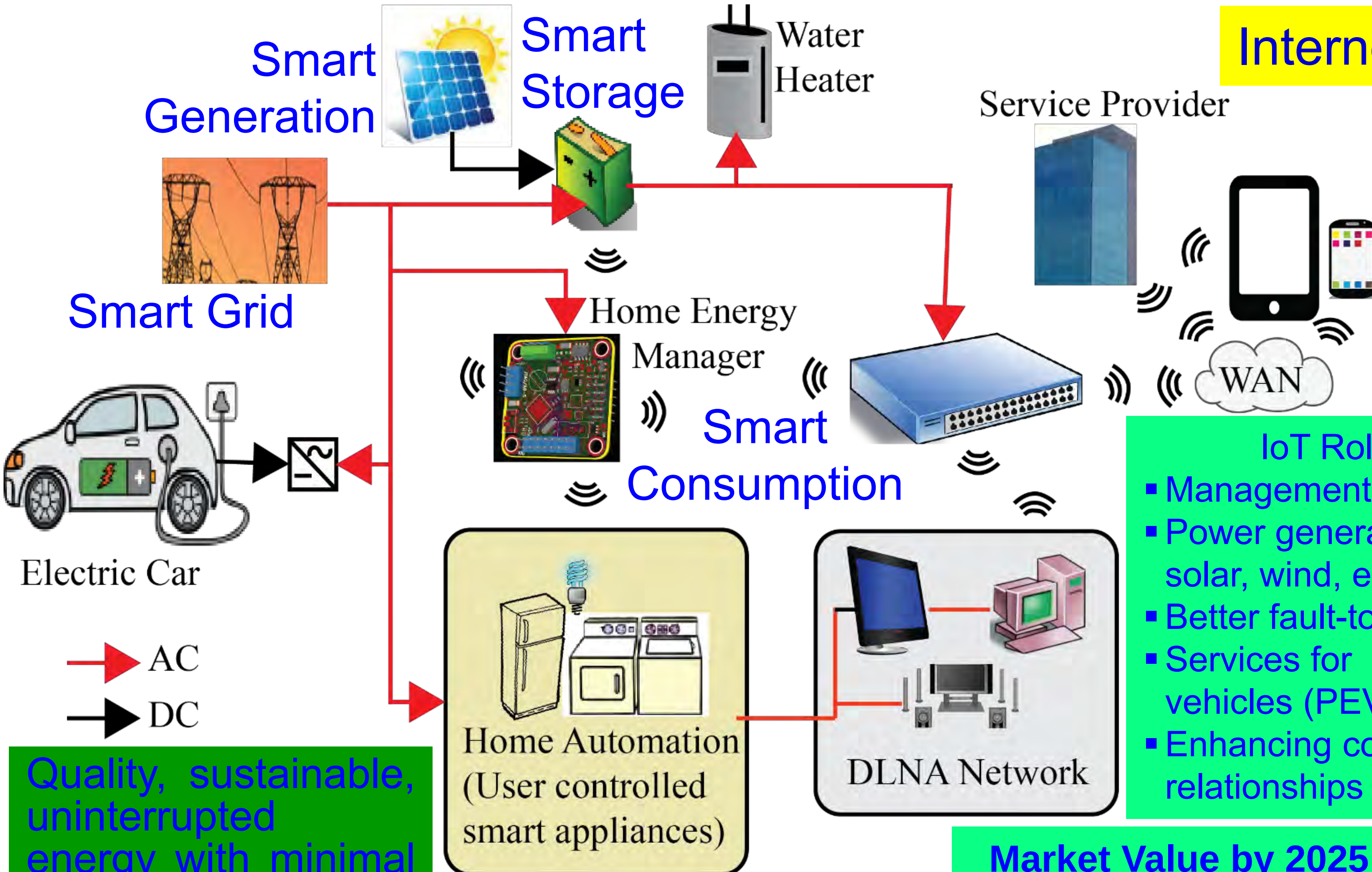
Source: Datta 2017, CE Magazine Oct 2017

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

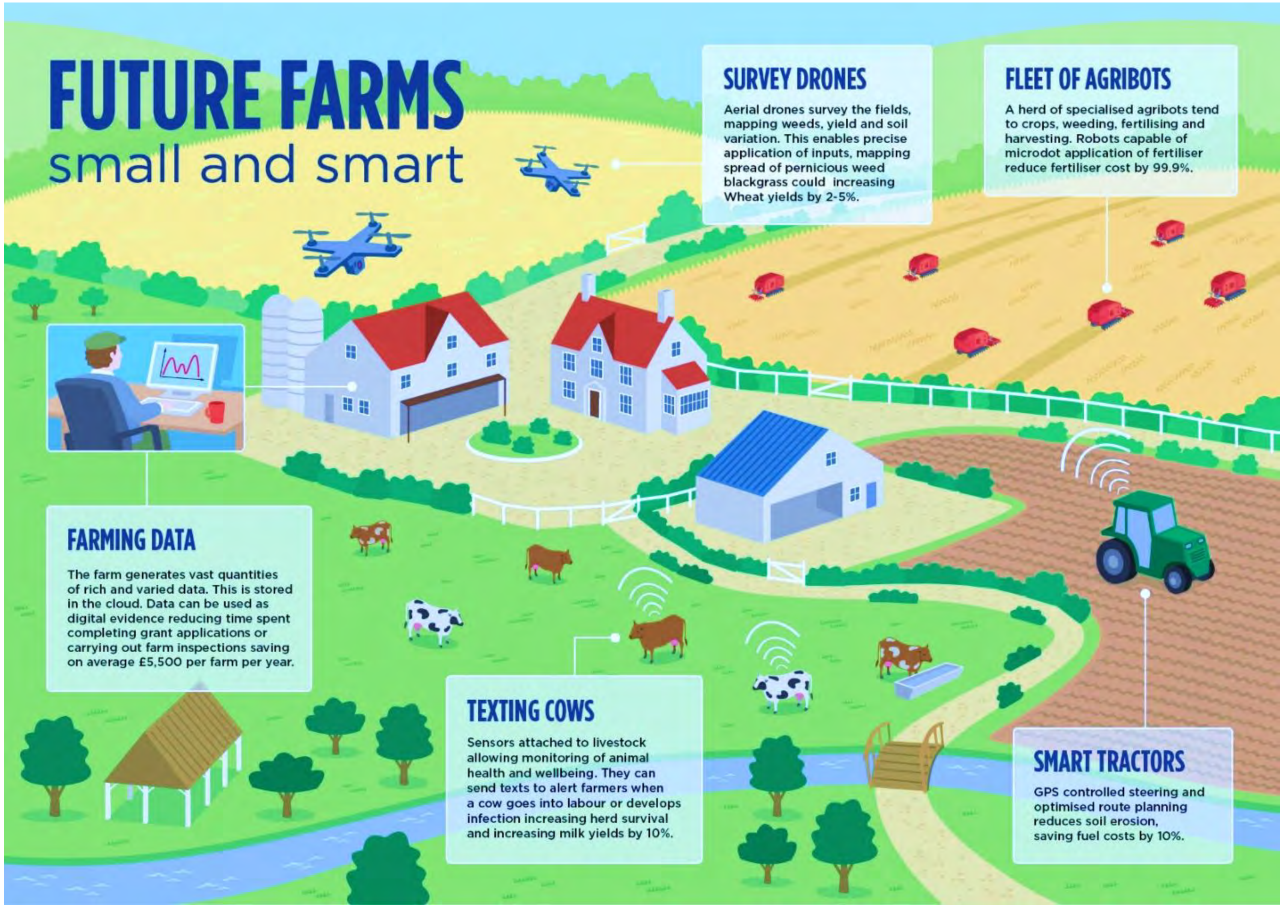
IoT Role Includes:
- Management of energy usage
- Power generation dispatch for solar, wind, etc.
- Better fault-tolerance of the grid
- Services for plug-in electric vehicles (PEV)
- Enhancing consumer relationships

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

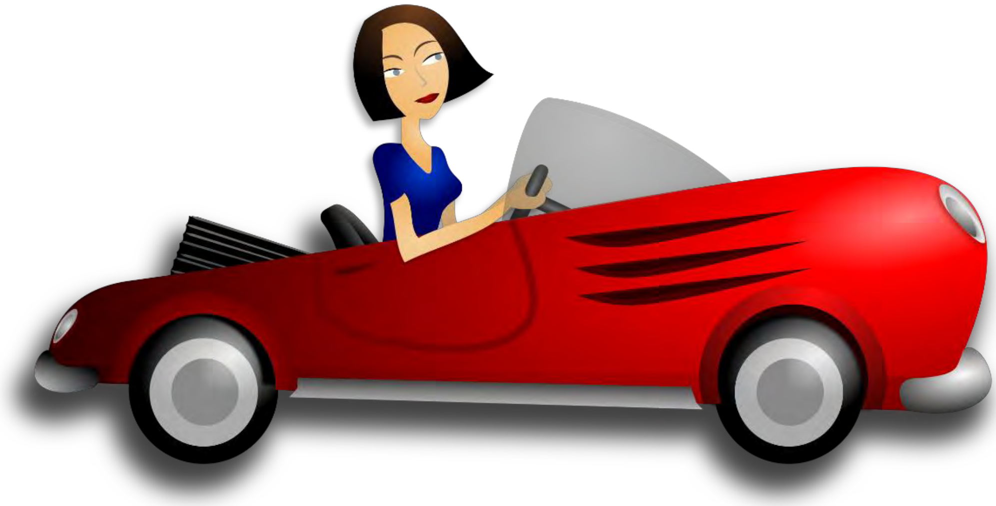
Automatic Irrigation System

Source: Maurya 2017, CE Magazine July 2017

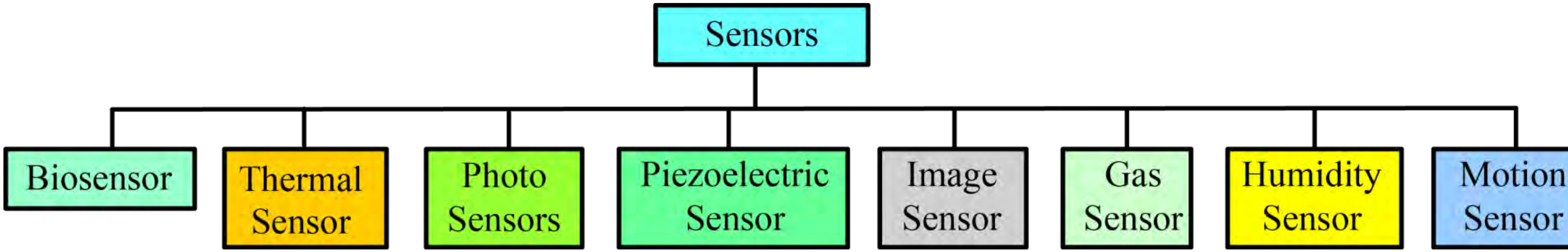
Smart Agriculture/Farming Market Worth $18.21 Billion By 2025

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

# 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

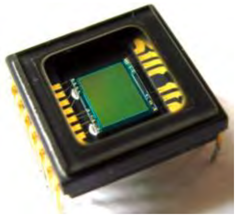

Water Sensor

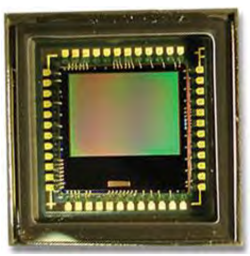

Dust Sensor

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

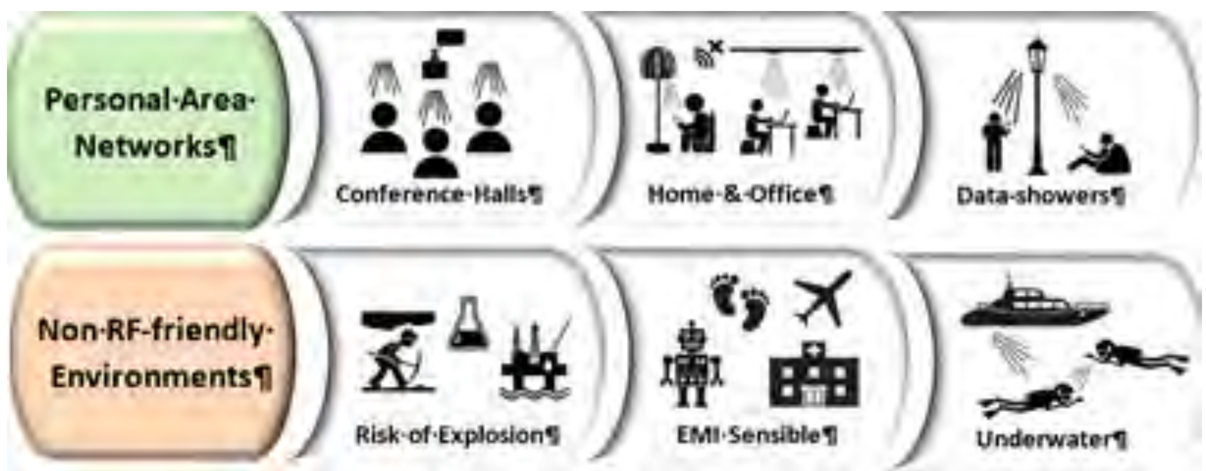
Source: http://www.grandviewresearch.com/press-release/global-cmos-image-sensors-market

# 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

# 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

# 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)

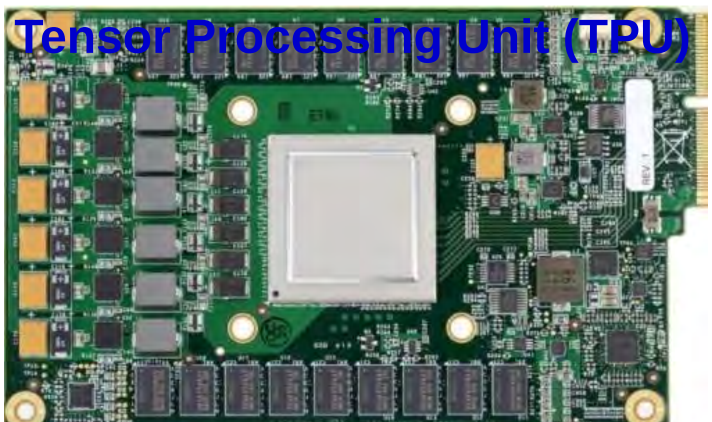
The flash memory market is expected to be worth $37.6 worldwide by 2020.

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

Source: Mohanty 2015, McGraw-Hill 2015

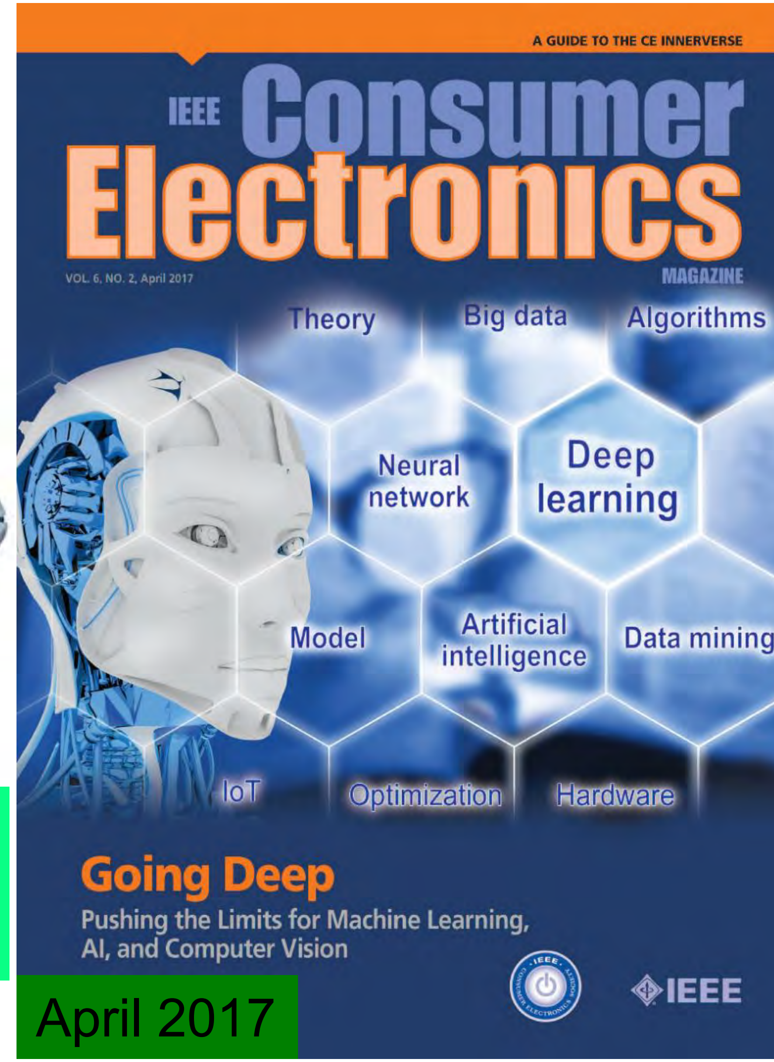
# Machine Learning Technology


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




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

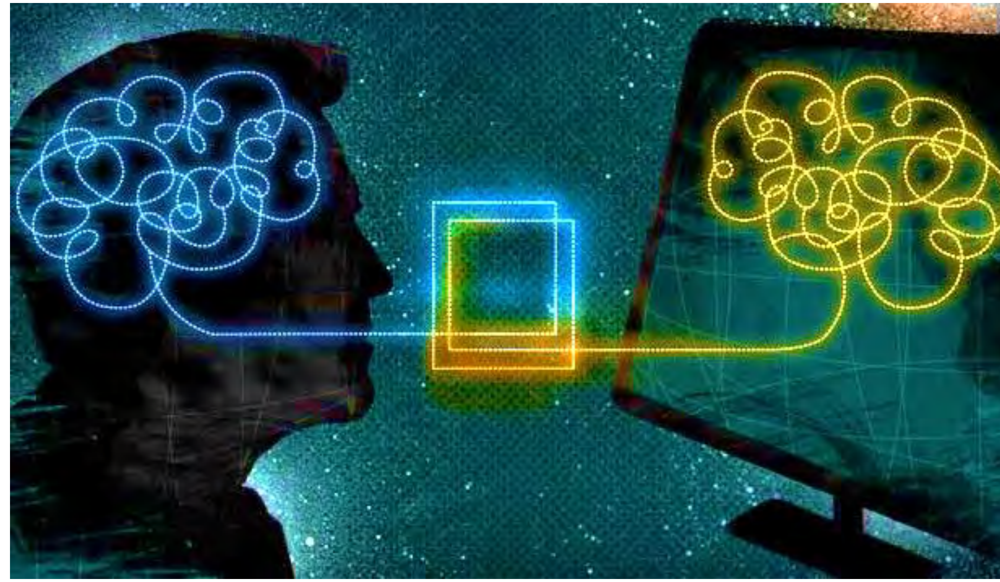
IoT Use:
- Better decision
- Faster response



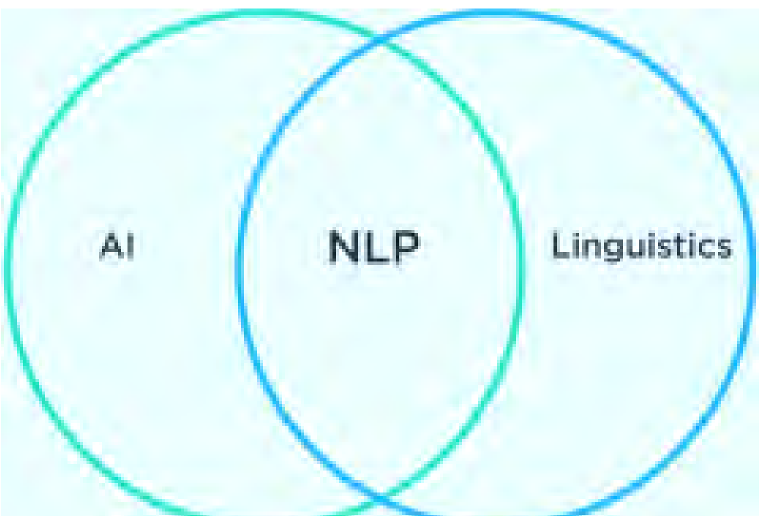

April 2017

# 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".

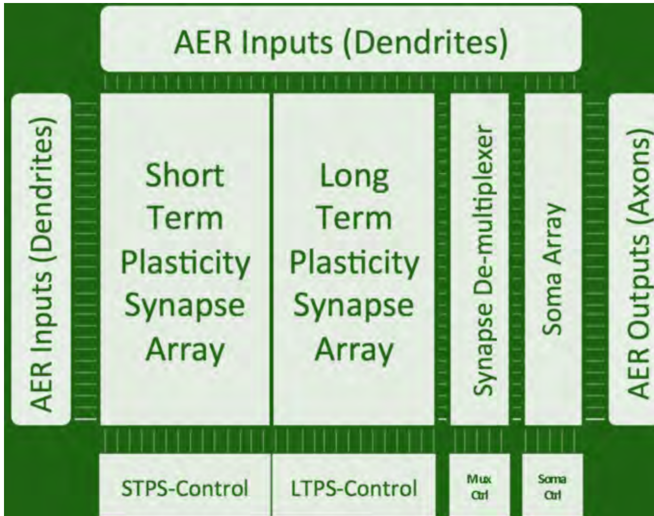
- Systems that learn at scale, reason with purpose and interact with humans naturally.
- Learn and reason from their interactions with humans and from their experiences with their environment; not programmed.

Usage:

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

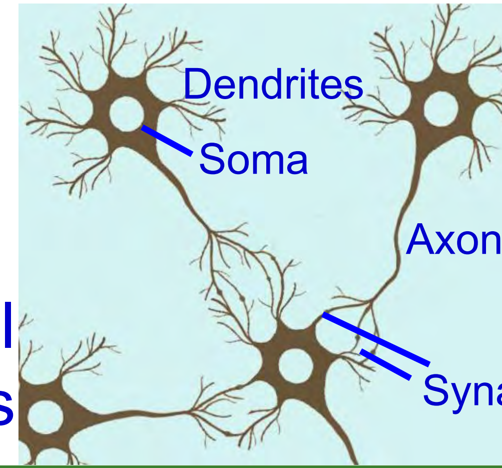
Source: http://www.research.ibm.com/software/IBMResearch/multimedia/Computing_Cognition_WhitePaper.pdf

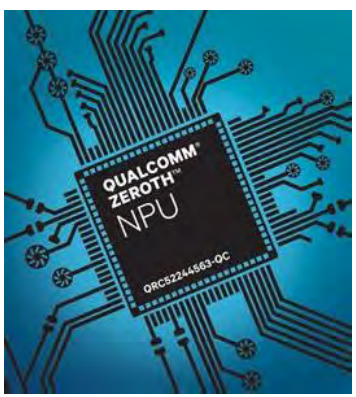
# Neuromorphic Computing or Brain-Inspired Computing




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

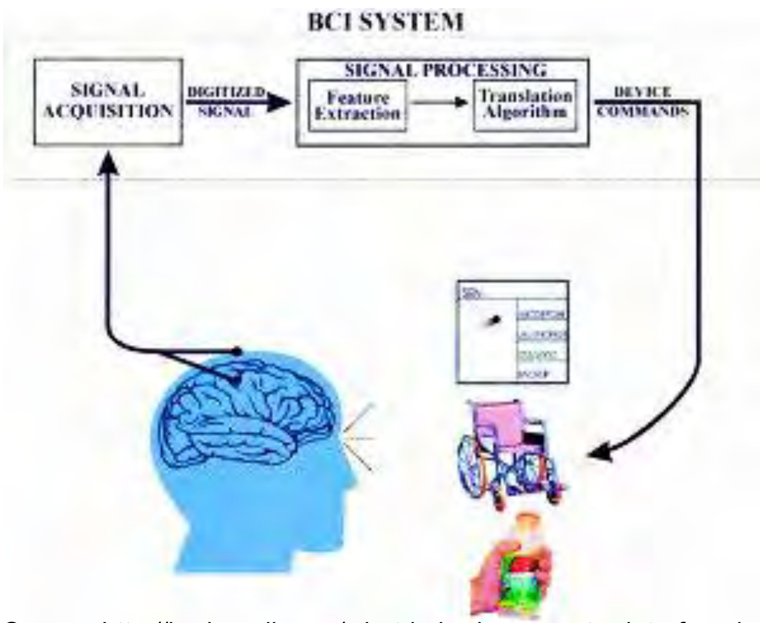
# Neuromorphic Computing or Brain-Inspired Computing


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/

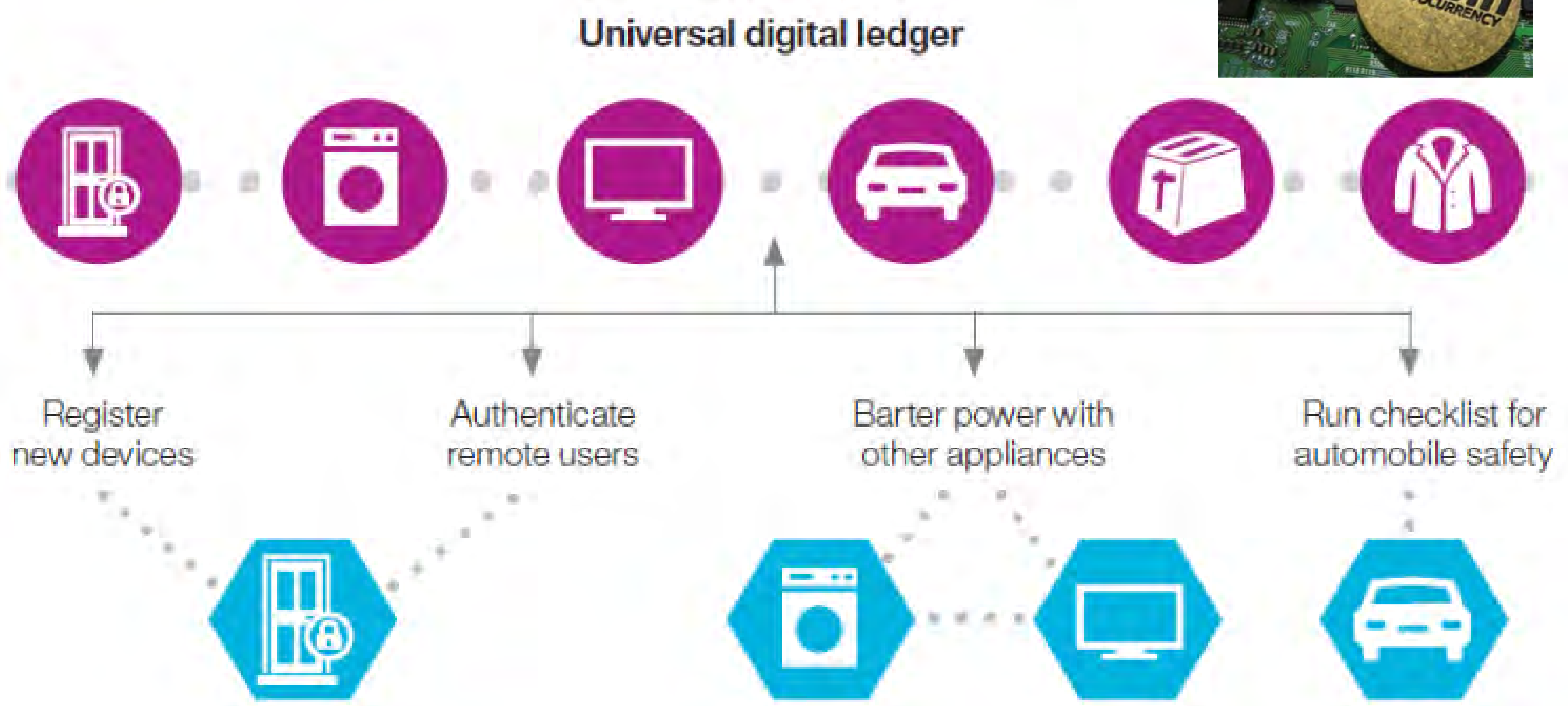
## Brain-Computer Interface Allows paralysis patients to Type Faster

"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/

# The Blockchain



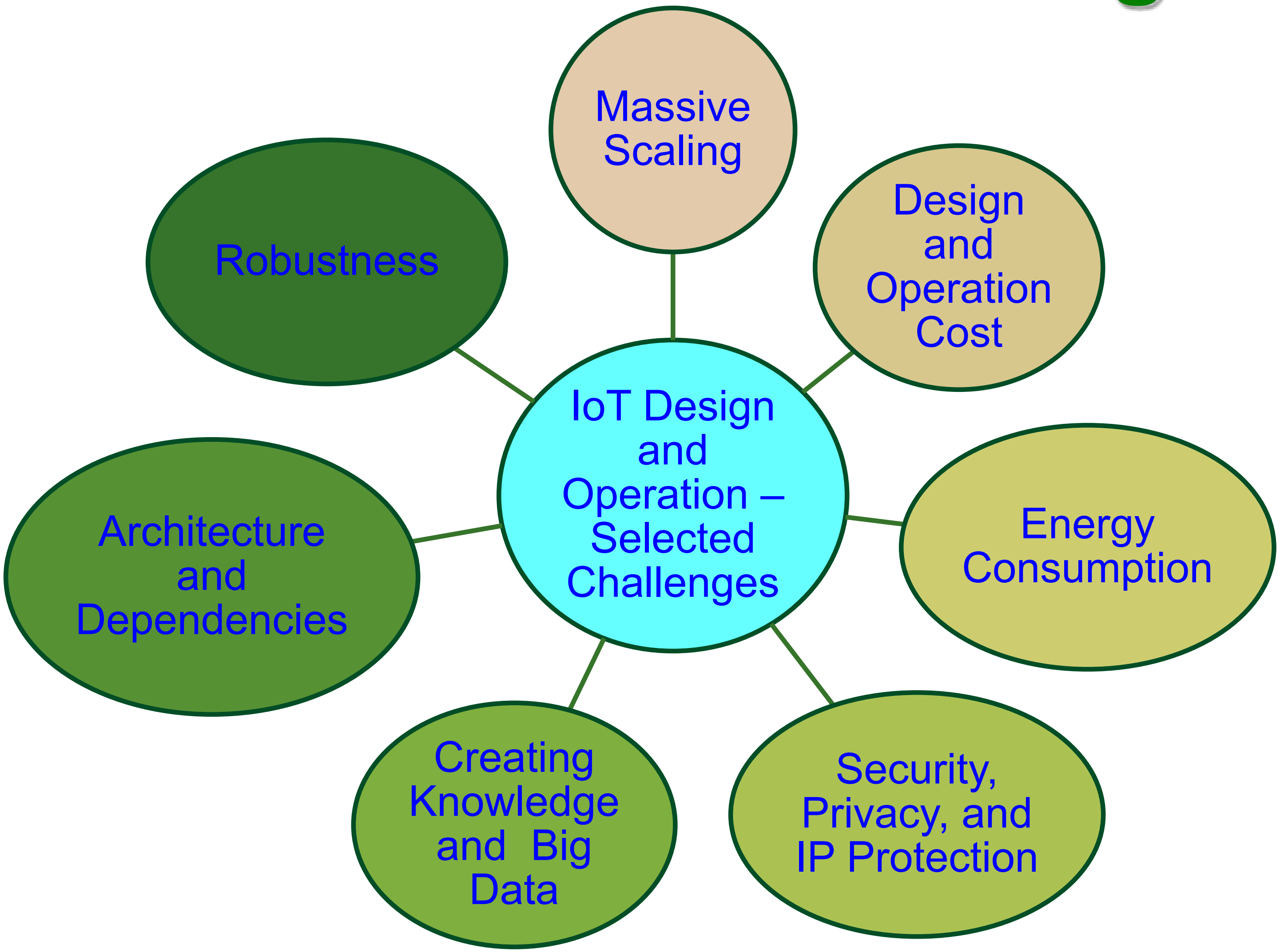

- Think of it as cloud based peer to peer ledger.
- A Blockchain is a cloud based database shared by every participant in a system.
- The Blockchain contains the complete transaction or other record keeping.

Source: https://www.linkedin.com/pulse/securing-internet-things-iot-blockchain-ahmed-banafa

Stay Tuned to: Puthal, Mohanty 2018, CE Magazine March 2018

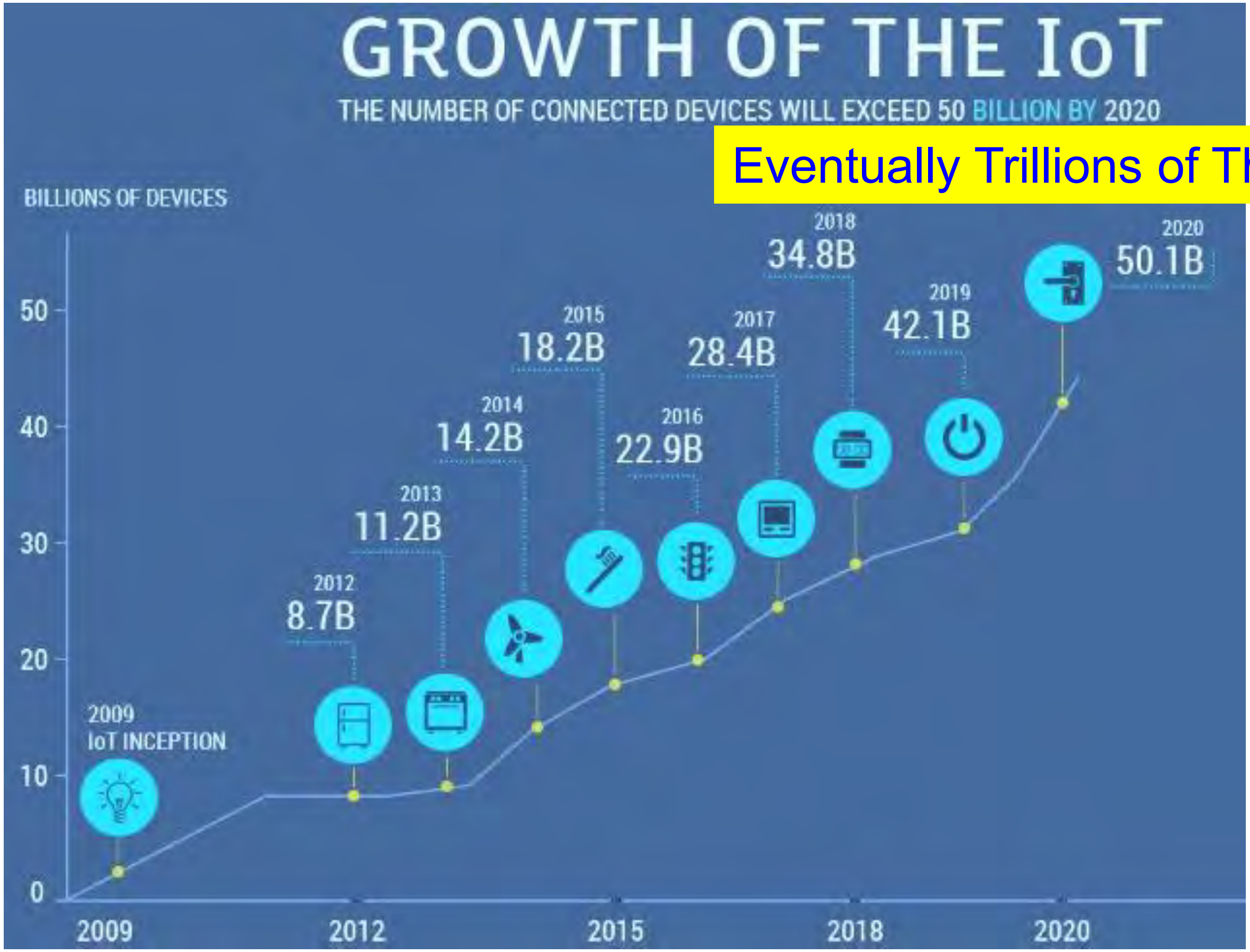
# Challenges and Research

# IoT – Selected Challenges




Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

# Massive Scaling




Eventually Trillions of Things

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."

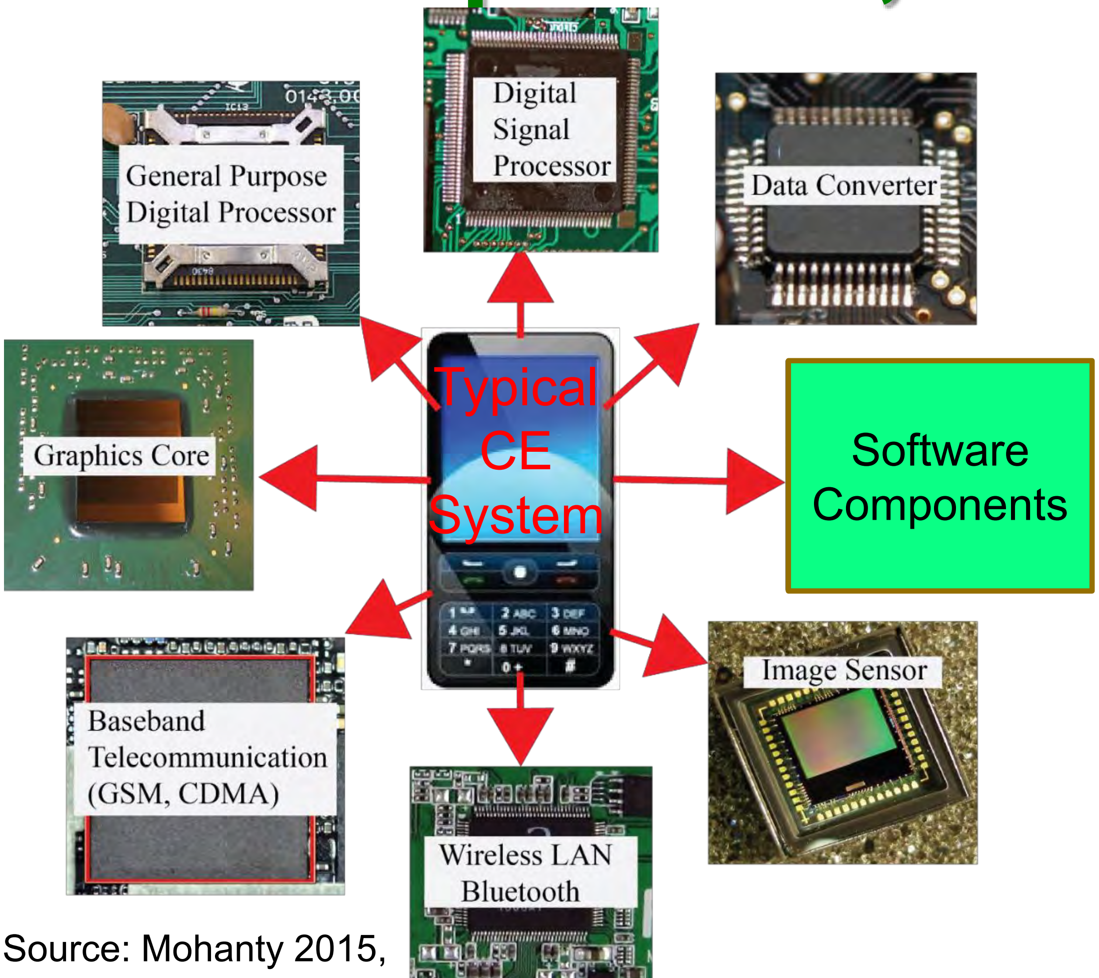
Source: http://www.cnbc.com/2016/10/25/spending-on-smart-cities-around-the-world-could-reach-41-trillion.html

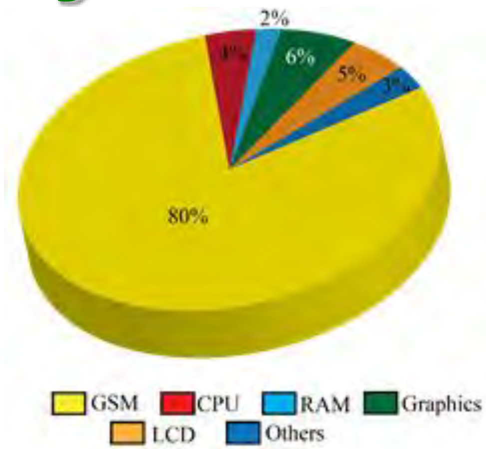
# Communication Latency and Energy Consumption

- 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?

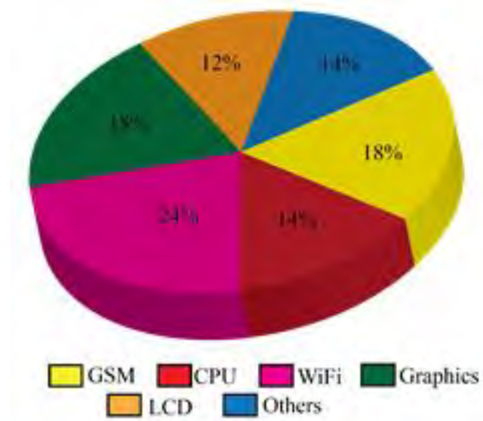
Source: https://www.linkedin.com/pulse/key-technologies-connected-world-cloud-computing-ioe-balakrishnan

# Energy Consumption of Sensors, Components, and Systems




During GSM Communications




During WiFi Communications

Source: Mohanty 2015, McGraw-Hill 2015

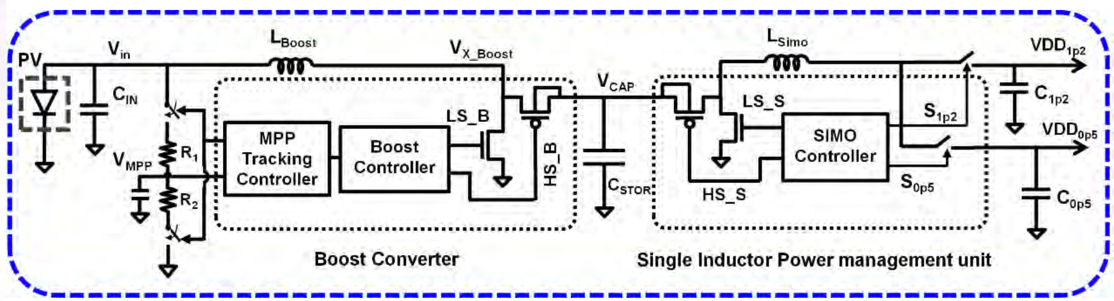
# Battery-Less IoT

Battery less operations can lead to reduction of size and weight of the edge devices.


Source: http://newscenter.ti.com/2015-02-25-TI-makes-battery-less-IoT-connectivity-possible-with-the-industrys-first-multi-standard-wireless-microcontroller-platform


Batter-Less SoC

Source: https://www.technologyreview.com/s/529206/a-batteryless-sensor-chip-for-the-internet-of-things/

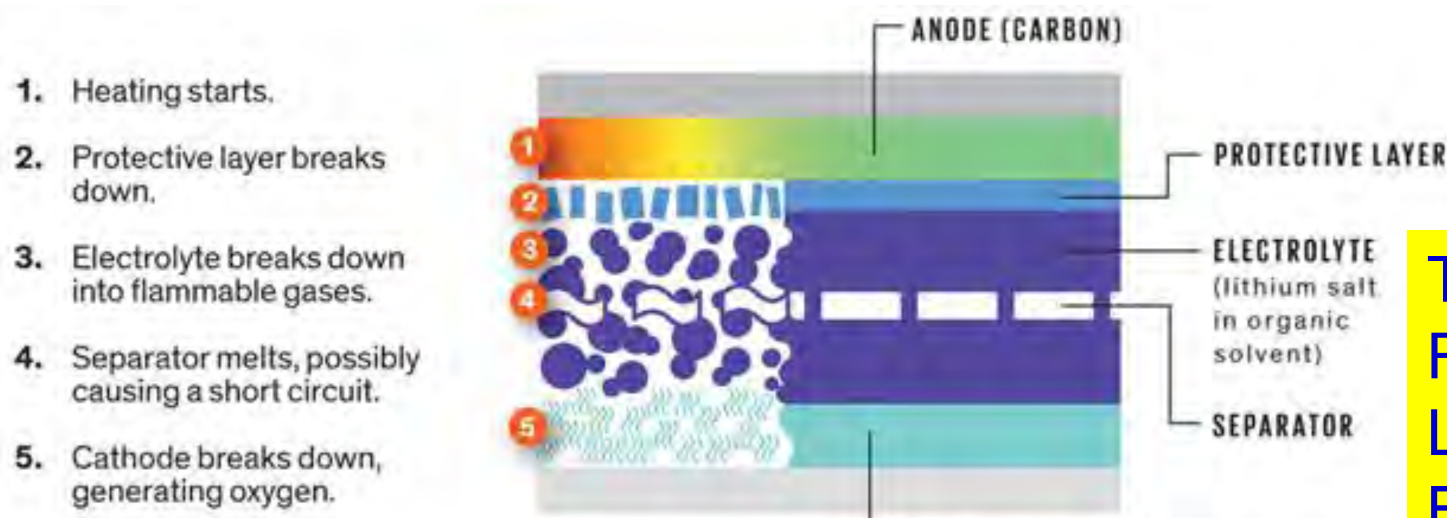



Energy Harvesting and Power Management

Source: http://rlpvlsi.ece.virginia.edu/node/368

# Safety of Electronics

Smartphone Battery



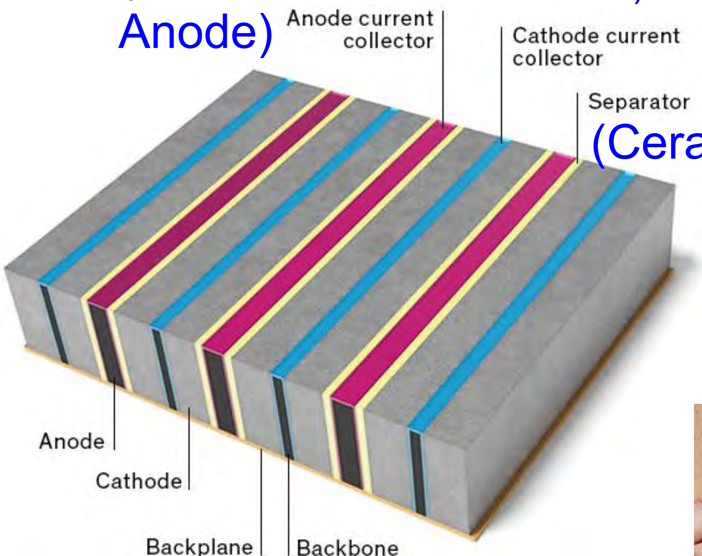

Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

Thermal Runaway in a Lithium-Ion Battery

# Energy Storage - High Capacity and Safer Needed

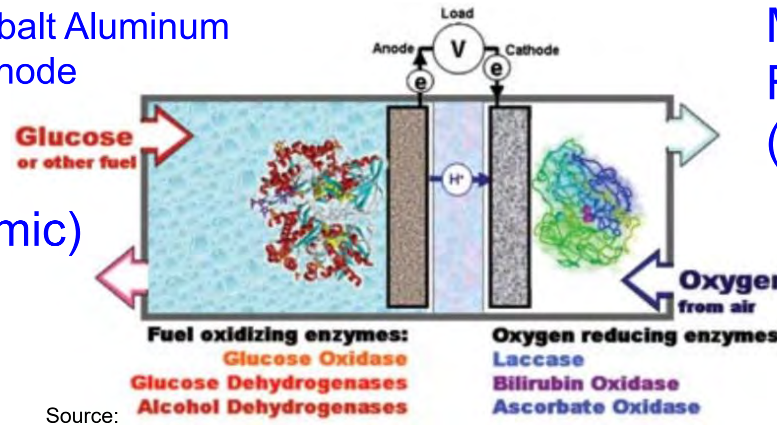
(Silicon Anode)

(Lithium Nickel Cobalt Aluminum Oxide - NCA) Cathode




(Ceramic)

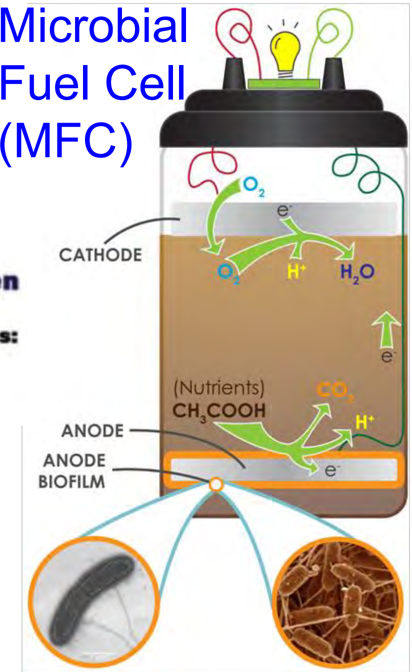

Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

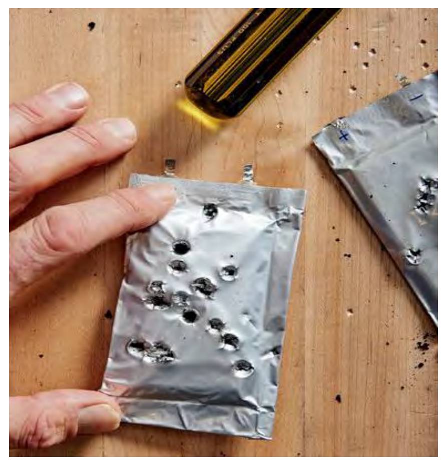



Source: https://www.electrochem.org/dl/interface/sum/sum07/su07_p28_31.pdf

Enzymatic Biofuel Cell

Microbial Fuel Cell (MFC)

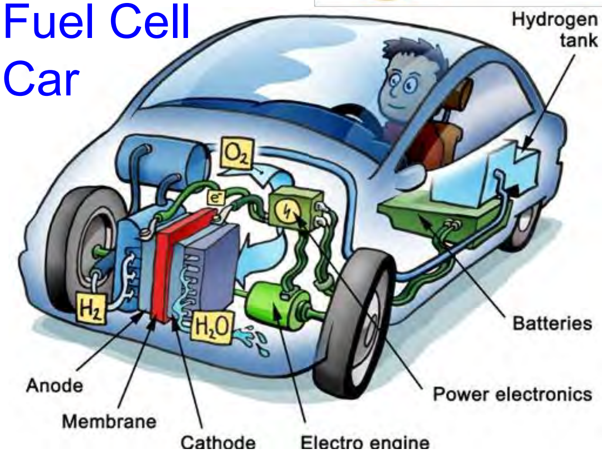


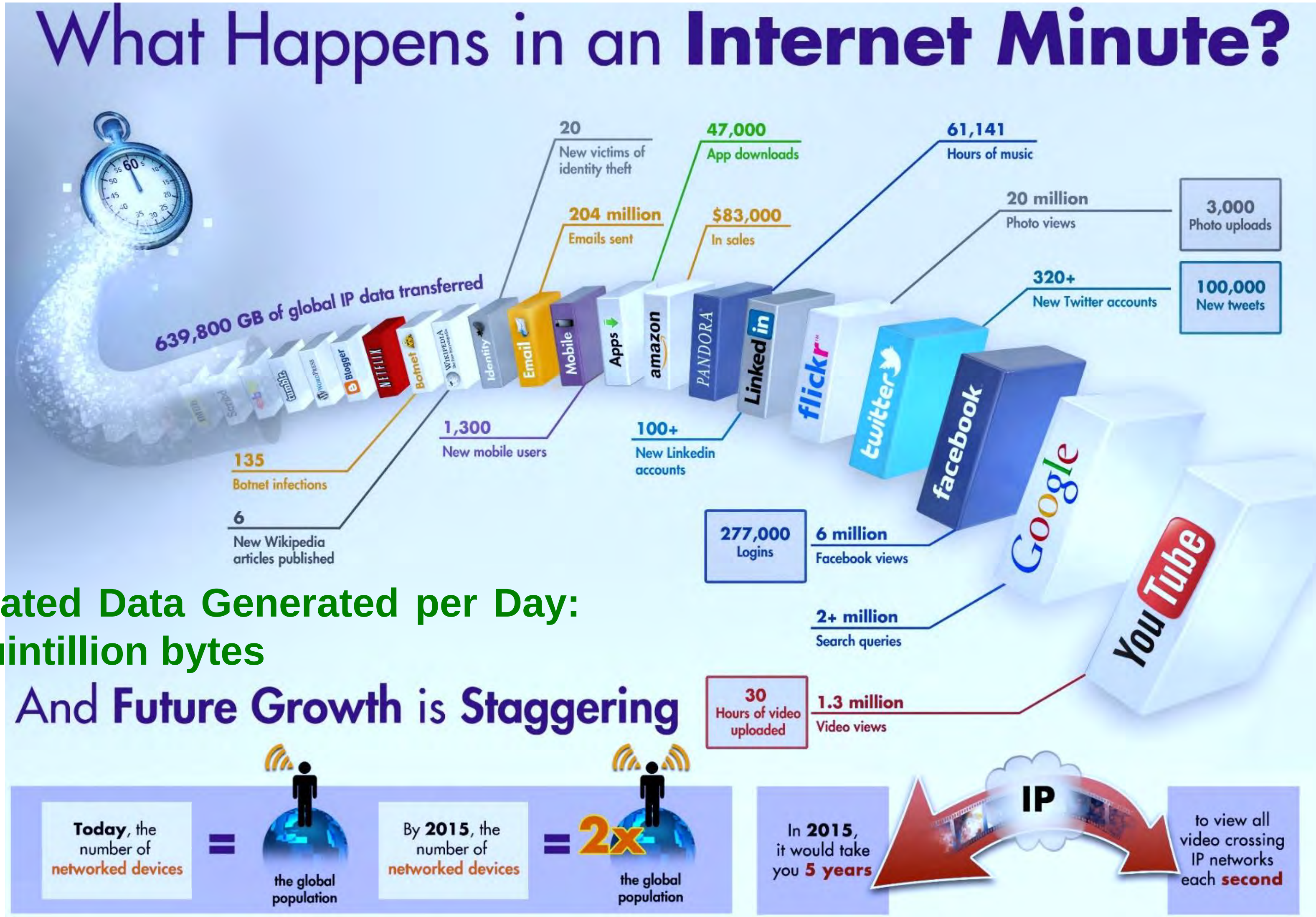
Solid Polymer Lithium Metal Battery

Source: https://www.nytimes.com/2016/12/11/technology/designing-a-safer-battery-for-smartphones-that-wont-catch-fire.html

Fuel Cell Car



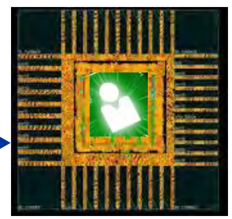
# Huge Amount of Data



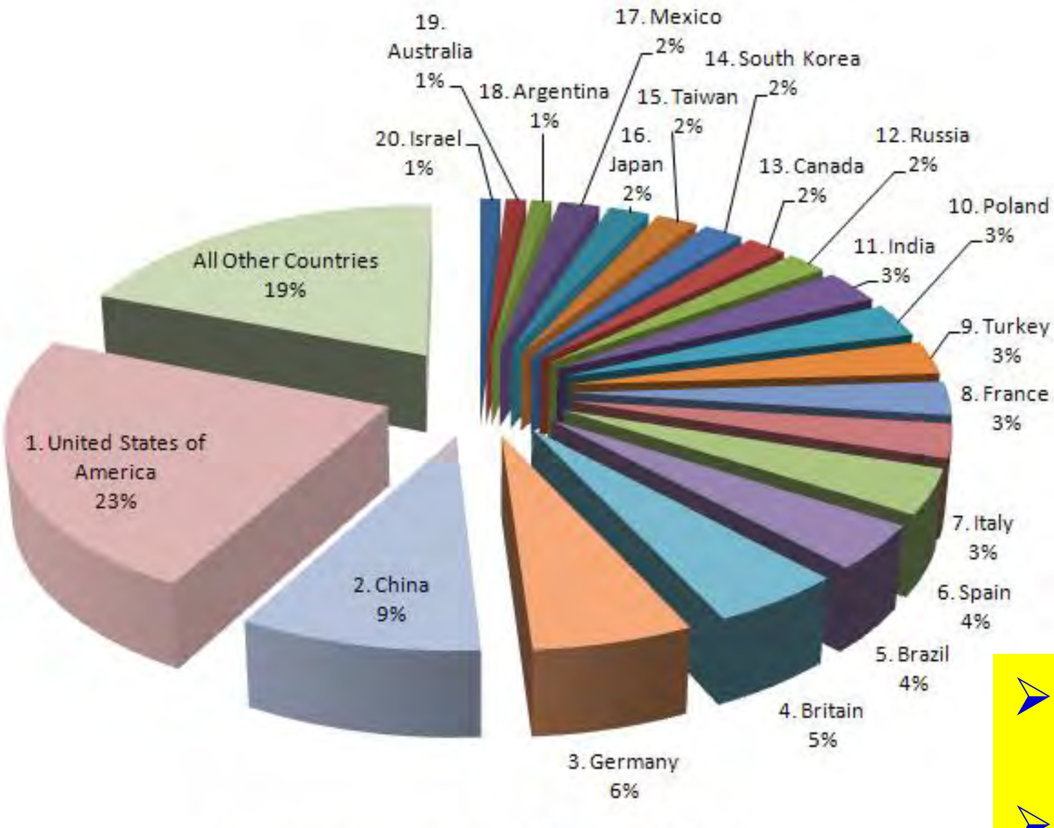

**Estimated Data Generated per Day:**
**2.5 quintillion bytes**

# Security, Privacy, and Copyright

Hardware Trojan



# 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

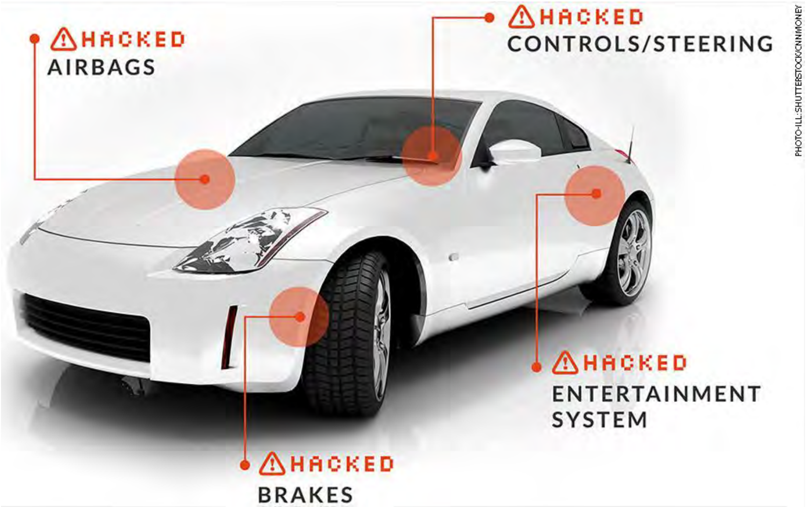
Source: http://www.csoonline.com/article/3153707/security/top-5-cybersecurity-facts-figures-and-statistics-for-2017.html

# Security in Communications Technology

# Security - Systems …

Power Grid Attack

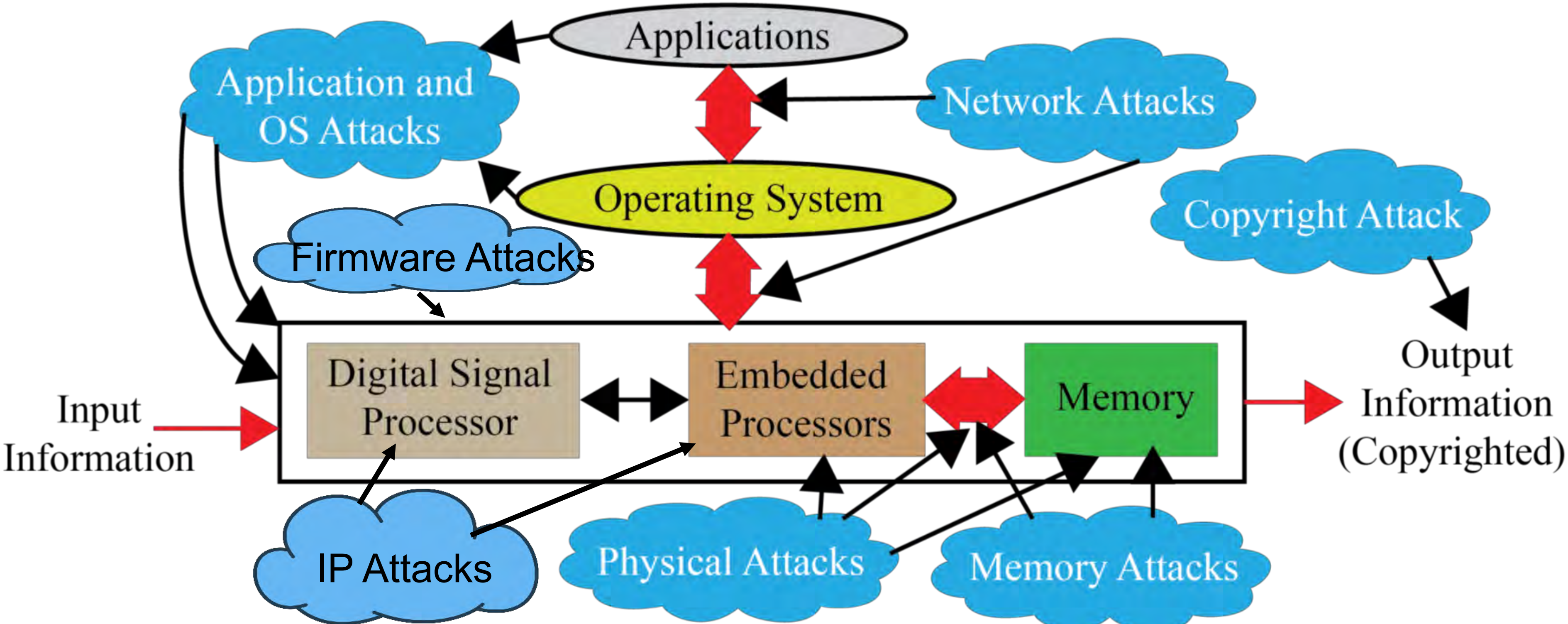
Source: http://www.csoonline.com/article/3177209/security/why-the-ukraine-power-grid-attacks-should-raise-alarm.html




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


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

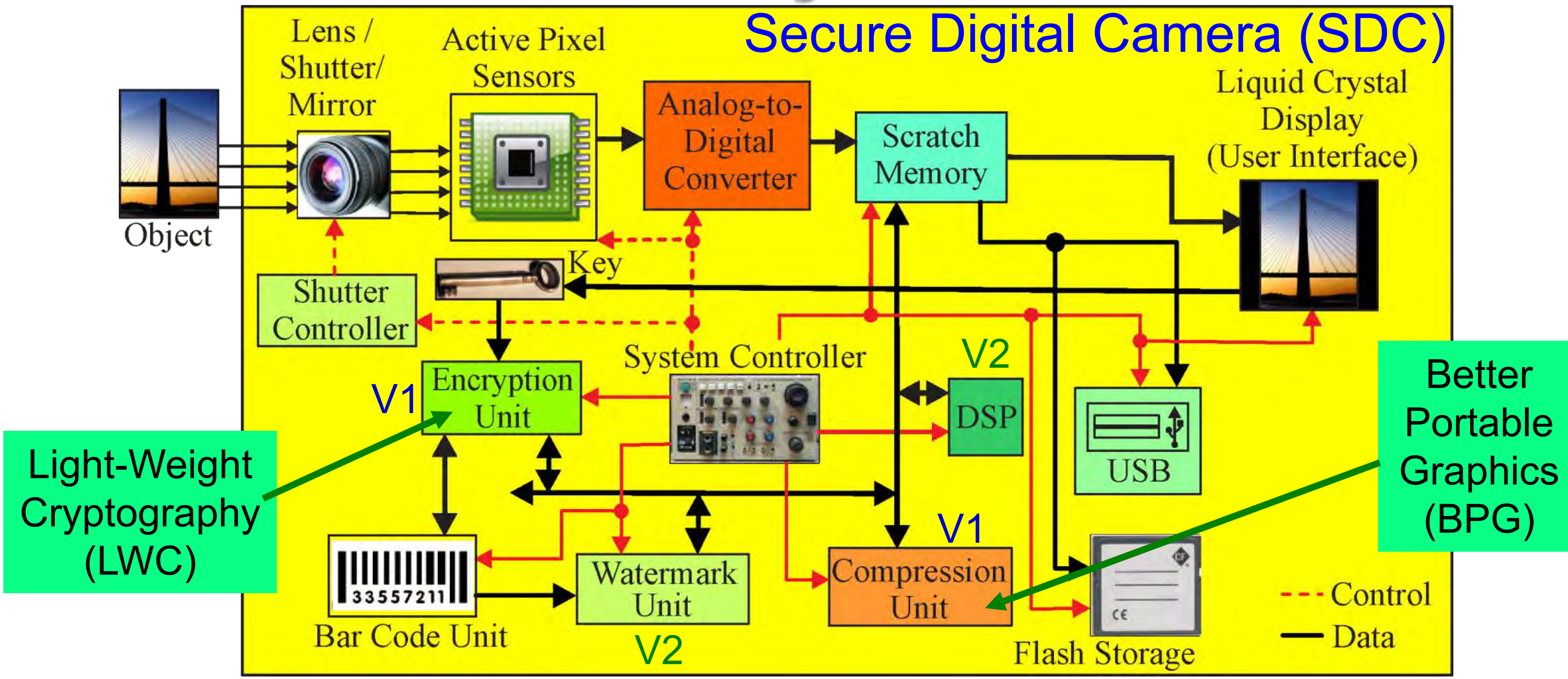
# Selected Attacks on a Typical CE System – Security, Privacy, IP Right




Source: Mohanty 2015, McGraw-Hill 2015

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

# CE System Energy & Security Tradeoff – System Level



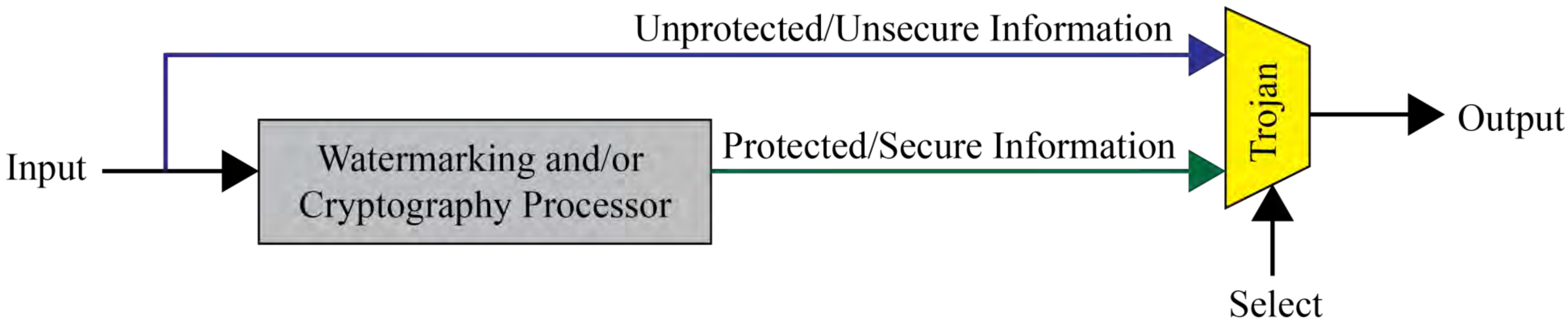

Include additional hardware components, but perform DVFS like technology for energy and performance optimization.

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

# Malicious Design Modifications Issue

Information may bypass giving a non-watermarked or non-encrypted output.

Hardware Trojans




Source: Mohanty 2015, McGraw-Hill 2015

Provide backdoor to adversary.
Chip fails during critical needs.

# Trojan Secure Digital Hardware Synthesis

HLS Library Comprising of Module info from Two Vendors

Datapath Resource configuration ($R_n$)

Vendor Allocation Type ($A_v$)

Unrolling Factor (U)

Trojan Detection Block

DMR Scheduling

Modified Allocation in DMR based on Distinct Vendor Rule

PSO-Driven Exploration for Optimizing Independent Factors Simultaneously

Optimizing Datapath Configuration

Optimizing Vendor Allocation Type

Optimizing Unrolling Factor

Binding

Cost Evaluation

Low Cost Trojan Secured Datapath

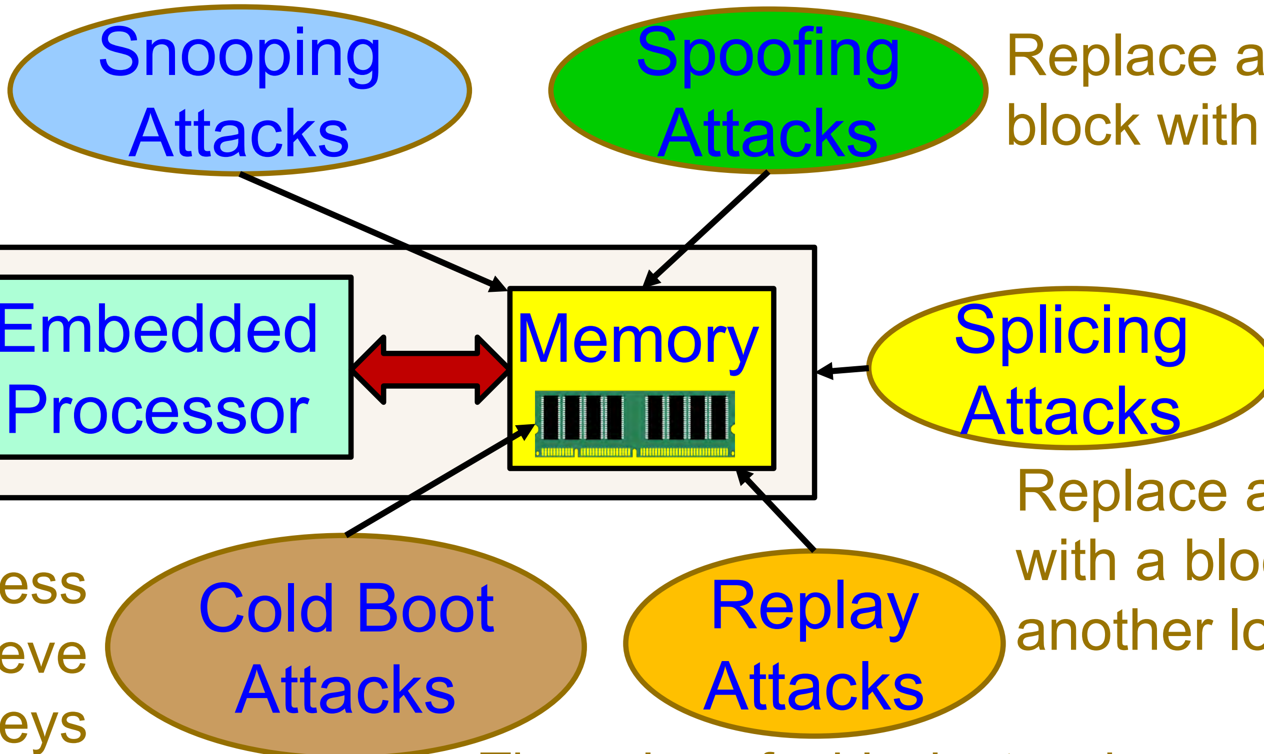
Provide backdoor to adversary.
Chip fails during critical needs.

Source: Sengupta, Mohanty 2017: TCAD April 2017

# Memory Attacks

Read confidential information in memory

Replace a block with fake




Replace a block with a block from another location

Physical access memory to retrieve encryption keys

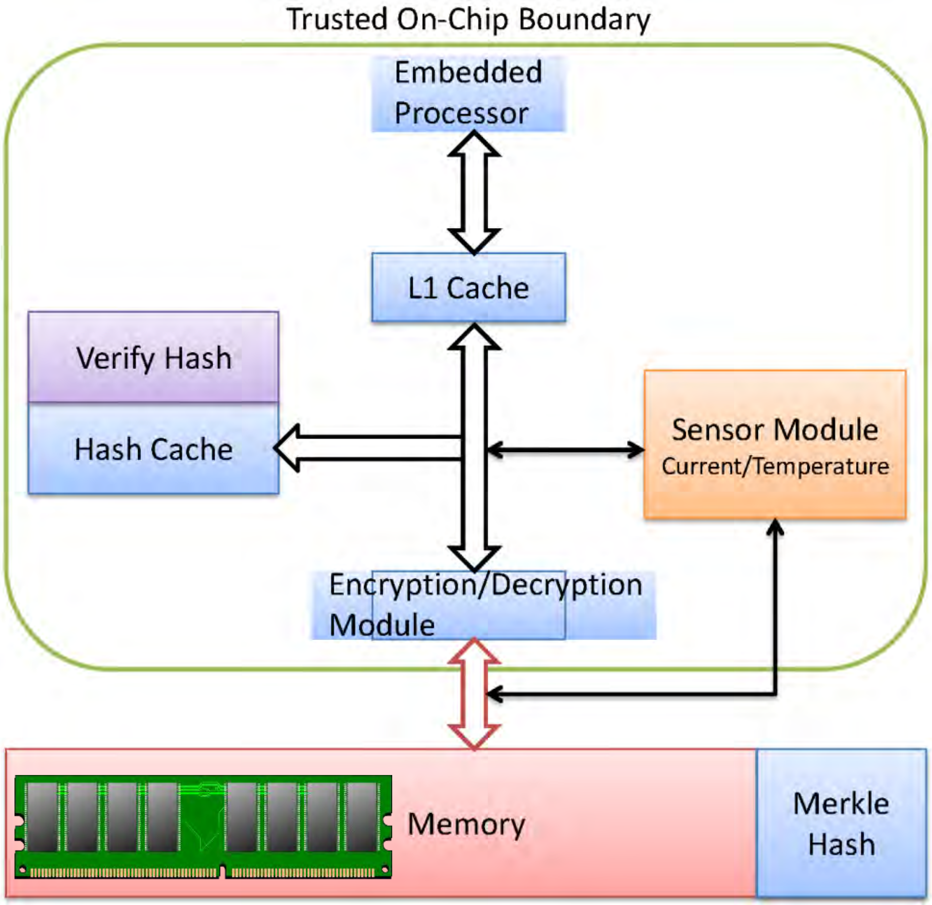
The value of a block at a given address at one time is written at exactly the same address at a different times; Hardest attack.

Source: Mohanty 2013, Springer CSSP Dec 2013

# Memory Security and Protection


Nonvolatile Storage

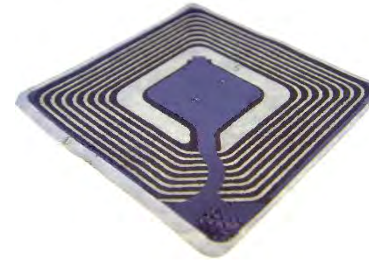
Source: http://datalocker.com




On-Chip/On-Board Memory Protection

Source: Mohanty 2013, Springer CSSP Dec 2013

# RFID Security - Attacks



- Selected RFID Attacks
  - Physical RFID Threats
    - Disabling Tags
    - Tag Modification
    - Cloning Tags
    - Reverse Engineering and Physical Exploration
  - RFID Channel Threats
    - Eavesdropping
    - Snooping
    - Skimming
    - Replay Attack
    - Relay Attacks
    - Electromagnetic  Interference
  - System Threats
    - Counterfeiting and Spoofing Attacks
    - Tracing and Tracking
    - Password Decoding
    - Denial of Service (DoS) Attacks


Numerous Applications

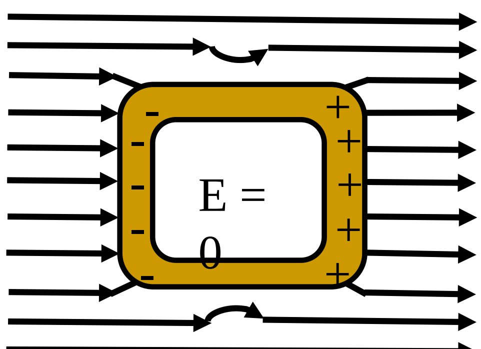
Source: Khattab 2017: Springer 2017 RFID Security

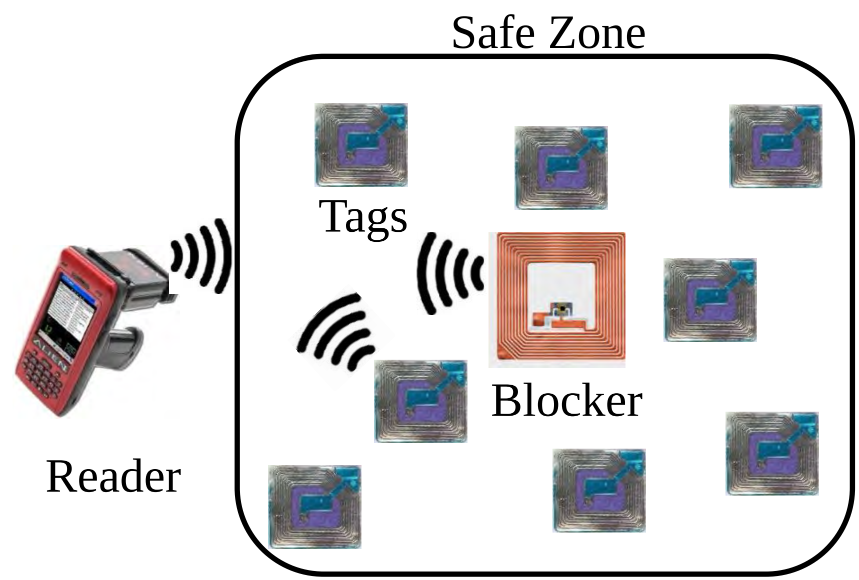
# RFID Security - Solutions

**Selected RFID Security Methods**

- Killing Tags
- Sleeping Tags
- Faraday Cage
- Blocker Tags
- Tag Relabeling
- Minimalist Cryptography
- Proxy Privacy Devices

Faraday Cage




Blocker Tags

Source: Khattab 2017, Springer 2017 RFID Security

# NFC Security - Attacks

Selected NFC Attacks

- Eavesdropping
- Data Modification
- Relay Attacks
- Data Corruption
- Spoofing
- Interception Attacks
- Theft


Source: http://www.idigitaltimes.com/new-android-nfc-attack-could-steal-money-credit-cards-anytime-your-phone-near-445497

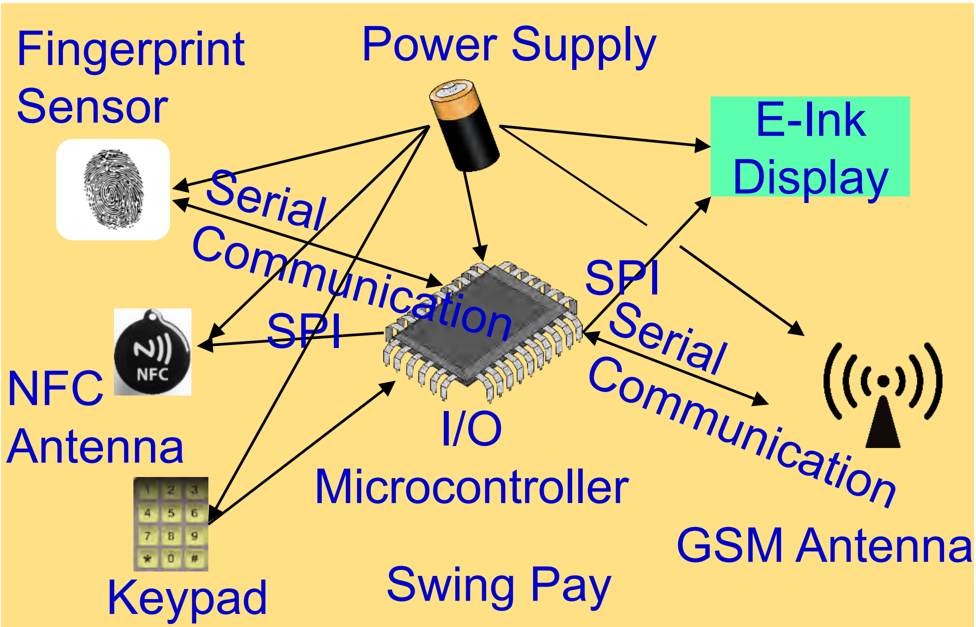

Eavesdropping

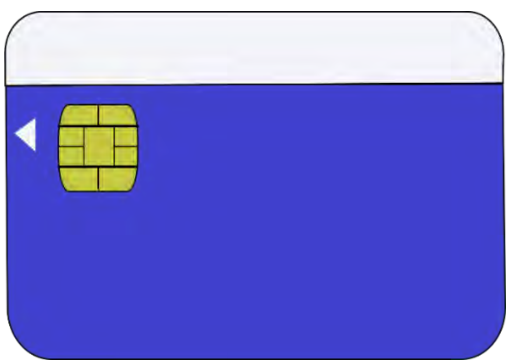
Source: http://resources.infosecinstitute.com/near-field-communication-nfc-technology-vulnerabilities-and-principal-attack-schema/

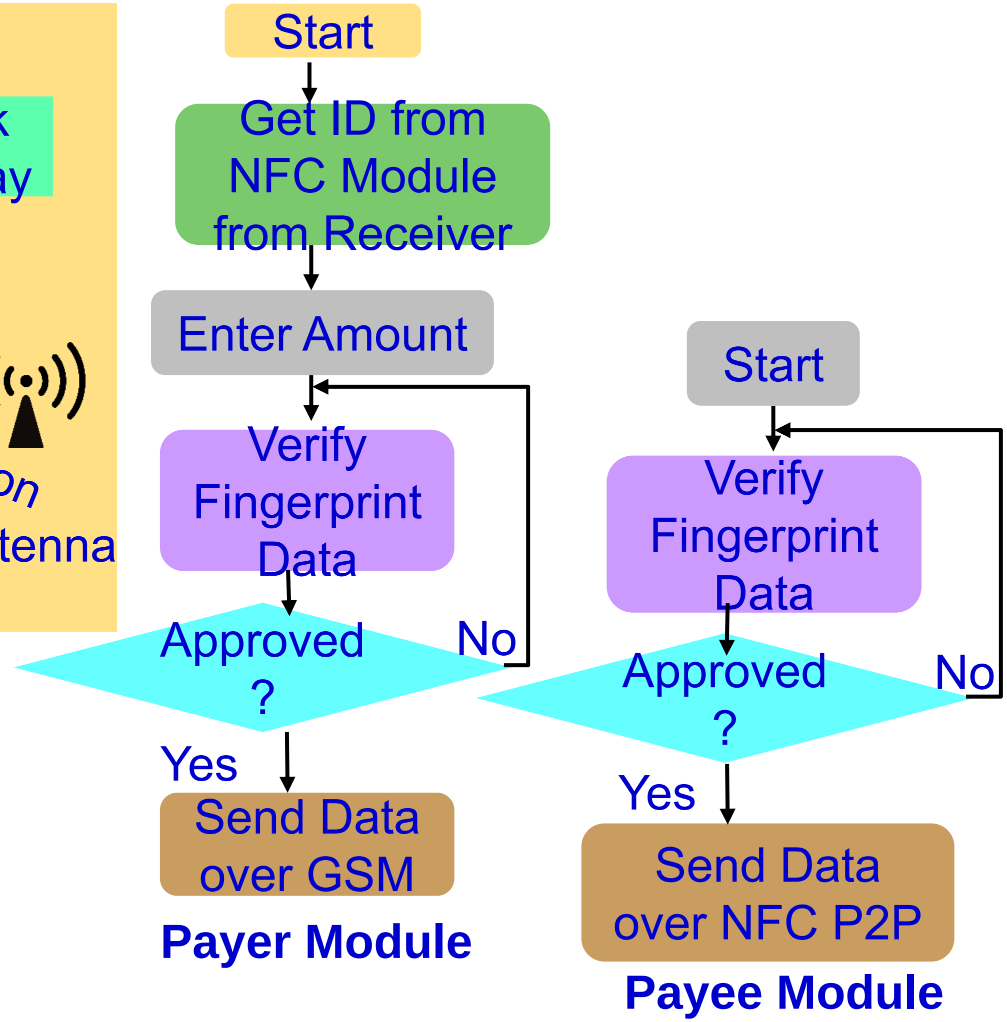
Relay Attack


Source: https://www.slideshare.net/cgvwzq/on-relaying-nfc-payment-transactions-using-android-devices

# NFC Security - Solution



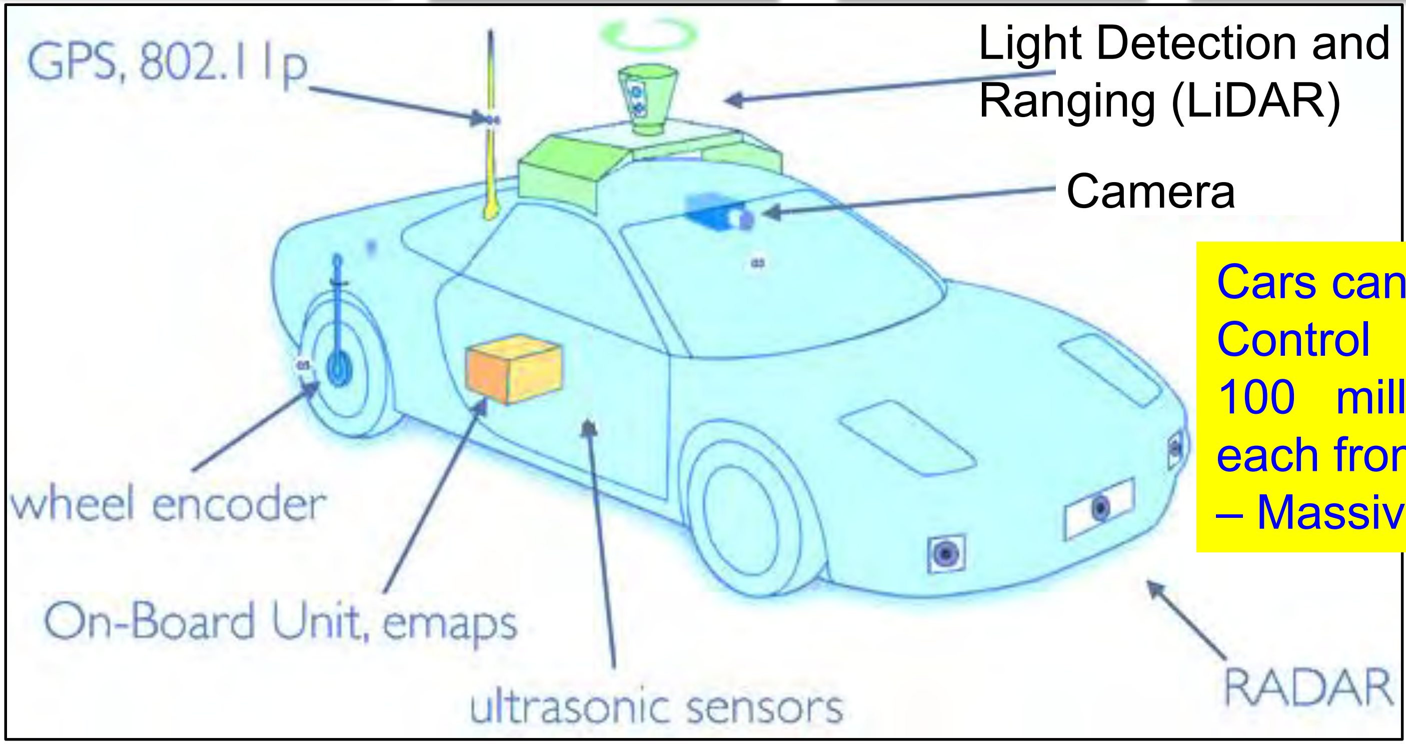



Source: Mohanty 2017, CE Magazine Jan 2017

# Autonomous Car – Security Venerability

Selected Attacks on Autonomous Cars

- Replay
- Relay
- Jamming
- Spoofing
- Tracking




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

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

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

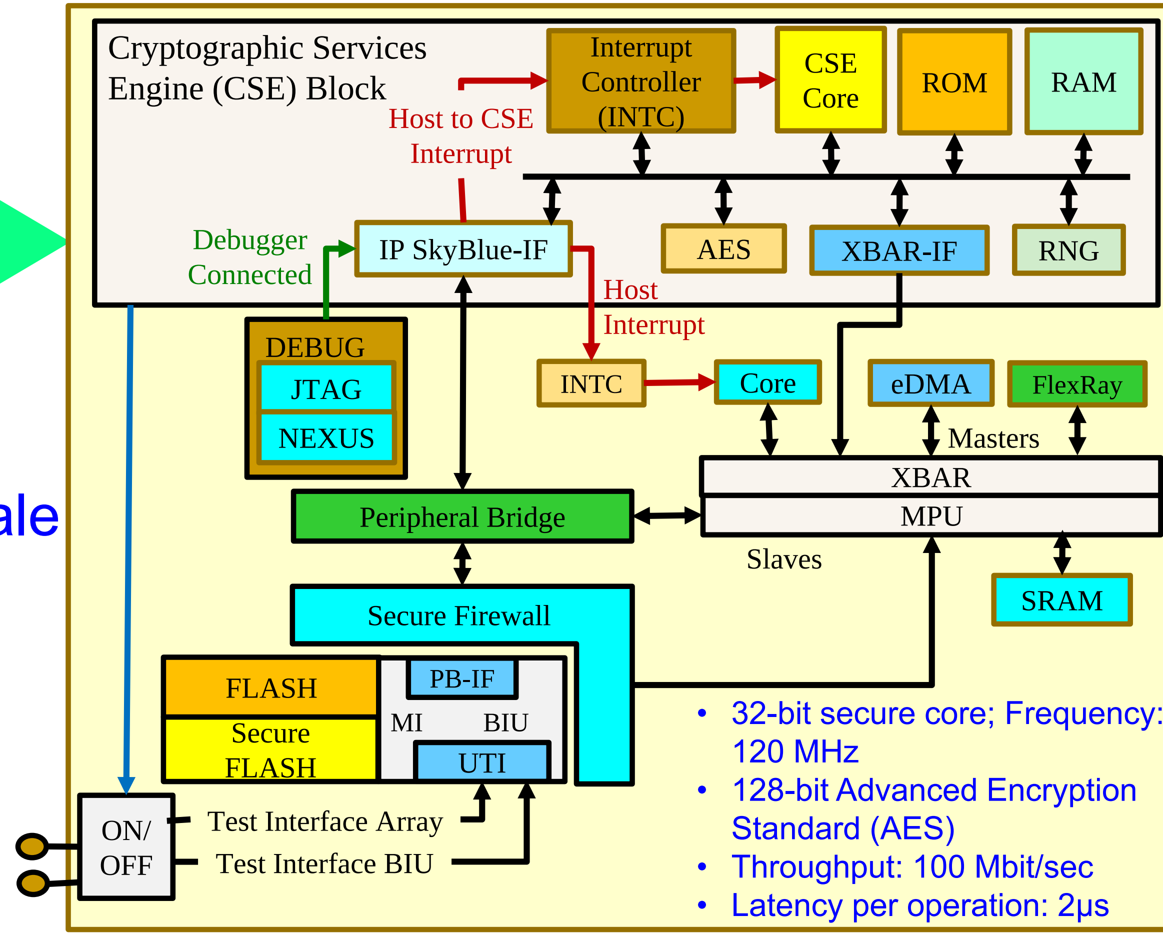
Source: Petit 2015: IEEE-TITS Apr 2015

# Autonomous Car Security – Cryptographic Hardware

Cryptographic Services Engine (CSE) Block

Qorivva MPC564xB/C Family from NXP/Freescale

Microcontroller Unit (MCU)




- 32-bit secure core; Frequency: 120 MHz
- 128-bit Advanced Encryption Standard (AES)
- Throughput: 100 Mbit/sec
- Latency per operation: 2μs

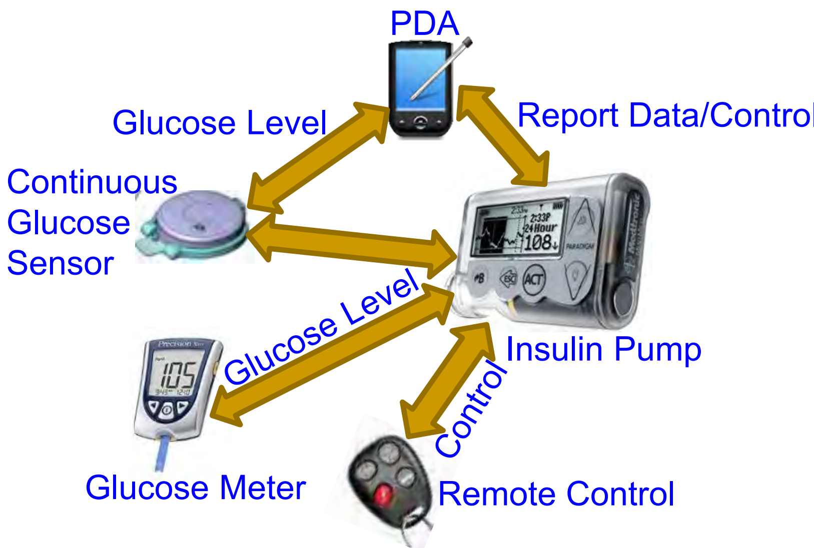
Source: http://www.nxp.com/assets/documents/data/en/supporting-information/DWF13_AMF_AUT_T0112_Detroit.pdf

# Smart Healthcare - Security and Privacy Issue

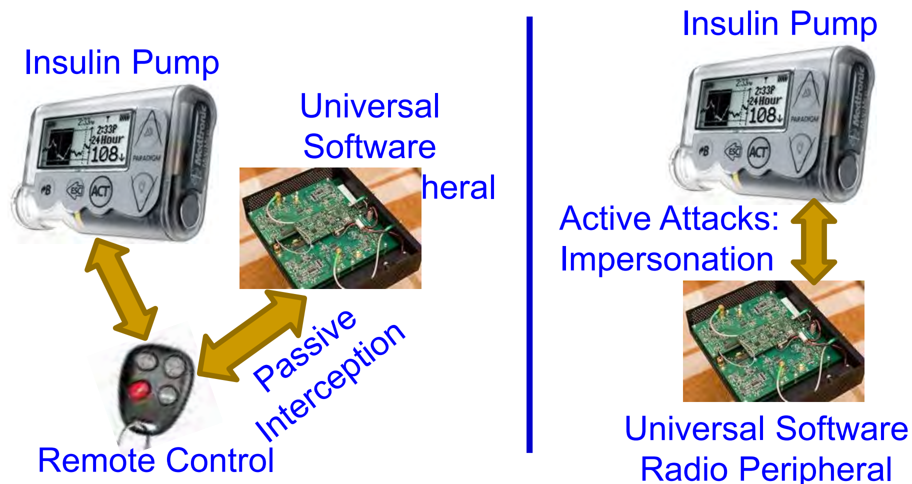
**Selected Smart Healthcare Security/Privacy Challenges**

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

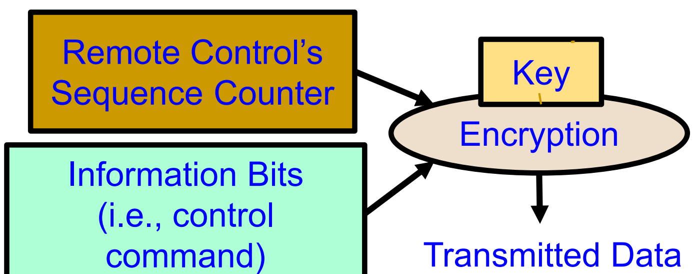
# Smart Healthcare Security



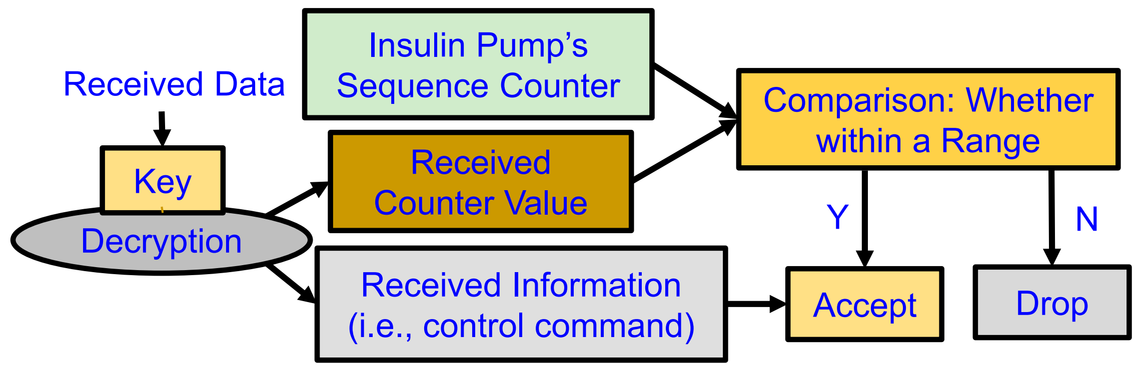

Insulin Delivery System




Security Attacks



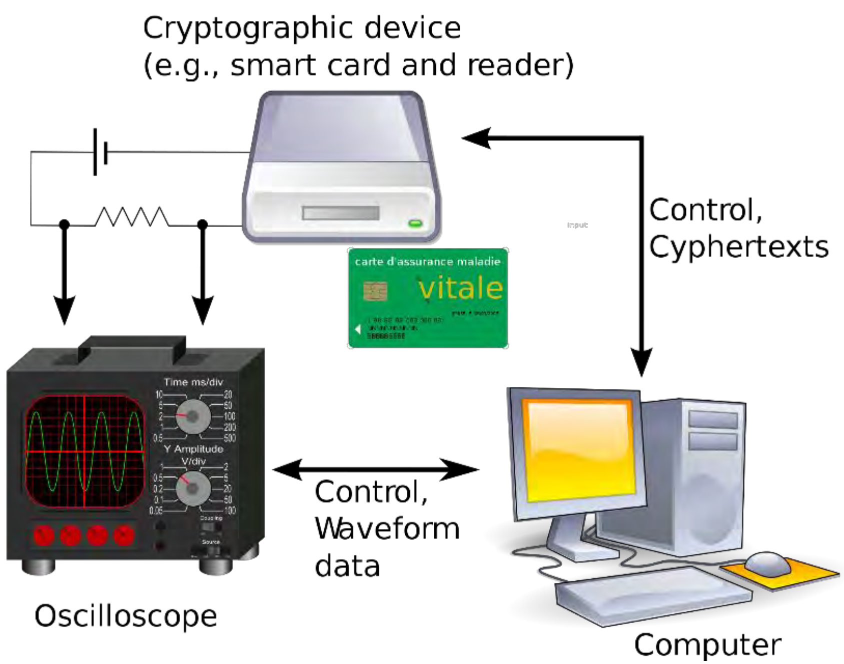

Rolling Code Encoder in Remote Control

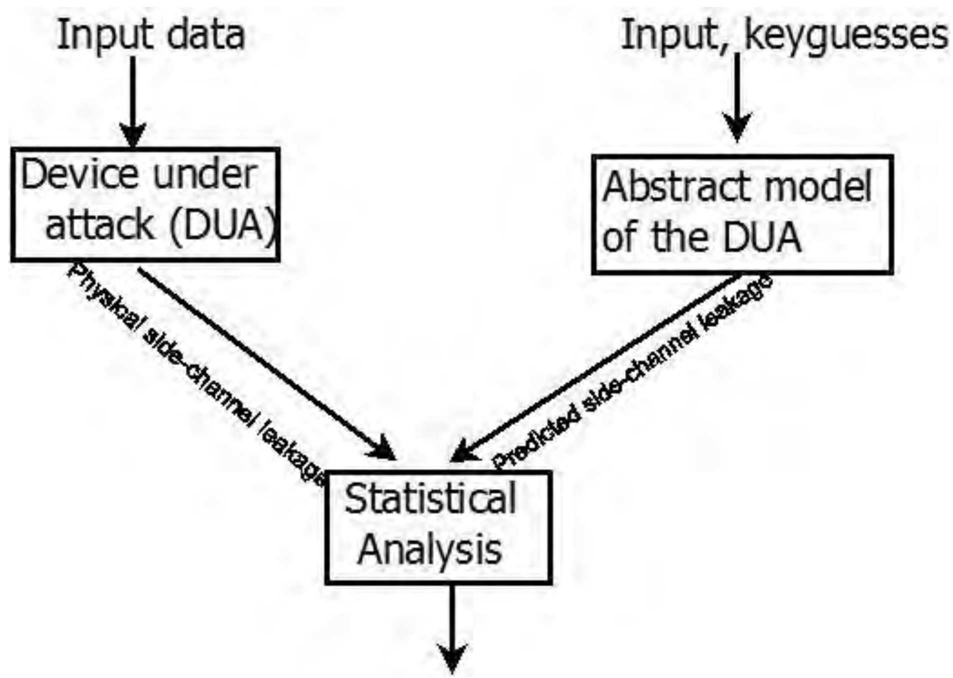



Rolling Code Decoder in Insulin Pump

Source: Li 2011, e-Health 2011

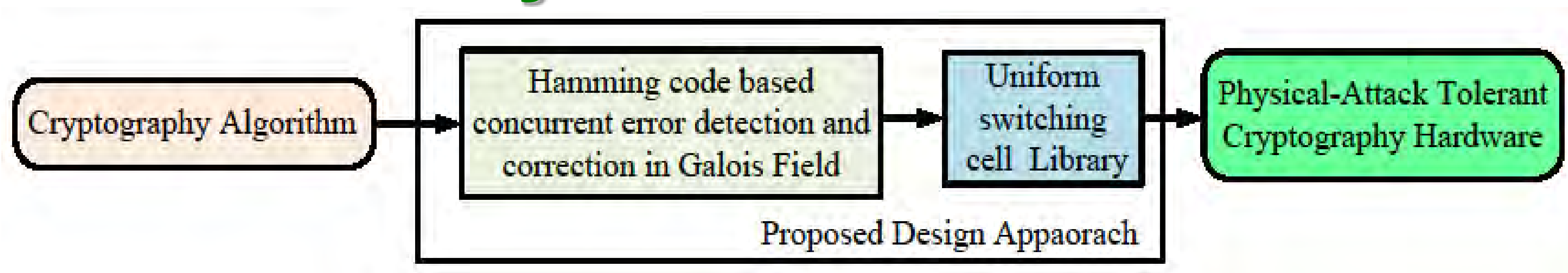
# Side Channel Attacks – Differential and Correlation Power Analysis (DPA/CDA)

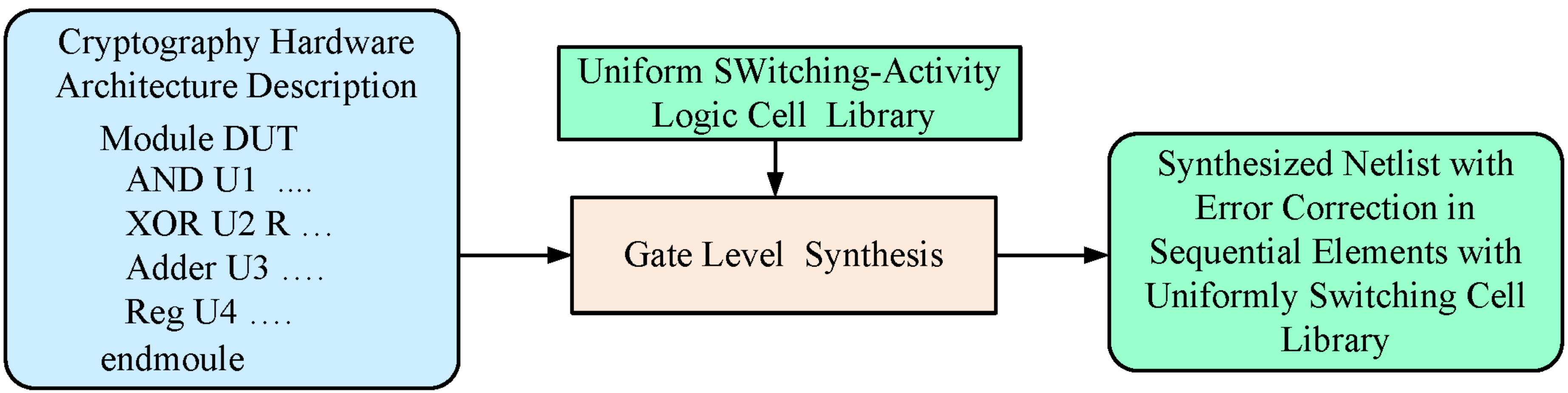



Decision on key guess

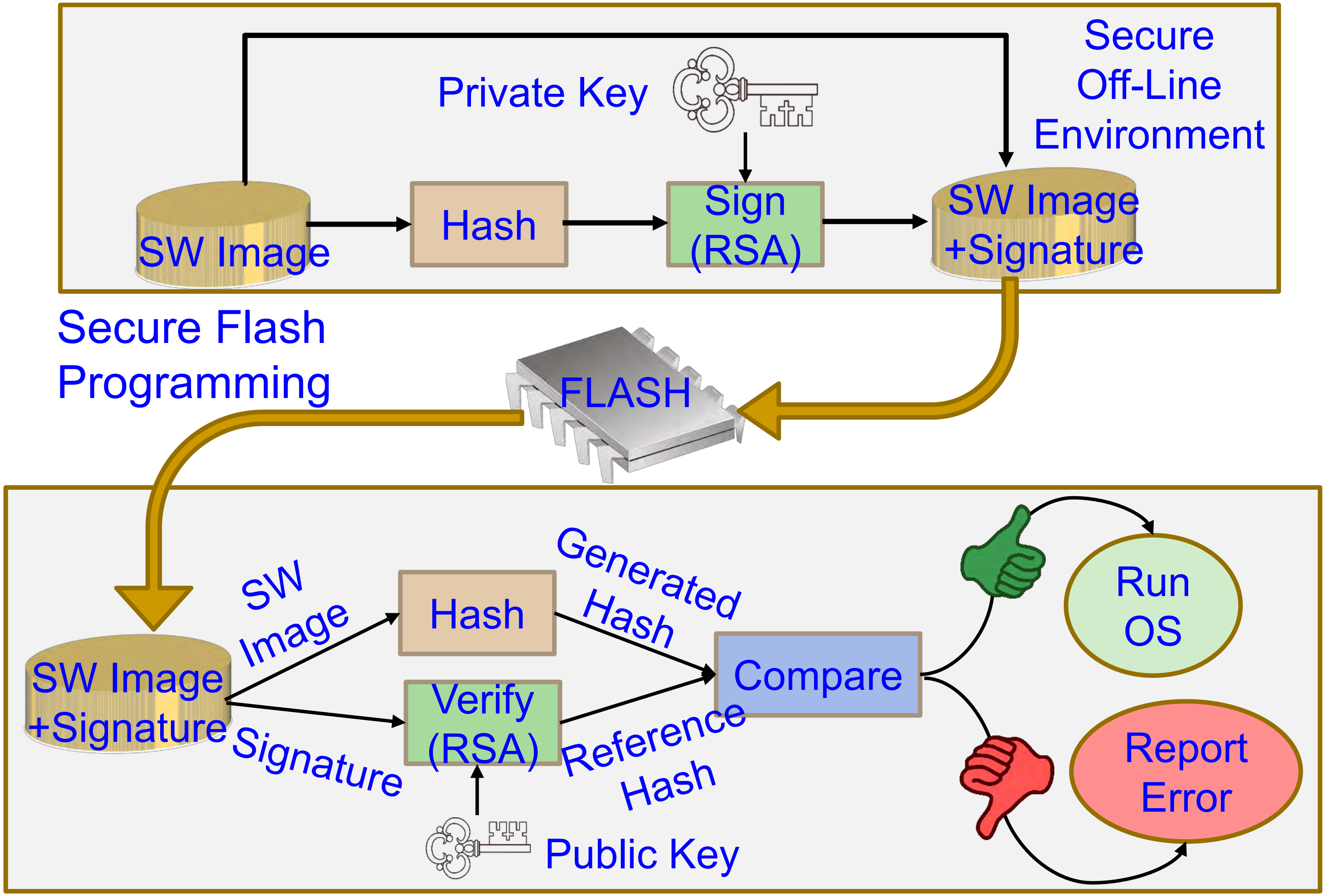
# DPA Resilience Hardware - Synthesis Flow




Source: Mohanty 2013, Elsevier CEE 2013

# Firmware Security




Source: https://www.nxp.com/docs/en/white-paper/AUTOSECURITYWP.pdf

# Multimedia Piracy – Movie/Video

High

Studio

Cinema


On-line

Video on Demand


Piracy Threat Level

DVD/Blu-ray

Pay-TV Broadcasting

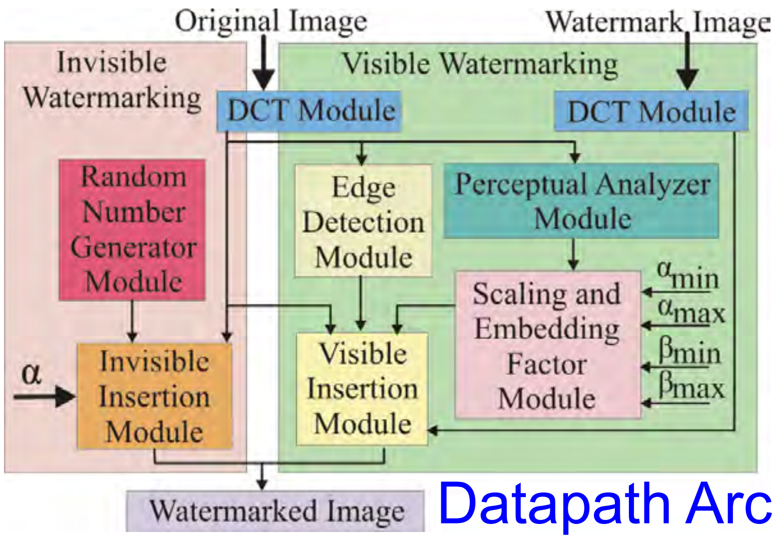
Free-to-Air Broadcasting

Low

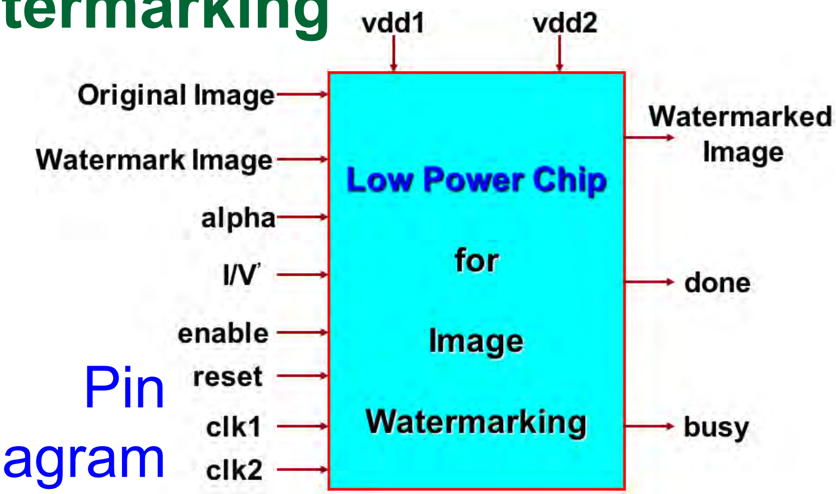
"Film piracy cost the US economy $20.5 billion annually."

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

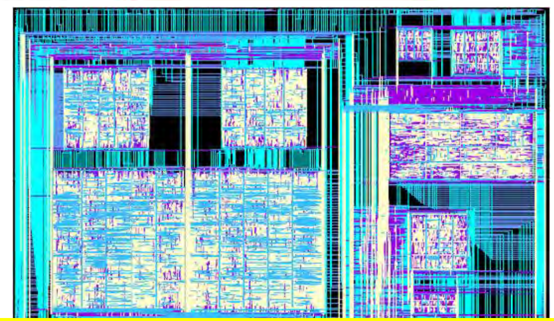
# Copyright Protection Hardwares – DCT Domain Watermarking



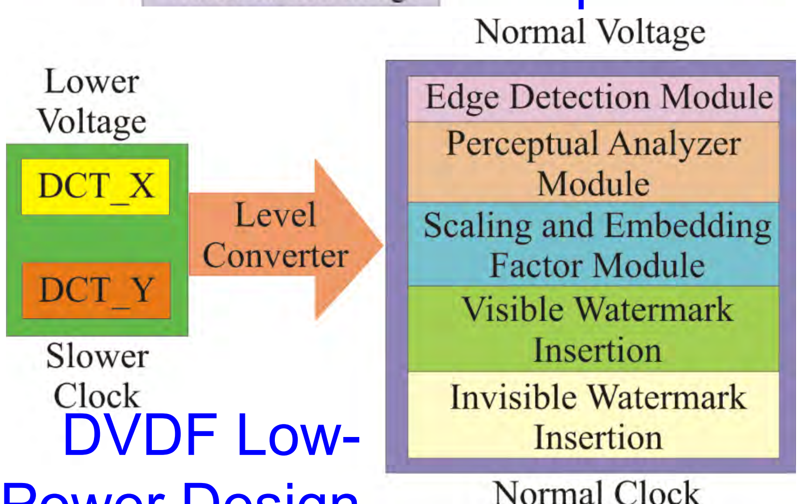

Datapath Architecture




Pin Diagram



Hardware Layout

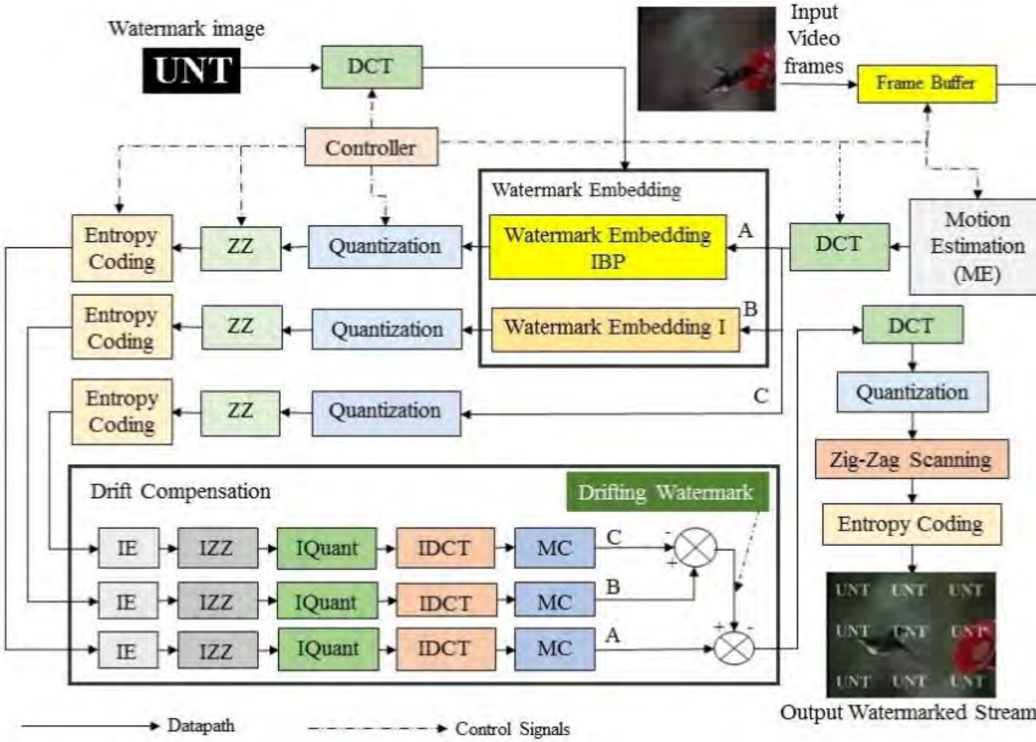



DVDF Low-Power Design

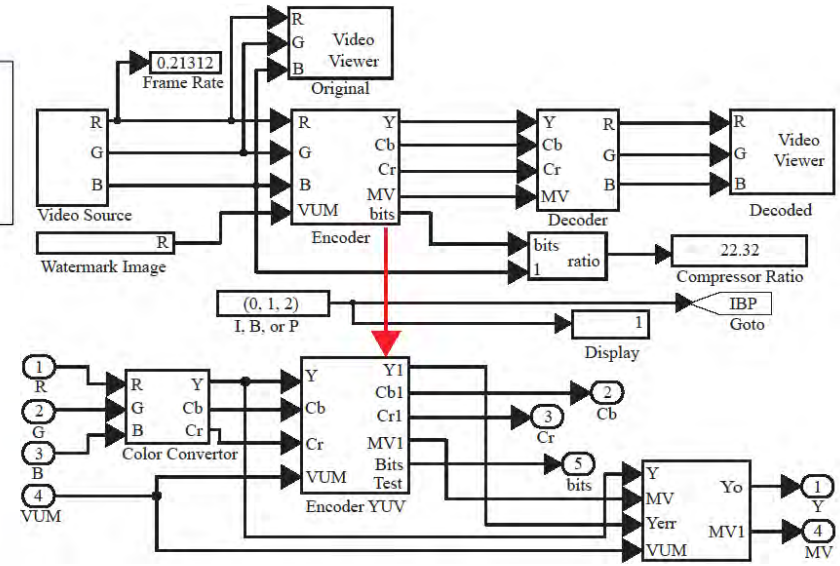
**Physical Design Data**
Total Area : 16.2 sq mm
No. of Transistors: 1.4 million
Power Consumption: 0.3 mW

Source: Mohanty 2006, TCASII May 2006

# Copyright Protection Hardware – MPEG-4 Video Watermarking




Video Watermarking Architecture Datapath




Video Watermarking Architecture: Simulink Model

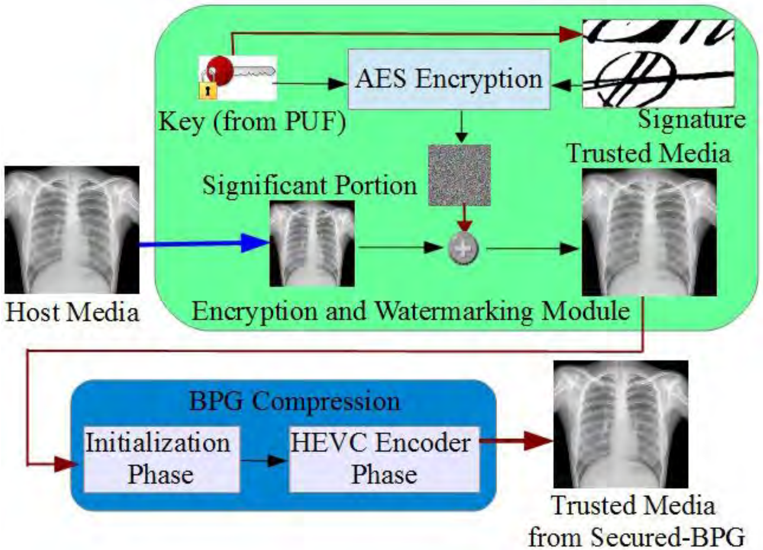
FPGA Prototyping

Throughput: 44 frames/sec

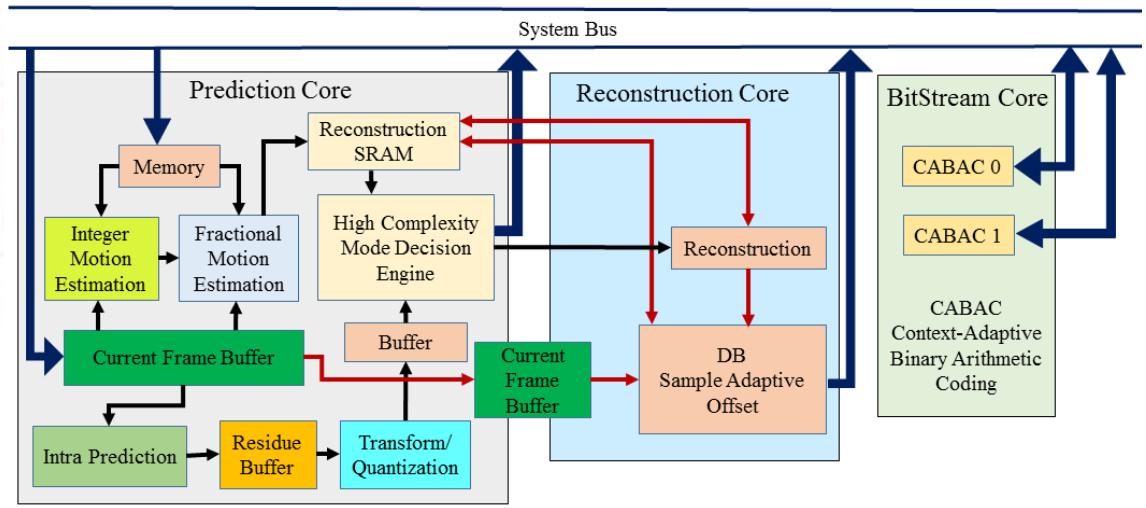
Logic Elements in FPGA Prototyping : 28322

Source: Mohanty 2011, JSS May 2011

# DRM Hardware - Secure Better Portable Graphics (SBPG)




Idea of Secure BPG (SBPG)

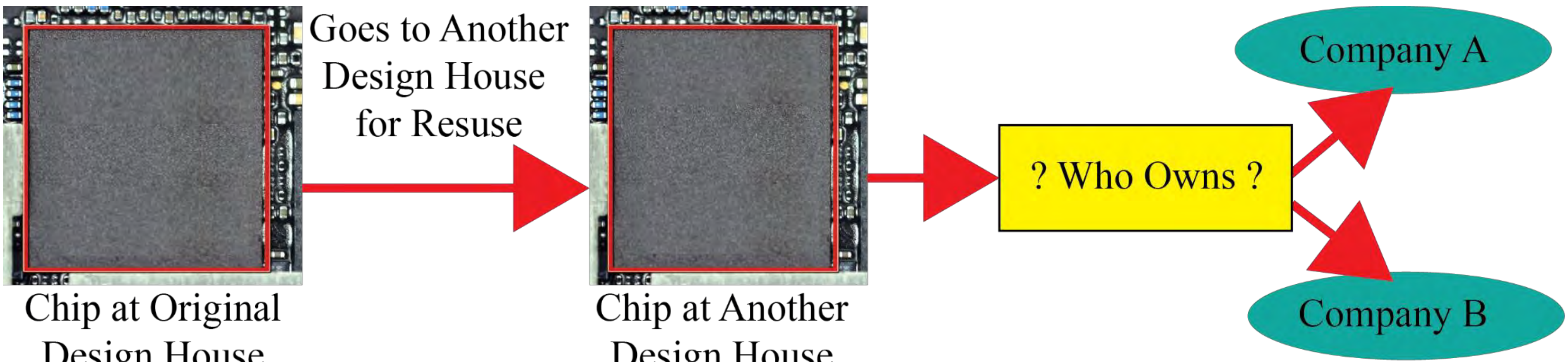



High-Efficiency Video Coding Architecture

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

Source: Mohanty 2016, ISVLSI 2016 and EuroSimE 2016

# Hardware IP Right Infringement




Source: Mohanty 2015, McGraw-Hill 2015

Hardware IPR Infringement

- False Ownership Claim
- Sub-licensing
- Piracy (Reverse Engineering)

# Hardware Reverse Engineering

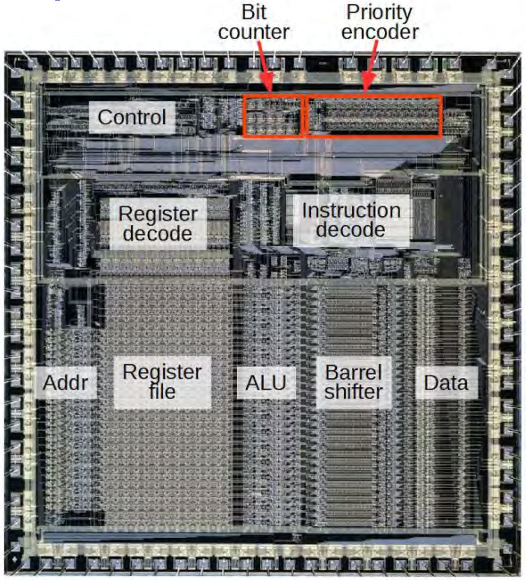
Source: http://legacy.lincolninteractive.org/html/CES%20Introduction%20to%20Engineering/Unit%203/u3l7.html

CE System disassembly
Subsystem identification, modification


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

Chip-Level Modification




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

# Counterfeit Hardware

2014 Analog Hardware Market (Total Shipment Revenue US $)

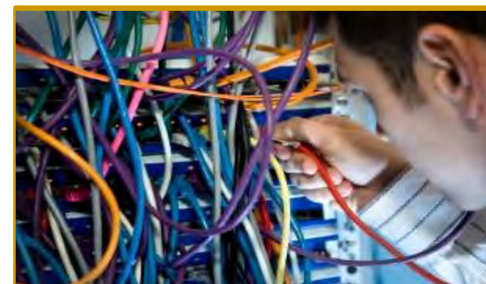

Wireless Market
$18.9 billion (34.8%)

Consumer Electronics
$9.0 billion (16.6%)

Industrial Electronics
$8.9 billion (16.5%)

Automotive
$8.5 billion (15.7%)

Data Processing
$6.0 billion (11%)

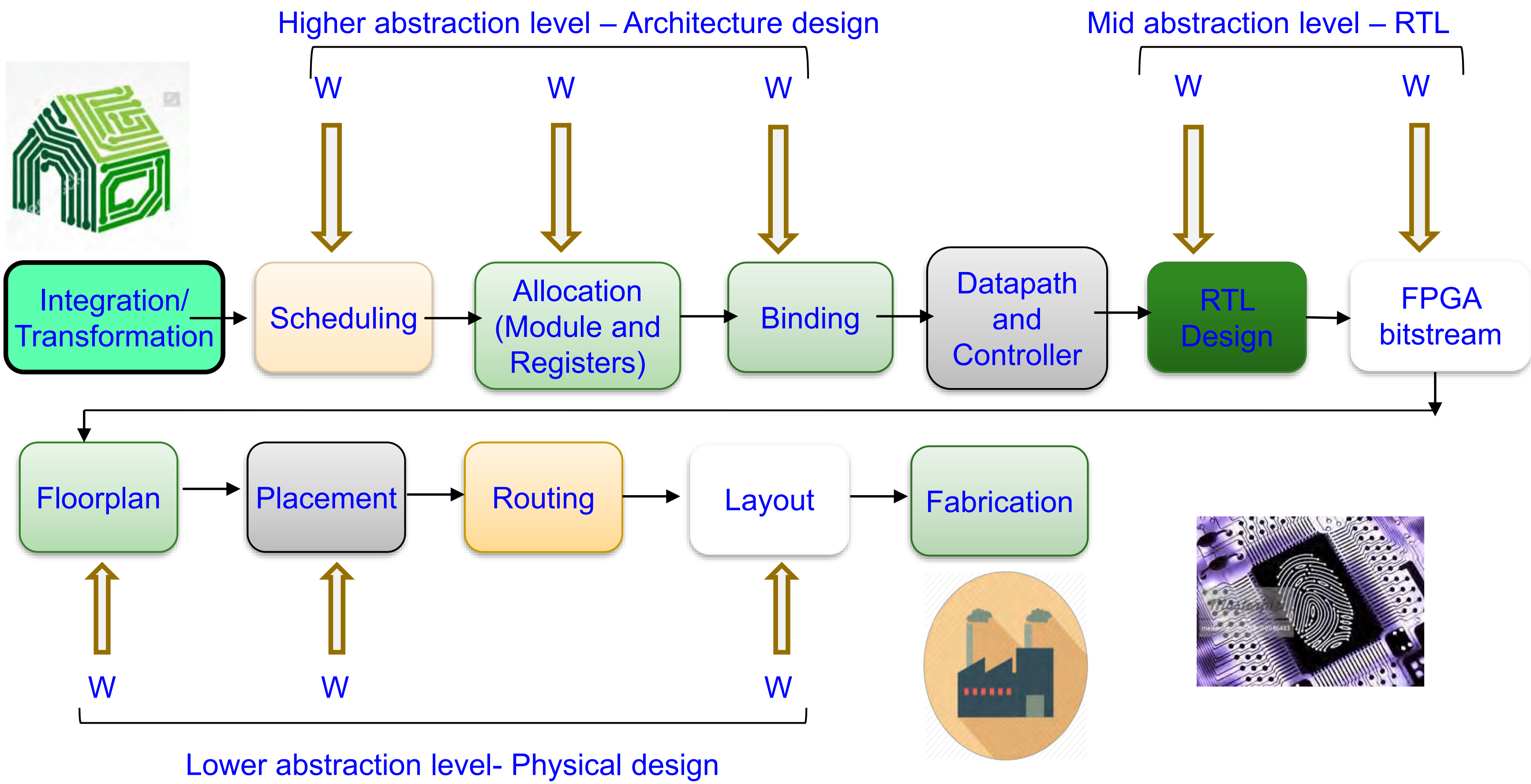


Wired Communications
$2.9 billion (5.4%)

Source: https://www.slideshare.net/rorykingihs/ihs-electronics-conference-rory-king-october

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

# Digital Hardware - Watermark



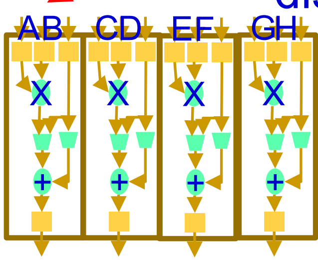

Source: Mohanty 2017: CE Magazine October 2017

# Digital Hardware Synthesis to Prevent Reverse Engineering

Attack Successful on Non-protected Design

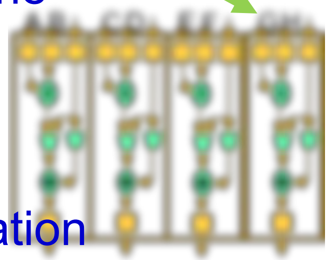
Attack Failed on Protected Design

Attacker trying to discover the design




Non-Obfuscated Design

Perform Obfuscation



Obfuscated Design

Secured DSP

CE Devices

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

Input Block

Input for Structural Obfuscation
- CDF/DFG
- Preprocessing of Unrolling Factors

Input for PSO-DSE
- Module Library
- User Constraints
- Maximum Iteration #
- Control Parameters, e.g. Swarm Size

Perform Structural Obfuscation based on 5 HLT Techniques

Obfuscated Design

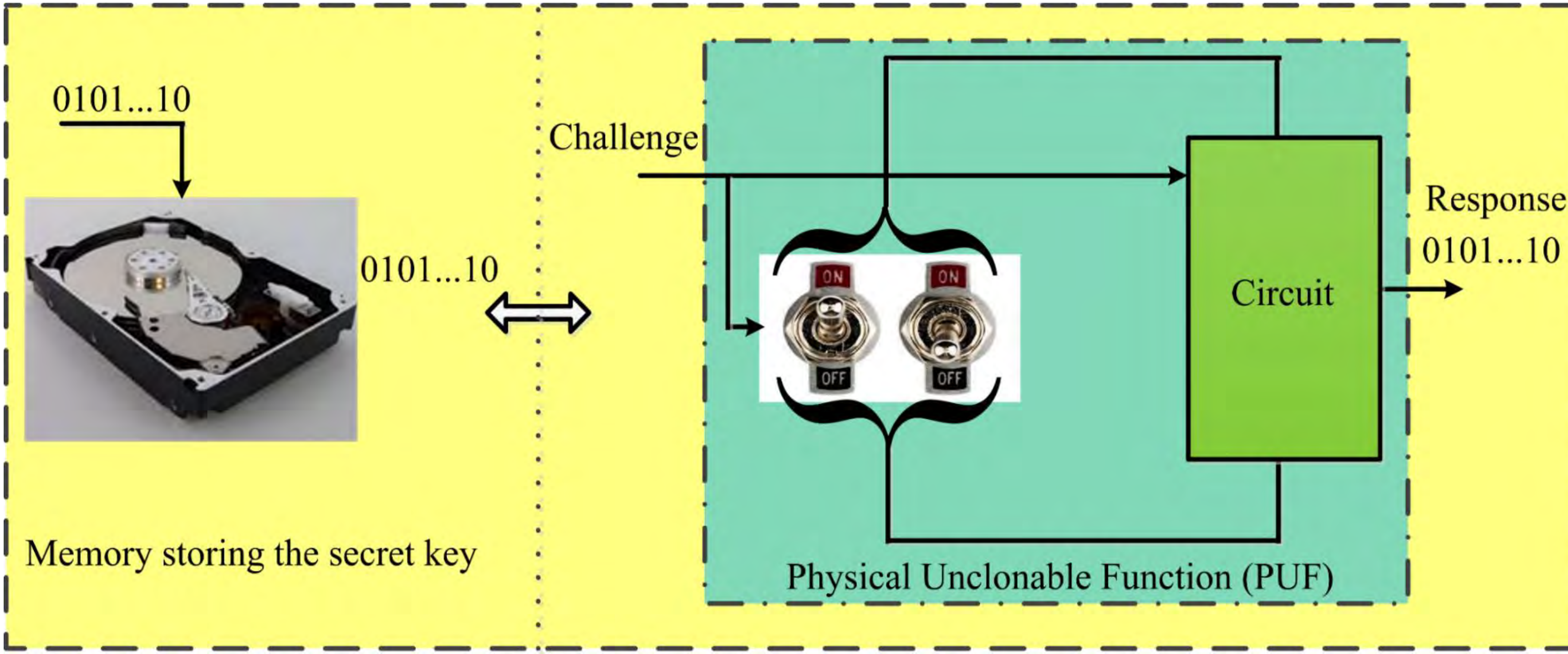
PSO based Design Space Exploration

Structurally Obfuscated Low Cost IP Core

Transformation Techniques
- Redundant Operation Elimination
- Logic Transformation
- Tree Height Transformation
- Loop Unrolling
- Loop Invariant Code Motion

Source: Sengupta, Mohanty 2017, TCE November 2017

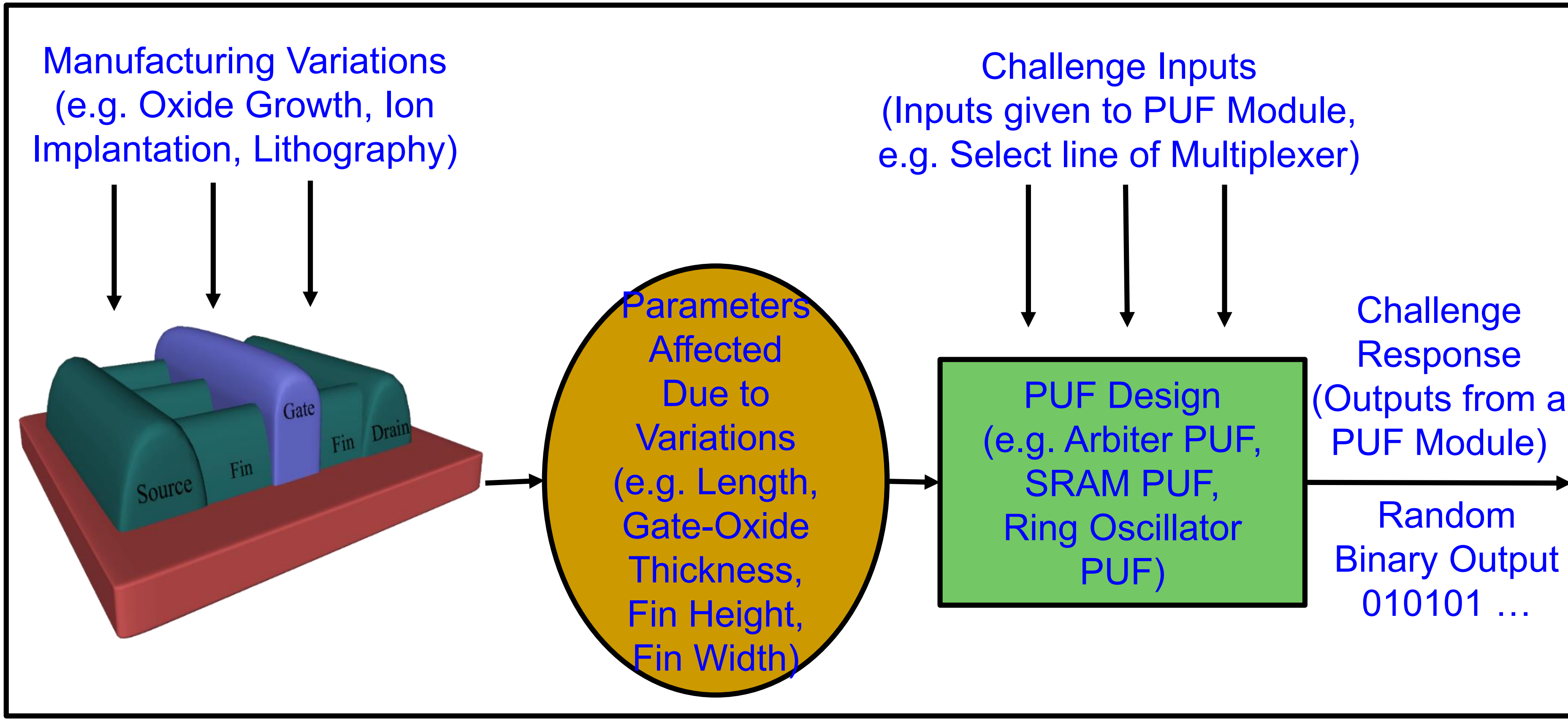
# PUF - Principle




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

Source: Mohanty 2017, IEEE Potentials Nov-Dec 2017

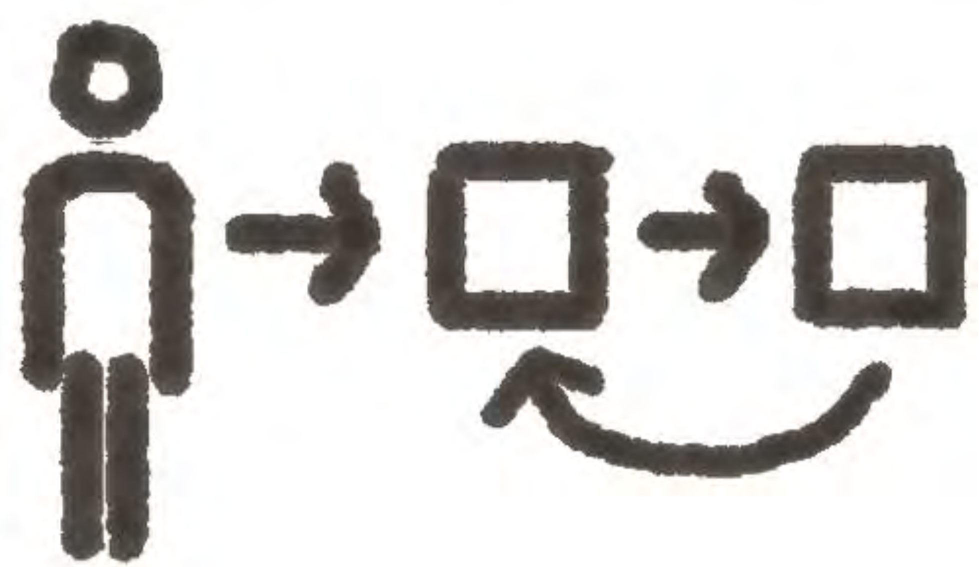
# PUF - Principle



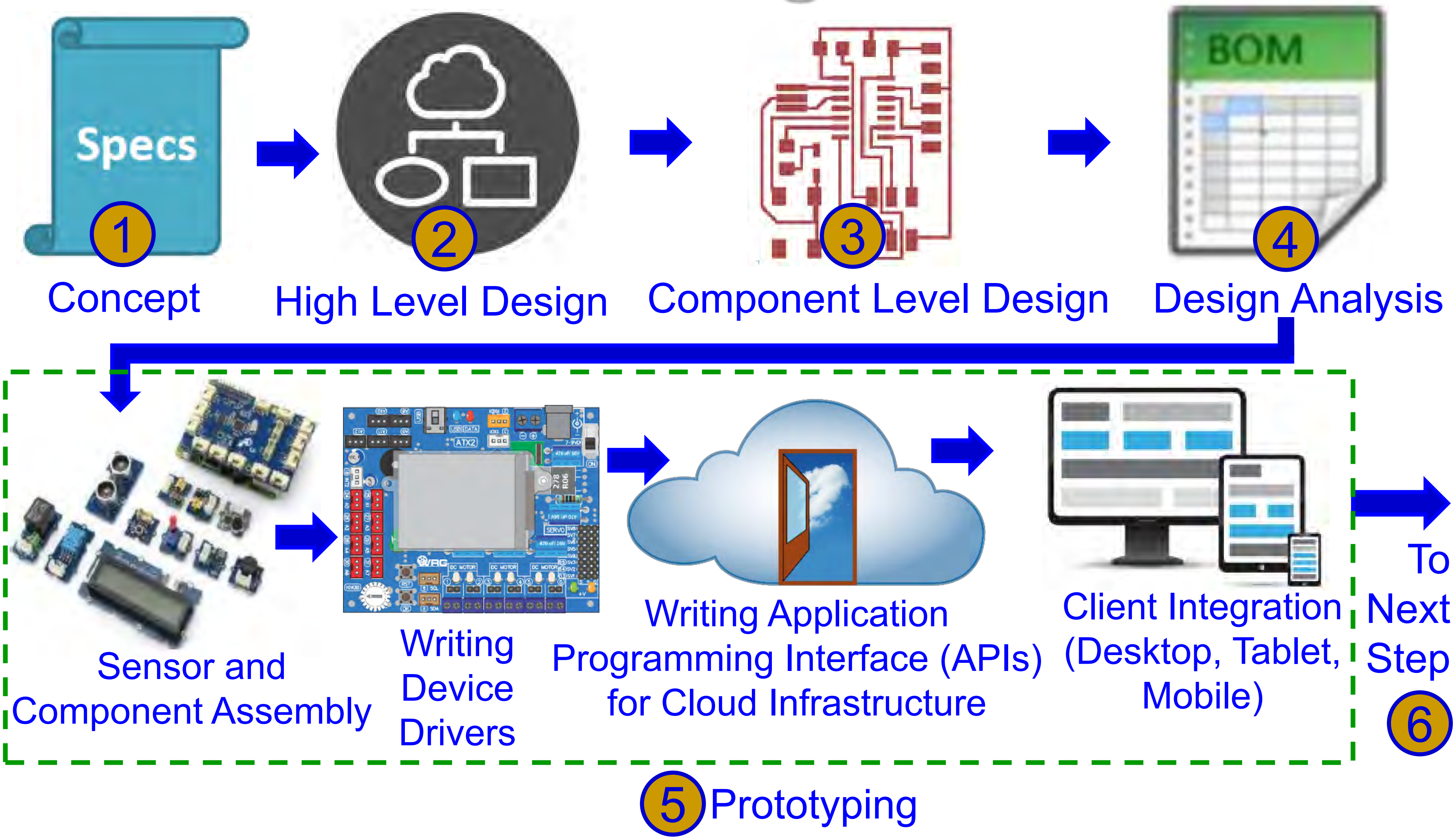

Silicon manufacturing process variations are turned into a feature rather than a problem.

Source: Mohanty 2017, Springer ALOG 2017

# 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

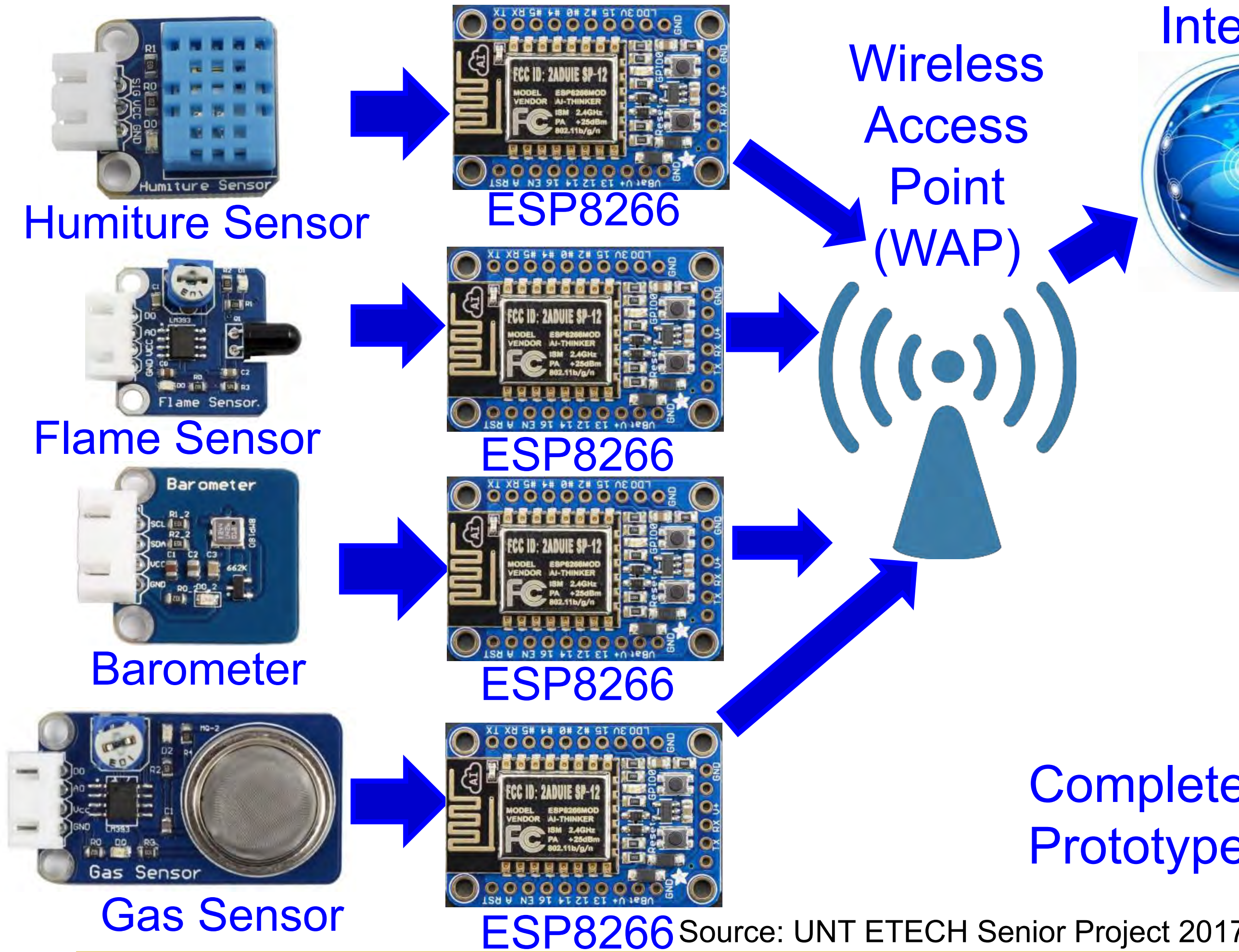

⑦ Release of Beta Version

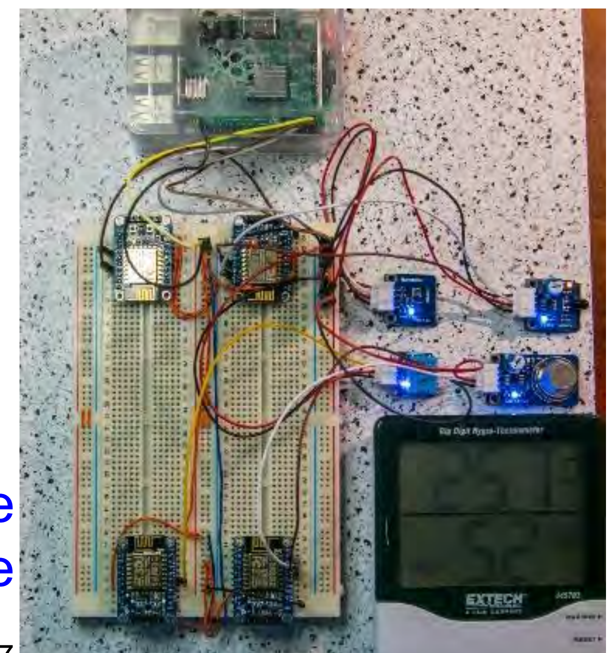
⑧ Production

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



Complete Prototype

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

- IoT Software Domains
  - Platforms
    - Temboo
    - Kaa
    - Carriots
    - Ubidots
    - ThingSpeak
    - Artik Cloud
    - Pinoccio
    - Smartliving
    - Samsung ARTIK
  - Languages
    - C/C++
    - Java
    - HTML5
    - Javascript
    - Python

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/

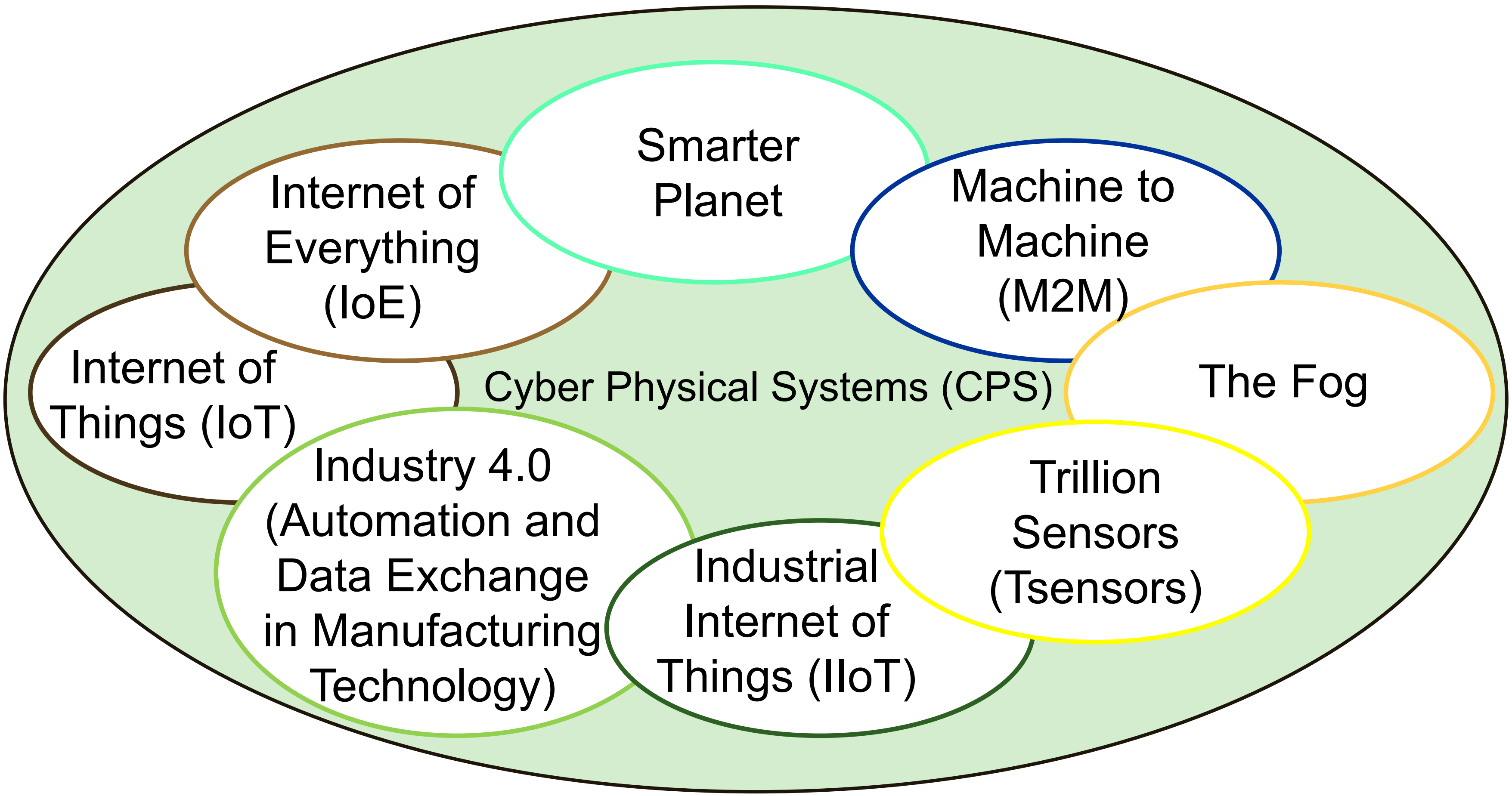
- **Environments**
  - Design of mobility scenarios and the generation of natural events such as fires and gas as well as the simulation of mobiles such as vehicles and flying objects (e.g. UAVs, insects, etc.).
  - A discrete event simulation of WSNs which takes into account the scenario designed on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

# Related Buzzwords

# Some related Buzzwords




Source: Sangiovanni-Vincentelli 2016, ISC2 2016

# IoT Vs Sensor Networks

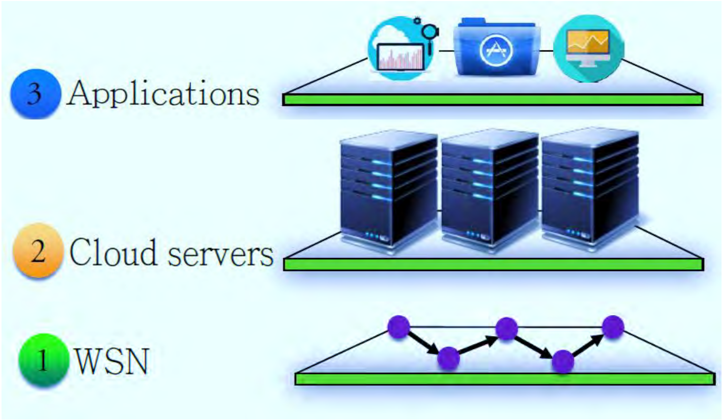
## Wireless Sensor Networks (WSN)

- 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

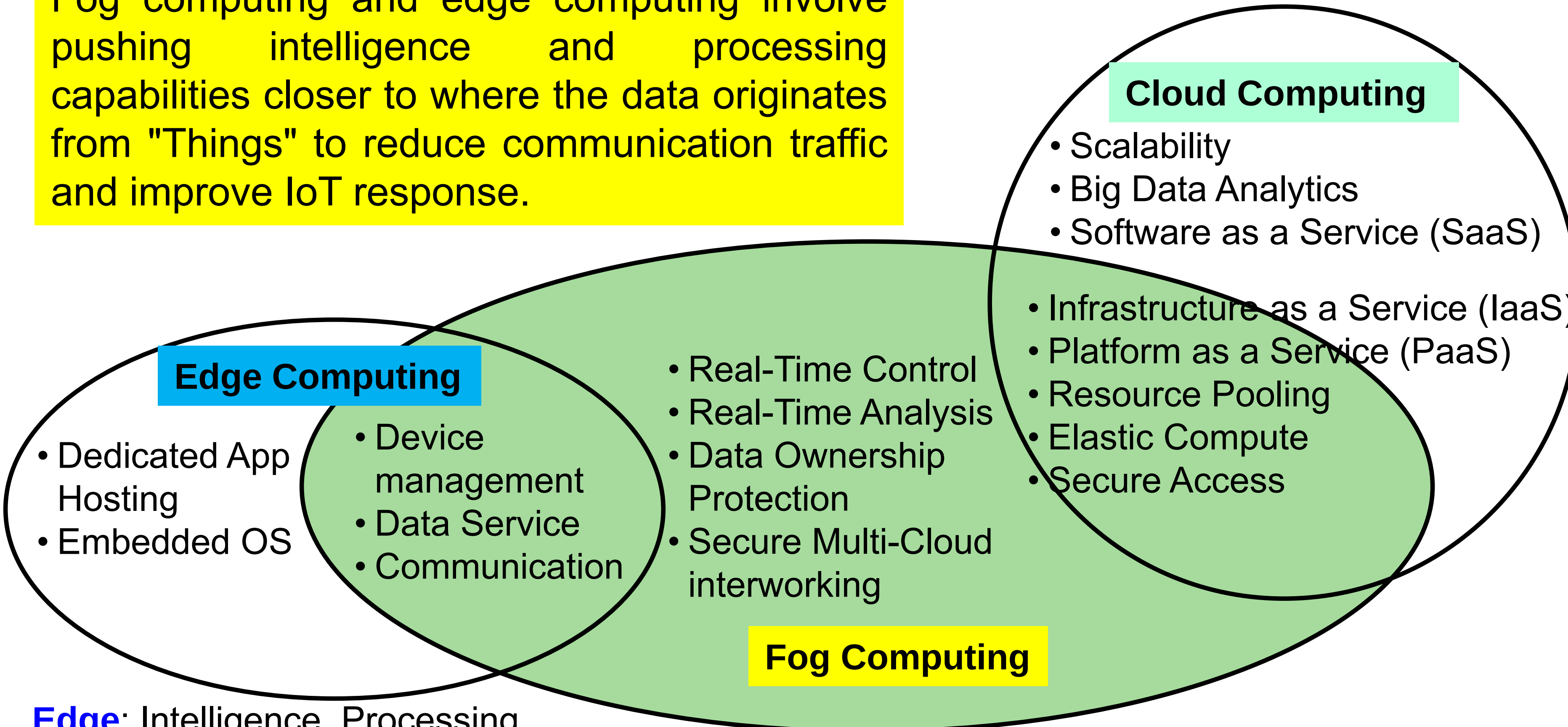
- IoT in a broad sense is like a brain.
- Store both real world data and can also be used to monitor the real world parameters and give meaningful interpretation.




Source: Nia 2017, IEEE TETC 2017

# 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.



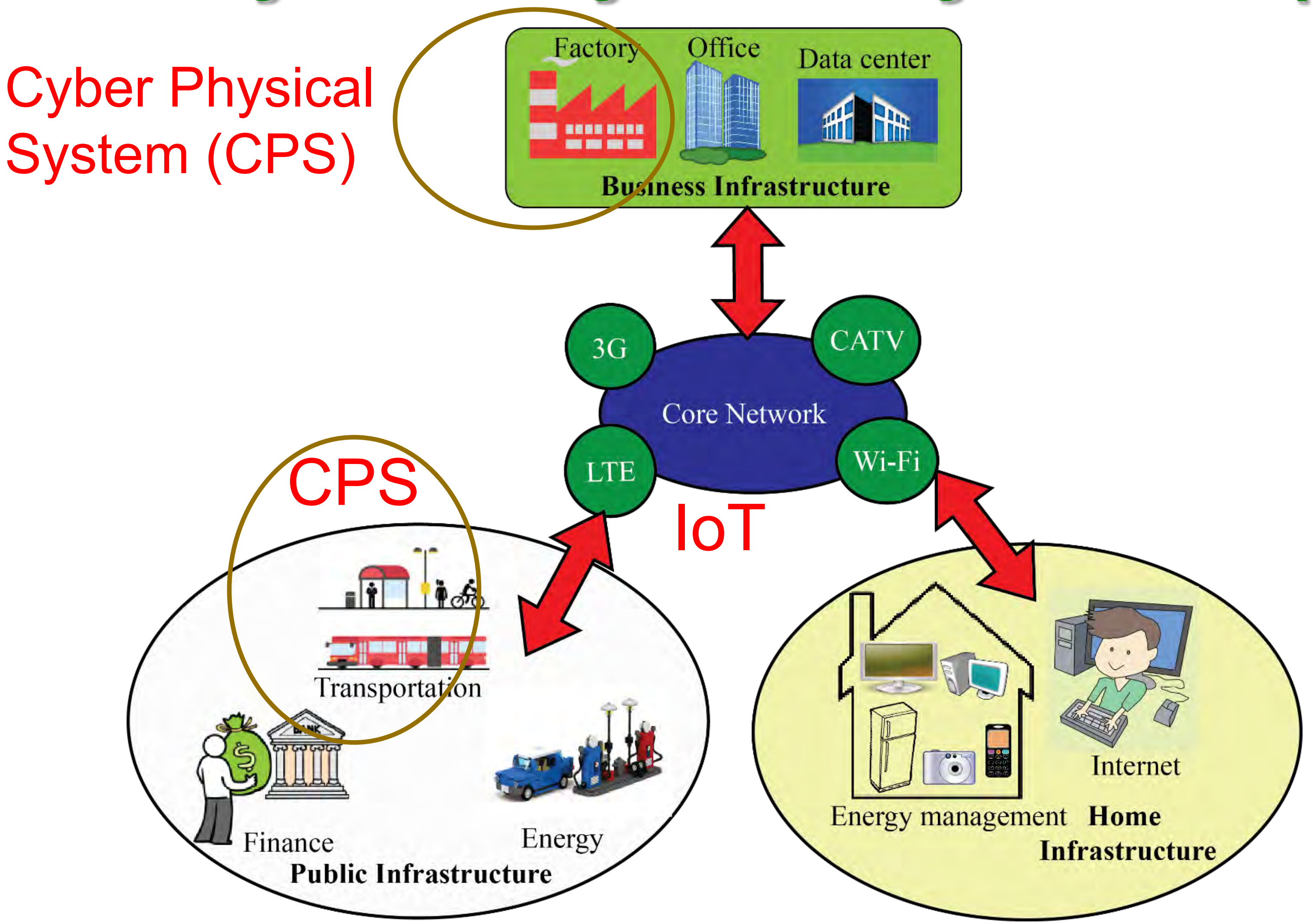

**Edge**: Intelligence, Processing, and Communication - Devices like Programmable Automation Controllers (PACs)

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

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

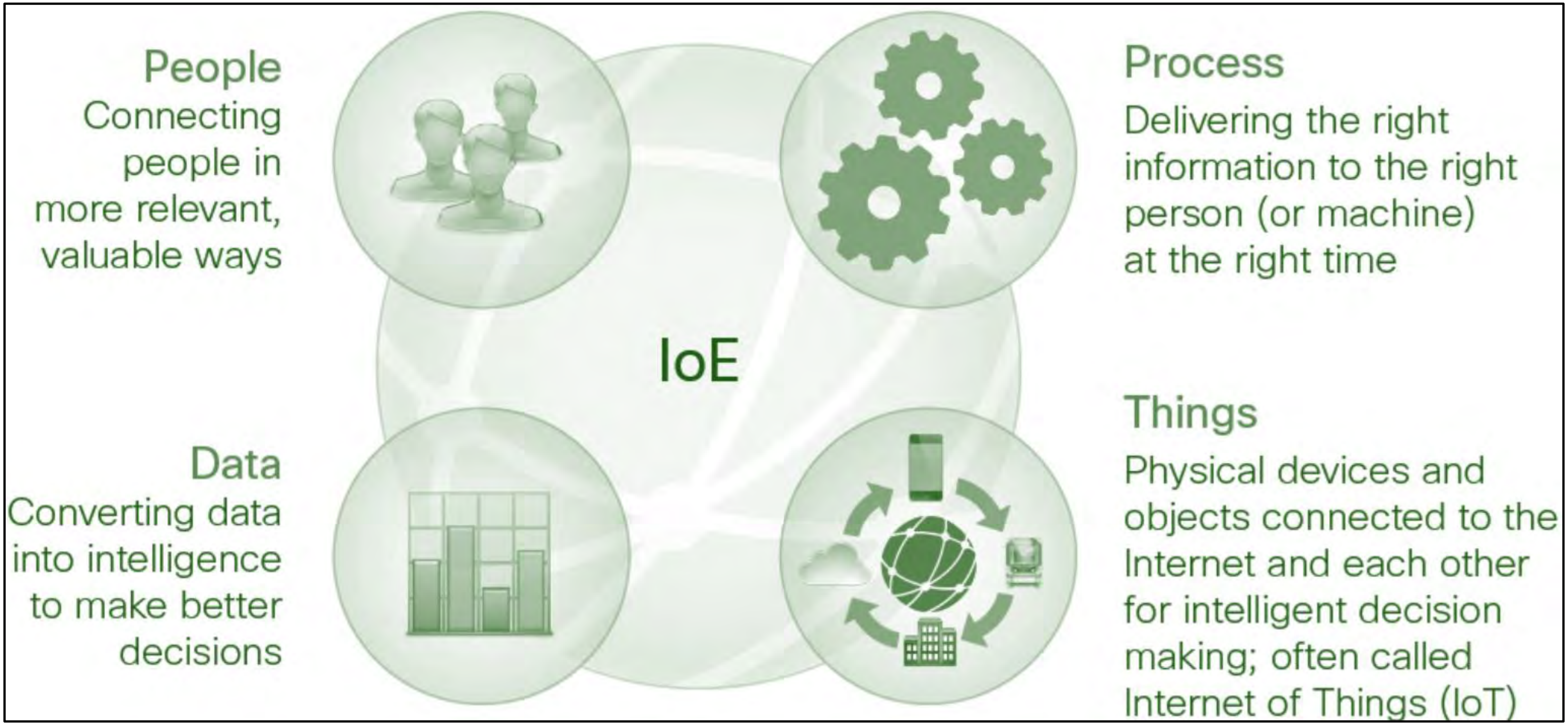
Source: https://www.nebbiolo.tech/wp-content/uploads/whitepaper-fog-vs-edge.pdf

# IoT Vs Cyber Physical Systems (CPS)




Source: Mohanty 2016, CE Magazine July 2016

# Internet of 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.

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http://www.ieee-tcvlsi.org

IEEE computer society

The IEEE Computer Society Technical Committee on VLSI

## What is TC-VLSI?

A technical committee of IEEE-CS serves as the focal point of the various technical activities within a technical discipline.

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

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