Security and Energy Tradeoffs in Electronic Systems

Faculty Development Program

Sponsored by

Ministry of Electronics & Information Technology, Govt. of India

MNIT Jaipur, 30 July - 3 August, 2018

Saraju P. Mohanty

University of North Texas, USA.

Email: saraju.mohanty@unt.edu

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

Talk - Outline

- Big picture of current trends in CE
- Challenges in the current generation CE design
- Security, Privacy, IP Rights solutions
- Energy consumption solutions
- Hardware vs Software in CE for tradeoffs
- Conclusions and Future Directions

Big Picture

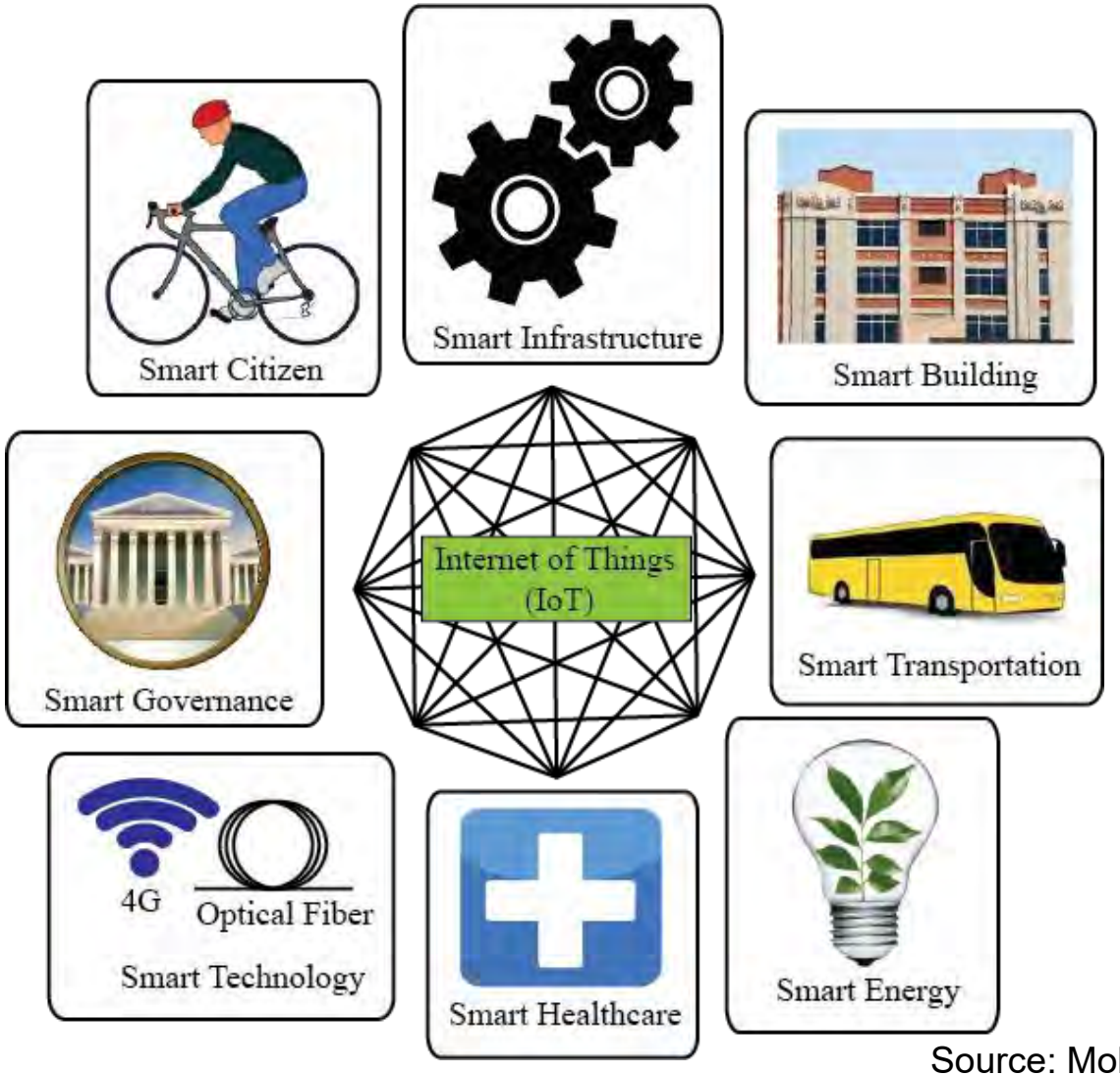
Smart Cities

- 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

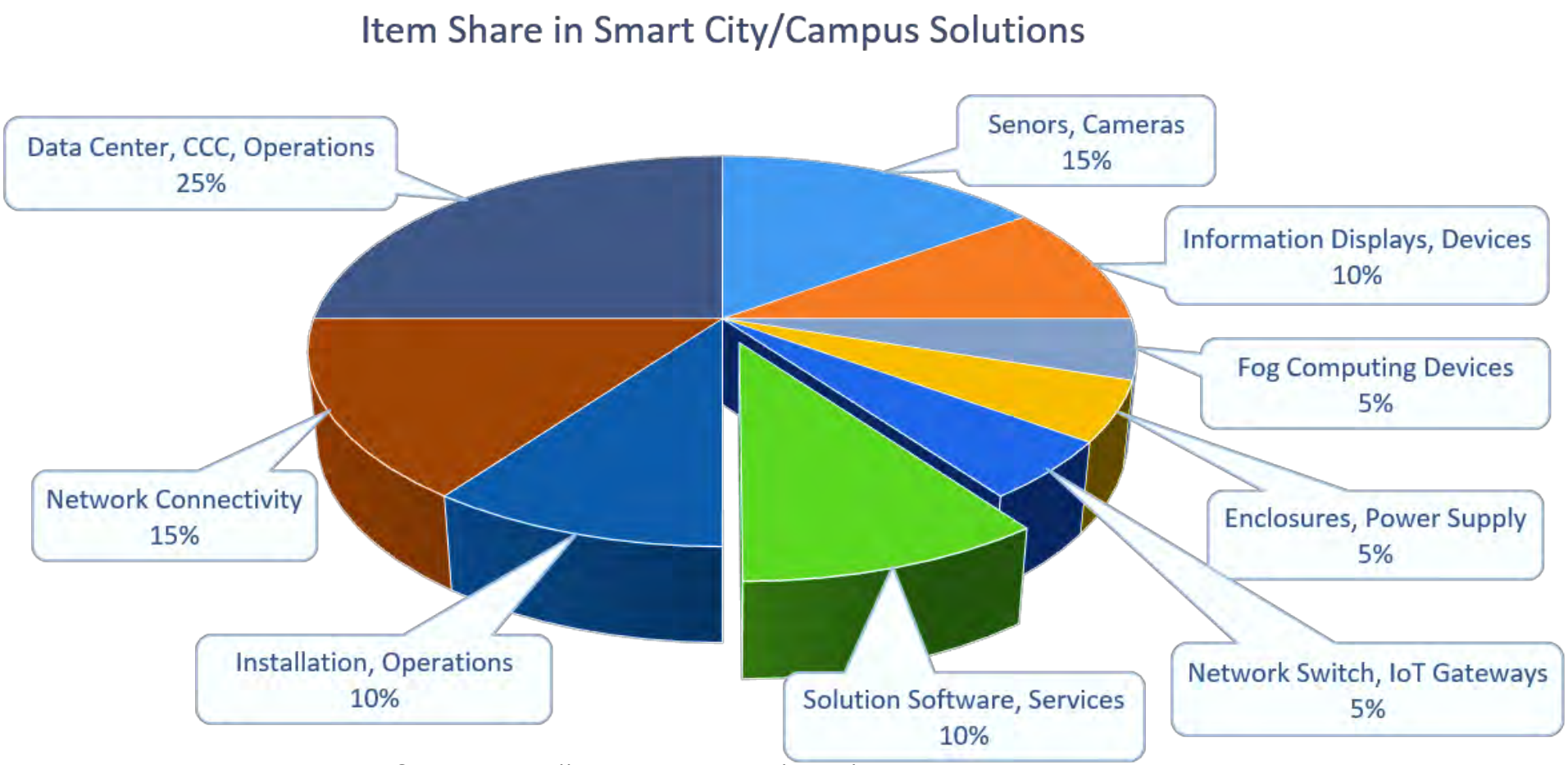
IoT is the Backbone Smart Cities



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

Source: Mohanty 2016, CE Magazine July 2016

Smart City Design - Verticals



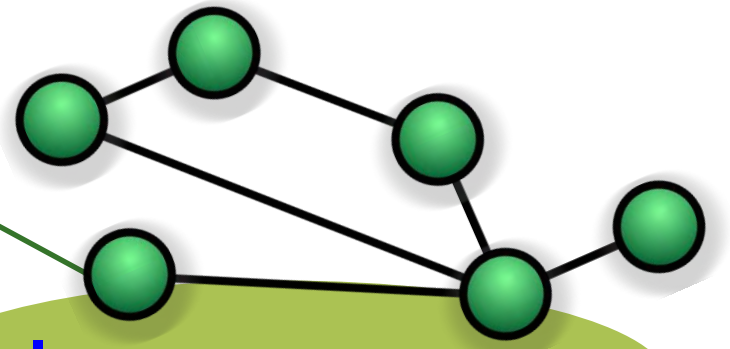
Source: https://www.linkedin.com/pulse/smart-citiescampus-what-could-your-share-suresh-kumar-kk

Smart Cities - 3 Is

Instrumentation

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

Smart Cities



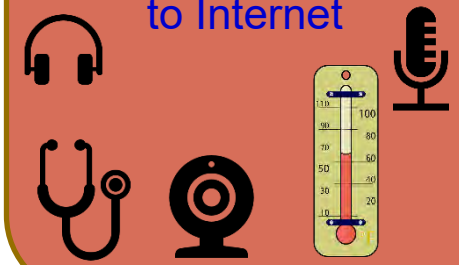
Intelligence

Interconnection

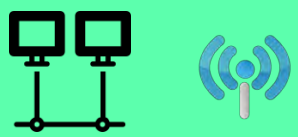
Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

Internet of Things (IoT) – Concept

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



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



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

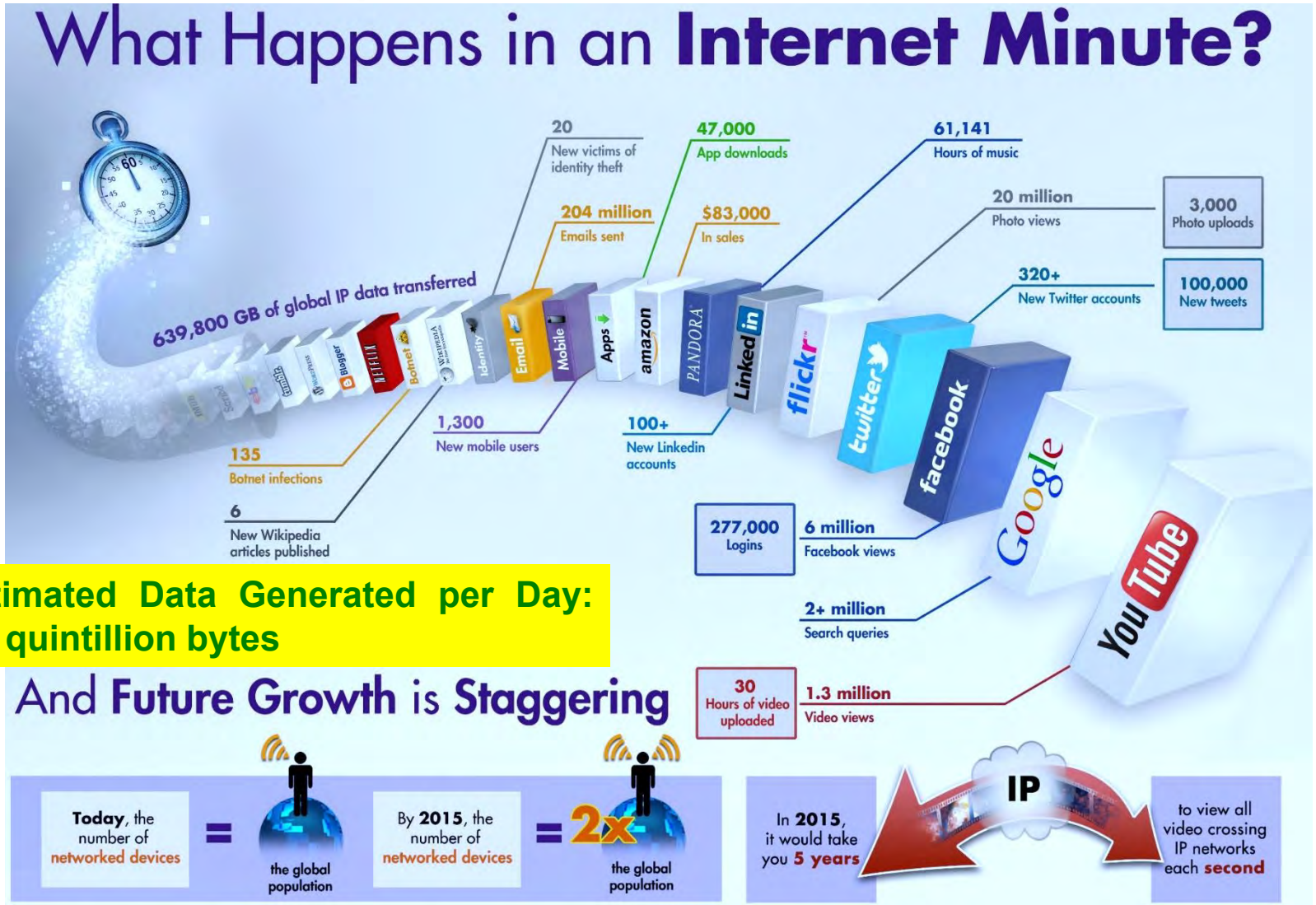
Global Network
Connecting bridge between the local network, cloud services and connected consumer devices

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

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

Source: Mohanty ICIT 2017 Keynote

Huge Amount of Data



Issues Challenging Sustainability

➢ Cyber Attacks

Hacked: US Department Of Justice

Who did it: Unknown

What was done: Information on 10,000 DHS and 20,000 FBI employees.

Details: The method of the attack is still a mystery and it's been said that it took a week for the DOJ to realize that the info had been stolen.

February 2016

Hacked: Yahoo #2

YAHOO!

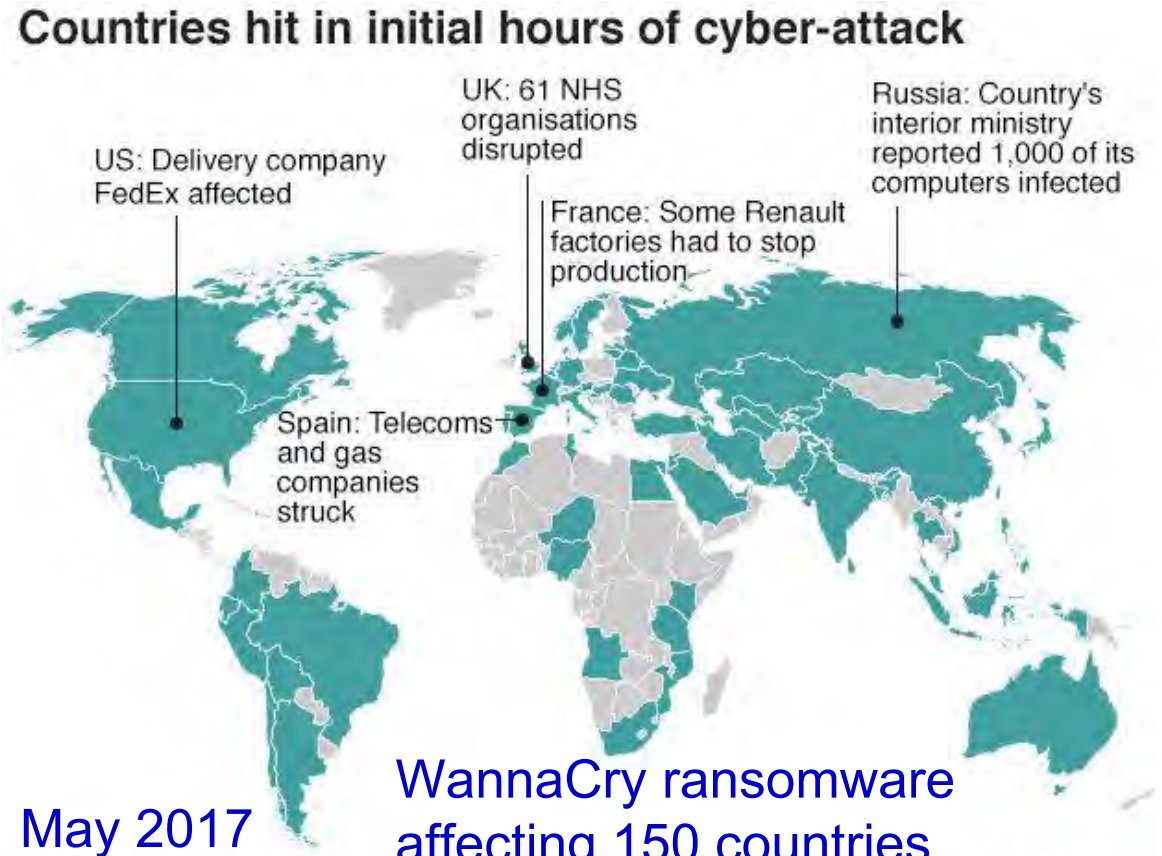
Who did it: Unknown

What was done: 1 billion accounts were compromised.

Details: Users names, email addresses, date of birth, passwords, phone numbers, and security questions were all taken.

December 2016

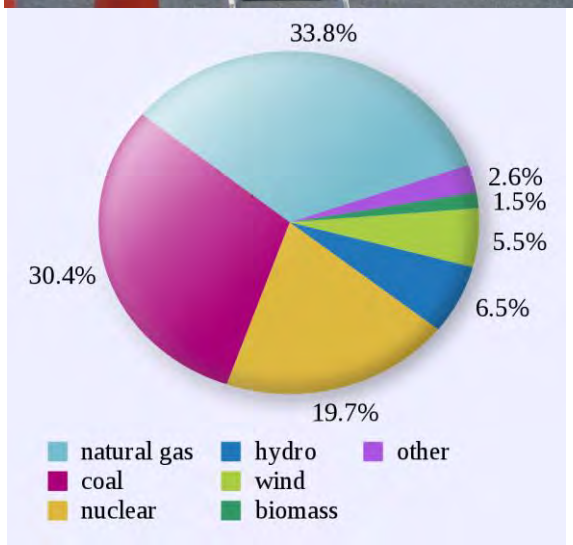
Source: https://www.forbes.com/sites/kevinanderton/2017/03/29/8-major-cyber-attacks-of-2016-infographic/#73bb0bee48e3



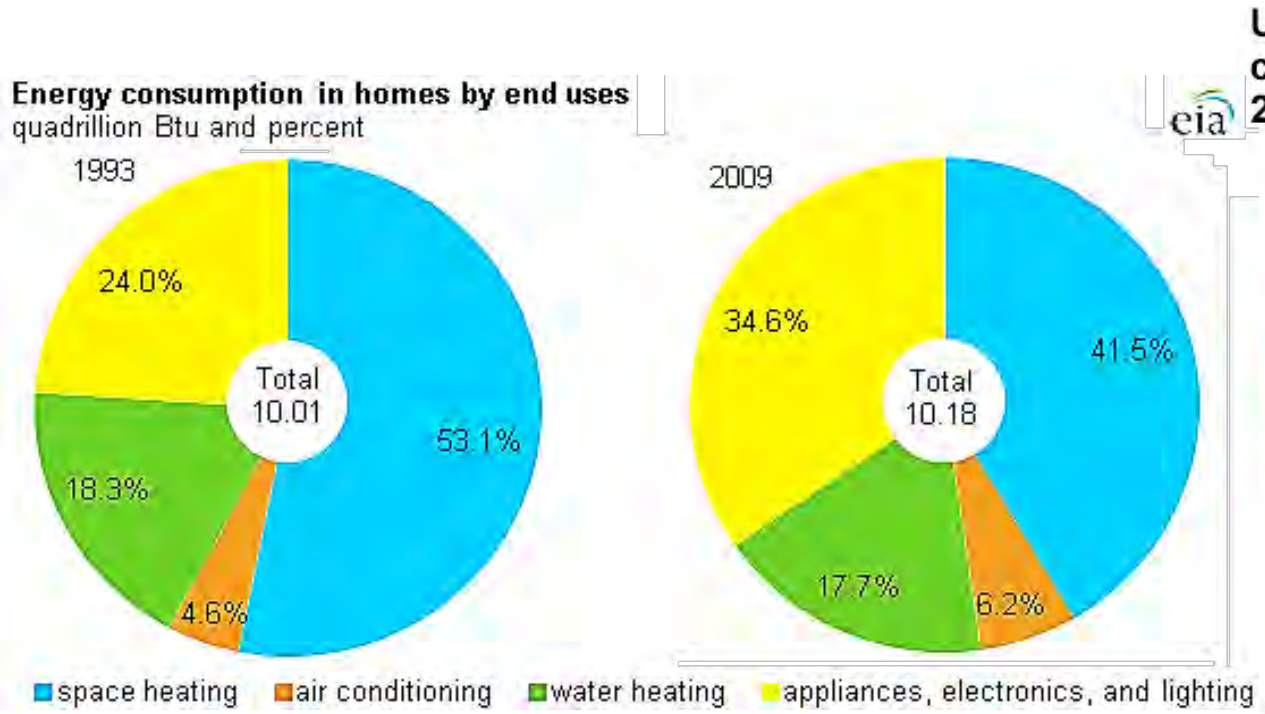
Source: http://www.bbc.com/news/technology-39920141

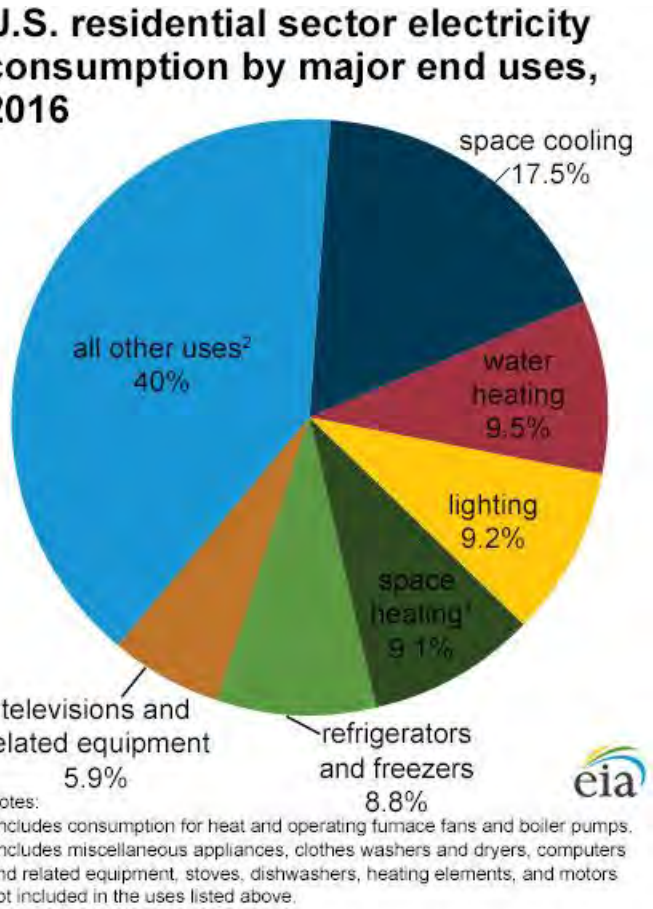
Issues Challenging Sustainability

- Energy Crisis



Consumer Electronics Demand More and More Energy



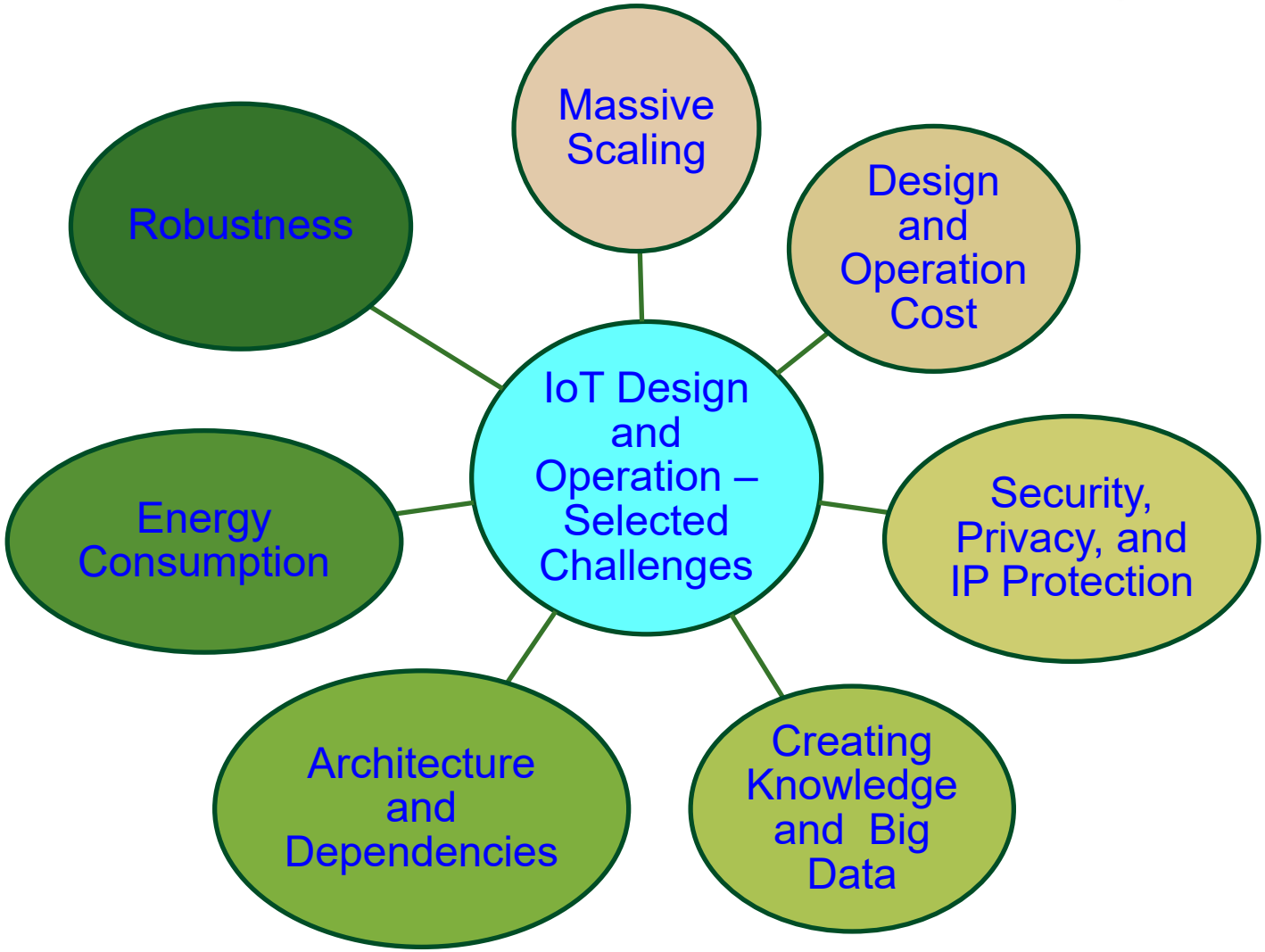


Quadrillion BTU (or quad): 1 quad = 10^{15} BTU = 1.055 Exa Joule (EJ).

Source: U.S. Energy Information Administration

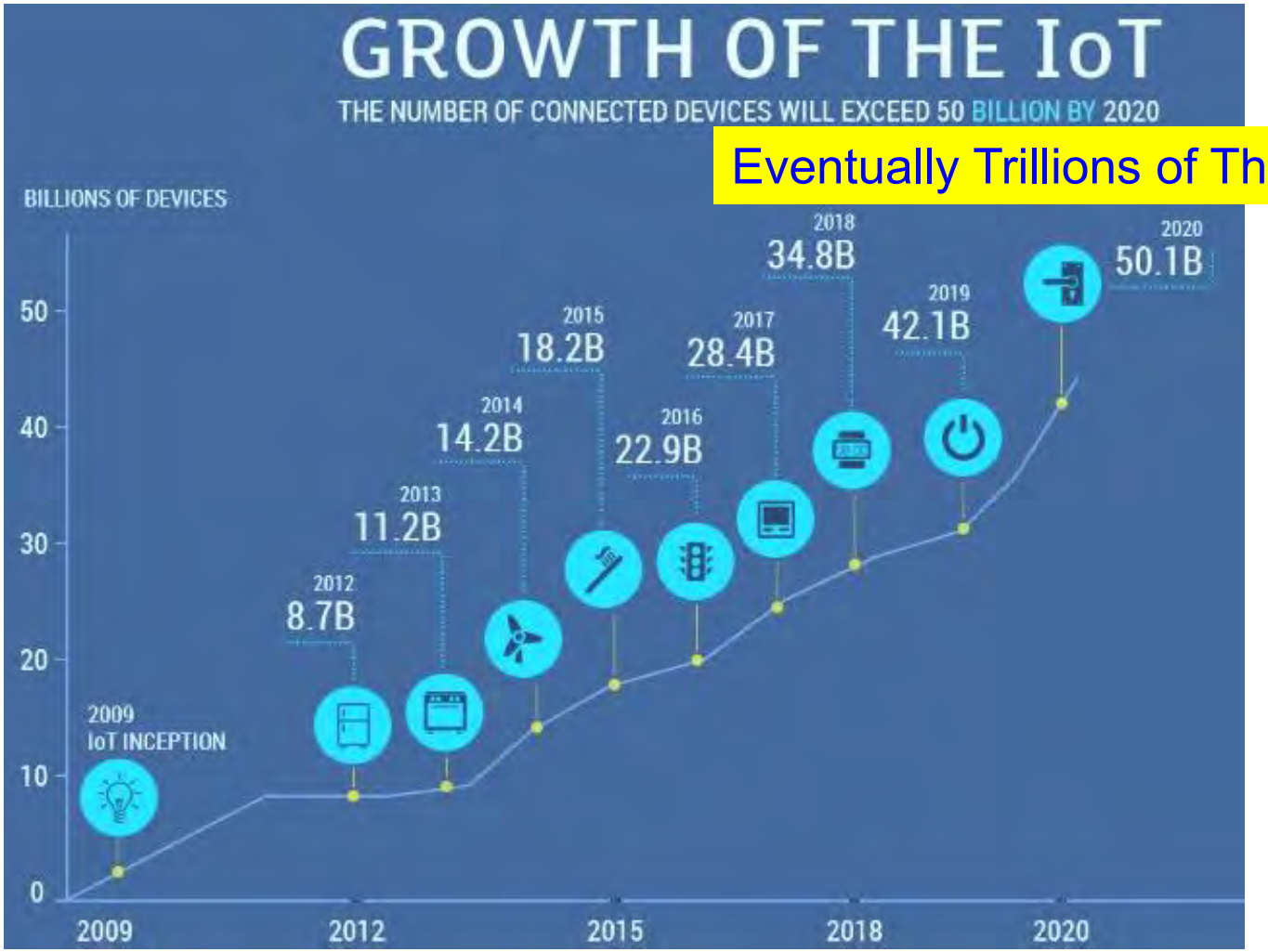
Challenges in Current Generation CE Design

IoT – Selected Challenges



Source: Mohanty ICIT 2017 Keynote

Massive Scaling



Eventually Trillions of Things

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

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

IoT Security - Attacks and Countermeasures

Threat	Against
Hardware Trojans	All
Side-channel attacks	C,AU,NR,P
Denial of Service (DoS)	A,AC,AU,NR,P
Physical attacks	All
Node replication attacks	All
Camouflage	All
Corrupted node	All
Tracking	P, NR
Inventorying	P, NR
Tag cloning	All
Counterfeiting	All
Eavesdropping	C,NR,P
Injecting fraudulent packets	P,I,AU,TW,NR
Routing attacks	C,I,AC,NR,P
Unauthorized conversation	All
Malicious injection	All
Integrity attacks against learning	C,I
Non-standard frameworks and inadequate testing	All
Insufficient/Inessential logging	C,AC,NR,P

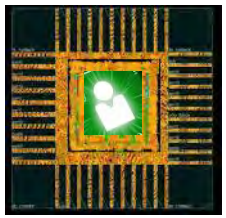
Countermeasures
Side-channel signal analysis
Trojan activation methods
Intrusion Detection Systems (IDSs)
Securing firmware update
Circuit/design modification
Kill/sleep command
Isolation
Blocking
Anonymous tag
Distance estimation
Personal firewall
Cryptographic schemes
Reliable routing
De-patterning and Decentralization
Role-based authorization
Information Flooding
Pre-testing
Outlier detection

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

Source: Nia 2017,IEEE TETC 2017

Security, Privacy, and IP Rights

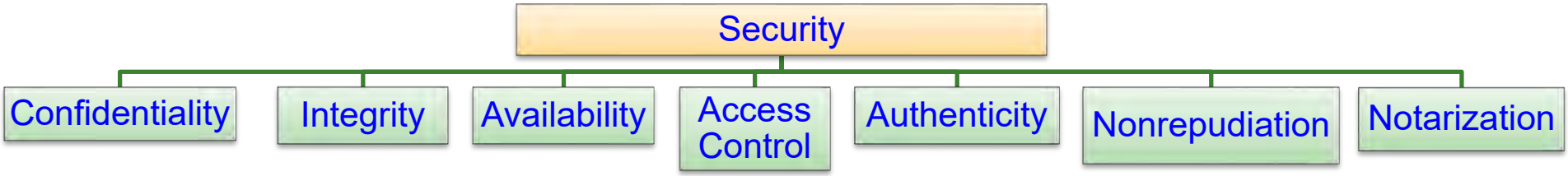
Hardware Trojan



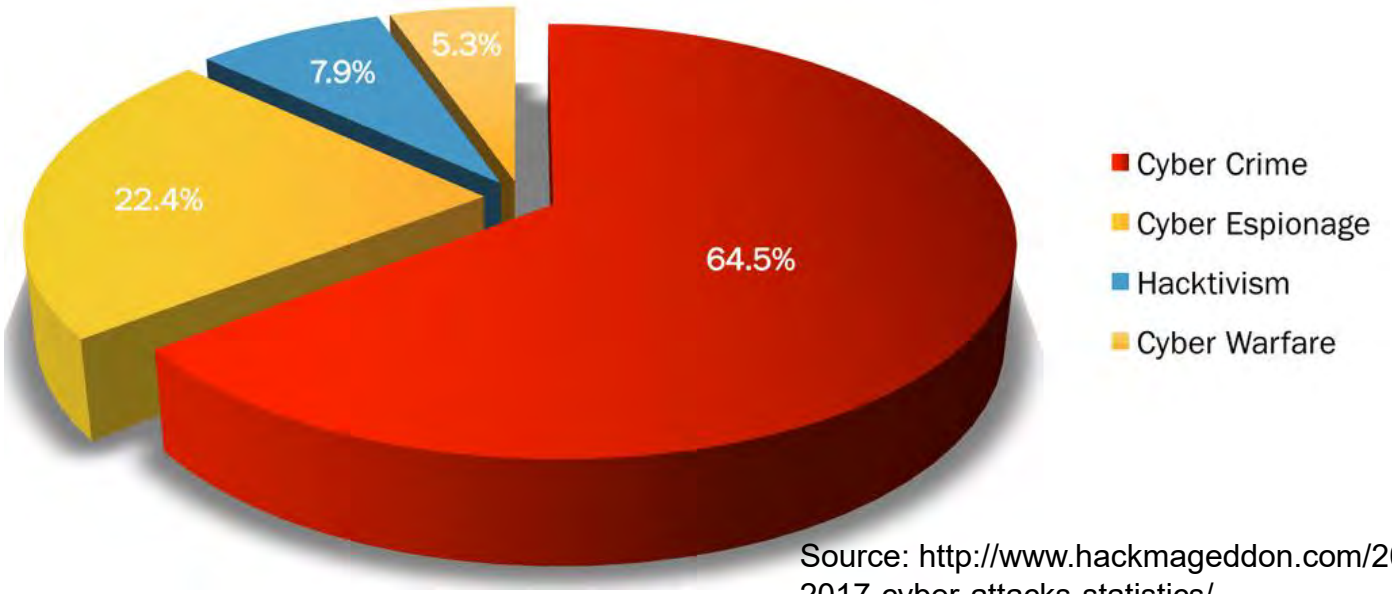
Counterfeit Hardware

Source: Mohanty ICIT 2017 Keynote

Security – Different Aspects



Security - Information, System …



Source: http://www.hackmageddon.com/2017/03/20/february-2017-cyber-attacks-statistics/

- 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 Challenge – Information

Online Banking

...

Credit Card Theft

Hacked: Linkedin, Tumbler, & Myspace

LinkedIn
tumblr.
myspace

Who did it: A hacker going by the name Peace.
What was done: 500 million passwords were stolen.

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

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

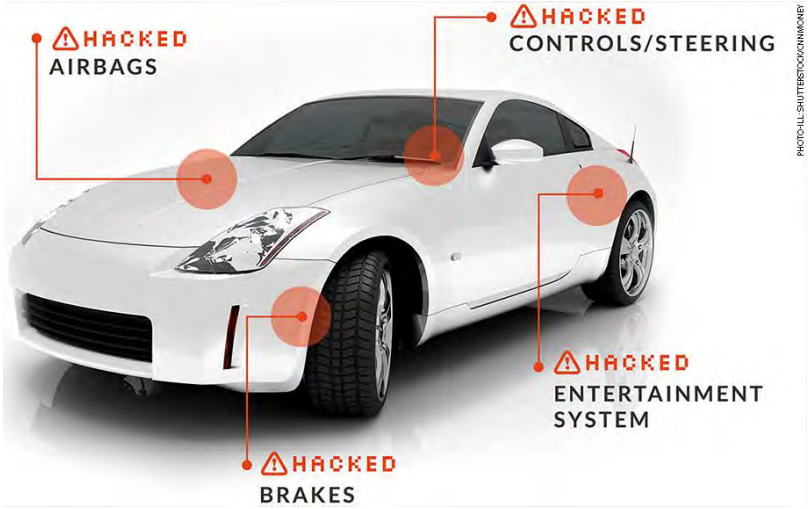
Personal Information

Credit Card/Unauthorized Shopping

Security Challenge - System …

Power Grid Attack

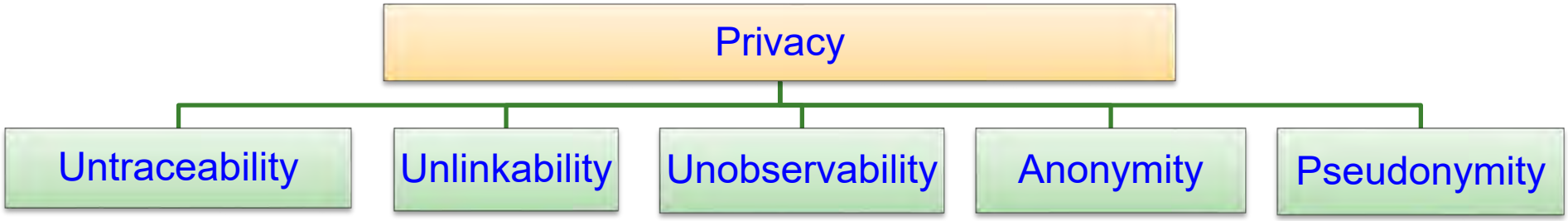
Source: http://www.csoonline.com/article/3177209/security/why-the-ukraine-power-grid-attacks-should-raise-alarm.html



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

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

Privacy – Different Aspects

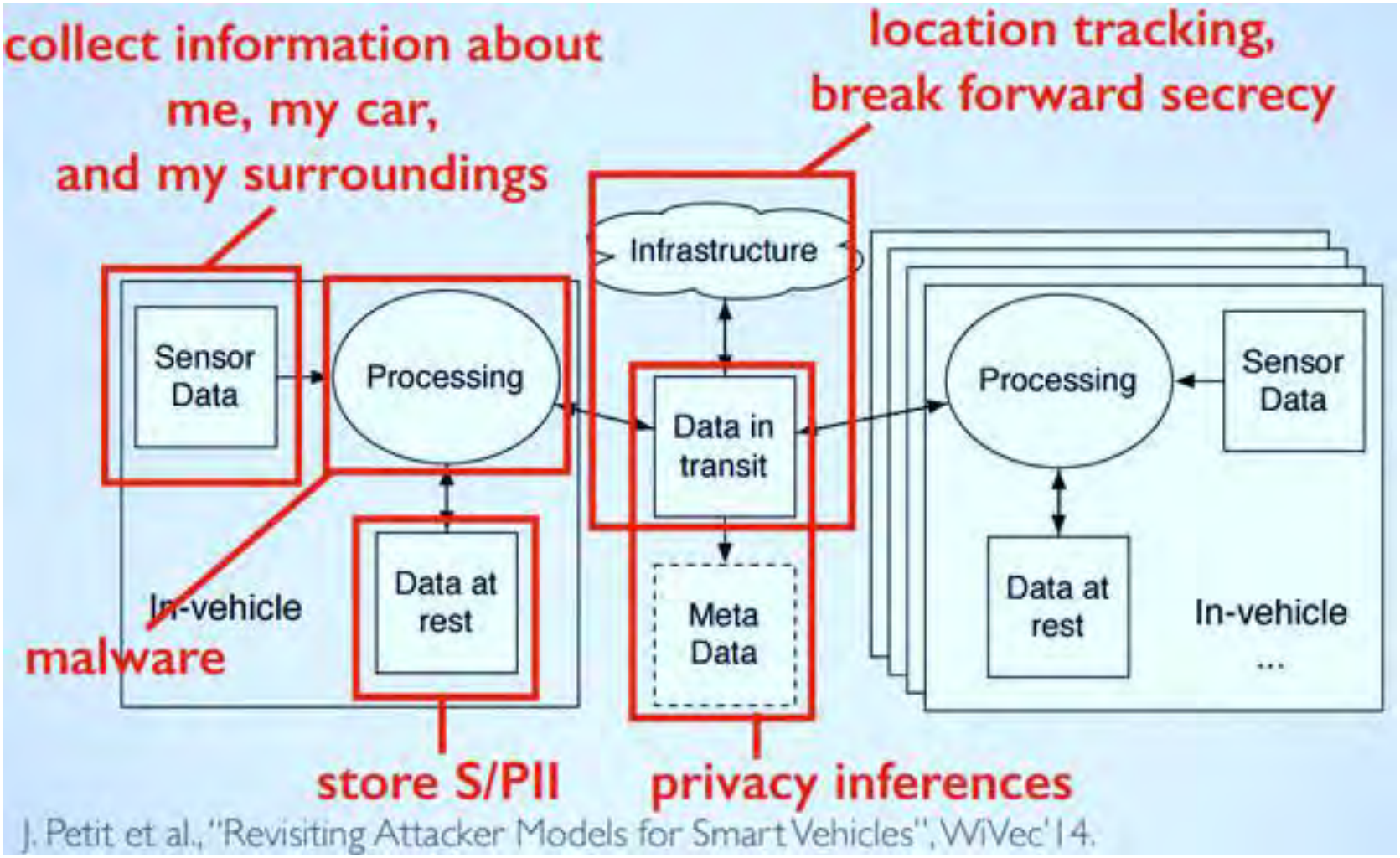


Privacy Challenge - Information

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

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

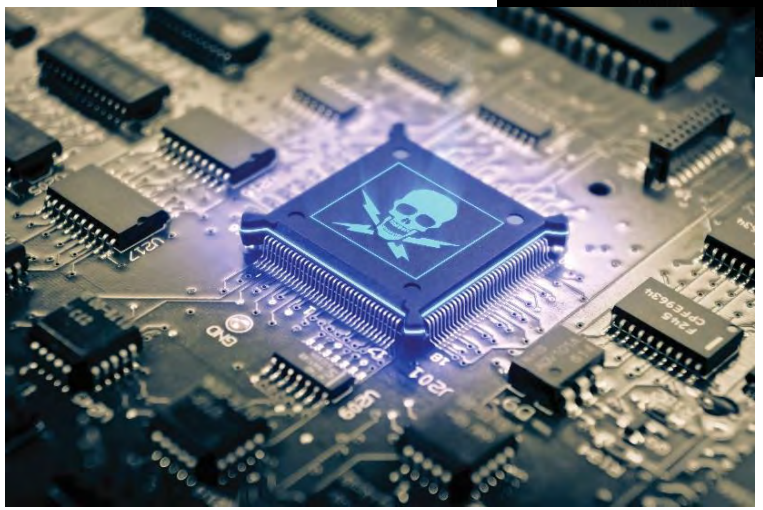
Privacy Challenge – System, Smart Car



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

Ownership - Media, Hardware, Software

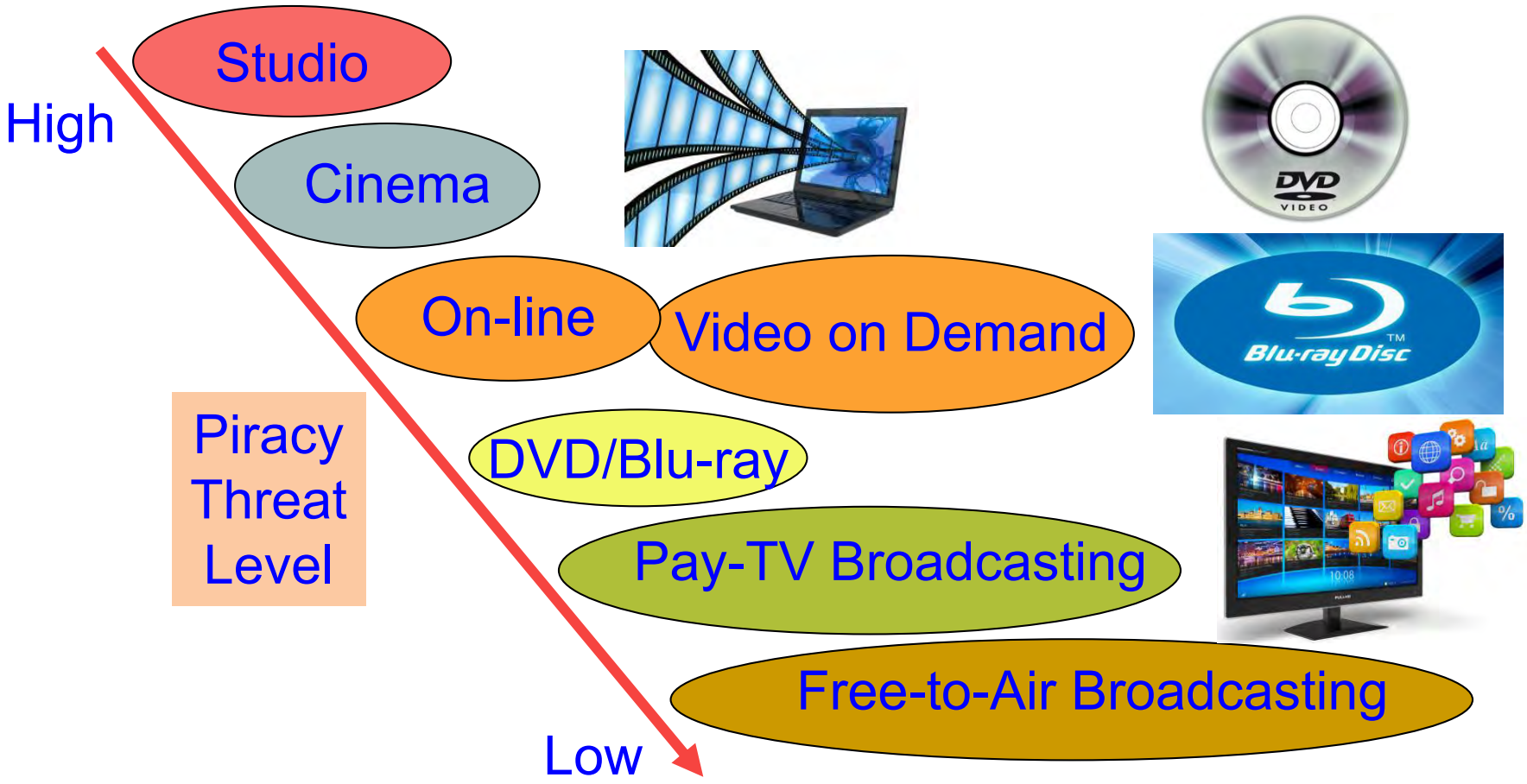
Media Piracy



Hardware Piracy → Counterfeit Hardware

Software Piracy

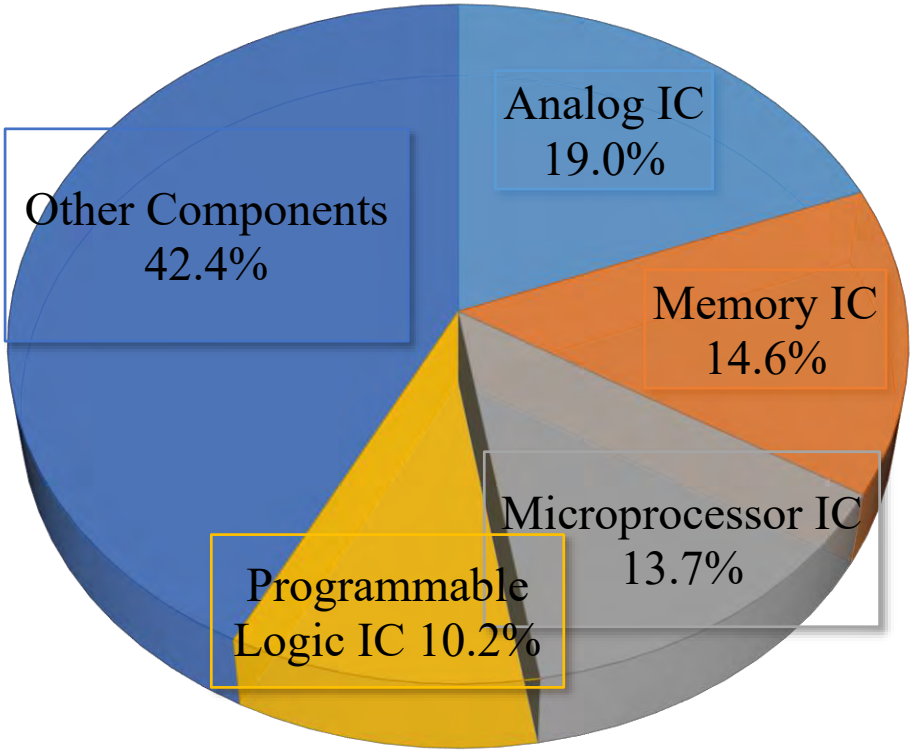
Media Piracy – Movie/Video



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

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

Counterfeit Hardware



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

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

Counterfeit Hardware Challenge

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%)

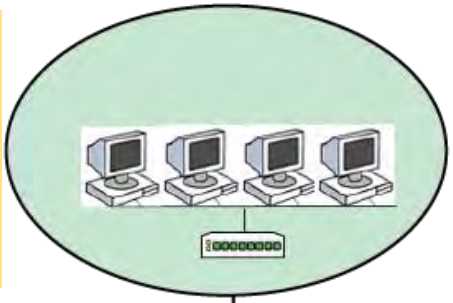
Wired Communications
$2.9 billion (5.4%)

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

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

Energy Consumption Challenge in IoT

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



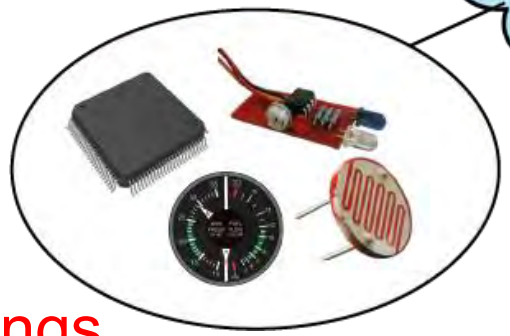
Local Area Network (LAN)

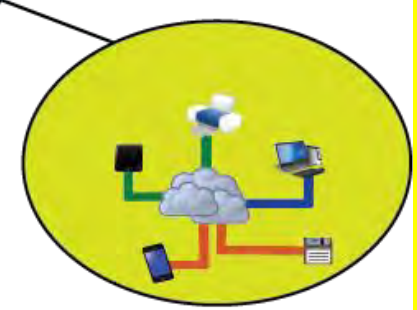
Energy from Supply/Battery - Energy consumed by Communications

Battery Operated - Energy consumed by Sensors, Actuators, Microcontrollers

Internet

The Cloud





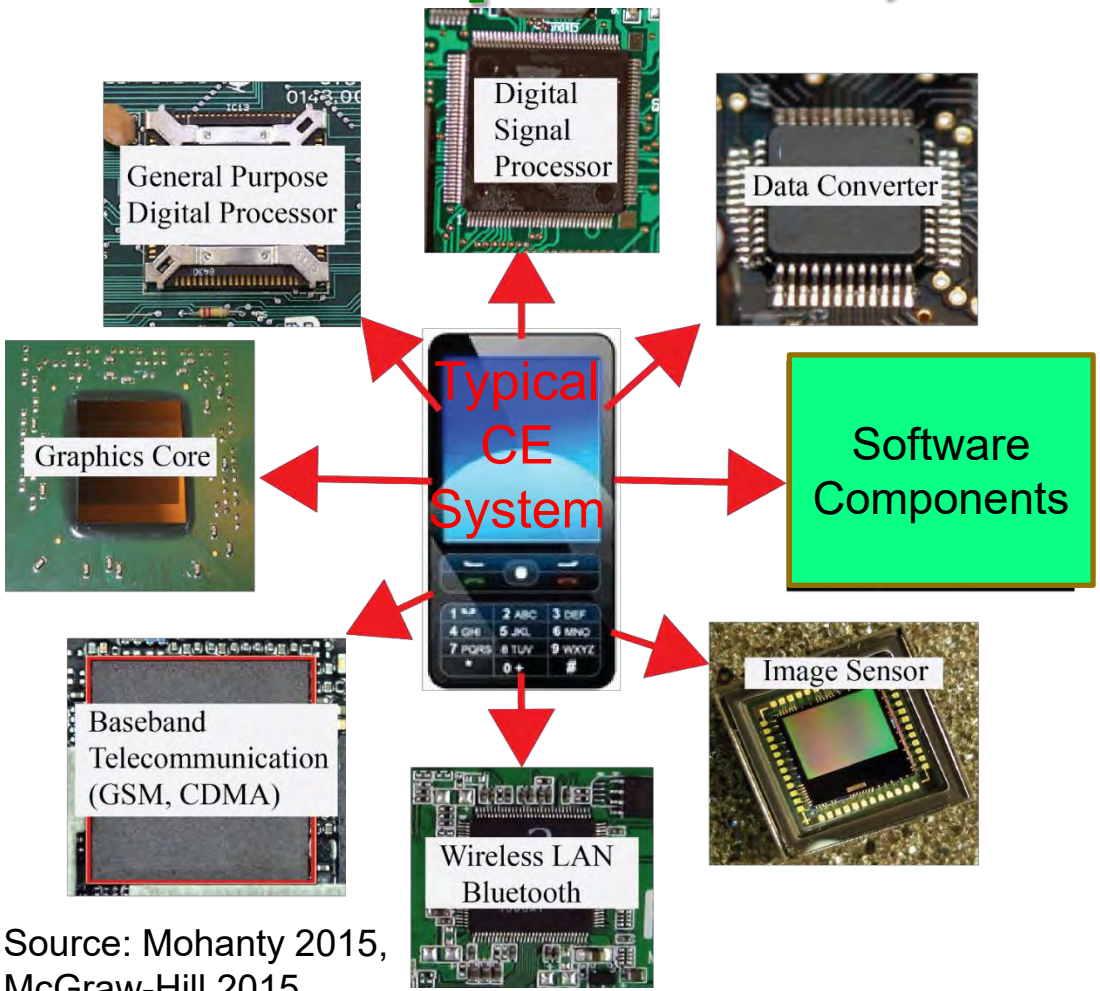
Energy from Supply - Energy consumed in Server, Storage, Software, Communications

The Things

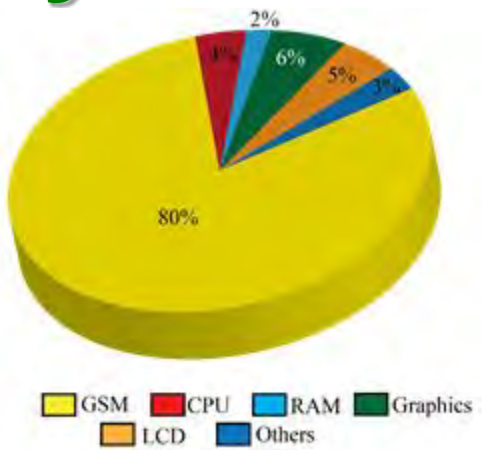
Four Main Components of IoT.

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

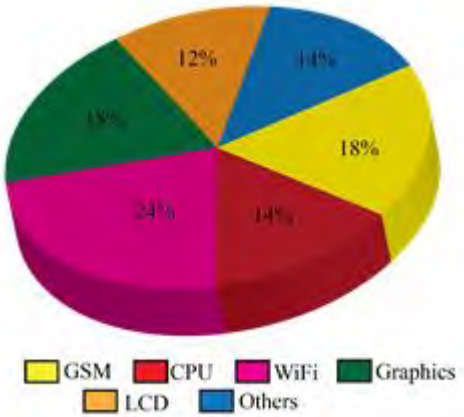
Energy Consumption of Sensors, Components, and Systems



Source: Mohanty 2015, McGraw-Hill 2015



During GSM Communications



During WiFi Communications

Energy Consumption and Latency in Communications

- Connected cars require latency of ms to communicate and avoid impending crash.
  - Faster connection
  - Low latency
  - Low power and energy

- 5G for connected world: Enables all devices to be connected seamlessly.
- LoRa: Long Range, low-powered, low-bandwidth, IoT communications as compared to 5G or Bluetooth.
- How about 5G, WiFi working together effectively?

Source: https://www.linkedin.com/pulse/key-technologies-connected-world-cloud-computing-ioe-balakrishnan
Source: https://eandt.theiet.org/content/articles/2016/08/lora-promises-cheap-low-power-alternative-to-5g-for-iot-devices/

Smart Transportation

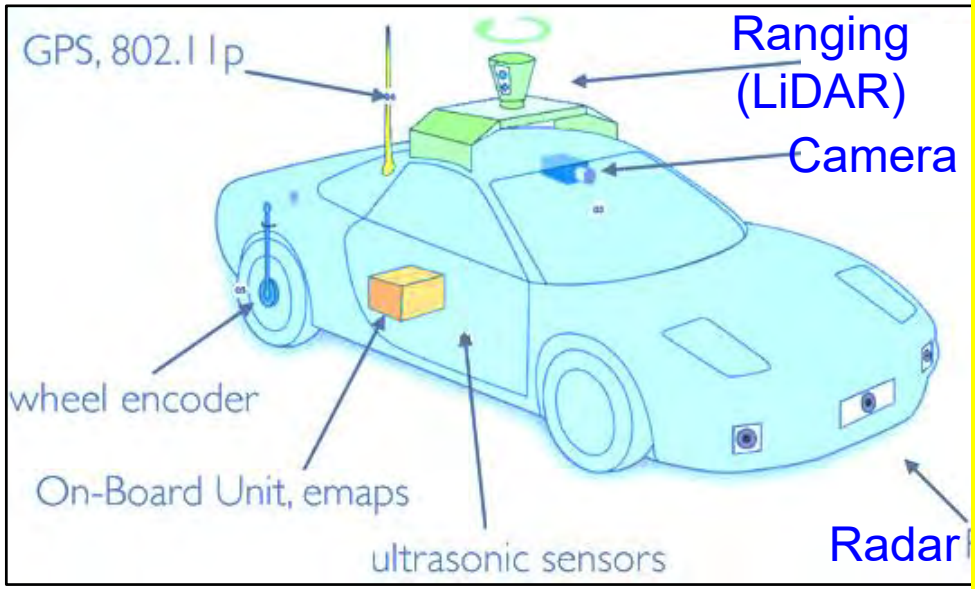
Autonomous/ Driverless/ Self-Driving/ Smart Care

Autonomous Vehicle (AV) is capable of sensing its environment and navigating without human input.

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

Datta 2017: CE Magazine Oct 2017

CE System Example - Autonomous Car



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

Level 0
- Complete Driver Control

Level 1
- Most functions by driver, some functions automated.

Level 2
- At least one driver-assistance system is automated.

Level 3
- Complete shift of critical safety systems to vehicle; Driver can intervene

Level 4
- Perform All Safety-Critical Functions
- Limited to Operational Domain

Level 5
- All Safety-Critical Functions in All Environments and Scenarios

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

Datta 2017: CE Magazine Oct 2017

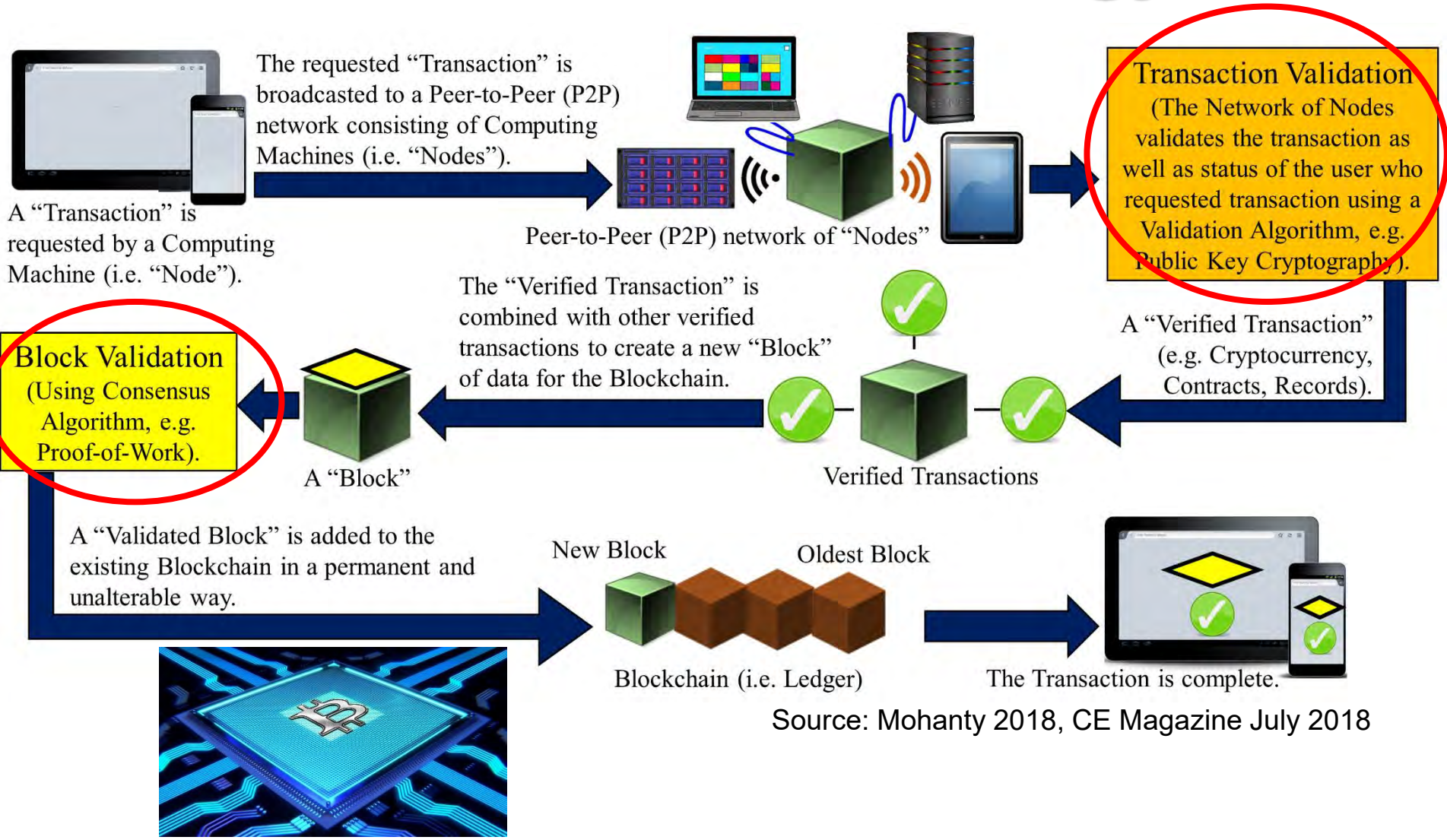
Autonomous Vehicle – Computing Need

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

Computing need in small server room stored in the trunk:

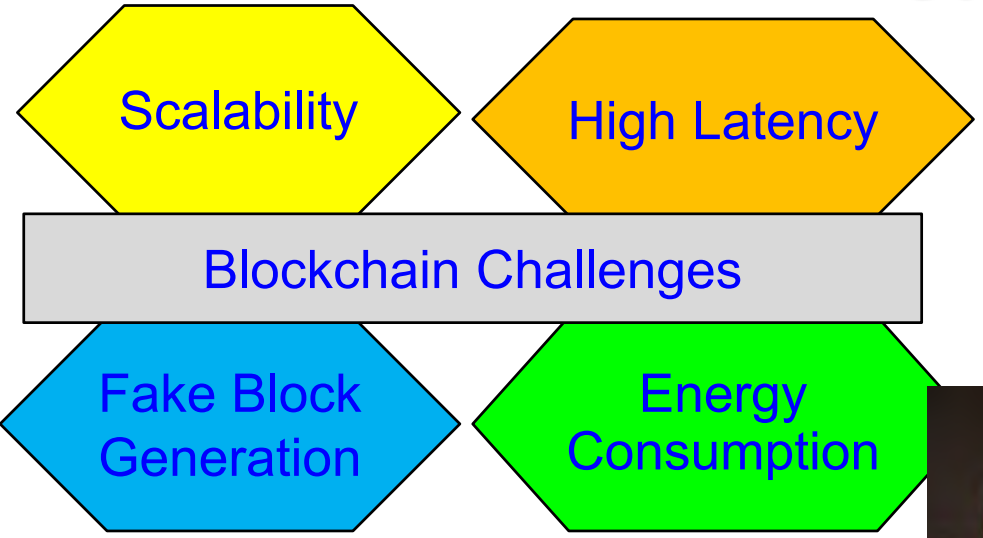
- ❖ Artificial Intelligence (AI) and data-crunching
- ❖ Huge amounts of data coming from dozens of cameras, LiDAR sensors, short and long-range radar

Blockchain Technology

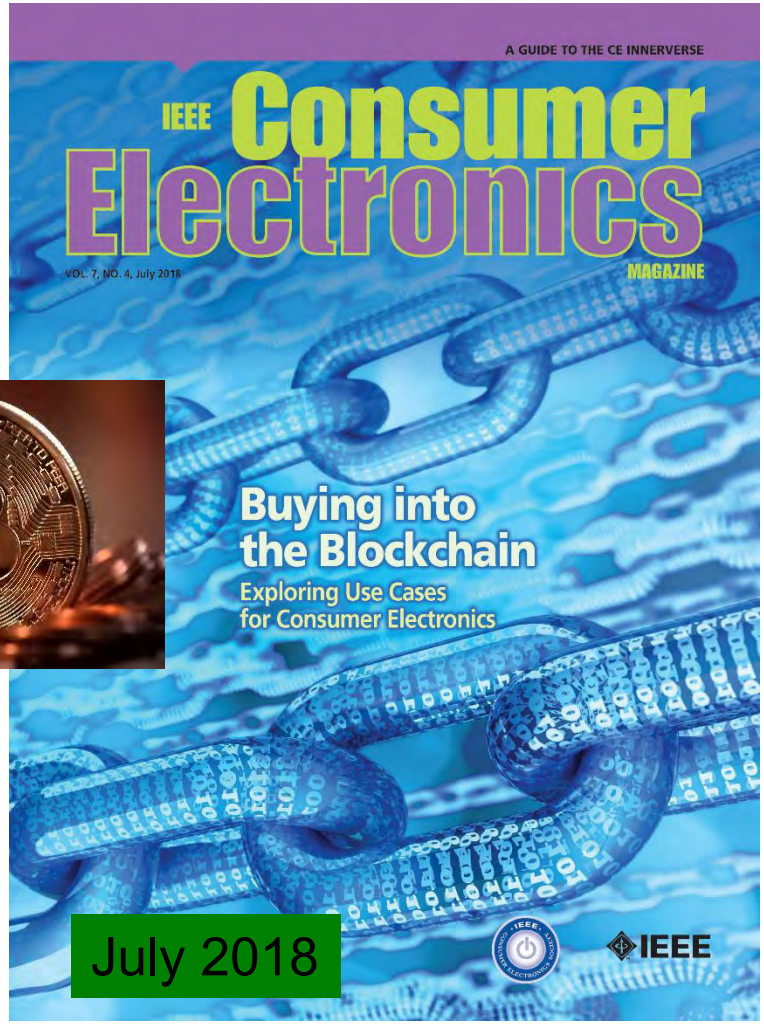


Source: Mohanty 2018, CE Magazine July 2018

Blockchain – Energy Consumption Issue



Source: Mohanty 2018, CE Magazine July 2018



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

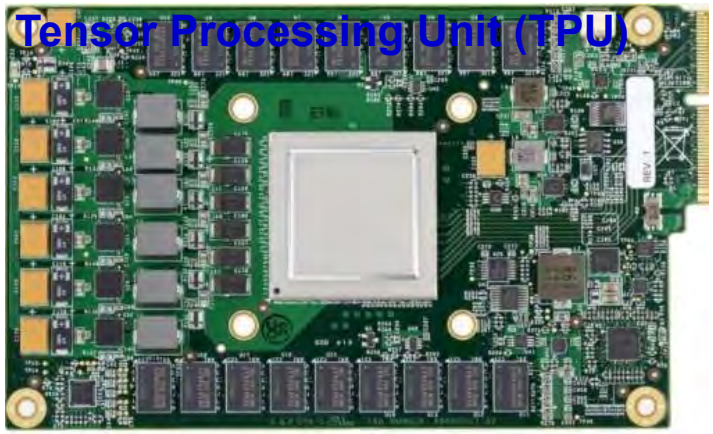
Source: N. Popper, "There is Nothing Virtual About Bitcoin's Energy Appetite", The New York Times, 21st Jan 2018, https://www.nytimes.com/2018/01/21/technology/bitcoin-mining-energy-consumption.html.

Artificial Intelligence Technology

Machine Learning

Deep Learning

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

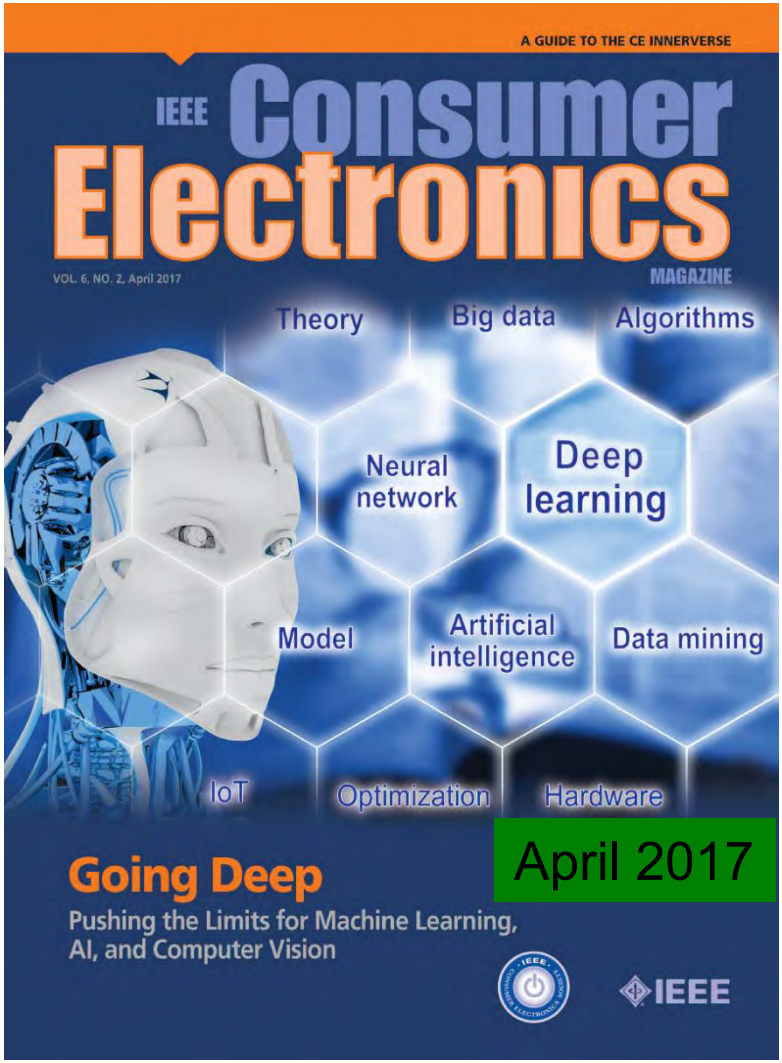


Tensor Processing Unit (TPU)

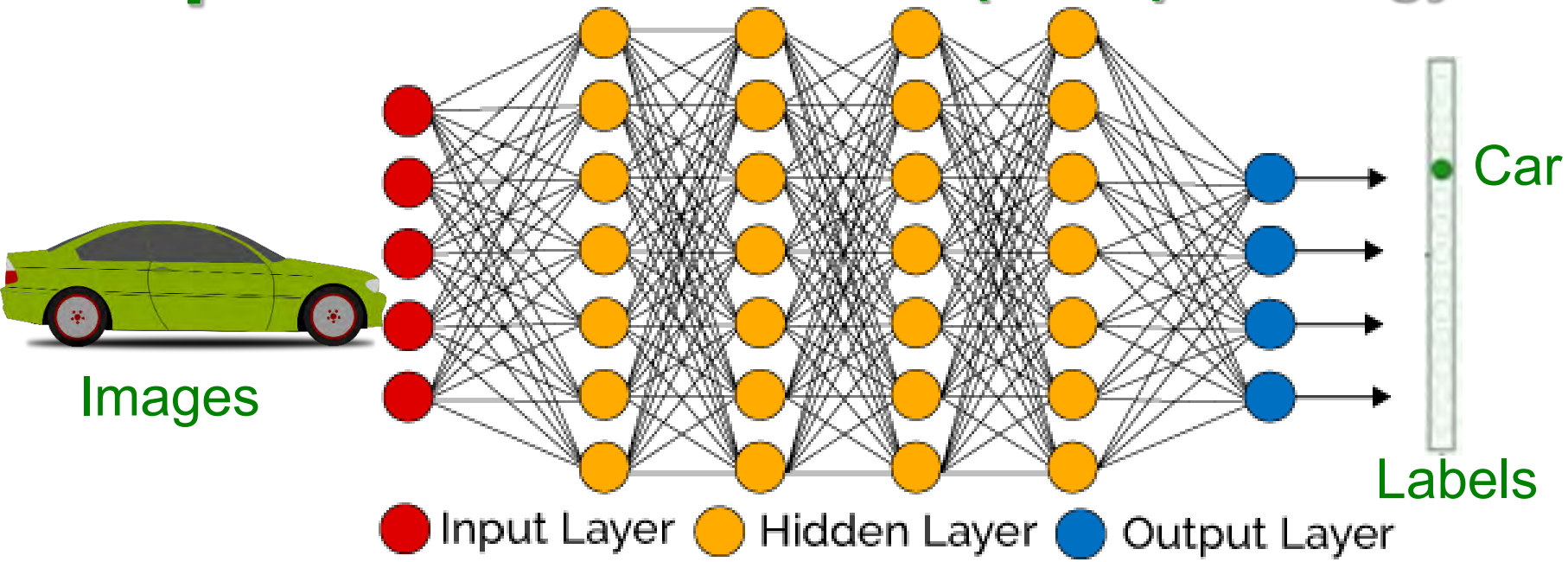
Source: https://fossbytes.com/googles-home-made-ai-processor-is-30x-faster-than-cpus-and-gpus/

Smart City Use:

- Better decision
- Faster response

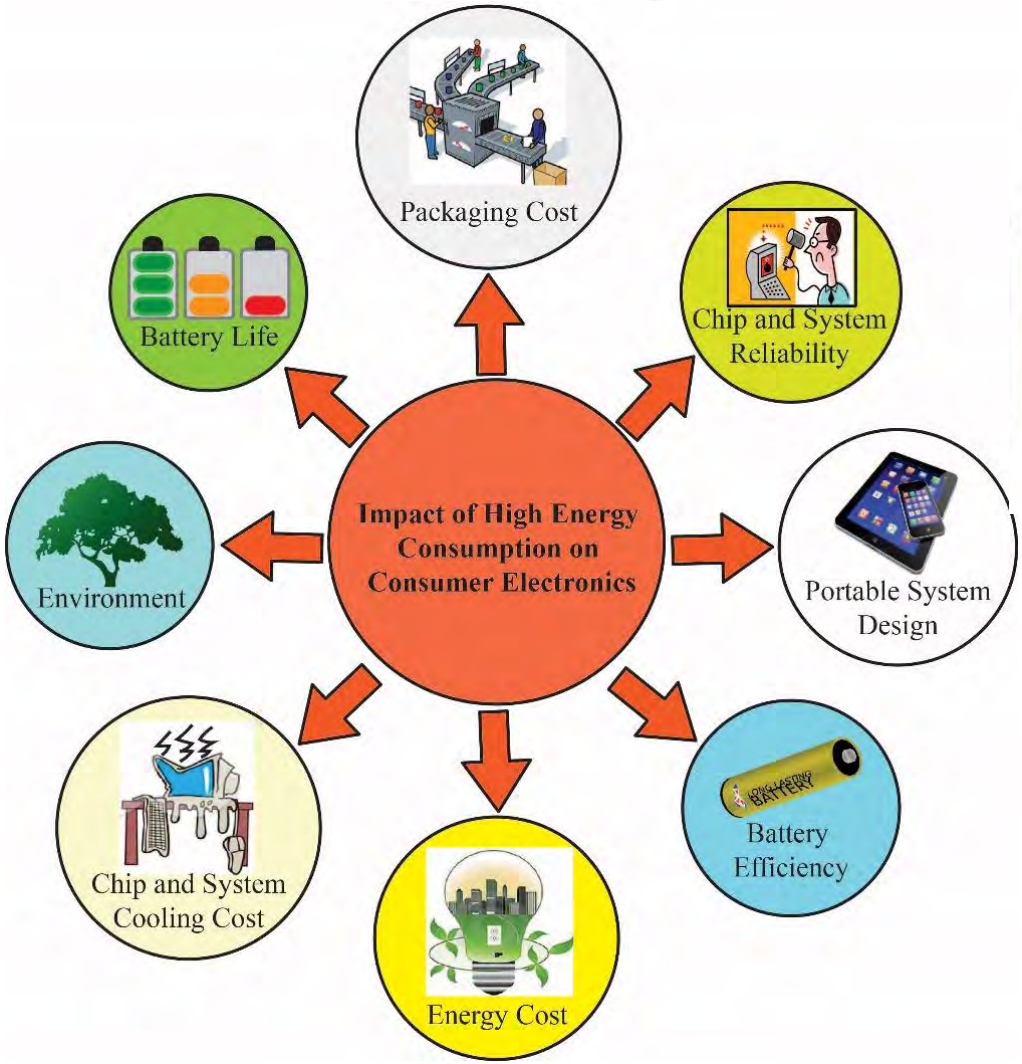


Deep Neural Network (DNN) - Energy Issue



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

Impact of High Energy Consumption



Source: Mohanty 2015, McGraw-Hill 2015

- Smartwatch → 1 day battery life of 1 time charging.

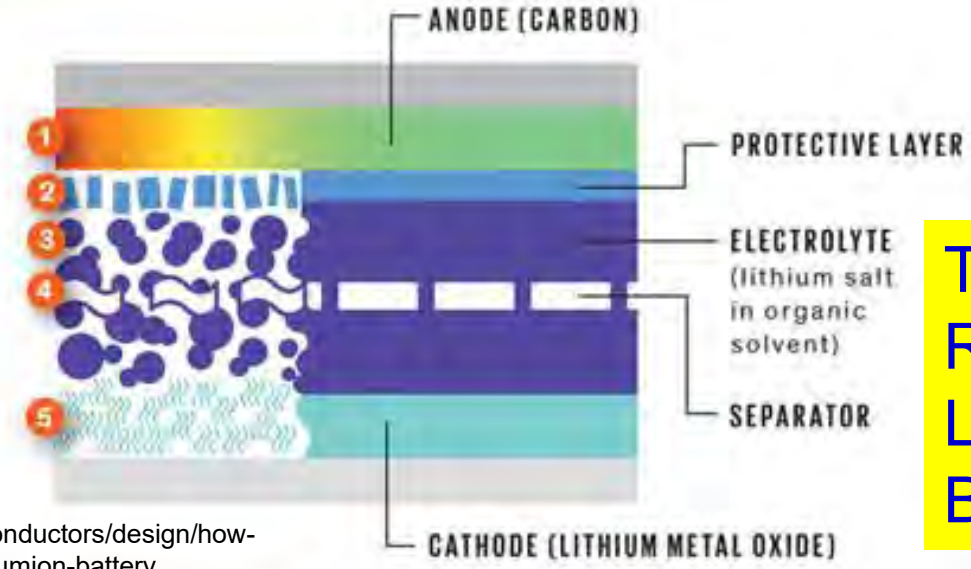
- Fitness Tracker → 3 hours battery life of 1 time charging if GPS is ON.

Source: Mohanty 2013, CARE 2013 Keynote

Safety of Electronics

Smartphone Battery

1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.

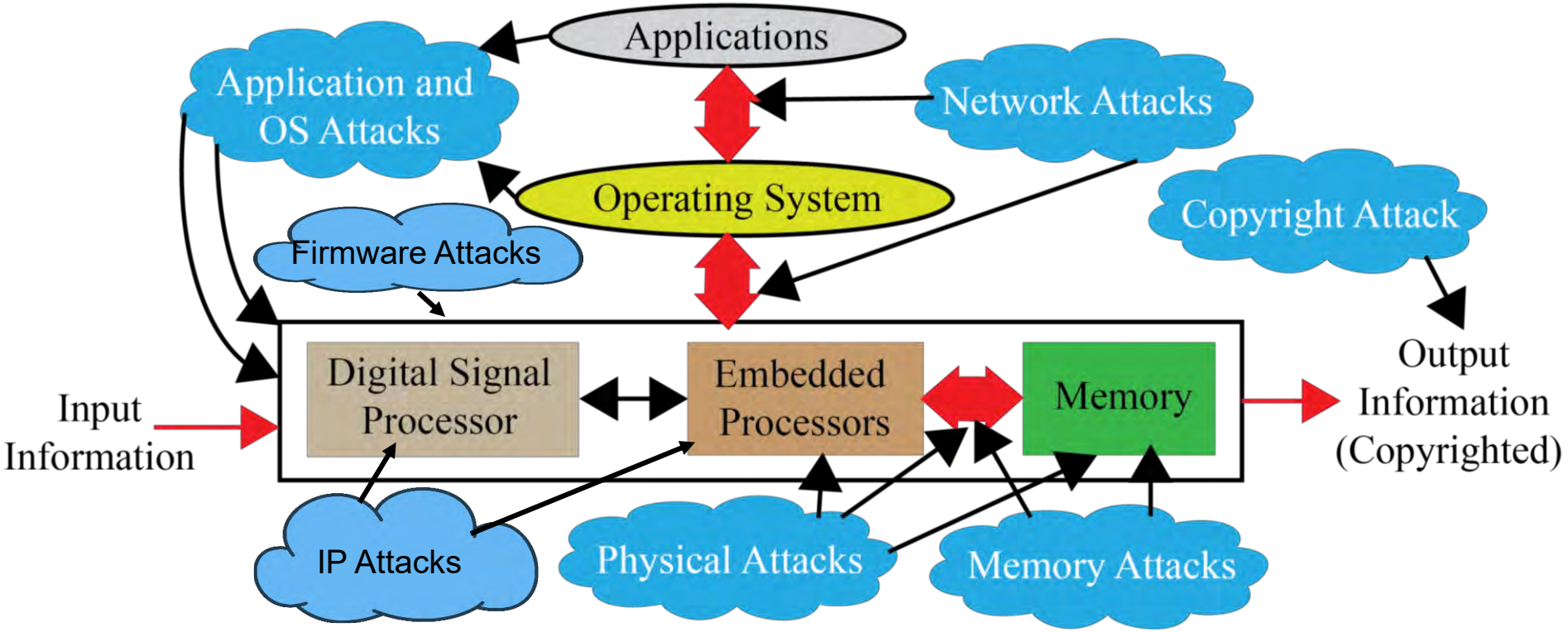


Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

Thermal Runaway in a Lithium-Ion Battery

Addressing Security Constraints in CE

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

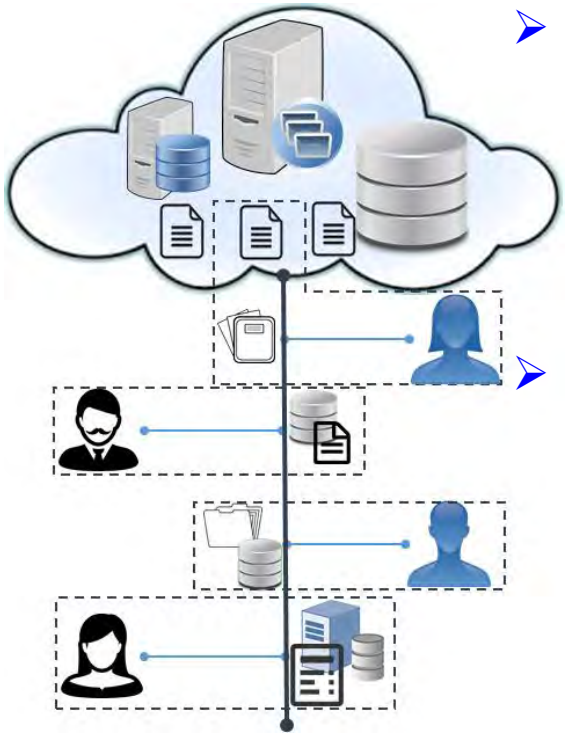


Diverse forms of Attacks, following are not the same: System Security, Information Security, Information Privacy, System Trustworthiness, Hardware IP protection, Information Copyright Protection.

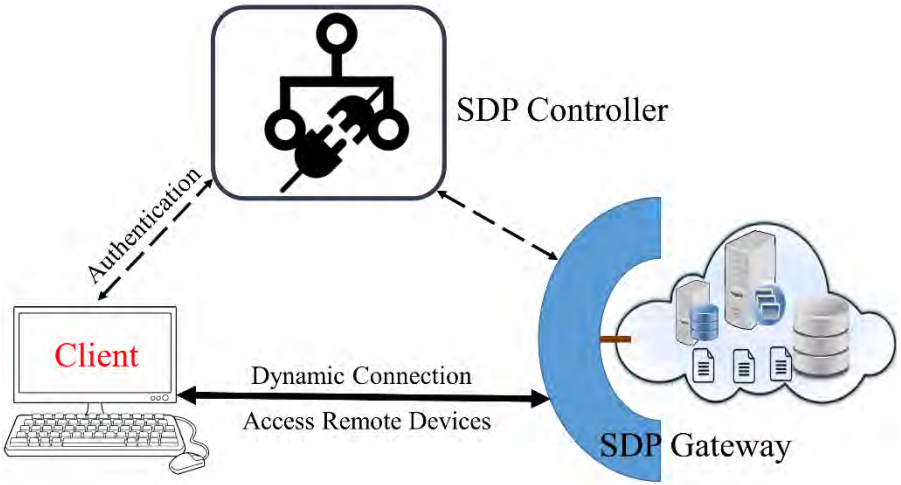
IoT Security - Software Defined Perimeter (SDP)

TCP/IP based security | Traditional | Connect First and then Authenticate

Software-Defined Perimeter | Advanced | Authenticate First and then Connect

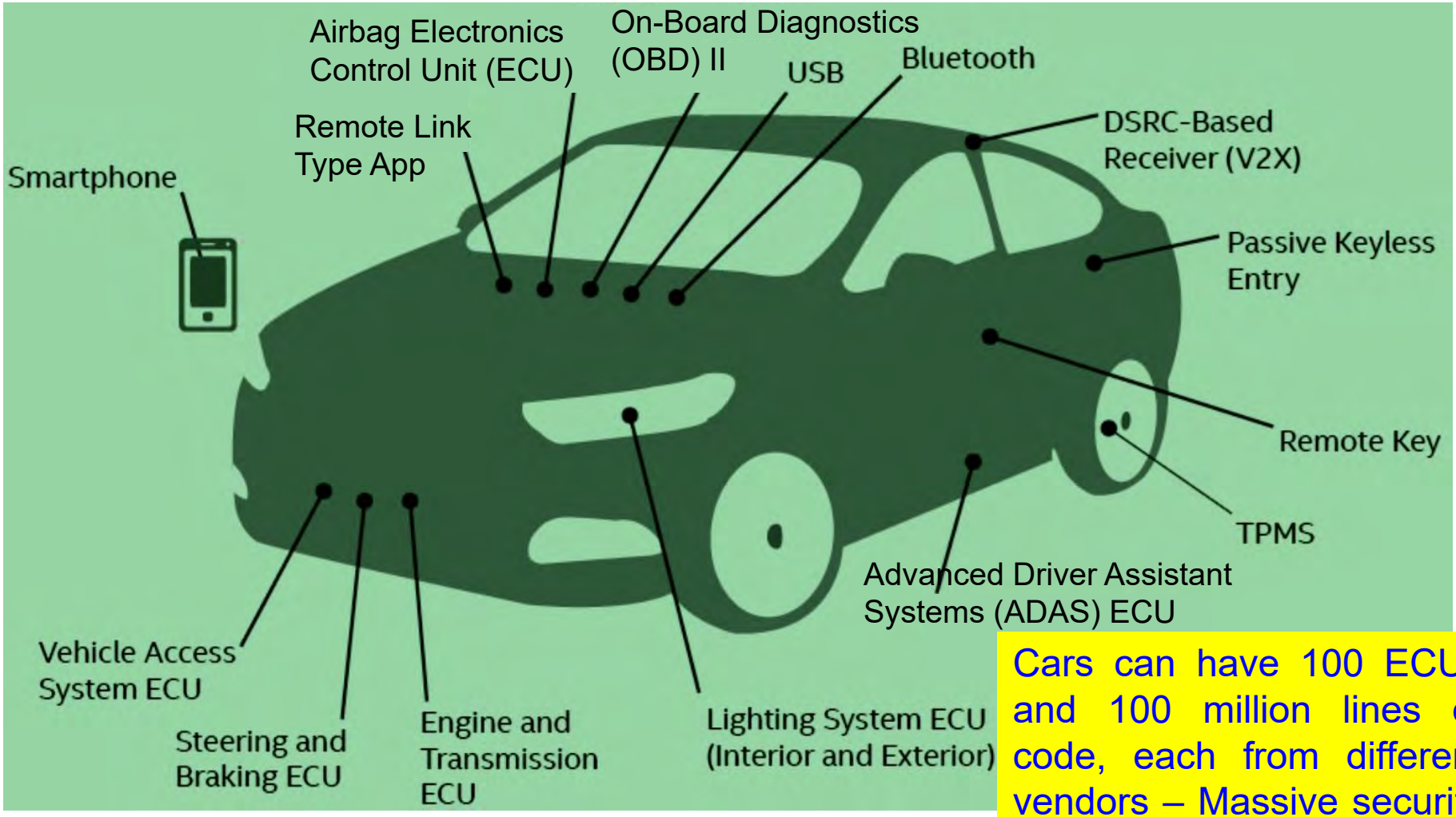


- SDP creates a cryptographic perimeter from a source device to the edges and cloud data center.
- SDP provides user-centric security solution by creating a perimeter to enclose source and destination within the perimeter.



Source: Mohanty 2017, CEM Oct 2017

Smart Car – Security Venerability



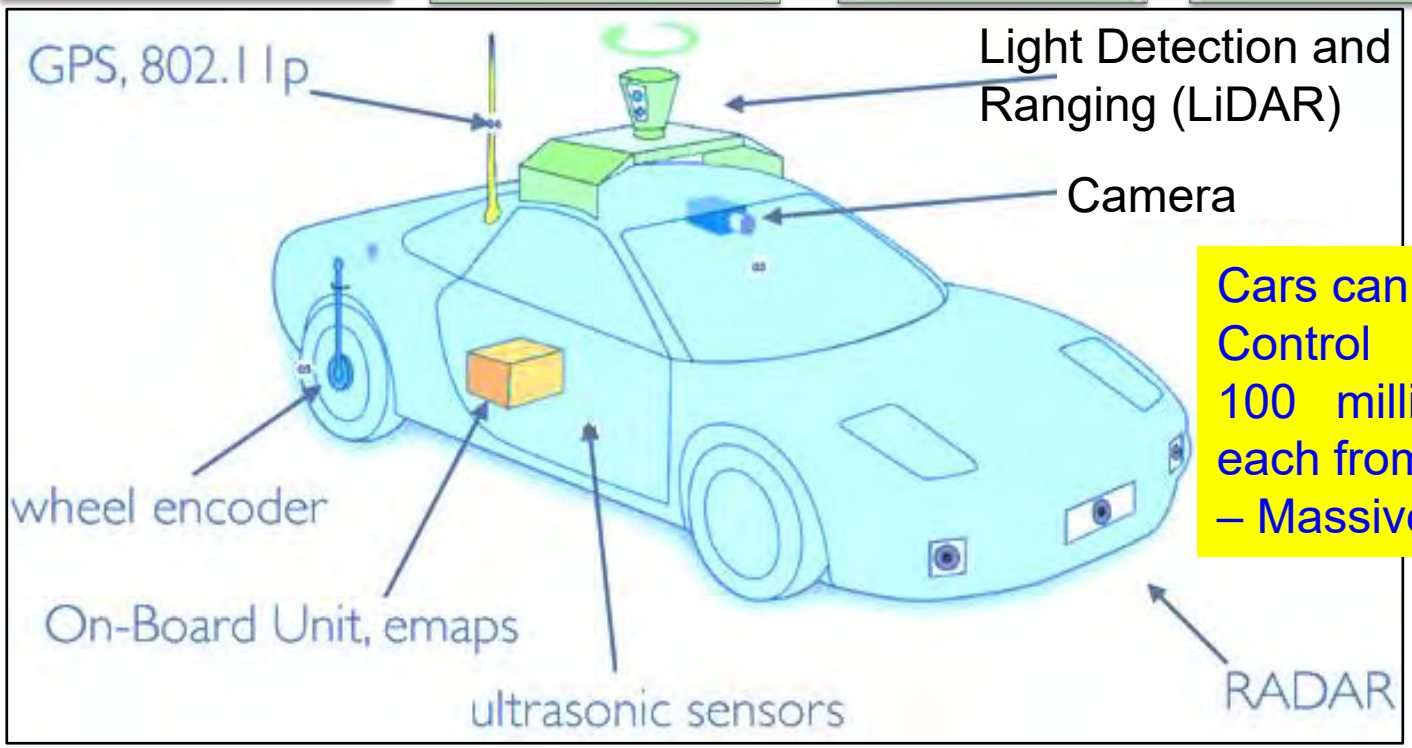
Cars can have 100 ECUs and 100 million lines of code, each from different vendors – Massive security issues.

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

CE System Security – Smart Car

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.

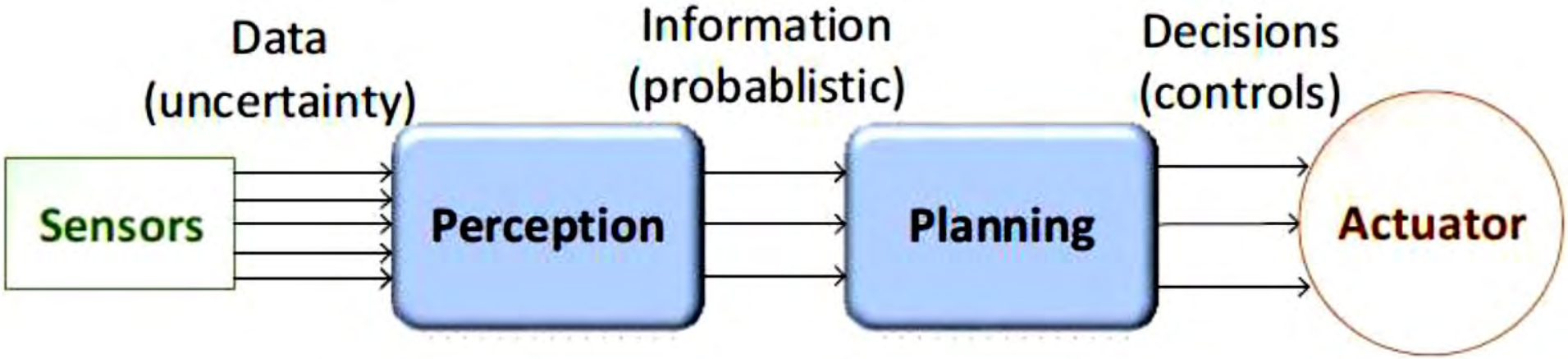
Source: http://www.computerworld.com/article/3005436/cybercrime-hacking/black-hat-europe-it-s-easy-and-costs-only-60-to-hack-self-driving-car-sensors.html

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

Source: Petit 2015: IEEE-TITS Apr 2015

Smart Car – Decision Chain

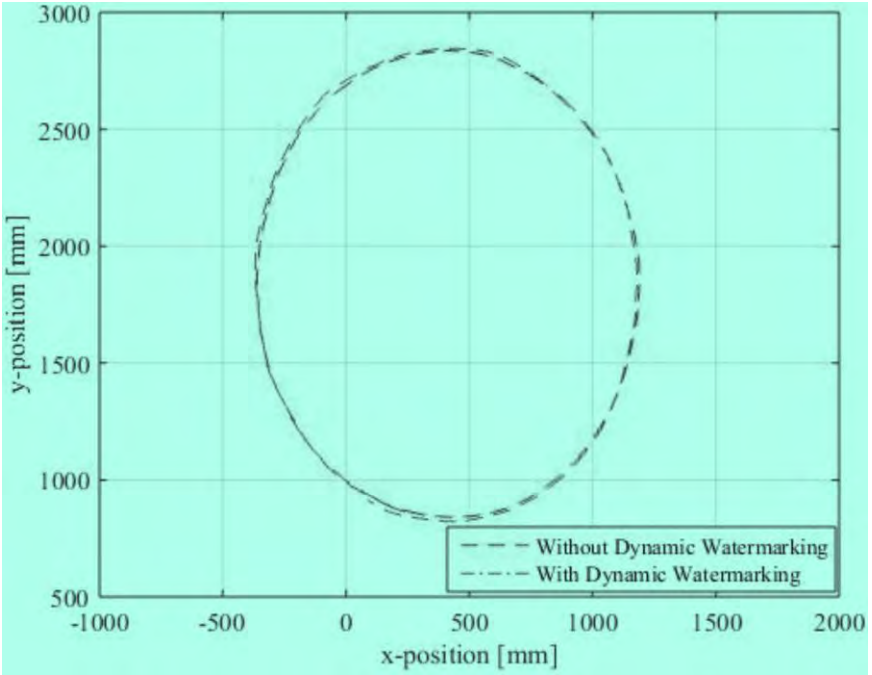
- Designing an AV requires decision chains.
- Human driven vehicles are controlled directly by a human.
- AV actuators controlled by algorithms.
- Decision chain involves sensor data, perception, planning and actuation.
- Perception transforms sensory data to useful information.
- Planning involves decision making.



Source: Plathottam 2018, COMSNETS 2018

Autonomous Car Security – Collision Avoidance

- Attack: Feeding of malicious sensor measurements to the control and the collision avoidance module. Such an attack on a position sensor can result in collisions between the vehicles.
- Solutions: "**Dynamic Watermarking**" of signals to detect and stop such attacks on cyber-physical systems.
- Idea: Superimpose each actuator *i* a random signal $e_i[t]$ (watermark) on control policy-specified input.

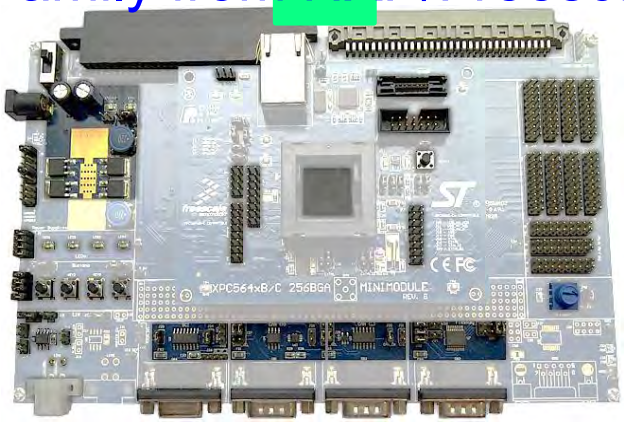


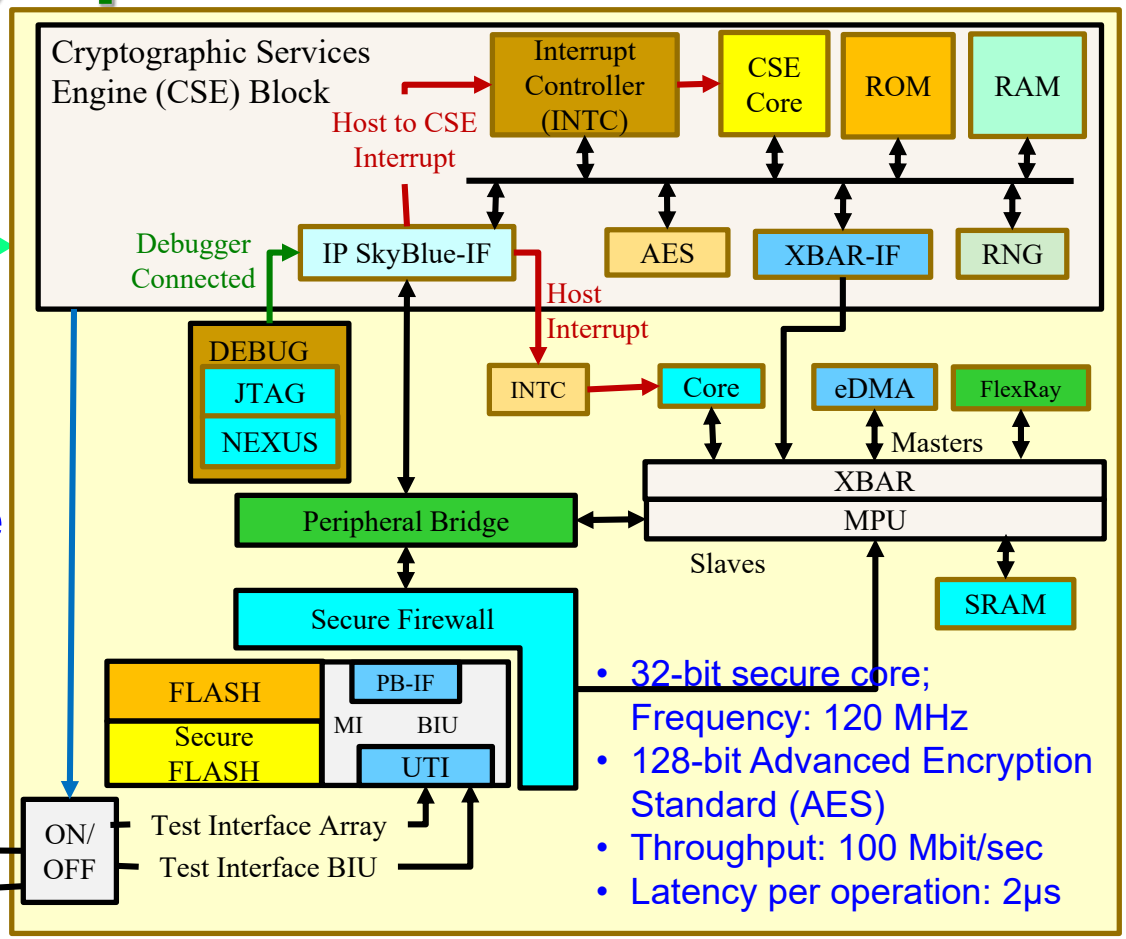
Source: Ko 2016, CPS-Sec 2016

Autonomous Car Security – Cryptographic Hardware

Cryptographic Services Engine (CSE) Block

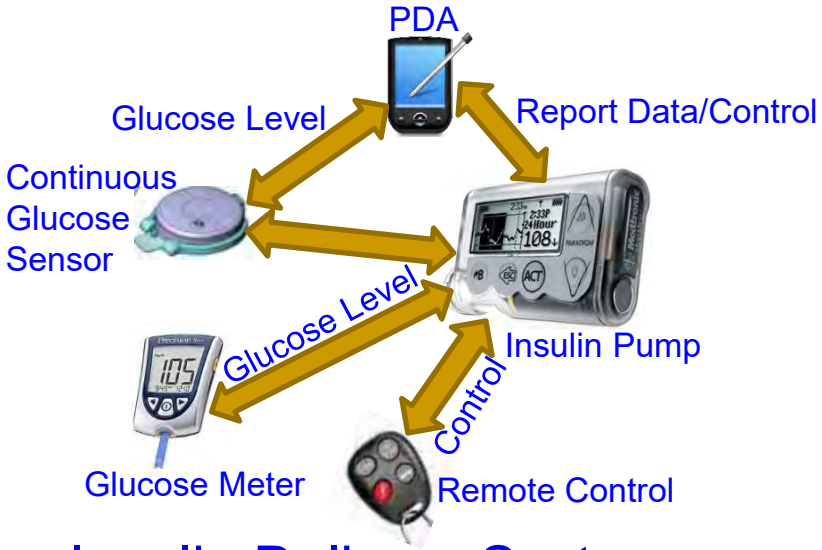
Qorivva MPC564xB/C Family from NXP/Freescale



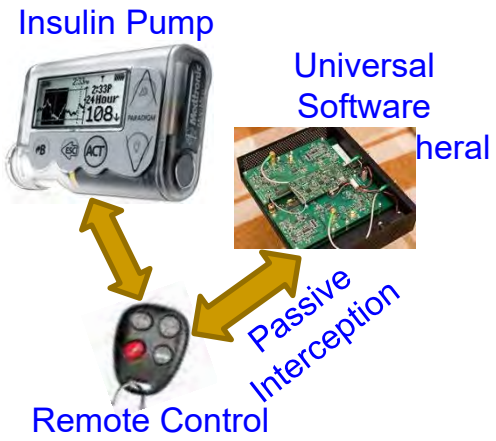


Source: http://www.nxp.com/assets/documents/data/en/supporting-information/DWF13_AMF_AUT_T0112_Detroit.pdf

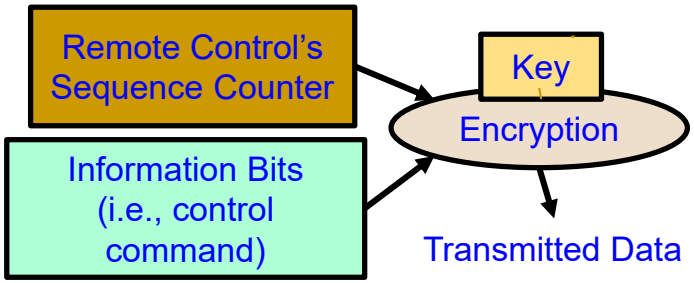
Smart Healthcare Security



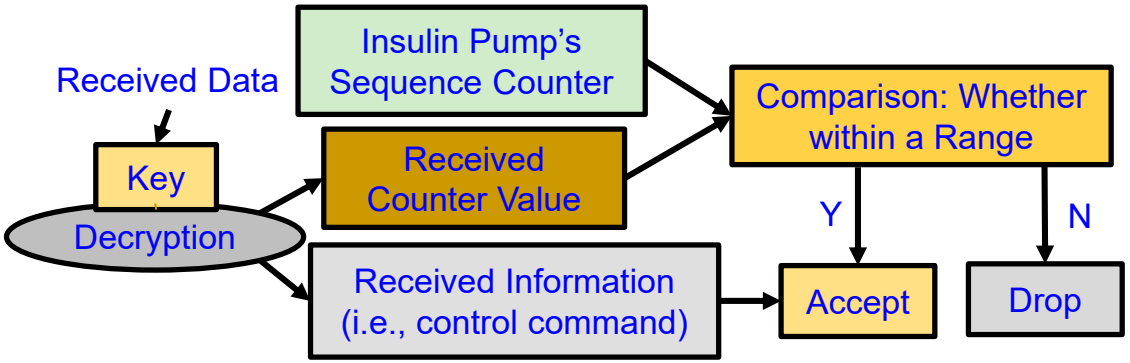
Insulin Delivery System



Security Attacks



Rolling Code Encoder in Remote Control

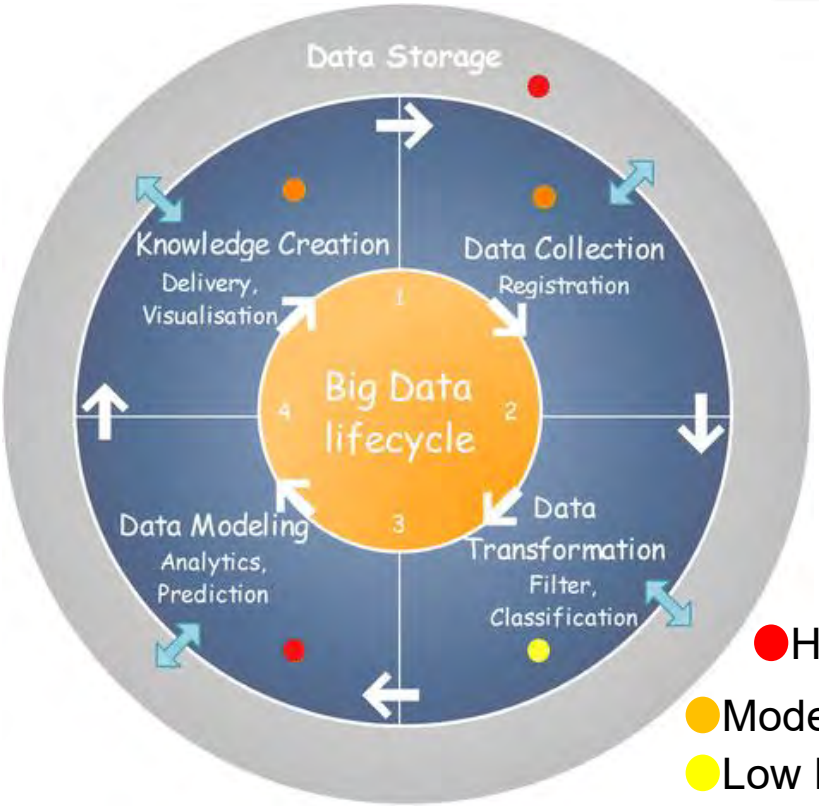


Rolling Code Decoder in Insulin Pump

Li 2011: HEALTH 2011

Smart Healthcare - Privacy Issue

- Privacy Protection
  - Untraceability
  - Unlinkability
  - Unobservability
  - Anonymity
  - Pseudonymity



High Risk

Moderate Risk

Low Risk

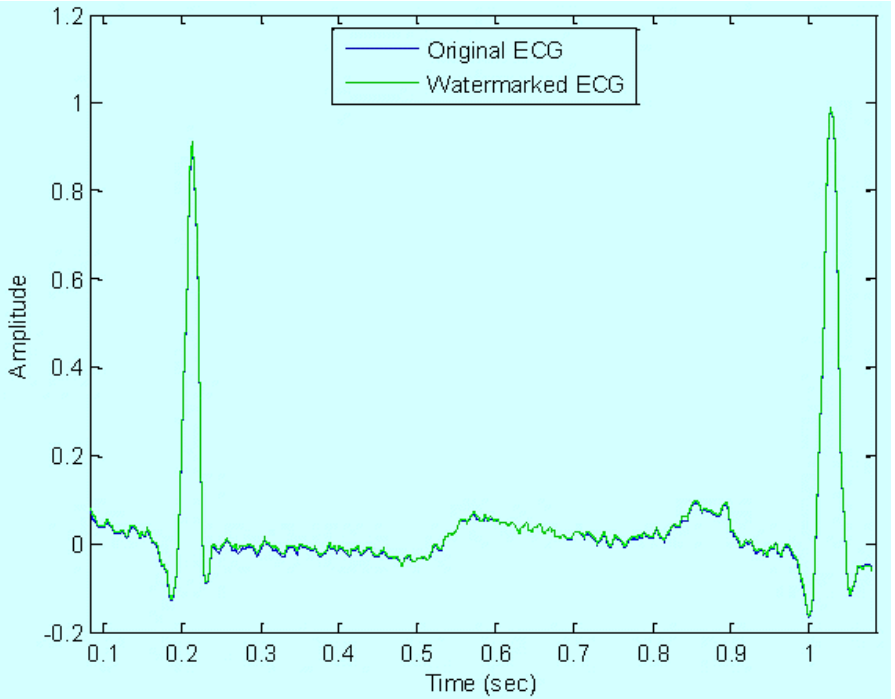
Smart Healthcare Security /Privacy Methods

- Authentication
- Data Encryption
- Data/Signal Watermarking
- Data Masking
- Access Control
- Monitoring and Auditing
- De-identification
- Hybrid Execution Model
- Identity-based Anonymization

Source: Abouelmehdi et al., Springer BigData 2018 Dec

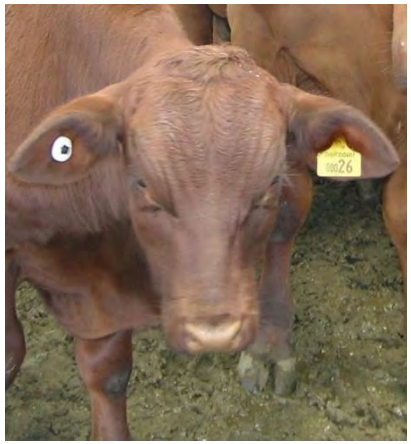
Smart Healthcare Data Integrity – Medical Signal Authentication

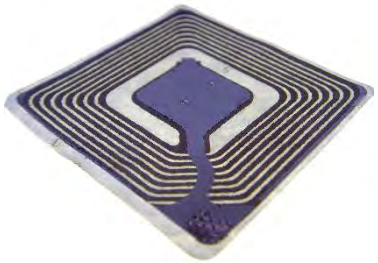
- Physiological signals like the electrocardiogram (EKG) are obtained from patients, transmitted to the cloud, and can also stored in a cloud repository.
- With increasing adoption of electronic medical records and cloud-based software-as-service (SaaS), advanced security measures are necessary.
- Protection from unauthorized access to Protected Health Information (PHI) also protects from identity theft schemes.
- From an economic stand-point, it is important to safeguard the healthcare and insurance system from fraudulent claims.



Source: Tseng 2014, Tseng Sensors Feb 2014

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

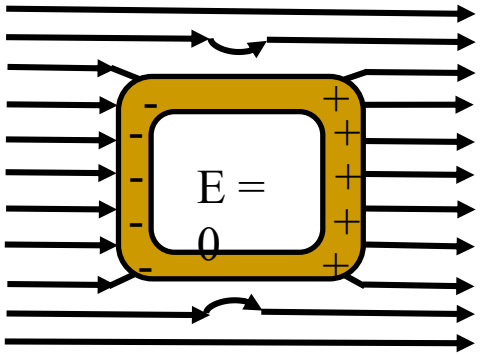
Source: Khattab 2017: Springer 2017 RFID Security

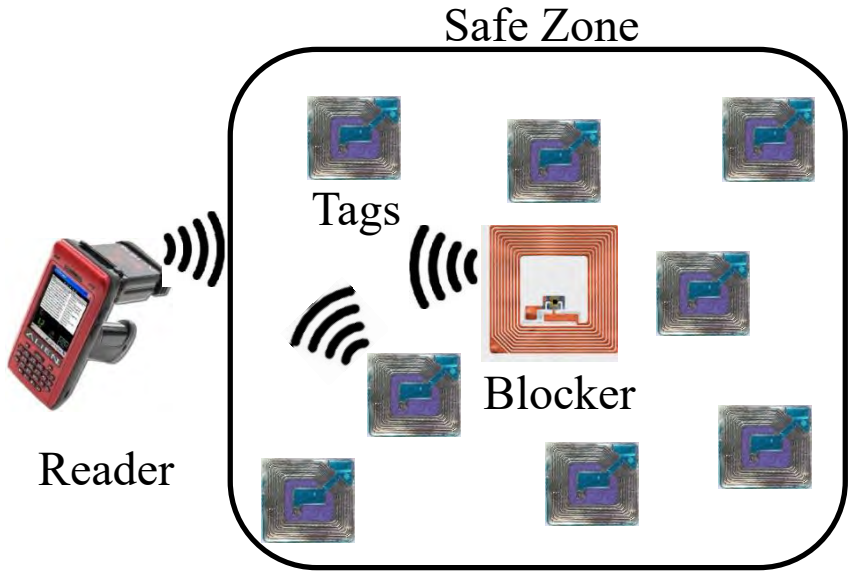
RFID Security - Solutions

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

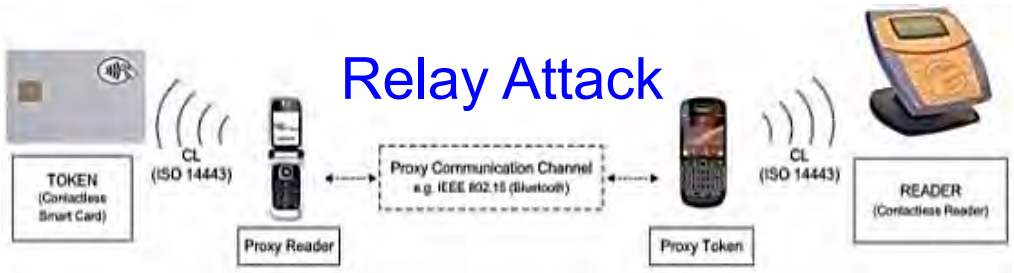
NFC Security - Attacks

- 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

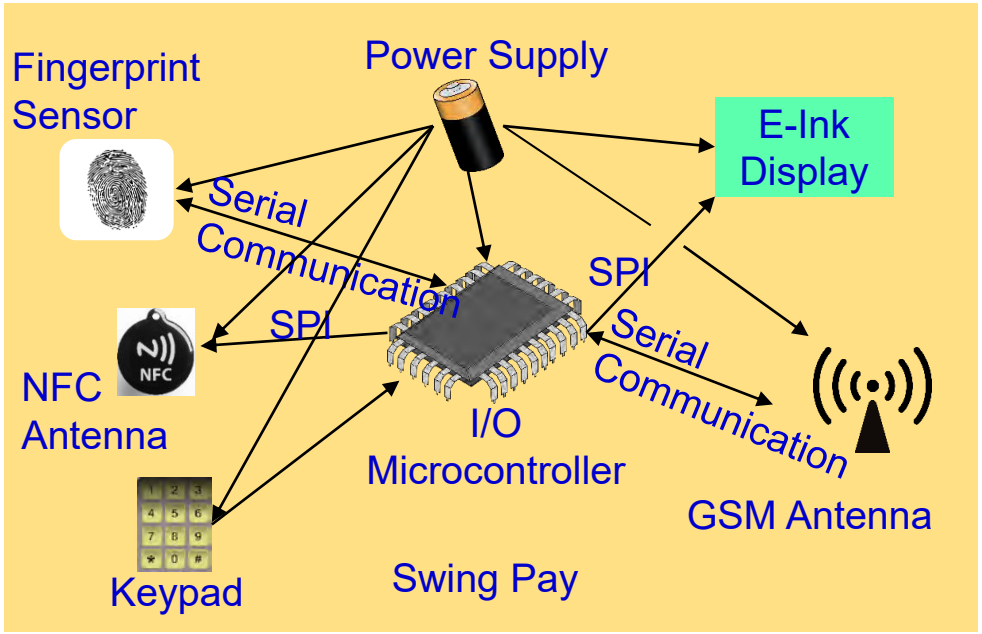
Eavesdropping

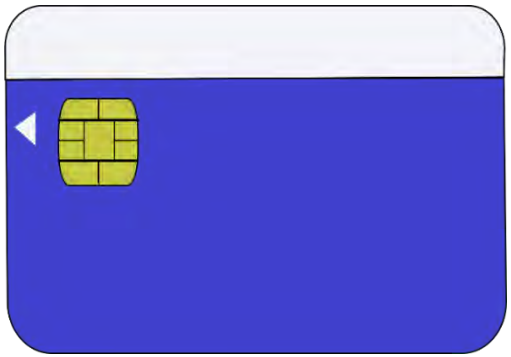
Source: http://resources.infosecinstitute.com/near-field-communication-nfc-technology-vulnerabilities-and-principal-attack-schema/

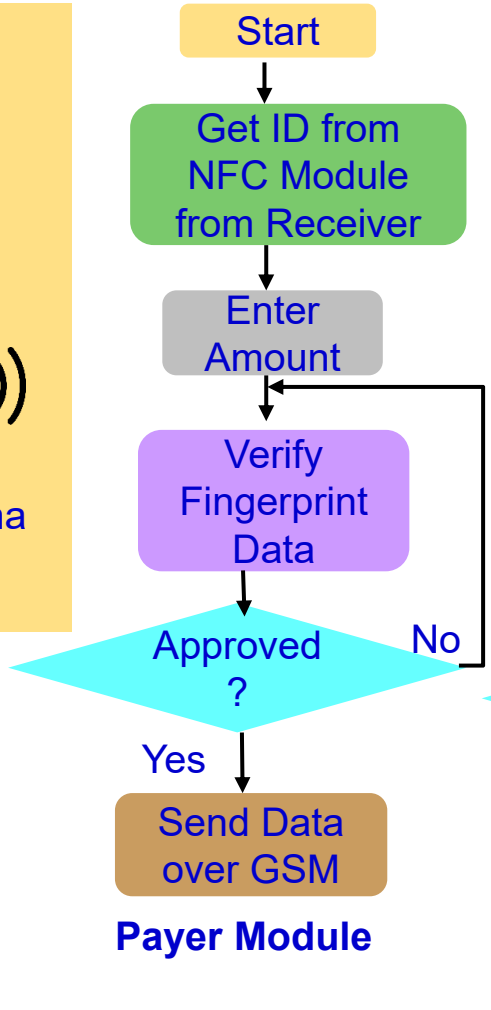


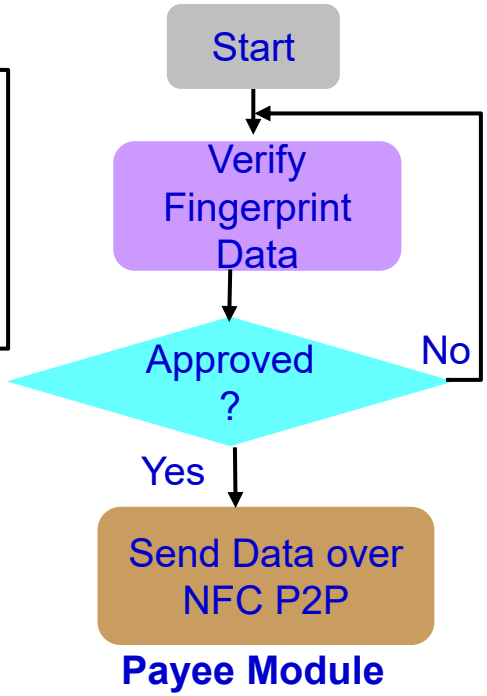
Source: https://www.slideshare.net/cgvwzq/on-relaying-nfc-payment-transactions-using-android-devices

NFC Security



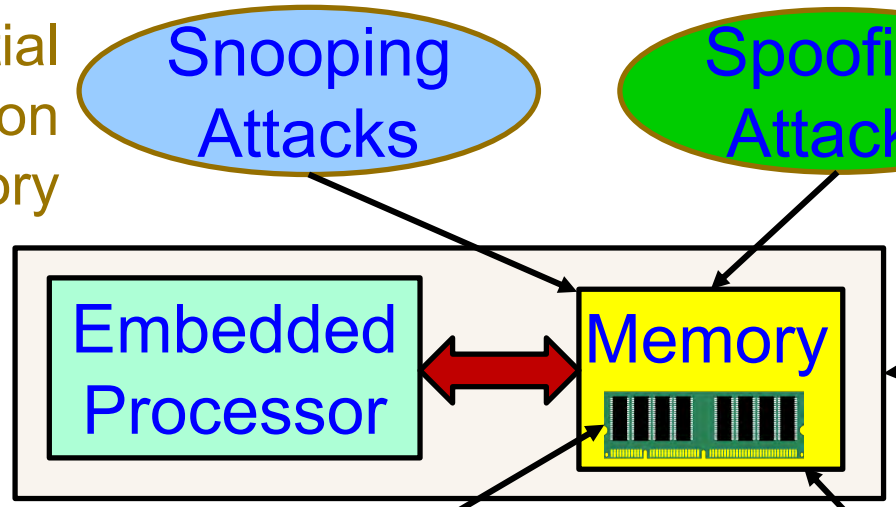






Source: Mohanty 2017, CE Magazine Jan 2017

Memory Attacks



Read confidential information in memory

Snooping Attacks

Spoofing Attacks

Replace a block with fake

Splicing Attacks

Replace a block with a block from another location

Physical access memory to retrieve encryption keys

Cold Boot Attacks

Replay Attacks

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

Source: Mohanty 2013, Springer CSSP Dec 2013

Nonvolatile Memory Security and Protection

Source: http://datalocker.com

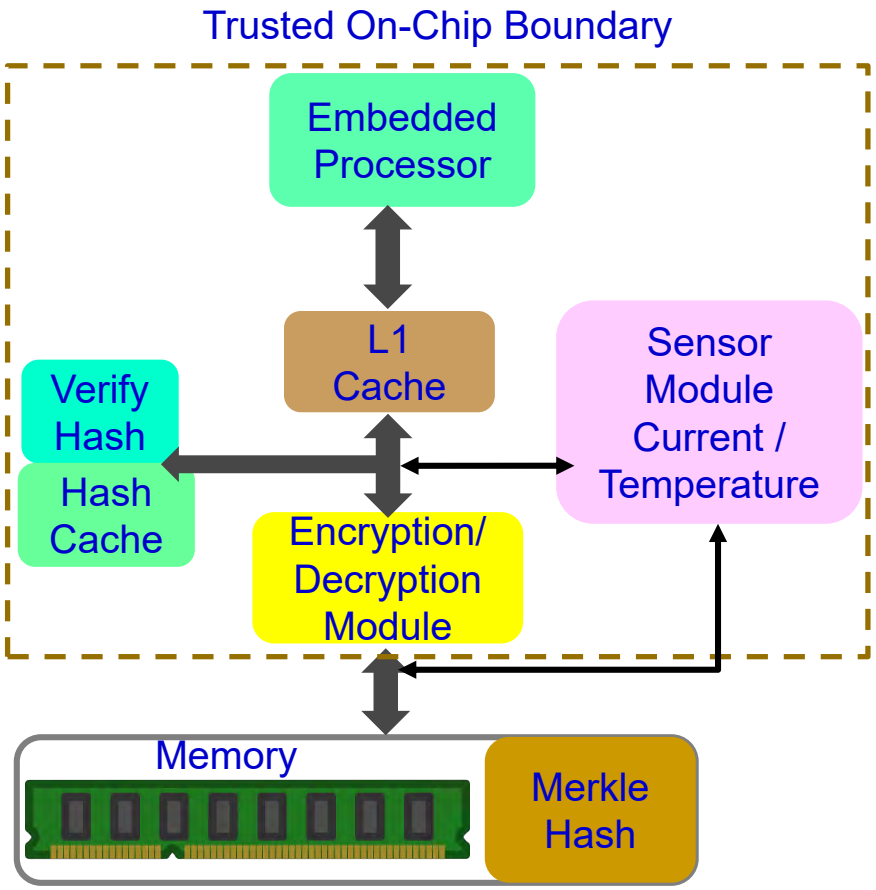
Hardware-based encryption of data secured/protected by strong password/PIN authentication.

Software-based encryption to secure systems and partitions of hard drive.

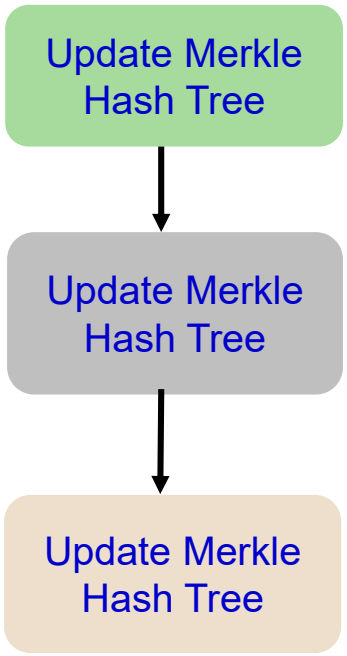
Nonvolatile / Harddrive Storage

Some performance penalty due to increase in latency!

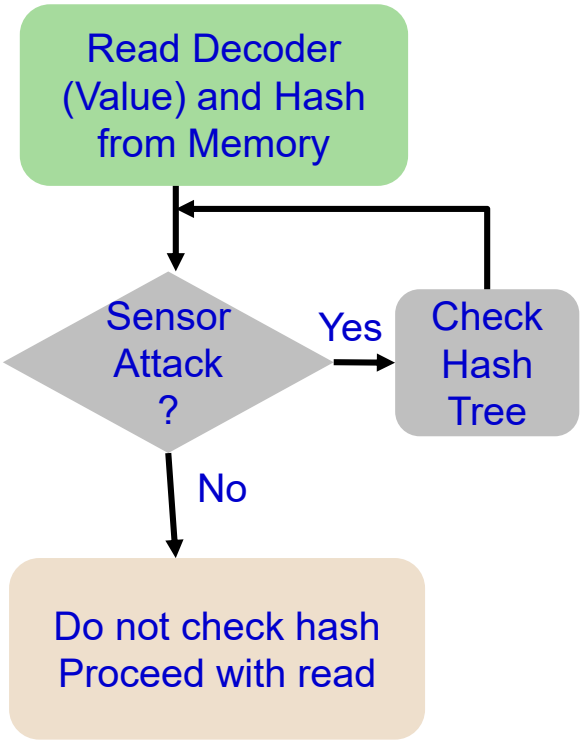
Embedded Memory Security and Protection



On-Chip/On-Board Memory Protection



Write Operation



Read Operation

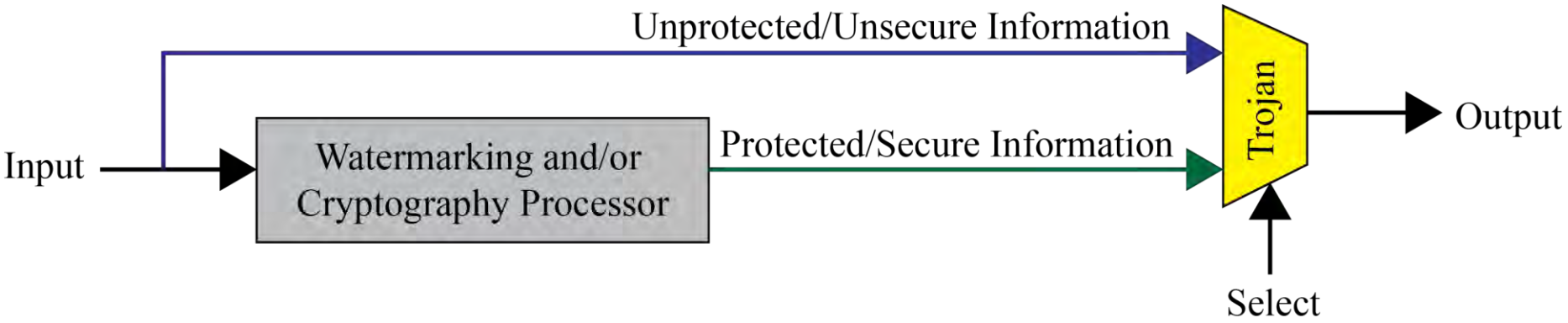
Some performance penalty due to increase in latency!

Source: Mohanty 2013, Springer CSSP Aug 2013

Malicious Design Modifications Issue

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

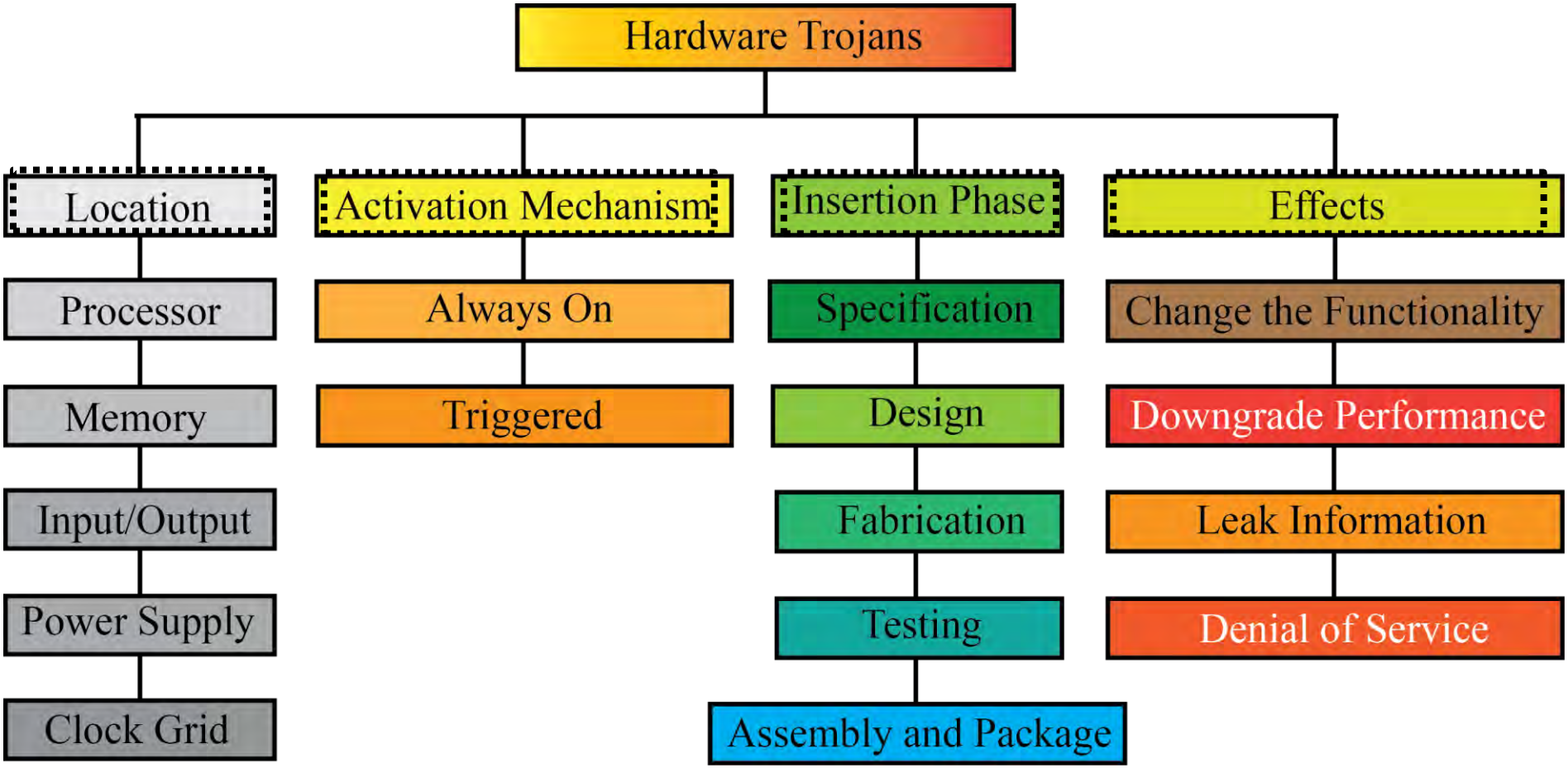
Hardware Trojans



Source: Mohanty 2015, McGraw-Hill 2015

Provide backdoor to adversary.
Chip fails during critical needs.

Different Types of Hardware Trojans



Source: Mohanty 2015, McGraw-Hill 2015

Trojan Secure Digital Hardware Synthesis

Architecture Module Library Comprising of Modules Info from Different Vendors

Datapath Resource configuration (R_n)

Vendor Allocation Type (A_v)

Unrolling Factor (U)

Trojan Detection Block

Dual Modular Redundant (DMR) Scheduling

Modified Allocation in DMR based on Distinct Vendor Rule

PSO-Driven Exploration for Optimizing Independent Factors Simultaneously

Optimizing Datapath Configuration

Optimizing Vendor Allocation Type

Optimizing Unrolling Factor

Binding

Cost Evaluation

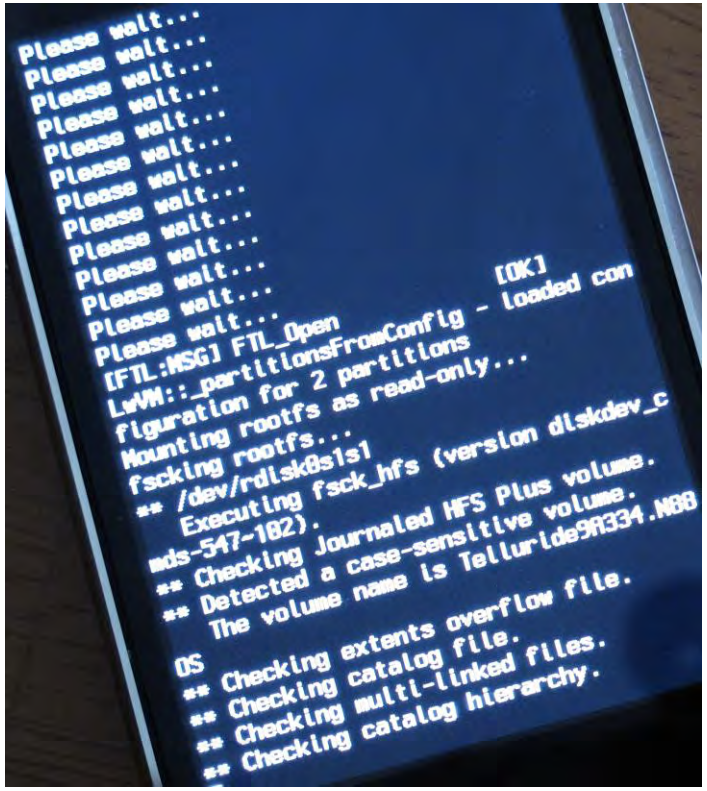
Provide backdoor to adversary. Chip fails during critical needs.

Low Cost Trojan Secured Datapath

Source: Sengupta, Mohanty 2017: TCAD April 2017

Firmware Reverse Engineering

Extract, modify, or reprogram code

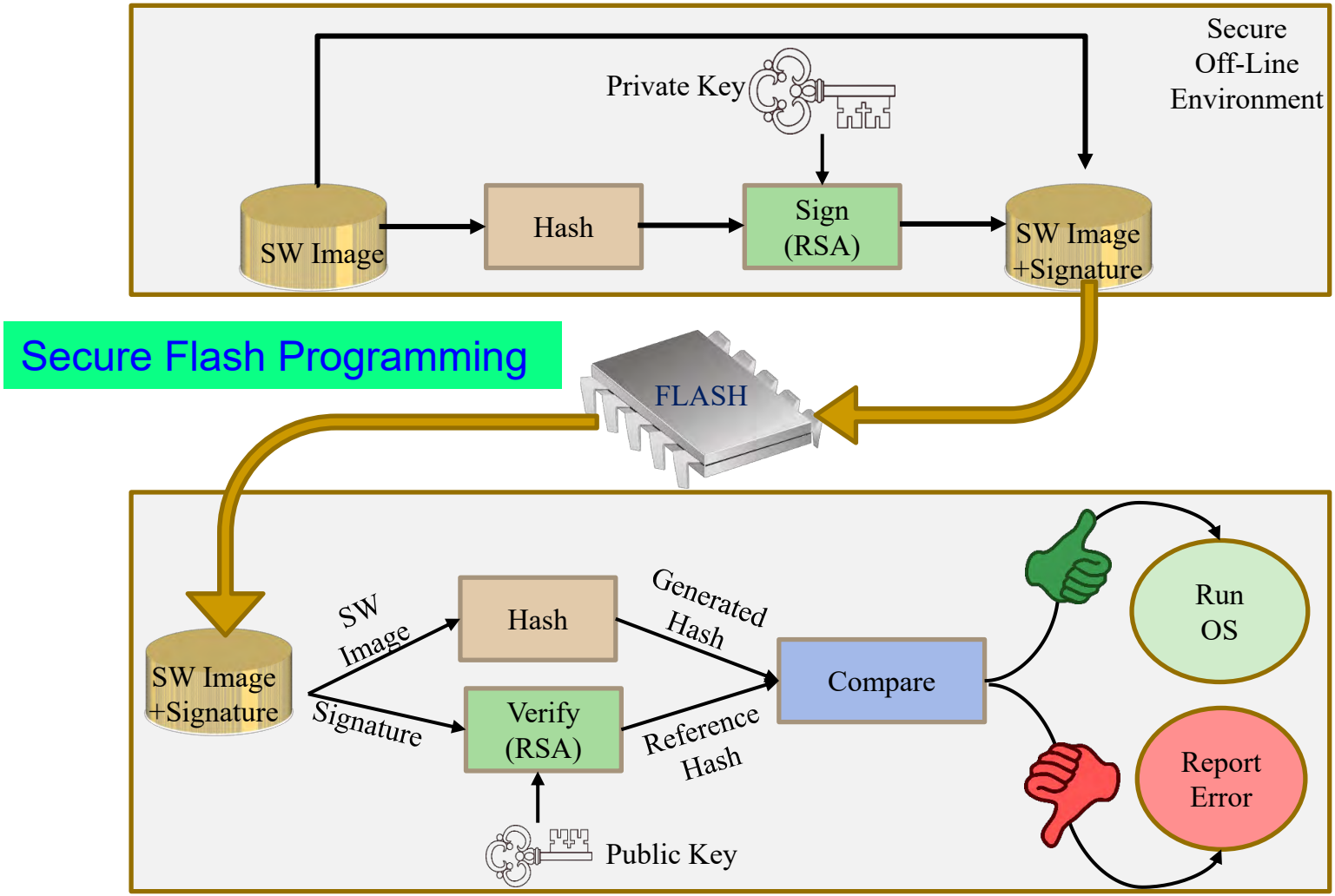


OS exploitation,
Device jailbreaking

Source: http://jcjc-dev.com/

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

Smart Car - Firmware Security



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

How Secure is AES Encryption?

- Brute force a 128 bit key ?
- If we assume:
  - Every person on the planet owns 10 computers
  - Each of these computers can test 1 billion key combinations per second
  - There are 7 billion people on the planet
  - On average, we can crack the key after testing 50% of the possibilities
  - Then the earth's population can crack one 128 bit encryption key in 77,000,000,000 years (77 billion years)

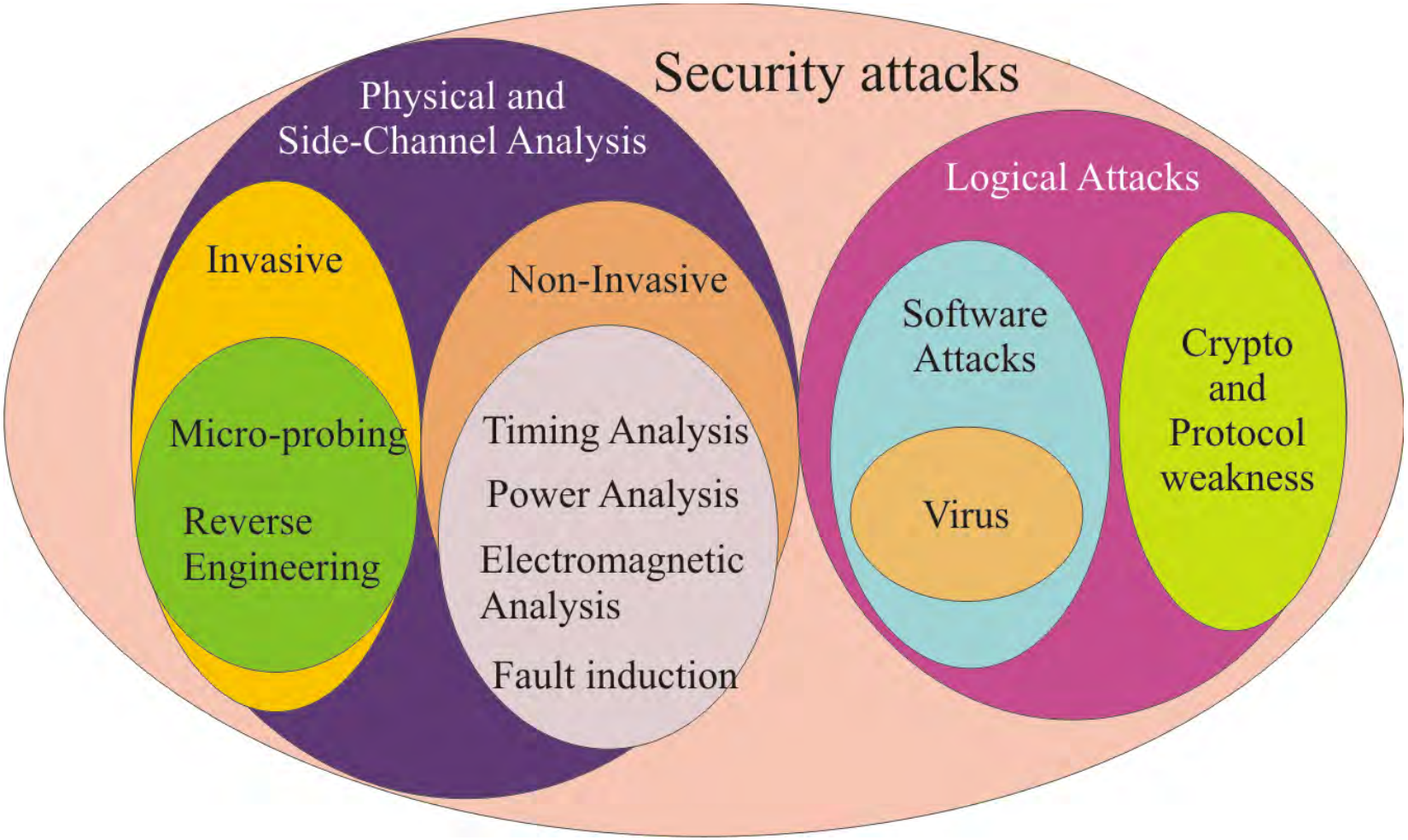
Encryptions ←→ Security

Age of the Earth 4.54 ± 0.05 billion years

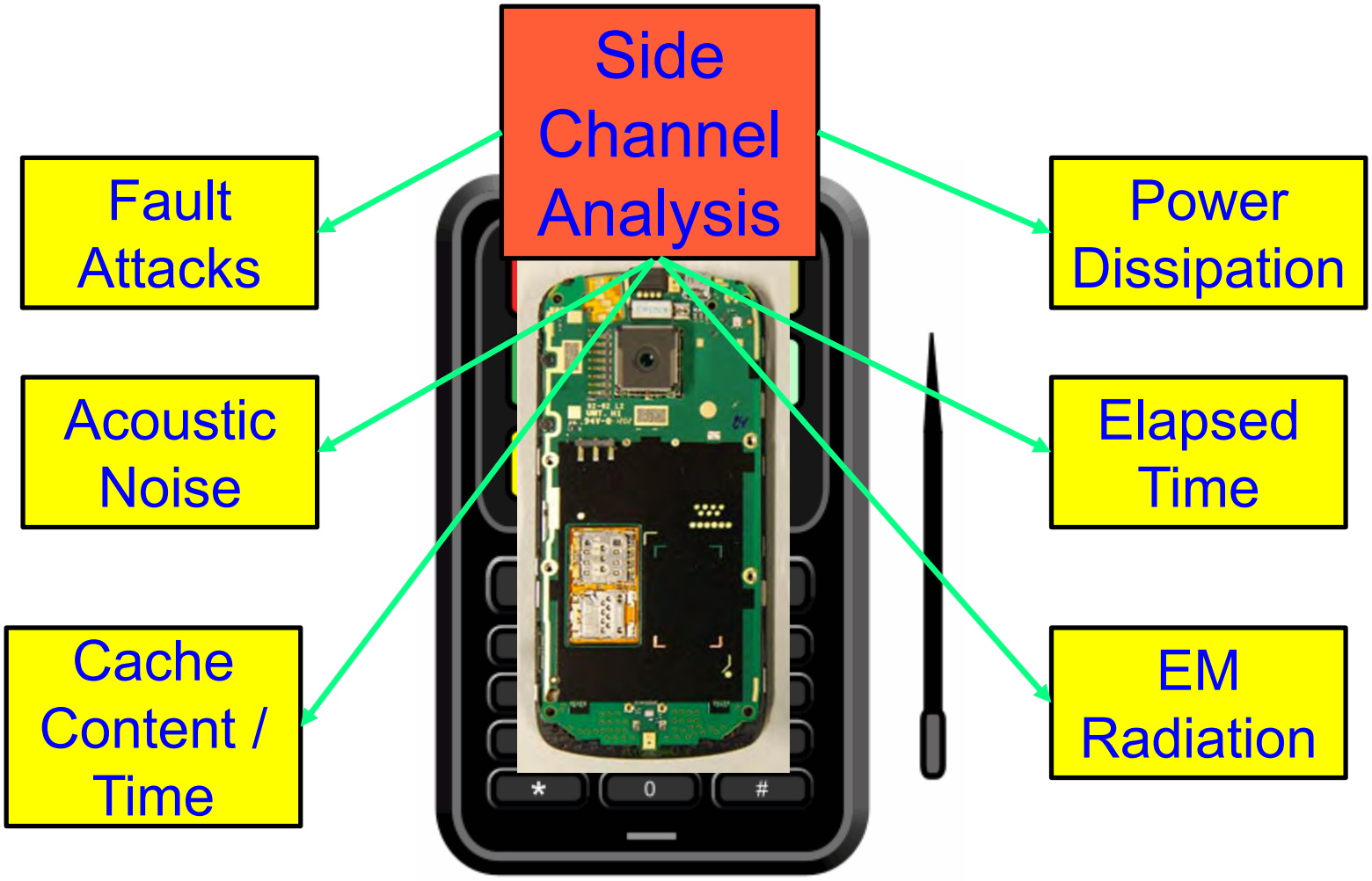
Age of the Universe 13.799 ± 0.021 billion years

Source: Parameswaran Keynote iNIS-2017

Different Attacks on a Typical CE System



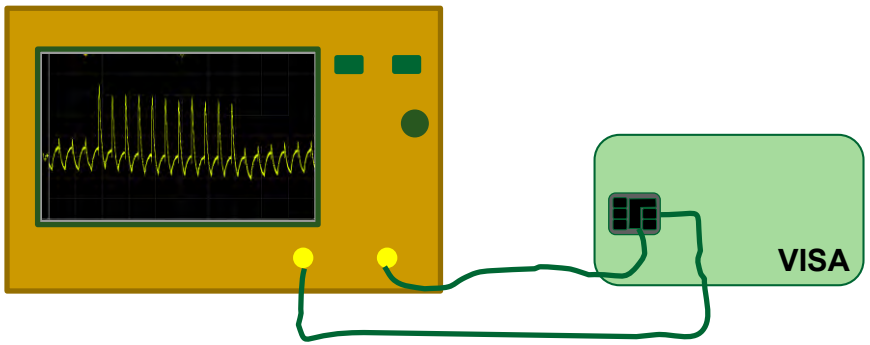
Side Channel Analysis Attacks



Source: Parameswaran Keynote iNIS-2017

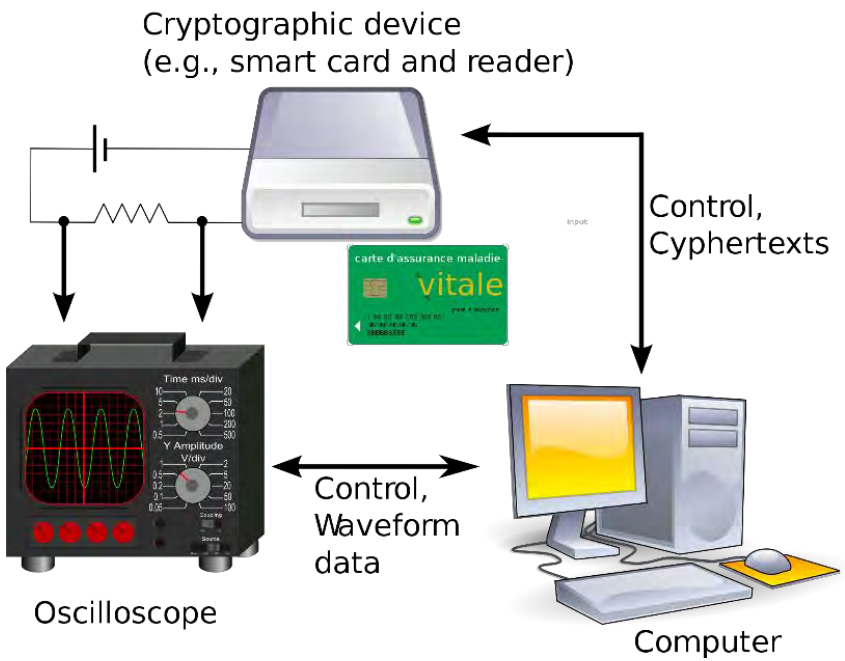
Power Analysis Attacks

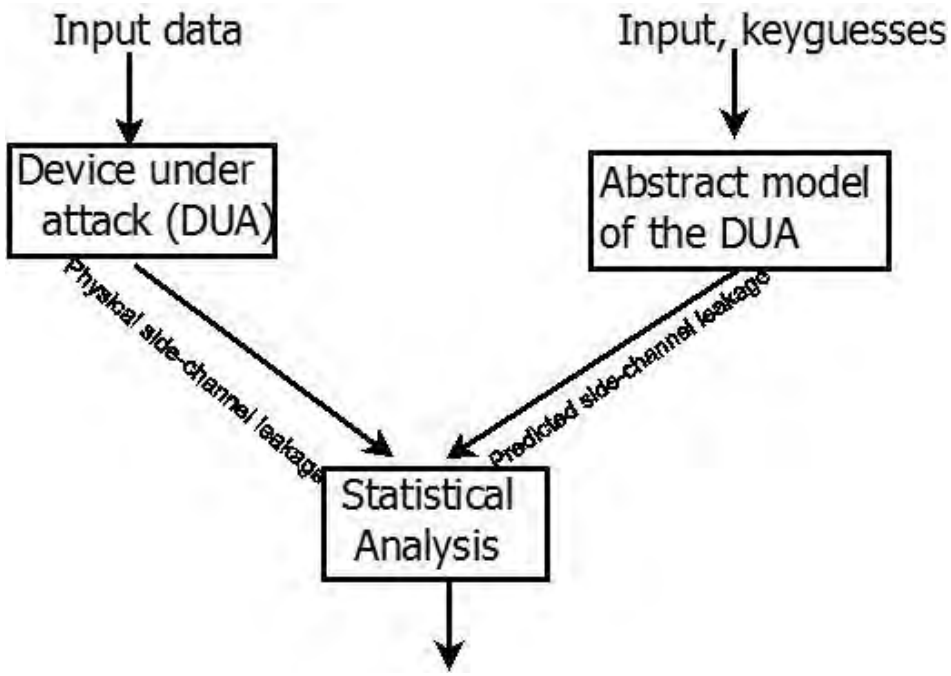
- Revealing the secret information via the power dissipation of the device
- Why?
  - CMOS gates are the most popular building blocks of IC manufacturing
  - Power dissipation of CMOS gates depend on inputs
  - The power consumption of a 0-1 transition is different to a 1-0 transition



Source: Parameswaran Keynote iNIS-2017

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





Decision on key guess

Side Channel Attacks - Correlation Power Analysis (CPA)

- CPA analyzes the correlative relationship between the plaintext/ cipher-text and instantaneous power consumption of the cryptographic device.
- CPA is a more effective attacking method compared with DPA.

Differential Power Analysis (DPA)

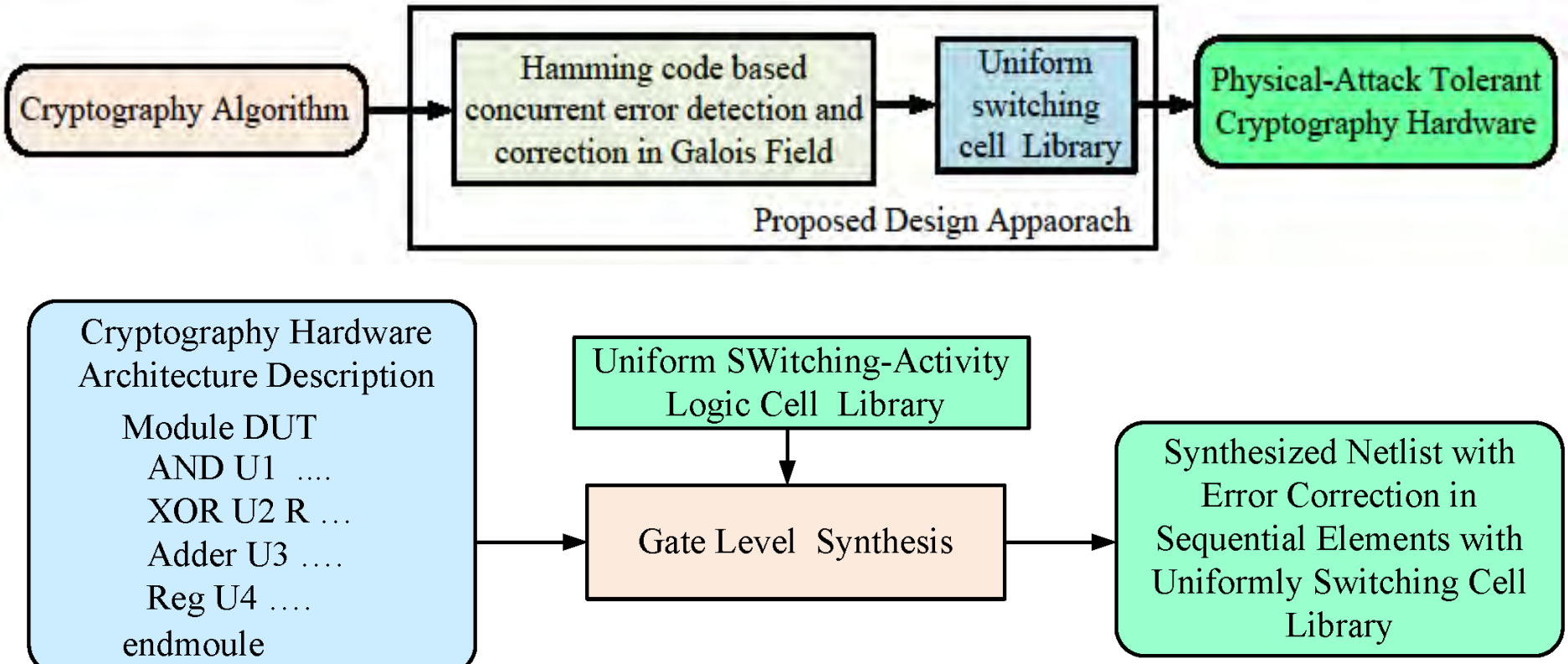
- Attacks using relationship between data and power.
- Looks at difference of category averages for all key guess.
- Requires more power traces than CPA.
- Slower and less efficient than CPA.

Correlation Power Analysis (CPA)

- Attacks using relationship between data and power.
- Looks at correlation between all key guesses.
- Requires less power traces than DPA.
- Faster, more accurate than DPA.

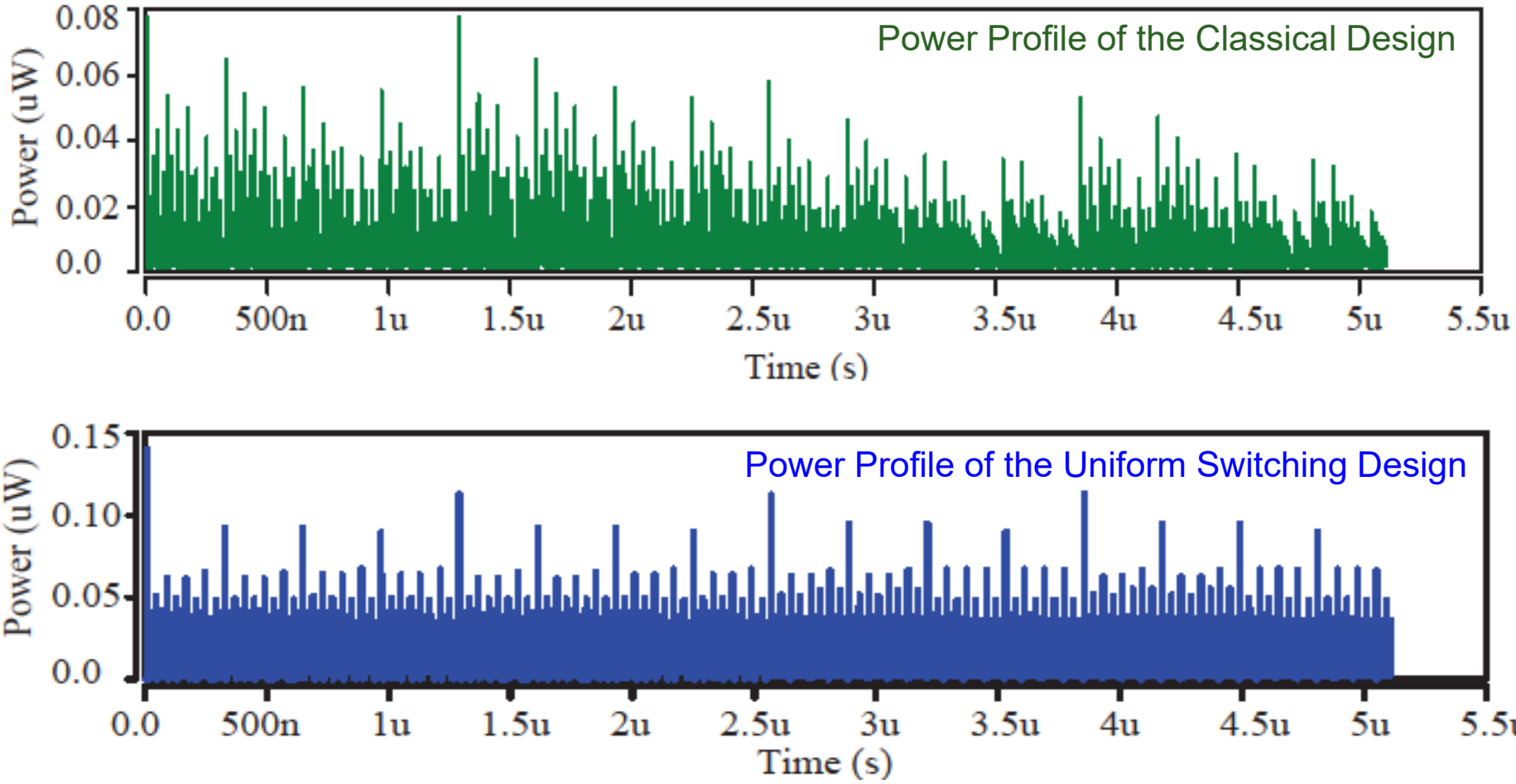
Source: Zhang and Shi ITNG 2011

DPA Resilience Hardware: Synthesis Flow



Source: Mohanty 2013, Elsevier CEE 2013.

DPA Resilience Hardware



Source: Mohanty 2013, Elsevier CEE 2013.

Copyright, Intellectual Property (IP), Or Ownership Protection

Media Ownership

Hacker

Image, Video, Audio

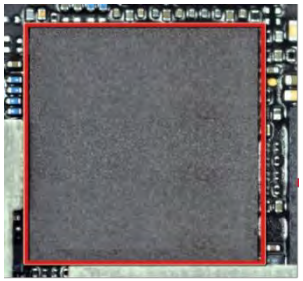
Multimedia Object

Owner

- Whose is it?
- Is it tampered with?
- Where was it created?
- Who had created it?
- ... and more.

Researcher

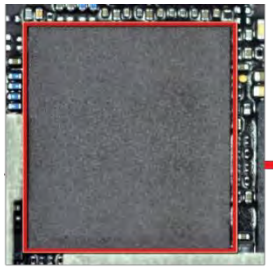
Hardware Ownership



Chip at Original Design House

IP cores or reusable cores are used as a cost effective SoC solution but sharing poses a security and ownership issues.

Goes to Another Design House for Resuse



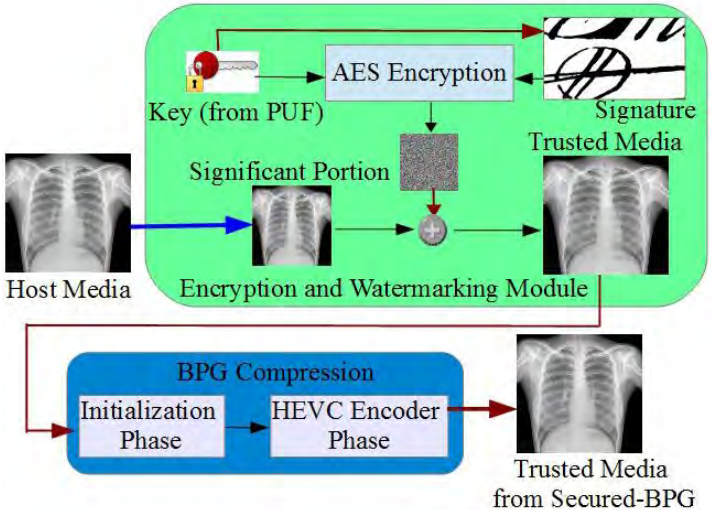
Chip at Another Design House

? Who Owns ?

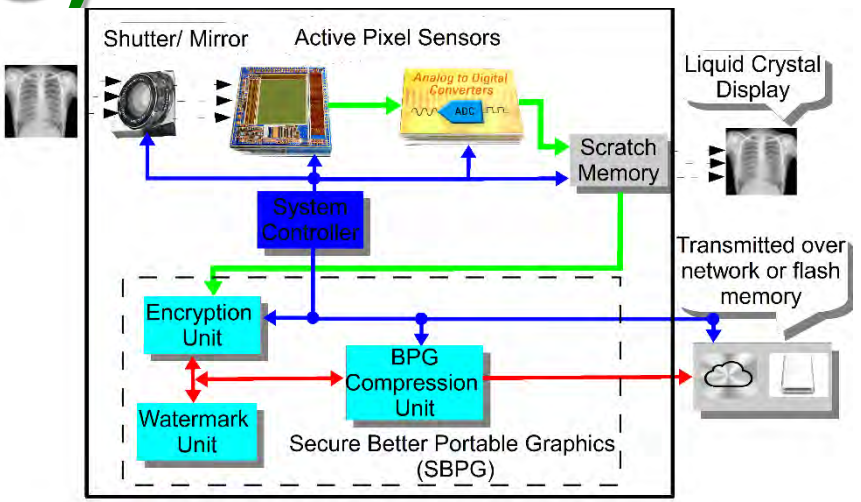
Company A

Company B

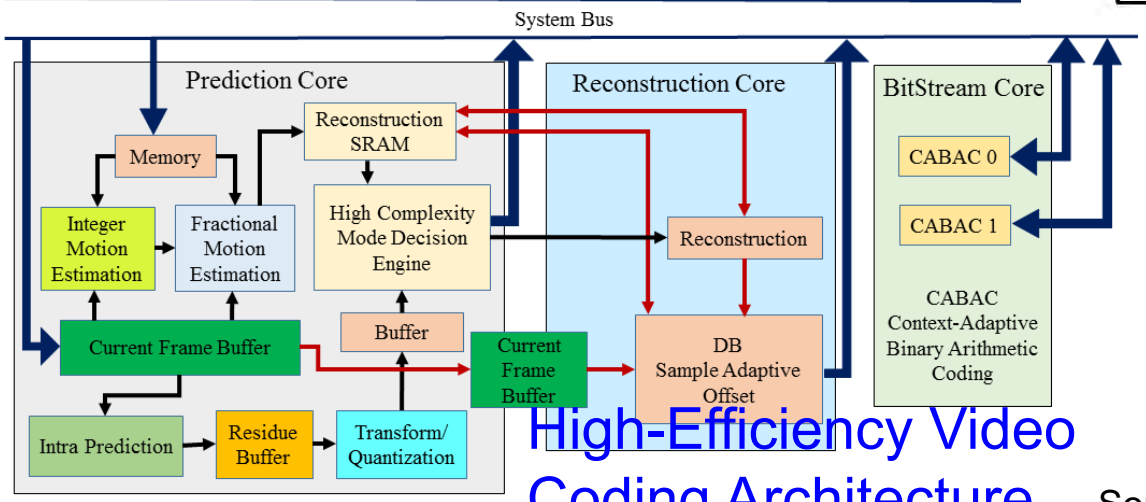
Secure Better Portable Graphics (SBPG)



Secure BPG (SBPG)



Secure Digital Camera (SDC) with SBPG

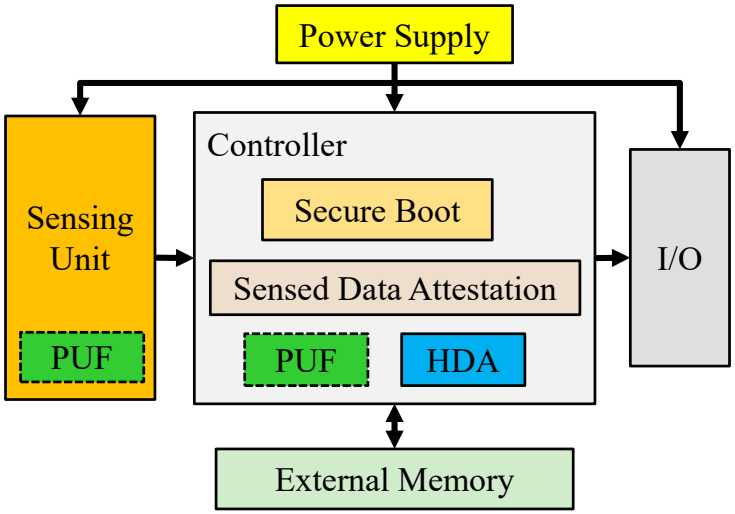


High-Efficiency Video Coding Architecture

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

Source: Mohanty 2018, IEEE-Access 2018

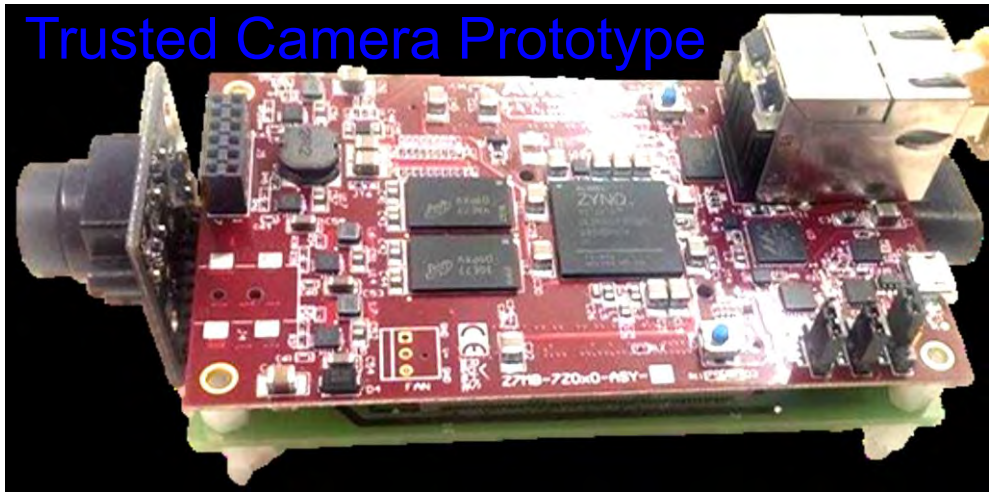
PUF-based Trusted Sensor



PUF-based Trusted Sensor

PUF-based Secure Key Generation and Storage module provides key:

- Sensed data attestation to ensure integrity and authenticity.
- Secure boot of sensor controller to ensure integrity of the platform at booting.

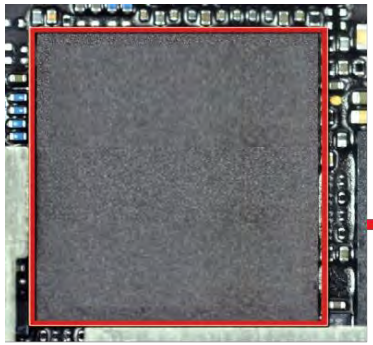


Source: https://pervasive.aau.at/BR/pubs/2016/Haider_IOTPTS2016.pdf

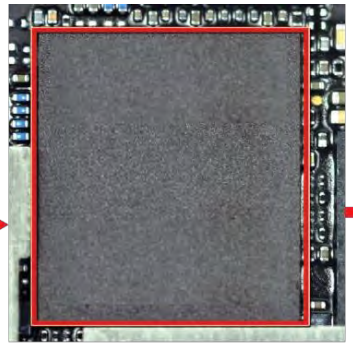
- On board SRAM of Xilinx Zynq7010 SoC cannot be used as a PUF.
- A total 1344 number of 3-stage Ring Oscillators were implemented using the Hard Macro utility of Xilinx ISE.

Process Speed: 15 fps
Key Length: 128 bit

Hardware IP Right Infringement



Goes to Another Design House for Resuse



Chip at Original Design House

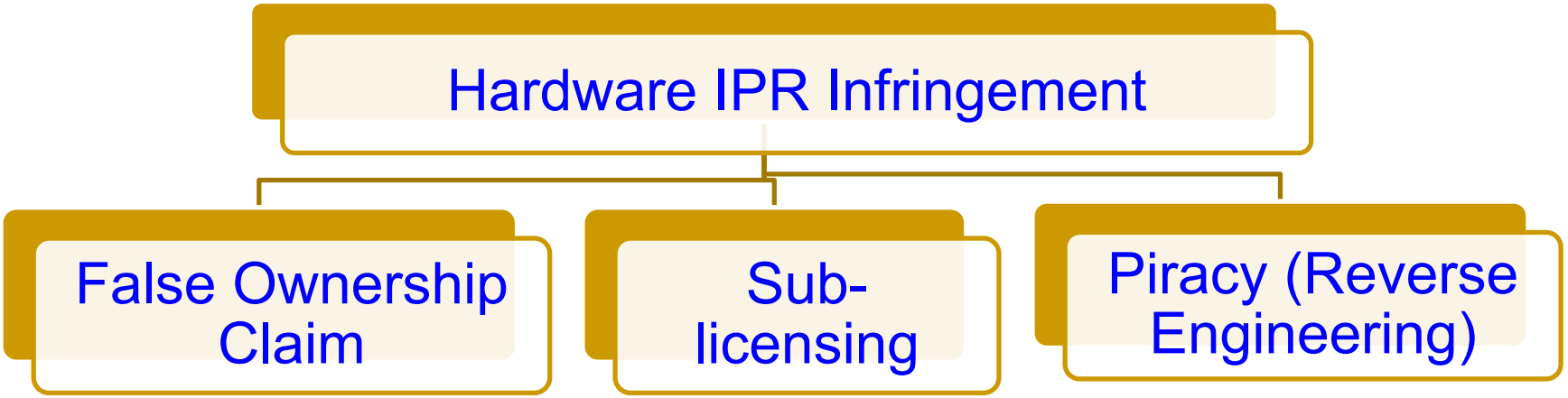
Chip at Another Design House

? Who Owns ?

Company A

Company B

Source: Mohanty 2015, McGraw-Hill 2015



Cloned/Fake Electronics Hardware – Example - 1

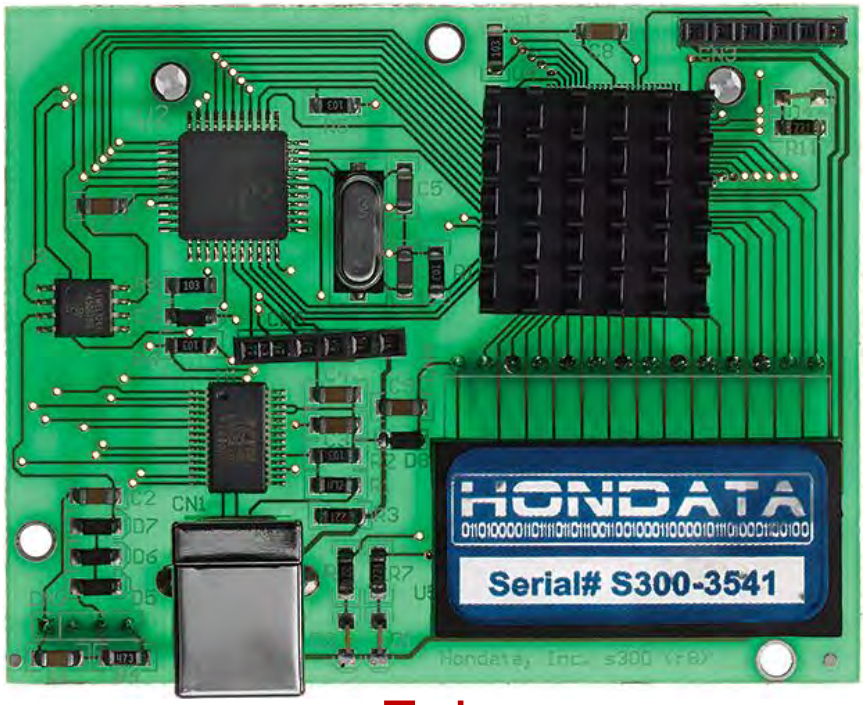
Source: https://petapixel.com/2015/08/14/i-bought-a-fake-nikon-dslr-my-experience-with-gray-market-imports/

Source: http://www.manoramaonline.com/

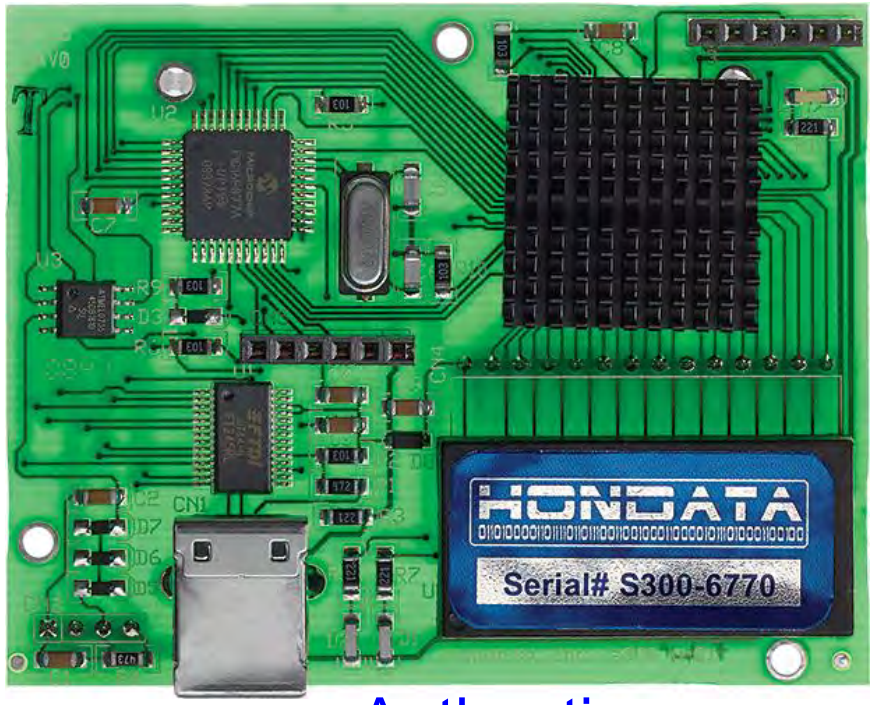
Source: http://www.cbs.cc/fake-capacity-usb-drives/

Typical Consumer Electronics

Cloned/Fake Electronics Hardware – Example - 2



Fake



Authentic

A plug-in for car-engine computers.

Source: http://spectrum.ieee.org/computing/hardware/invasion-of-the-hardware-snatchers-cloned-electronics-pollute-the-market

Cloned/Fake Electronics Hardware – Example - 3

Fake

Authentic

A typical rechargeable battery in a CE system.

Source: https://www.premiumbeat.com/blog/how-to-spot-counterfeit-camera-gear/

Cloned/Fake/Counterfeit Electronics

- Consumer Electronics is the 2nd most counterfeit product in USA.
- Between November 2007 and May 2010, U.S. Customs officials seized 5.6 million counterfeit microprocessors.
- The market value of the 2016 seized counterfeit goods, had they been genuine, amounted to $1.4 billion.

Source: https://www.scientificamerican.com/article/electronic-chip-counterfeit-china/
Source: http://247wallst.com/special-report/2017/04/29/10-most-counterfeited-products-in-america/

Cloned/Fake Electronics Hardware - What is the Problem? It is cheaper!

- Installing cloned hardware into networks can open door to hackers: man-in-the-middle attacks or secretly alter a secure communication path between two systems to bypass security mechanisms.
- Cloned hardware may lack the security modules intended to protect IoT devices, and so it opens up the user to cyberattack.
- If a hacker embeds a malicious hardware in a drone then he could shut it down or retarget it when it reached preset GPS coordinates.

Source: https://www.scientificamerican.com/article/electronic-chip-counterfeit-china/

Source: http://spectrum.ieee.org/computing/hardware/invasion-of-the-hardware-snatchers-cloned-electronics-pollute-the-market

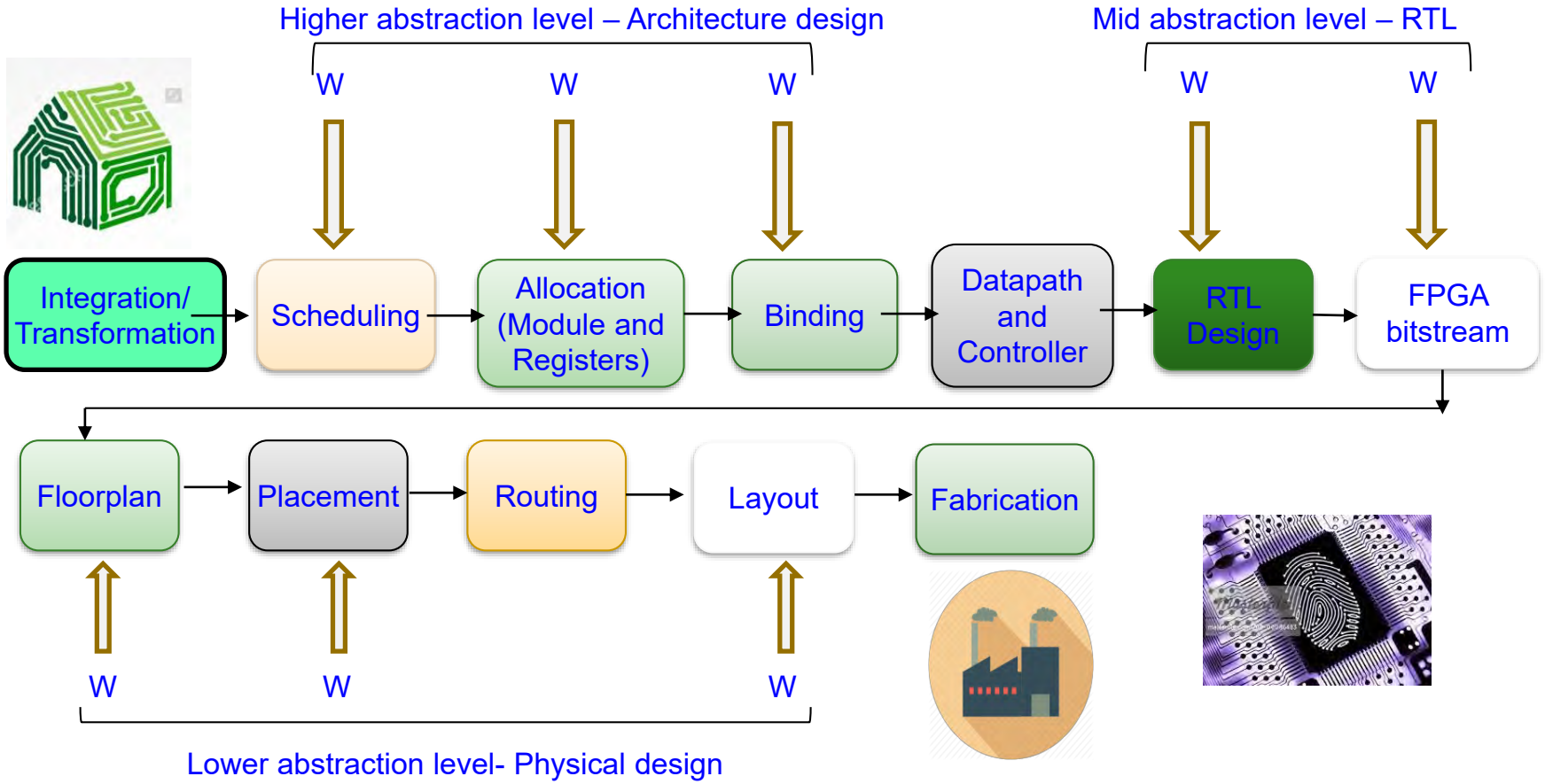
Cloned/Fake Electronics Hardware - What is the Problem? It is cheaper!

- Counterfeit battery can cause safety hazards.
- Counterfeit electronics embedded in missile guidance systems and aircrafts can have serious problems for the defense systems.
- According to the International AntiCounterfeiting Coalition, lost profits due to counterfeiting has resulted in the loss of more than 750,000 jobs in the United States.

Source: https://www.scientificamerican.com/article/electronic-chip-counterfeit-china/

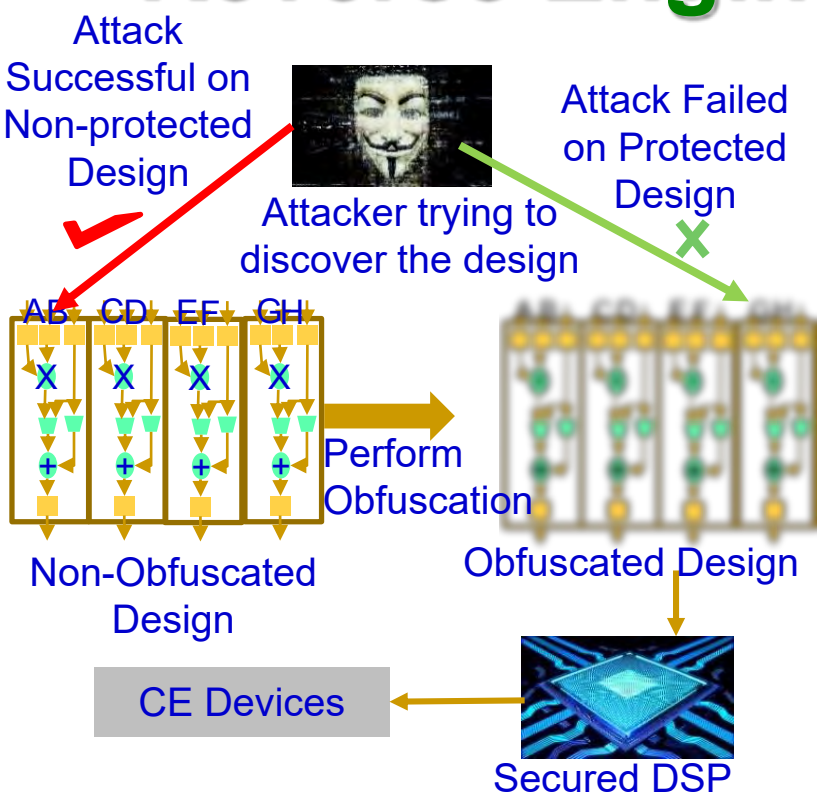
Source: http://spectrum.ieee.org/computing/hardware/invasion-of-the-hardware-snatchers-cloned-electronics-pollute-the-market

Digital Hardware - Watermark

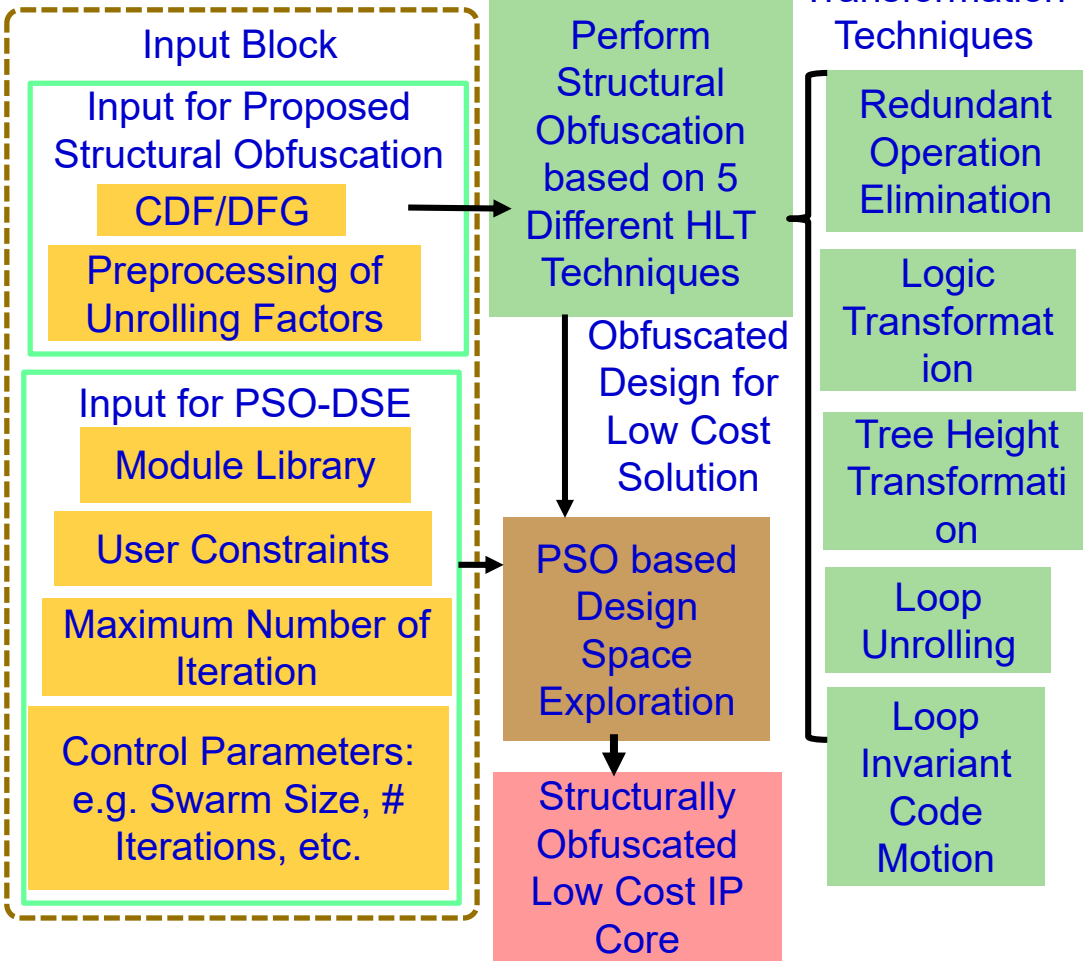


Source: Mohanty 2017: CE Magazine October 2017

Digital Hardware Synthesis to Prevent Reverse Engineering - Obfuscation



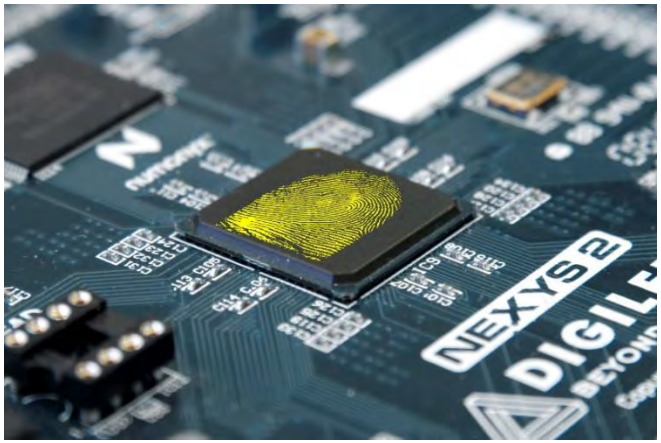
Obfuscation – Intentional modification of the description or the structure of electronic hardware to conceal its functionality for making reverse-engineering difficult.



Source: Sengupta, Mohanty 2017, TCE November 2017

Protecting Hardware using PUF

- A countermeasure against electronics cloning is a physical unclonable function (PUF).
- It can potentially protect chips, PCBs, and even high-level products like routers.
- PUFs give each chip a unique "fingerprint."



Source: https://phys.org/news/2011-02-fingerprint-chips-counterfeit-proof.html

An on-chip measuring circuit (e.g. a ring oscillator) can generate a characteristic clock signal which allows the chip's precise material properties to be determined. Special electronic circuits then read these measurement data and generate the component-specific key from the data.

Source: http://spectrum.ieee.org/computing/hardware/invasion-of-the-hardware-snatchers-cloned-electronics-pollute-the-market

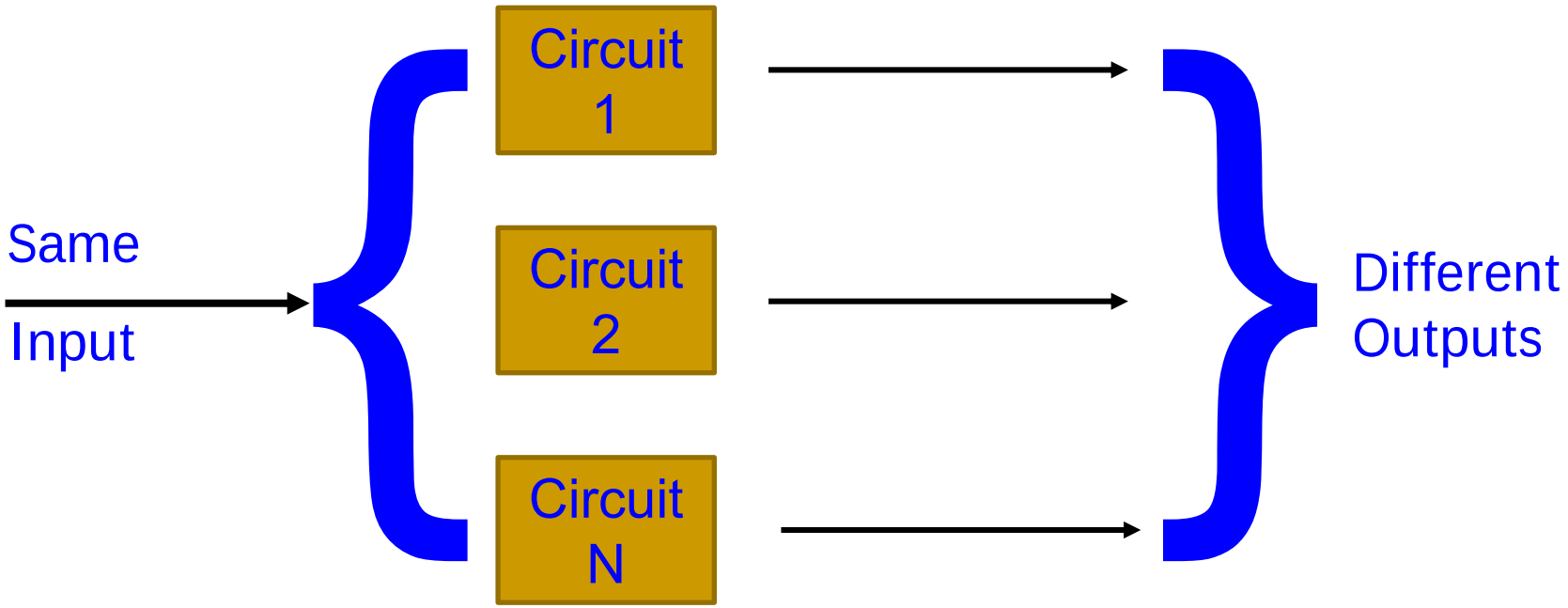
Physical Unclonable Function (PUF)

- Physical Unclonable Functions are simple primitives for security.
- PUFs are easy to build and impossible to duplicate (Theoretically).
- Input and Output are called Challenge Response Pair (CRP).

Only an authentic hardware can produce a correct Response for a Challenge.

Source: Mohanty 2017, Springer ALOG Dec 2017

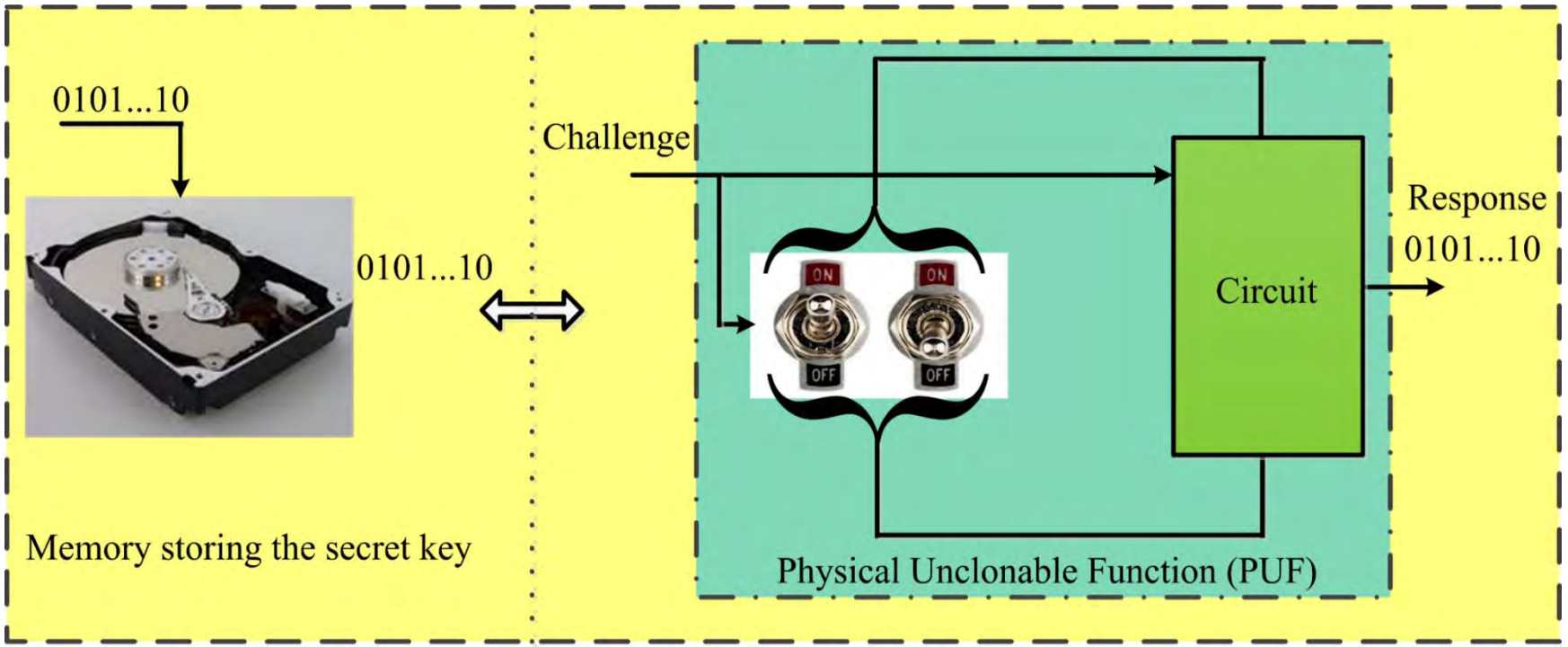
PUF – Principle …



- With the same input to different copies of the same circuit, different outputs are obtained, each unique to each circuit.

Source: http://rijndael.ece.vt.edu/puf/background.html

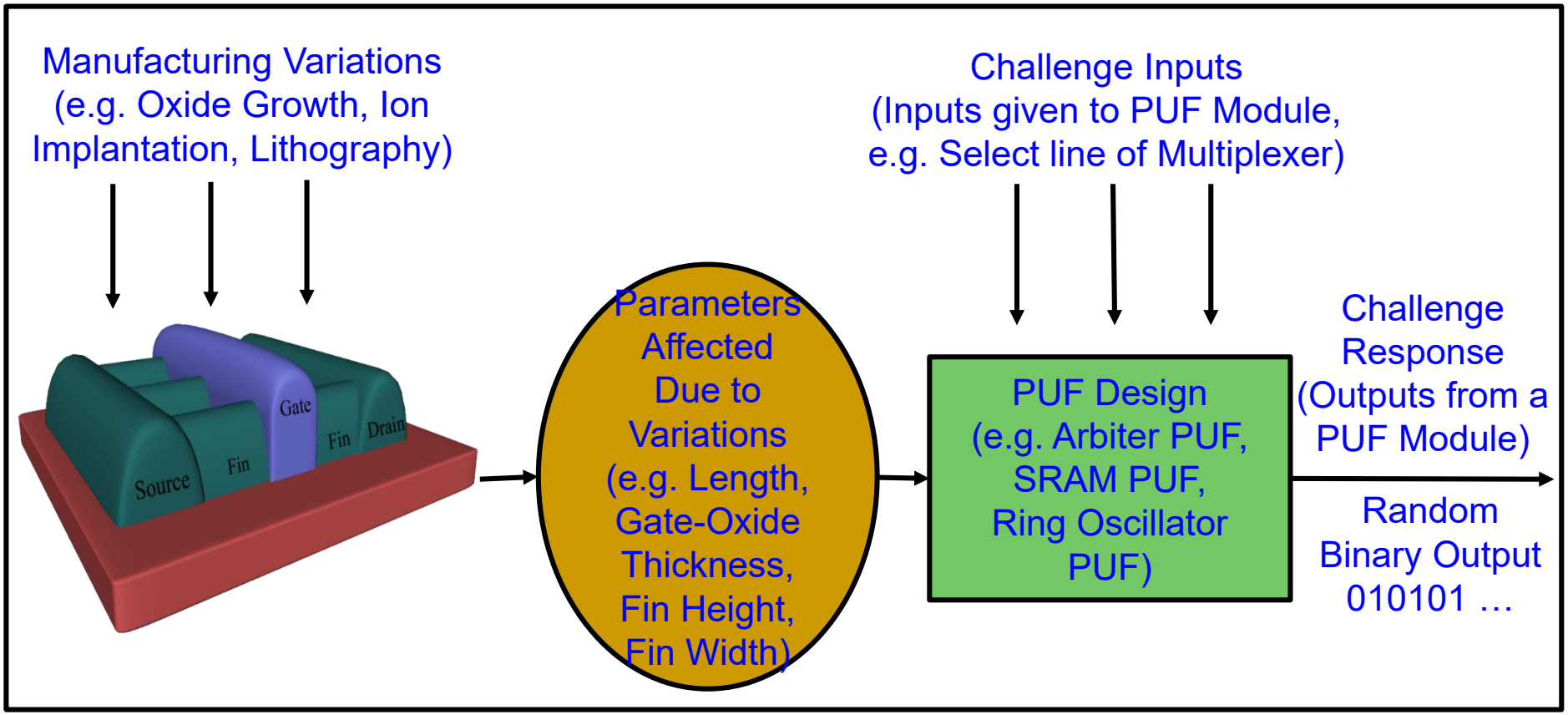
PUF – Principle …



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

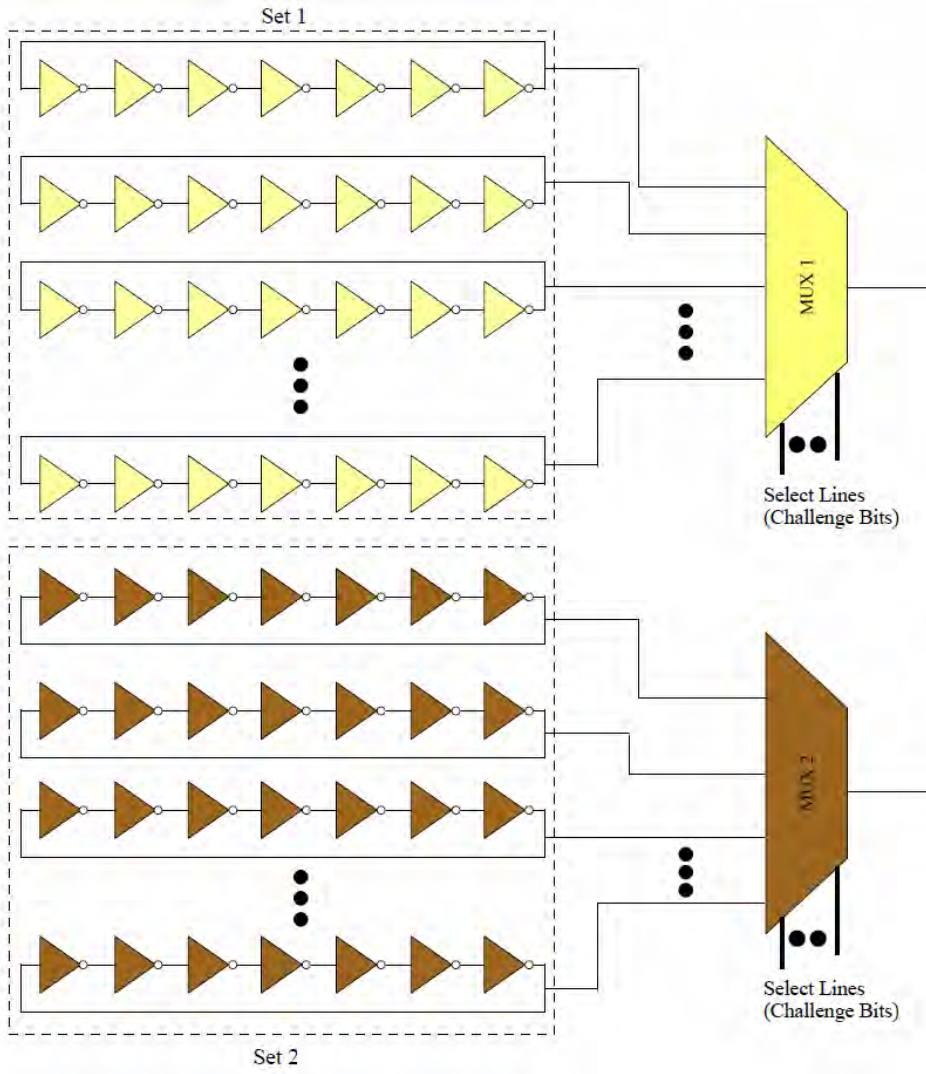
PUF - Principle

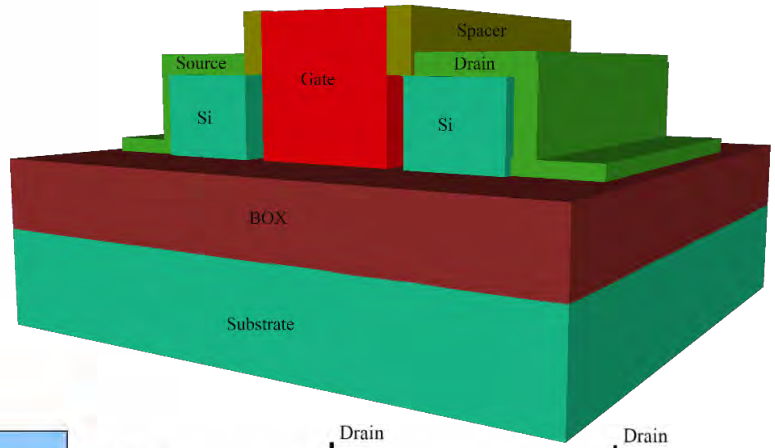


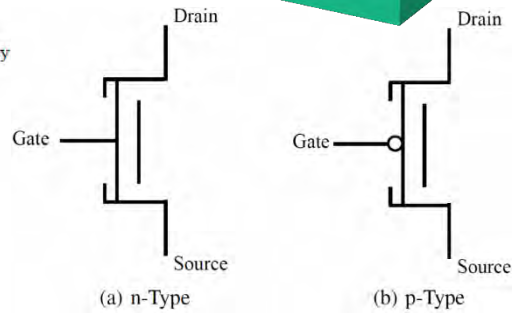
Silicon manufacturing process variations are turned into a feature rather than a problem.

Source: Mohanty 2017, Springer ALOG 2017

Power Optimized Hybrid Oscillator Arbiter PUF





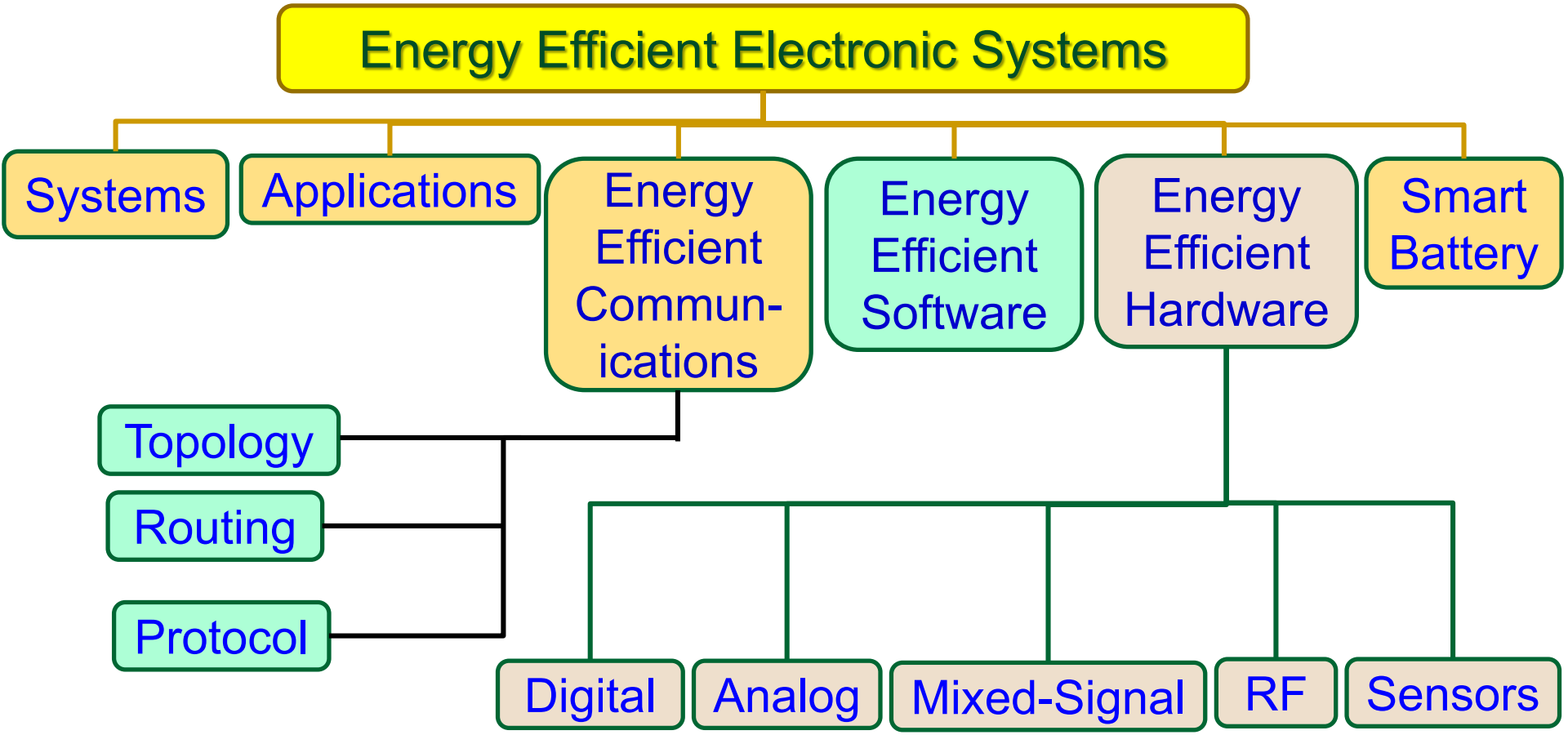


Characteristics	FinFET Technology	DLFET Technology
Average Power	219.34 μW	121.3 μW
Hamming Distance	49.3 %	48 %
Time to generate key	150 ns	150 ns

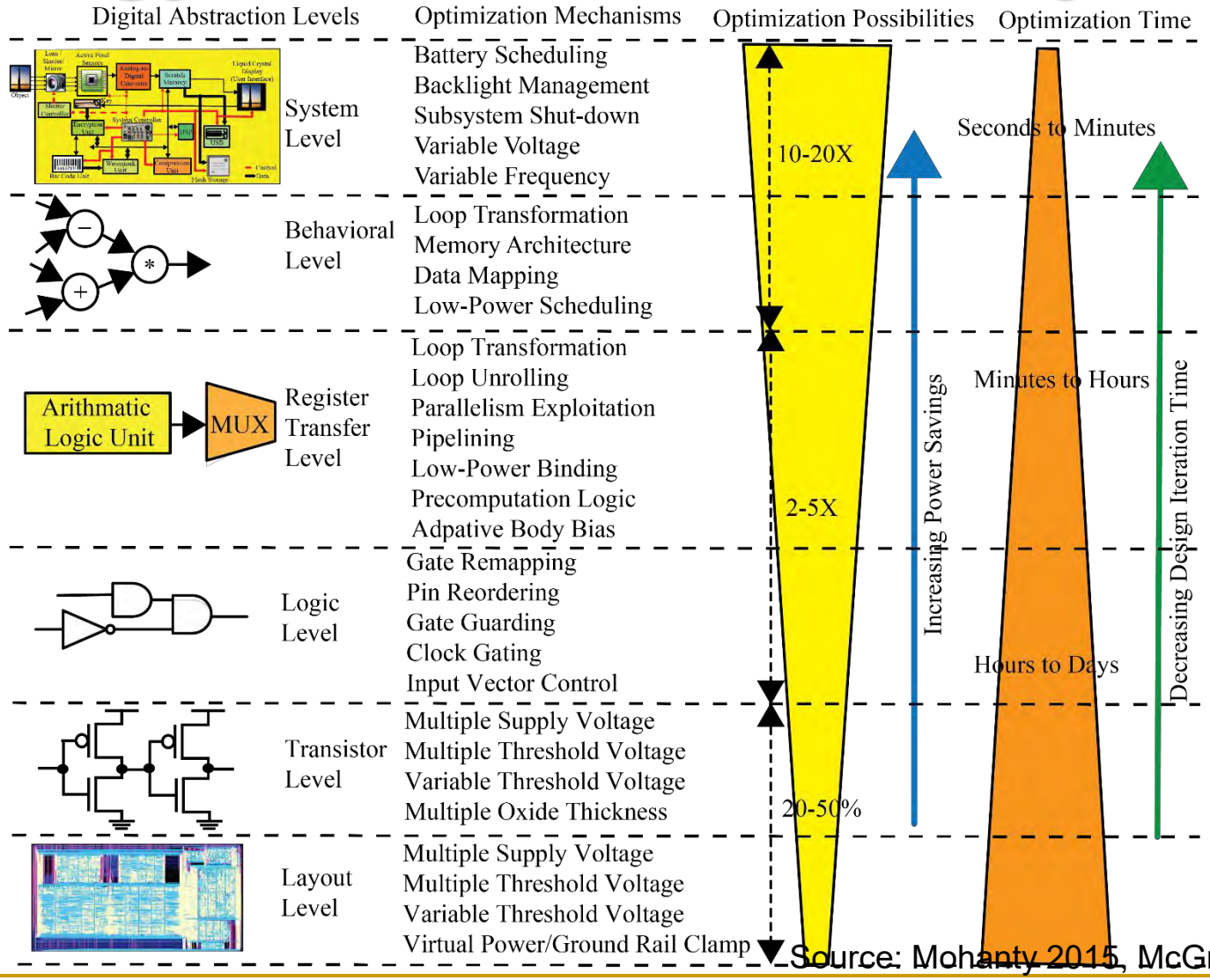
Source: Mohanty 2018, TSM May 2018

Addressing Energy Constraints in CE

Energy Efficient Electronic Systems: Possible Solution Fronts

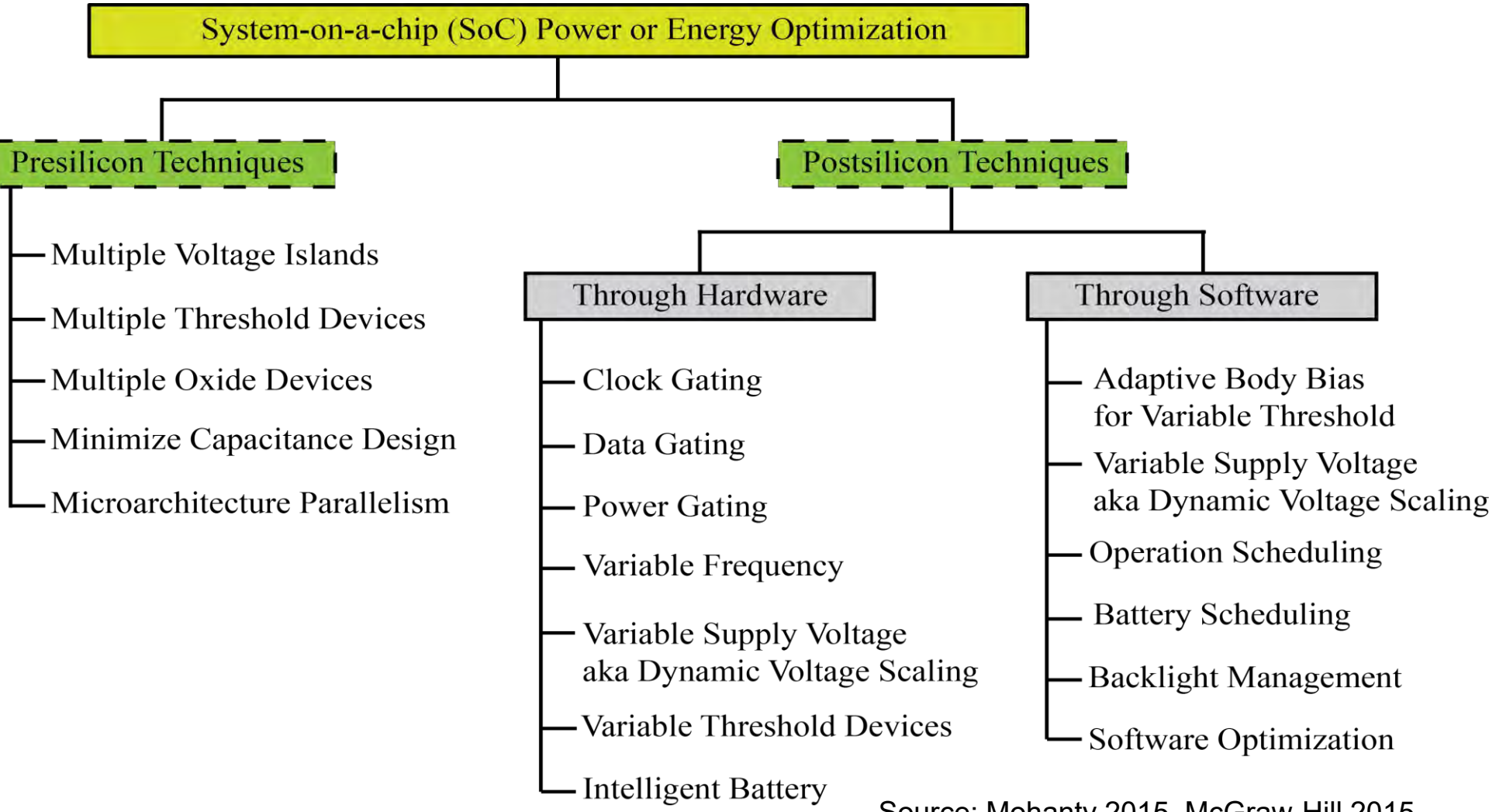


Energy Reduction in CE Systems



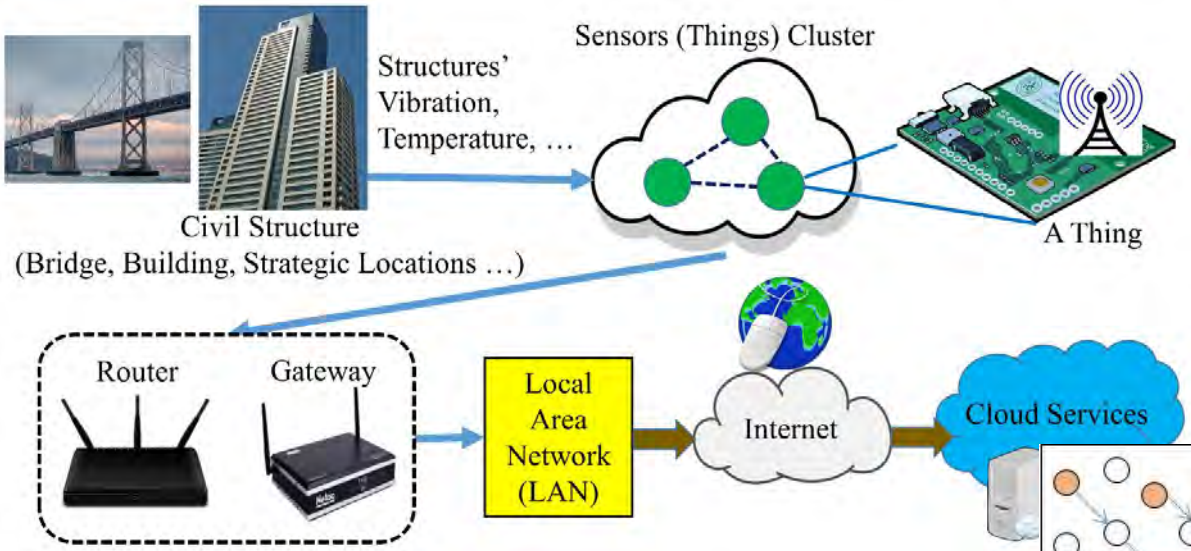
Source: Mohanty 2015, McGraw-Hill 2015

Energy Reduction in CE Hardware

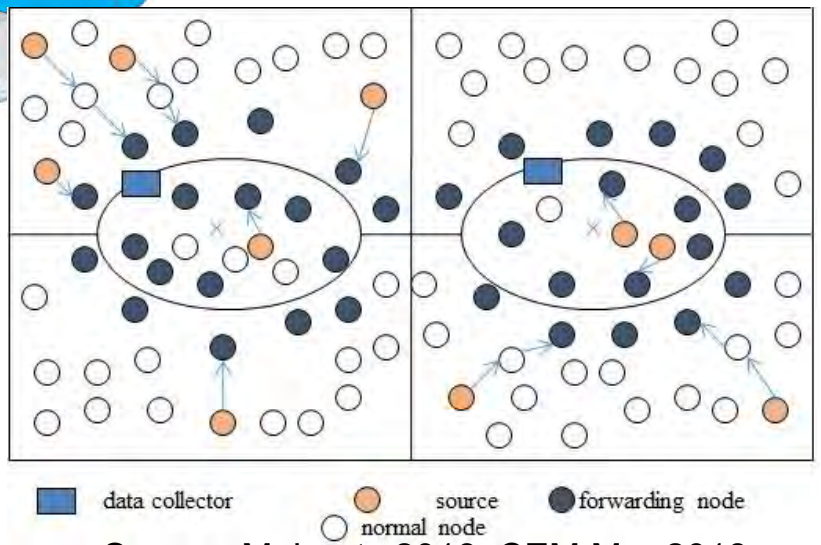


Source: Mohanty 2015, McGraw-Hill 2015

Sustainable IoT – Low-Power Sensors and Efficient Routing

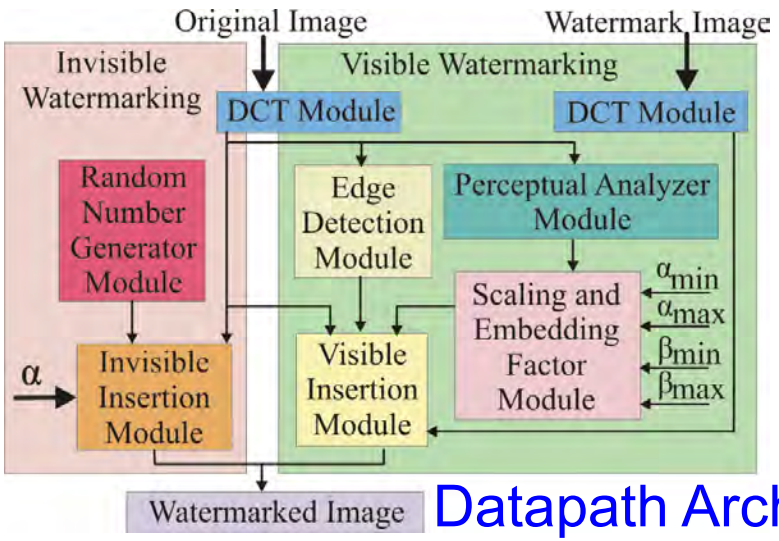


- IoT - sensors near the data collector drain energy faster than other nodes.
- Solution Idea - Mobile sink in which the network is balanced with node energy consumption.
- Solution Need: New data routing to forward data towards base station using mobile data collector, in which two data collectors follow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

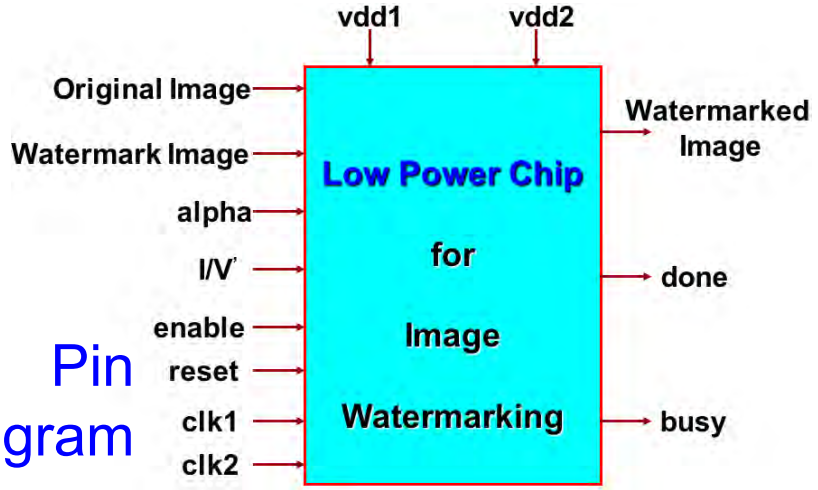


Source: Mohanty 2018, CEM Mar 2018

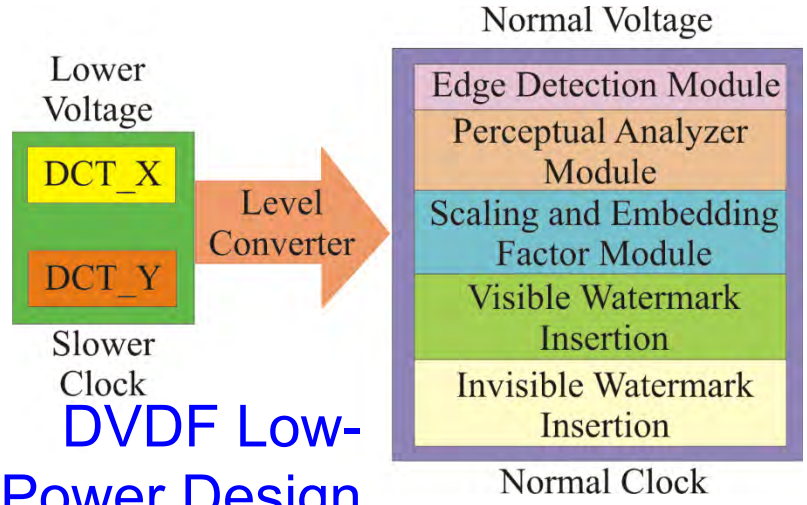
Dual-Voltage/Frequency Based Hardware



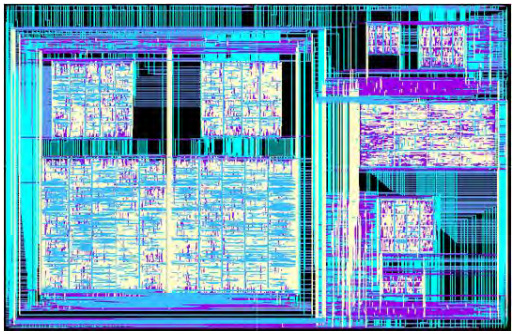
Datapath Architecture



Pin Diagram



DVDF Low-Power Design



Hardware Layout

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

Source: Mohanty 2006, TCASII May 2006

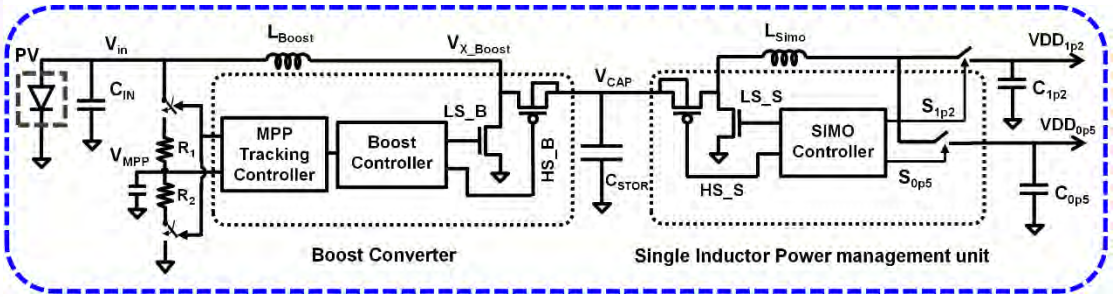
Battery-Less IoT

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/

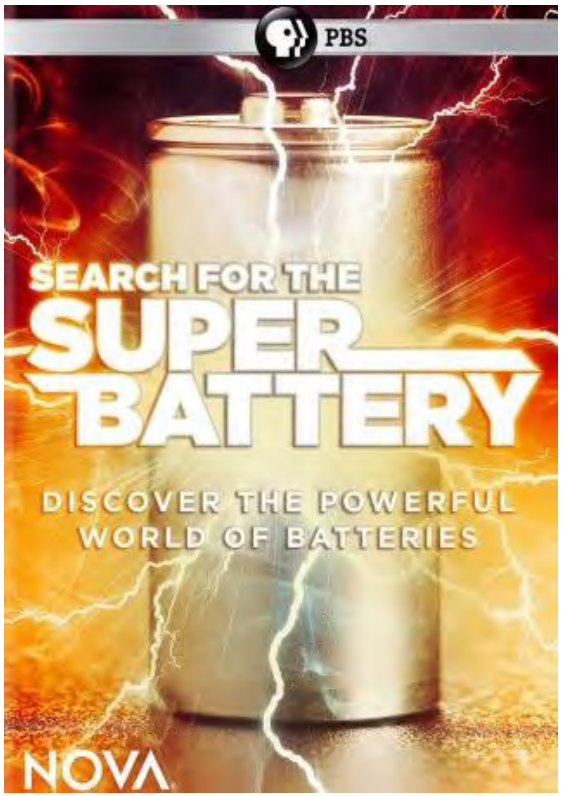


Energy Harvesting and Power Management

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

Energy Storage - High Capacity and Efficiency Needed

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



Intelligent Battery

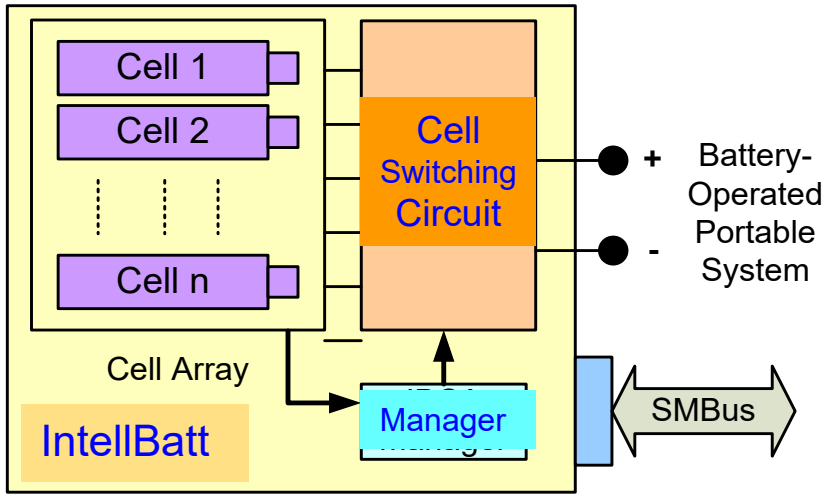


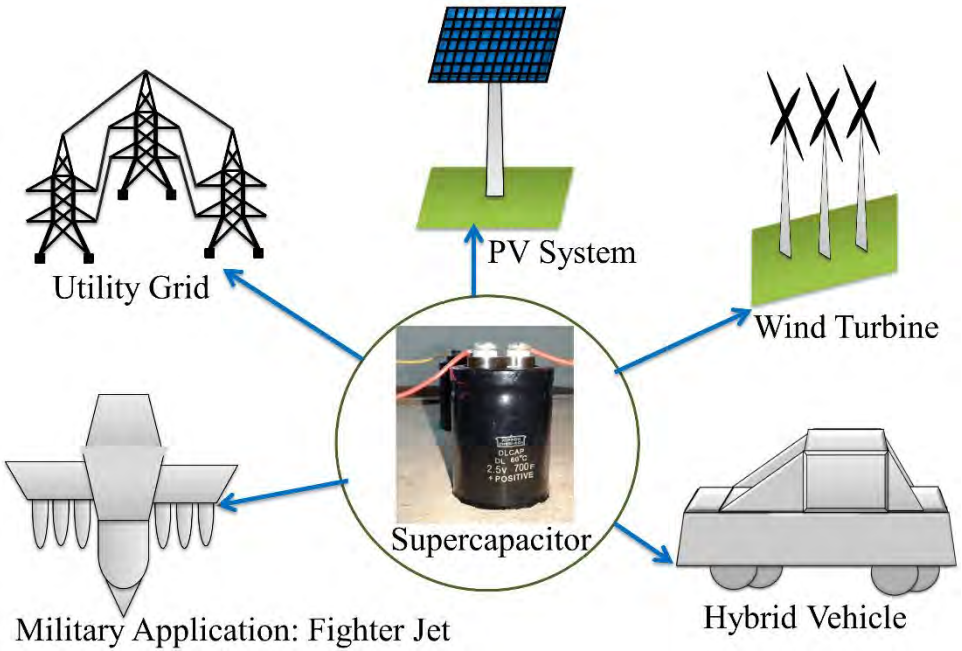
Figure 1: IntelliBatt Architecture

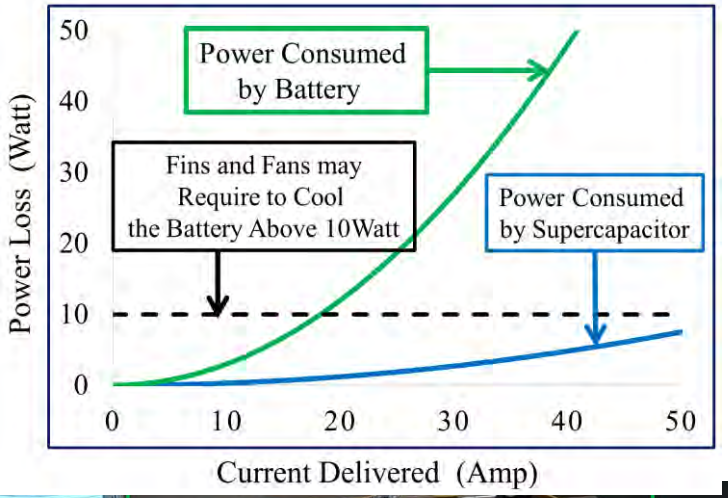
Mohanty 2010: IEEE Computer, March 2010.
Mohanty 2018: ICCE 2018

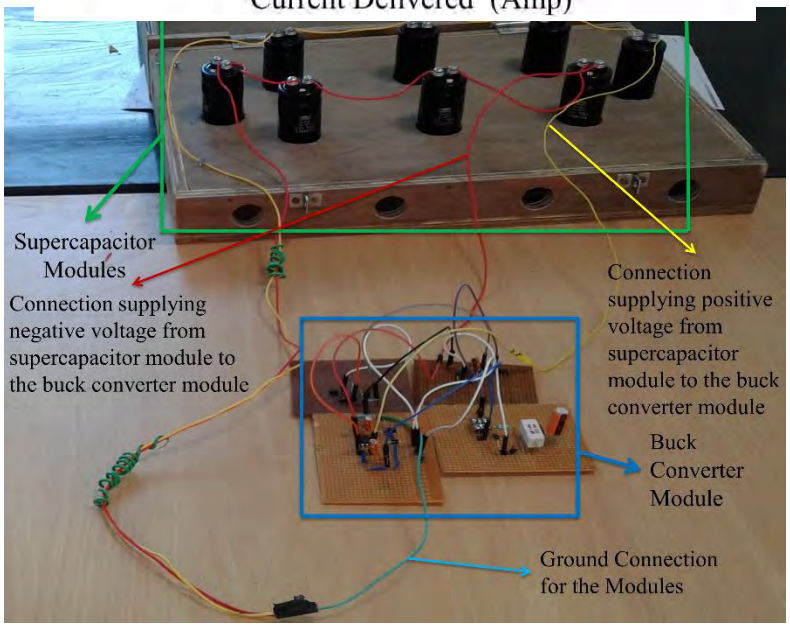
Lithium Polymer Battery

Supercapacitor

Supercapacitor based Power for CE







Source: Mohanty 2018, CEM Sep 2018

EV Charging System …

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

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

India

IIT Kanpur
Dr. Shantanu K. Mishra

IIT Kharagpur
Dr. Souvik Chattopadhyay

IIT BHU
Dr. Rajeev K. Singh

International

University of Texas
Dr. Saraju P. Mohanty

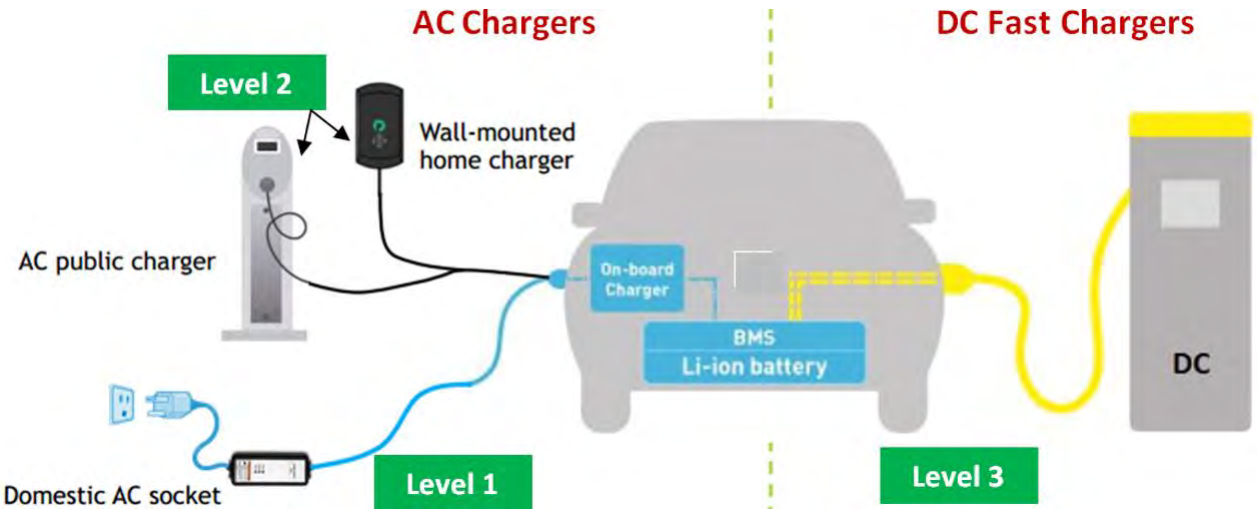
Virginia Tech
Dr. Khai D. T. Ngo

Concordia University
Dr. Akshay K. Rathore

Imperial College London
Dr. Balarko Chaudhuri

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

EV Charging System



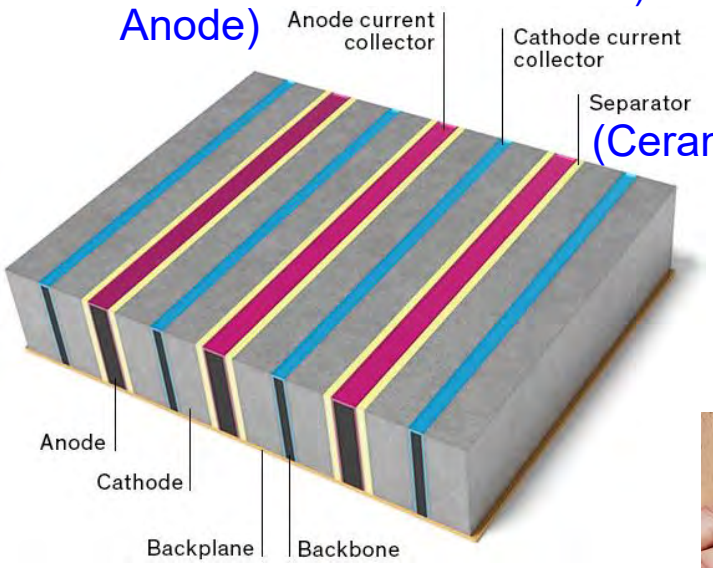
- Design and deployment of Level 2 (AC) and combined charging system
- Design and deployment of hybrid input DC Fast charger
  - (a) with multi-input source and single-output
  - (b) with 5-10 kW output EV charger for E-Rickshaws
  - (c) universal charger design and implementation
- Impact study of storage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

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

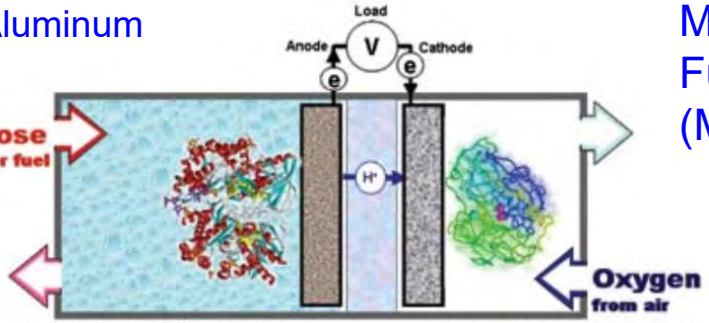
Energy Storage - High Capacity and Safer Needed

(Silicon Anode)

(Lithium Nickel Cobalt Aluminum Oxide - NCA) Cathode



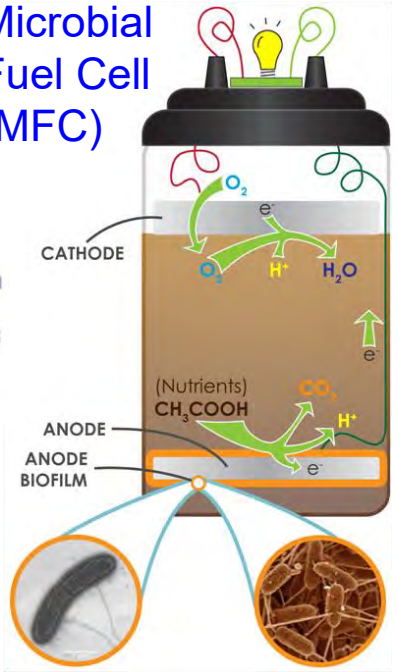
Source: http://spectrum.ieee.org/semiconductors/design/how-to-build-a-safer-more-energydense-lithiumion-battery

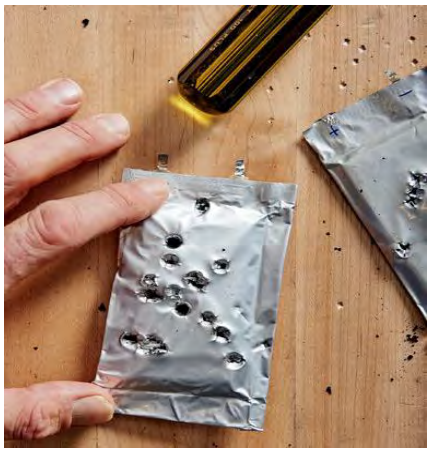


Source: https://www.electrochem.org/dl/interface/sum/sum07/su07_p28_31.pdf

Enzymatic Biofuel Cell

Microbial Fuel Cell (MFC)

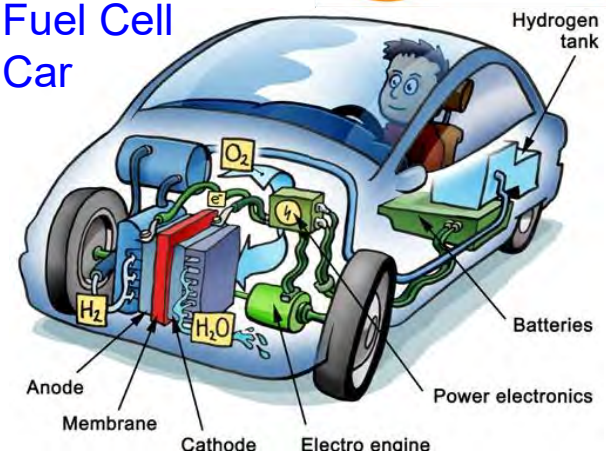




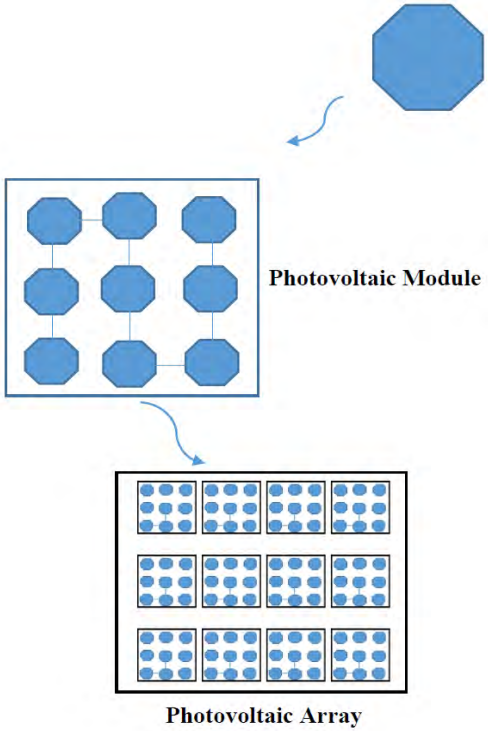
Solid Polymer Lithium Metal Battery

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

Fuel Cell Car



Energy Conversion Efficiency

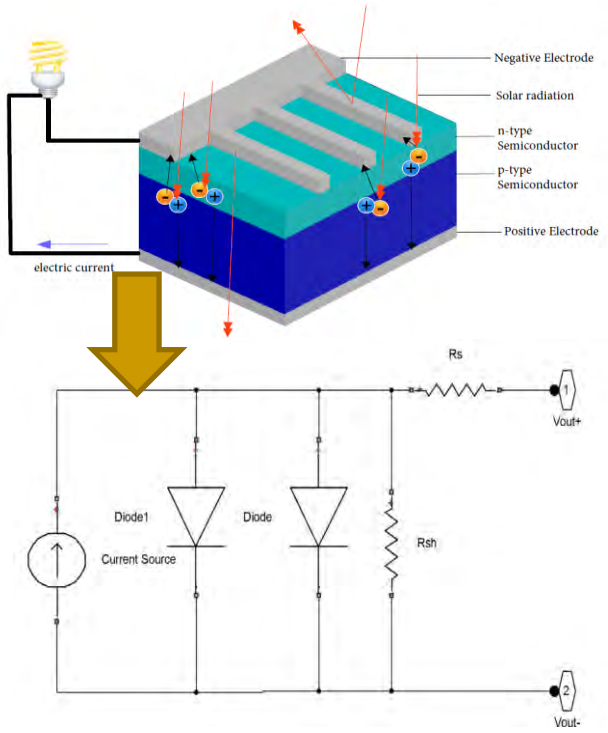


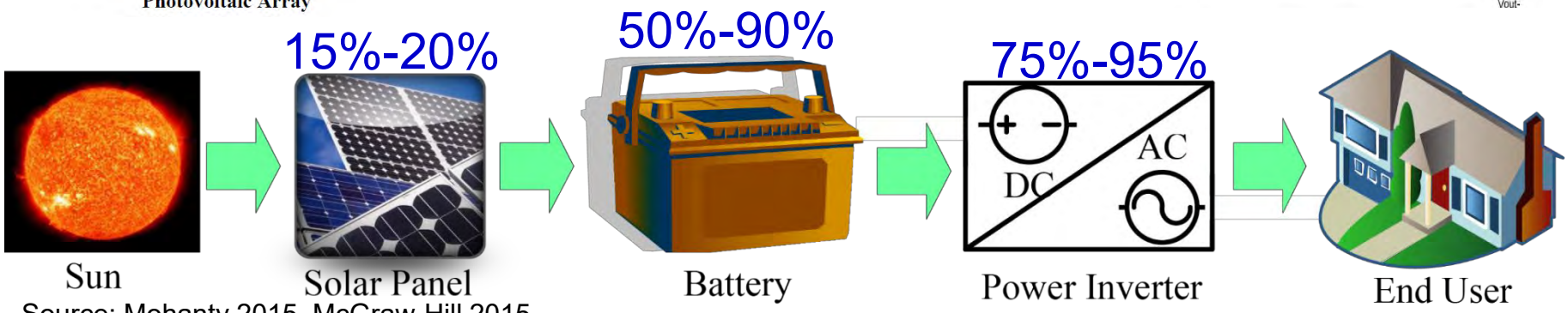
Small solar cells in CE systems to big solar panels in smart grids.

Solar Cell Efficiency:

Research stage: 46%

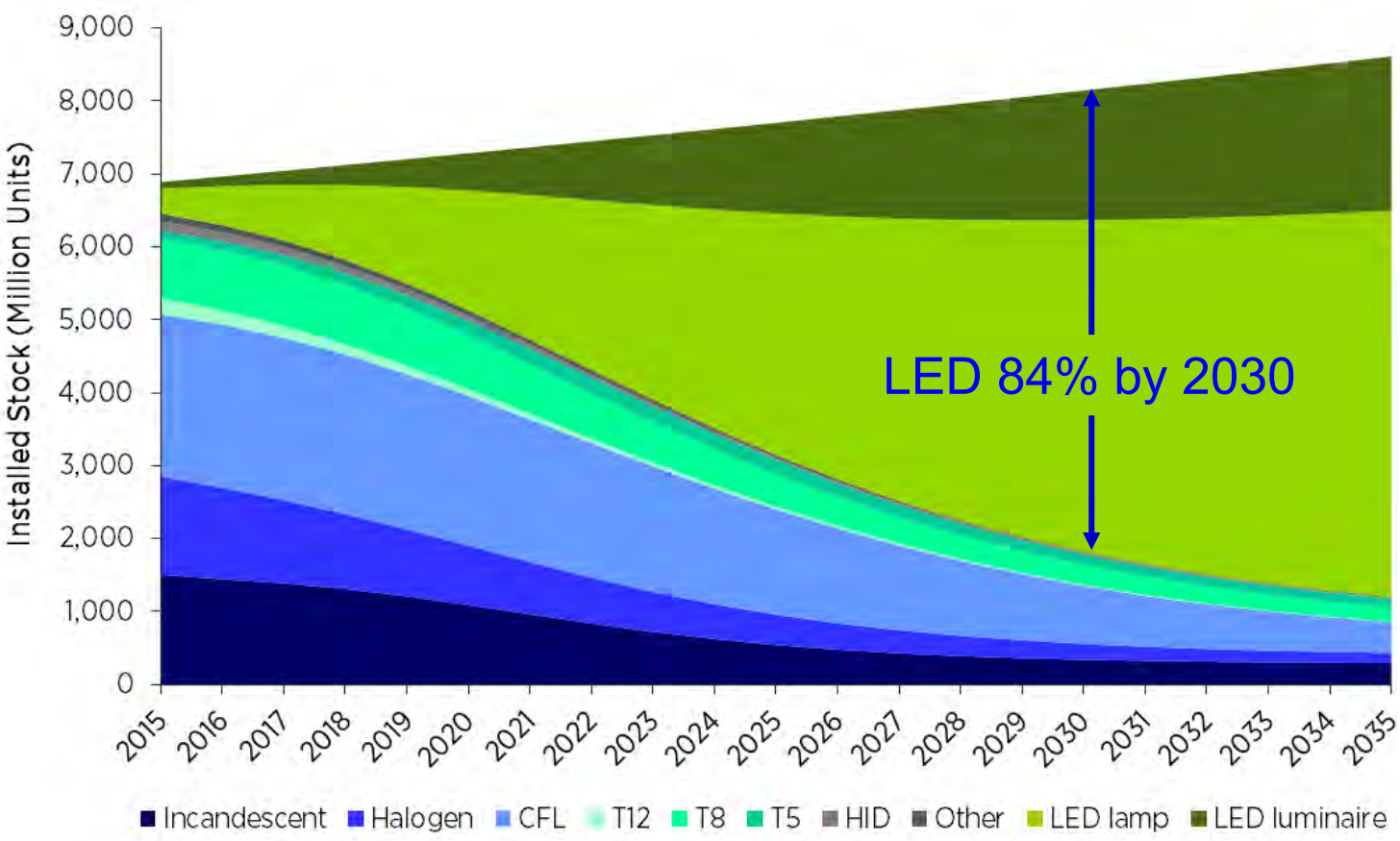
Commercial: 18%

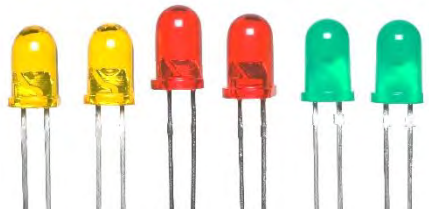




Source: Mohanty 2015, McGraw-Hill 2015

Energy Conversion Efficiency





Conversion Efficiency: 4% - 53%

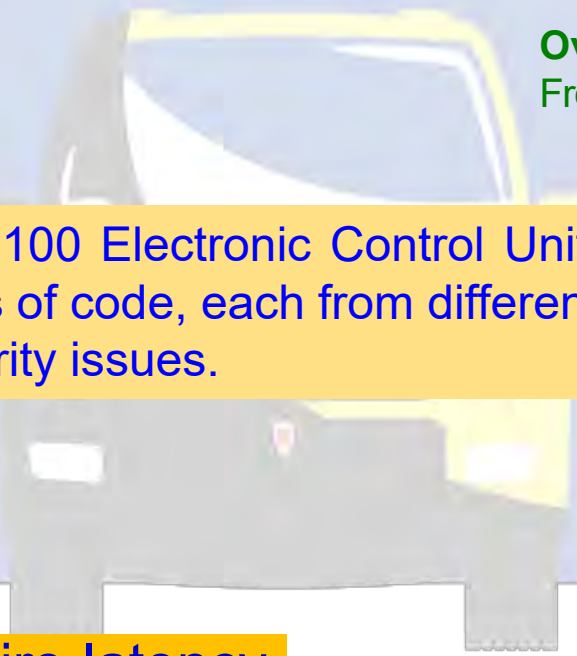
Source: https://energy.gov/sites/prod/files/2016/09/f33/energysavingsforecast16_2.pdf

Software Vs Hardware Attacks and Solutions in CE

CE System Security – Smart Car

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

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



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

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

Mitigating Advanced Threats
Analytics in the Car and in the Cloud

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

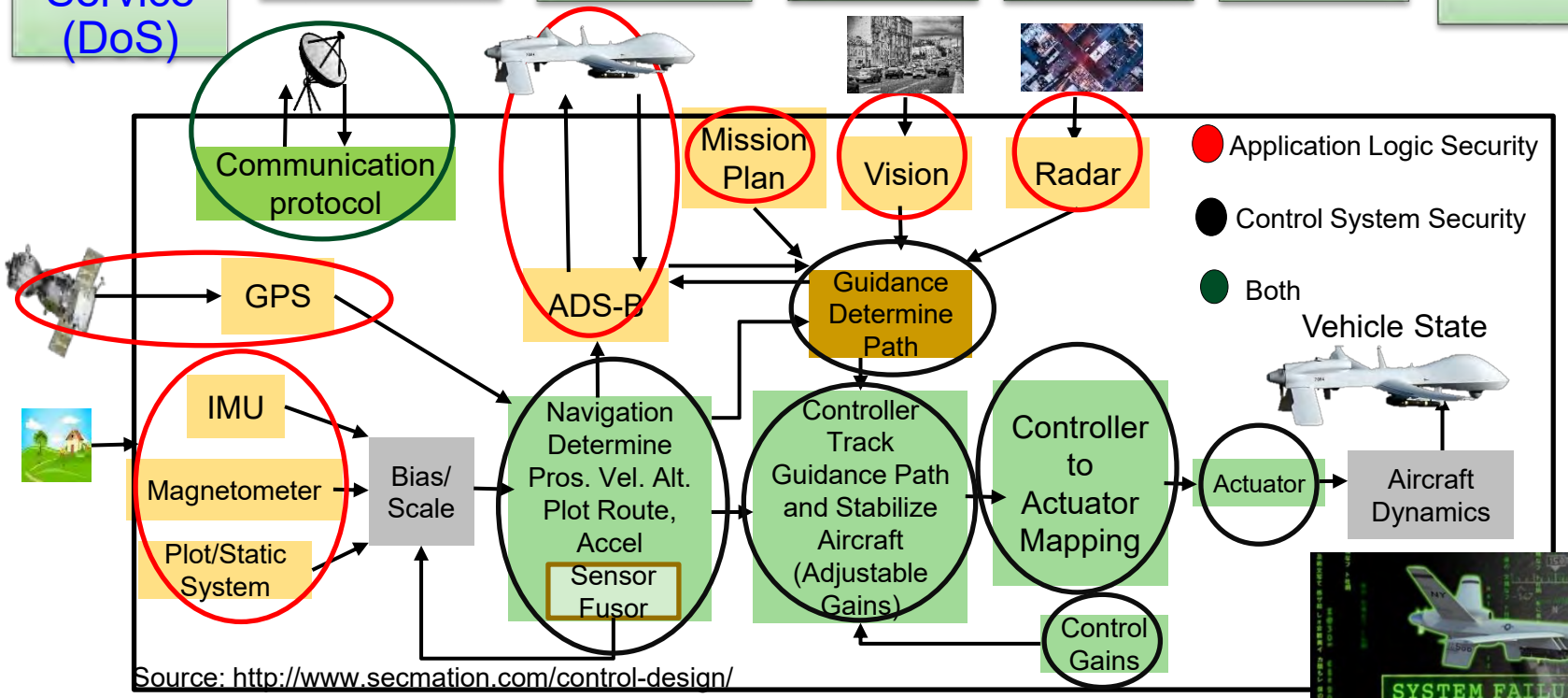
Security Mechanism Affects:
- Latency
- Mileage
- Battery Life

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

CE System Security – UAV

Selected Attacks on UAV

Denial of Service (DoS) | Replay | Relay | Jamming | Spoofing | Tracking | Eavesdropping



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

Security Mechanisms Affect:

Battery Life | Latency | Weight | Aerodynamics

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

Attacks - Software Vs Hardware

Software Based

- Software attacks via communication channels
- Typically from remote
- More frequent
- Selected Software based:
  - Denial-of-Service (DoS)
  - Routing Attacks
  - Malicious Injection
  - Injection of fraudulent packets
  - Snooping attack of memory
  - Spoofing attack of memory and IP address
  - Password-based attacks

Hardware Based

- Hardware or physical attacks
- Maybe local
- More difficult to prevent
- Selected Hardware based:
  - Hardware backdoors (e.g. Trojan)
  - Inducing faults
  - CE system tampering/jailbreaking
  - Eavesdropping for protected memory
  - Side channel attack
  - CE hardware counterfeiting

Security - Software Vs Hardware

Software Based

- Flexible - Easy to use, upgrade and update
- Wider-Use - Use for all devices in an organization
- Higher recurring operational cost
- Tasks of encryption easy compared to hardware – substitution tables
- Needs general purpose processor
- Can't stop hardware reverse engineering

Hardware Based

- High-Speed operation
- Energy-Efficient operation
- Low-cost using ASIC and FPGA
- Tasks of encryption easy compared to software – bit permutation
- Easy integration in CE systems
- Possible security at source-end like sensors, better suitable for IoT
- Susceptible to side-channel attacks
- Can't stop software reverse engineering

Maintaining of Security of Consumer Electronics, CE Systems, IoT, CPS, etc. needs Energy and affects performance.

Hardware Assisted Security

- Software based Security:
  - A general purposed processor is a deterministic machine that computes the next instruction based on a program counter.
  - Software based security approaches that rely on some form of encryption can't be full proof as breaking them is just matter of time.
  - Quantum computers that use different paradigms than the existing computers will make things worse.
- Hardware-Assisted Security: Security/ Protection provided by the hardware:
  - for information being processed by a CE system,
  - for hardware itself, and/or
  - for the overall CE system.

Hardware Assisted Security

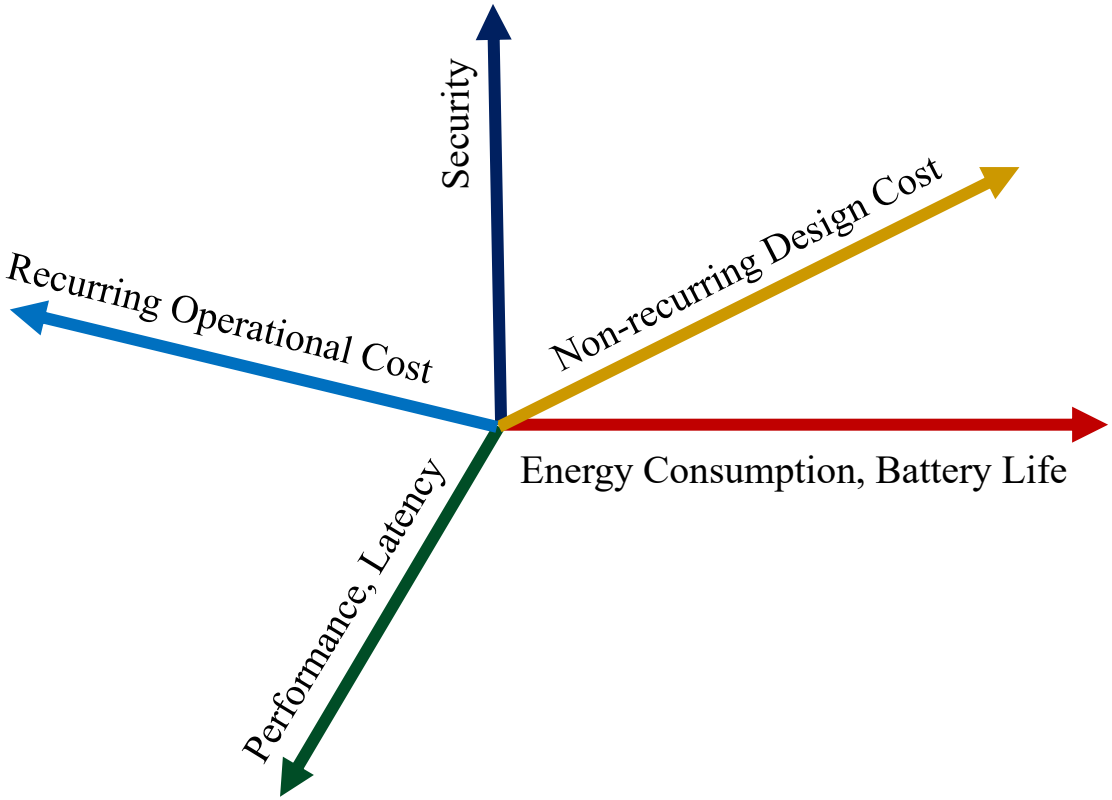
- Hardware-Assisted Security: Security provided by hardware for:
  (1) information being processed,
  (2) hardware itself, and/or
  (3) overall system.
- Additional hardware components used for security.
- Hardware design modification is performed.
- System design modification is performed.

RF Hardware Security | Digital Hardware Security – Side Channel

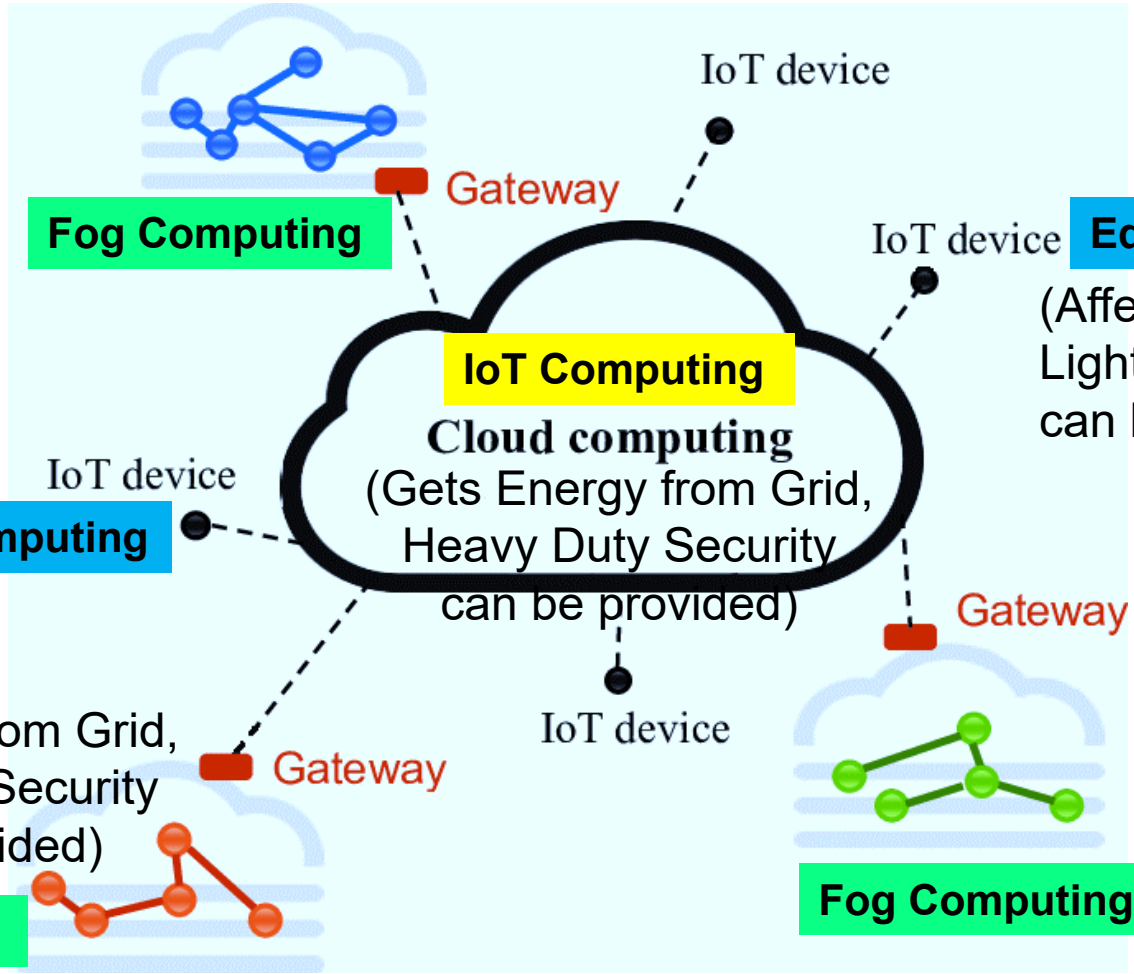
Hardware Trojan Protection | Information Security, Privacy, Protection

IR Hardware Security | Memory Protection | Digital Core IP Protection

CE System Design and Operation Tradeoffs

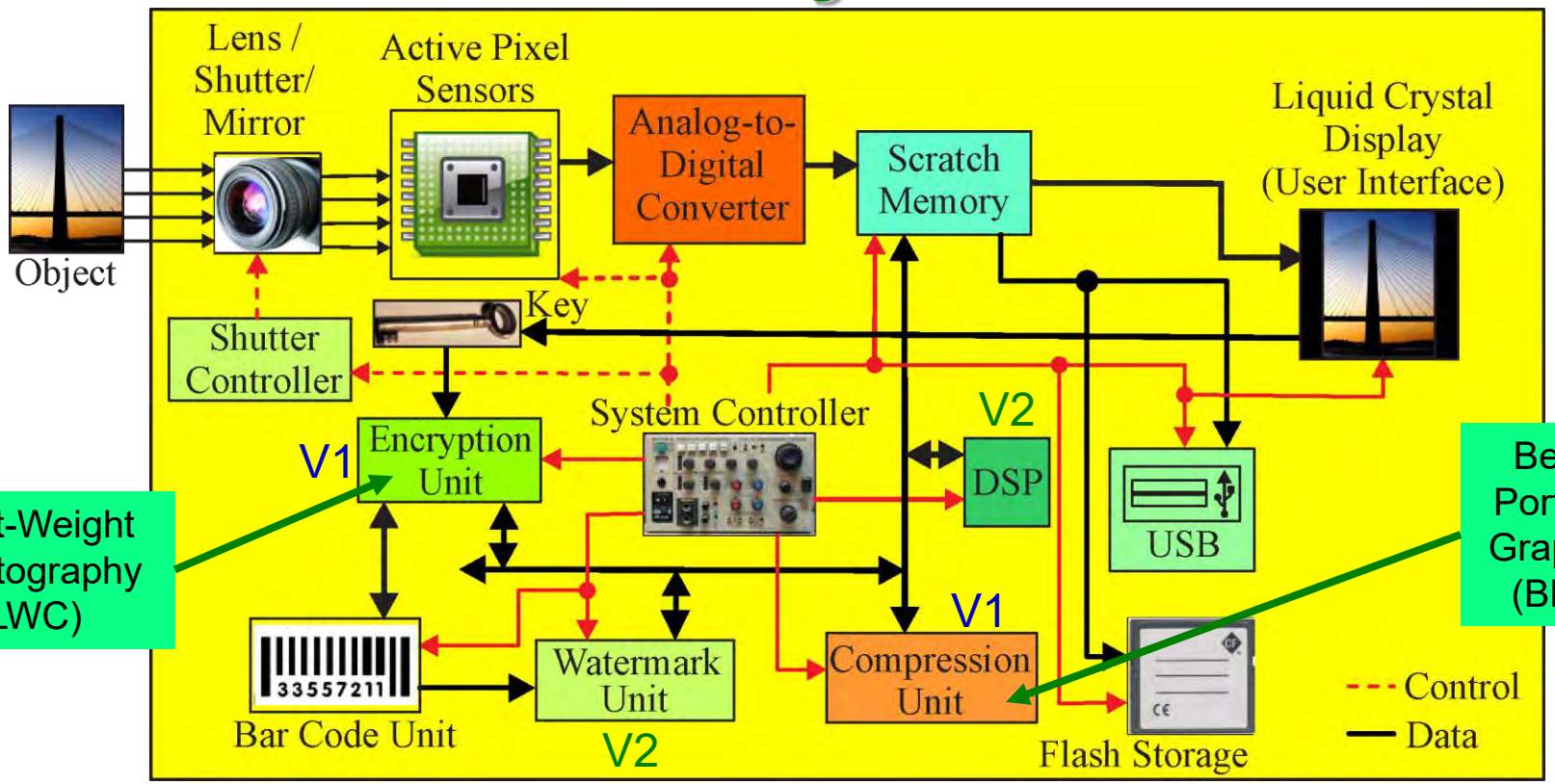


IoT Vs Fog Vs Edge Computing – Security, Energy Tradeoffs



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

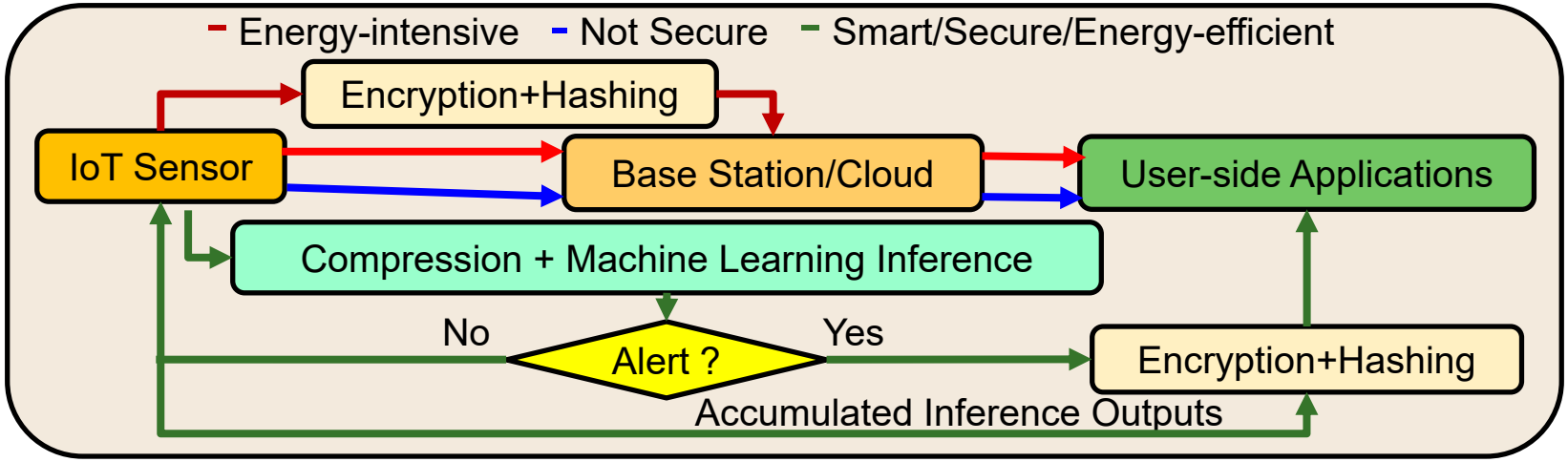
CE System Security & Energy Tradeoffs – System Level



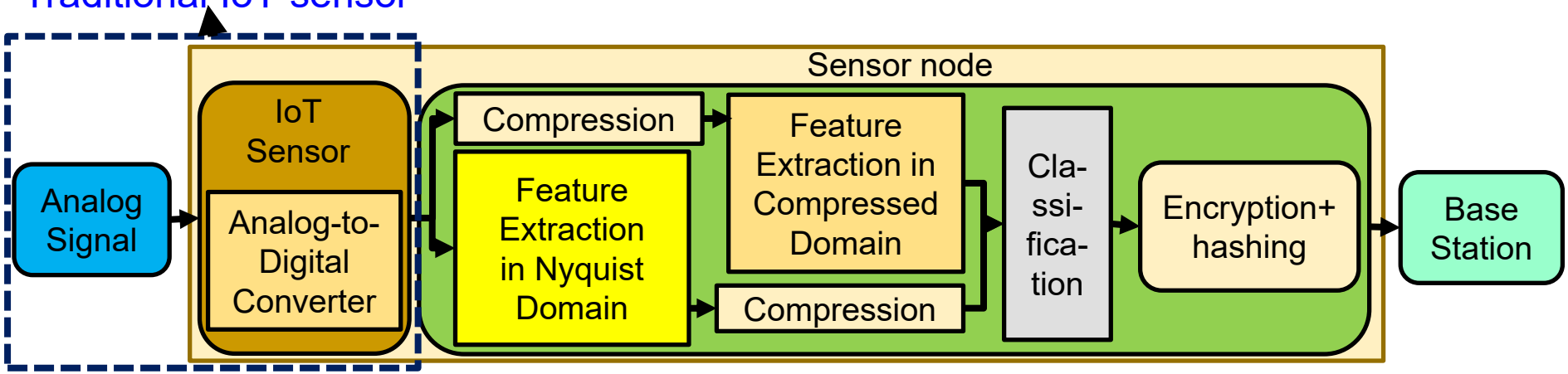
Include additional/alternative hardware/software components and uses DVFS like technology for energy and performance optimization.

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

Security & Energy Tradeoff - Sensor



Scenarios in IoT sensor data processing



Smart, secure, and energy-efficient IoT sensor architecture

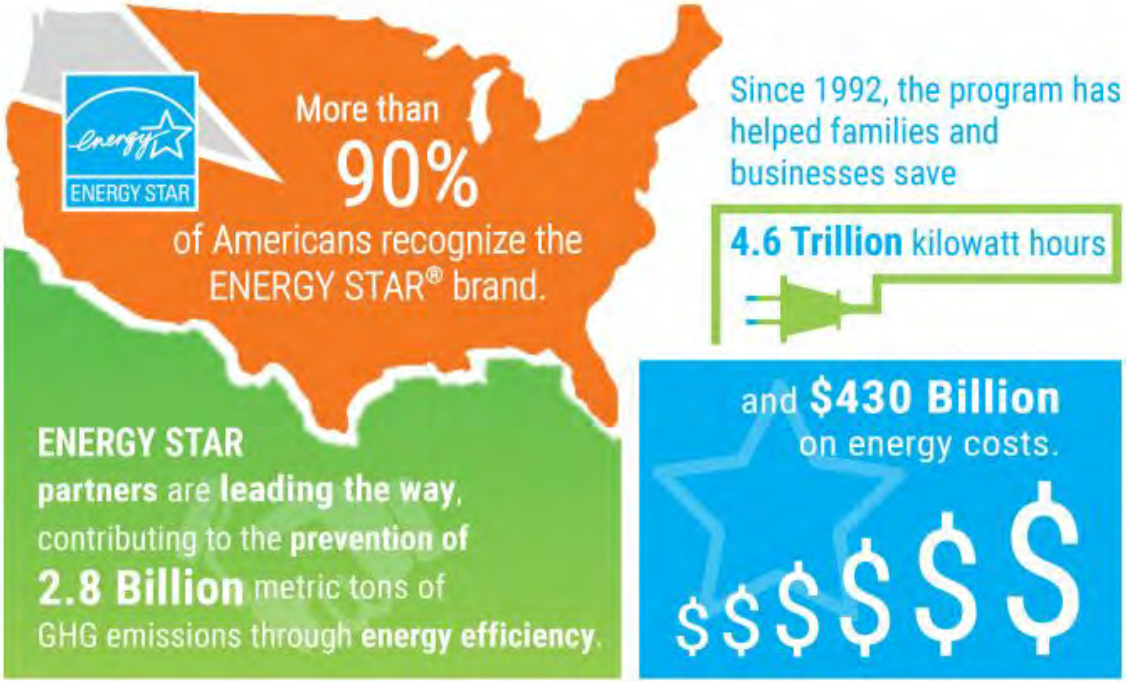
Source: Akmandor 2018: CICC 2018

Trustworthy CE System

- A selective attributes of CE system to be trustworthy:
  - It must maintain integrity of information it is processing.
  - It must conceal any information about the computation performed through any side channels such as power analysis or timing analysis.
  - It must perform only the functionality it is designed for, nothing more and nothing less.
  - It must not malfunction during operations in critical applications.
  - It must be transparent only to its owner in terms of design details and states.
  - It must be designed using components from trusted vendors.
  - It must be built/fabricated using trusted fabs.

Can there be Security Rating for CE Appliances or Systems?

Energy Star Ratings

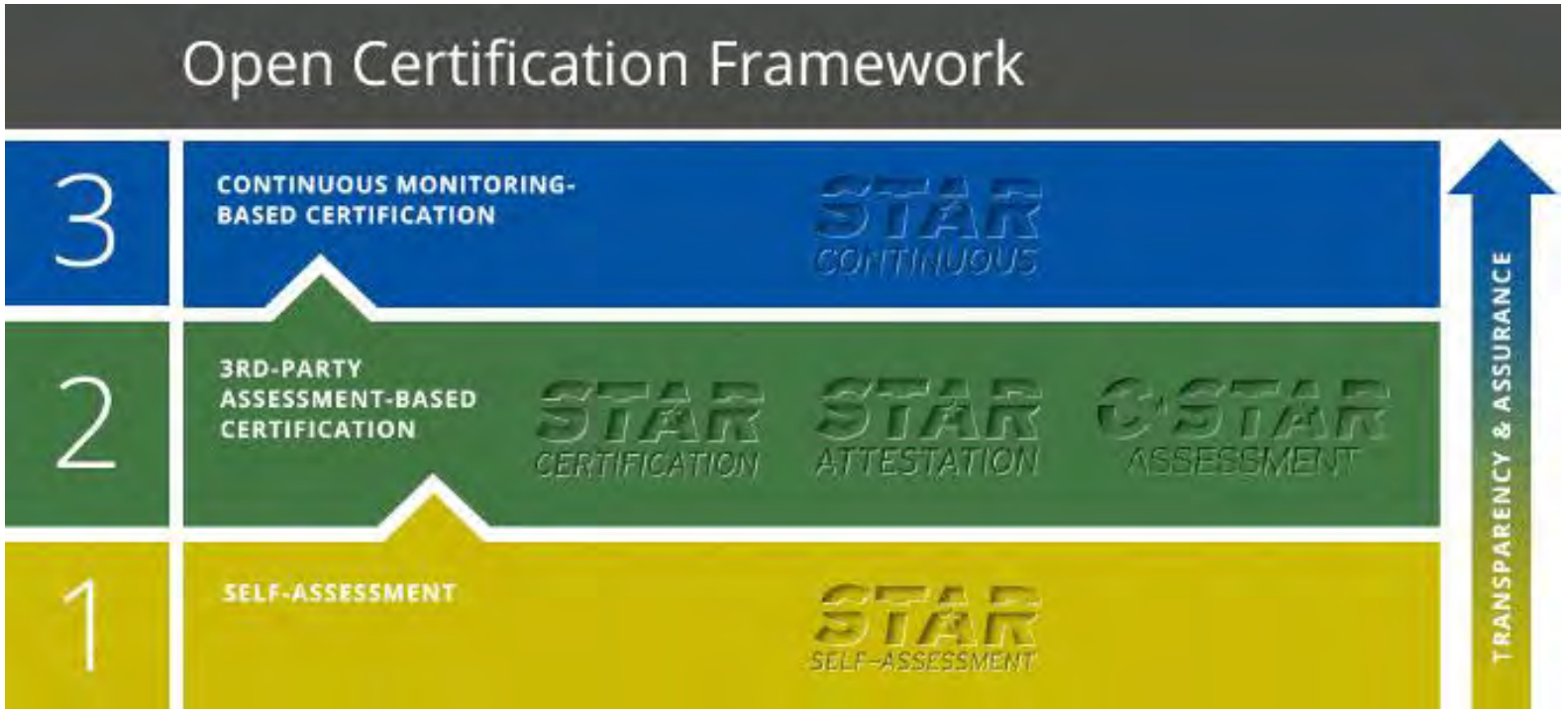


Source: https://www.energystar.gov/about/2017_energy_star_award_winners

Source: https://www.breeam.com/

Source: https://new.usgbc.org/leed

Security Star Ratings



Source: https://cloudsecurityalliance.org/star/#_overview

Cloud Security Alliance (CSA) Security, Trust & Assurance Registry (STAR)

Conclusions

Conclusions

- Privacy, security, and ownership rights are important problems in CE systems.
- Energy dissipation and performance are also key challenges.
- Hardware-Assisted Security: Security provided by hardware for: (1) information being processed, (2) hardware itself, (3) overall system.
- It is low-cost and low-overhead solution as compared to software only based.
- Many hardware based solutions exist for media copyright and information security.
- Many hardware design solutions exist for IP protection and security of the CE systems that use such hardware.
- NFC and RFID security are important for IoT and CE security.
- Privacy and security in smart healthcare need research.

Future Directions

- Energy-Efficient CE is needed.
- Security, Privacy, IP Protection of Information and System need more research.
- Security of the CE systems (e.g. smart healthcare device, UAV, Smart Cars) needs research.
- Safer and efficient battery need research.
- Important aspect of smart CE design: trade-offs among energy, response latency, and security

2018 IEEE CONSUMER ELECTRONICS SOCIETY NEW MEMBER APPLICATION

Society Website: https://cesoc.ieee.org/

Membership Fee: $20
Student Membership Fee: $10

These offers apply to full conference and full conference attendees during the conference only.

Free CE Society memberships are open to all current IEEE members. Membership periods end Dec 31 2018 and must be renewed by the member through IEEE.

Incomplete or illegible applications cannot be processed. Write legibly
Enter your name as you want it to appear on you membership card and IEEE correspondence.

Your Contact information

Male ☐ Female ☐ Date of Birth (DD/MM/YYYY) / / _____

Title First/Given Name Middle Name Last/Family Surname

Home

Street Address

City State/Province

Postal Code Country

Home Phone

Home Email

Your Professional Experience

(circle your choices below)

I have graduated from a three-to-five-year academic program with a university-level degree.

This academic institution or program is accredited in the country where the institution is located.
Yes No Do not know

I have _____ years of professional experience in teaching, creating, developing, practicing, or managing within the following field:

Engineering

Computer Sciences and Information Technologies

Physical Sciences

Biological and Medical Sciences

Mathematics

Technical Communications, Education, Management, Law and Policy
Other (please specify): _____

Are you or were you ever a member of the IEEE? Yes No
If Yes, provide, if known:

Membership Number _____

Grade _____

Year of Expiration if no longer a member _____

Select Your Membership

☐ **Students, IEEE Members, Joining CE Society**

☐ **IEEE Member, joining CE Society**

Online at: https://cesoc.ieee.org/membership.html

Benefits Include:
1) A nice color magazine shipped to your door step to update you on latest CE
2) Discount in conference registration
3) Networking opportunity with global peers

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**

Editorial Board

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

WINNER 2013 APEX AWARDS FOR PUBLICATION EXCELLENCE

IEEE CONSUMER ELECTRONICS SOCIETY

IEEE

Smart Electronic Systems Laboratory (SESL)

UNT EST. 1890

CONTACT: TCVLSI CHAIR | SARAJU.MOHANTY@UNT.EDU 2018

Technical Committee on VLSI (TCVLSI), IEEE-CS

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.

TCVLSI is a constituency of the IEEE-CS that oversees various technical activities related to VLSI.

Key People

Chair
Saraju P. Mohanty, University of North Texas
Vice Chair for Conferences –
Jia Di, University of Arkansas
Treasurer –
Hai (Helen) Li, Duke University
Vice Chair for Membership –
Dhruva Ghai, Oriental University Indore, India
Vice Chair for Liaison –
Nagi Naganathan, Avago Technologies
Vice Chair Outreach and Webmaster –
Mike Borowczak, University of Wyoming
Newsletter EiCs –
Saraju P. Mohanty, University of North Texas
Anirban Sengupta, Indian Institute of Technology Indore
Past Chair –
Joseph Cavallaro, Rice University

TCVLSI Sister Conferences

Sponsored

ARITH: www.arithsymposium.org
ASAP: http://www.asapconference.org/
ASYNC: http://asyncsymposium.org/
iNIS: http://www.ieee-inis.org
ISVLSI: http://www.isvlsi.org
IWLS: http://www.iwls.org
MSE: http://www.mseconference.org
SLIP: http://www.sliponline.org
ECMSM: http://ecmsm2017.mondragon.edu/en

Technically Co-Sponsored

ACSD: http://pn2017.unizar.es/
VLSID: http://vlsidesignconference.org

Join TCVLSI

It's free to join @ bit.ly/join-tcvlsi

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

TCVLSI Offers

- Student travel grants
- Best paper awards
- Timely CFP info
- Free membership
- Venue to contribute to VLSI
- Circuits & Systems

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

Thank You !!!

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