# Everything you Wanted to Know about Smart Cities

## IEEE Distinguished Lecture

## CE Society Webinar, 5th Oct 2017 (Thu)

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# Talk: Outline

- Smarty City Drivers
- Smarty City Components
- Smarty City Technologies
- Design and Operation of Smarty Cities
- Challenges and Research on Smarty Cities
- Tools and Solutions for Smarty Cities
- Initiatives on Smarty Cities
- Standards for Smarty Cities
- Conclusions and Future Directions

# Drivers

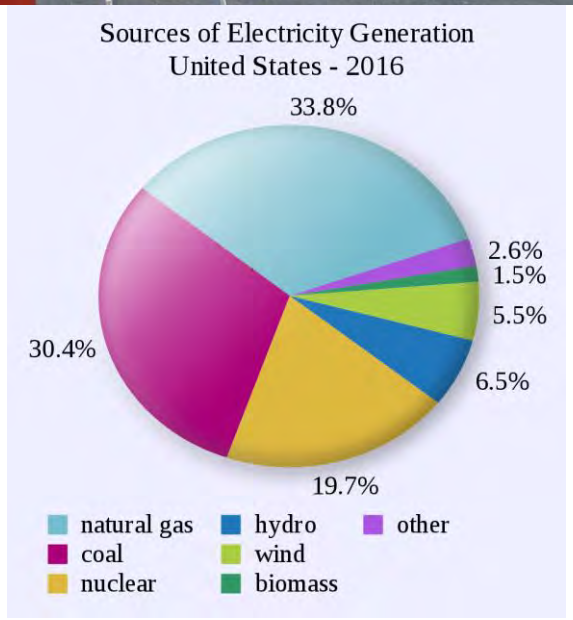
# Population Trend

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

Source: http://www.urbangateway.org

# Issues Challenging Sustainability


- Energy crisis




# Issues Challenging Sustainability

- Pollutions

# The Problem

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

Source: https://humanitycollege.org

# The Solution

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

# Smart Cities: Formal Definition

- Definition - 1: A city "connecting the physical infrastructure, the information-technology infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city".

- Definition - 2: "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects".

Source: Mohanty 2016, CE Magazine July 2016

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# Other drivers …

- Managing vital services
  - Waste management
  - Traffic management
  - Quality Healthcare
  - Crime prevention
- Making the city competitive
  - Investment
  - Tourism
- Technology push
  - IoT, CPS, Sensor, Wireless

Source: Sangiovanni-Vincentelli 2016, ISC2 2016

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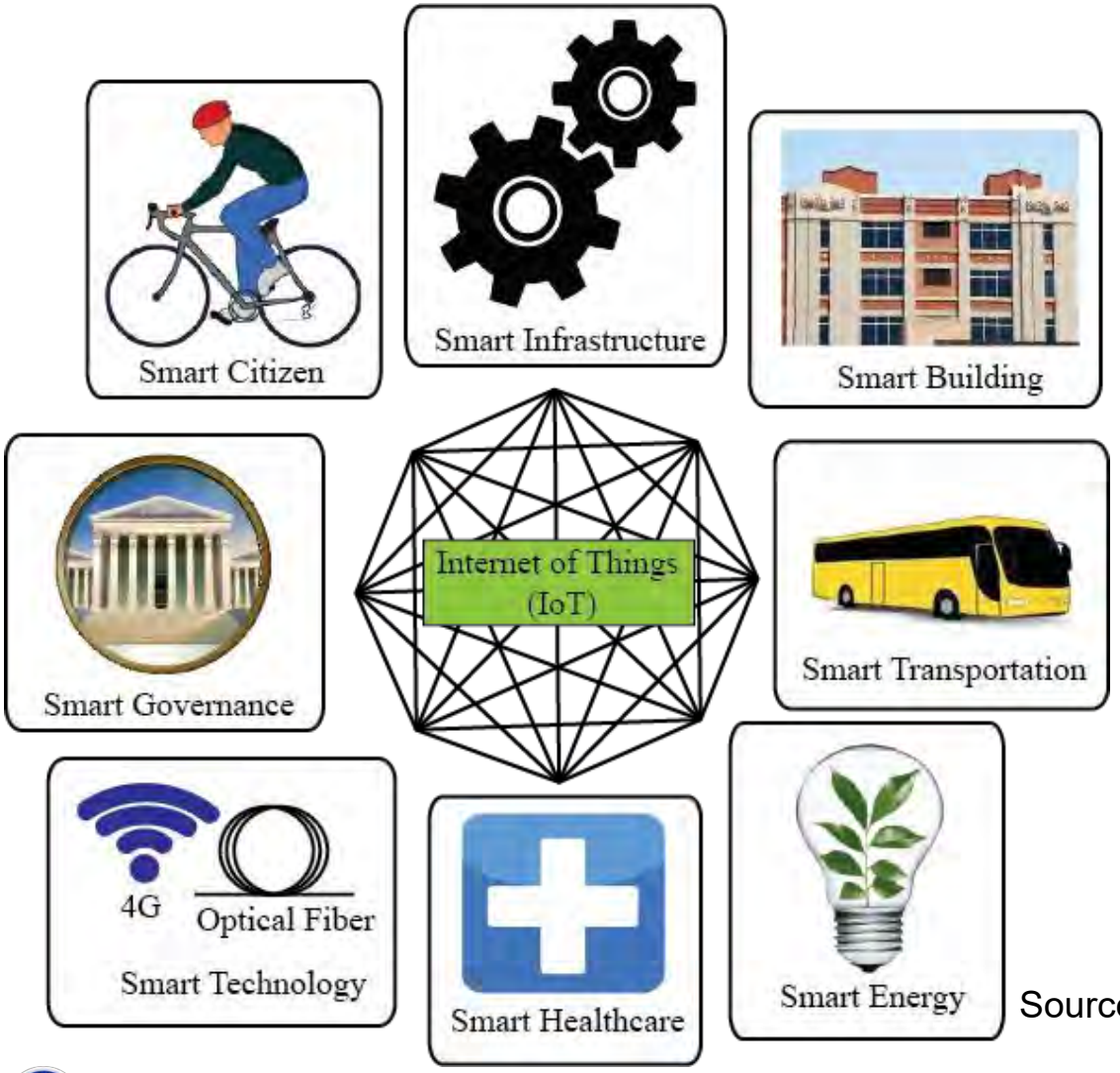
# Components

# Smart Cities: Components




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

Source: Mohanty 2016, CE Magazine July 2016

# Smart Transportation

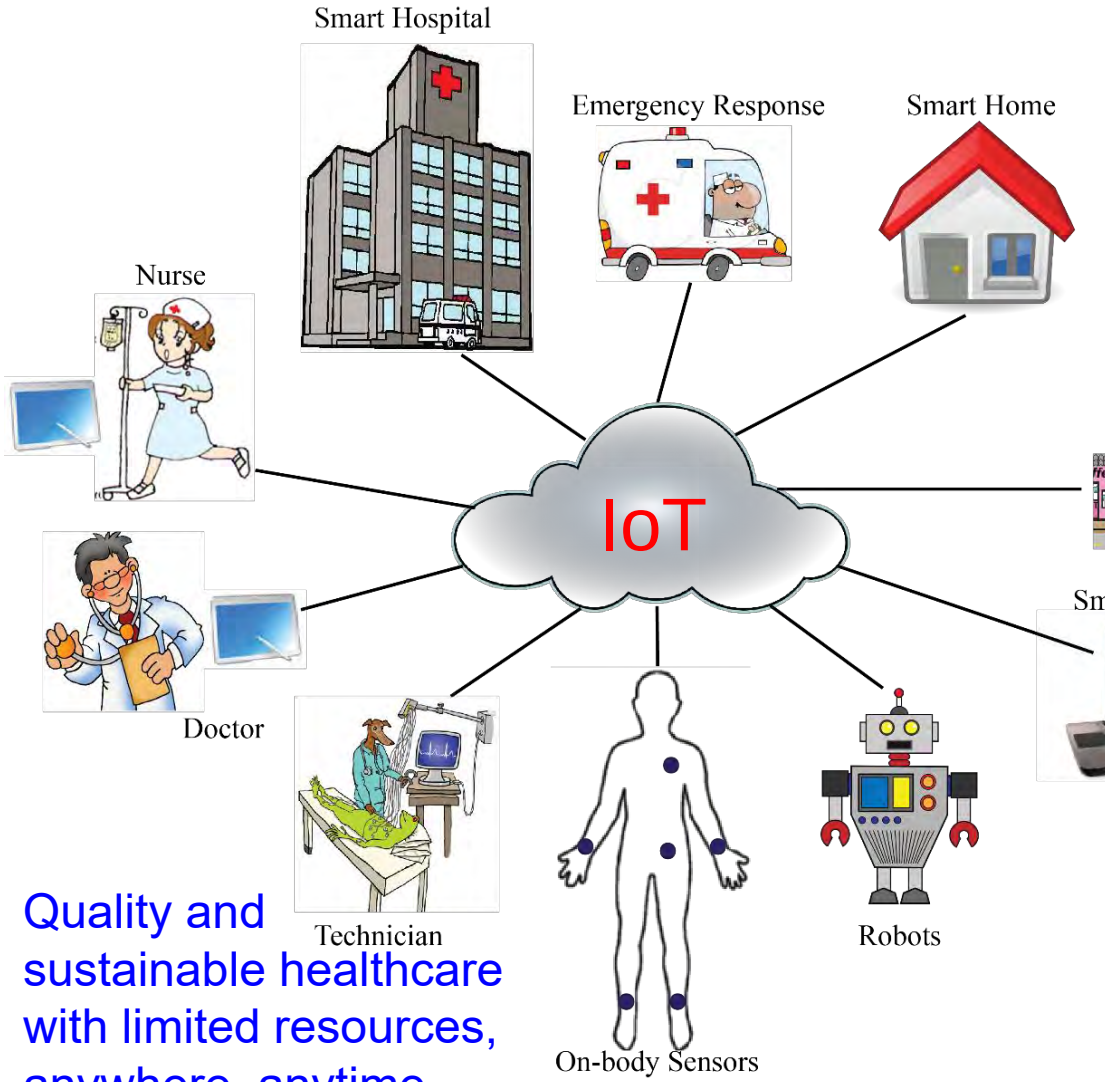

Smart Transportation Features:

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


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

Source: Mohanty 2016, CE Magazine July 2016

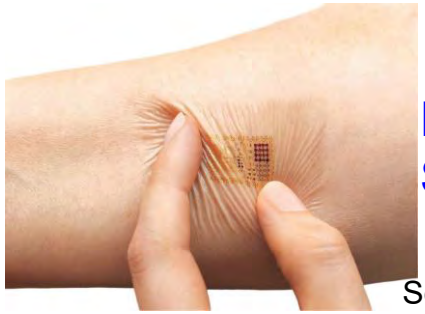
# Smart Healthcare




Fitness Trackers

Headband with Embedded Neurosensors

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

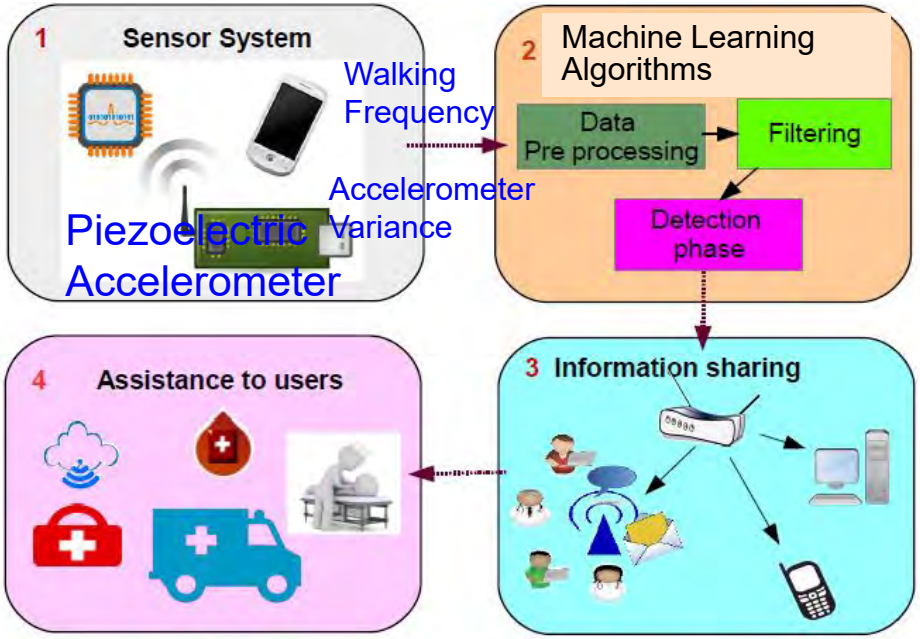


Embedded Skin Patches

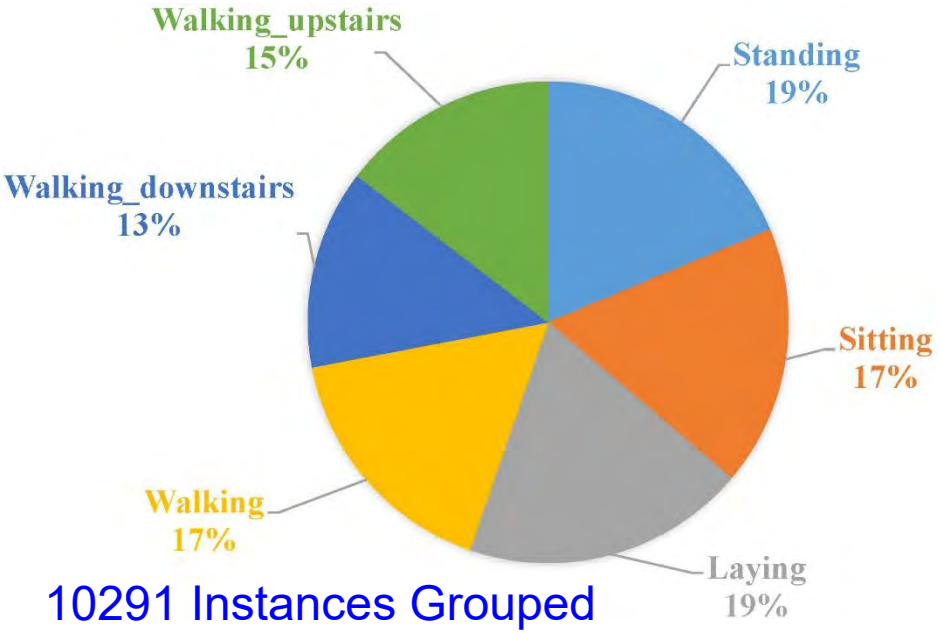
Sethi 2017: JECE 2017

Source: Mohanty 2016, CE Magazine July 2016

# Smart Healthcare: Smart-Walk




Automated Physiological Monitoring System




10291 Instances Grouped Under 6 Activities - Kaggle

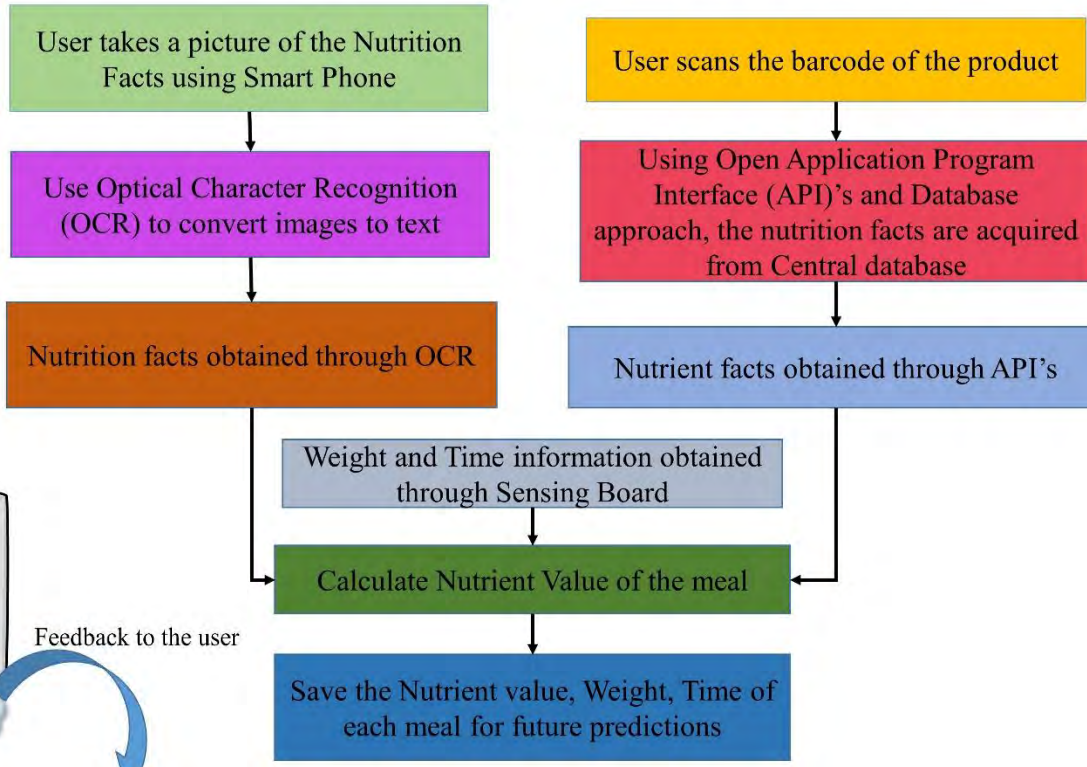
| Research Works | Method | Features considered | Activities | Accuracy (%) |
|---|---|---|---|---|
| **This Work** | Adaptive algorithm based on feature extraction (WEKA) | Step detection and Step length estimation | Walking, sitting, standing, etc. | 97.9 |

Source: Mohanty ICCE 2018

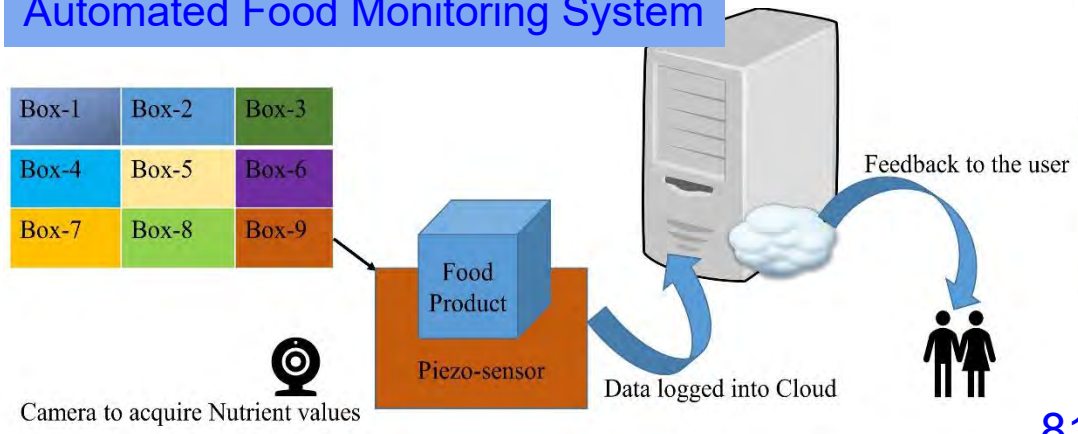
# Smart Healthcare: Smart-Log

- Smart Sensor Board
- Data Acquisition
- Future Meal Predictions

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




## Automated Food Monitoring System

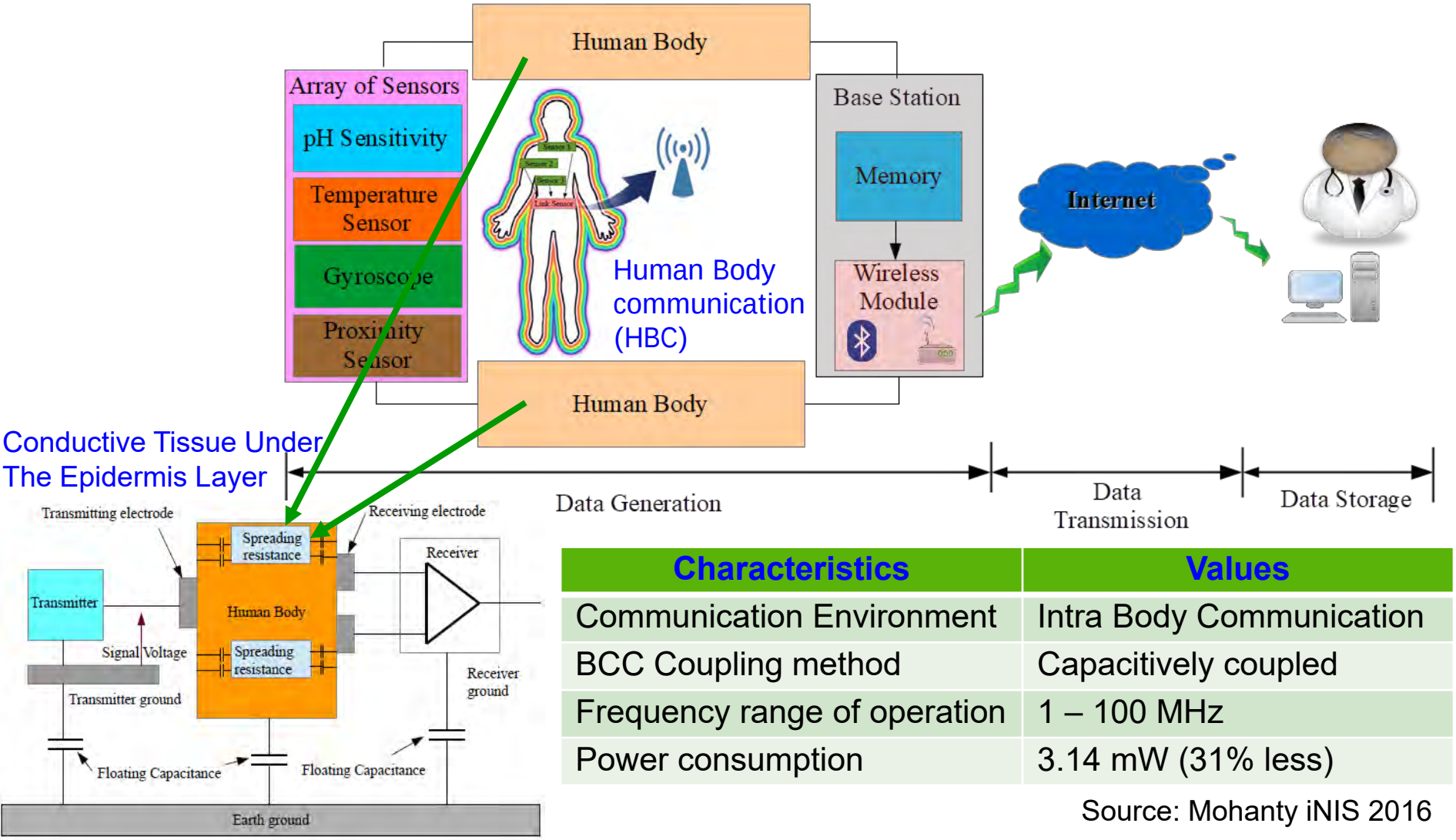



8172 user instances were considered

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

Source: Mohanty ICCE 2018

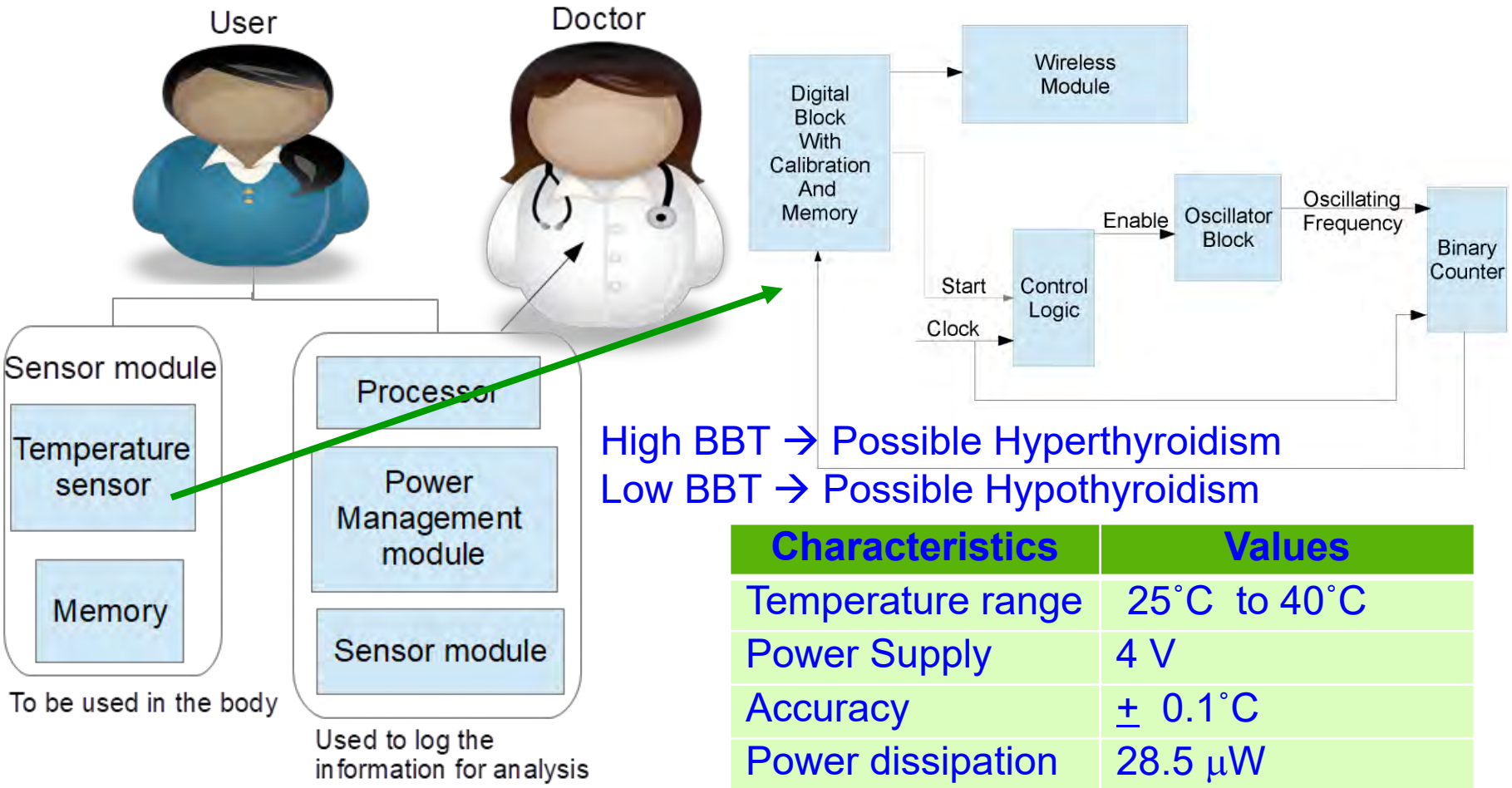
# Smart Healthcare: Ambulatory Health Monitoring System




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

Source: Mohanty iNIS 2016

# Smart Healthcare: Thyroid Monitoring System



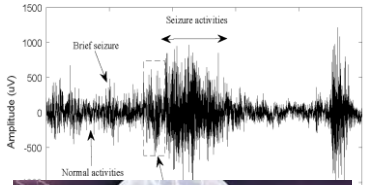

High BBT → Possible Hyperthyroidism
Low BBT → Possible Hypothyroidism

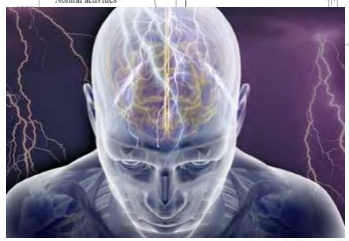
| Characteristics | Values |
|---|---|
| Temperature range | 25˚C to 40˚C |
| Power Supply | 4 V |
| Accuracy | ± 0.1˚C |
| Power dissipation | 28.5 μW |
| Frequency range | 42.906 – 43.5 MHz |

Source: Mohanty EuroSimE 2016

Continuously monitors the basal body temperature (BBT)

# Smart Healthcare: Epileptic Seizure Detector



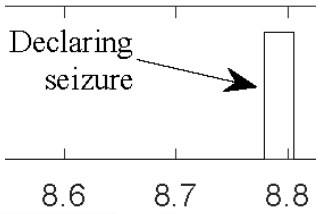
EEG Signal

Input Signal

Clock

Over-excitation Threshold

Signal Rejection Algorithm (SRA)

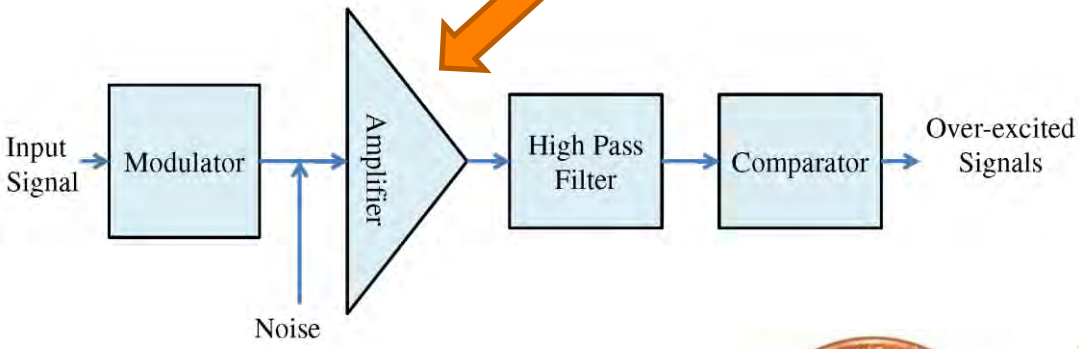



Over-excitation Detection Circuit

Count Seizure Activity

Declare Seizure Event

Seizure prediction

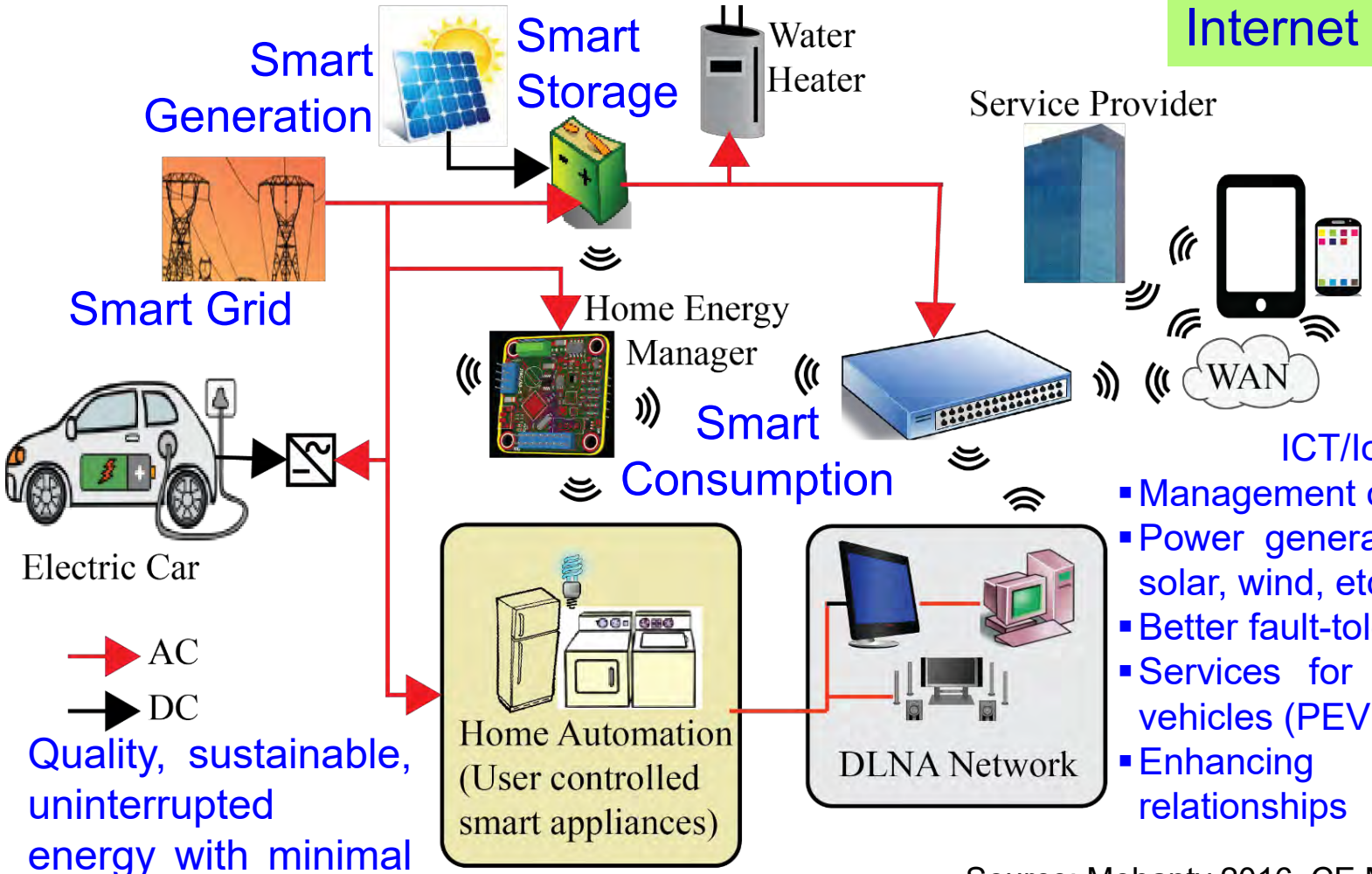



| Parameter | Value |
|---|---|
| Seizure Frequency (Minimum) | 5 Hz |
| Seizure Frequency (Minimum) | 25 HZ |
| Voltage Level Detector (Avg. Lower Threshold) | 210 mV |
| Voltage Level Detector (Avg. Upper Threshold) | 380 mV |
| Total power consumption | 6.18 µW |

Source: Mohanty ICCE 2018


Source: Zaveri, Yale University

# Smart Energy




Internet of Energy

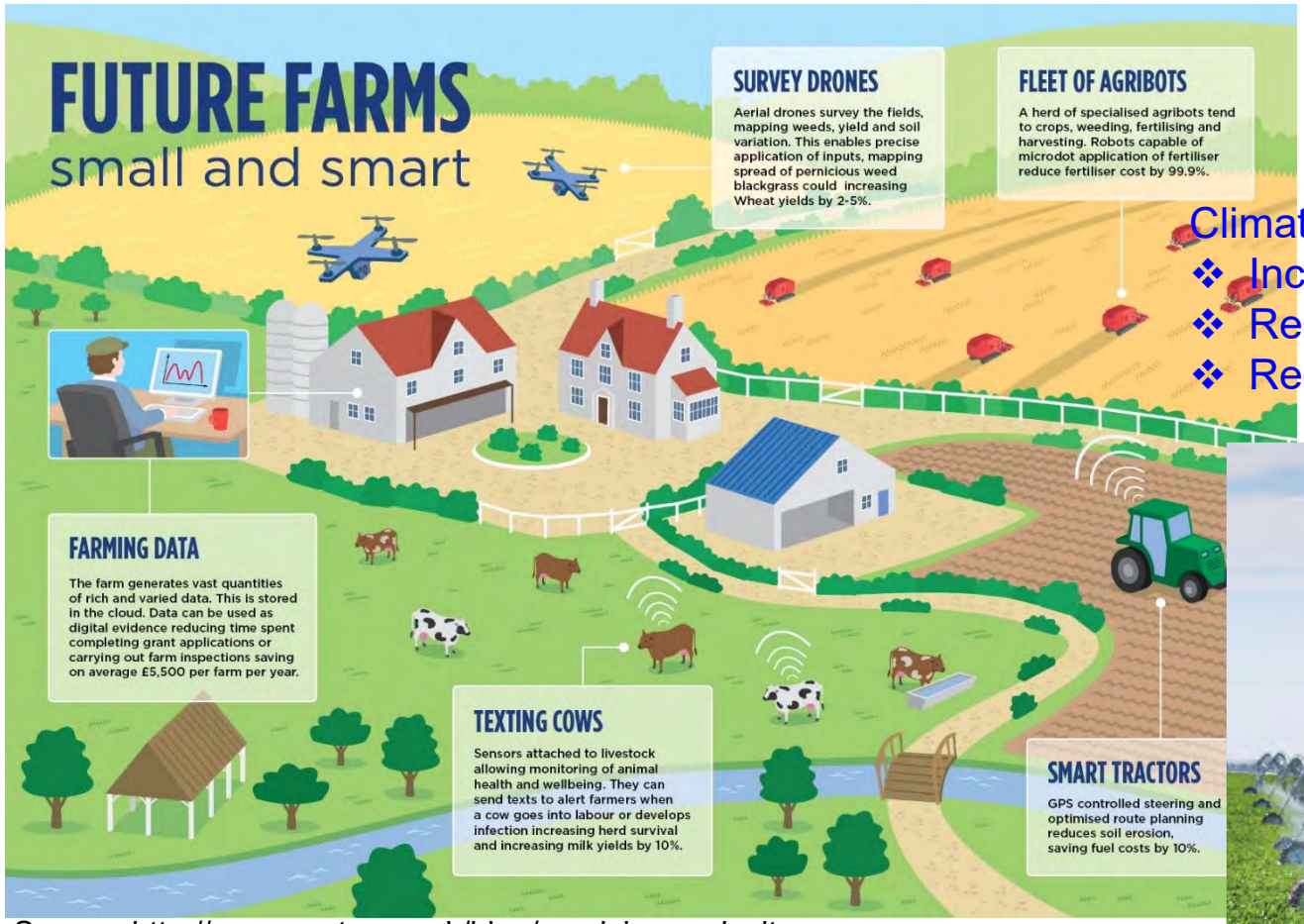
ICT/IoT Role:

- 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.

Source: Mohanty 2016, CE Magazine July 2016

# Smart Agriculture




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

Climate-Smart Agriculture Objectives:

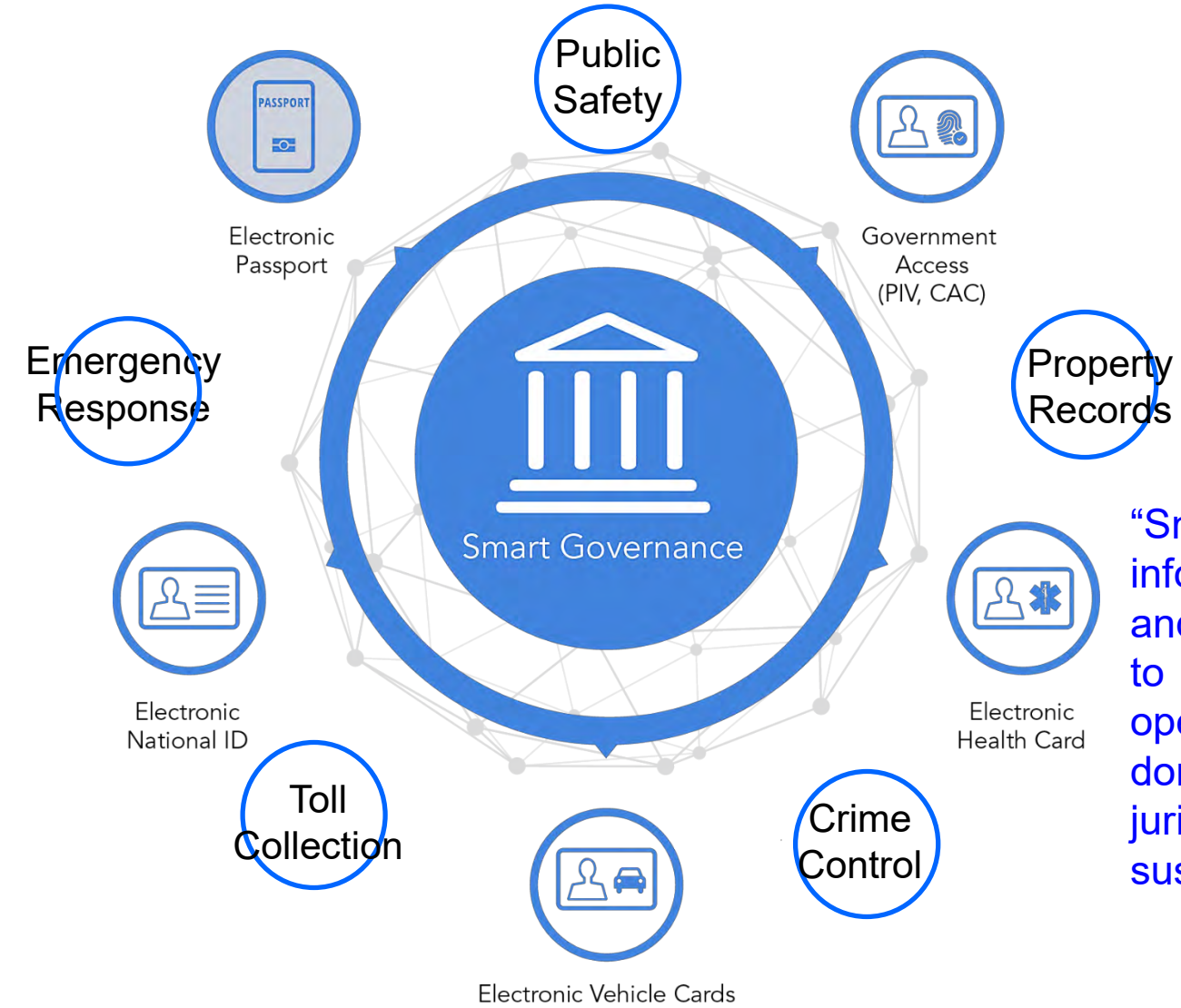
- Increasing agricultural productivity
- Resilience to climate change
- Reducing greenhouse gas

http://www.fao.org

Automatic Irrigation System

Source: Maurya 2017: CE Magazine July 2017

# Smart Government




"Smart government integrates information, communication and operational technologies to planning, management and operations across multiple domains, process areas and jurisdictions to generate sustainable public value."

-- http://www.gartner.com

Source: http://www.nxp.com/applications/internet-of-things/secure-things/smart-government-identification:SMART-GOVERNANCE

# Technologies

# Smart Cities

Smart Cities ←

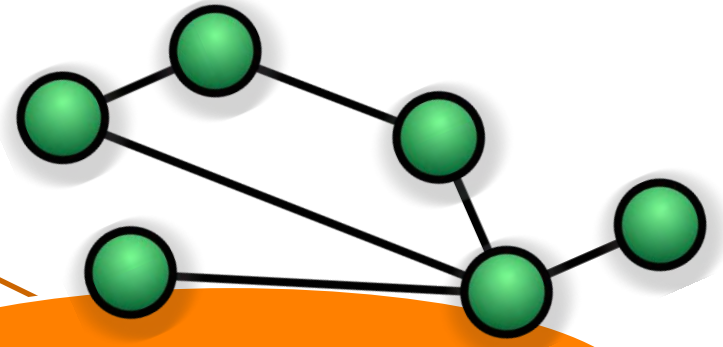
Regular Cities
+ Information and Communication Technology (ICT)
+ Smart Components
+ Smart Technologies

# Smart Cities: 3 Is


Instrumentation

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

Smart Cities



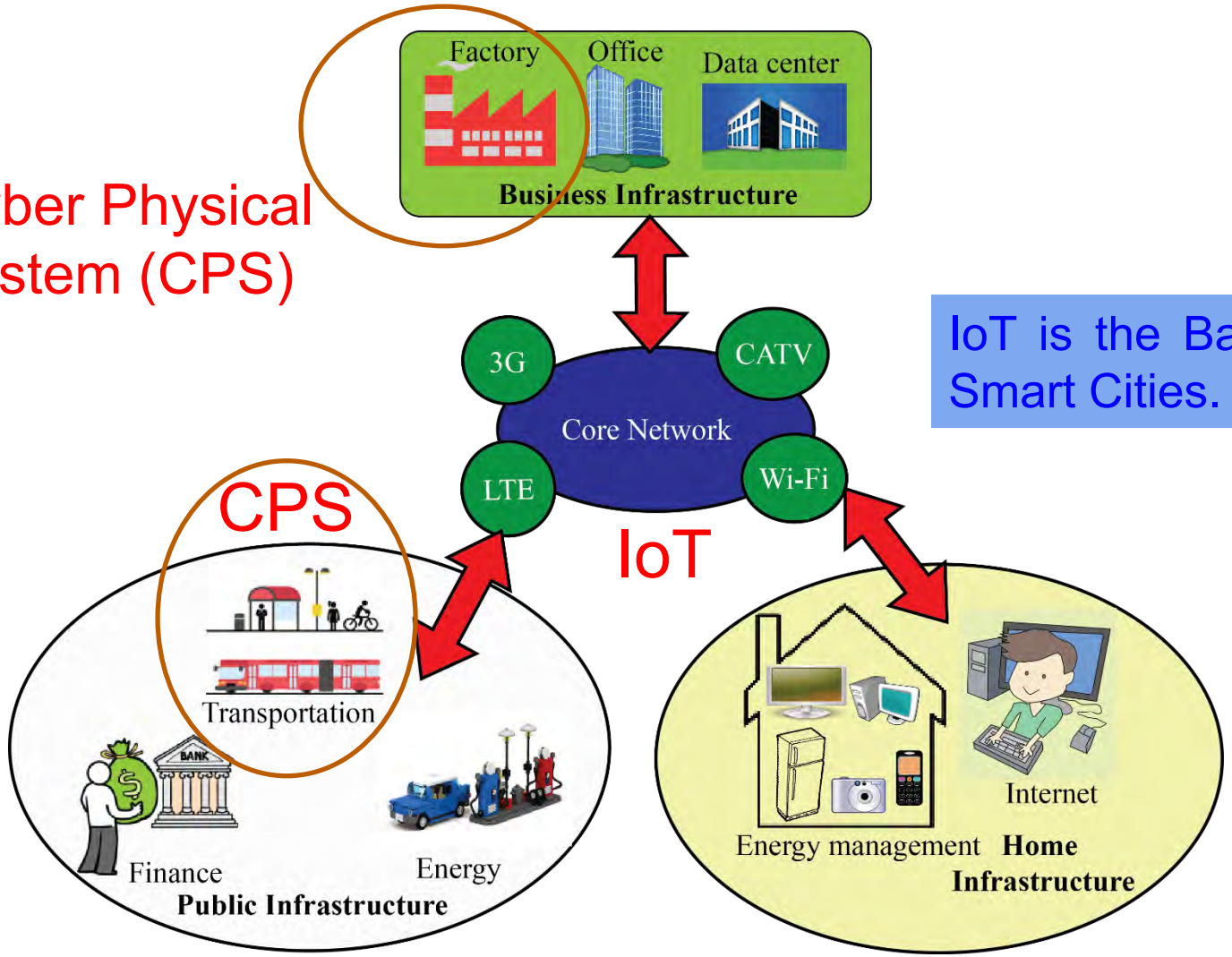
Intelligence

Interconnection

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

# Smart Infrastructure

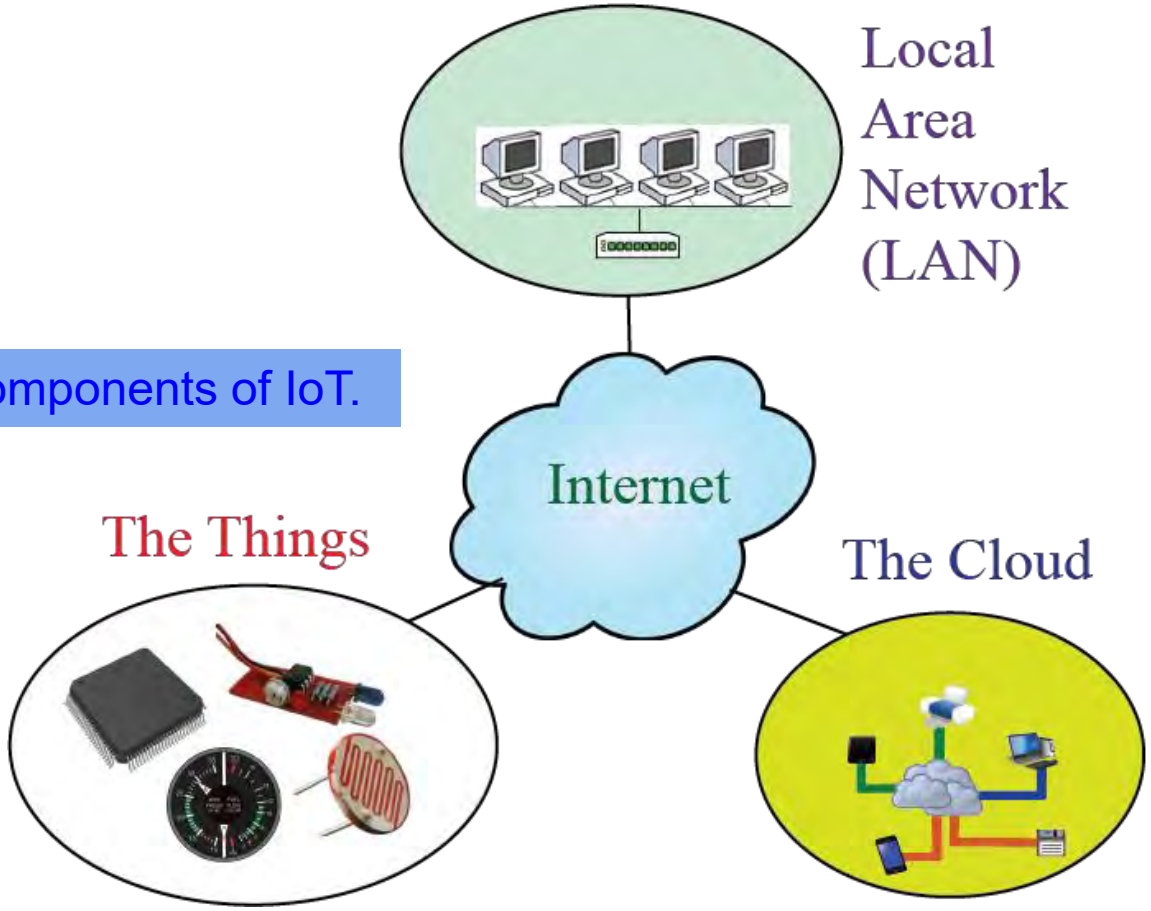
Cyber Physical System (CPS)




IoT is the Backbone Smart Cities.

Source: Mohanty 2016, CE Magazine July 2016

# IoT: Architecture




Four Main Components of IoT.

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

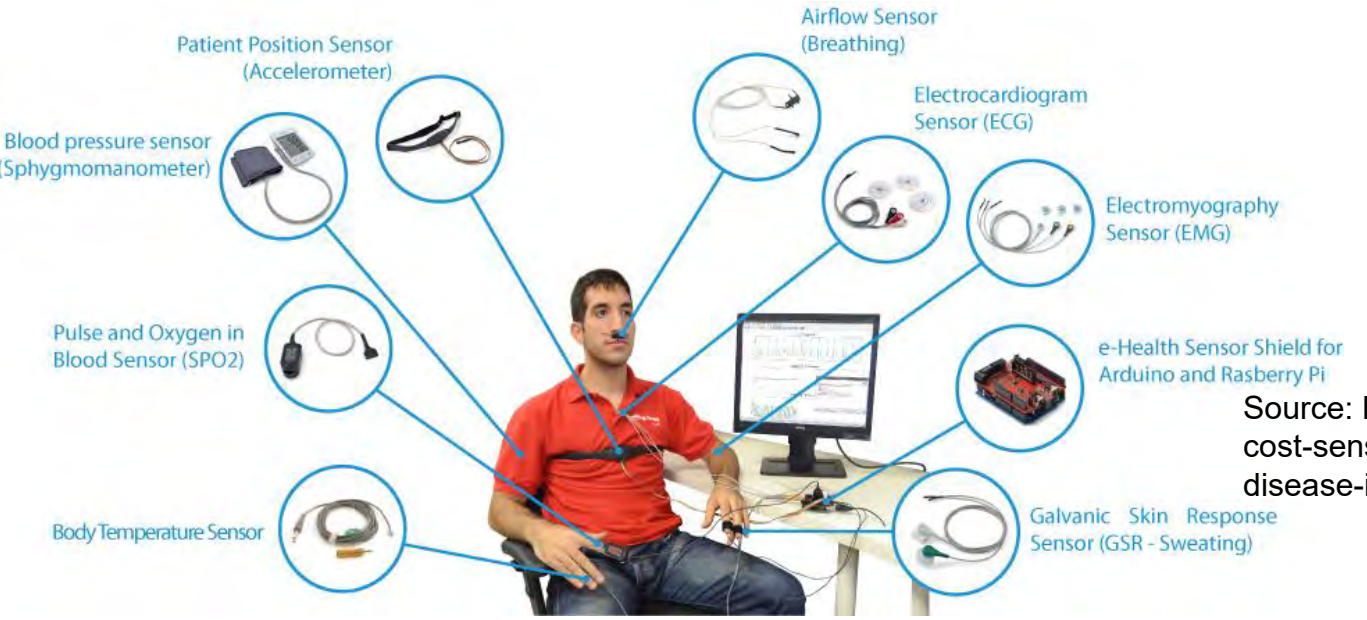
Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

# IoT: The Things

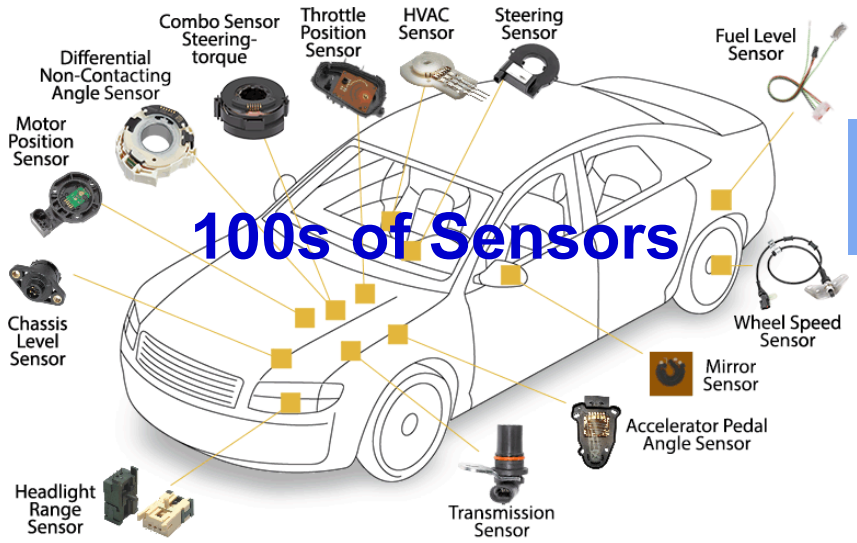
- EveryTHING is connected
- EveryTHING emits signals
- EveryTHING communicates

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.

# Sensor Technology: Wide Variety



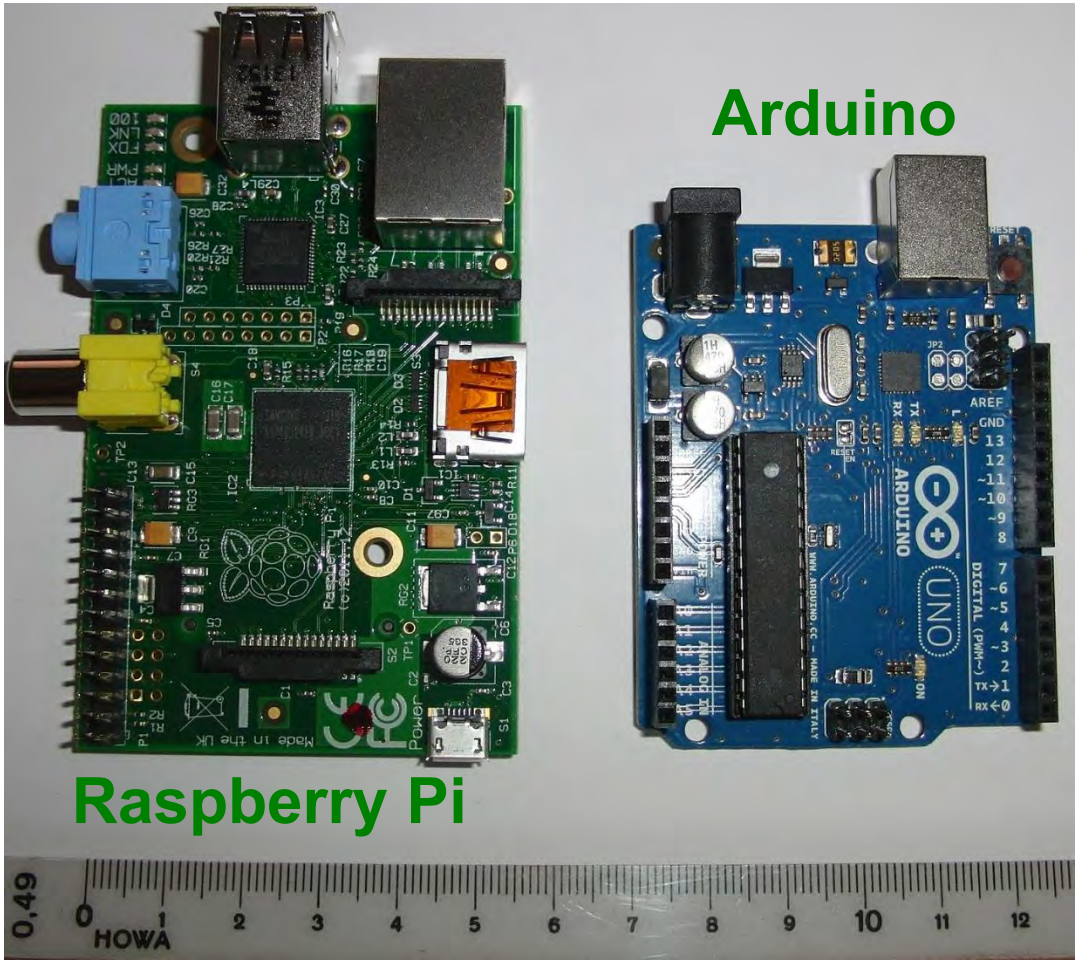

Source: http://www.libelium.com/e-health-low-cost-sensors-for-early-detection-of-childhood-disease-inspire-project-hope/

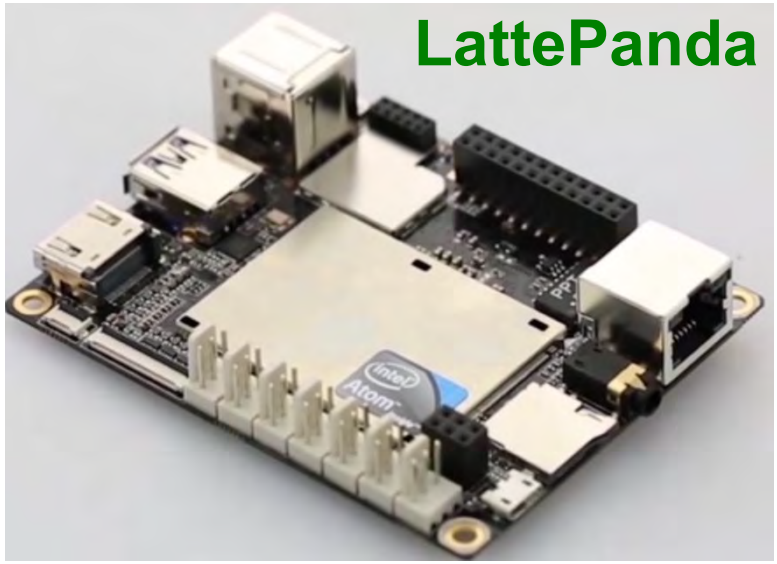



Thing ← Sensor
+ Device with its own IP address

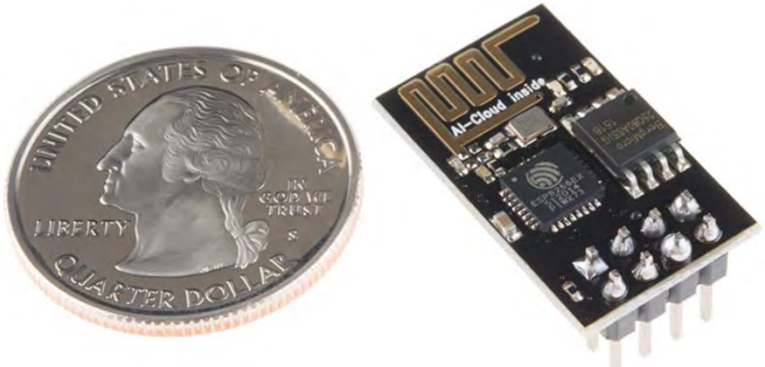
# Communications Technology: Wide Variety

# Computing Technology: Cheaper



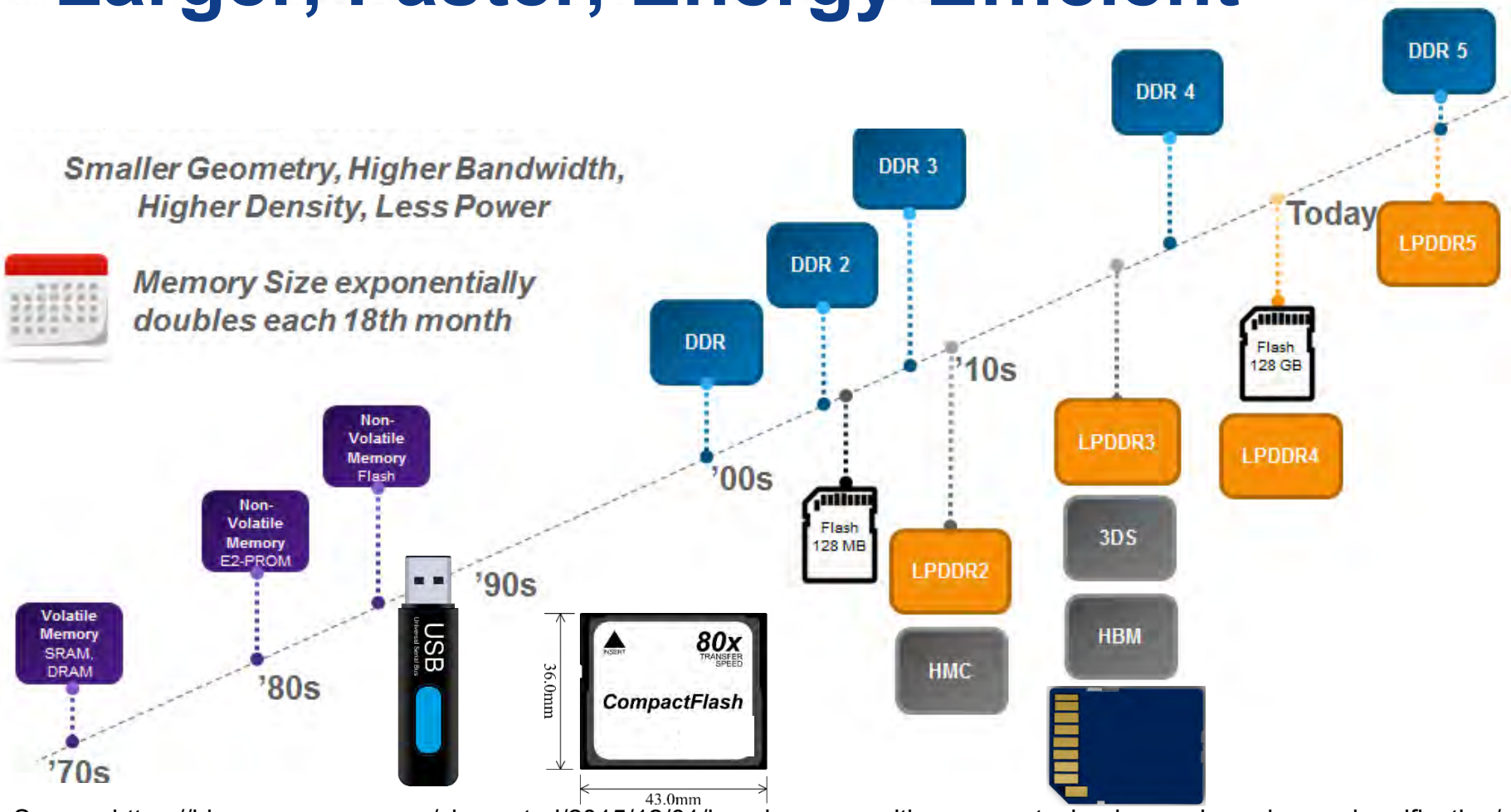




Source: http://www.lattepanda.com




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

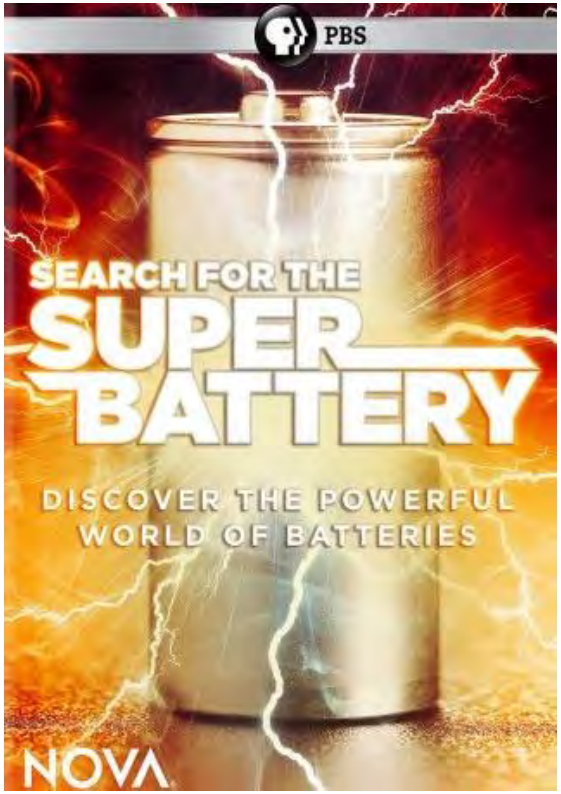
# Memory Technology: Cheaper, Larger, Faster, Energy-Efficient




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

# Energy Storage: High Capacity and Efficiency

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




Intelligent Battery

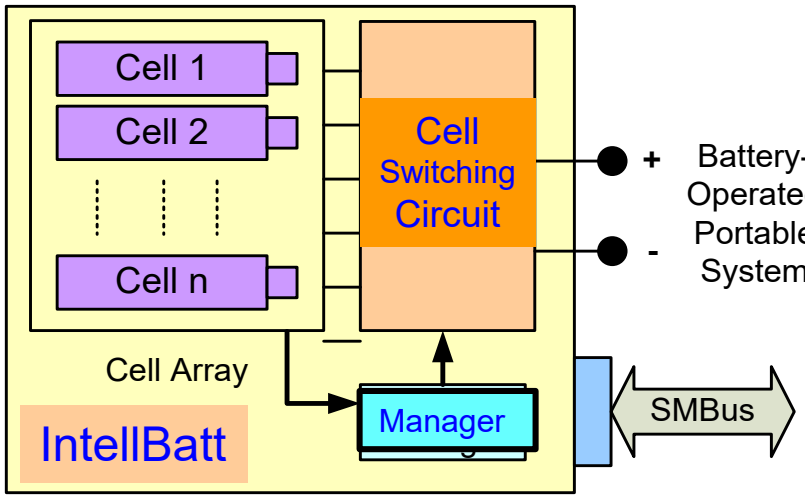


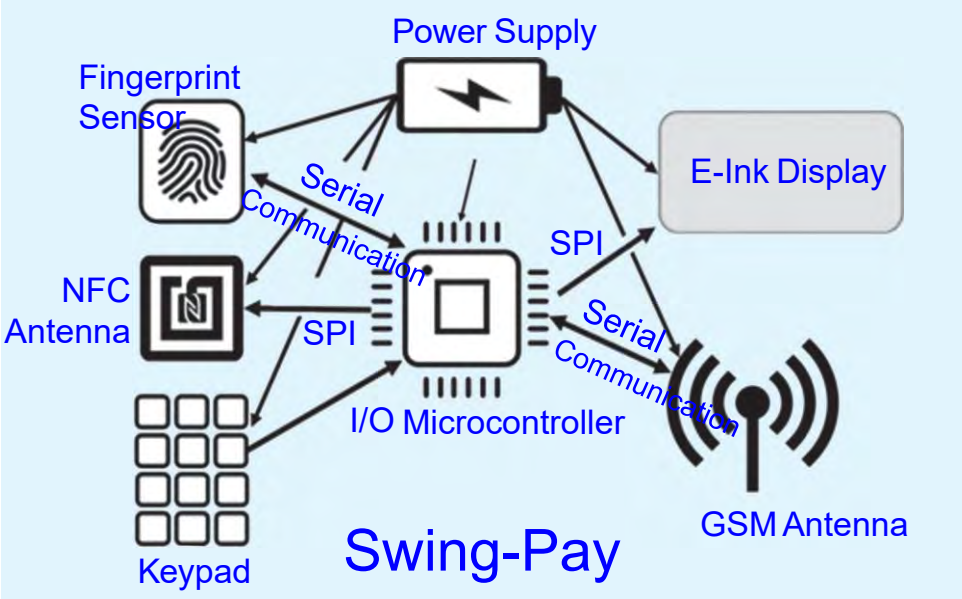

Figure 1: IntellBatt Architecture

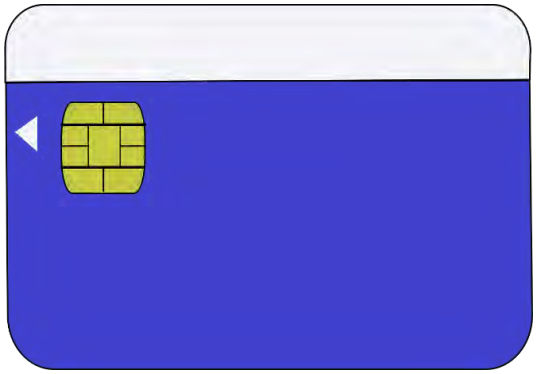
Mohanty 2010: IEEE Computer, March 2010.
Mohanty 2018: ICCE 2018


Lithium Polymer Battery


Supercapacitor

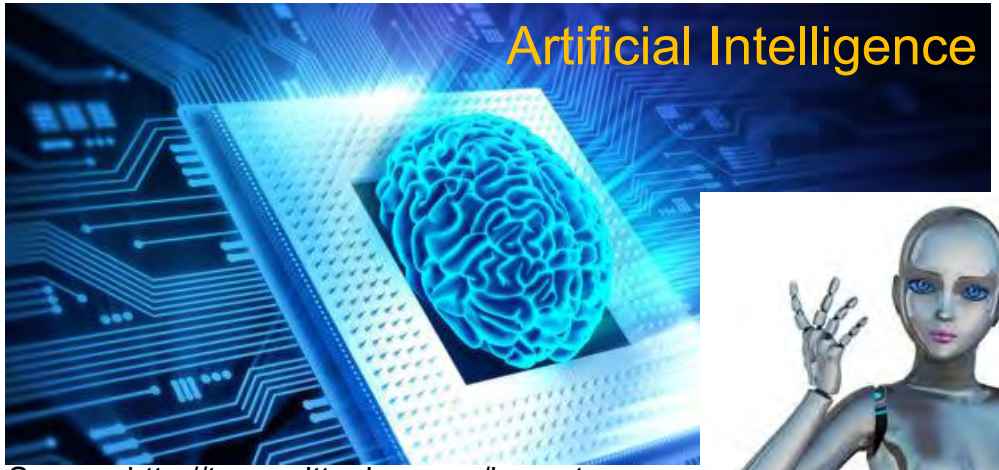
# Cashless Payment Technology: An Example



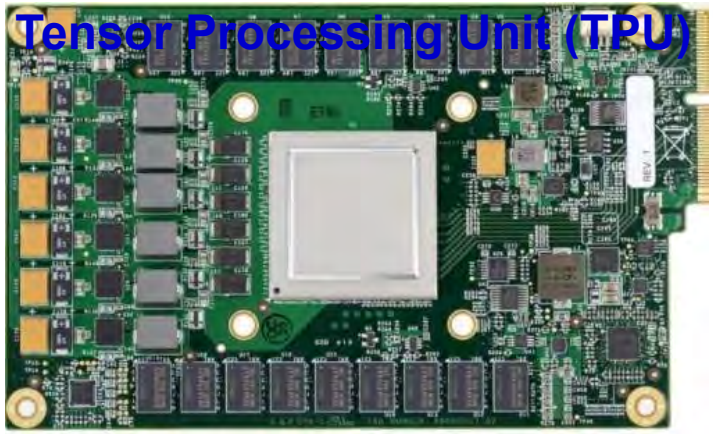



Source: Mohanty 2017, CE Magazine Jan 2017

# Machine Learning Technology

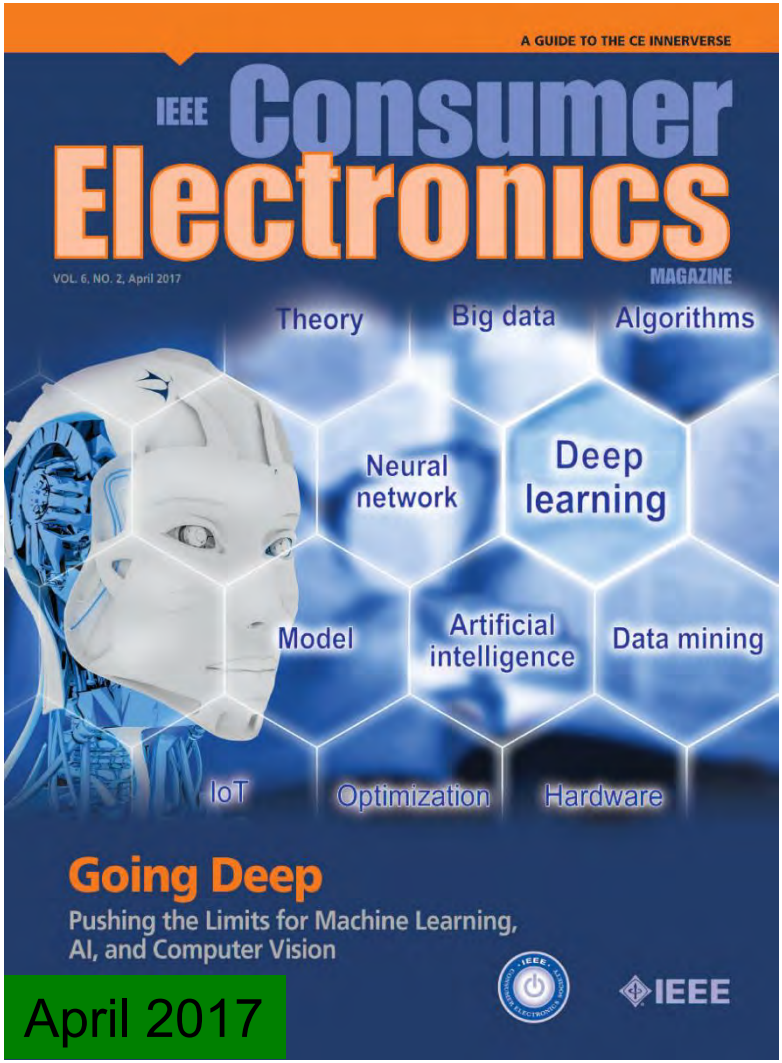



Source: http://transmitter.ieee.org/impact-aimachine-learning-iot-various-industries/




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

Smart City Use:
- Better decision
- Faster response



# Virtual and Augmented Reality Technology


Virtual Reality

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

Augmented Reality


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

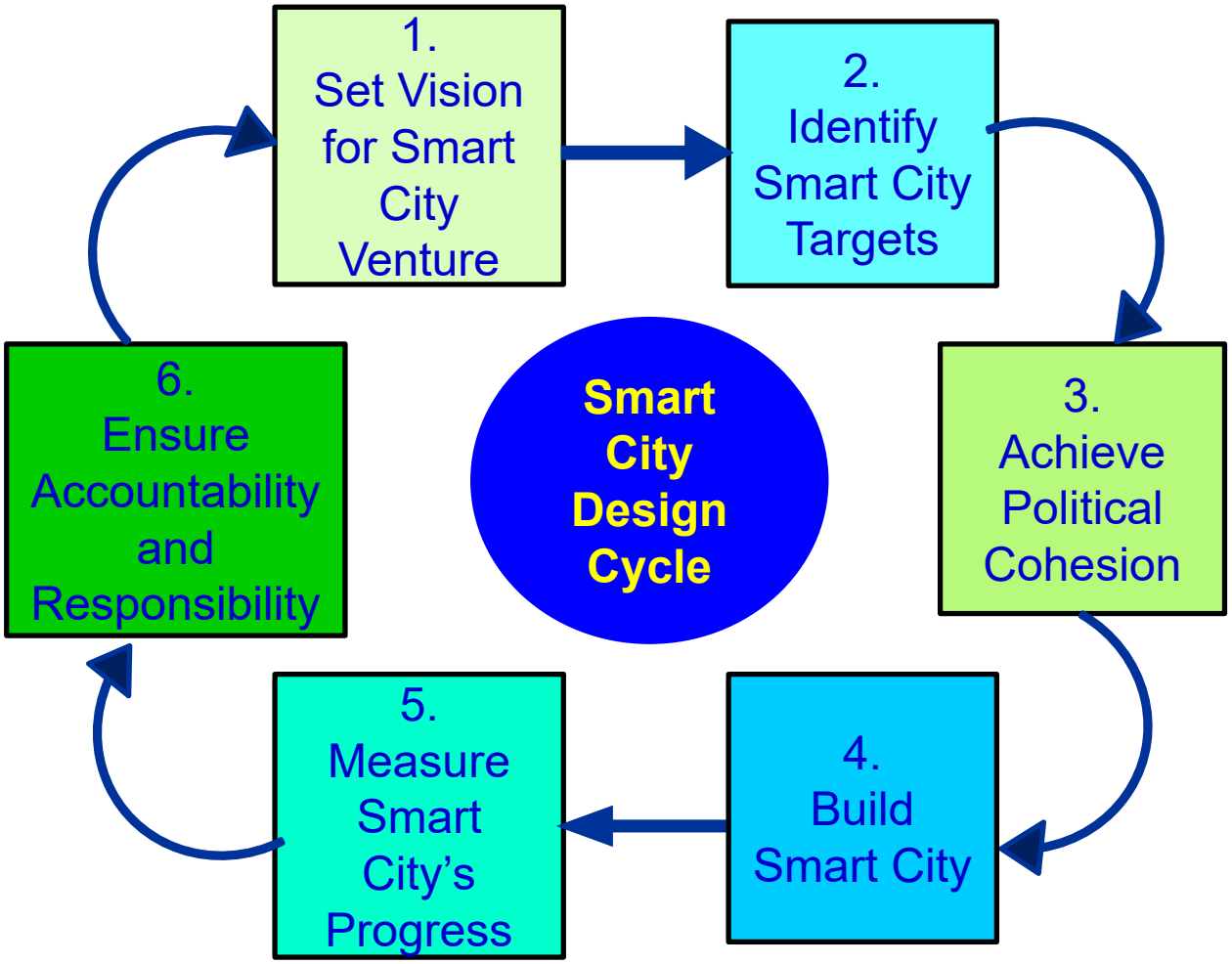
# Technology in Smart Cities

| Smart Cities Technology | % of Cities Adopting |
|---|---|
| Geospatial/mapping | 69 |
| Virtualization | 67 |
| Performance benchmarking | 60 |
| Transaction processing | 58 |
| Project management | 57 |
| Consolidation | 57 |

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

# Design and Operation

# Smart Cities: Design Cycle




Source: Paolo Gemma 2016, ISC2 2016

# Smart City Design: Vision and Target

1. Set Vision for Smart City Venture

2. Identify Smart City Targets

Source: Paolo Gemma 2016, ISC2 2016

# Smart City Design: Stakeholders

3. Achieve Political Cohesion

4. Build Smart City

International, Regional and Multilateral Organizations

Academia, Research Organizations and Specialized Bodies

ICT Companies

City Service Companies

Utility Providers

Urban Planners

Municipalities, City Council and City Administration

Standardization Bodies

National and Regional Governments

Citizens and Citizen Organizations

Non-Governmental Organization (NGO)

Industry Associations

Source: Paolo Gemma 2016, ISC2 2016

# Smart City Design: Sustainable Goals

5. Measure City's Progress

Dimensions of Key Performance Indicators (KPIs)

| Environment | Society and Culture | Economy |
|---|---|---|
| • Air quality<br>• Water<br>• Noise<br>• Biodiversity<br>• Energy<br>• Environmental quality | • Education<br>• Health<br>• Safety<br>• Housing<br>• Culture<br>• Social inclusion | • Innovation<br>• Employment<br>• Trade<br>• Productivity<br>• Physical infrastructure<br>• ICT infrastructure and Access/Usage<br>• Public Sector |

Source: Paolo Gemma 2016, ISC2 2016

# Smart City Design: Building Trust

6. Ensure Accountability and Responsibility

Citizen-Centric

Smart Tools

Data-Driven Decision

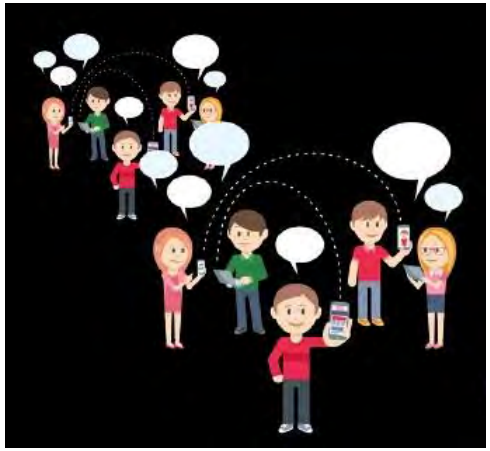
Cost Effective

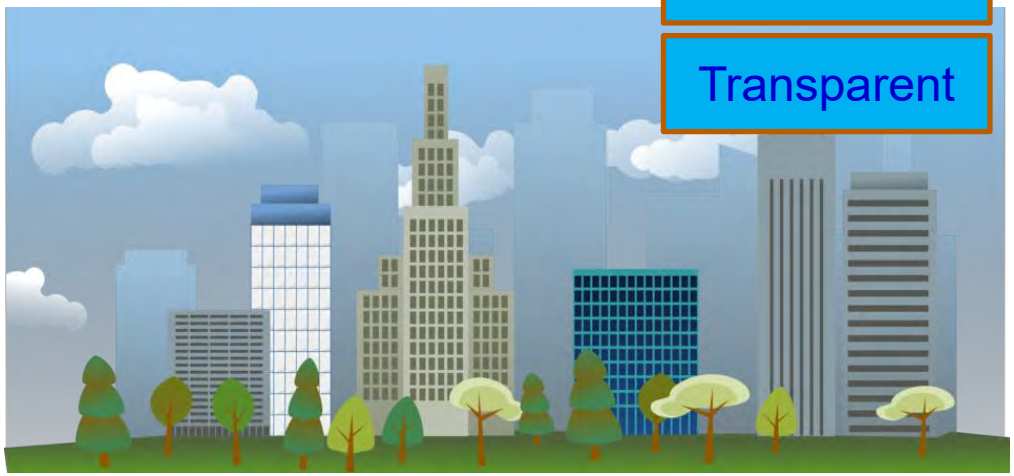
Collaborative

Responsive

Accountable

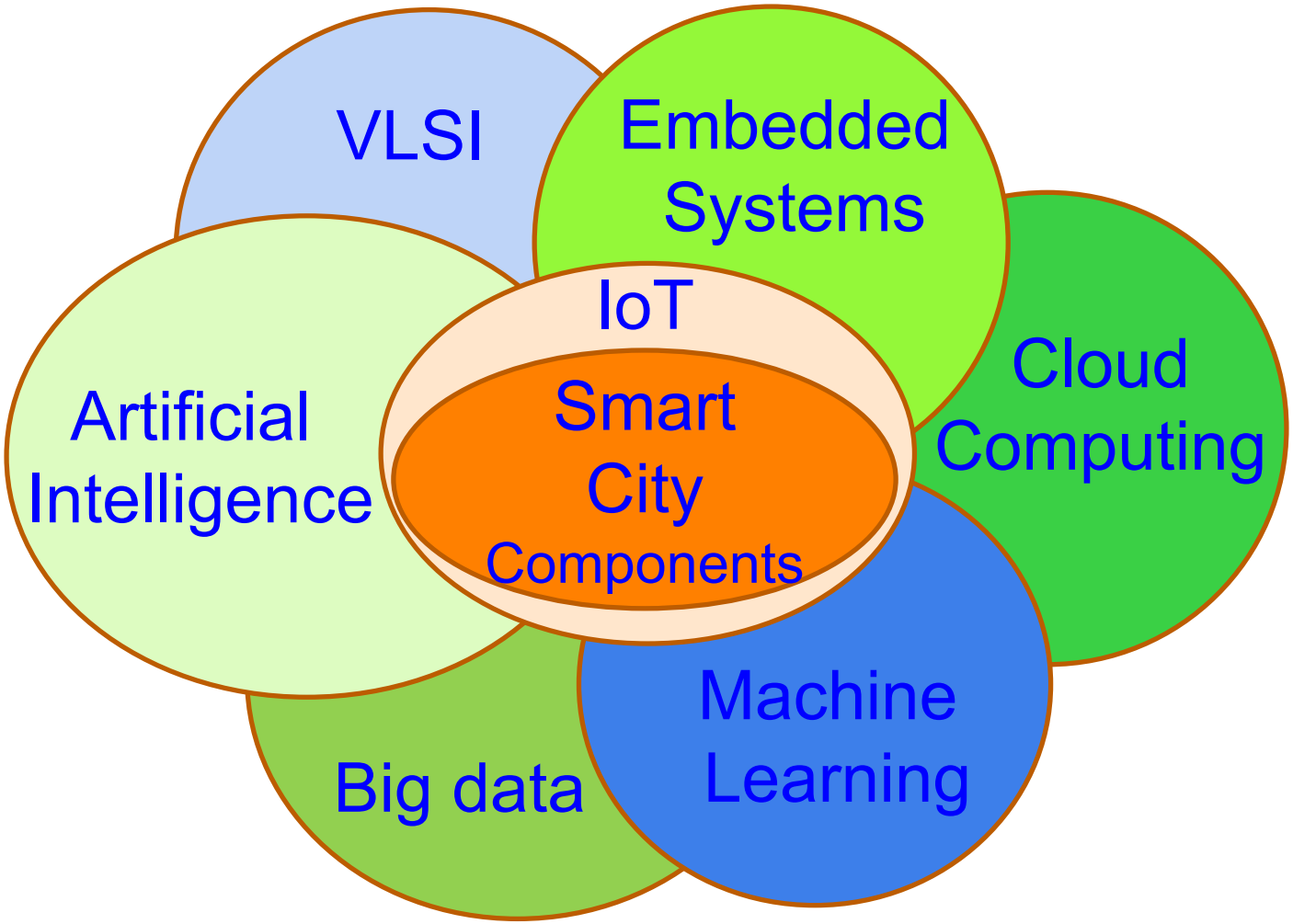
Transparent





Source: Paolo Gemma 2016, ISC2 2016

# Smart City Design: Verticals



# Smart City Design: ICT/IoT is Key


Source: https://www.pinterest.com/source/hitachi.com/

# Challenges and Research

# Smart City: Selected Design Challenges


Smart City Design Challenges

- Design Cost
- Operation Efficiency
- Carbon Emission ($CO_2$)
- City Growth
- Disaster Resilience
- Reliable Communication
- Information Security
- Operation Cost
- City Waste
- City Sustainability
- System Failure
- Data Volume
- Public Safety

Source: Mohanty 2016, CE Magazine July 2016

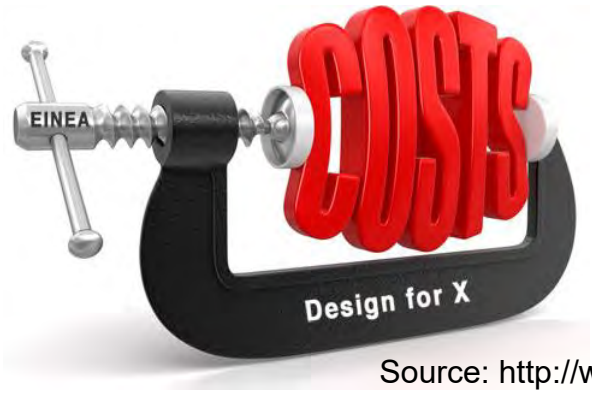
# Cost

- "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

# Design Cost

- The design cost is a one-time cost.
- Design cost needs to be small to make a smart city realization possible.




Source: http://www.industrialisation-produits-electroniques.fr

# Operational Cost

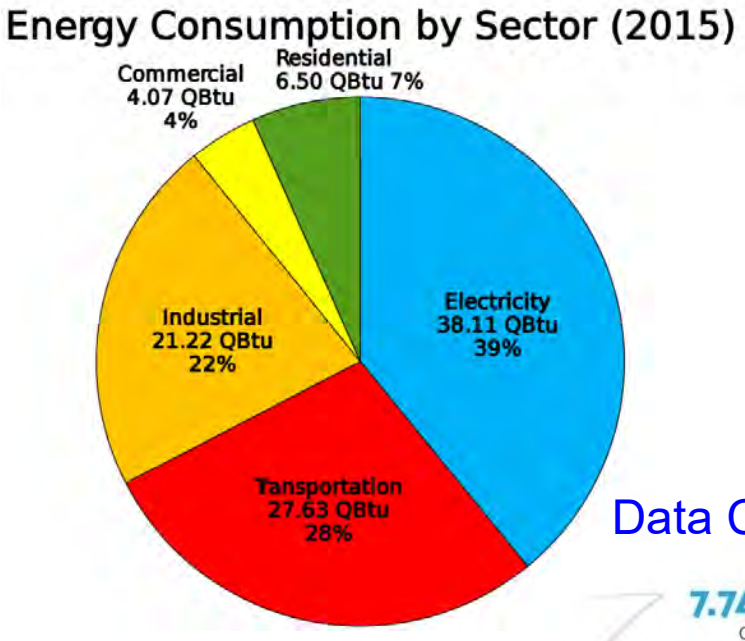
- The operations cost is that required to maintain the smart city.
- A small operations cost will make it easier for cities to operate in the long run with minimal burden on the city budget.

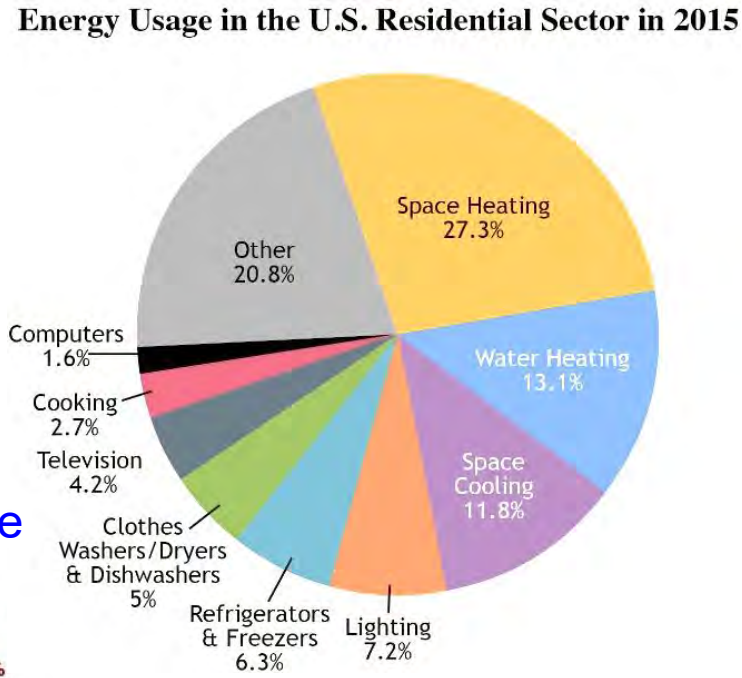
# Cost: Technology

| Smart Cities Technology | % Net Increase in All Cities |
|---|---|
| Cloud apps | 86 |
| Mobile devices | 66.6 |
| Business applications | 61.9 |
| Outsourcing | 53.8 |
| Security & privacy | 53.8 |

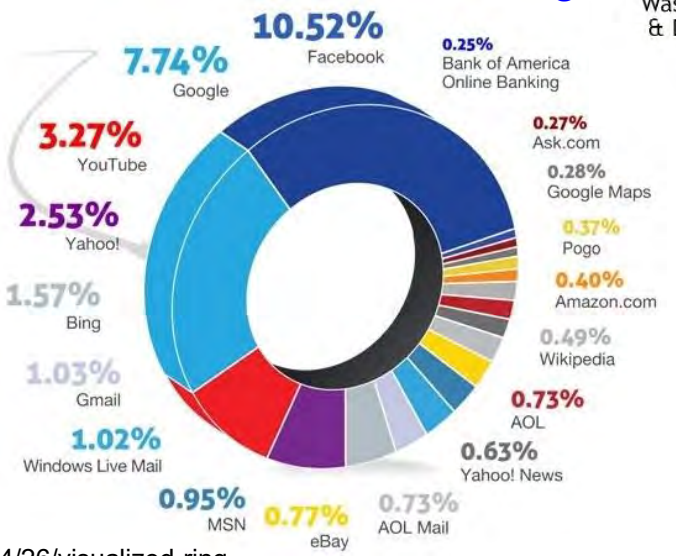
Source: http://www.cnbc.com/2016/10/25/spending-on-smart-cities-around-the-world-could-reach-41-trillion.html

# Energy Consumption



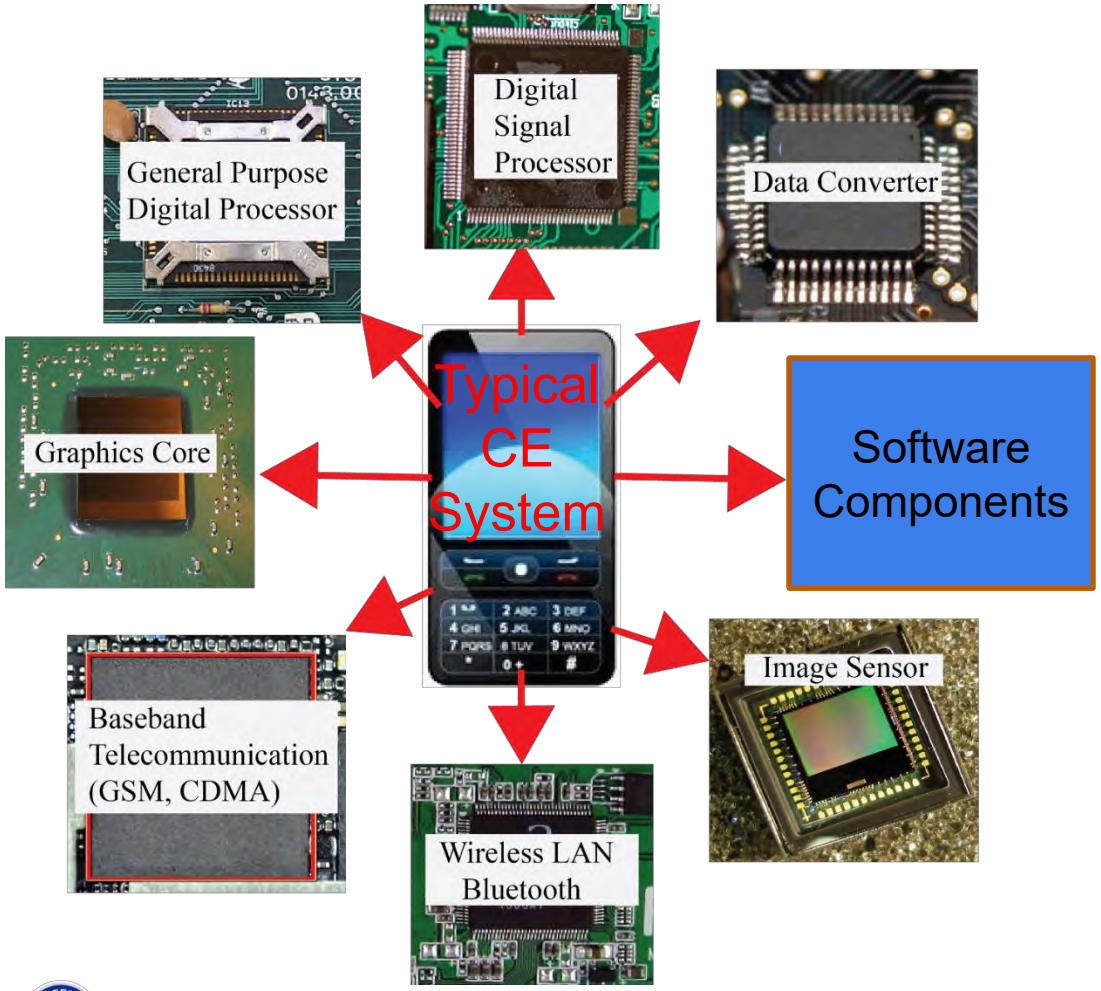

## Data Center Power Usage

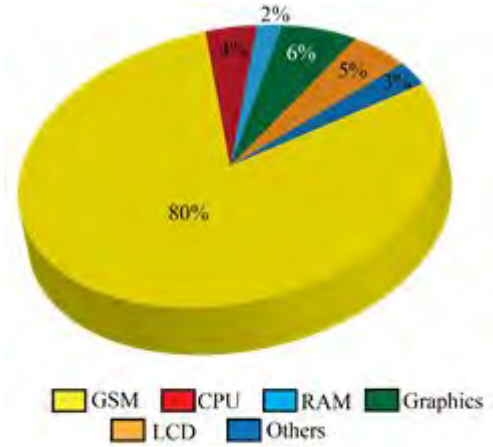



Individual Level:
Imagine how often we charge our portable CE!

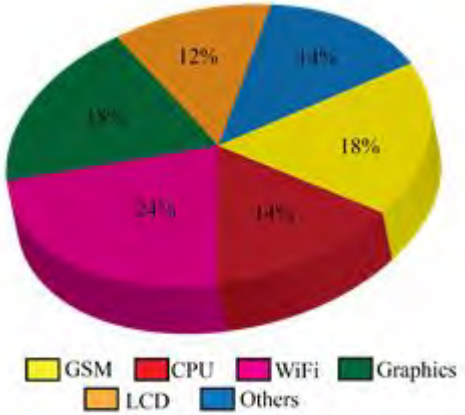
Source:
https://www.engadget.com/2011/04/26/visualized-ring-around-the-world-of-data-center-power-usage/

# Energy Efficient Sensors, Components, and Systems



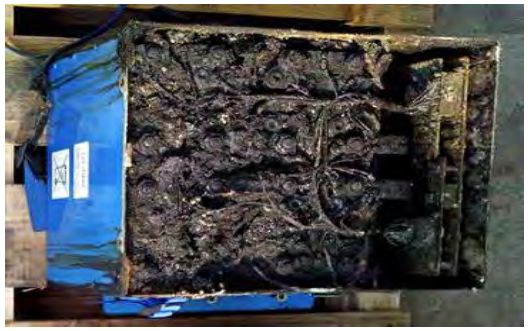




During GSM Communications




During WiFi Communications

# Energy Storage Efficiency and Safety

One 787 Battery: 12 Cells / 32 V DC

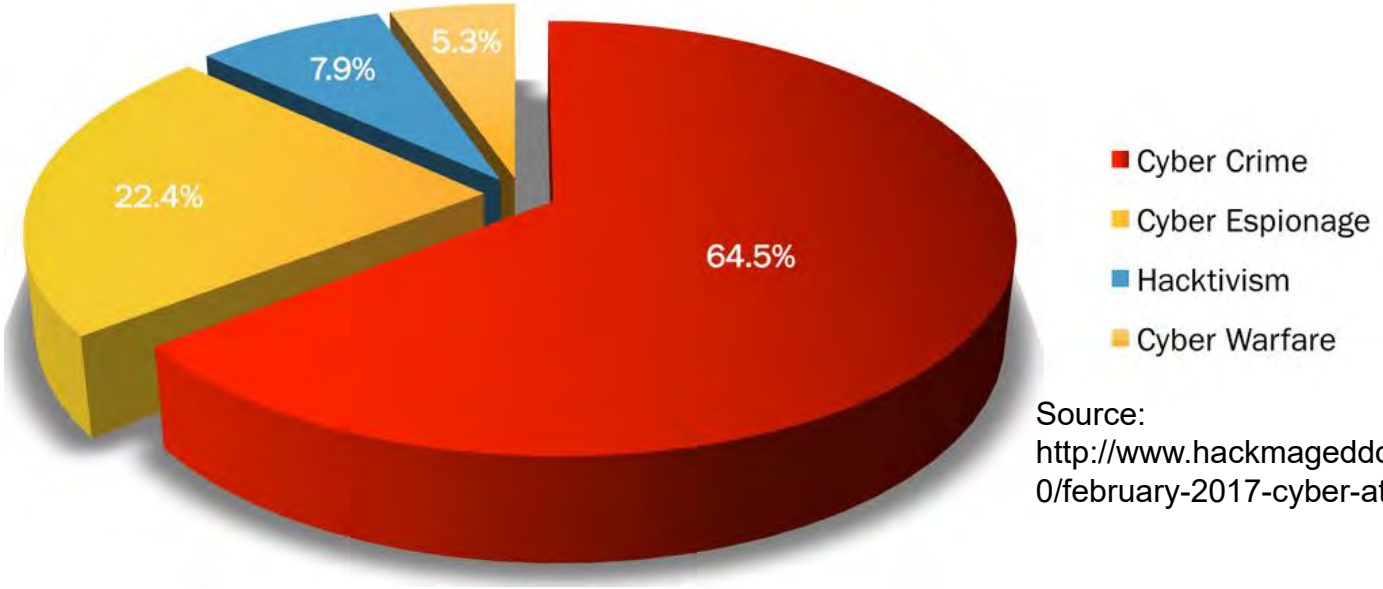
Source: http://www.newairplane.com

- Boeing 787's across the globe were grounded in 2016.

Smartphone Battery

# Security, Privacy, and Copyright


# Security: Information, System …

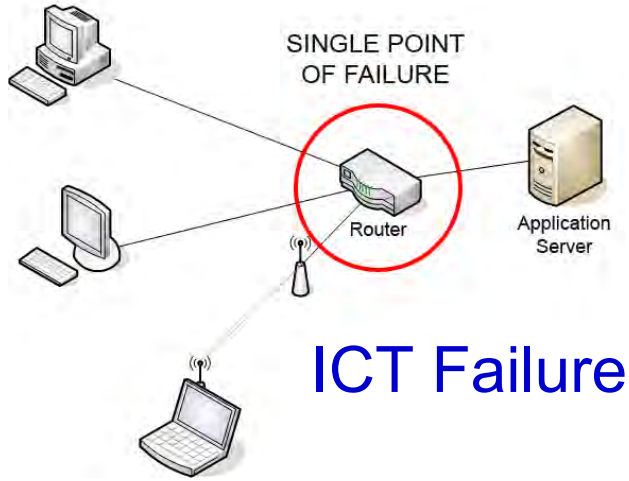



Source: http://www.hackmageddon.com/2017/03/20/february-2017-cyber-attacks-statistics/


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

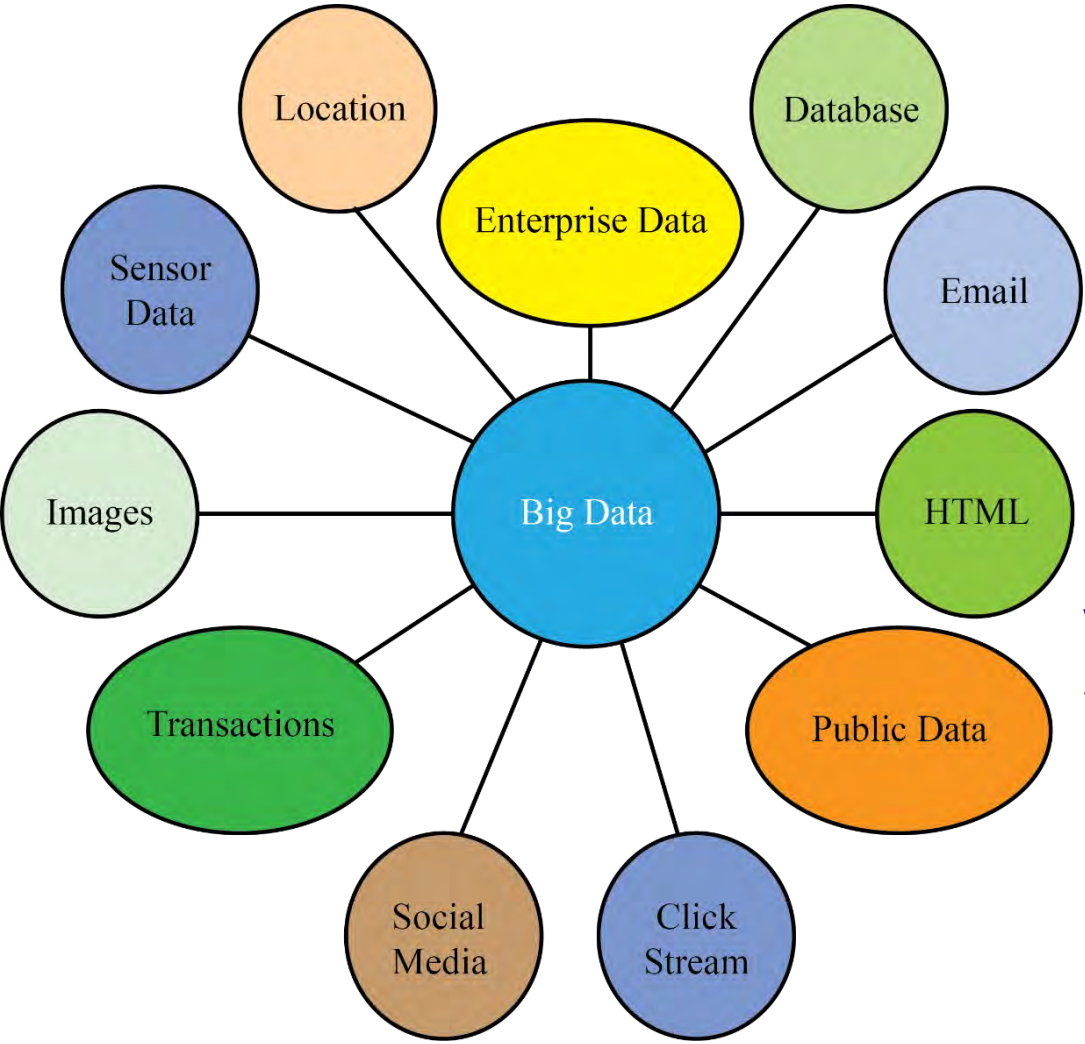
Source: http://www.csoonline.com/article/3153707/security/top-5-cybersecurity-facts-figures-and-statistics-for-2017.html

# Failure Tolerance and Resilience


ICT Failure

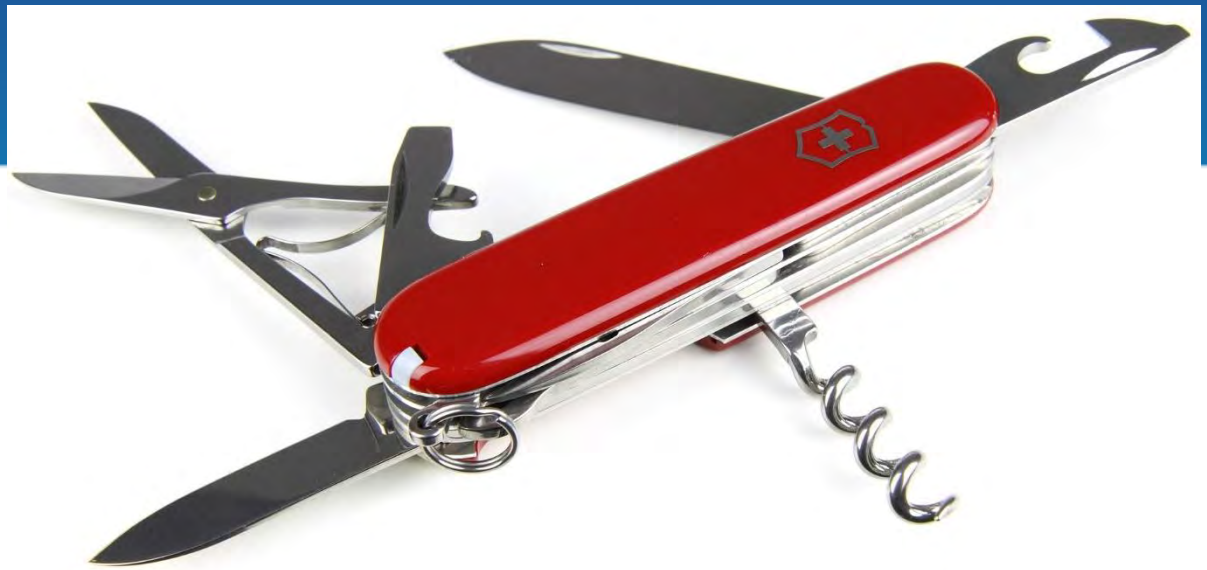
# Bigdata in Smart Cities




Source: Mohanty 2016, CE Magazine July 2016

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

# Tools and Solutions



# Market Opportunities

- "The 100 largest cities in the world produce 25 per cent of the planet's wealth, which will be smart cities".
- "New research predicts that global urbanization will fuel smart cities market growth by nearly 19% over the next 10 years."
- Together these 4 sectors make up 70 per cent of the total opportunity (This is trillions of dollars opportunity):
  - Energy
  - Building automation
  - Transportation and logistics
  - Financial services.

Source: https://www.em360tech.com/tech-news/tech-features/smart-cities-trillion-dollar-opportunity-according-new-report/

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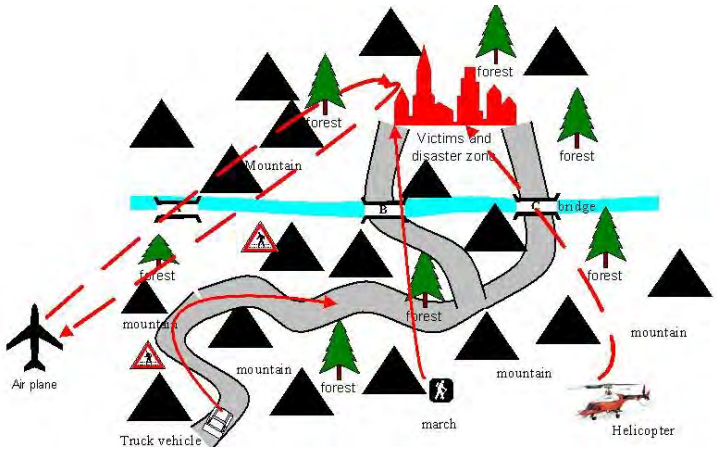
# Smart Cities Simulator

- Simulator is needed to verify and characterize a smart city component (or a cyber physical system (CPS)), before deployment.
- Smart city is too large, complex, and diverse.
- For different components of smart cities, different simulator may be needed.



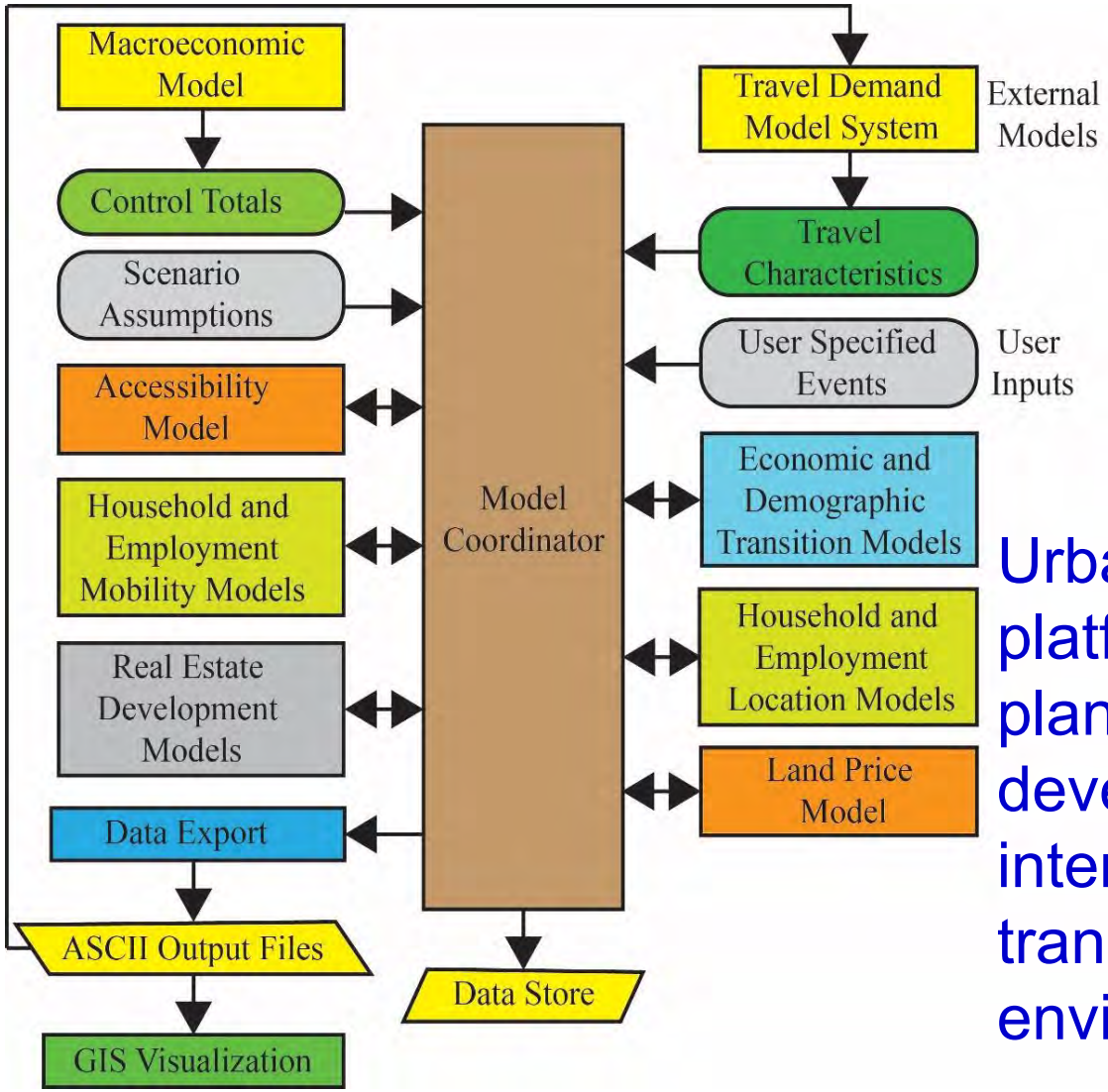
# Smart Cities Simulator: CUPCARBON

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

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

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

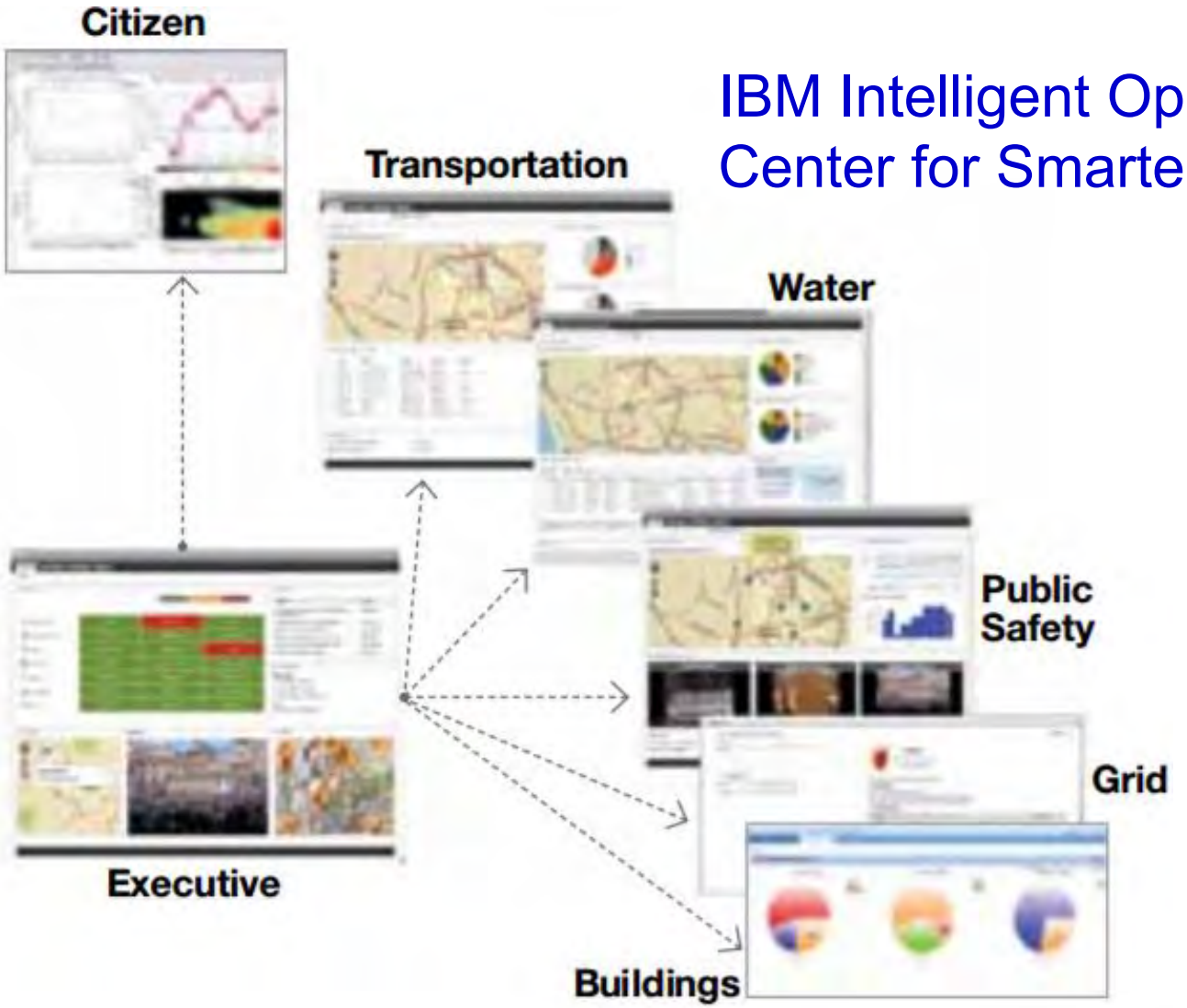
# Smart Cities Simulator: UrbanSim




UrbanSim is a simulation platform for supporting planning and analysis of urban development, incorporating the interactions between land use, transportation, economy, and environment.

Source: http://www.urbansim.com/home

# Industry Solutions: IBM




IBM Intelligent Operations Center for Smarter Cities

# Industry Solutions: Cisco

- Cisco Smart+Connected Communities have solutions along 8 tracks:
  - Smart+Connected Real Estate
  - Smart+Connected Utilities
  - Smart+Connected Transportation
  - Smart+Connected Safety & Security
  - Smart+Connected Learning
  - Smart+Connected Health
  - Smart+Connected Government
  - Smart+Connected Sports and Entertainment

# Initiatives

# IEEE Smart Cities

- IEEE Technical Community created: http://smartcities.ieee.org
- The IEEE International Smart Cities Conference (ISC2) is the flagship event of the IEEE Smart Cities Initiative.
- IEEE Smart Cities initiative: IEEE Core Smart Cities program recognizes/helps cities which establish and invest both human/financial capital into smart city plans.
- Current IEEE Core Smart Cities: Casablanca, Morocco; Guadalajara, Mexico; Kansas City, USA; Trento, Italy; and Wuxi, China.
- IEEE Affiliated Smart Cities program: Allow more cities to participate in and enjoy benefits of the IEEE Smart Cities program and network.

Source: http://smartcities.ieee.org/

# UN Initiative: United 4 Smart Sustainable Cities (U4SSC)


U4SSC is a global platform for smart city stakeholders which advocates for public policy to encourage the use of ICTs to facilitate the transition to smart sustainable cities.

**WG 01** — Setting the Framework
- Urban Planning
- Policy, Standards and Regulation
- Key Performance Indicators

**WG 02** — Connecting Cities and Communities
- Smart Living
- Smart Mobility
- Smart Environment

**WG 03** — Enhancing Innovation and Participation
- Smart Governance
- Smart People
- Smart Economy

Source: http://wftp3.itu.int/pub/epub_shared/TSB/2016-ITUT-SSC-Brochure/en/index.html Source: Paolo Gemma 2016, ISC2 2016

# Smart Cities Council

- The Smart Cities Council is a network of leading companies advised by top universities, laboratories and standards bodies.
- Help cities become smarter through a combination of advocacy and action:
  - Readiness Guides
  - Financing templates and case studies
  - Policy frameworks and case studies
  - Visibility campaigns
  - Regional networking events

Source: http://smartcitiescouncil.com/

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# Smart Cities Connect

- Smart Cities Connect is the largest city-first membership organization for global smart city leaders.
- This group is advancing the growth of smart cities by working together, discussing projects, and sharing common goals and challenges.
- Smart Cities Connect Conference and Expo brings together over 200 cities and their respective leadership.

Source: http://smartcitiesconnect.org/

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# USA: National Science Foundation (NSF)

- Smart and Connected Communities (S&CC)
- Smart and Connected Health (SCH)
- Smart and Autonomous Systems (S&AS)

Source: https://www.nsf.gov

# India Smart Cities Mission

- By Ministry of Urban Development, Govt. of India
- With increasing urbanization, urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030.
- 20 Smart Cities in 1st round: Bhubaneswar, Pune, Jaipur, Surat, Kochi, Ahmedabad, Jabalpur, Visakhapatnam, Solapur, Davanagere, Indore, New Delhi Municipal Council, Coimbatore, Kakinada, Belagavi, Udaipur, Guwahati, Chennai, Ludhiana, Bhopal
- Two Type of Value Capture
  - Project-based
  - Area-based
- Statistics:
  - Total Urban Population Impacted - 72,266,232
  - Total Cost of Projects - INR 1,317,620 Million
  - Total Area Based Development Cost - INR 1,056,210 Million

Source: http://smartcities.gov.in/upload/uploadfiles/files/SmartCityGuidelines(1).pdf

# Smart Cities: Case Study: Barcelona

Source: http://www.ioti.com/smart-cities/world-s-5-smartest-cities

- Sensors monitor traffic levels, road pollution, crowds
- Sensors monitor the weather
- Sensors measure rainfall and analyze irrigation levels in the ground
- LED lighting arrangements

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-

# Smart Cities: Case Study: San Francisco

Source: http://www.ioti.com/smart-cities/world-s-5-smartest-cities

- LEED-certified buildings than any other in the USA and a connected city initiative
- Smart transportation: Smart parking, Contactless payments
- LED lighting arrangements.

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-

# Standards

# Standards: Why

- To determine entry points for investment in city markets and make informed decisions through data analysis
- To benchmark investments and monitor progress
- To evaluate the “impact” of infrastructure projects on the sustainability and efficiency of the city
- To build smart and sustainable cities
- To evaluate the investment in comparative perspective across cities nationally and globally
- To strengthen the effectiveness of city governance

Source: https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2015/SSC/S6-MrDWelsh_MrFDadaglio.pdf

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# Standards: What

- International Organization for Standards (ISO) initiatives.
- International Telecommunication Union (ITU), United Nations specialized agency on ICT has been working.
- International Electrotechnical Commission (IEC) has initiatives.
- IEEE has been developing standards for smart cities for its different components including smart grids, IoT, eHealth, and intelligent transportation systems (ITS).
- Selected indicators: economy, education, energy, and environment.

# Standards: ISO

- ISO 37120 Sustainable development & resilience of communities - Indicators for city services & quality of life
- ISO/TR 37150 Smart community infrastructures - Review of existing activities relevant to metrics
- ISO 37101 Sustainable development of communities -- Management systems -- Requirements with guidance for resilience and smartness
- ISO 37102 Sustainable development & resilience of communities – Vocabulary
- ISO/TR 37121 Inventory & review of existing indicators on sustainable development & resilience in cities
- ISO/TS 37151 Smart community infrastructures -- Principles and requirements for performance metrics
- ISO/TR 37152 Smart community infrastructures -- Common framework for development & operation

Source: https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2015/SSC/S6-MrDWelsh_MrFDadaglio.pdf

# Standards: IEEE

- Standards activities are underway:
  - Smart Grid
  - Cloud Computing
  - Internet of Things (IoT)
  - Intelligent Transportation
  - eHealth

Source: http://standards.ieee.org/develop/msp/smartcities.pdf

IEEE

# Conclusions

# Conclusions

- Smart cities is not a technological trend, rather it is a necessity.
- Smart cities technology is an ongoing R & D.
- Multi-Front research on smart cities from academia and industries are in full swing.
- Smart cities still need significant maturity for effective design and operation.
- R & D seems to be in right direction.

# Future Research

- Energy-efficient, accurate sensors
- Security
- Privacy
- IP or content protection
- Energy efficiency
- Big data processing
- Efficient, Safer Battery
- Larger, cheaper, faster memory

# Thank You !!!

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

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