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.”

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

**1969**
The Internet Emerges
The first nodes of what would eventually become known as ARPANET, the precursor to today’s Internet, are established at UCLA and Stanford universities.

**1982**
TCP/IP Takes Shape
Internet Protocol (TCP/IP) becomes a standard, ushering in a worldwide network of fully interconnected networks called the Internet.

**1990**
A Thing Is Born
John Romkey and Simon Hackett create the world’s first connected device (other than a computer): a toaster powered through the Internet.

**1999**
The IoT Gets a Name
Kevin Ashton coins the term “Internet of things” and establishes MIT’s Auto-ID Center, a global research network of academic laboratories focused on RFID and the IoT.

**2005**
Getting Global Attention
The United Nations first mentions IoT in an International Telecommunications Union report. Three years later, the first international IoT conference takes place in Zurich.

**2008**
Connections Count
The IPSO Alliance is formed to promote IP connections across networks of “smart objects.” The alliance now boasts more than 50 member firms.

**2011**
IPV6 Launches
The protocol expands the number of objects that can connect to the Internet by introducing 340 undecillion IP addresses (2128).

**2013**
Google Raises the Glass
Google Glass, controlled through voice recognition software and a touchpad built into the device, is released to developers.

**2014**
Apple Takes a Bite
Apple announces HealthKit and HomeKit, two health and home automation developments. The firm’s iBeacon advances context and geolocation services.

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.


IEEE also provides a formal, comprehensive definition of IoT.

IoT Keynote by Prof./Dr. Saraju P. Mohanty
IoT – Definition - International Telecommunication Union (ITU)

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

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

1. WSN
2. Cloud servers
3. Applications

Five Level Model

1. Edge nodes
2. Object abstraction
3. Service management
4. Service composition
5. Applications

Source: Nia 2017, IEEE TETC 2017
IoT Architecture - 7 Level Model

1. Physical Devices & Controllers (The “Things” in IoT)
2. Connectivity (Communication & Processing Units)
3. Edge (Fog) Computing (Data Element Analysis & Transformation)
4. Data Accumulation (Storage)
5. Data Abstraction (Aggregation & Access)
6. Application (Reporting, Analytics, Control)
7. Collaboration & Processes (Involving People & Business Processes)

Overall architecture:

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

Four Main Components of IoT.
IoT – Sensors


100s of Sensors
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

Data rate, log scale

Power consumption, indicative


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

• Software as a Service (SaaS)
• Platform as a Service (PaaS)
• Infrastructure as a Service (IaaS)

Source: Gubbi 2013, Elsevier FGCS 2013
IoT - Applications
Quality and sustainable healthcare with limited resources, anywhere, anytime.

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

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

Source: Mohanty 2016, CE Magazine July 2016

"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

IoT in Smart Energy

Smart Grid

Smart Generation

Smart Storage

Water Heater

Service Provider

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.

Home Automation (User controlled smart appliances)

DLNA Network

Home Energy Manager

Electric Car

AC

DC

Market Value by 2025: $781.66 Billion
Source: Frost & Sullivan

Source: Mohanty 2016, CE Magazine July 2016

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Internet of Energy
IoT in Smart Agriculture

FUTURE FARMS
small and smart

SURVEY DRONES
Aerial drones survey the fields, mapping weeds, yield and soil variation. This enables precise application of inputs, mapping spread of pernicious weed blackgrass could increasing Wheat yields by 2-5%.

FLEET OF AGRIBOTS
A herd of specialized agribots tend to crops, weeding, fertilizing and harvesting. Robots capable of microdial application of fertilizer reduce fertilizer cost by 95.9%.

FARMING DATA
The farm generates vast quantities of rich and varied data. This is stored in the cloud. Data can be used as digital evidence reducing time spent completing grant applications or carrying out farm inspections saving on average £3.500 per farm per year.

TEXTING COWS
Sensors attached to livestock allowing monitoring of animal health and wellbeing. They can send texts to alert farmers when a cow goes into labour or develops illness increasing herd survival and increasing milk yields by 10%.

SMART TRACTORS
GPS controlled steering and optimised route planning reduces soil erosion, saving fuel costs by 10%.

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

Automatic Irrigation System

Smart Agriculture/Farming Market Worth $18.21 Billion By 2025


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

Source: Maurya 2017, CE Magazine July 2017

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Cheap and Compact Sensor Technology

Gas Sensor
Temperature Sensor
Air Quality Sensor
Humidity and Temperature Sensor
Light Sensor
Barometer Sensor
Water Sensor
Dust Sensor


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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)

Digital Pixel Sensor (DPS)

Based on Sensing Element

Photodiode-Type APS

Photogate-Type APS

Based on Operation Mode

Linear-Mode APS

Logarithmic-Mode APS

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


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).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>LiFi</th>
<th>WiFi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>Huge</td>
<td>Limited</td>
</tr>
<tr>
<td>Requires Line of Sight</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>EMI + Hazard Concerns</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Susceptibility to Eavesdropping</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Range</td>
<td>Short</td>
<td>Medium</td>
</tr>
<tr>
<td>Data Density</td>
<td>High</td>
<td>Limited</td>
</tr>
</tbody>
</table>

Source: VLCS-2014

Source: Ribeiro 2017, CE Magazine October 2017

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22nd Dec 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.

Variety of 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 billion worldwide by 2020.


Machine Learning Technology

Artificial Intelligence

Tensor Processing Unit (TPU)

IoT Use:
- Better decision
- Faster response

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/

April 2017

IoT Keynote by Prof./Dr. Saraju P. Mohanty
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

Selected NLP Applications

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

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

Neuromorphic Computing or Brain-Inspired Computing

Processing Powers

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


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IoT Keynote by Prof./Dr. Saraju P. Mohanty
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: IBM
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.

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.

Stay Tuned to: Puthal, Mohanty 2018, CE Magazine March 2018
Challenges and Research
IoT – Selected Challenges

- Massive Scaling
- Design and Operation Cost
- Energy Consumption
- Security, Privacy, and IP Protection
- Creating Knowledge and Big Data
- Architecture and Dependencies
- Robustness

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation
Massive Scaling

Eventually Trillions of Things

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.

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

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-iae-balakrishnan
Energy Consumption of Sensors, Components, and Systems

Typical CE System


During GSM Communications

During WiFi Communications

Source: IoT Keynote by Prof./Dr. Saraju P. Mohanty
Battery-Less IoT

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

Go Battery-Less

Battery-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


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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
Energy Storage - High Capacity and Safer Needed

(Silicon Anode)

(Lithium Nickel Cobalt Aluminum Oxide - NCA) Cathode

Anode current collector

Cathode current collector

Separator (Ceramic)

Fuel oxidizing enzymes:
- Glucose Oxidase
- Glucose Dehydrogenases
- Alcohol Dehydrogenases

Oxygen reducing enzymes:
- Laccase
- Bilirubin Oxidase
- Ascorbate Oxidase

Microbial Fuel Cell (MFC)

Enzymatic Biofuel Cell

Solid Polymer Lithium Metal Battery


Fuel Cell Car

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

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

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22nd Dec 2017
Huge Amount of Data

What Happens in an Internet Minute?

Estimated Data Generated per Day:
2.5 quintillion bytes

And Future Growth is Staggering

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Security, Privacy, and Copyright

Hardware Trojan

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Security - Information, System

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

Cybercrime: Top 20 Countries

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

Security in Communications Technology

- NFC
- Bluetooth
- 4G LTE 2600mhz

Routing Attacks

Malicious Injection

Denial-of-Service (DoS) Attacks

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Security - Systems ...

Power Grid Attack


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

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

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

Malicious Design Modifications Issue

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

Hardware Trojans

Unprotected/Unsecure Information

Select

Trojan

Protected/Secure Information

Output

Watermarking and/or Cryptography Processor

Input

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

Optimizing Datapath Configuration
Optimizing Vendor Allocation Type
Optimizing Unrolling Factor

Binding

Cost Evaluation

Low Cost Trojan Secured Datapath

Source: Sengupta, Mohanty 2017: TCAD April 2017

Provide backdoor to adversary. Chip fails during critical needs.

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Memory Attacks

- Snooping Attacks: Read confidential information in memory.
- Spying Attacks: Replace a block with fake.
- Splicing Attacks: Replace a block with a block from another location.
- 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.
- Cold Boot Attacks: Physical access memory to retrieve encryption keys.

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

Safe Zone

Tags

Blocker

Blocker Tags

Source: Khattab 2017, Springer 2017 RFID Security

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NFC Security - Attacks

Selected NFC Attacks

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

Eavesdropping


Relay Attack

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

NFC Security - Solution

Source: Mohanty 2017, CE Magazine Jan 2017
Autonomous Car – Security Vulnerability

Selected Attacks on Autonomous Cars

Replay  Relay  Jamming  Spoofing  Tracking

Light Detection and Ranging (LiDAR)

Camera

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


Source: Petit 2015: IEEE-TITS Apr 2015

Source: IoT Keynote by Prof./Dr. Saraju P. Mohanty

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Autonomous Car Security – Cryptographic Hardware

Qorivva MPC564xB/C Family from NXP/Freescale

Microcontroller Unit (MCU)

Cryptographic Services Engine (CSE) Block


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Smart Healthcare - Security and Privacy Issues

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

Remote Control's Sequence Counter

Information Bits (i.e., control command)

Rolling Code Encoder in Remote Control

Transmitted Data

Key Encryption

Received Data

Rolling Code Decoder in Insulin Pump

Received Counter Value

Received Information (i.e., control command)

Key Decryption

Comparison: Whether within a Range

Y

Accept

N

Drop

Insulin Pump’s Sequence Counter

Insulin Pump

Security Attacks

Active Attacks: Impersonation

Universal Software Radio Peripheral

Remote Control

Passive Interception

Insulin Pump

Universal Software

Report Data/Control

Glucose Level

Continuous Glucose Sensor

Glucose Meter

Remote Control

Insulin Pump

Encryption

Decryption

PDA

Glucose Level

Remote Control

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Source: Li 2011, e-Health 2011
Side Channel Attacks — Differential and Correlation Power Analysis (DPA/CDA)

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DPA Resilience Hardware - Synthesis Flow

Cryptography Algorithm → Hamming code based concurrent error detection and correction in Galois Field → Uniform switching cell Library → Physical-Attack Tolerant Cryptography Hardware

Proposed Design Approach

Cryptography Hardware Architecture Description
- Module DUT
- AND U1 ....
- XOR U2 R ...
- Adder U3 ....
- Reg U4 ....
- endmodule

Uniform SWitching-Activity Logic Cell Library → Gate Level Synthesis → Synthesized Netlist with Error Correction in Sequential Elements with Uniformly Switching Cell Library

Source: Mohanty 2013, Elsevier CEE 2013
Firmware Security

Secure Flash Programming

SW Image → Hash → Sign (RSA) → SW Image + Signature

Private Key

Secure Off-Line Environment

Secure Flash Programming

SW Image + Signature

Hash → Verify (RSA) → Compare

Generated Hash Reference Hash

Public Key

Run OS

Report Error

Multimedia Piracy – Movie/Video

High

Studio

Cinema

On-line

Video on Demand

DVD/Blu-ray

Pay-TV Broadcasting

Free-to-Air Broadcasting

Piracy Threat Level

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

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Copyright Protection Hardwares –

DCT Domain Watermarking

Datapath Architecture

Invisible Watermarking

Visible Watermarking

DCT Module

Edge Detection Module

Perceptual Analyzer Module

Scaling and Embedding Factor Module

Visible Insertion Module

Invisible Insertion Module

Watermarked Image

Lower Voltage

DCT_X

DCT_Y

Slower Clock

DVDF Low-Power Design

Normal Voltage

Edge Detection Module

Perceptual Analyzer Module

Scaling and Embedding Factor Module

Visible Watermark Insertion

Invisible Watermark Insertion

Normal Clock

Source: Mohanty 2006, TCASII May 2006

Pin Diagram

Low Power Chip

for

Image

Watermarking

Watermarked Image

vdd1

vdd2

Original Image

Watermark Image

alpha

I/V

enable

reset

clk1

clk2

done

busy

Physical Design Data

Total Area: 16.2 sq mm

No. of Transistors: 1.4 million

Power Consumption: 0.3 mW
Copyright Protection Hardware – MPEG-4 Video Watermarking

Video Watermarking Architecture Datapath

FPGA Prototyping
Throughput: 44 frames/sec
Logic Elements in FPGA Prototyping: 28322

Source: Mohanty 2011, JSS May 2011

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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

Hardware IP Right Infringement

Chip at Original Design House

Goes to Another Design House for Resuse

Chip at Another Design House

? Who Owns ?

Company A

Company B


Hardware IPR Infringement

False Ownership Claim

Sub-licensing

Piracy (Reverse Engineering)
Hardware Reverse Engineering

CE System disassembly
Subsystem identification, modification

Chip-Level Modification

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

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


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

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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.

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Digital Hardware - Watermark

Integration/Transformation → Scheduling → Allocation (Module and Registers) → Binding → Datapath and Controller → RTL Design → FPGA bitstream

Floorplan → Placement → Routing → Layout → Fabrication

Lower abstraction level - Physical design

Higher abstraction level – Architecture design

Mid abstraction level – RTL

Source: Mohanty 2017: CE Magazine October 2017
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

Obfuscated Design
- PSO based Design Space Exploration
- Structurally Obfuscated Low Cost IP Core

Perform Structural Obfuscation based on 5 HLT Techniques

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

Source: Sengupta, Mohanty 2017, TCE November 2017

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

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

Source: Mohanty 2017, Springer ALOG 2017
Design Flow
IoT – Design Flow

1. Concept
2. High Level Design
3. Component Level Design
4. Design Analysis
5. Prototyping

Sensor and Component Assembly
Writing Device Drivers
Writing Application Programming Interface (APIs) for Cloud Infrastructure
Client Integration (Desktop, Tablet, Mobile)


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IoT – Design Flow

6 Field Testing

7 Release of Beta Version

8 Production

9 Release and Documentation


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IoT Design – Case Study – Indoor Air Quality Monitoring

Humiture Sensor
Flame Sensor
Barometer
Gas Sensor

ESP8266
ESP8266
ESP8266
ESP8266

Wireless Access Point (WAP)
Internet

Complete Prototype

Source: UNT ETECH Senior Project 2017

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# Hardware for IoT

## 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)

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

Source: Singh 2017, CE Magazine, April 2017

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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
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

- Bevywise IoT Simulator
- CUPCARBON
- IoTIFY
- Meshify
- Node-RED
- NetSim
- SimpleIoT Simulator
# 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

## 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.

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

- Internet of Things (IoT)
- Internet of Everything (IoE)
- Smarter Planet
- Machine to Machine (M2M)
- The Fog
- Trillion Sensors (Tsensors)
- Industry 4.0 (Automation and Data Exchange in Manufacturing Technology)
- Industrial Internet of Things (IIoT)
- Cyber Physical Systems (CPS)

Source: Sangiovanni-Vincentelli 2016, ISC2 2016
**IoT Vs Sensor Networks**

**Wireless Sensor Networks (WSN)**
- WSN is like the eyes and ears of the IoT.
- A network of small wireless electronic nodes which consists of different sensors.
- The purpose is to collect data from the environment.

**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.

**IoT adds value to data!**

Source: Nia 2017, IEEE TETC 2017

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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.

Cloud Computing
- Scalability
- Big Data Analytics
- Software as a Service (SaaS)
- Infrastructure as a Service (IaaS)
- Platform as a Service (PaaS)
- Resource Pooling
- Elastic Compute
- Secure Access

Edge Computing
- Dedicated App Hosting
- Embedded OS
- Device management
- Data Service
- Communication
- Real-Time Control
- Real-Time Analysis
- Data Ownership Protection
- Secure Multi-Cloud interworking

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

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

Fog vs Edge Computing
- IoT Keynote by Prof./Dr. Saraju P. Mohanty

Source: https://www.automationworld.com/fog-computing-vs-edge-computing-whats-difference
Internet of Every Things (IoE)

People
Connecting people in more relevant, valuable ways

Process
Delivering the right information to the right person (or machine) at the right time

Data
Converting data into intelligence to make better decisions

Things
Physical devices and objects connected to the Internet and each other for intelligent decision making; often called Internet of Things (IoT)

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.
Membership Fee: $20
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1) A nice color magazine shipped to your doorstep to update you on the latest CE
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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

Vice Chair for Membership –
Hai (Helen) Li, Duke University

Vice Chair for Liaison –
Dhruva Ghai, Oriental University Indore, India

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Nagi Naganathan, Avago Technologies

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

Thank You !!!

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