Everything You Wanted to Know about Smart Cities

Fulbright Lecture 2023 – KL Deemed University

Guntur, India, 1-31 July 2023

Homepage

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University of North Texas, USA.

Talk - Outline

- Smarty City Drivers
- Smarty City Components
- Smarty City Technologies
- Design and Operation of Smarty Cities
- Challenges and Research on Smarty Cities
- Design Optimization for smart city components
- Tools and Solutions for Smarty Cities
- Standards for Smarty Cities
- Initiatives on 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

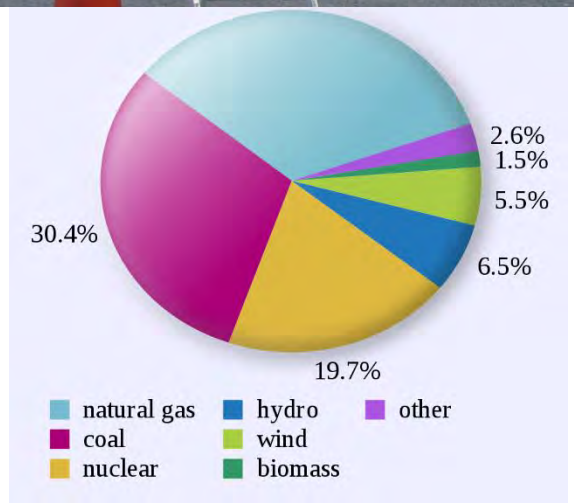
- Pollutions

Issues Challenging Sustainability

- Water crisis

Issues Challenging Sustainability

- Energy crisis



Issues Challenging Sustainability

- Traffic

The Problem

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

Source: https://humanitycollege.org

Smart City Technology - As a Solution

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

At Different Levels:
- Smart Village
- Smart State
- Smart Country

- Year 2050: 70% of world population will be urban

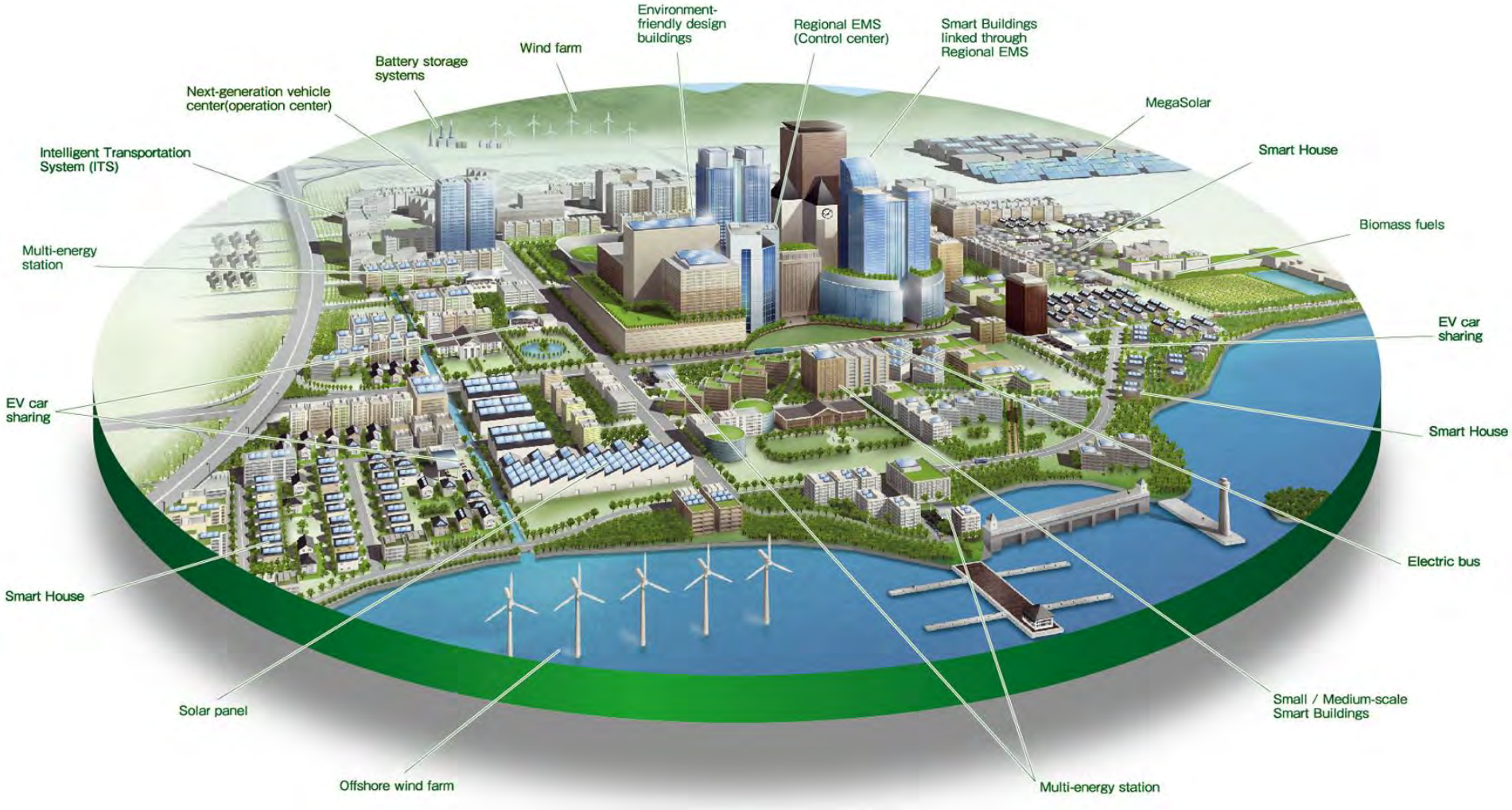
Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

Other Drivers …

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

Source: Sangiovanni-Vincentelli 2016, ISC2 2016

Smart Cities – A Broad View



Source: http://edwingarcia.info/2014/04/26/principal/

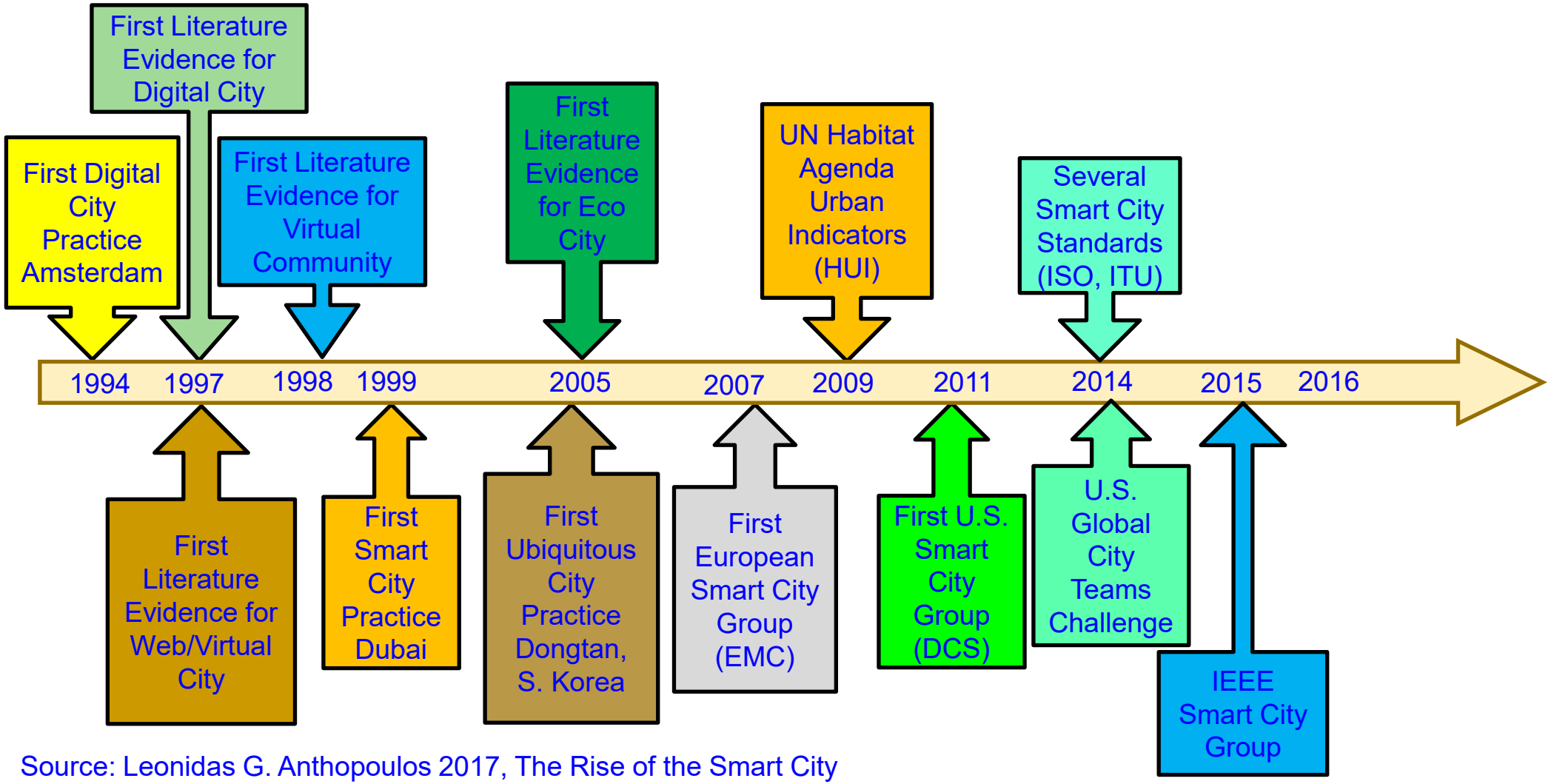
Smart Cities - Formal Definition

- 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: S. P. Mohanty, U. Choppali, and E. Kougianos, “Everything You wanted to Know about Smart Cities”, *IEEE Consumer Electronics Magazine (MCE)*, Volume 5, Issue 3, July 2016, pp. 60--70.

Smart Cities - History



Source: Leonidas G. Anthopoulos 2017, The Rise of the Smart City

Cities - History

City - An inhabited place of greater size, population, or importance than a town or village

-- Merriam-Webster

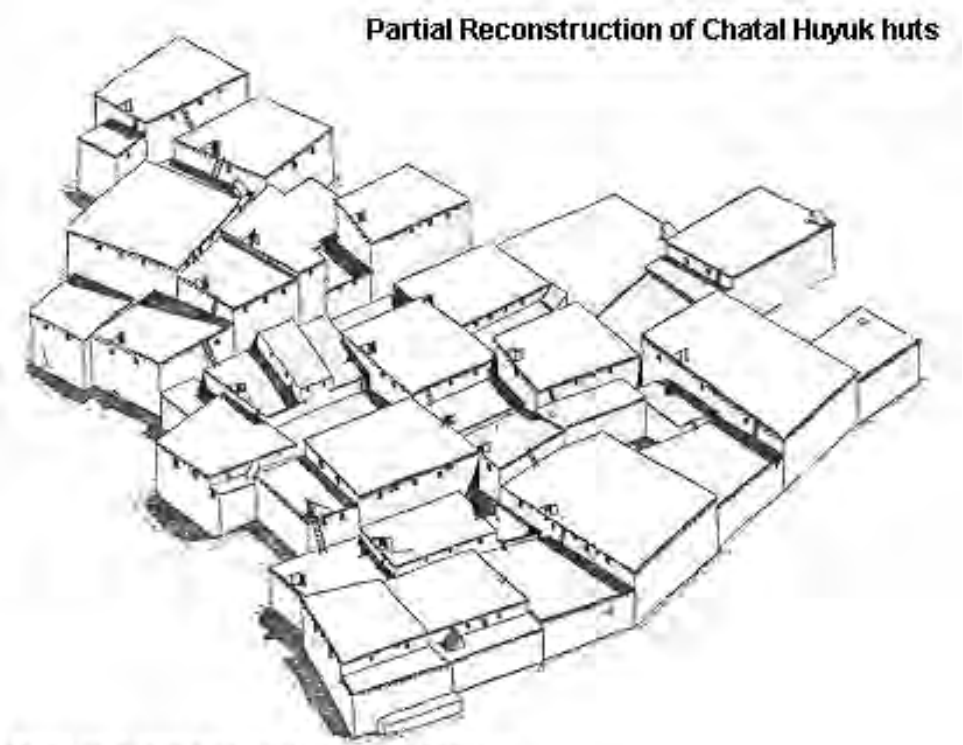
"First true cities arose in Mesopotamia, and in the Indus and Nile valleys sometime around 3500 BCE."

-- LeGates and Stout 2016, The City Reader

Hippodamus of Miletus, 498-408 BC, the first Greek city planner, considered as "the Father of European Urban Planning".

-- Edward Glaeser - 2011, Triumph of the City

Cities and Villages - History



Source: http://www1.biologie.uni-hamburg.de/b-online/library/darwin/prerm5.htm

"First true cities arose in Mesopotamia, and in the Indus and Nile valleys sometime around 3500 BCE."

-- LeGates and Stout 2016, The City Reader

After 10.000 BC humans settled down in villages. One of the best preserved is the Neolithic village at Chatal Huyuk in Anatolia (now modern Turkey). The partial reconstruction of the village gives an idea of buildings.

Smart Cities Vs Smart Villages

City - An inhabited place of greater size, population, or importance than a town or village

-- Merriam-Webster

Smart City: 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".

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 5, No. 3, July 2016, pp. 60--70.

Smart Village: A village that uses information and communication technologies (ICT) for advancing economic and social development to make villages sustainable.

Source: S. K. Ram, B. B. Das, K. K. Mahapatra, S. P. Mohanty, and U. Choppali, "Energy Perspectives in IoT Driven Smart Villages and Smart Cities", *IEEE Consumer Electronics Magazine (MCE)*, Vol. XX, No. YY, ZZ 2021, DOI: 10.1109/MCE.2020.3023293.

Smart Cities Vs Smart Villages

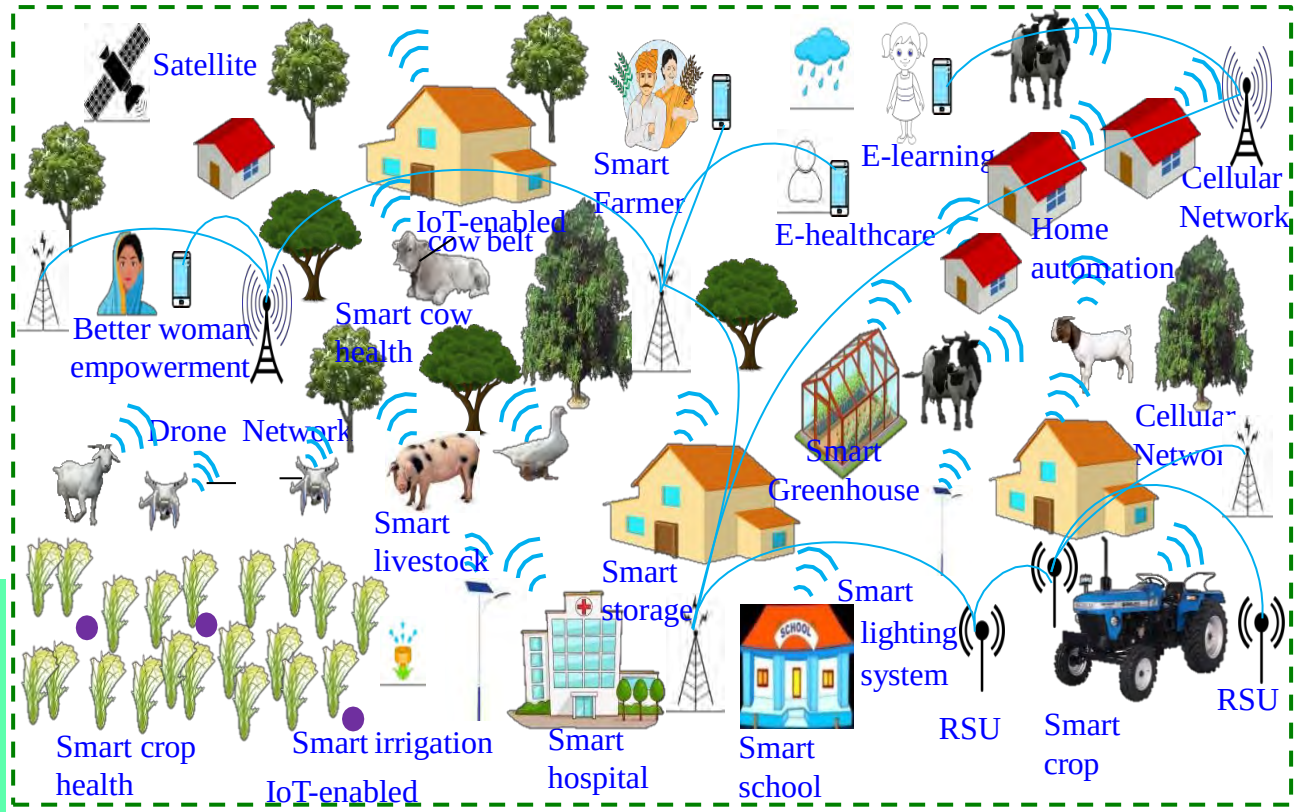
Source: http://edwingarcia.info/2014/04/26/principal/

Smart Cities

CPS Types - More
Design Cost - High
Operation Cost – High
Energy Requirement - High

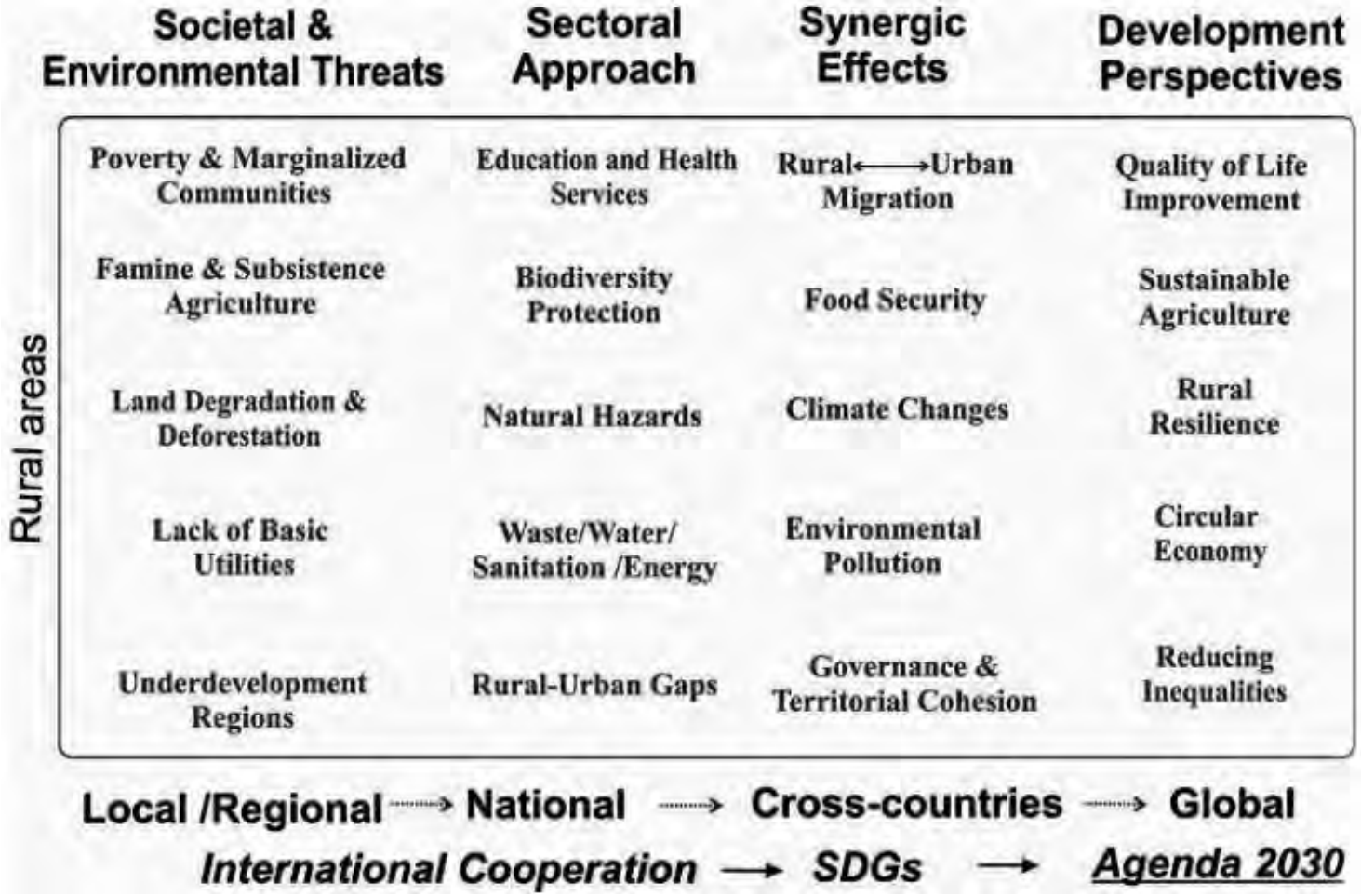
Smart Villages

CPS Types - Less
Design Cost - Low
Operation Cost – Low
Energy Requirement - Low



Source; P. Chanak and I. Banerjee, "Internet of Things-enabled Smart Villages: Recent Advances and Challenges," *IEEE Consumer Electronics Magazine*, DOI: 10.1109/MCE.2020.3013244.

Population Urban Migration is not a Problem for Smart Villages – Why to Bother?



- Efficient usage of limited resources
- Sustainability at low-cost
- Reverse urban migration of population

Source: M. Adamowicz and M. Zwolińska-Ligaj, "The "Smart Village" as a Way to Achieve Sustainable Development in Rural Areas of Poland", Sustainability, Vol. 12, No. 16, 2020, DOI: 10.3390/su12166503.

The Components

Smart Cities - Components

Smart Citizen: Civic Digital Natives

- Use of Green Mobility Options
- Smart Lifestyle Choices
- Energy Conscious

Smart Infrastructure: Digital Management of Infrastructure

- Sensor Networks
- Digital Water and Waste Management

Smart Buildings: Automated Intelligent Buildings

- Building Automation
- Intelligent Buildings, Advanced heating, ventilation, and air conditioning (HVAC), Lighting Equipment

Smart Governance: Government-on-the-Go

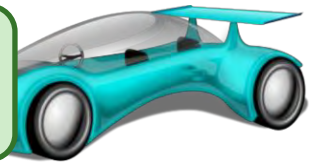
- E-Government
- E-Education
- Disaster Management Solutions

Smart Security: Safe Cities

- Surveillance
- Biometrics
- Simulation modelling and crime prediction
- Command-and-Control (C2) and response

Smart Transportation: Intelligent Mobility

- Low-emission
- Integrated Mobility Solutions
- Multimodal Transport



Smart Technology: Seamless Connectivity

- Broadband penetration rate
- Location Based Services,
- Augmented Reality,
- GPS enabled devices/phones

Smart Healthcare: Intelligent Healthcare Technology

- Use of ehealth and mhealth systems
- Intelligent and connected medical devices

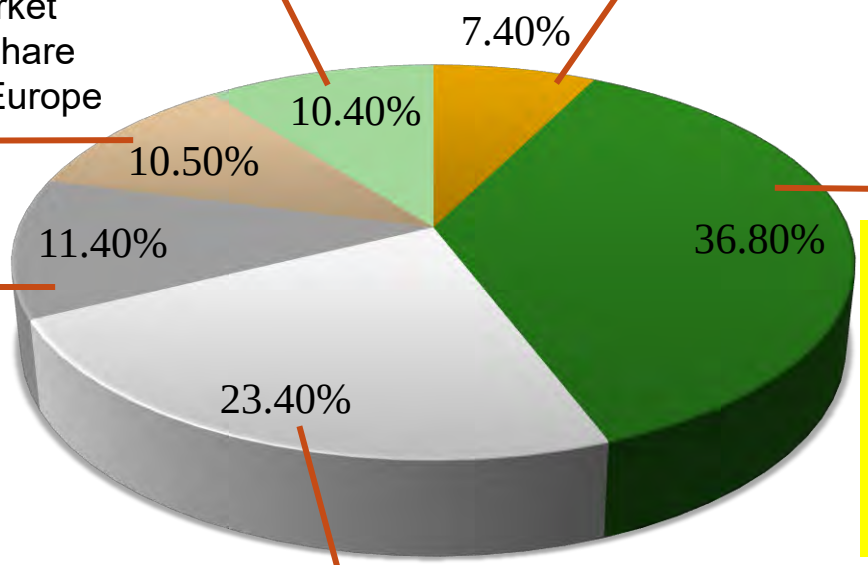
Source: Frost & Sullivan analysis.

Smart Energy: Digital Management of Energy

- Smart Grids
- Smart Meters
- Intelligent Energy Storage

Source: Paolo Gemma 2016, ISC2 2016

Smart City Market Segments – by 2025



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

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

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

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

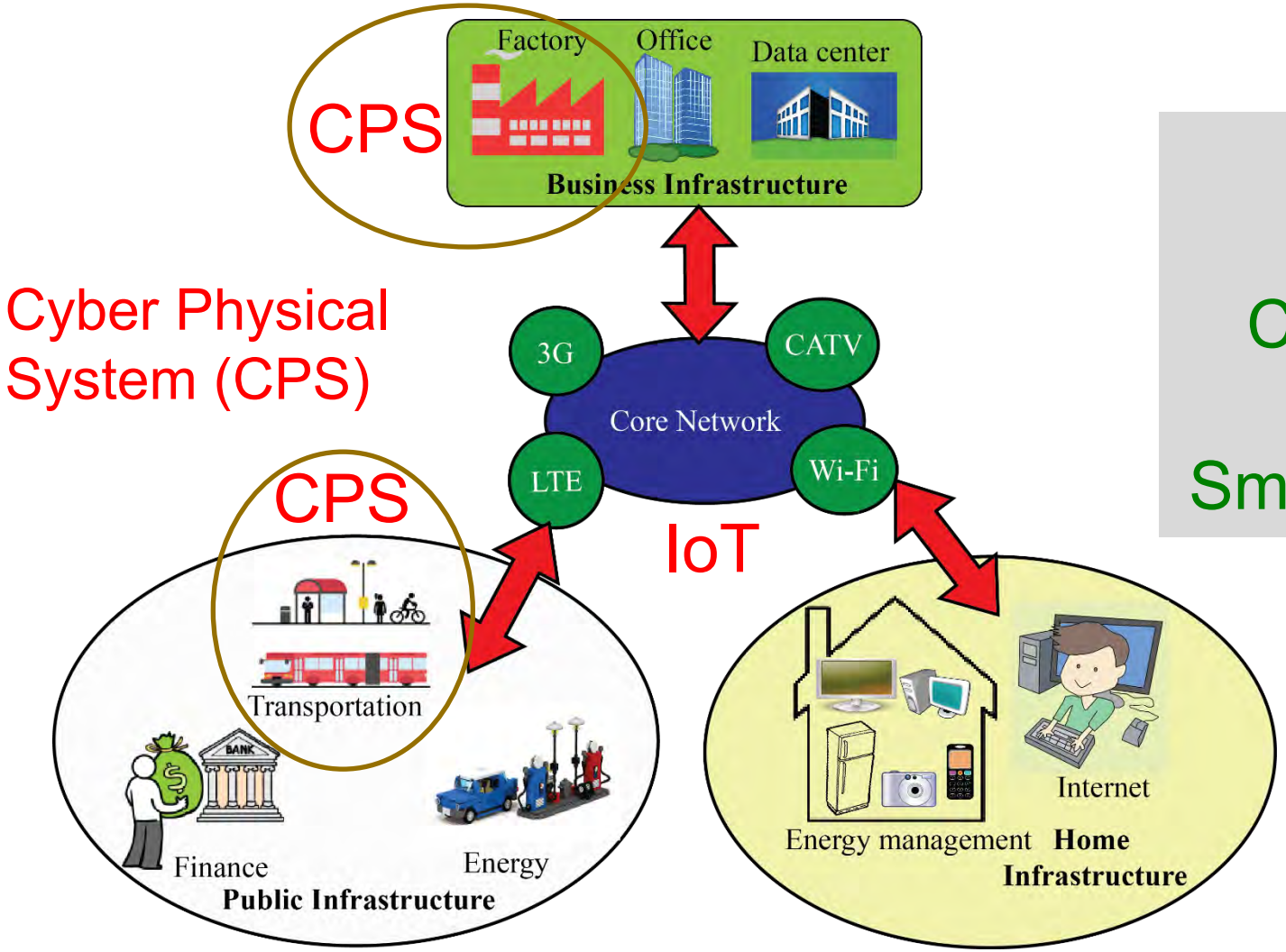
3
Smart Infrastructure
Market Value: $381.53 Billion
CAGR: 12.0% (2012-2025)
Highest growth in North America and Asia

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

Source: Frost & Sullivan

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

IoT → CPS → Smart Cities or Smart Villages



IoT
→
CPS (Smart Components)
→
Smart Cities or Smart Villages

IoT is the backbone

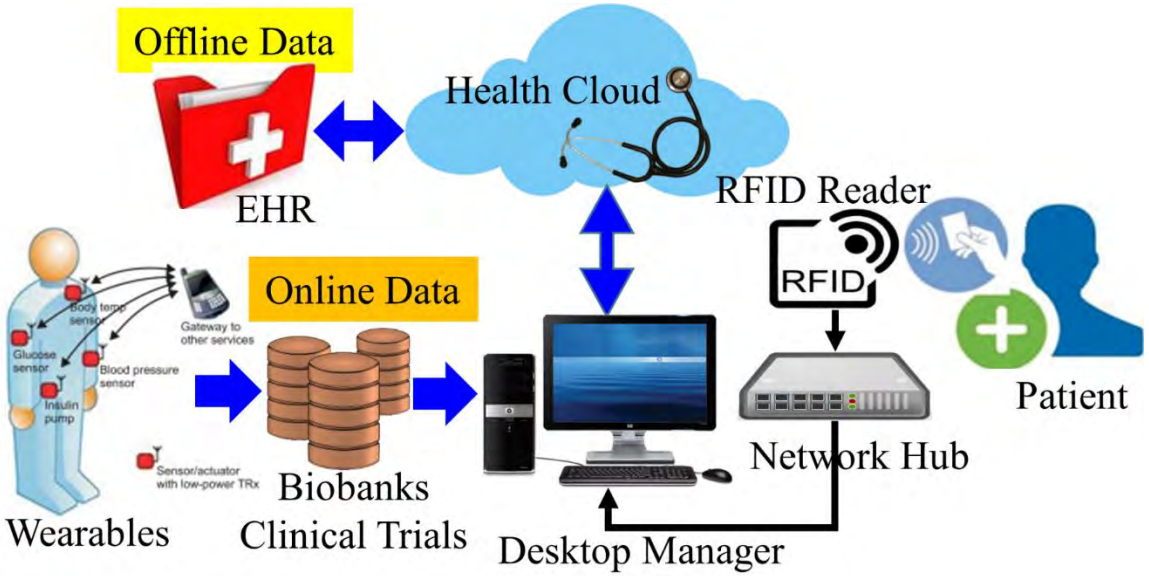
Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

Healthcare Cyber-Physical System (H-CPS)

Internet-of-Medical-Things (IoMT)

OR

Internet-of-Health-Things (IoHT)



Requires:

- Data and Device Security
- Data Privacy

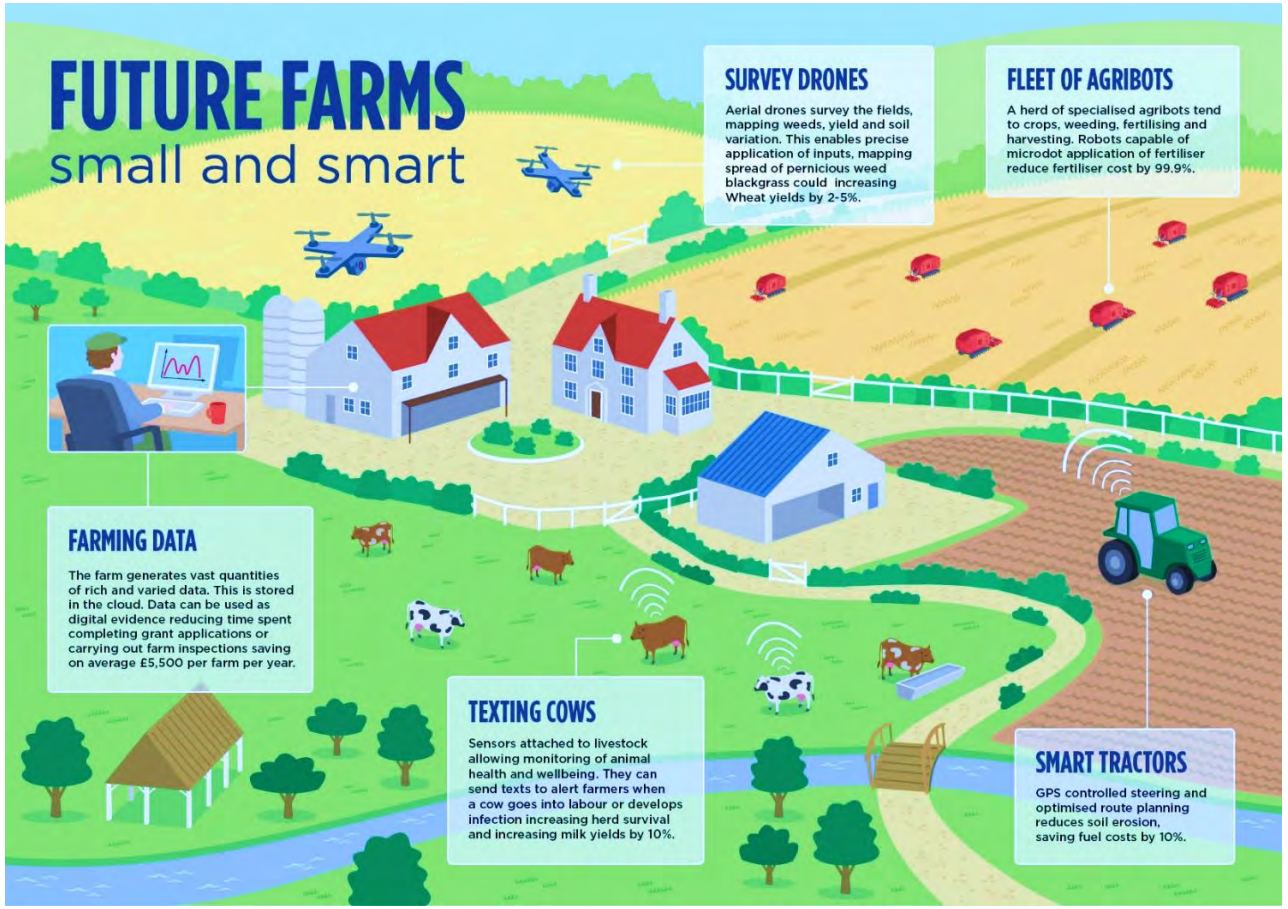
H-CPS ← Biosensors + Medical Devices + Wearable Medical Devices (WMDs) + Implantable Medical Devices (IMDs) + Internet + Healthcare database + AI/ML + Applications that connected through Internet.

IEEE CTSoc CONSUMER TECHNOLOGY SOCIETY
http://ctsoc.ieee.org

IEEE

Frost and Sullivan predicts smart healthcare market value to reach US$348.5 billion by 2025.

Agriculture Cyber-Physical System (A-CPS)



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

Smart Agriculture/Farming Market Worth $18.21 Billion By 2025

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

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

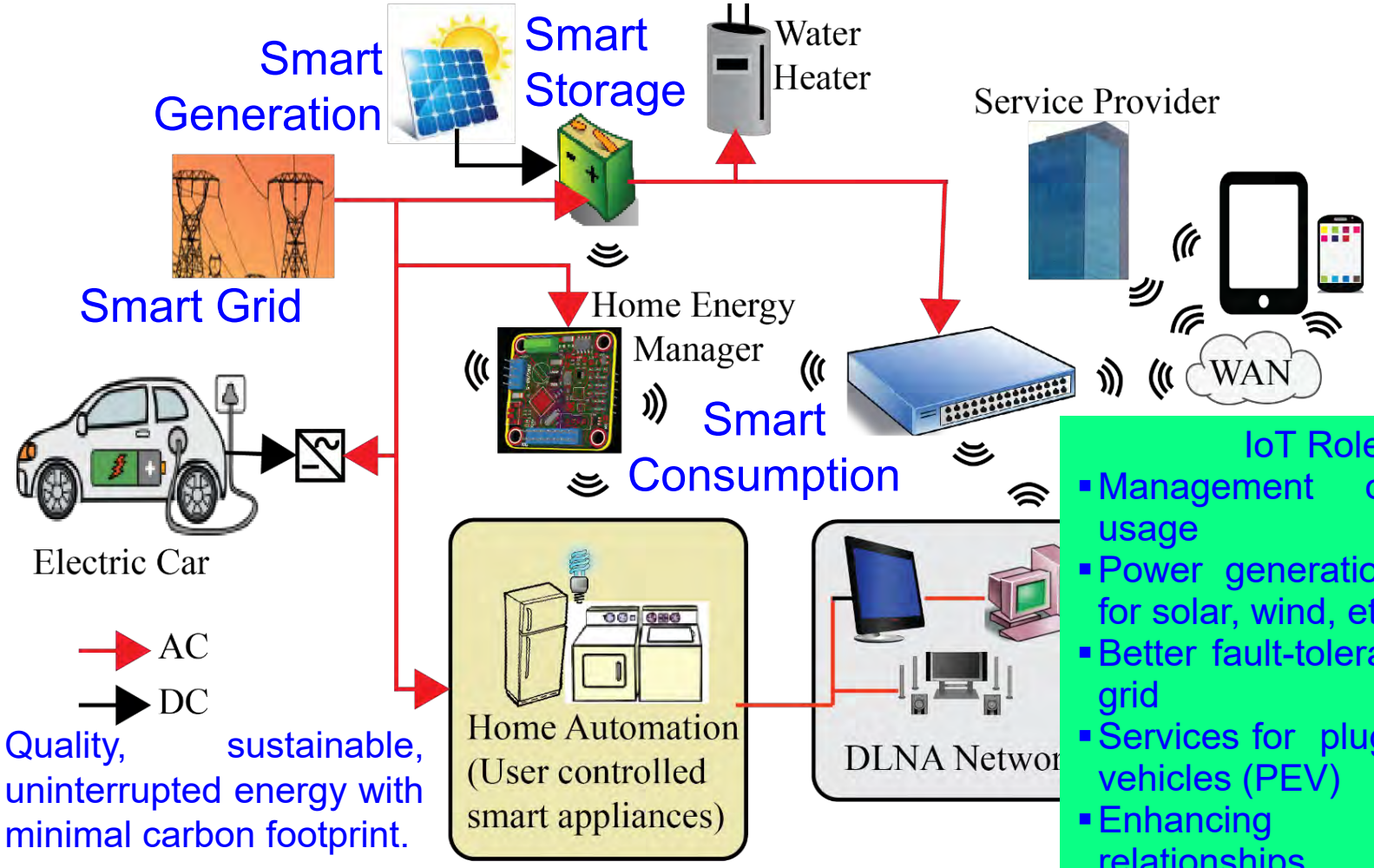
http://www.fao.org

Internet-of-Agro-Things (IoAT)

Automatic Irrigation System

Source: Maurya 2017, CE Magazine July 2017

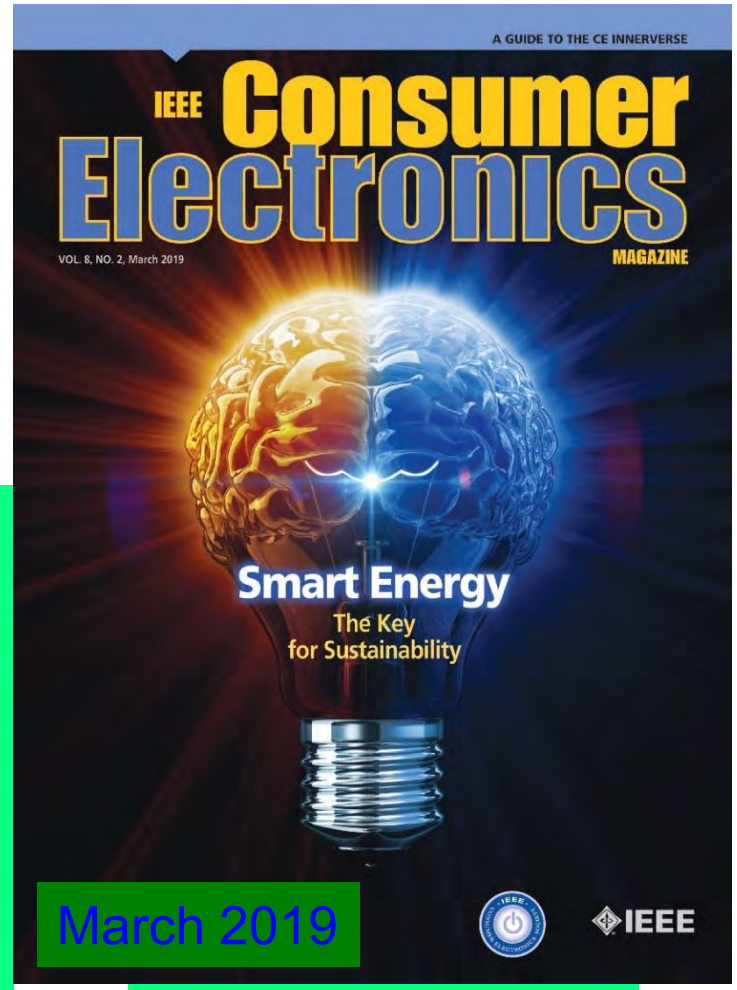
Energy Cyber-Physical System (E-CPS)



Quality, sustainable, uninterrupted energy with minimal carbon footprint.

IoT Role:

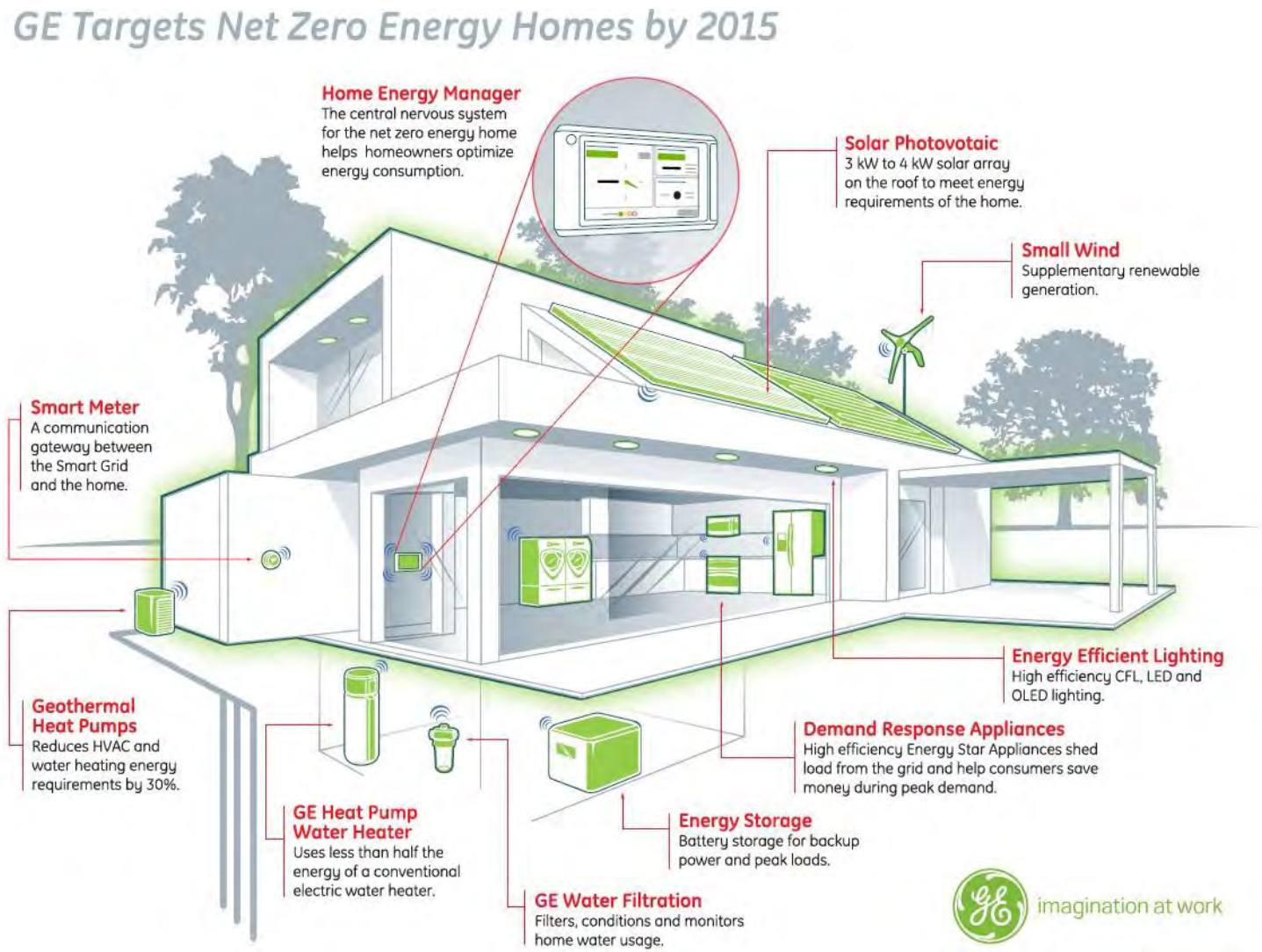
- Management of energy usage
- Power generation dispatch for solar, wind, etc.
- Better fault-tolerance of the grid
- Services for plug-in electric vehicles (PEV)
- Enhancing consumer relationships



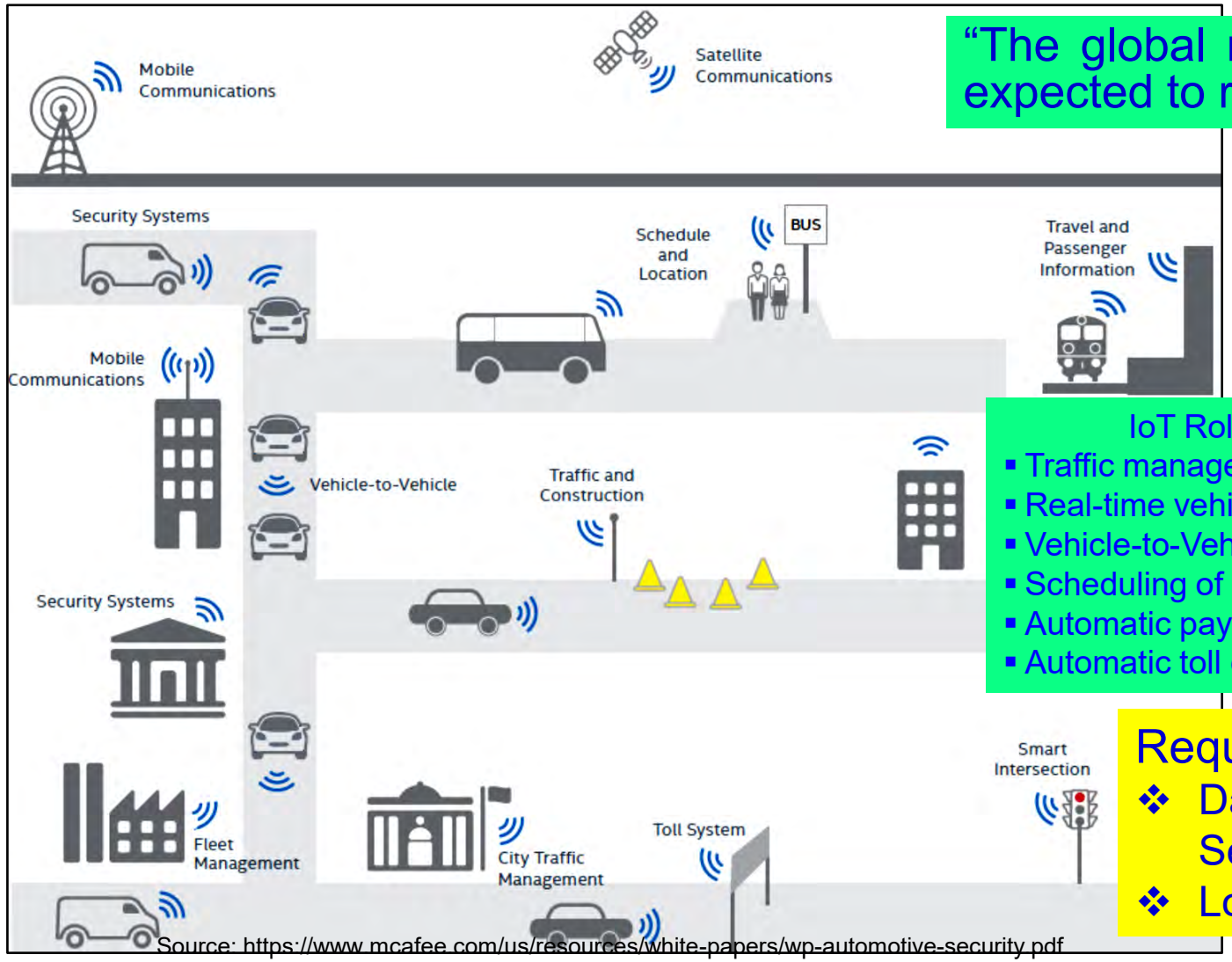
Internet of Energy

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything You wanted to Know about Smart Cities", *IEEE Consumer Electronics Magazine*, Vol. 5, No. 3, July 2016, pp. 60--70.

Smart Energy – At Home



Transportation Cyber-Physical System (T-CPS)



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

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

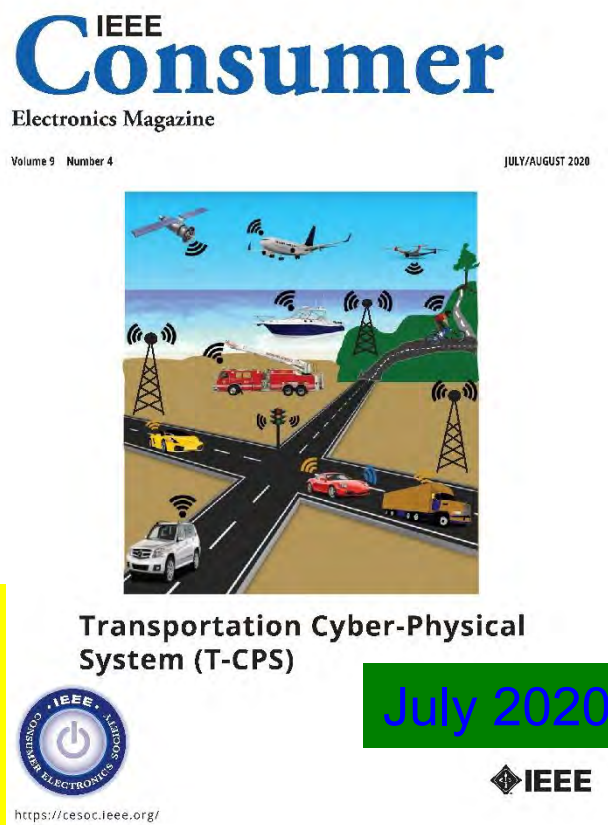
Source: Datta 2017, CE Magazine Oct 2017

IoT Role Includes:

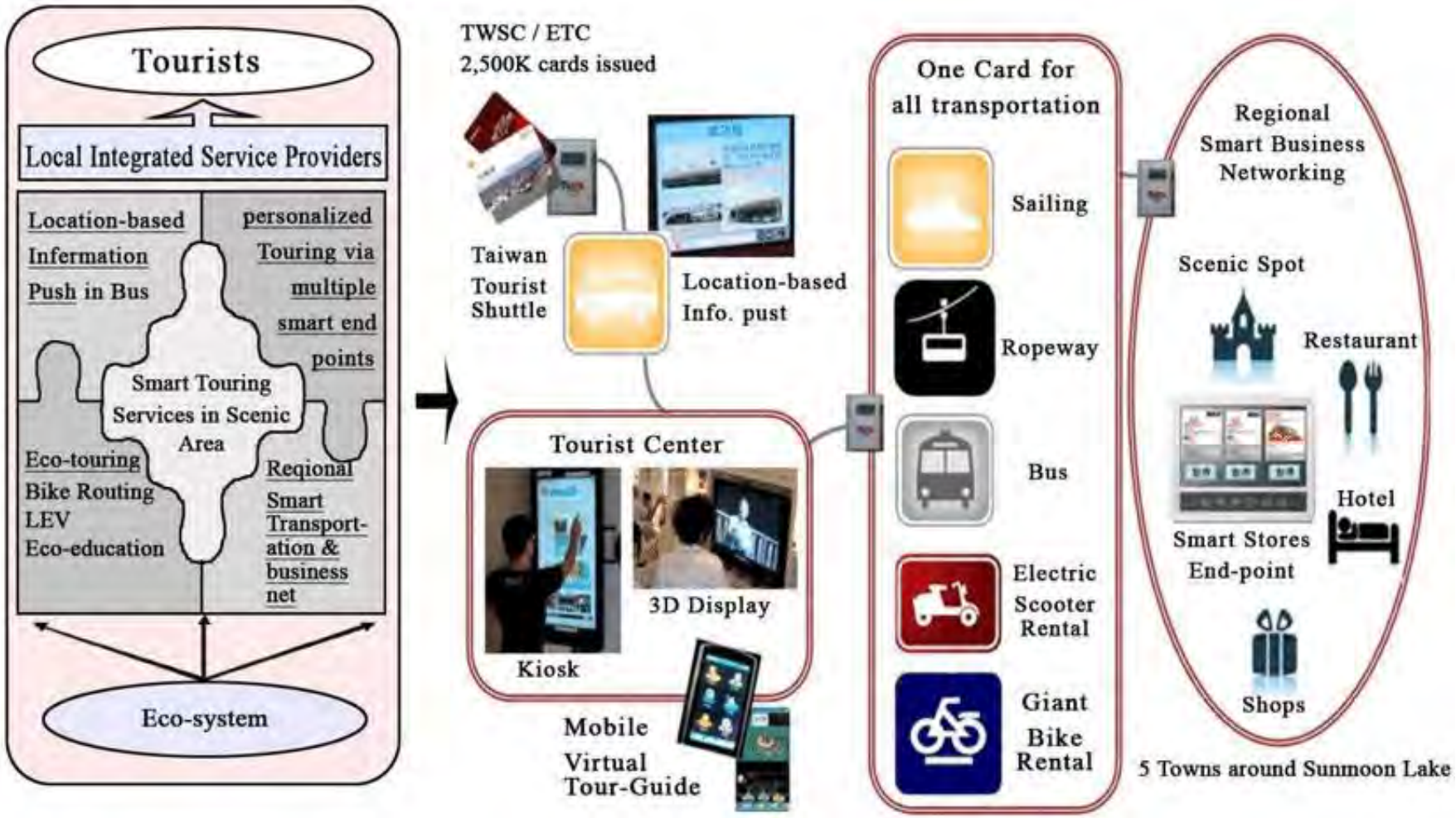
- Traffic management
- Real-time vehicle tracking
- Vehicle-to-Vehicle communication
- Scheduling of train, aircraft
- Automatic payment/ticket system
- Automatic toll collection

Requires:

- Data and Device Security
- Location Privacy

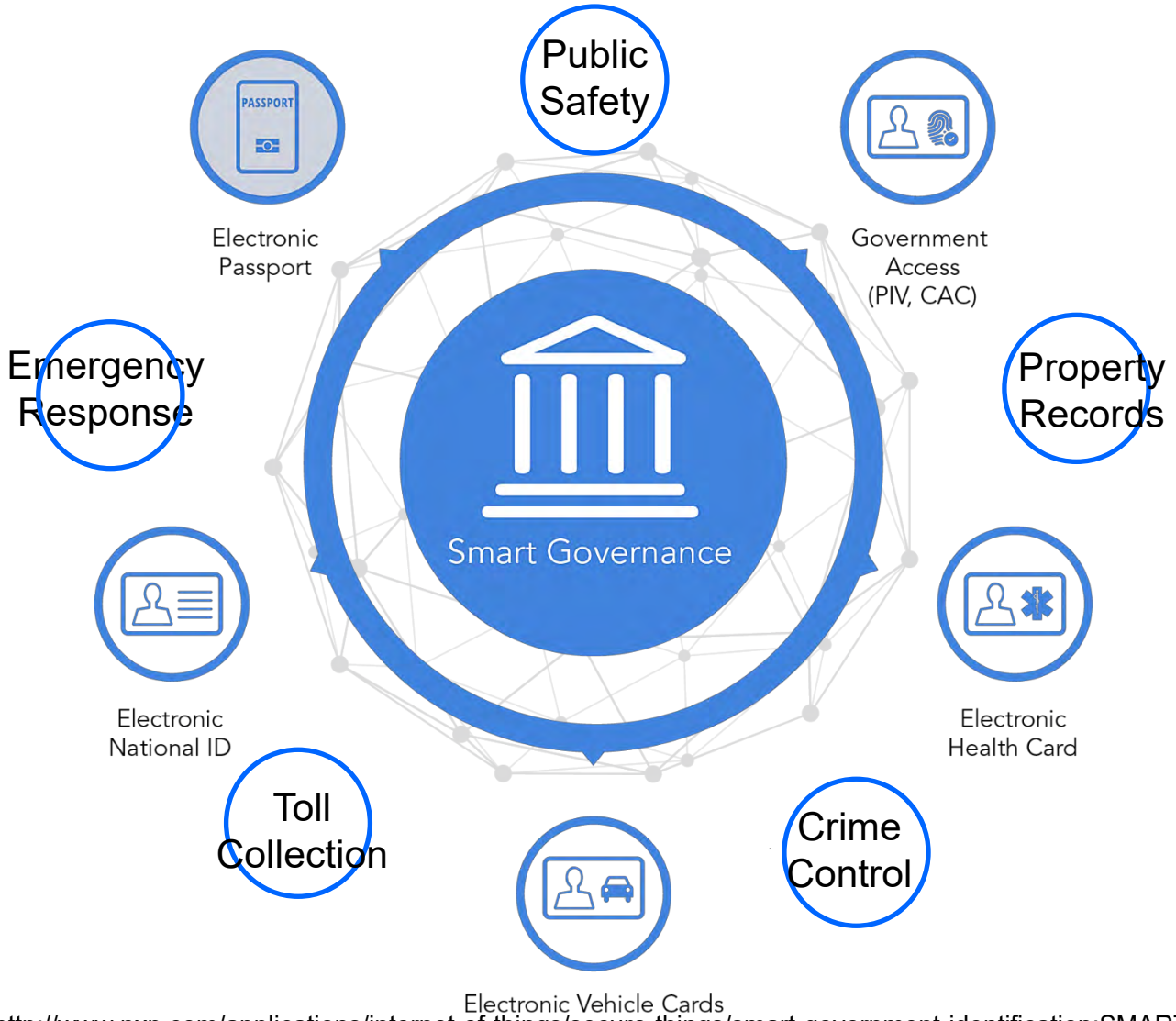


Smart Tourism



Source: Chih-Kung Lee: https://www.researchgate.net/figure/Concept-of-In-Joy-Life-smart-tourism-8_fig4_269666526

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

Smart Structure

Smart Building

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

Smart Structure

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

Smart Home

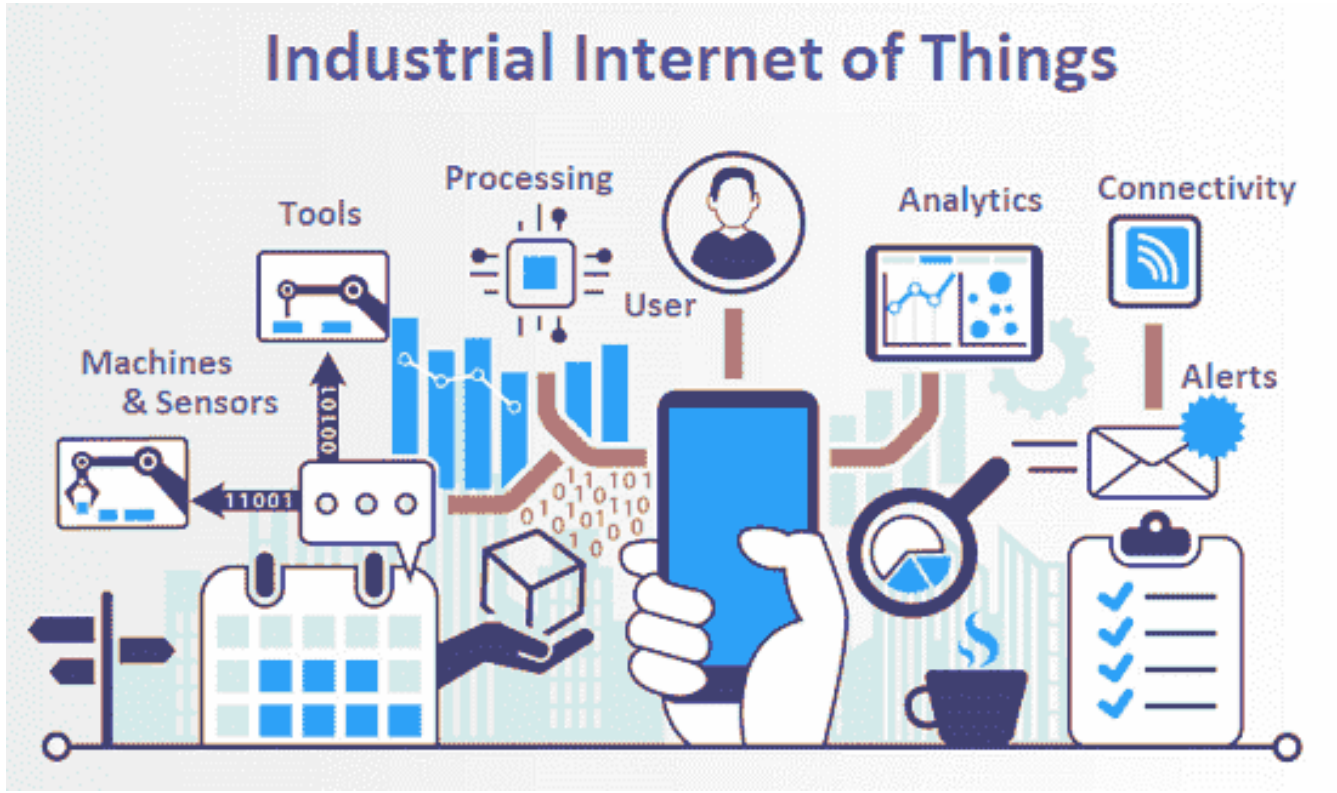
Source: https://community.cadence.com/cadence_blogs_8/b/ip/archive/2014/08/28/jot-applications-wrestling-with-energy_2c00_-cost-and-time-to-market-considerations

Services in Smart Cities and Smart Village

In Smart Cities	In Smart Village	Communication Type	Energy Source	Feasibility
Waste Management	Waste Management	WiFi, Sigfox, Neul, LoRaWAN	Battery Powered and Energy Harvesting	Feasible but smart containers adds in cost
Air Quality Monitoring	Smart Weather and Irrigation	BLE, ZigBee, 6LoWPAN, WiFi, Cellular, Sigfox, LoRaWAN	Solar Panels, Battery Power and Energy Harvesting	Feasible
Smart Surveillance	NA	BLE, WiFi, ZigBee, Cellular, Sigfox, LoRaWAN	Battery Power and Energy Harvesting	Feasible but additional sensors needed
Smart Energy	Smart Energy	ZigBee, Z-Wave, 6LoWPAN, Sigfox, LoRaWAN	PowerGrid, Solar Power, Wind Power, Energy Harvesting	Feasible
Smart Lighting	Smart Lighting	WiFi, ZigBee, Z-Wave, Sigfox, LoRaWAN	Power Grid, Solar Power, Energy Harvesting	Feasible
Smart Healthcare	Smart Healthcare	BLE, Bluetooth, WiFi, Cellular, Sigfox	Power Grid, Battery Power, and Energy Harvesting	Feasible
Smart Education	Smart Education	LR-WPAN, WiFi and Ethernet	Power Grid, Battery Power, and Energy Harvesting	Feasible
Smart Parking	NA	Z-Wave, WiFi, Cellular, Sigfox, LoRaWAN	Power Grid, Solar Power, Energy Harvesting	Feasible
Structural Health Monitoring	NA	BLE, WiFi, ZigBee, 6LoW-PAN, Sigfox	Power Grid, Solar Power, Battery Power, Energy Harvesting	Energy harvesting can be useful for power specs
Noise Monitoring	NA	6LoWPAN, WiFi, Cellular	Battery Power, Energy Harvesting, and Energy Scavenging	Sound pattern identification is a bottleneck
NA	Smart Farming	BLE, Bluetooth, WiFi, 6LoW-PAN, Sigfox, LoRaWAN	Power Grid, Battery Power and Energy Harvesting	Feasible
NA	Smart Diary	Bluetooth, WiFi, ZigBee, 6LoWPAN, LoRaWAN	Power Grid, Battery Power and Energy Harvesting	Feasible

Source: S. K. Ram, B. B. Das, K. K. Mahapatra, S. P. Mohanty, and U. Choppali, "Energy Perspectives in IoT Driven Smart Villages and Smart Cities", *IEEE Consumer Electronics Magazine (MCE)*, Vol. XX, No. YY, ZZ 2021, pp. Accepted on 08 Sep 2020, DOI: 10.1109/MCE.2020.3023293.

Industrial Internet of Things (IIoT)

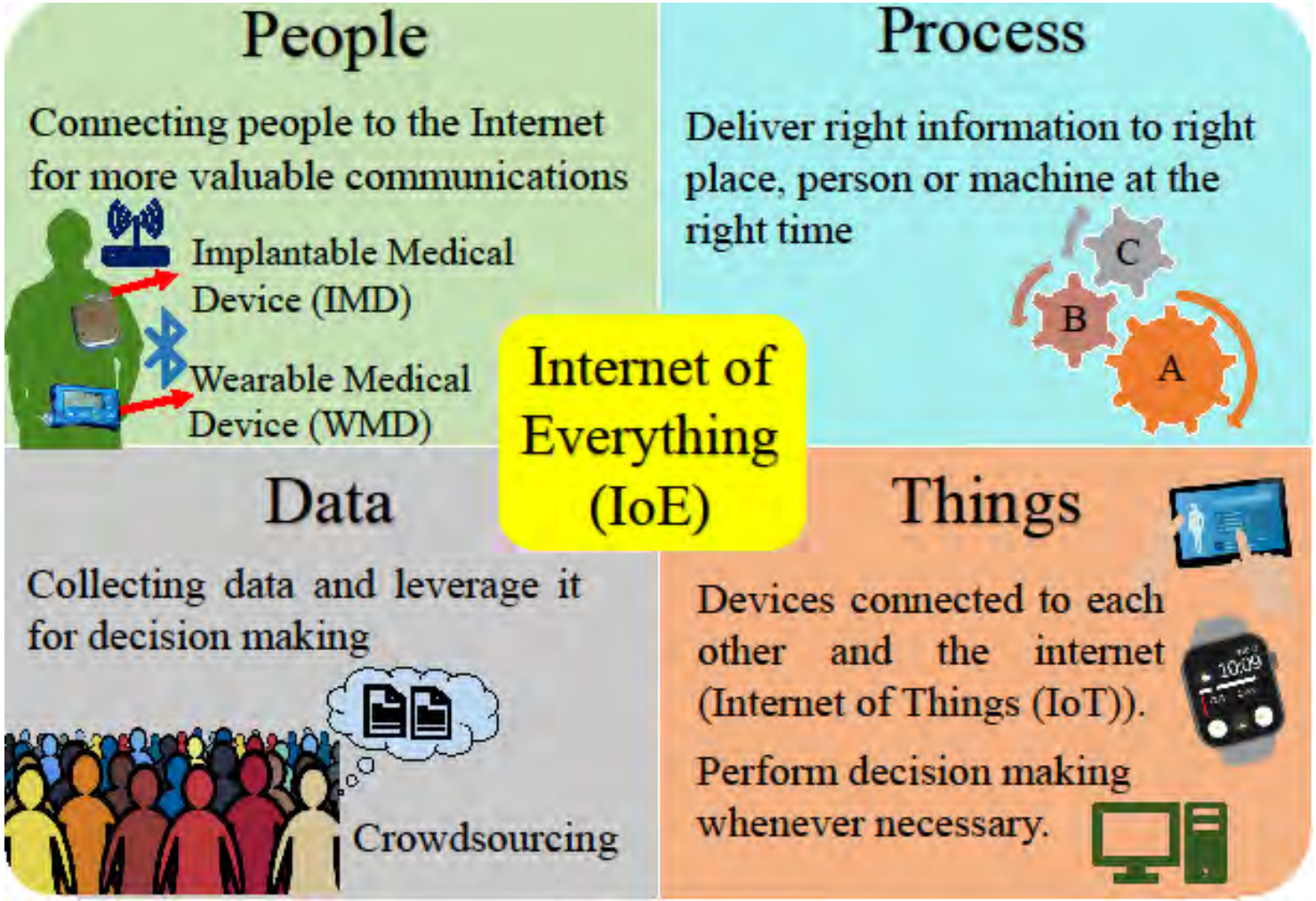


Source: https://www.rfpage.com/applications-of-industrial-internet-of-things/

Applications

- Industrial Automation
- Smart Robotics
- Predictive Maintenance
- Integration of Tools / Wearables
- Smart Logistics

Internet of Every Things (IoE)



Requires:

- Data, Device, and System Security
- Data, Location, and System Privacy

Source: S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "PUFchain: Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in the Internet of Everything (IoE)", arXiv Computer Science, arXiv:1909.06496, September 2019, 37-pages.

The Technologies

Smart Cities

Smart Cities ←

Regular Cities

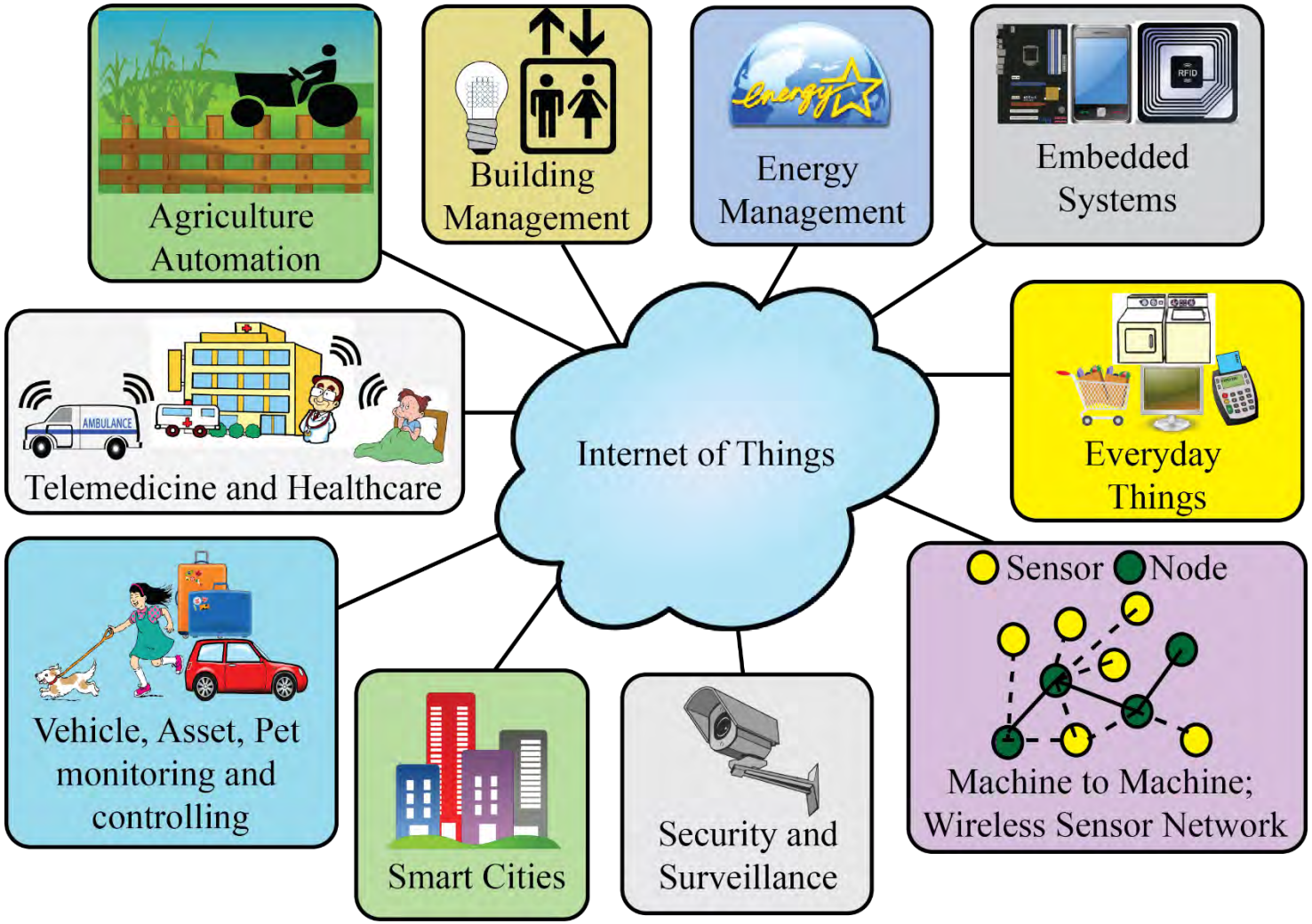
+ Information and Communication Technology (ICT)

+ Smart Components

+ Smart Technologies

Source: S. P. Mohanty, U. Choppali, and E. Kougianos, “Everything You wanted to Know about Smart Cities”, IEEE Consumer Electronics Magazine (CEM), Volume 5, Issue 3, July 2016, pp. 60--70.

IoT is the Backbone Smart Cities



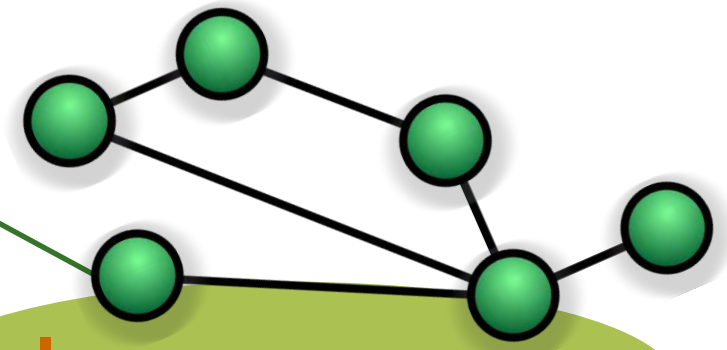
Source: Mohanty 2016, CE Magazine July 2016

Smart Cities - 3 Is

Instrumentation

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

Smart Cities

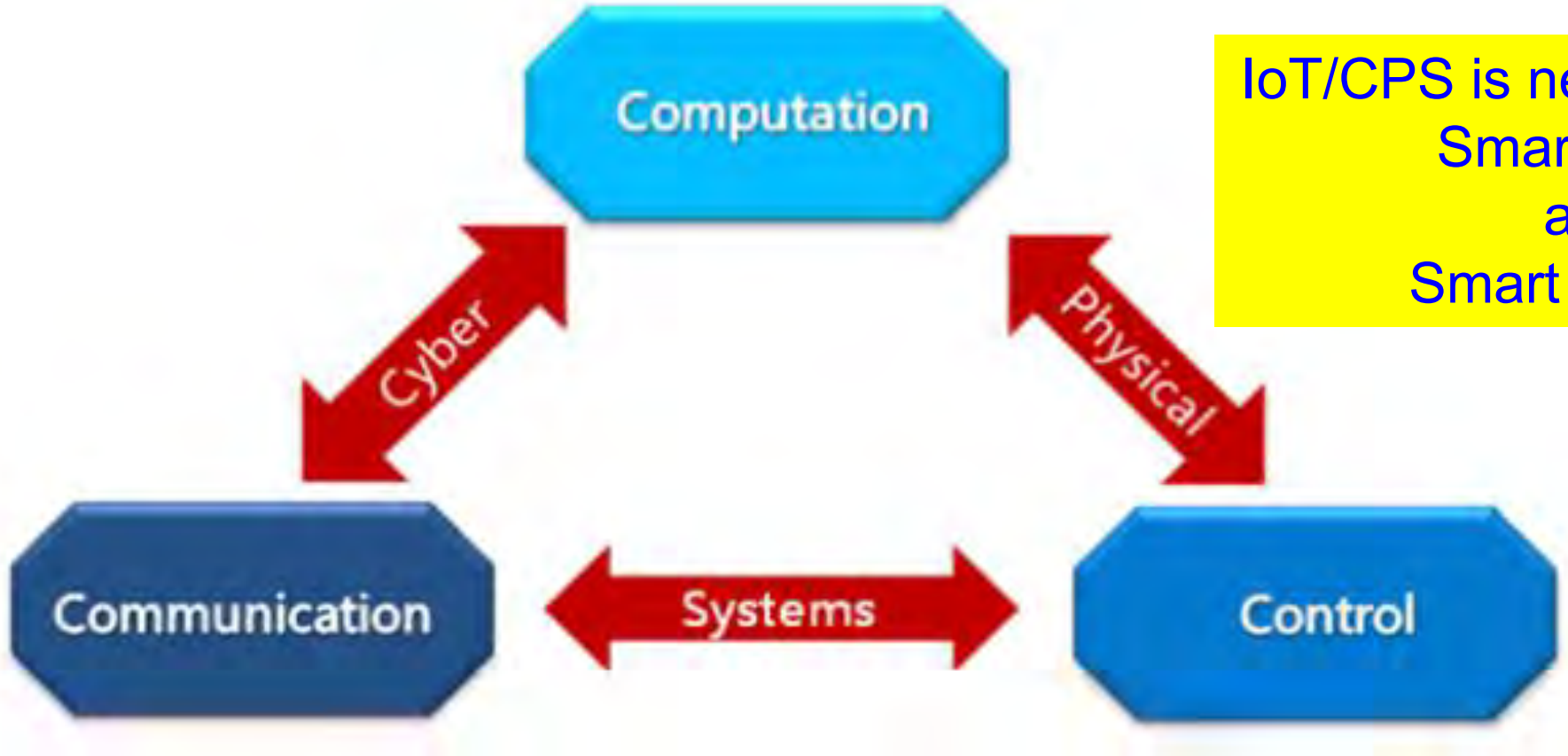


Intelligence

Interconnection

Source: Mohanty IEEE Smart Cities Conference 2019 Keynote Address (Security and Energy Trade-Offs in Smart City Cyber-Physical Systems)

Cyber-Physical Systems (CPS) - 3 Cs

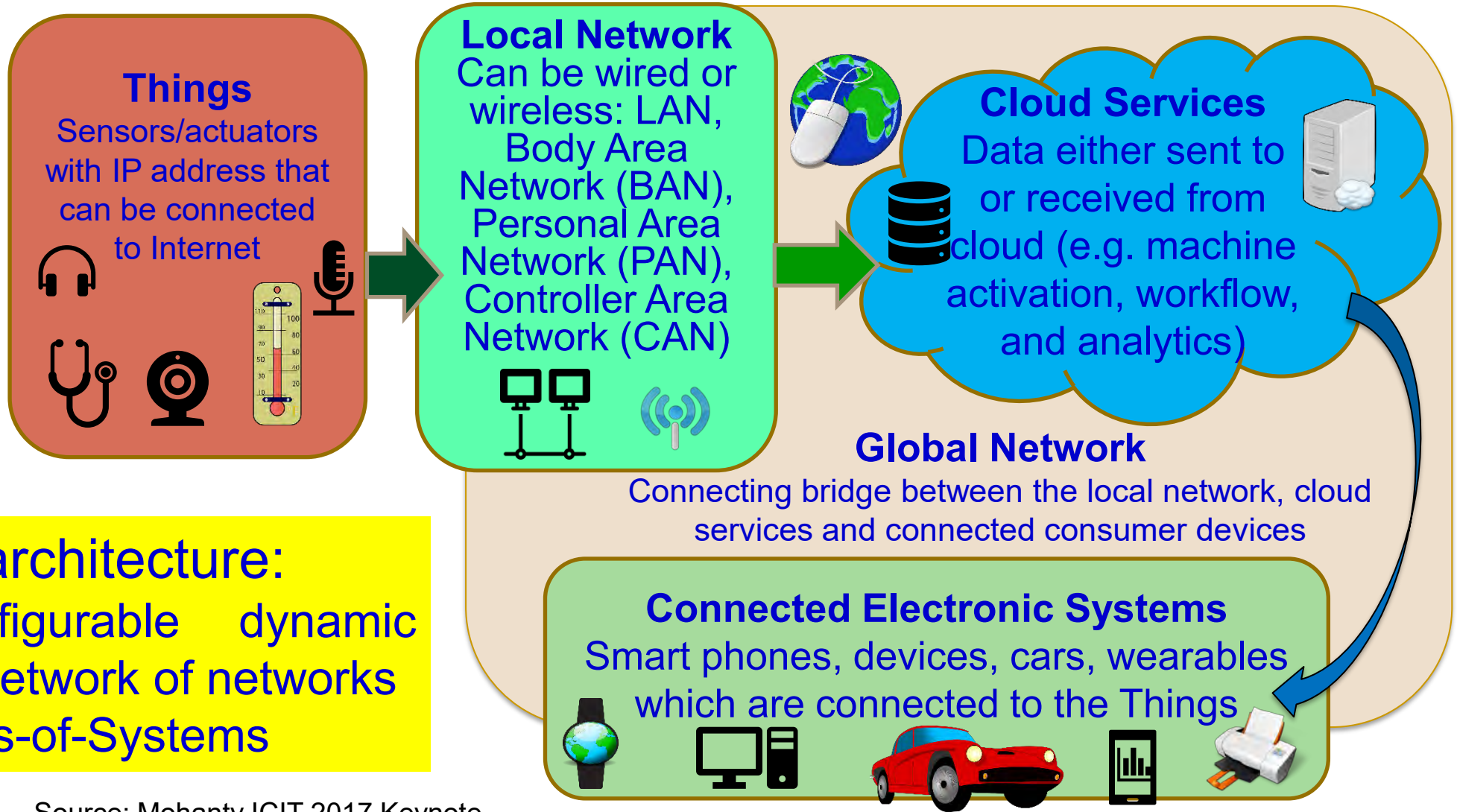


IoT/CPS is needed for both:
Smart Cities
and
Smart Villages

3 Cs of IoT - Connect, Compute, Communicate

Source: G. Jinghong, H. Ziwei, Z. Yan, Z. Tao, L. Yajie and Z. Fuxing, "An overview on cyber-physical systems of energy interconnection," in *Proc. IEEE International Conference on Smart Grid and Smart Cities (ICSGSC)*, 2017, pp. 15-21.

Internet of Things (IoT) – Concept

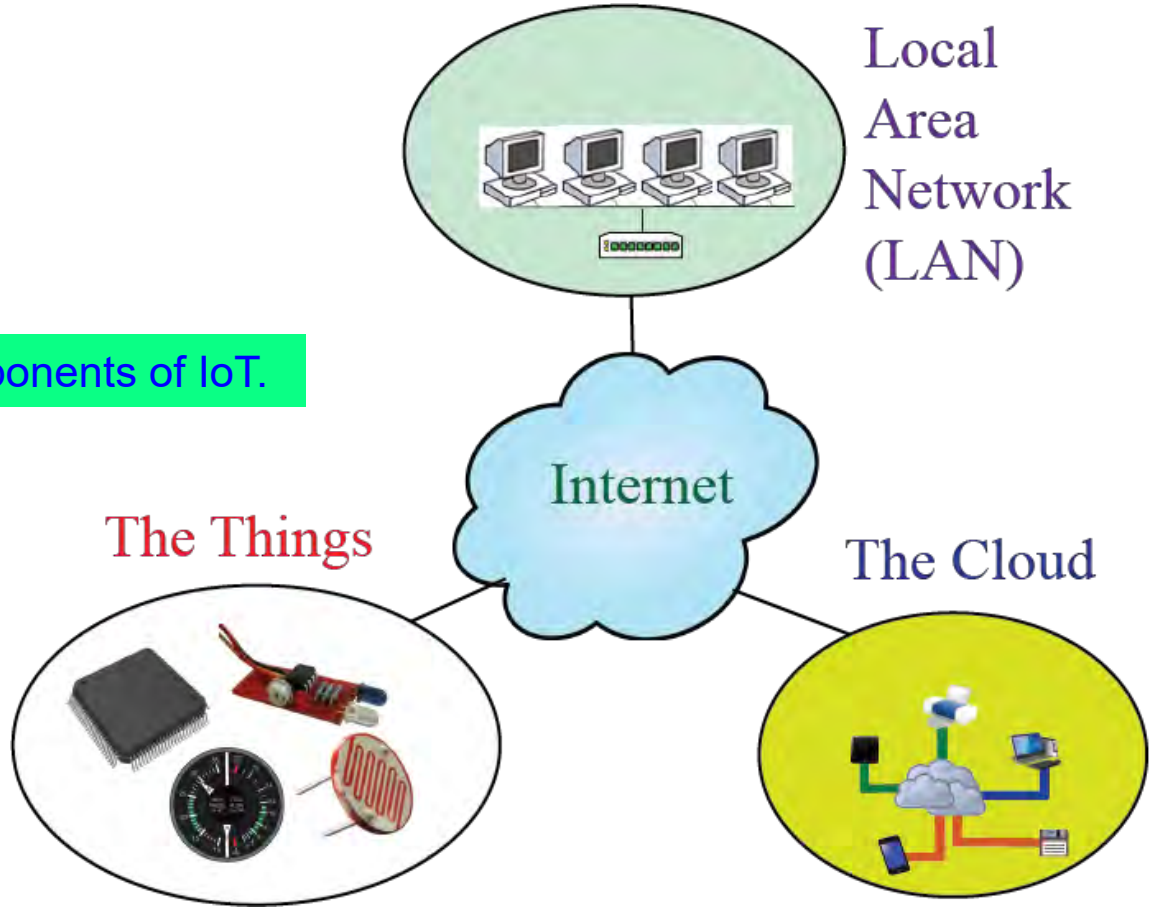


Overall architecture:

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

Source: Mohanty ICIT 2017 Keynote

IoT - Architecture

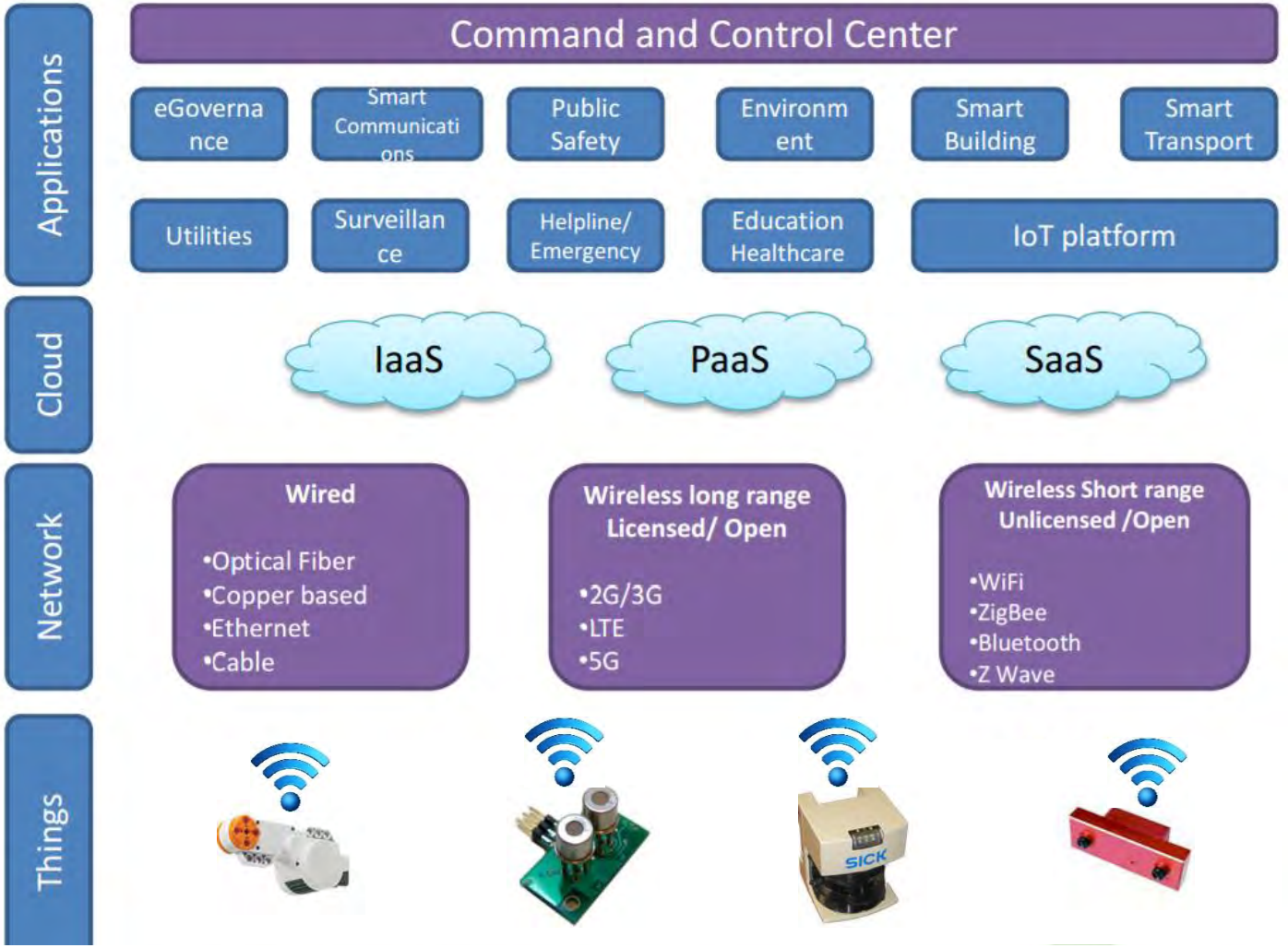


Four Main Components of IoT.

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

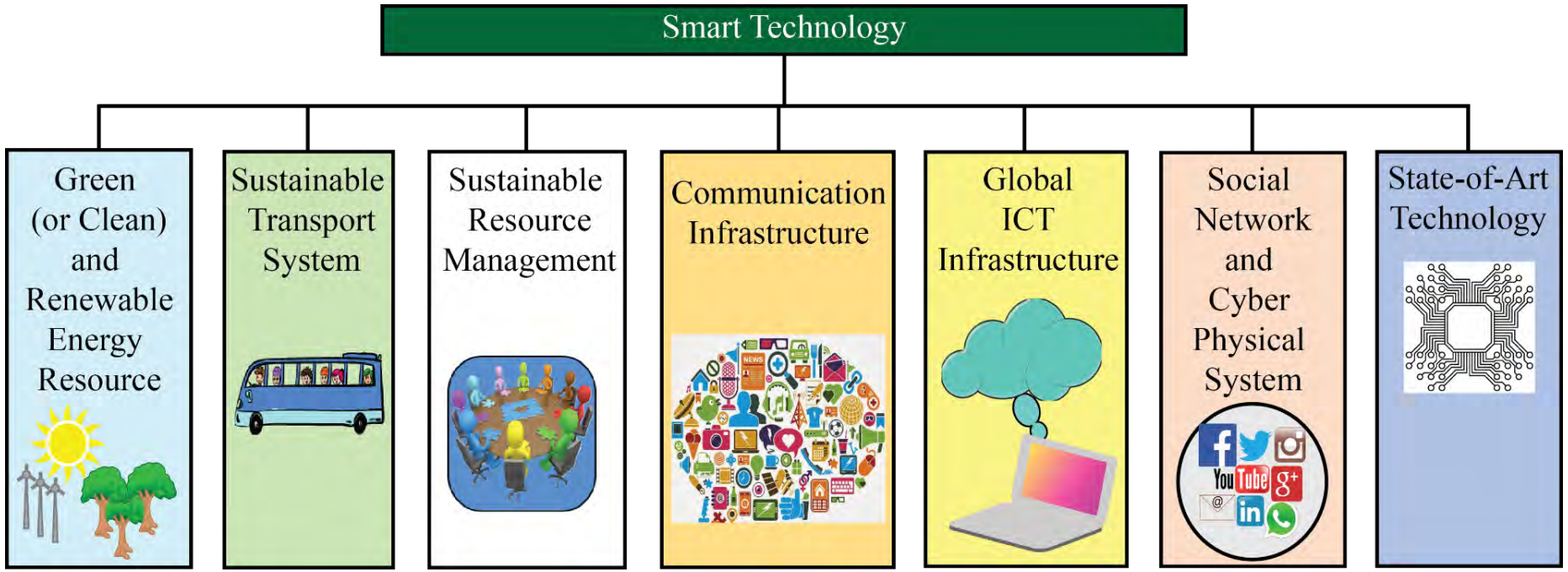
Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation

Smart Cities – Hierarchical Perspective



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

Smart Technology



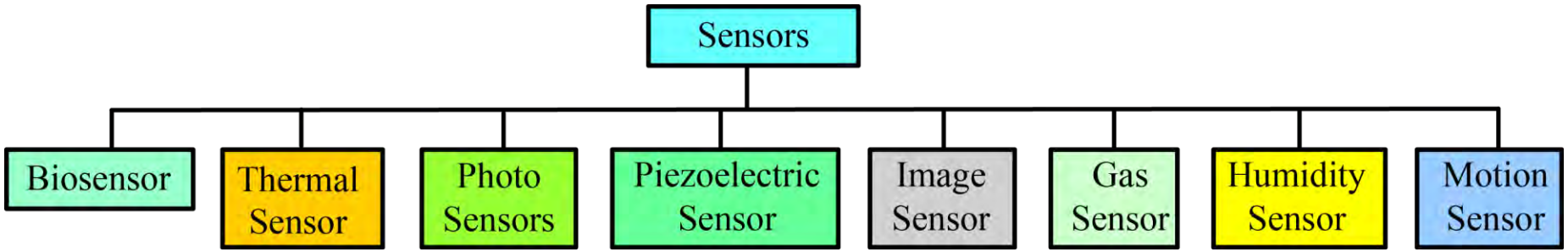
Source: Mohanty 2016, CE Magazine July 2016

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.

Cheap and Compact Sensor Technology



Source: S. P. Mohanty, Nanoelectronic Mixed-Signal System Design, McGraw-Hill, 2015, ISBN-13: 978-0071825719.

Gas Sensor

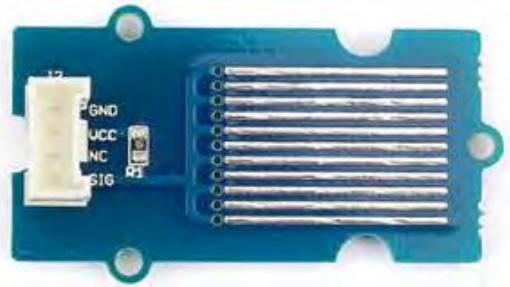
Temperature Sensor

Air Quality Sensor

Humidity and Temperature Sensor

Light Sensor

Barometer Sensor

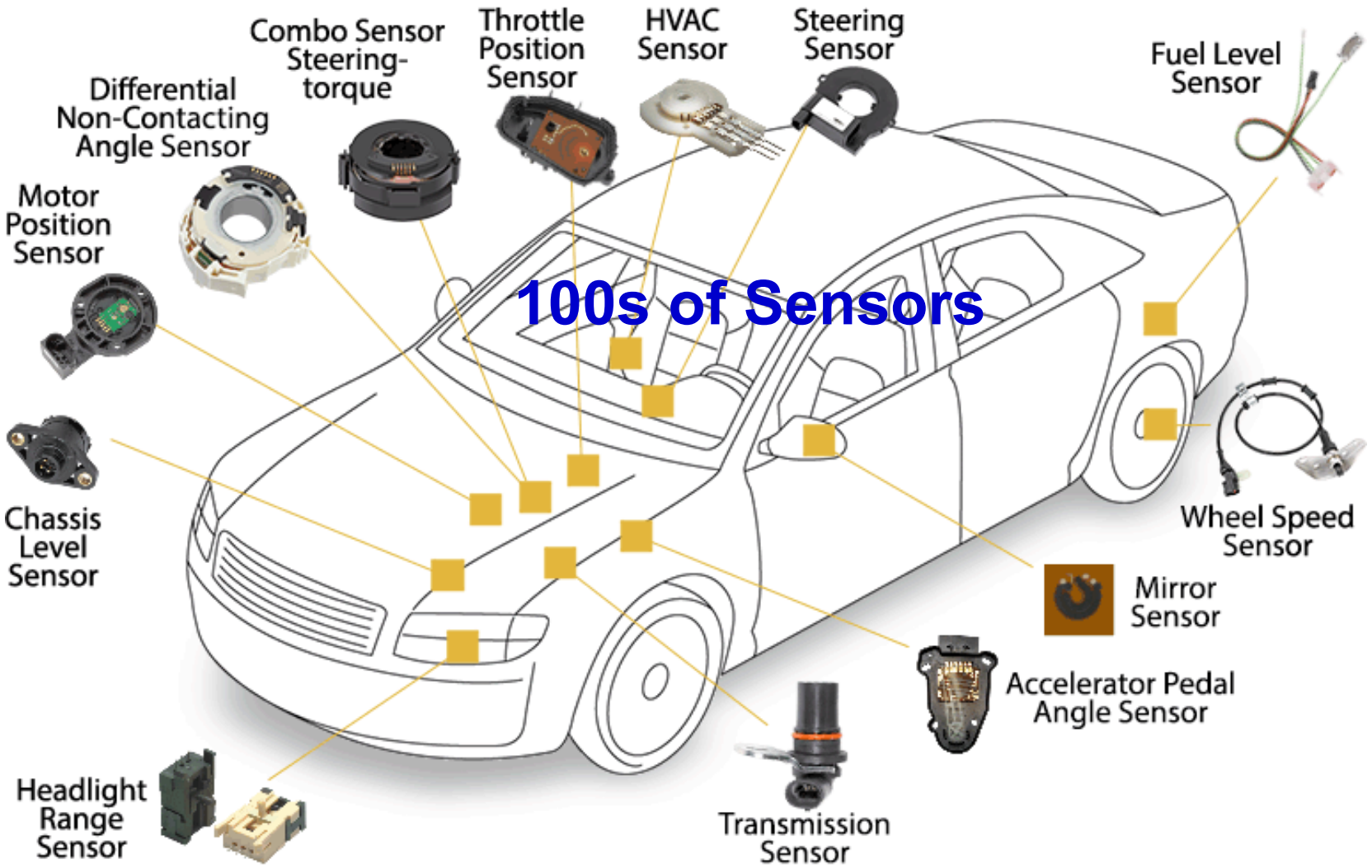


Water Sensor

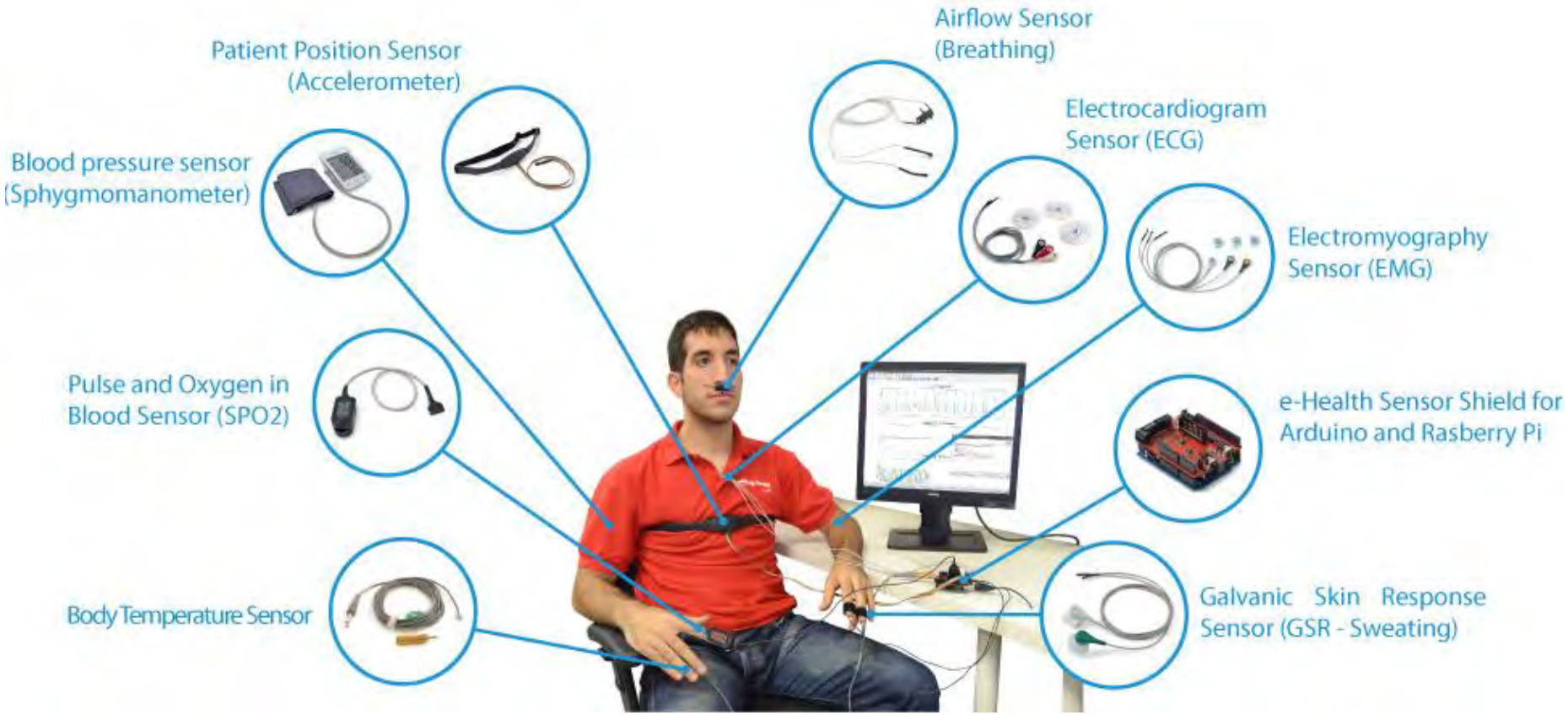
Dust Sensor

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

Sensor Technology - Automobile



Sensor Technology - Healthcare



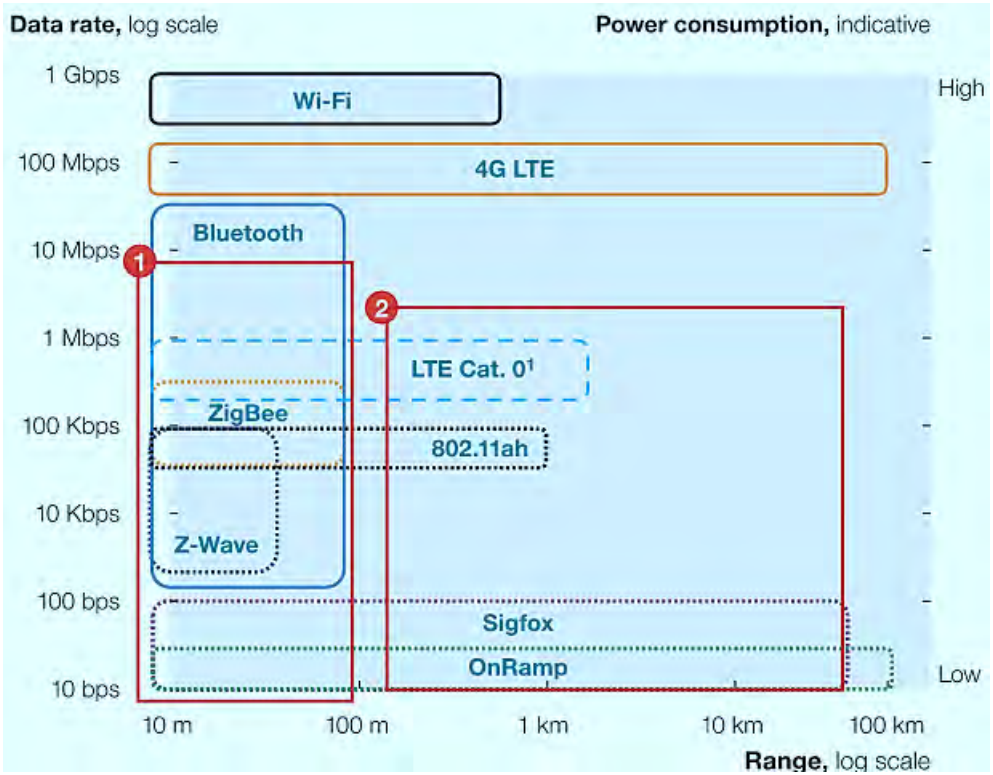
Source: http://www.libelium.com/e-health-low-cost-sensors-for-early-detection-of-childhood-disease-inspire-project-hope/

Communications Technology - Wide Variety

IoT - Communications Technology

Selected IoT Communications Technology

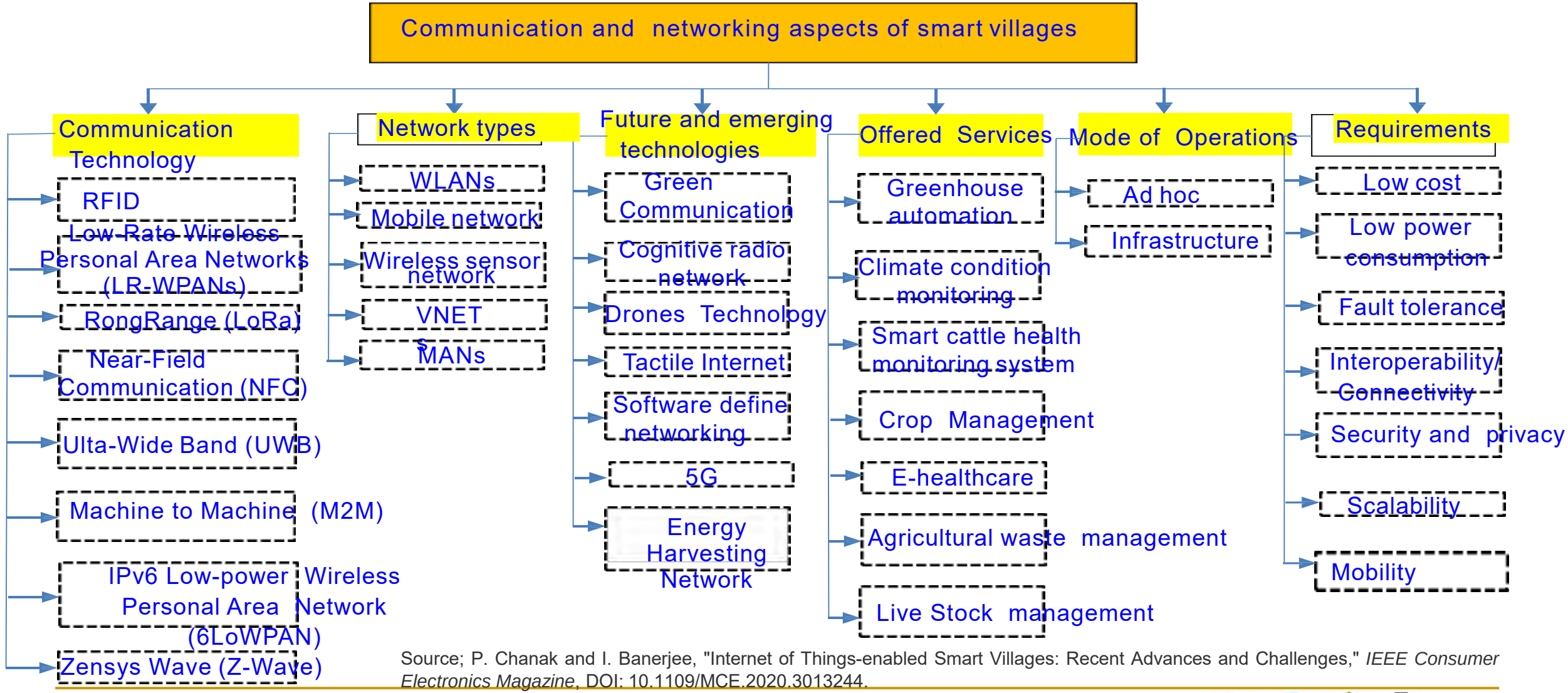
- Bluetooth Low-Energy (BLE)
- Zigbee
- Z-Wave
- 6LowPAN
- Thread
- WiFi
- Cellular
- NFC
- Sigfox
- Neul
- LoRaWAN



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

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

Smart Villages - Communication and networking



Source; P. Chanak and I. Banerjee, "Internet of Things-enabled Smart Villages: Recent Advances and Challenges," *IEEE Consumer Electronics Magazine*, DOI: 10.1109/MCE.2020.3013244.

Energy Consumption and Latency in Communications

- IoT with Cloud: Sensor big data goes to cloud for storage and analytics – Consumes significant energy in communications network
- Connected cars require latency of ms to communicate and avoid impending crash:
  - Faster connection
  - Low latency
  - Lower power
- 5G for connected world: Enables all devices to be connected seamlessly.

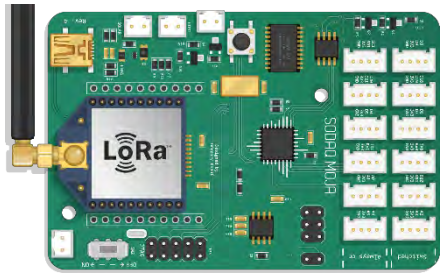
Source: https://www.linkedin.com/pulse/key-technologies-connected-world-cloud-computing-ioe-balakrishnan

Communications – Energy, Data Rate, and Range Tradeoffs

- LoRa: Long Range, low-powered, low-bandwidth, IoT communications as compared to 5G or Bluetooth.
- SigFox: SigFox utilizes an ultra-narrowband wide-reaching signal that can pass through solid objects.

Technology	Protocol	Maximum Data Rate	Coverage Range
ZigBee	ZigBee Pro	250 kbps	1 mile
WLAN	802.11x	2-600 Mbps	0.06 mile
Cellular	5G	1 Gbps	Short - Medium
LoRa	LoRa	50 kbps	3-12 miles
SigFox	SigFox	1 kbps	6-30 miles

Effective for smart villages where Internet may not be available for villages.



Source: Mohanty iSES Keynote 2018

Visible Light for High-Bandwidth Wireless Communications

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

High Data Density

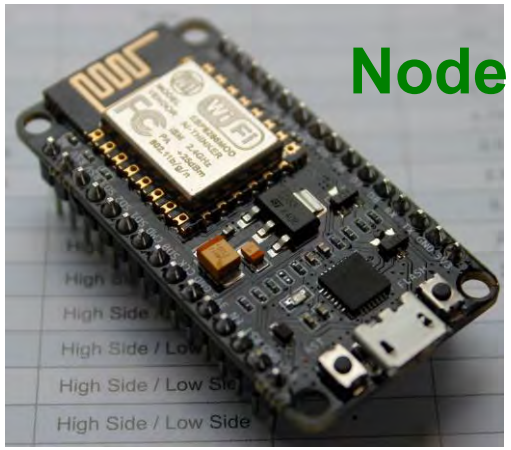
Short Range

Source: VLCS-2014
Source: Ribeiro 2017, CE Magazine October 2017

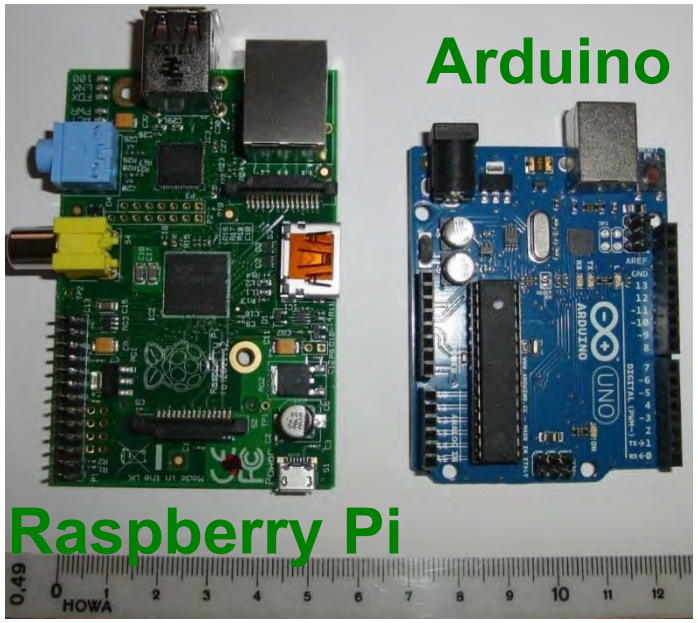
Computing Technology - IoT Platform

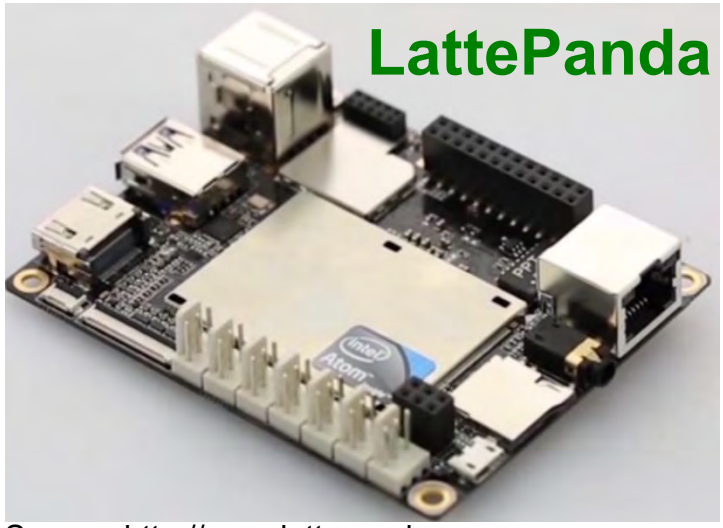
ESP8266

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



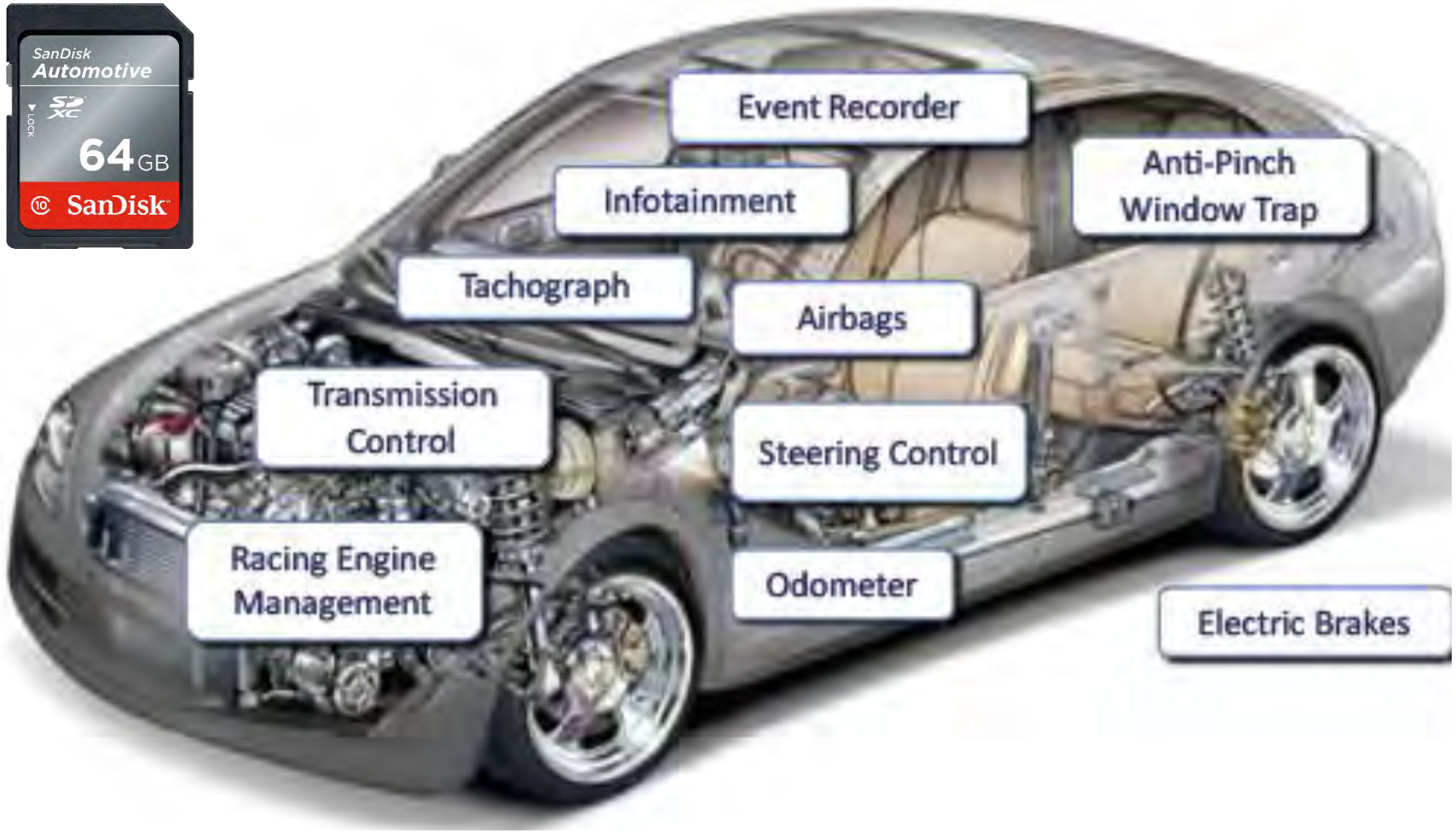
NodeMCU





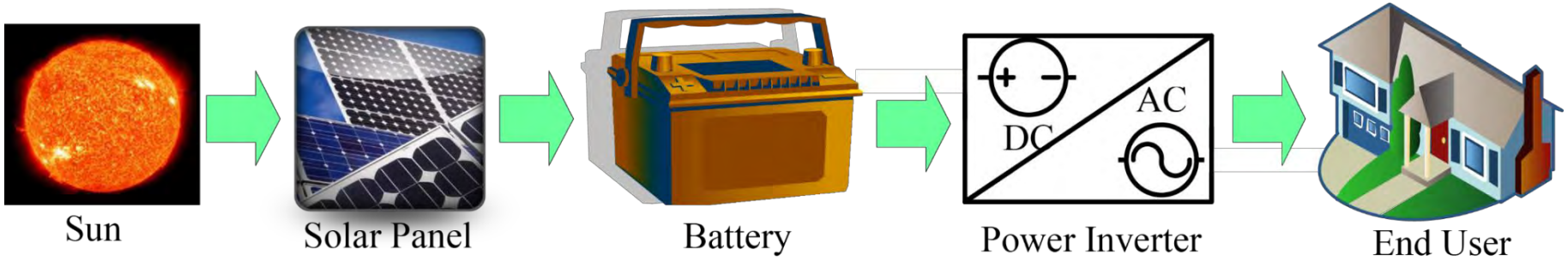
Source: http://www.lattepanda.com

Memory Technology – Car Example

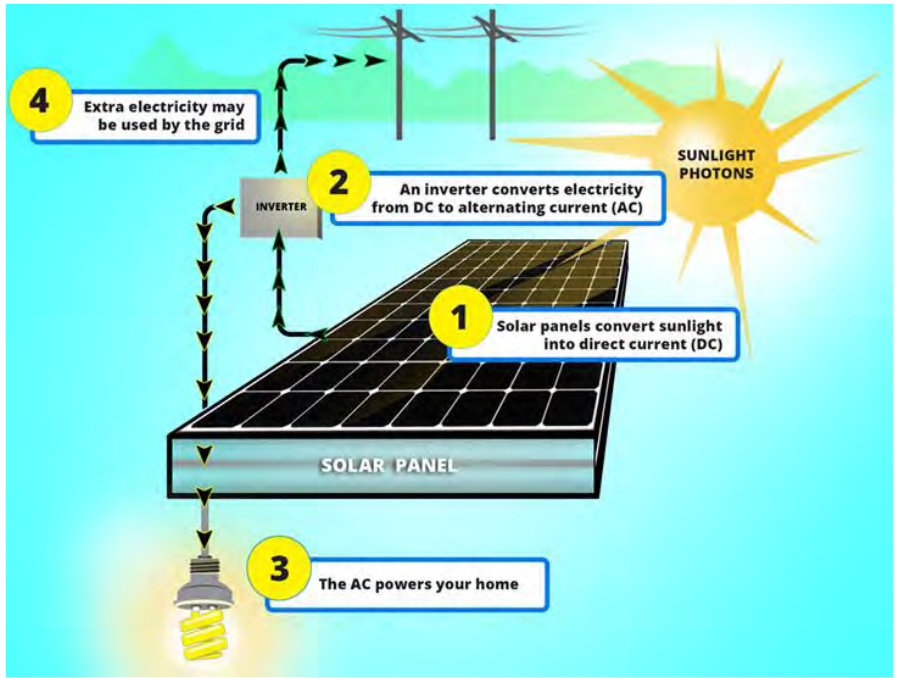


Source: Coughlin 2016, CE Magazine October 2016

Green or Renewable Energy – Solar



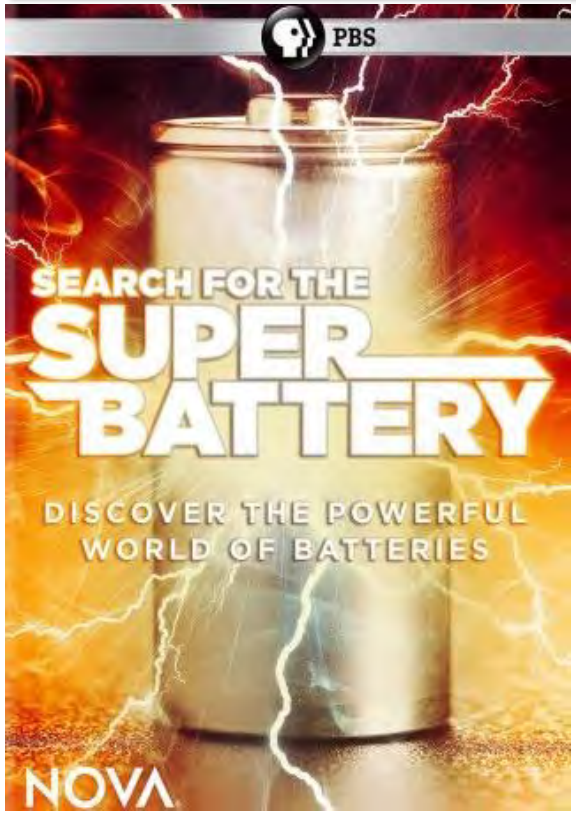
Source: Mohanty 2015, McGraw-Hill 2015



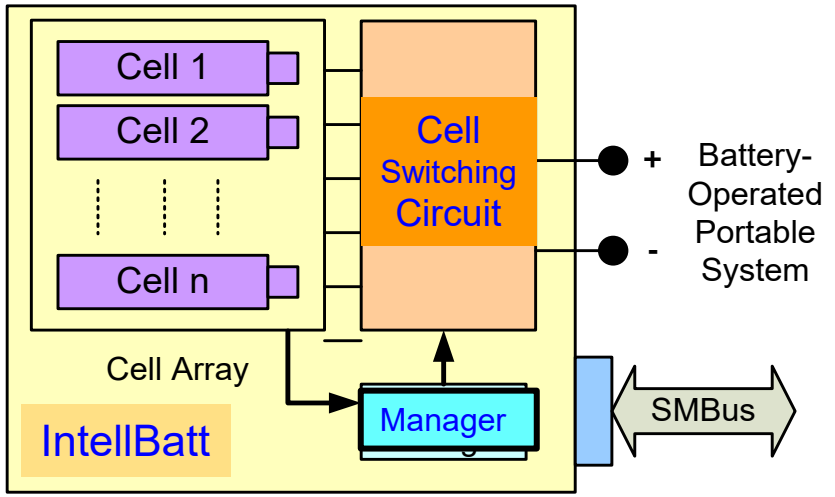
Source: https://us.sunpower.com/blog/2017/10/25/how-does-solar-energy-work/

Energy Storage - High Capacity & Efficiency

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



Intelligent Battery



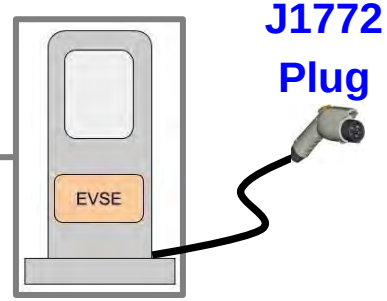
Mohanty 2010: IEEE Computer, March 2010
Mohanty 2018: ICCE 2018

Lithium Polymer Battery

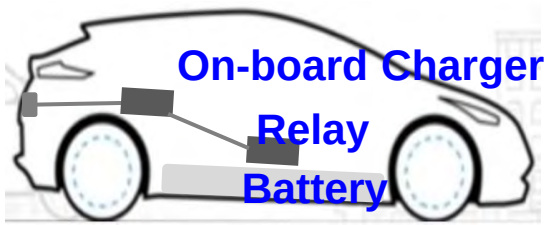
Supercapacitor

EV Charging Technology

Grid



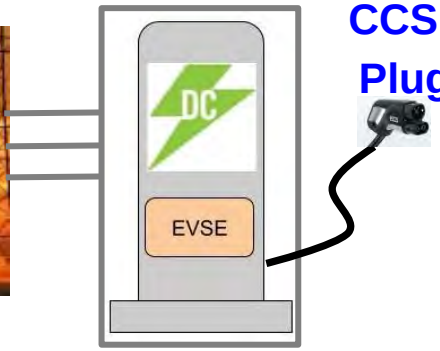
J1772 Plug



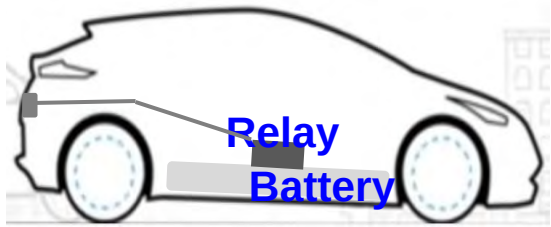
AC charging station

- Monitoring function
- Communication and safety

3 phase AC supply



CCS1 Plug



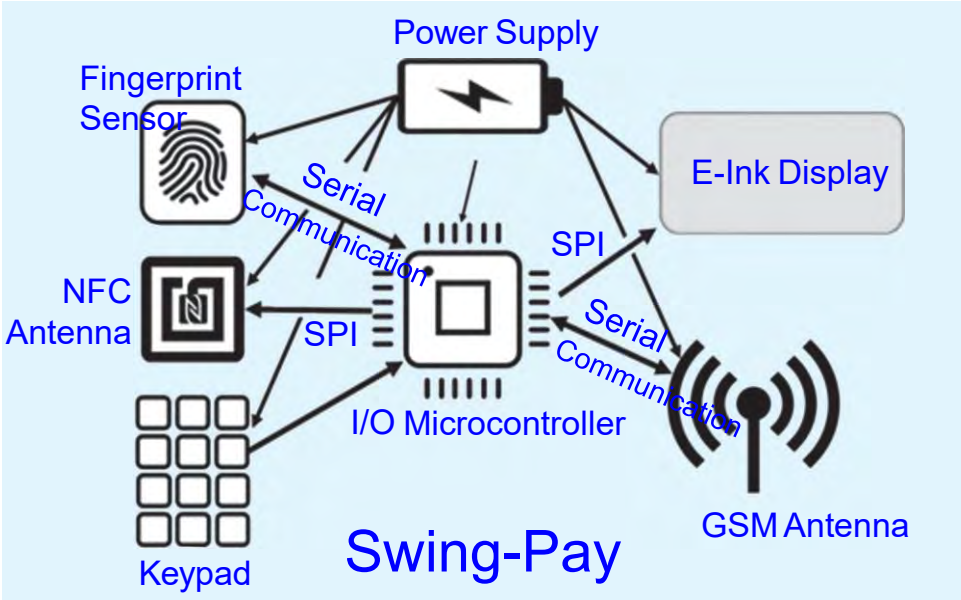
DC charging station

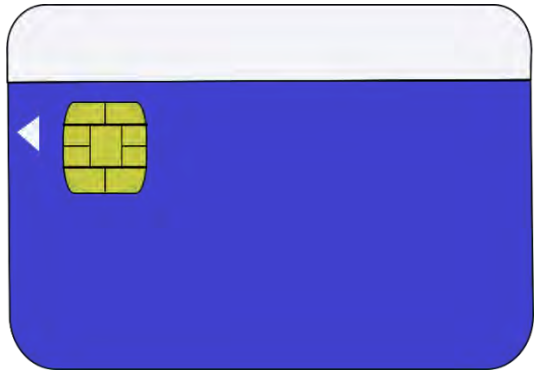
- AC-DC Off board conversion
- Monitoring Power flow
- EV to grid communication
- Safety monitoring

Electric Vehicle Supply Equipment (EVSE)

Source: S. K. Rastogi, A. Sankar, K. Manglik, S. K. Mishra, and S. P. Mohanty, "Toward the Vision of All-Electric Vehicles in a Decade", IEEE Consumer Electronics Magazine (CEM), Volume 8, Issue 2, March 2019, pp. 103--107.

Cashless Payment Technology – An Example





Source: Mohanty 2017, CE Magazine Jan 2017

Artificial Intelligence Technology

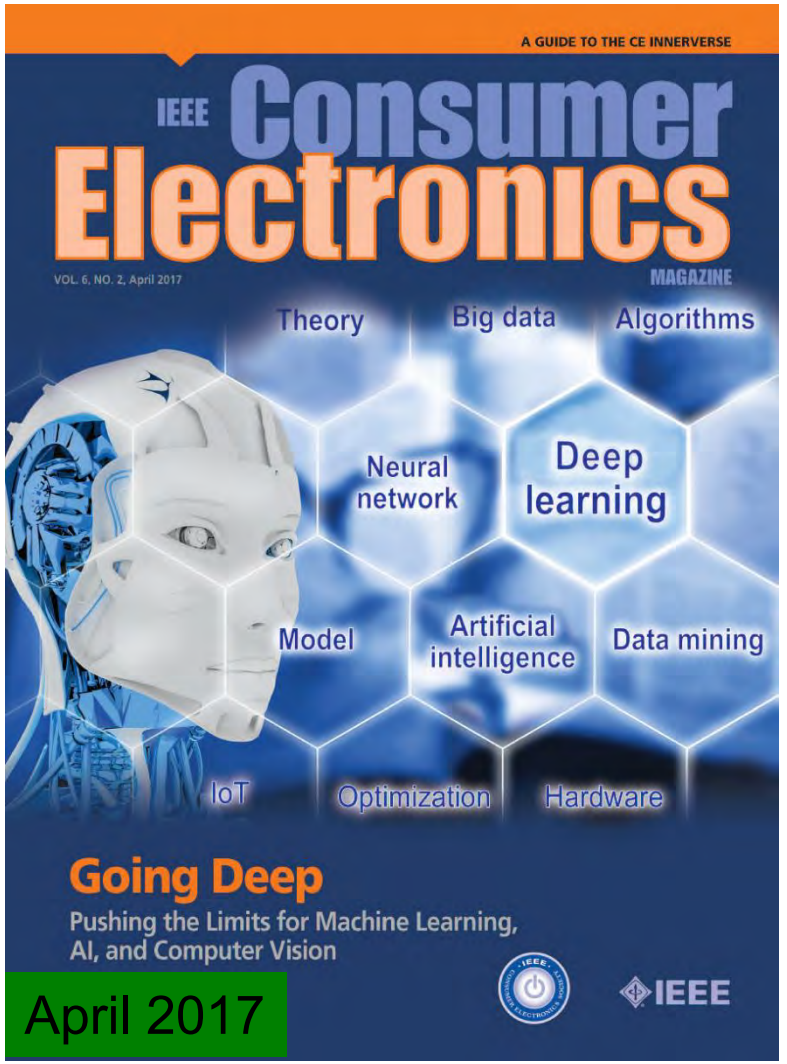
Source: http://transmitter.ieee.org/impact-aimachine-learning-iot-various-industries/

Tensor Processing Unit (TPU)

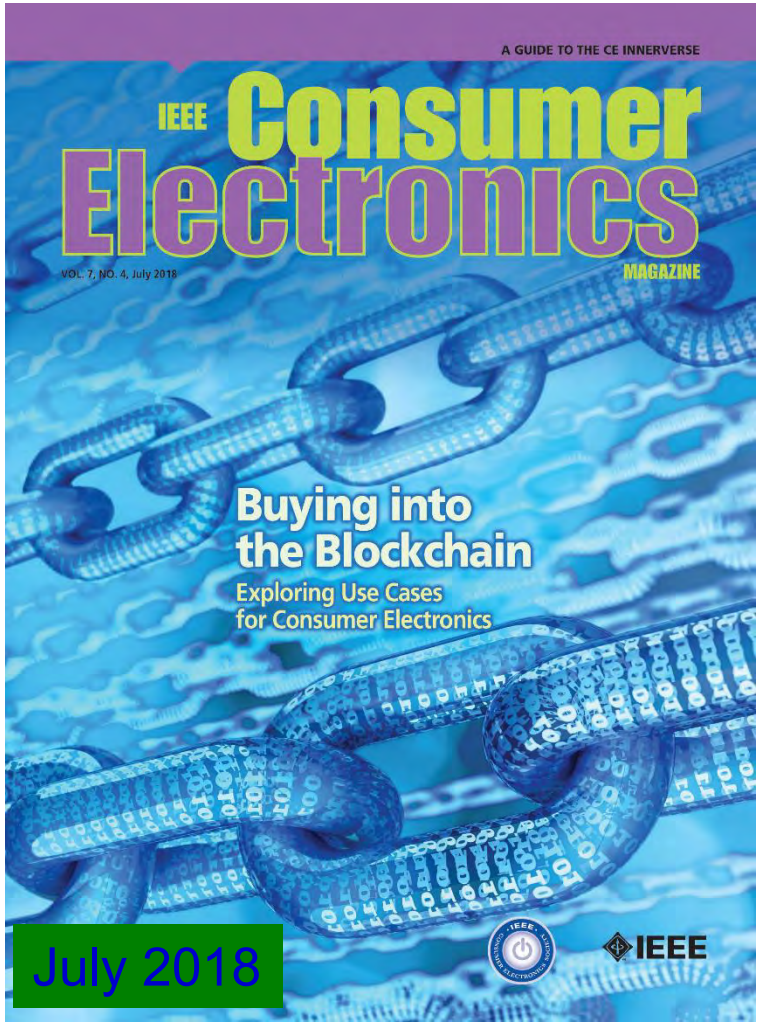
Source: https://fossbytes.com/googles-home-made-ai-processor-is-30x-faster-than-cpus-and-gpus/

Smart City Use:

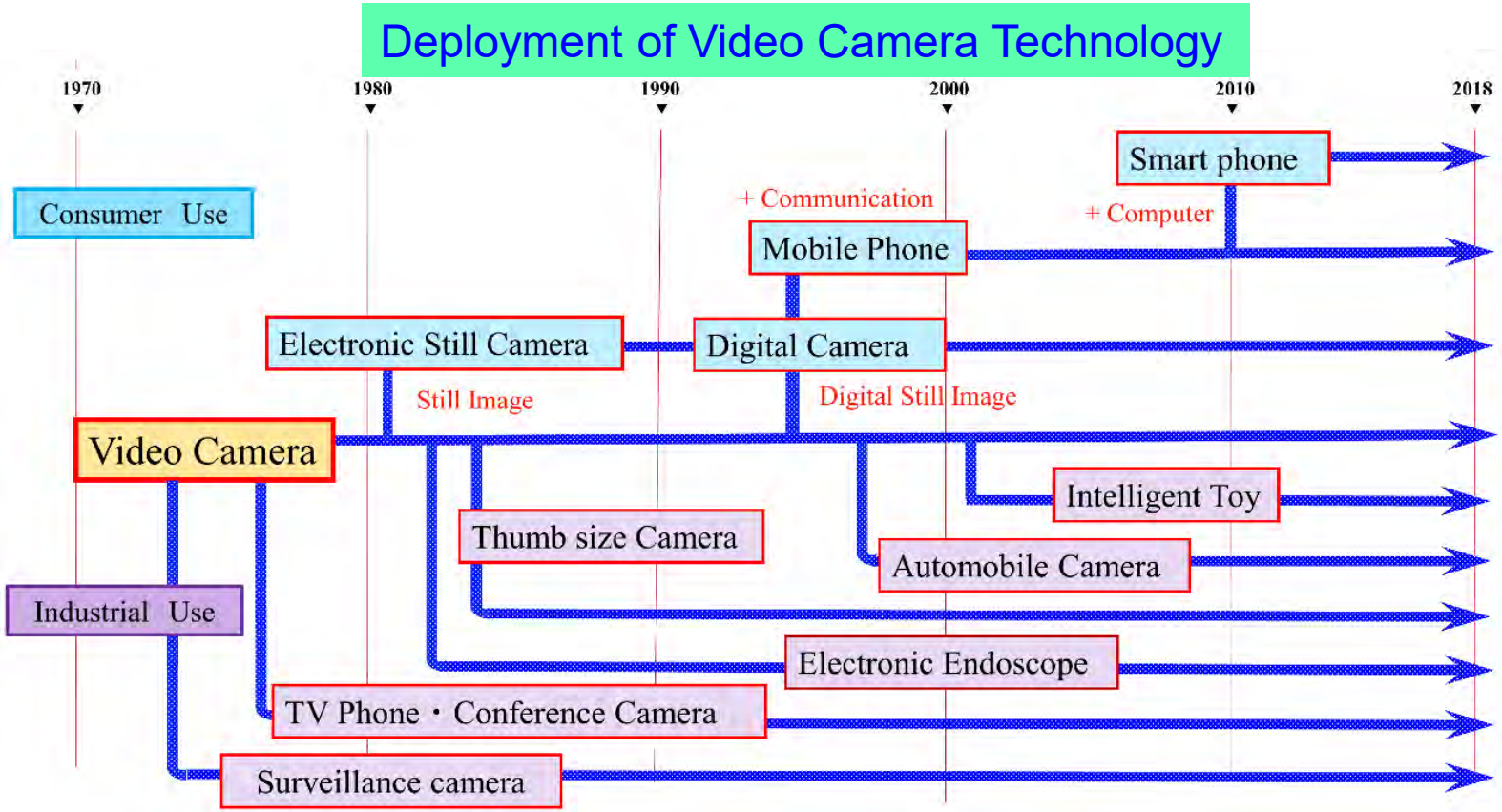
- Better analytics
- Better decision
- Faster response



Blockchain Technology



Cameras are Everywhere



Source: Y. Takemura, "The Development of Video-Camera Technologies: Many Innovations Behind Video Cameras Are Used for Digital Cameras and Smartphones," *IEEE Consumer Electronics Magazine*, vol. 8, no. 4, pp. 10-16, July 2019.

CMOS image sensors →
Cameras of any size, part of any device, and placed at any location.

Unmanned Ariel Vehicle (UAV)

Unmanned Arial Vehicles or Remotely Piloted Vehicles is an aircraft without a human pilot on board.

- Unmanned Aerial Vehicle
- Drone - remotely piloted
- Controlled autonomously

UAV Applications - 4 Categories

Data collection & surveying

Monitoring & Tracking

Temporary Infrastructure

Delivery of Goods

Source: Christos Kyrkou, Stelios Timotheou, Panayiotis Kolios, Theocharis Theocharides, and Christos Panayiotou, "Drones: Augmenting Our Quality of Life", *IEEE Potentials Magazine*, vol. 38, no. 1, pp. 30-36, Jan-Feb 2019.

Virtual and Augmented Reality Technology

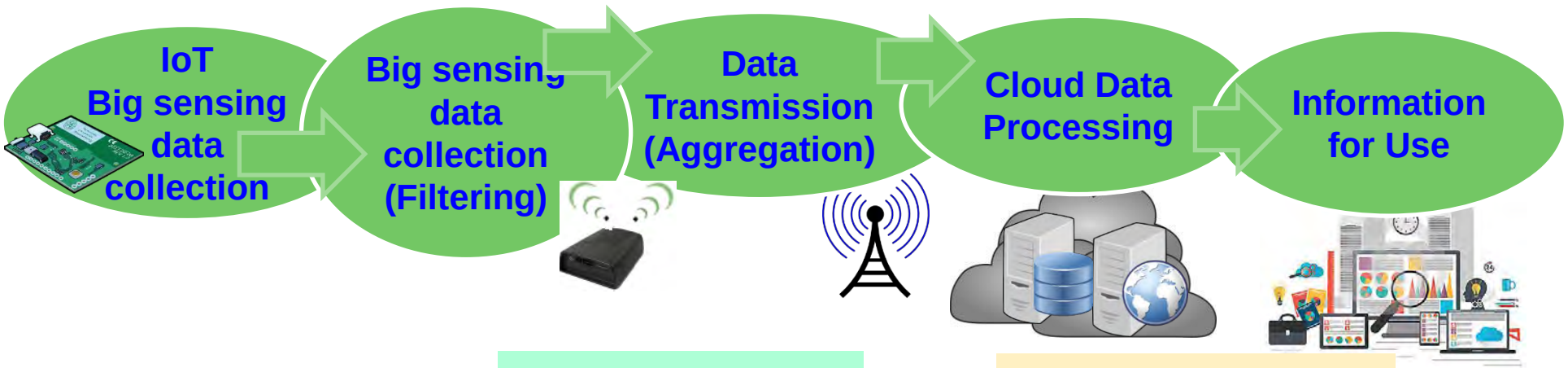
Virtual Reality

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

Augmented Reality

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

Secure Data Curation



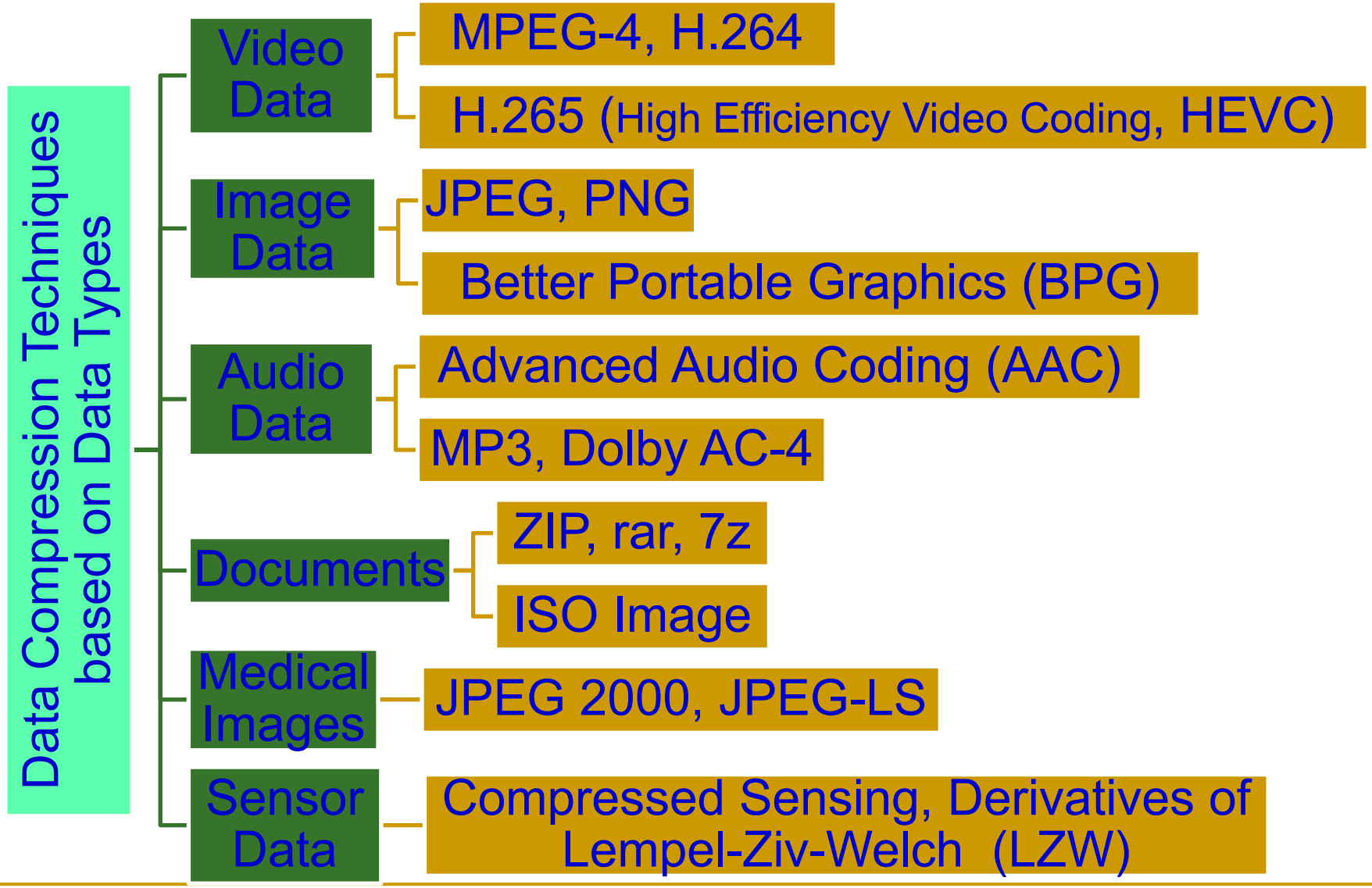
Edge Training:
- Data Signature
- Model Signature

Cloud Training:
- Data Signature
- Model Signature

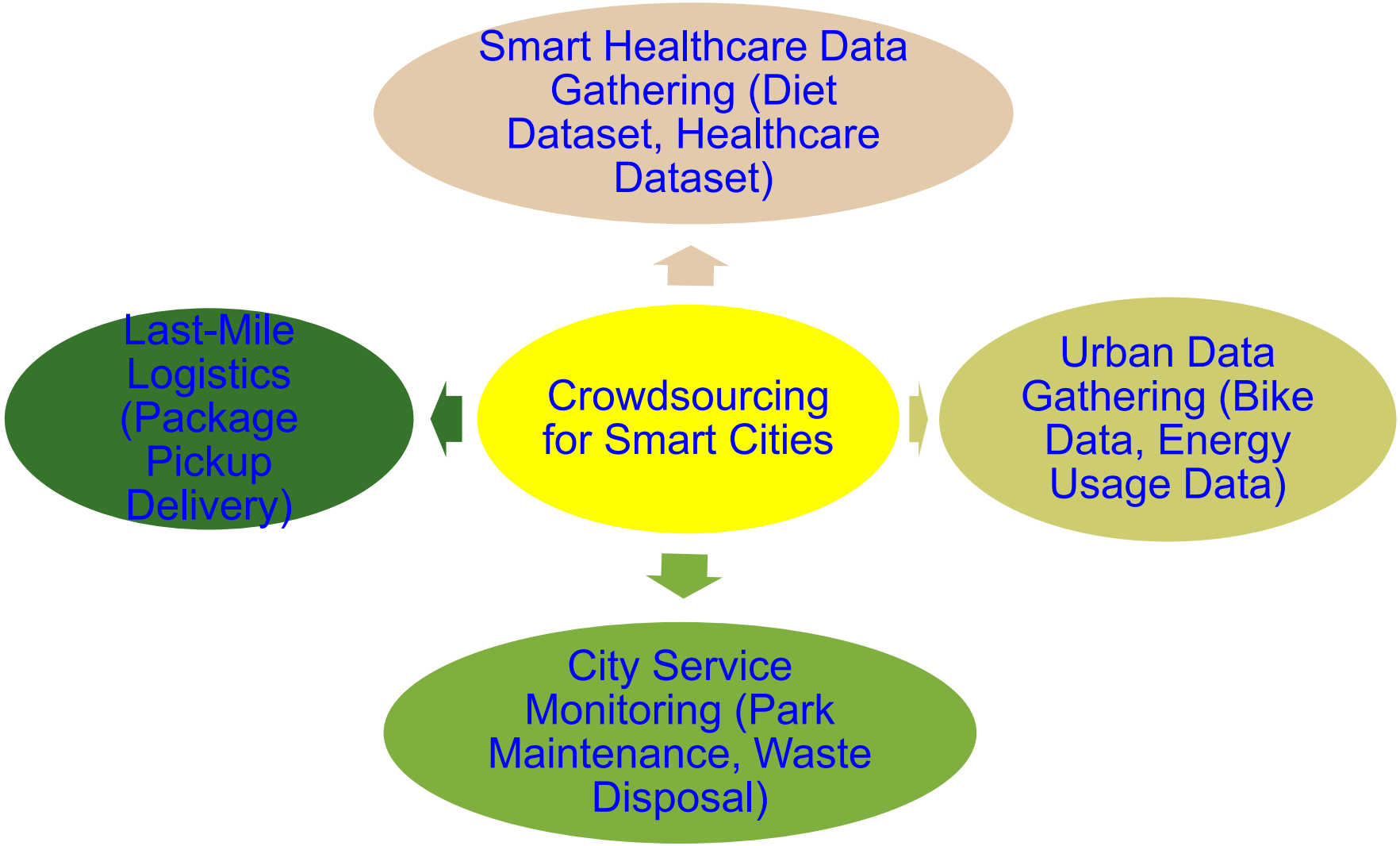
Fake Data Defense:
- Stop (Shield)
- Detect

Source: C. Yang, D. Puthal, S. P. Mohanty, and E. Kougianos, “Big-Sensing-Data Curation for the Cloud is Coming”, IEEE Consumer Electronics Magazine (CEM), Volume 6, Issue 4, October 2017, pp. 48--56.

Data Compression in Smart Cities



Crowdsourcing for Smart Cities



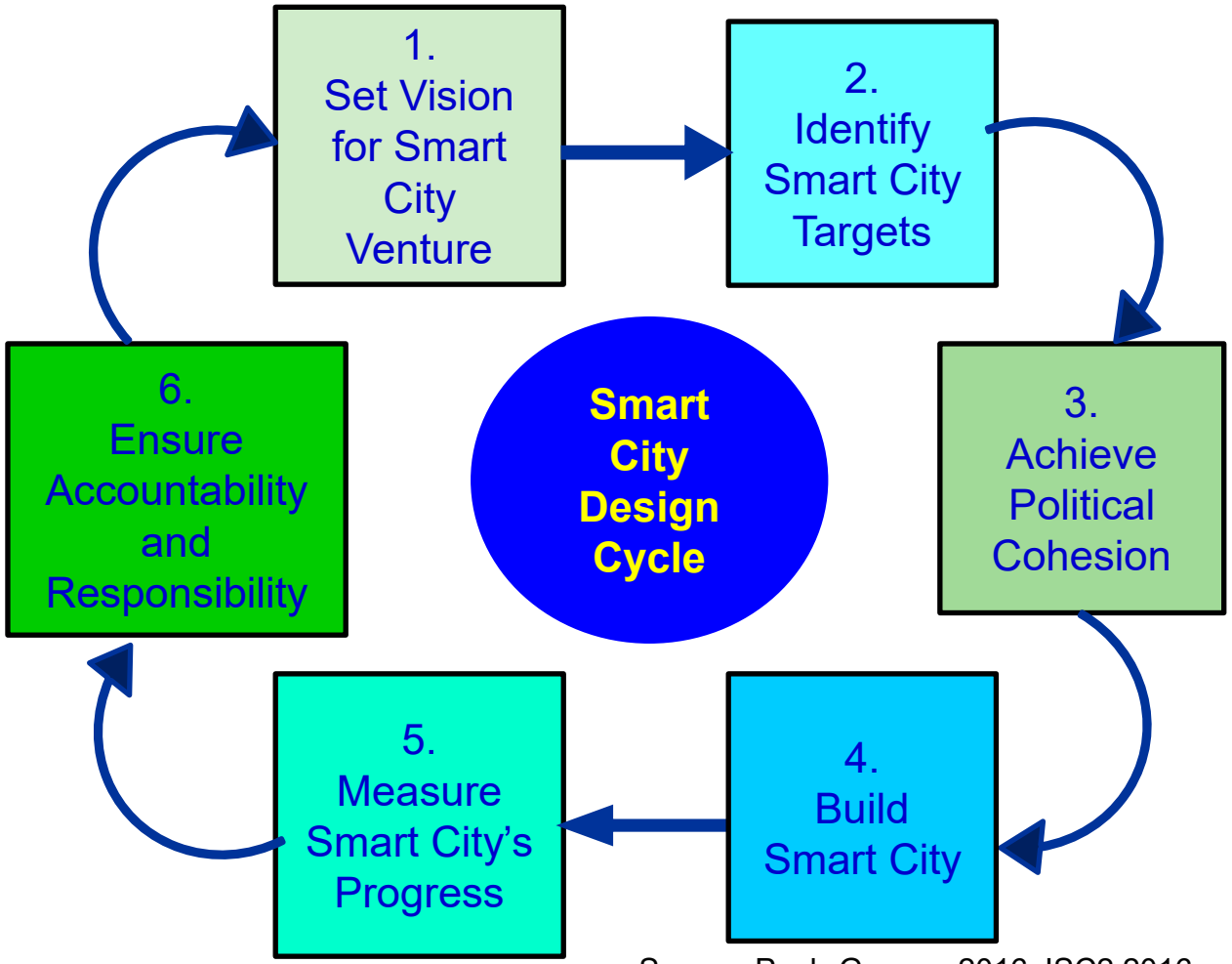
Technology in Smart Cities

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

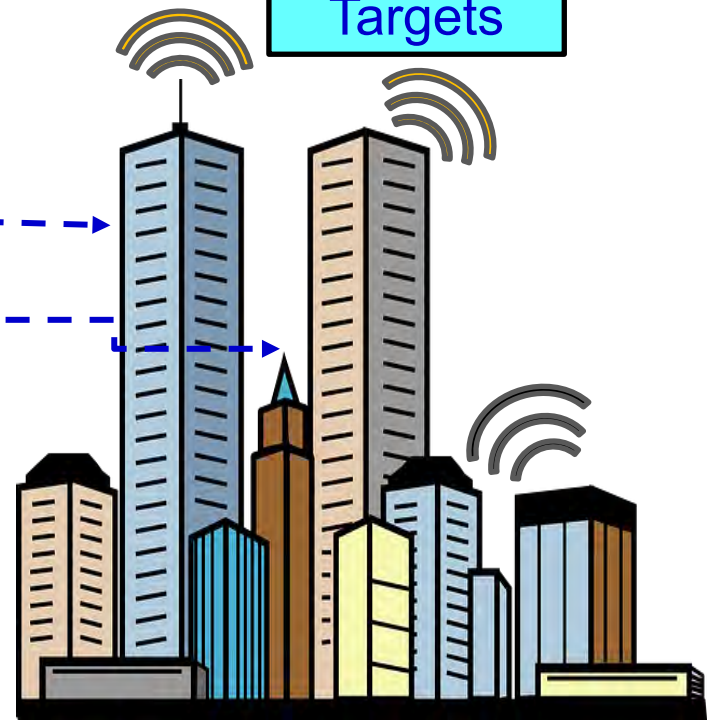


Source: Paolo Gemma 2016, ISC2 2016

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

Source: Paolo Gemma 2016, ISC2 2016

Smart City Design - Sustainable Developmental Goals

5. Measure City's Progress

Dimensions of Key Performance Indicators (KPIs)

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

Source: Paolo Gemma 2016, ISC2 2016

Smart City Design – Building Trust

6. Ensure Accountability and Responsibility

Citizen-Centric

Data-Driven Decision

Cost Effective

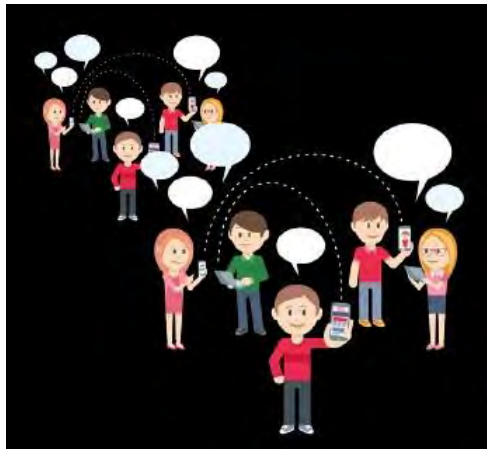
Smart Tools

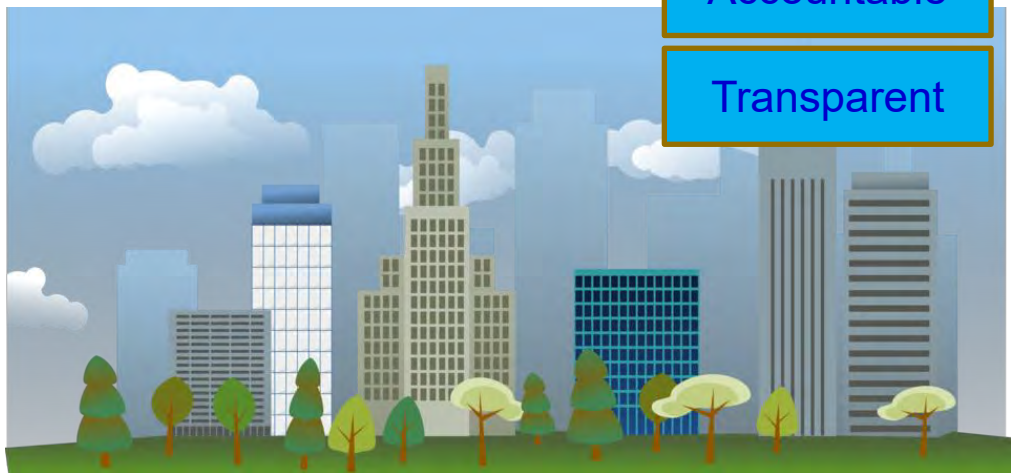
Collaborative

Responsive

Accountable

Transparent





Source: Paolo Gemma 2016, ISC2 2016

Top Smart Cities Using 4 KPIs in 2018

	Mobility	Health	Safety	Productivity
1	Singapore	Singapore	Singapore	Singapore
2	San Francisco	Seoul	New York	London
3	London	London	Chicago	Chicago
4	New York	Tokyo	Seoul	San Francisco
5	Barcelona	Berlin	Dubai	Berlin
6	Berlin	New York	Tokyo	New York
7	Chicago	San Francisco	London	Barcelona
8	Portland	Melbourne	San Francisco	Melbourne
9	Tokyo	Barcelona	Rio de Janeiro	Seoul
10	Melbourne	Chicago	Nice	Dubai
11	San Diego	Portland	San Diego	San Diego
12	Seoul	Dubai	Melbourne	Nice
13	Nice	Nice	Bhubaneswar	Portland
14	Dubai	San Diego	Barcelona	Tokyo
15	Mexico City	Wuxi	Berlin	Wuxi
16	Wuxi	Mexico City	Portland	Mexico City
17	Rio de Janeiro	Yinchuan	Mexico City	Rio de Janeiro
18	Yinchuan	Hangzhou	Wuxi	Yinchuan
19	Hangzhou	Rio de Janeiro	Yinchuan	Hangzhou
20	Bhubaneswar	Bhubaneswar	Hangzhou	Bhubaneswar

Source: https://newsroom.intel.com/wp-content/uploads/sites/11/2018/03/smart-cities-whats-in-it-for-citizens.pdf

Smart City - How Many Facilities?

- Number of city facilities required is a function of city population.
- Calculated as follows:

$$N_f = N_p\ People\left(\frac{R_p}{Year}\right)\left(\frac{1\ Year}{D\ Days}\right)\left(\frac{1\ Hour}{N_c\ People}\right)\left(\frac{1\ Day}{H\ Hours}\right)$$

where N_f is the number of facilities, N_p is the city population in millions, R_p is the rate per person use in year/week, D is days per year, N_c is the customers per hours, and H is the hours per day.

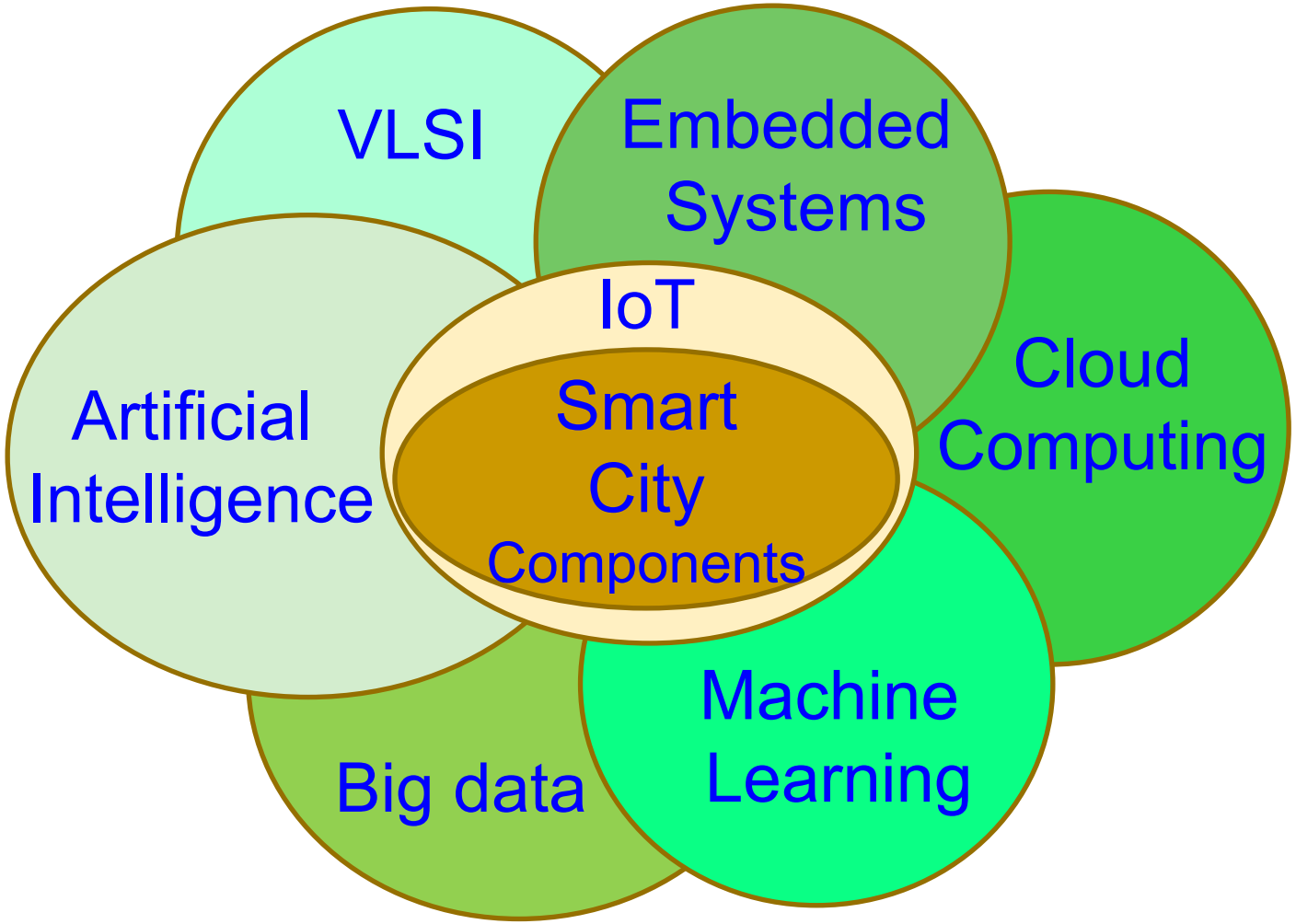
- For example: How many dental offices might there be for a city population of one million? One Solution:

$$N_f = 10^6\ People\left(\frac{1}{Year}\right)\left(\frac{1\ Year}{300\ Days}\right)\left(\frac{1\ Hour}{5\ People}\right)\left(\frac{1\ Day}{8\ Hours}\right)$$

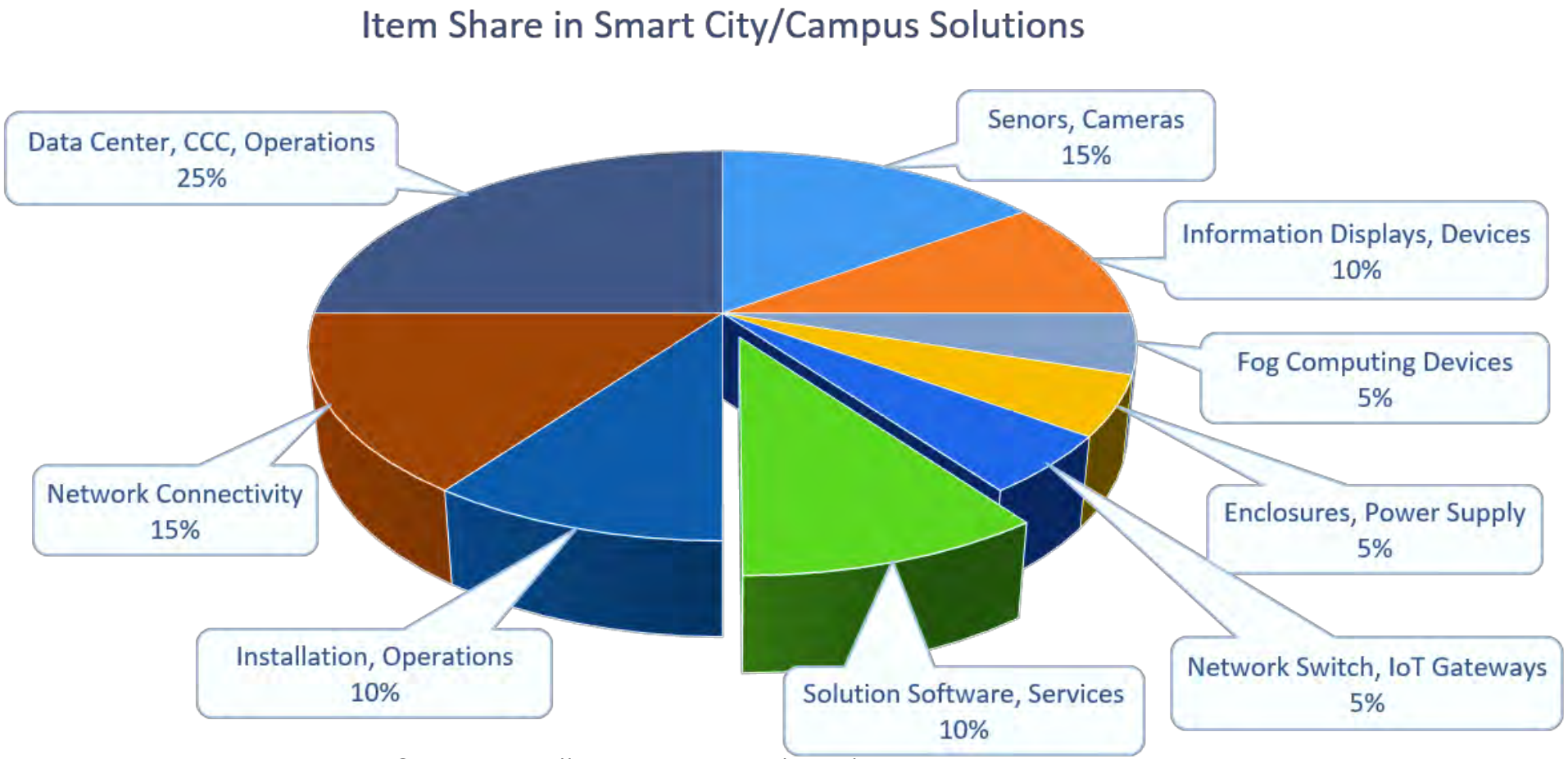
$$= \left(\frac{10^6}{1.2 \times 10^4}\right) \simeq 100$$

Source: Adam 2012, X and the city : modeling aspects of urban life

Smart City Design - Verticals

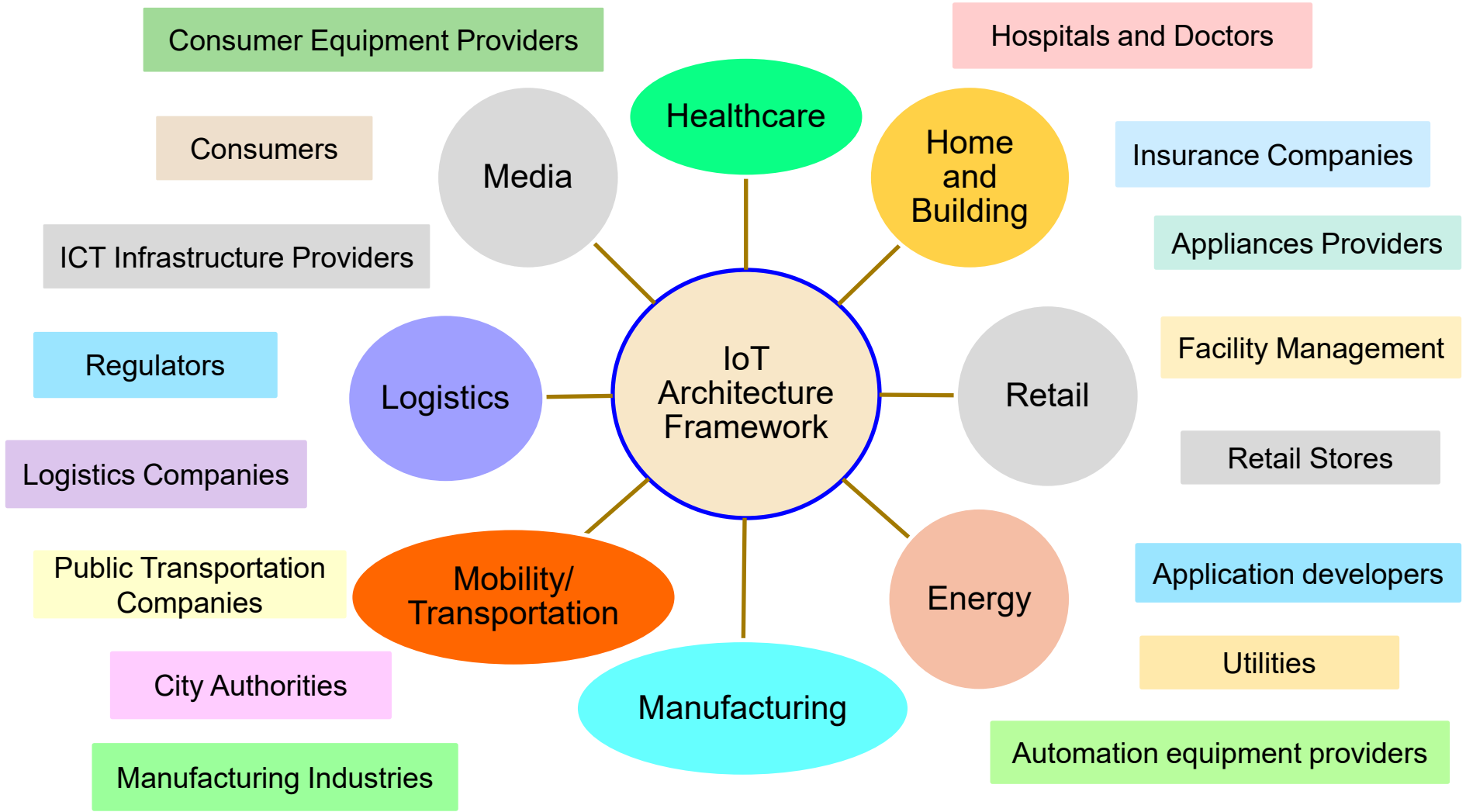


Smart City Design - Verticals



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

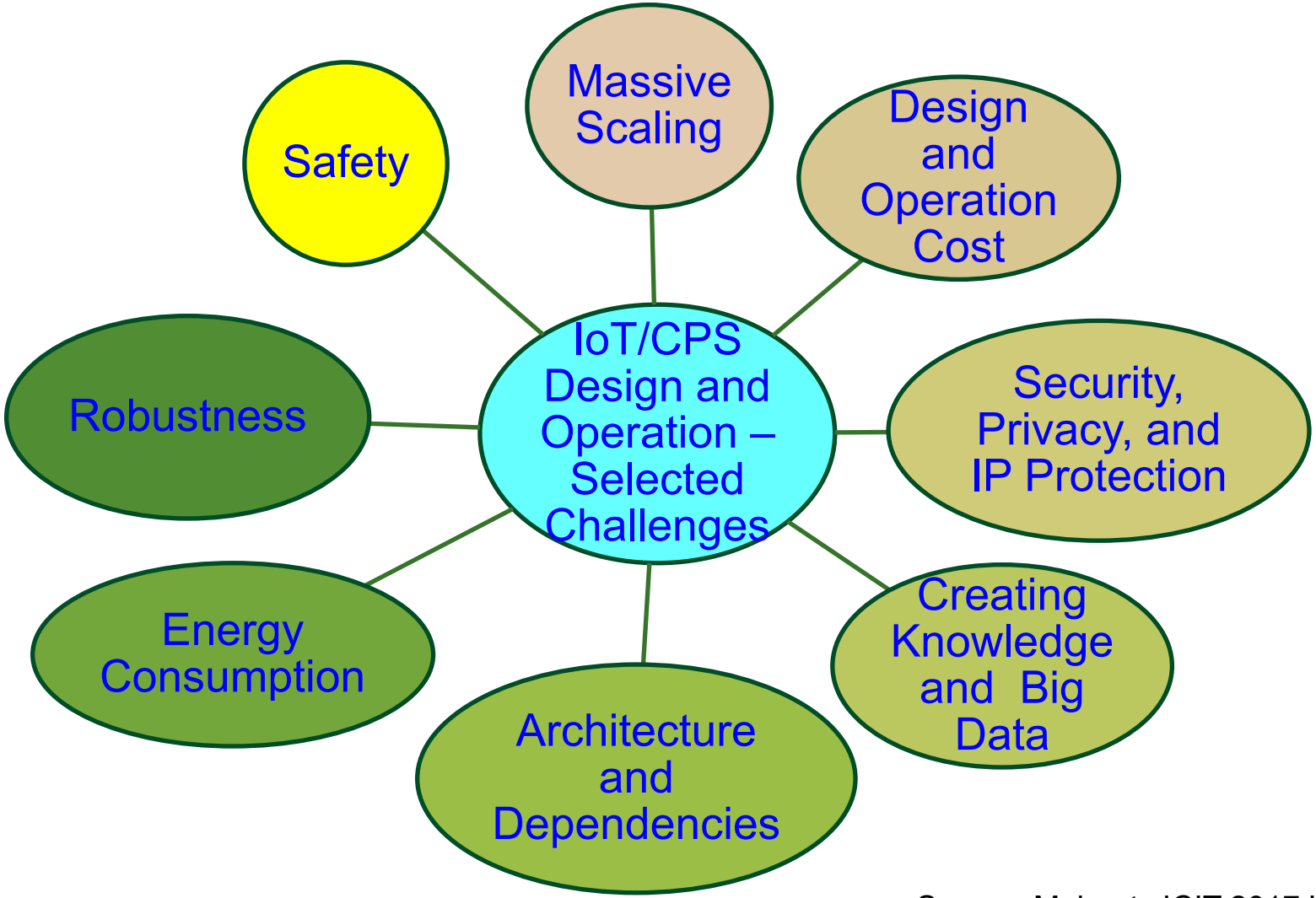
IoT: Markets and Stakeholders



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

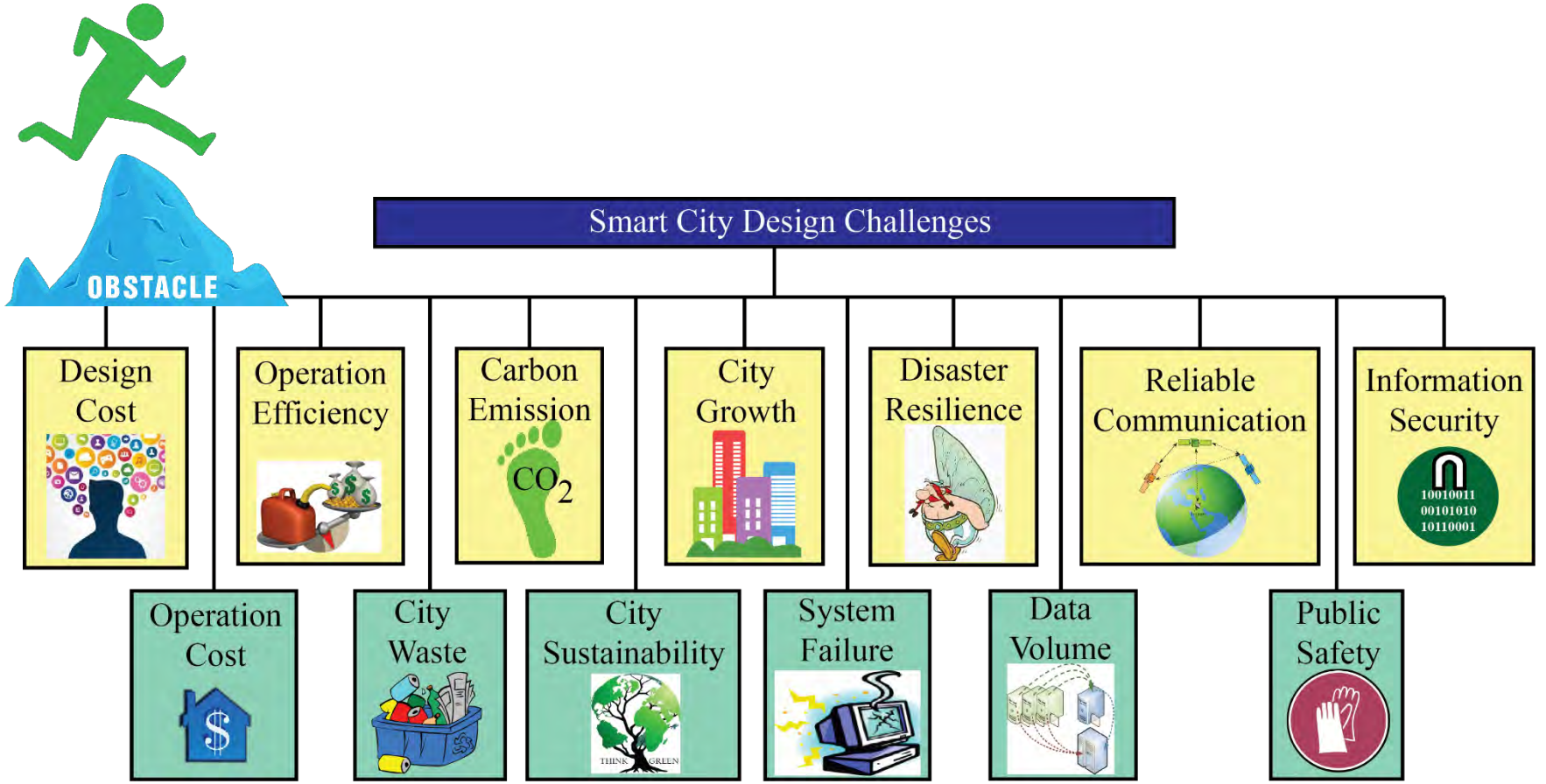
Challenges and Research

IoT/CPS – Selected Challenges



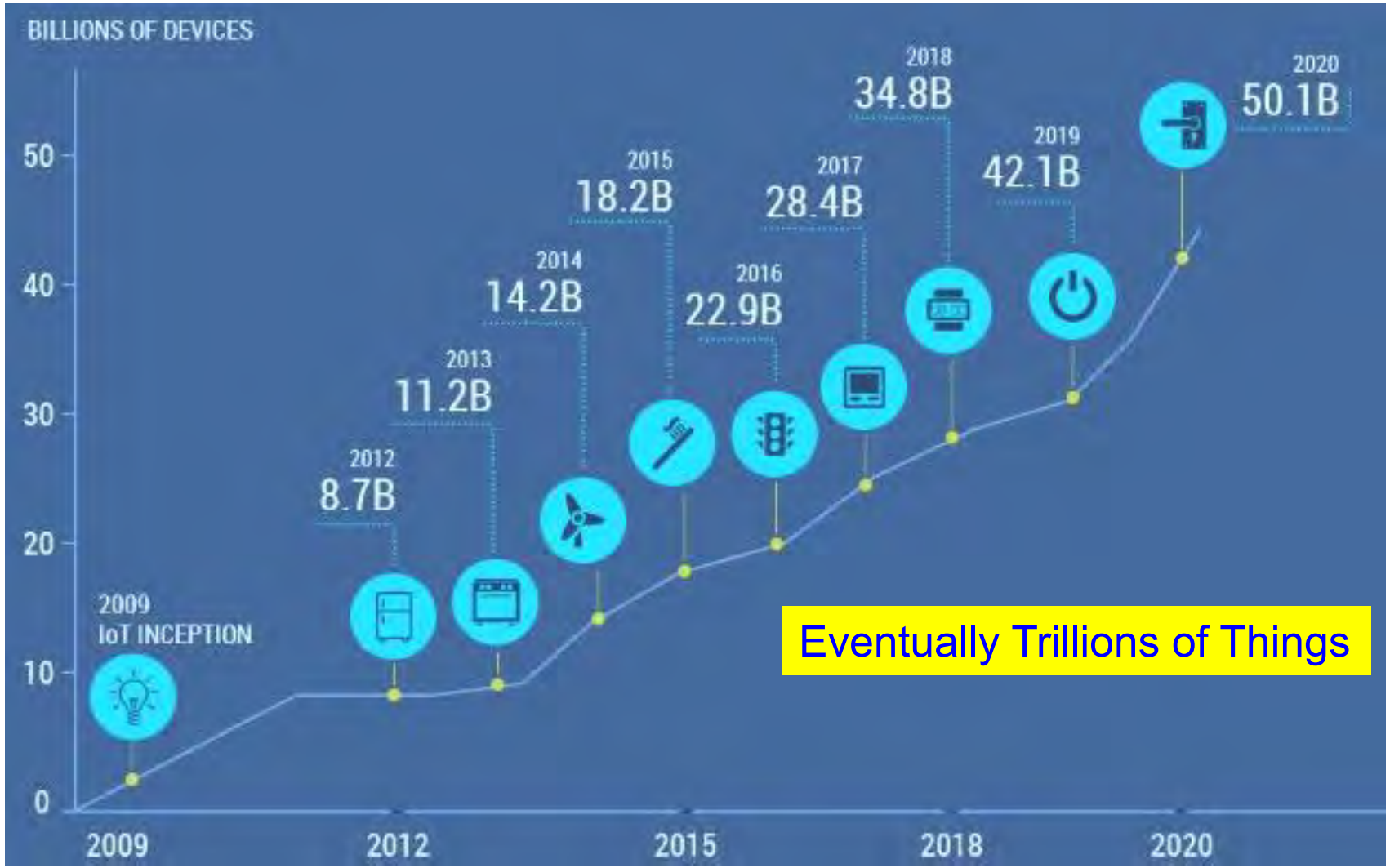
Source: Mohanty ICIT 2017 Keynote

Smart City - Selected Design Challenges



Source: Mohanty 2016, CE Magazine July 2016

Massive Growth of Sensors/Things



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

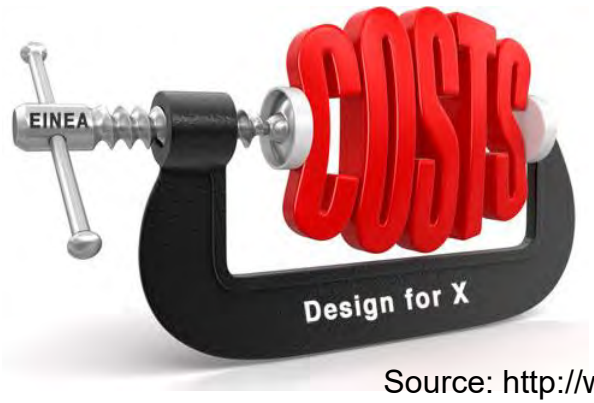
Cost

- "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

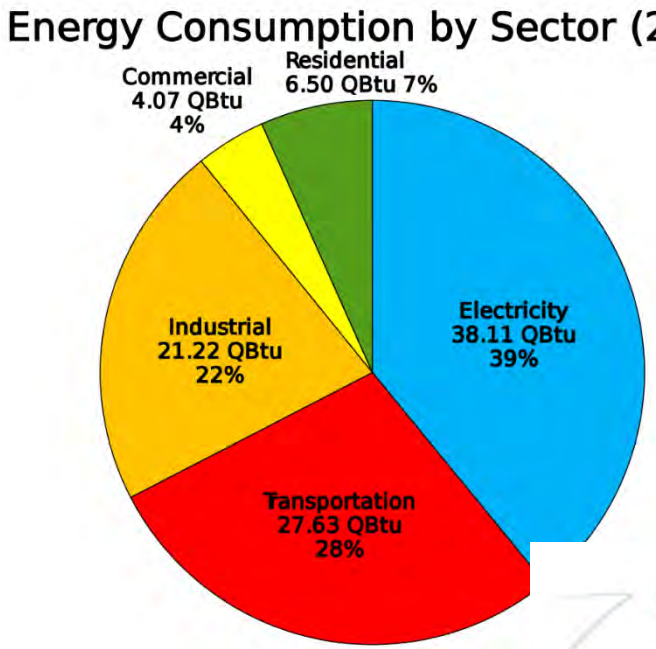
- The operations cost is that required to maintain the smart city.
- A small operations cost will make it easier for cities to operate in the long run with minimal burden on the city budget.

Cost - Technology

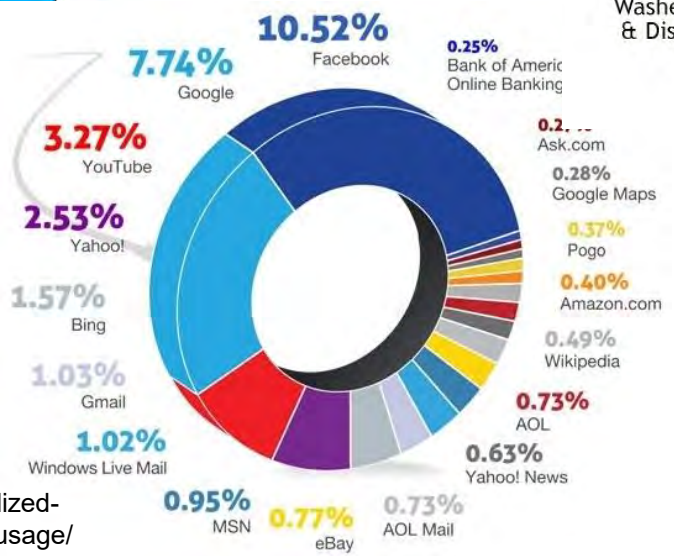
Smart Cities Technology	% Net Increase in All Cities
Cloud apps	86
Mobile devices	66.6
Business applications	61.9
Outsourcing	53.8
Security & privacy	53.8

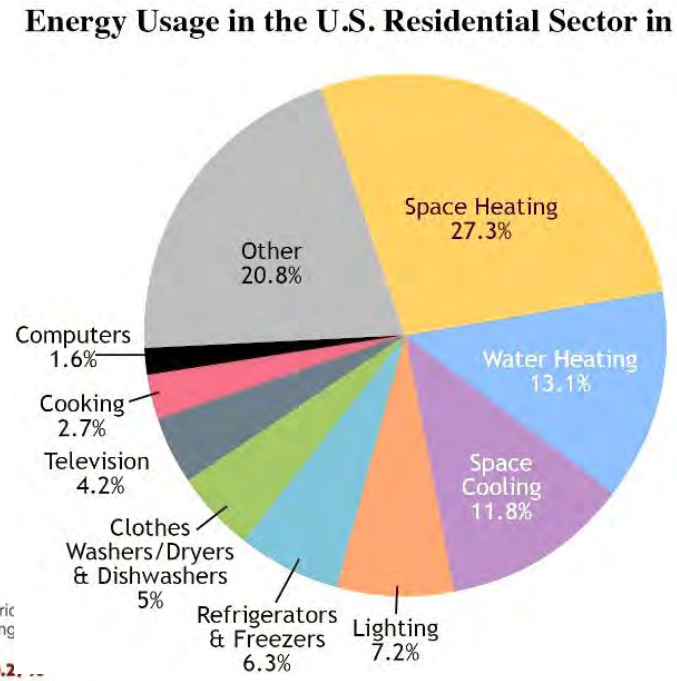
Source: http://www.cnbc.com/2016/10/25/spending-on-smart-cities-around-the-world-could-reach-41-trillion.html

Energy Consumption



Data Center Power Usage

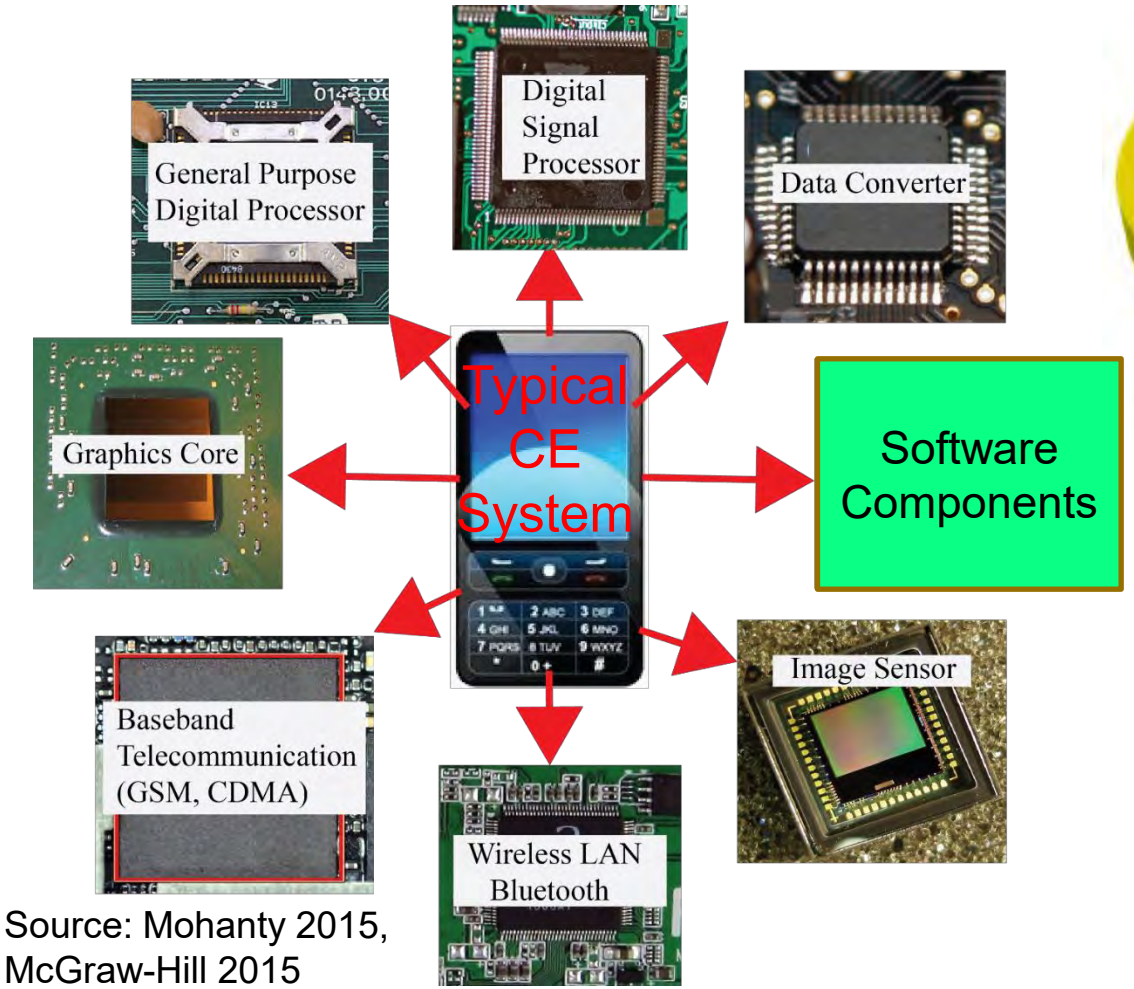




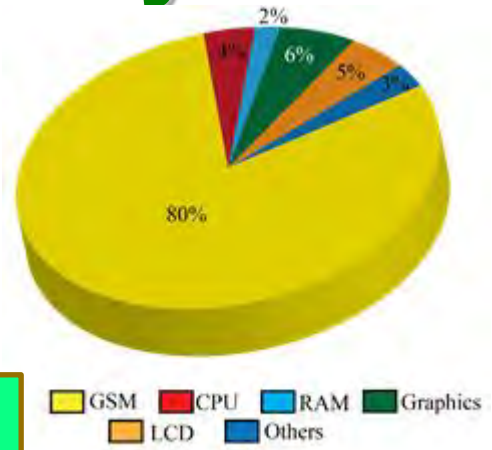
Individual Level: Imagine how often we charge our portable CE!

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

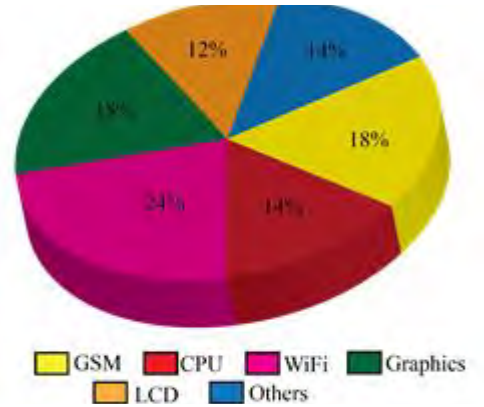
Energy Efficient Sensors, Components, and Systems



Source: Mohanty 2015, McGraw-Hill 2015

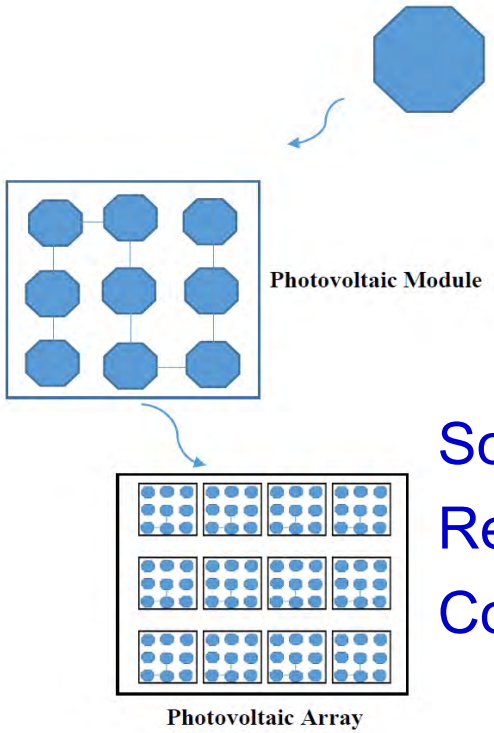


During GSM Communications



During WiFi Communications

Energy Conversion Efficiency

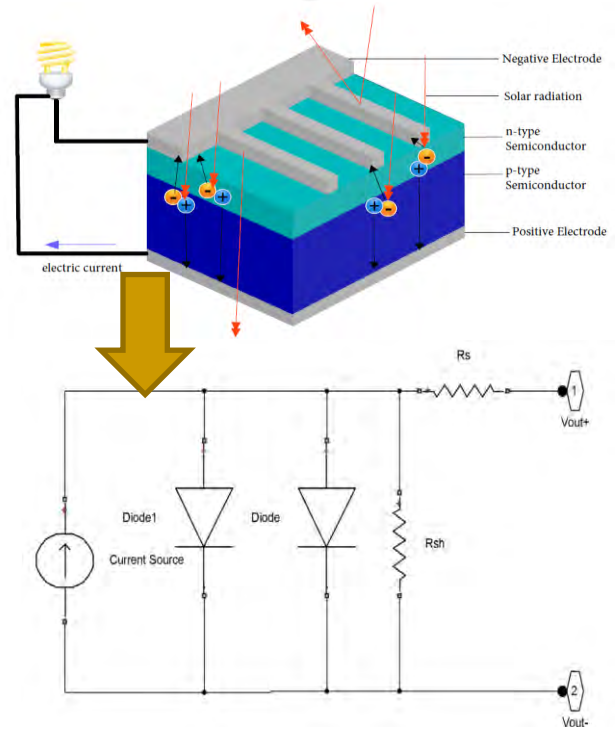


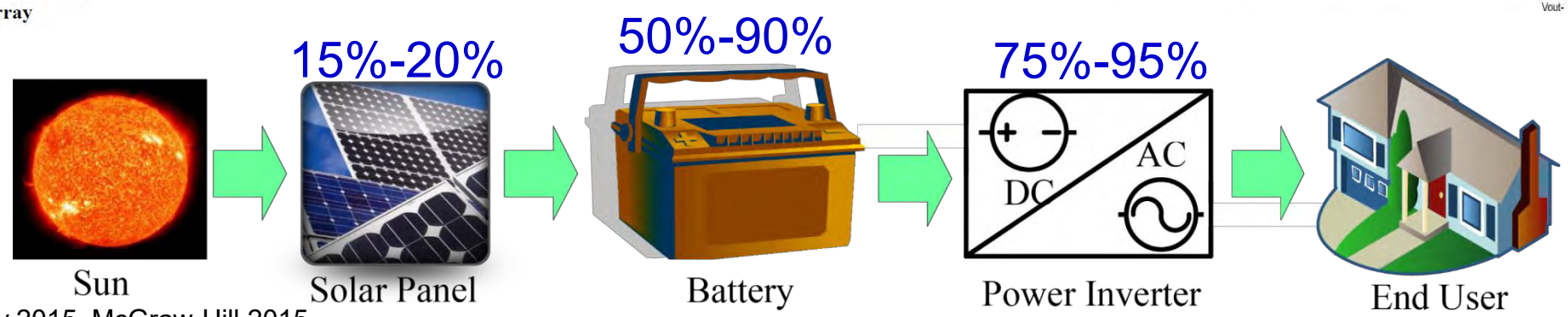
Small solar cells in CE systems to big solar panels in smart grids.

Solar Cell Efficiency:

Research stage: 46%

Commercial: 18%





Source: Mohanty 2015, McGraw-Hill 2015

Energy Storage Efficiency and Safety

- Boeing 787's across the globe were grounded in 2013.

One 787 Battery: 12 Cells / 32 V DC

Source: http://www.newairplane.com

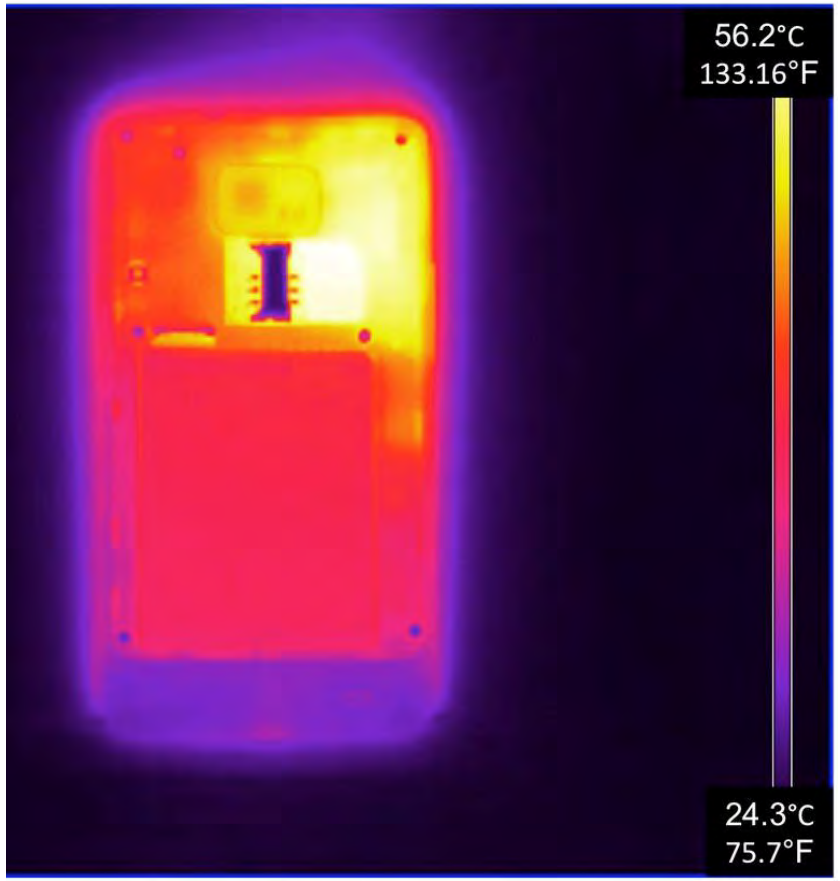
Energy Storage Efficiency and Safety

Tesla SUV crashed into a barrier on Highway 101 in Mountain View, California, on March 23, 2018.

- Lithium-ion batteries, once ignited, are extremely difficult to extinguish.
- Lithium-ion batteries inside EVs, once ignited, can't be put out with chemicals from a conventional extinguisher.

Source: https://www.bloomberg.com/news/articles/2019-03-25/tesla-fires-what-first-responders-don-t-know-about-fiery-evs

Energy Storage Efficiency and Safety



Temperatures can run high inside a smartphone

Source: https://www.cnet.com/news/six-things-to-know-about-smartphone-batteries/

Smartphone Battery is a Key design and operation constraint

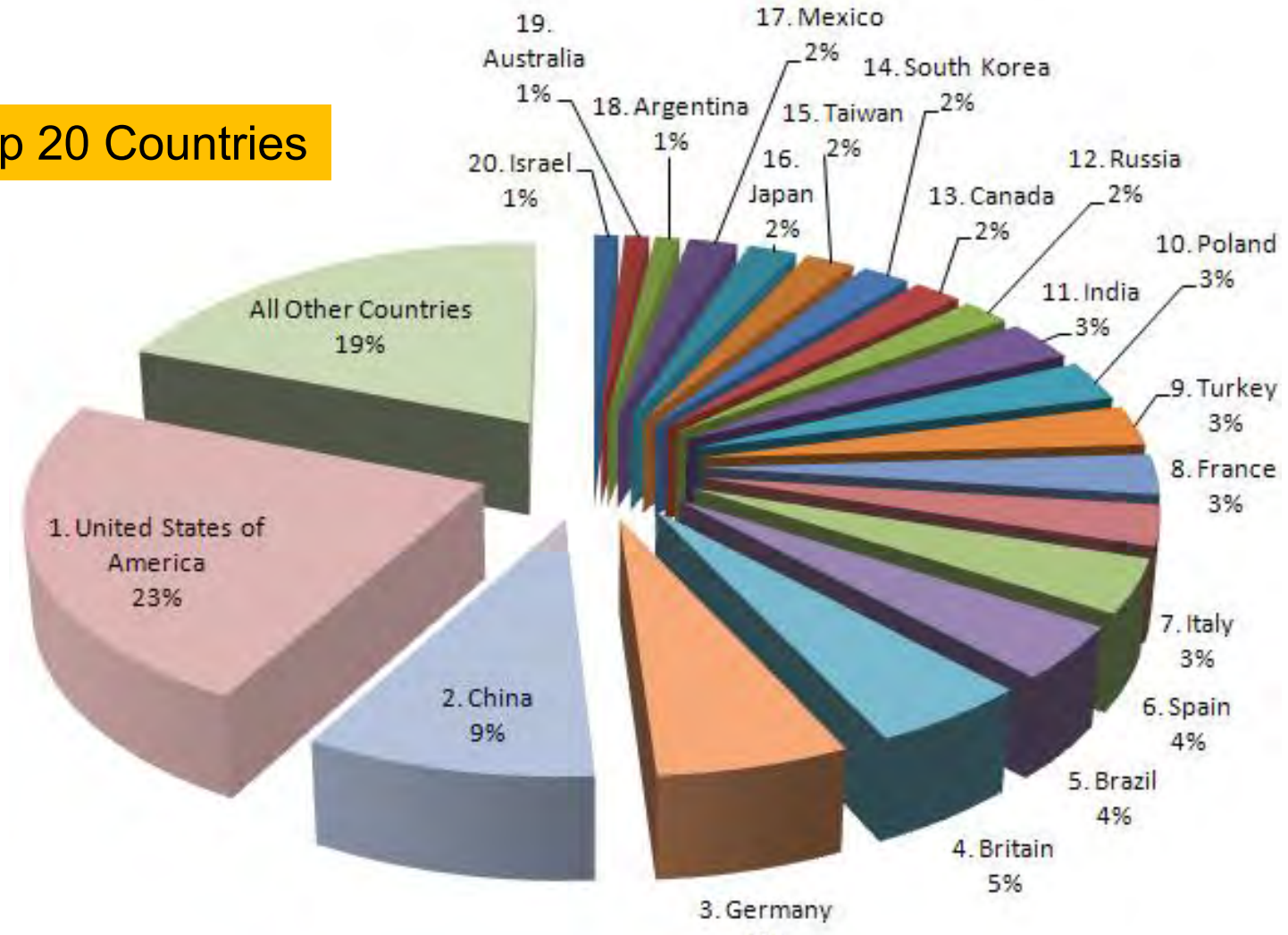
Typical Specs:

- 5 V
- 10 Wh
- 4000 mAh

Security, Privacy, and Copyright

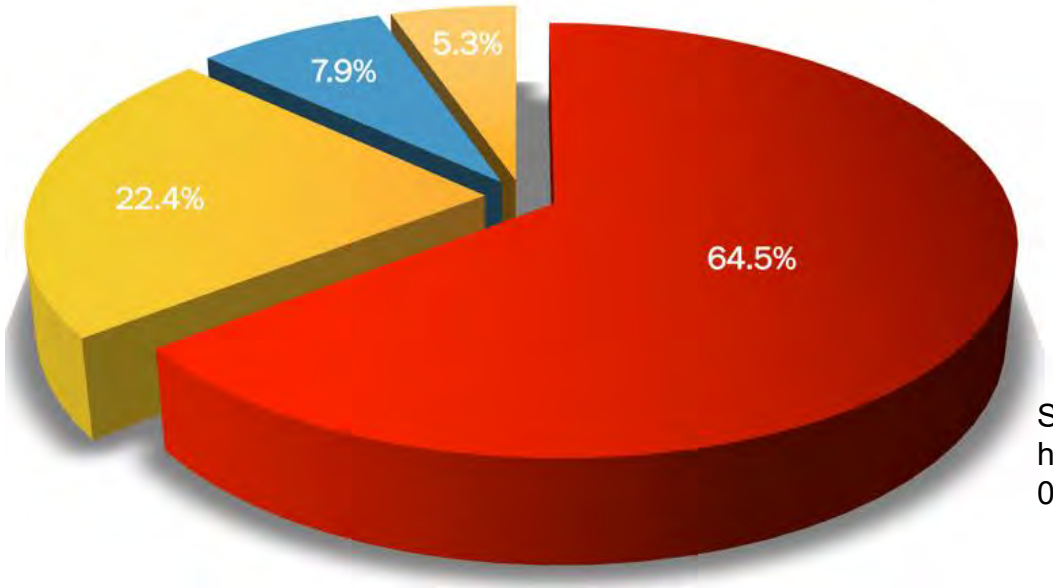
Security - Information, System …

Cybercrime – Top 20 Countries



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

Security - Information, System …



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

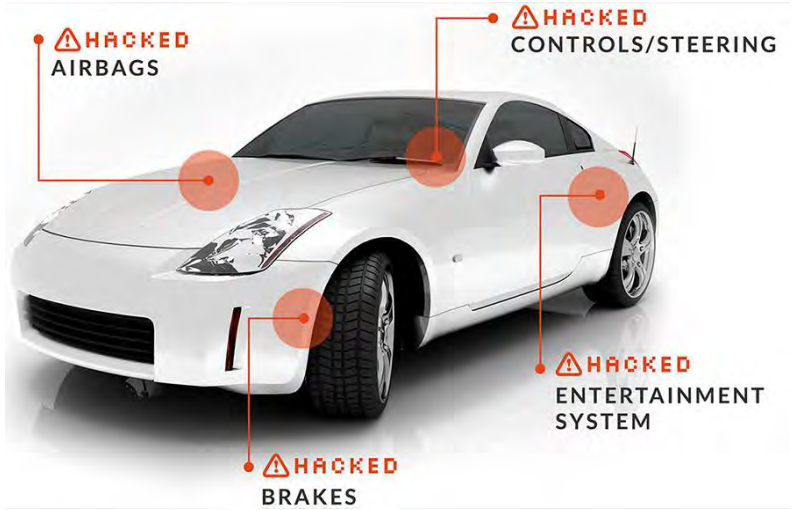
- Cybercrime damage costs to hit $6 trillion annually by 2021
- Cybersecurity spending to exceed $1 trillion from 2017 to 2021

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

Security Challenge - 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/

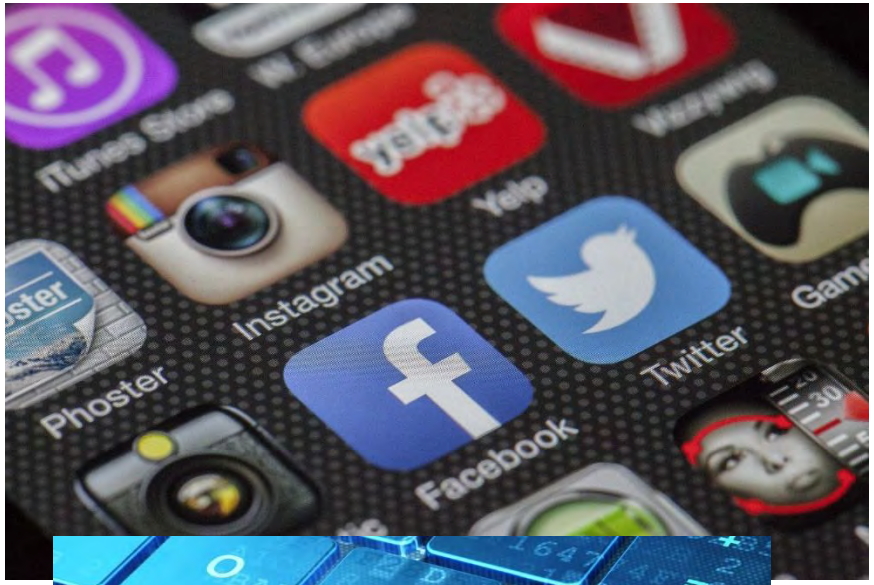
Source: http://politicalblindspot.com/u-s-drone-hacked-and-hijacked-with-ease/

Smart Grid Attacks can be Catastrophic

Threats	Vulnerabilities	Source of Threats	Attacks	Impacts
Security group knowledge	Management deficiencies of network access rules	Phishers	Stuxnet	Ukraine power attack, 2015
Information leakage	Inaccurate critical assests documentation	Nation	Night Dragon	Stuxnet attack in Iran, 2010
Access point	Unencrypted services in IT systems	Hacker	Virus	Browns Ferry plant, Alabama 2006
Unpatched System	Weak protection credentials	Insider	Denial of service	Emergency shut down of Hatch Nuclear Power Plant, 2008
Weak cyber security	Improper access point	Terrorist	Trojan horse	Slammer attack at Davis-Besse power plant, 2001
	Remote access deficiency	Spammers	Worm	Attacks at South Korea NPP, 2015
	Firewall filtering deficiency	Spyware / Malware authors	Zero day exploit	
	Unpatched operating system		Logical bomb	
	Unpatched third party application		Phishing	
	Buffer overflow in control system services		Distributed DoS	
	SQL injection vulnerability		False data Injection attack	

Source: R. K. Kaur, L. K. Singh and B. Pandey, "Security Analysis of Smart Grids: Successes and Challenges," *IEEE Consumer Electronics Magazine*, vol. 8, no. 2, pp. 10-15, March 2019.

Privacy



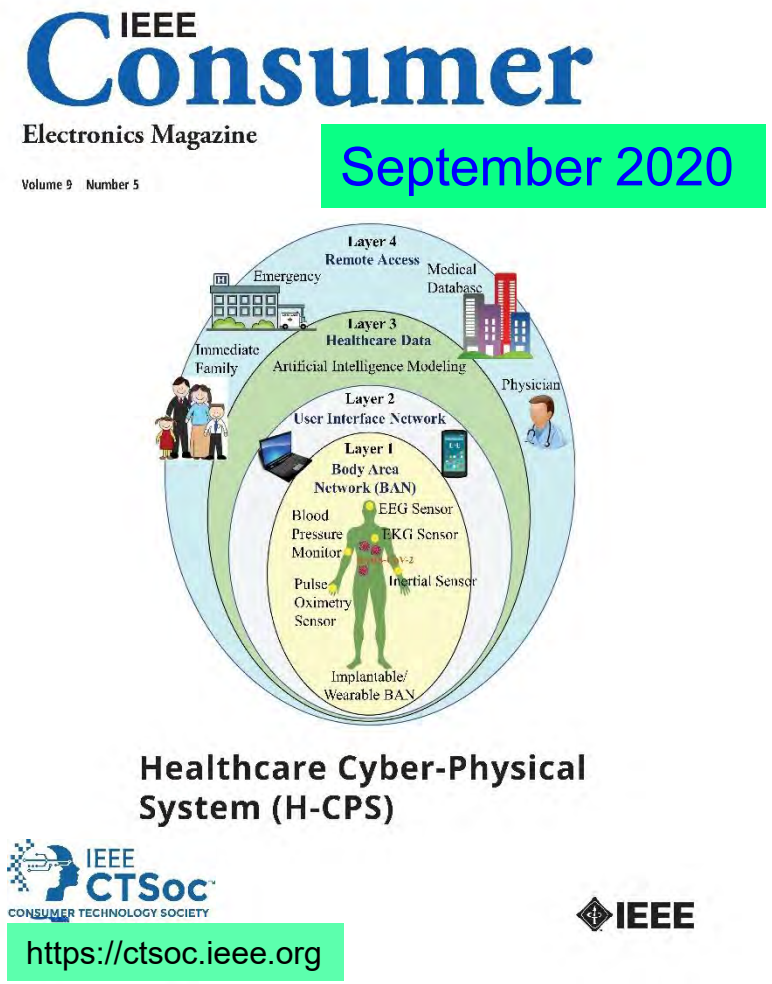
Source: http://ciphercloud.com/three-ways-pursue-cloud-data-privacy-medical-records/

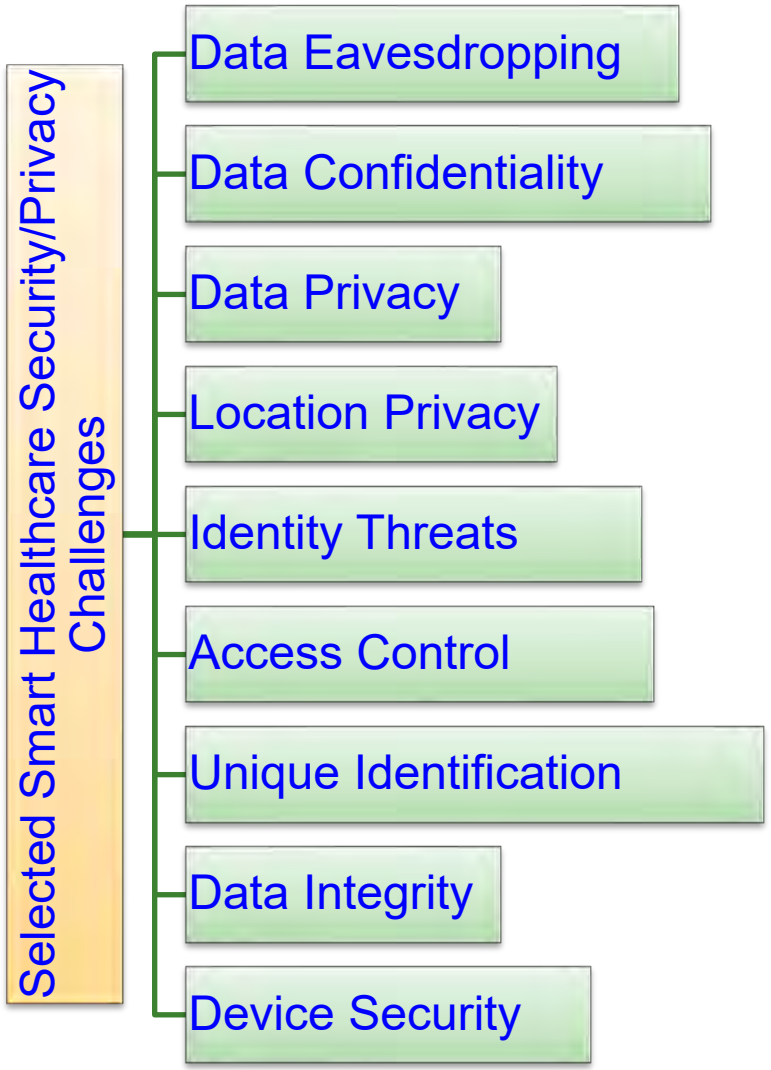
Source: http://blog.veriphyr.com/2012/06/electronic-medical-records-security-and.html

Copyright - Media, Hardware, Software

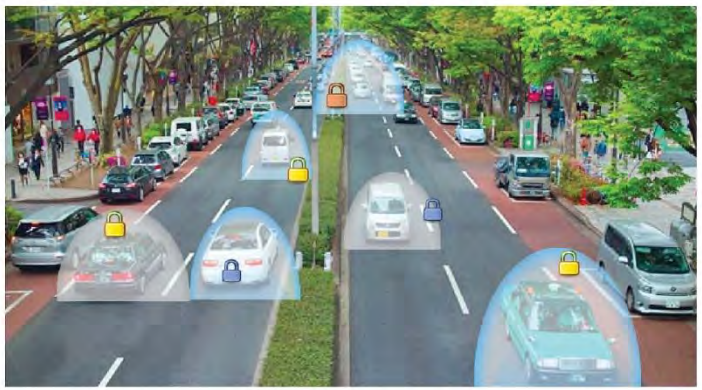
Software Piracy

Smart Healthcare - Security and Privacy Issue





T-CPS Security is Hard – Time Constrained



IEEE Consumer Electronics Magazine

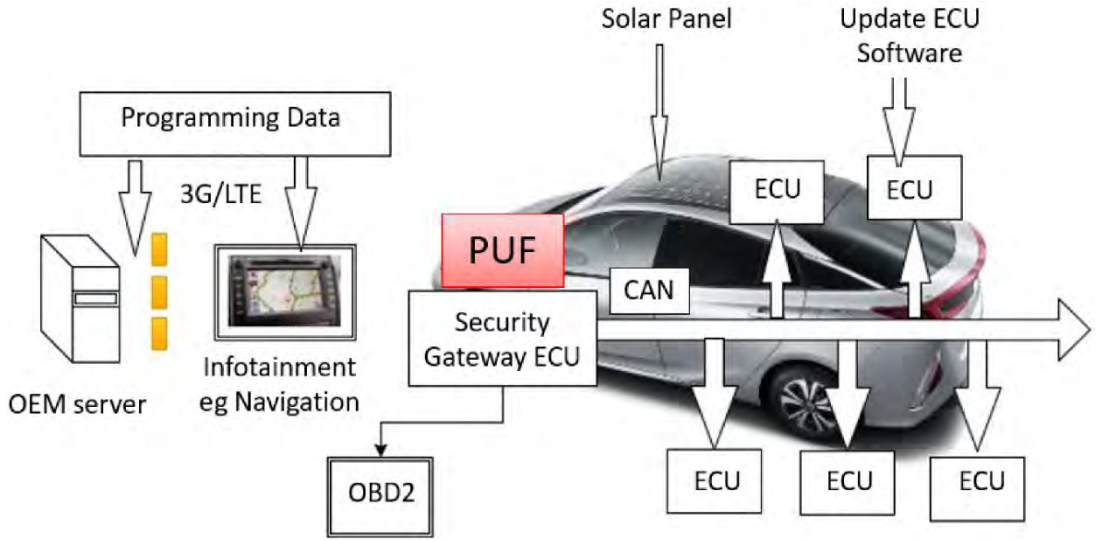
Volume 8 Number 6 NOVEMBER/DECEMBER 2019

Vehicular Security

November 2019

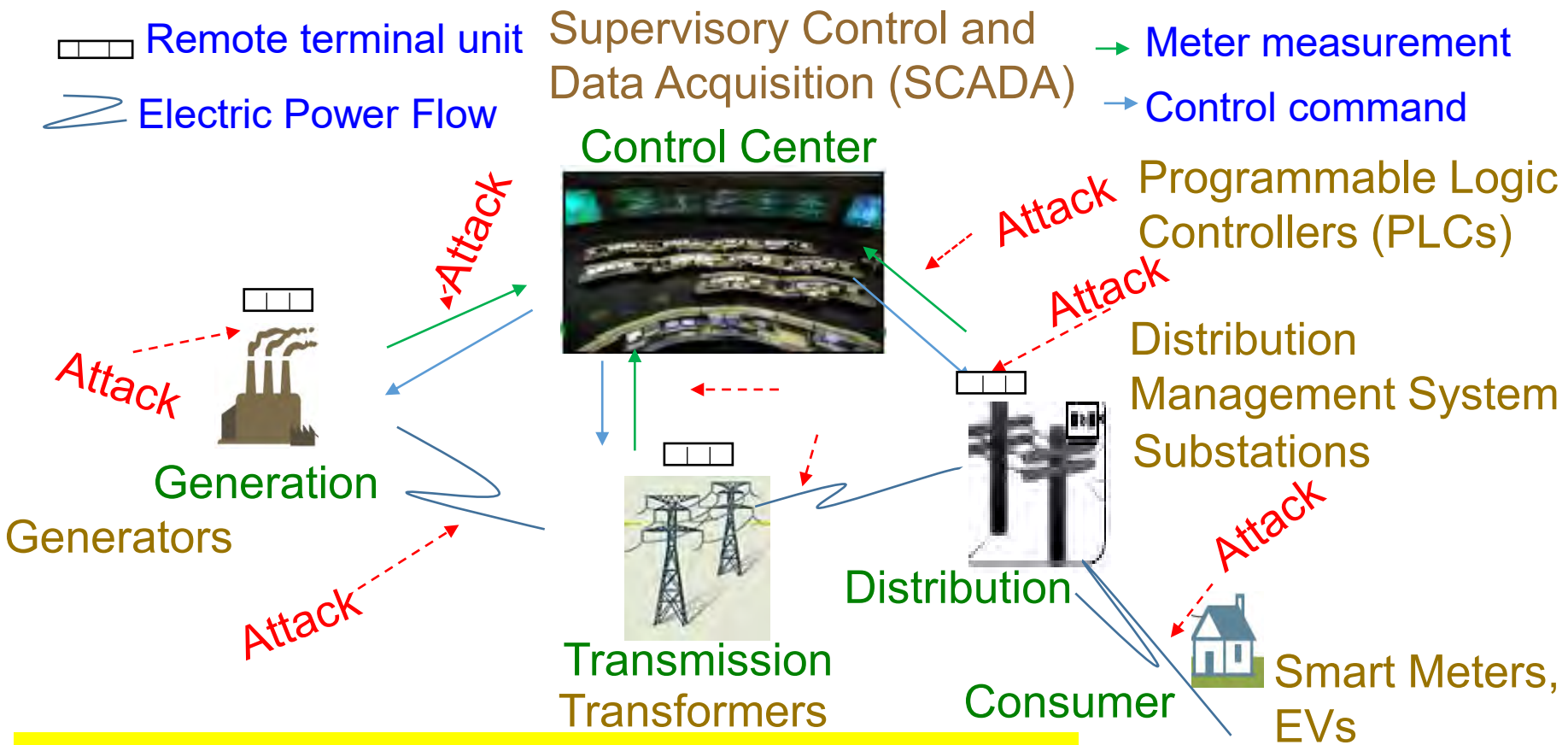
IEEE

https://cesoc.ieee.org/



Source: C. Labrado and H. Thapliyal, "Hardware Security Primitives for Vehicles," *IEEE Consumer Electronics Magazine*, vol. 8, no. 6, pp. 99-103, Nov. 2019.

Smart Grid - Vulnerability

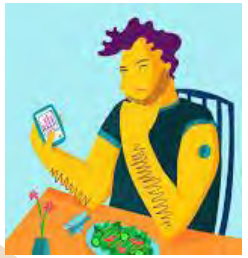


ICT components of smart grid is cyber vulnerable.

Source: (1) R. K. Kaur, L. K. Singh and B. Pandey, "Security Analysis of Smart Grids: Successes and Challenges," *IEEE Consumer Electronics Magazine*, vol. 8, no. 2, pp. 10-15, March 2019.
(2)https://www.enisa.europa.eu/topics/critical-information-infrastructures-and-services/smart-grids/smart-grids-and-smart-metering/ENISA_Annex%20II%20-%20Security%20Aspects%20of%20Smart%20Grid.pdf

Food Supply Chain: Farm → Dinning

How to ensure quality food through legitimate supply chain?



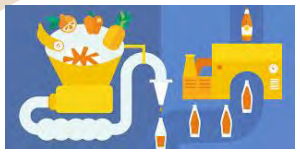
Trading

Consumption By Users

Retails Service of Food

Transportation

Processing

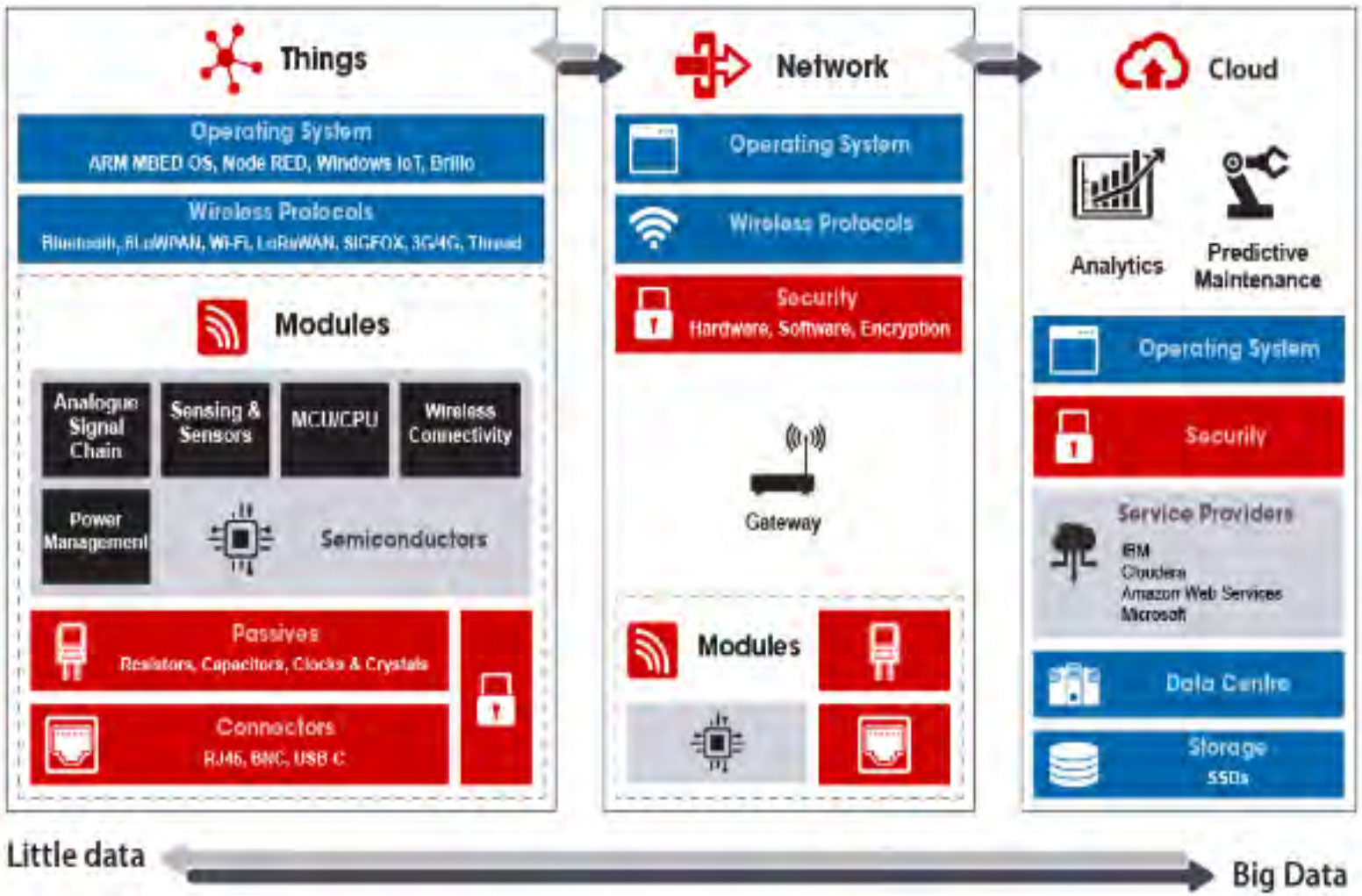


Farming & Growing

Similarly, Pharmaceutical Supply Chain

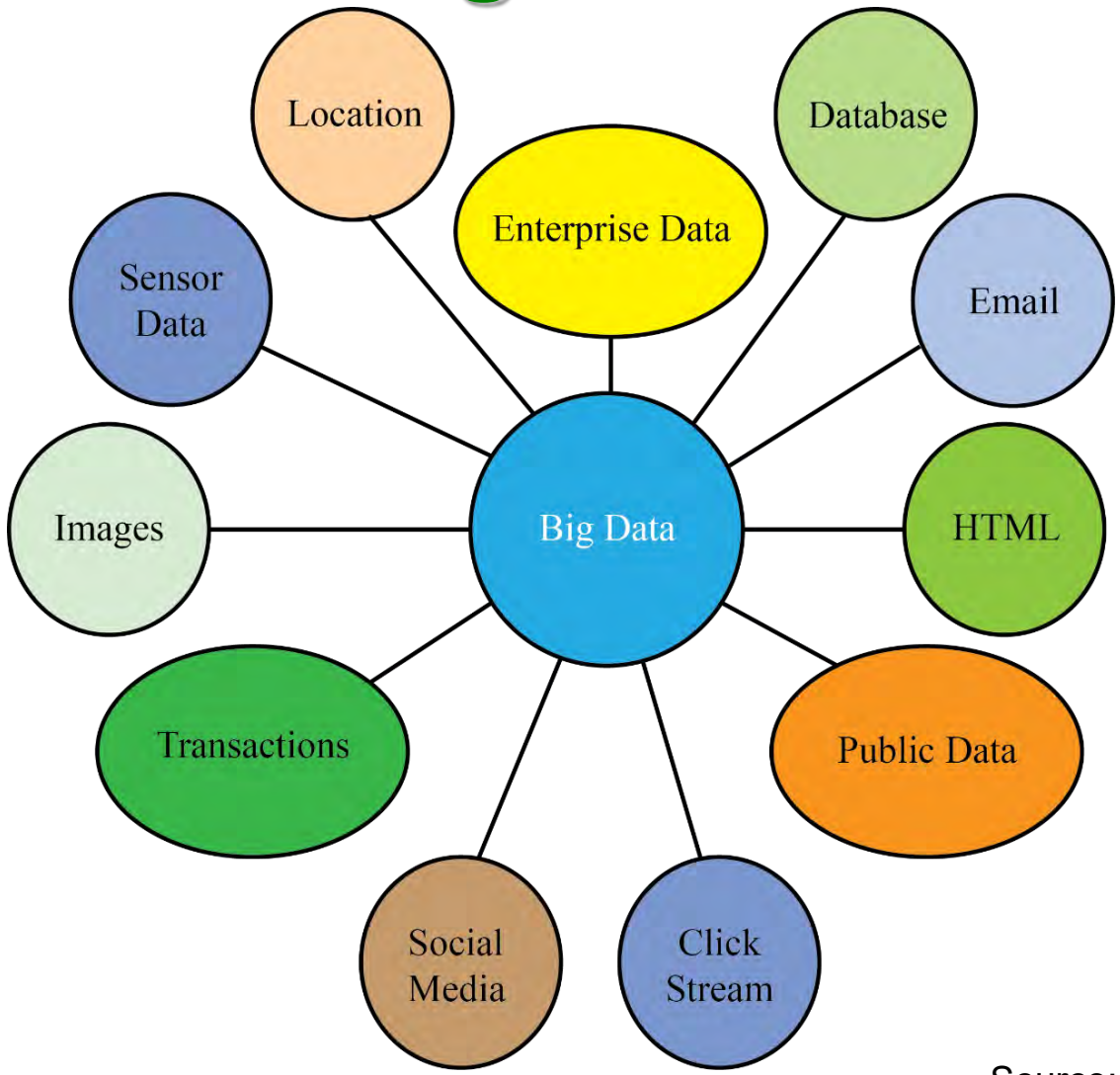
Source: A. M. Joshi, U. P. Shukla, and S. P. Mohanty, "Smart Healthcare for Diabetes: A COVID-19 Perspective", *arXiv Quantitative Biology*, arXiv:2008.11153, August 2020, 18-pages.

Bigdata in IoT and Smart Cities



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

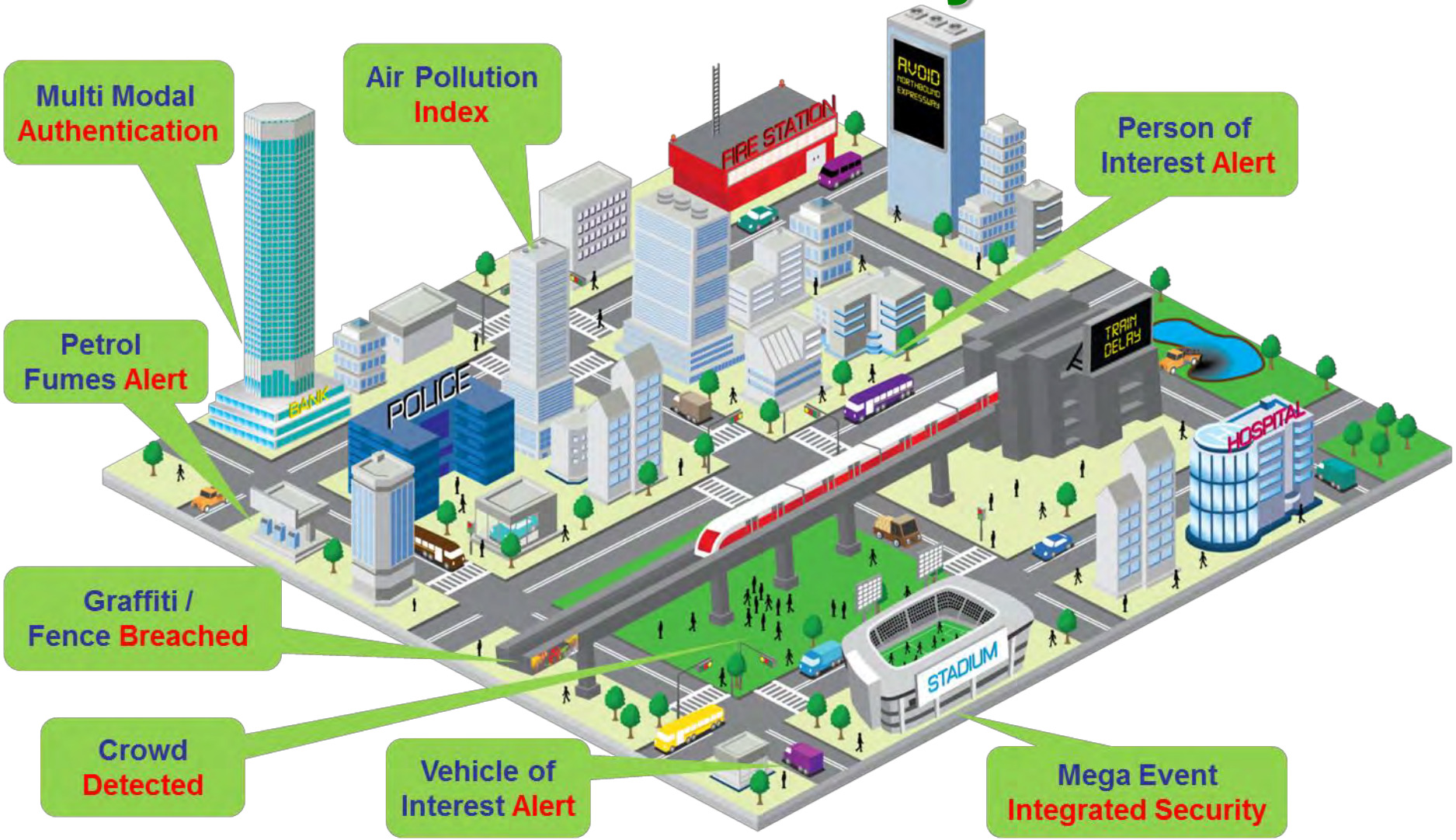
Bigdata in Smart Cities



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

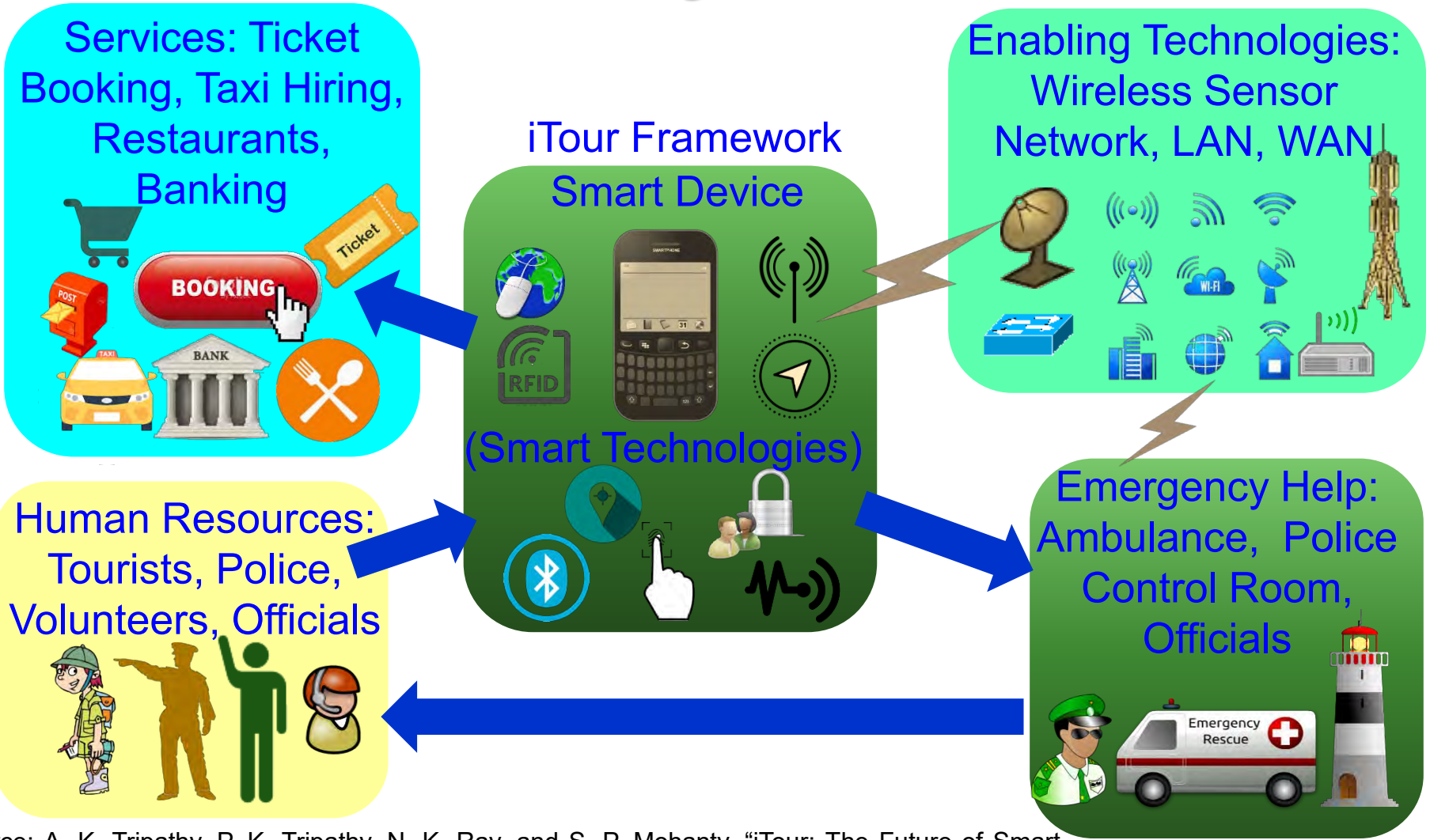
Source: Mohanty 2016, CE Magazine July 2016

Public Safety



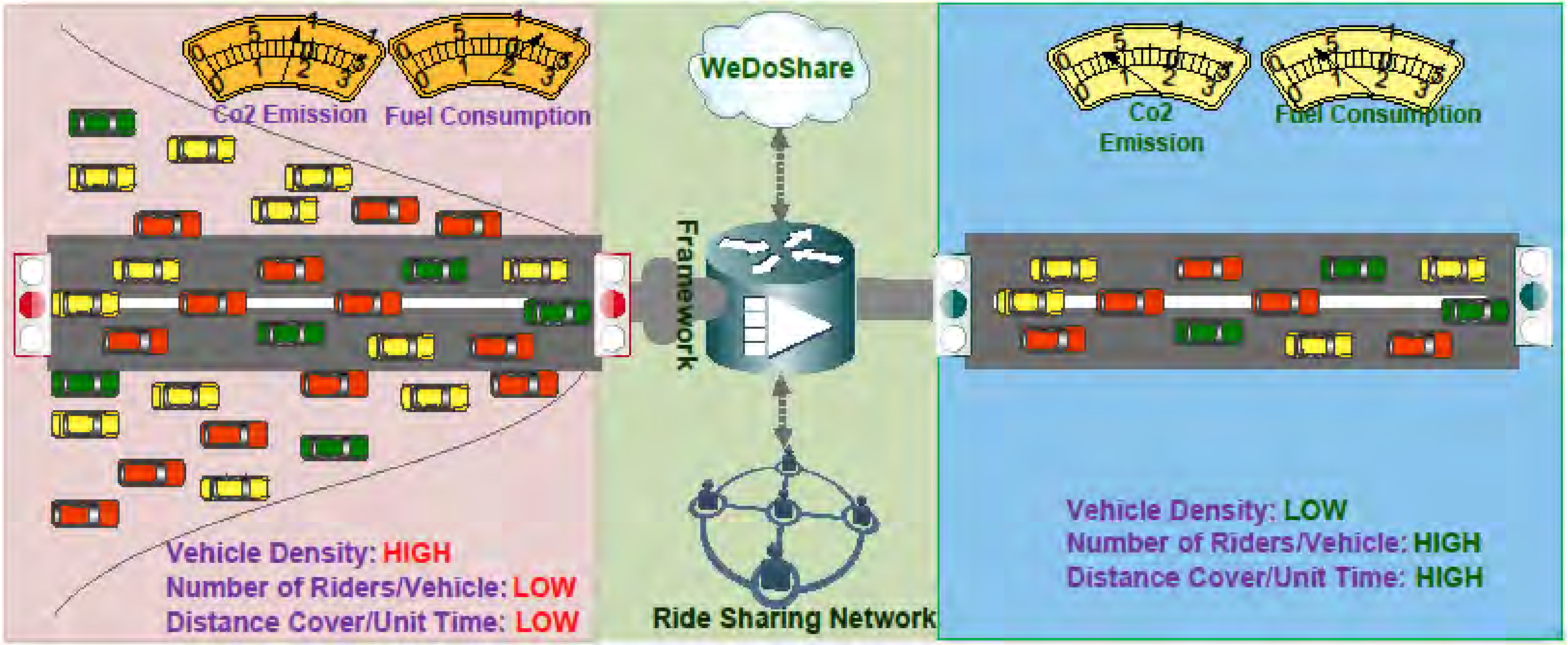
Source: http://www.nec.com/en/global/solutions/safety/Inter-Agency/index.html

iTour: Safety Framework



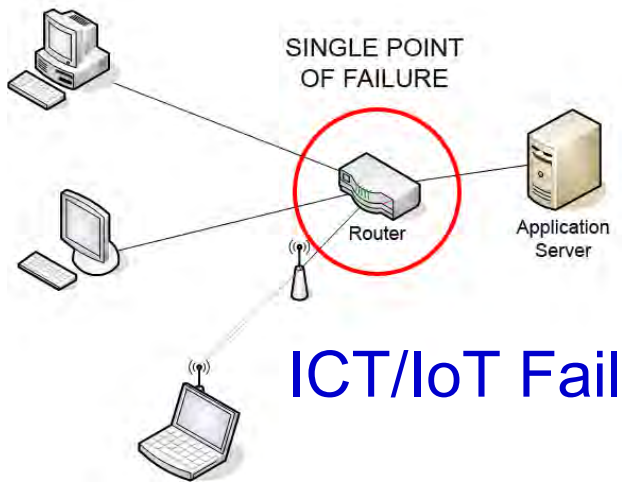
Source: A. K. Tripathy, P. K. Tripathy, N. K. Ray, and S. P. Mohanty, "iTour: The Future of Smart Tourism", *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 3, May 2018, pp. 32--37.

WeDoShare: Ridesharing Framework in T-CPS



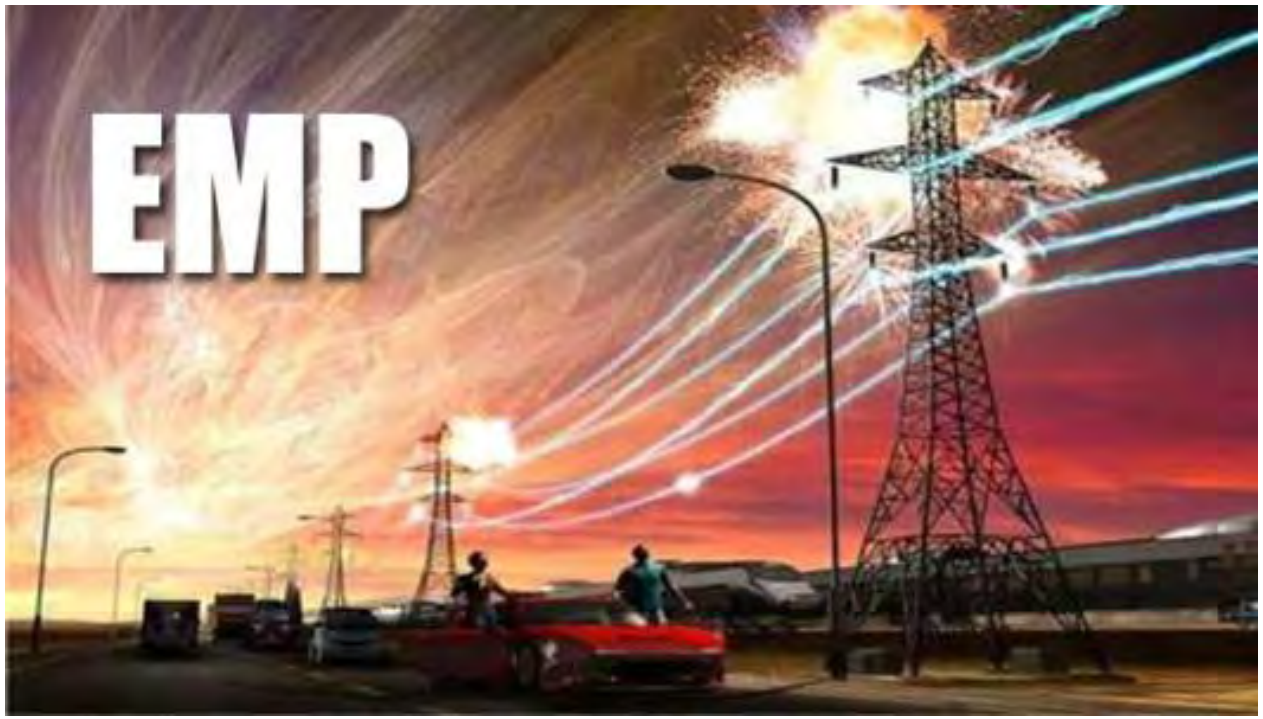
Source: A. K. Tripathy, P. K. Tripathy, A. G. Mohapatra, N. K. Ray, and **S. P. Mohanty**, "WeDoShare: A Ridesharing Framework in Transportation Cyber-Physical System for Sustainable Mobility in Smart Cities", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 4, July 2020, pp. 41--48.

Failure Tolerance and Resilience



ICT/IoT Failure

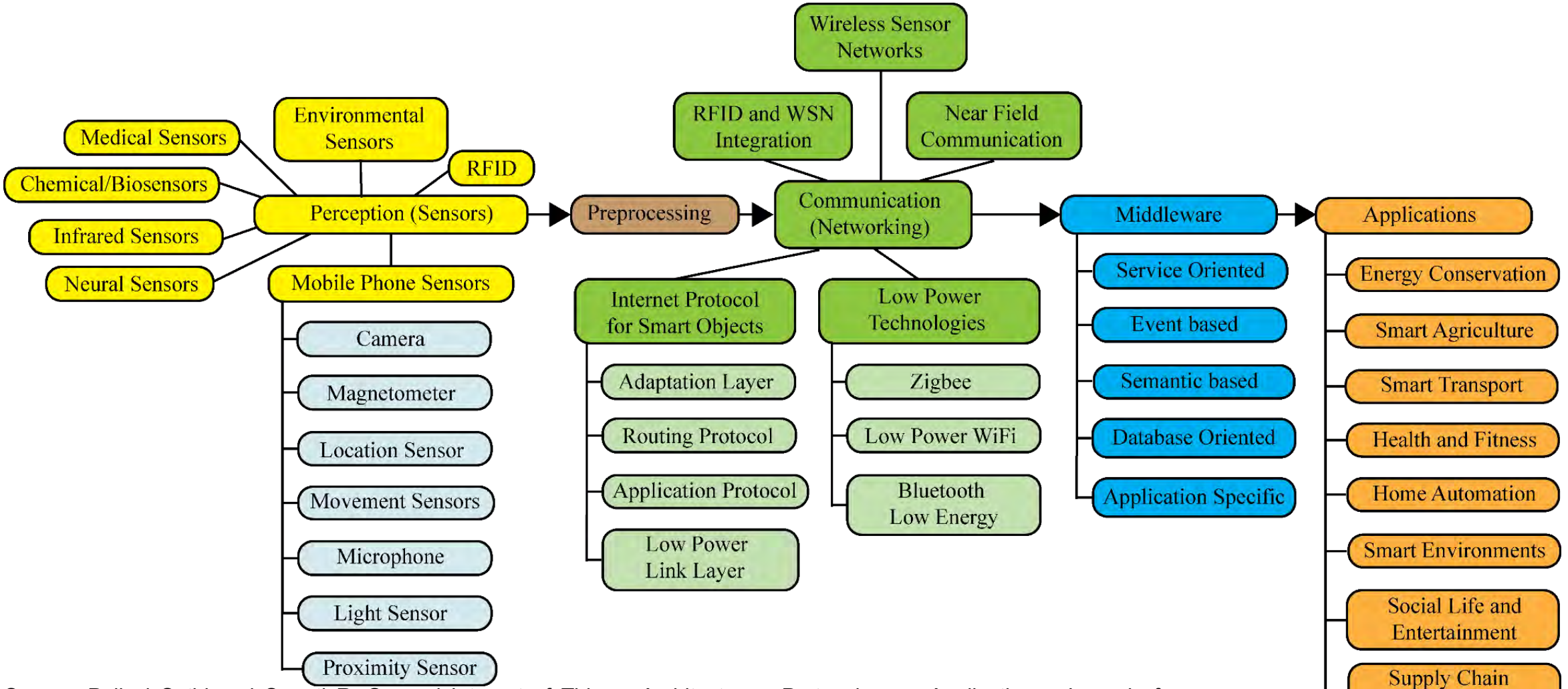
Electromagnetic Pulse (EMP) Attack



- An electromagnetic pulse (EMP) is the electric wave produced by nuclear blasts which can knocking out electronics and the electrical grid as far as 1,000 miles away.
- The disruption could cause catastrophic damage and loss of life if power is not restored or backed up quickly.

Source: http://bwcentral.org/2016/06/an-electromagnetic-pulse-emp-nuclear-attack-may-end-modern-life-in-america-overnight/

Smart City - Multidiscipline Research



Source: Pallavi Sethi and Smruti R. Sarangi Internet of Things: Architectures, Protocols, and Applications, *Journal of Electrical and Computer Engineering*, Volume 2017, Article ID 9324035, 25 pages.

Design Optimization

IoT/CPS Design – Multiple Objectives

Non-recurring Design Cost

Recurring Operational Cost

Energy Consumption, Battery Life

Ethics, Safety

Security, Privacy, IP Rights

Smart Cities
Vs
Smart Villages

Performance, Latency

Intelligence

Source: Mohanty ICCE 2019 Keynote

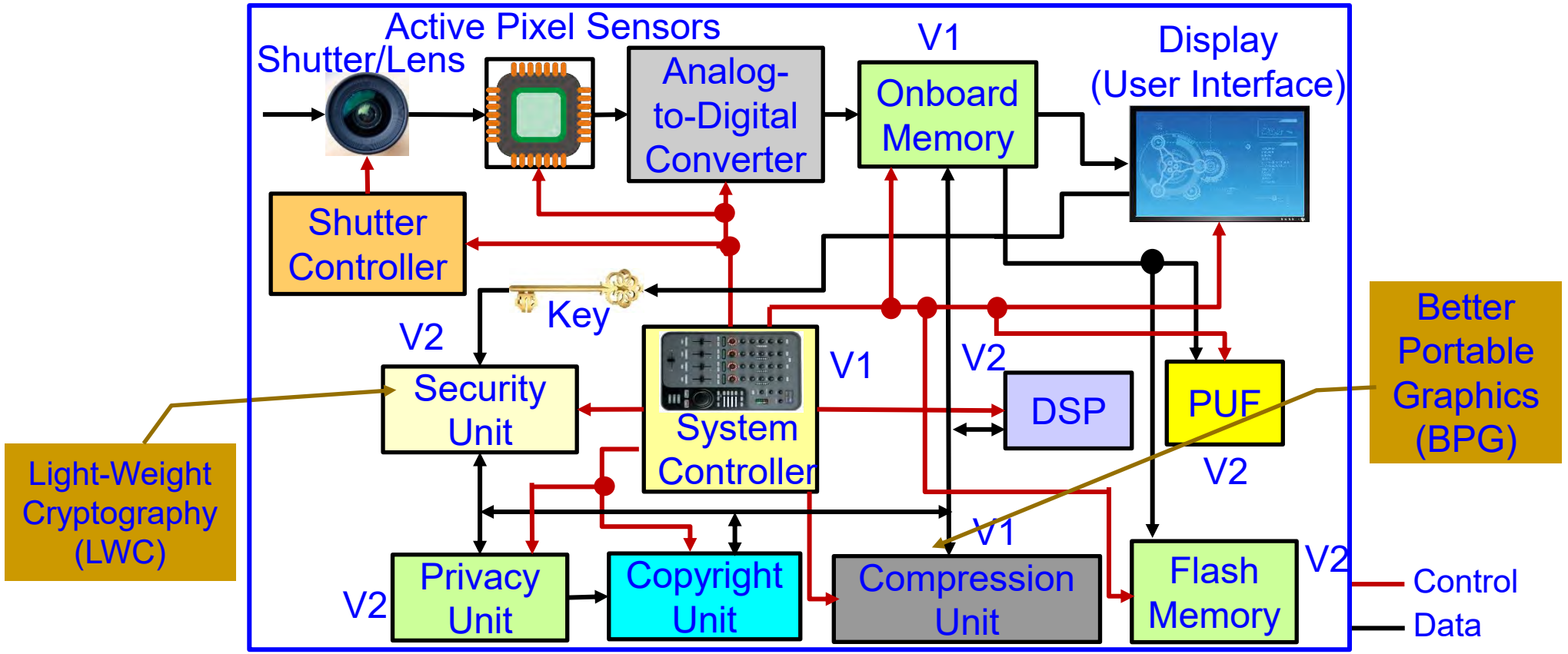
Security by Design (SbD) and/or Privacy by Design (PbD)

Embedding of security/privacy into the architecture (hardware+software) of various products, programs, or services.

Retrofitting: Difficult → Impossible!

Source: https://teachprivacy.com/tag/privacy-by-design/

Secure Digital Camera (SDC) – My Invention

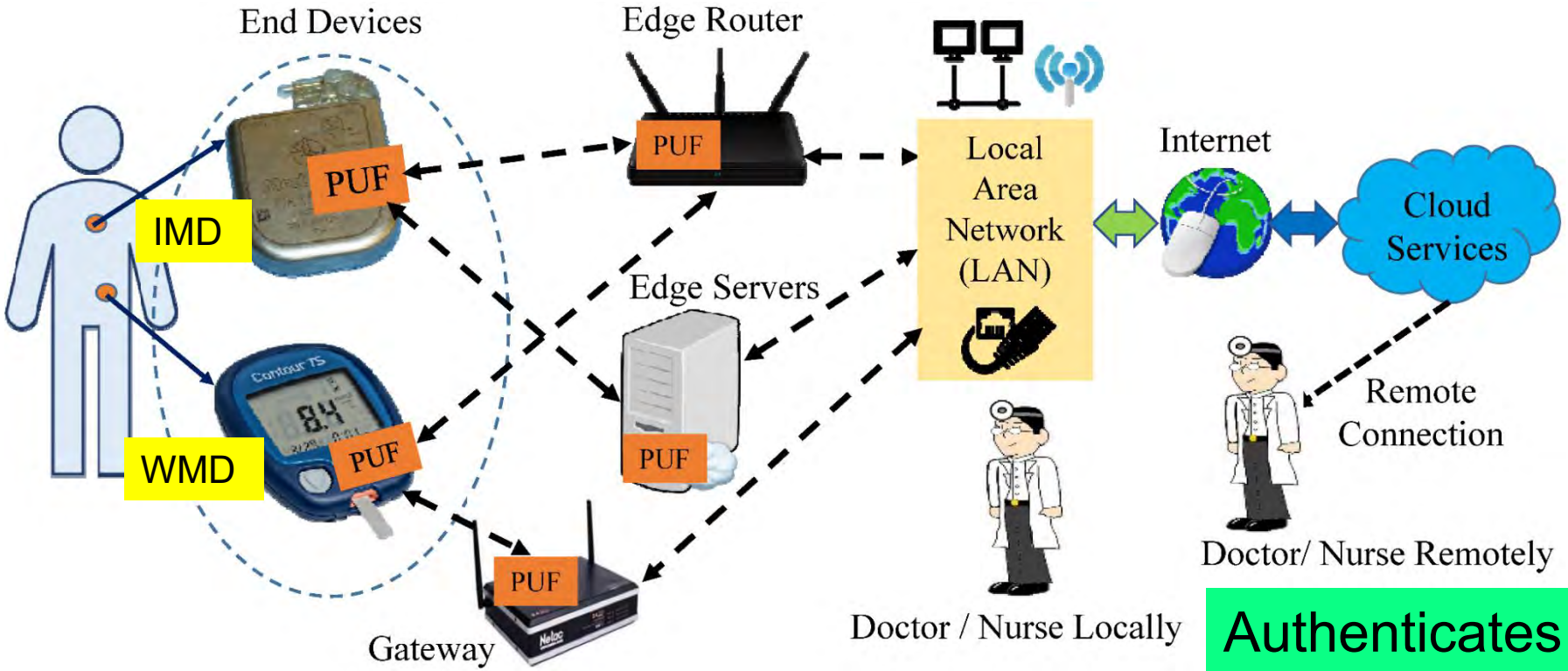


Include additional/alternative hardware/software components and uses DVFS like technology for energy and performance optimization.

Security and/or Privacy by Design (SbD and/or PbD)

Source: S. P. Mohanty, "A Secure Digital Camera Architecture for Integrated Real-Time Digital Rights Management", *Elsevier Journal of Systems Architecture (JSA)*, Volume 55, Issues 10-12, October-December 2009, pp. 468-480.

PMsec: Our Secure by Design Approach for Robust Security in Healthcare CPS



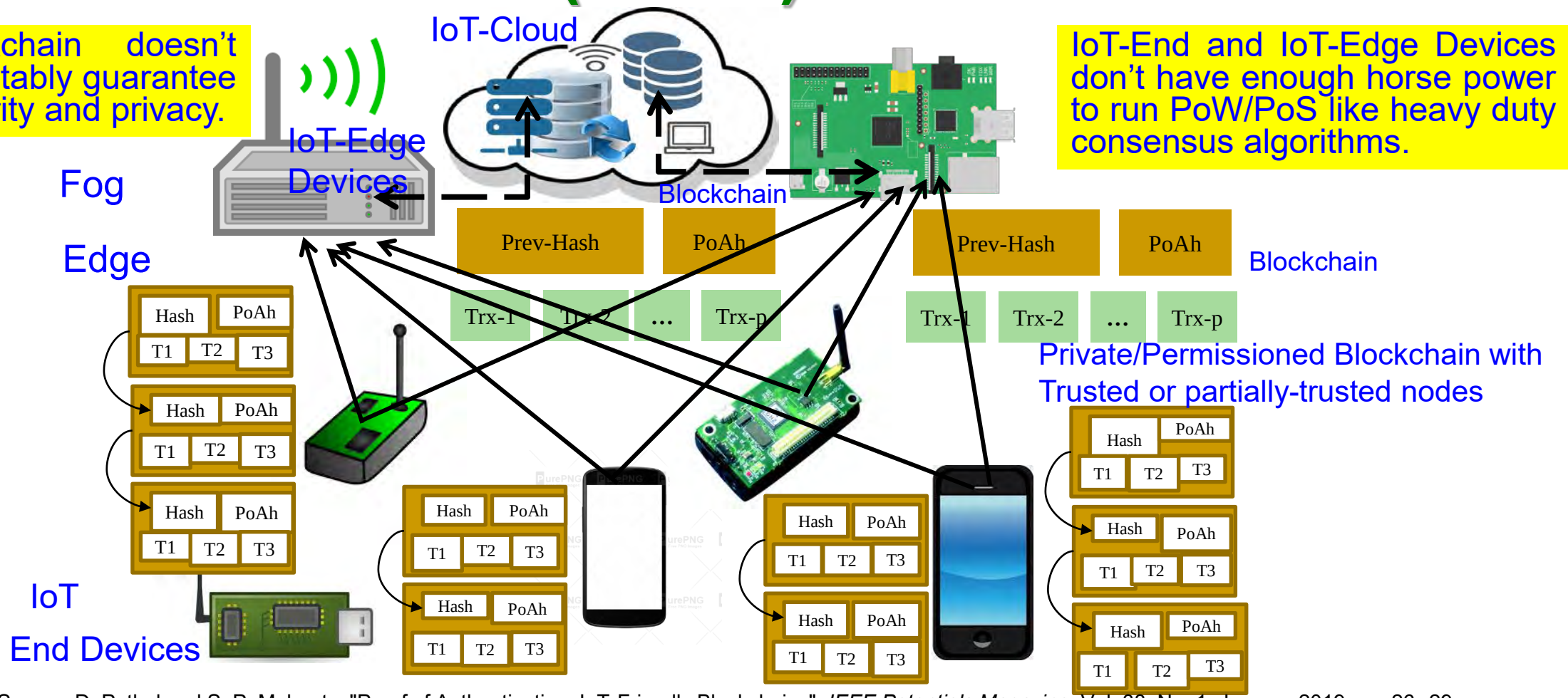
Authenticates Time - 1 sec
Power Consumption - 200 μW

Source: V. P. Yanambaka, S. P. Mohanty, E. Kougianos, and D. Puthal, "PMsec: Physical Unclonable Function-Based Robust and Lightweight Authentication in the Internet of Medical Things", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 388--397.

IoT-Friendly Blockchain – Our Proof-of-Authentication (PoAh) based Blockchain

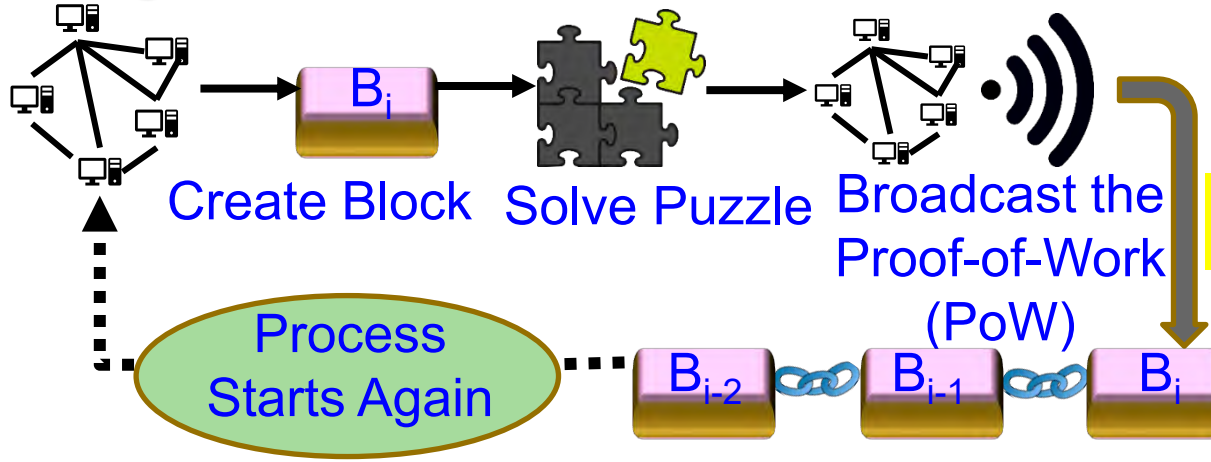
Blockchain doesn't inheritably guarantee security and privacy.

IoT-End and IoT-Edge Devices don't have enough horse power to run PoW/PoS like heavy duty consensus algorithms.



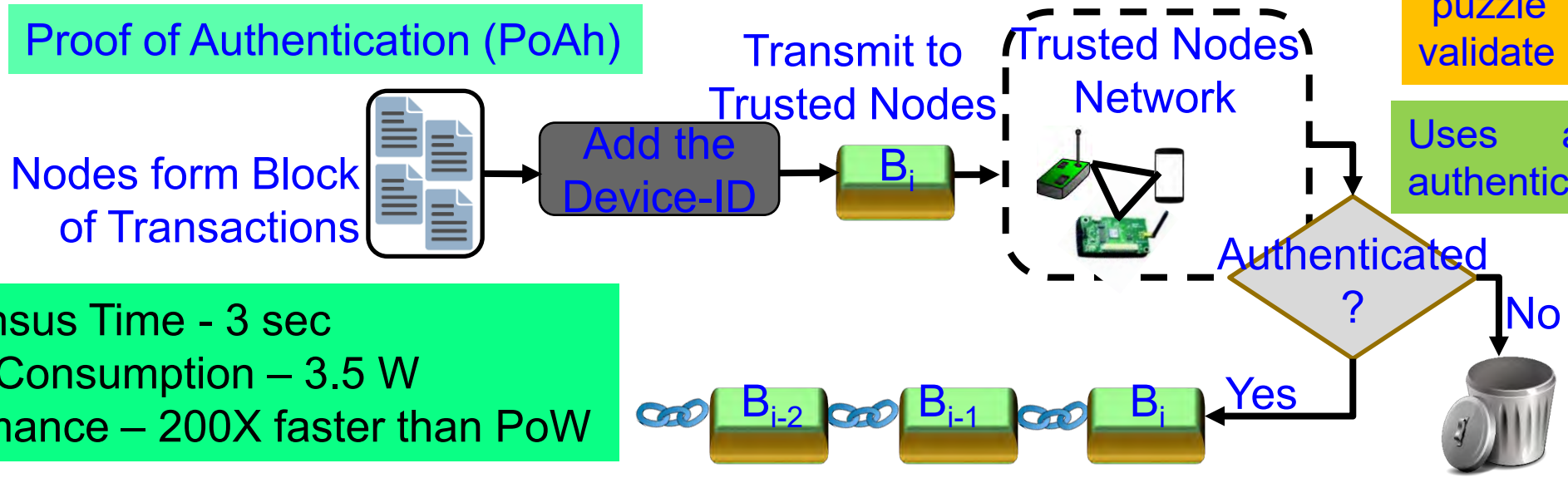
Source: D. Puthal and S. P. Mohanty, "Proof of Authentication: IoT-Friendly Blockchains", *IEEE Potentials Magazine*, Vol. 38, No. 1, January 2019, pp. 26--29.

Our EasyChain: Proof-of-Authentication (PoAh)



Eliminates cryptographic "puzzle" solving to validate blocks.

Proof of Authentication (PoAh)

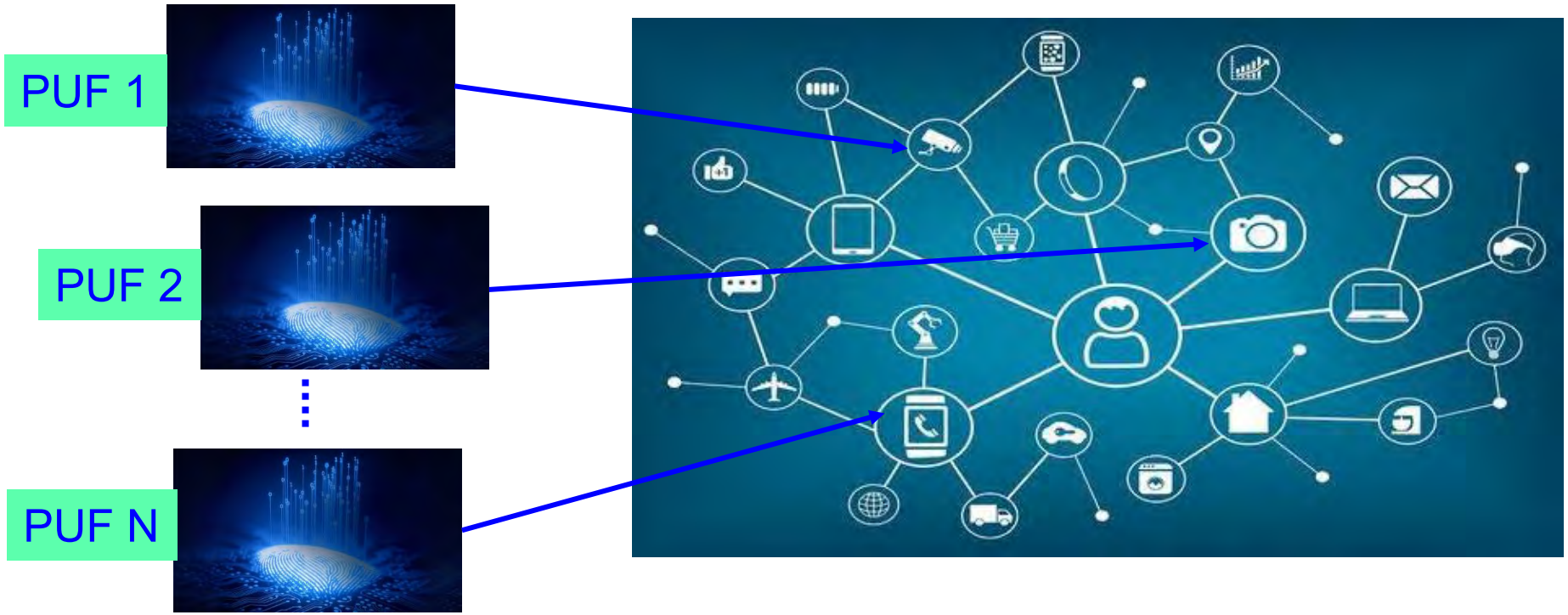


Uses a cryptographic authentication mechanism.

Consensus Time - 3 sec
Power Consumption – 3.5 W
Performance – 200X faster than PoW

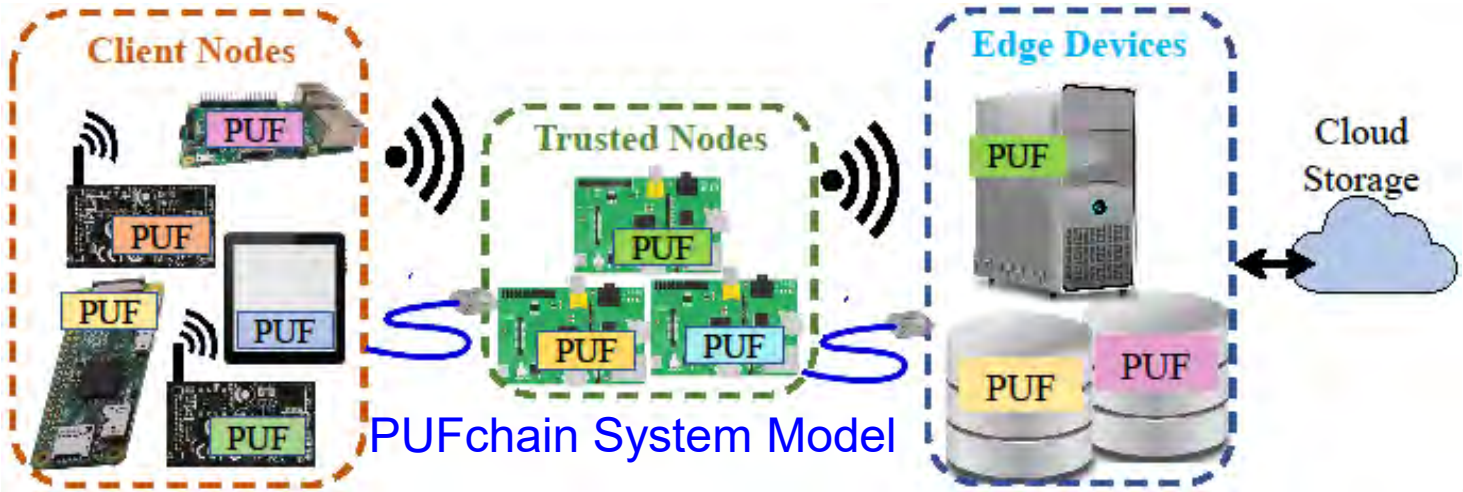
Source: D. Puthal and S. P. Mohanty, "Proof of Authentication: IoT-Friendly Blockchains", *IEEE Potentials Magazine*, Vol. 38, No. 1, January 2019, pp. 26--29.

We Proposed World's First Hardware-Integrated Blockchain (PUFchain) that is Scalable, Energy-Efficient, and Fast



Source: S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "PUFchain: Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in Internet of Everything (IoE)", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 2, March 2020, pp. 8-16.

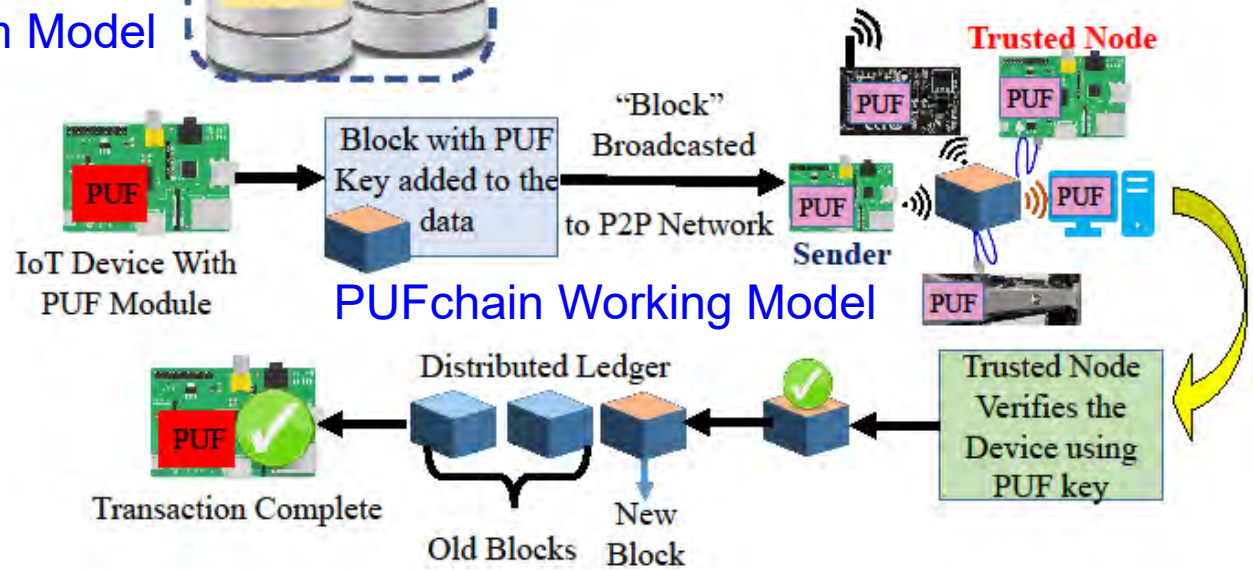
PUFchain: Our Hardware-Assisted Scalable Blockchain



PUFchain System Model

Can provide:
Device, System, and Data Security

PUFChain 2 Modes:
(1) PUF Mode and
(2) PUFChain Mode

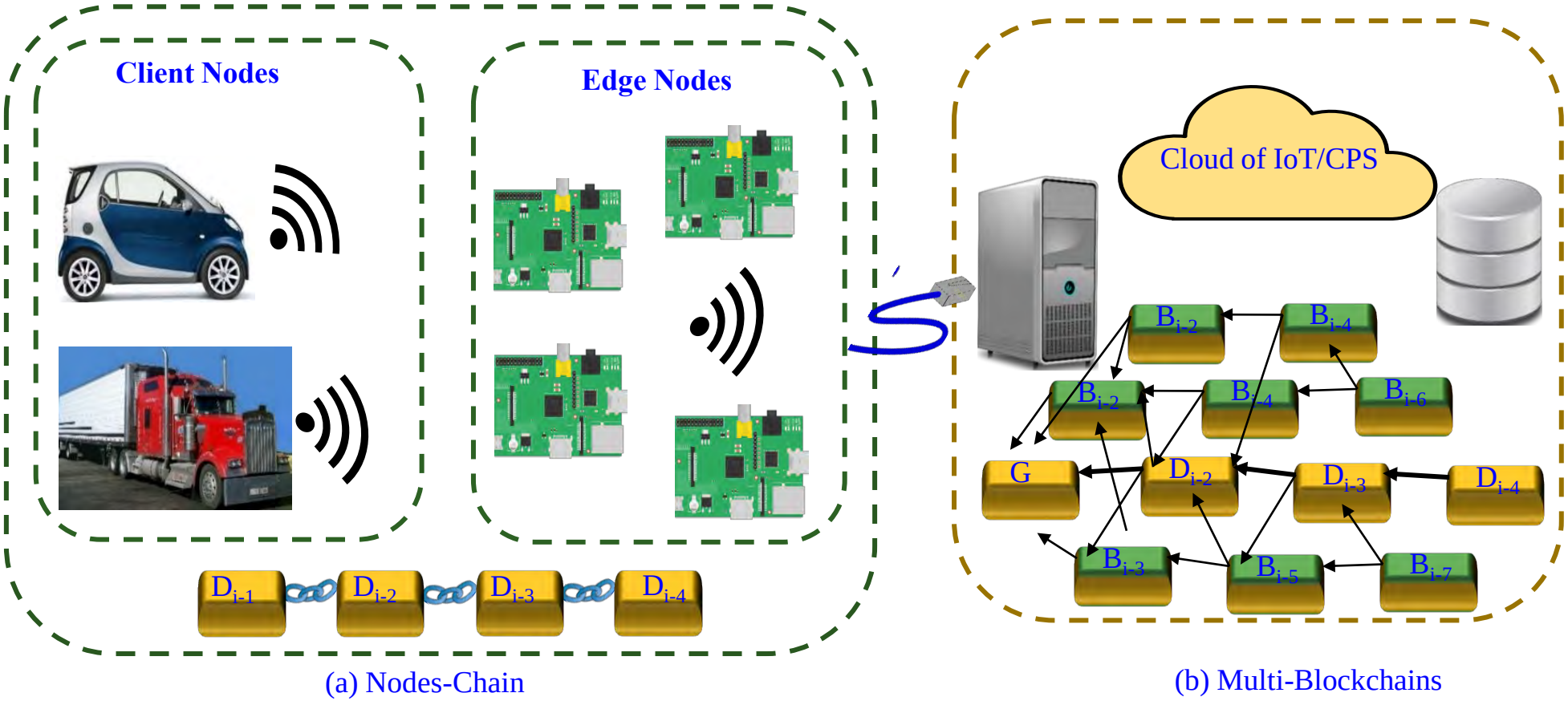


PUFchain Working Model

- ✓ PoP is 1,000X faster than PoW
- ✓ PoP is 5X faster than PoAh

Source: S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "PUFchain: Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in Internet of Everything (IoE)", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 2, March 2020, pp. 8-16.

Our FlexiChain: Multi-Chain Technology to Enhance Blockchain Scalability



(a) Nodes-Chain

(b) Multi-Blockchains

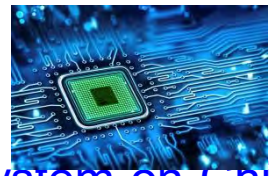
Source: A. J. Alkhodair, S. P. Mohanty, E. Kougianos, and D. Puthal, "McPoRA: A Multi-Chain Proof of Rapid Authentication for Post-Blockchain based Security in Large Scale Complex Cyber-Physical Systems", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020, pp. 446--451.

Our Eternal-Thing 1.0 is Useful for Sustainable IoT in Smart Cities and Smart Villages

Solar Cell

Harvesting System with Physically Unclonable Function (PUF)

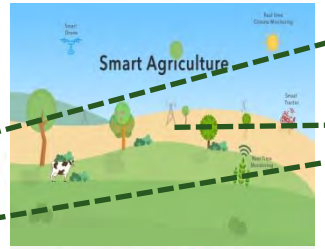
Sensors

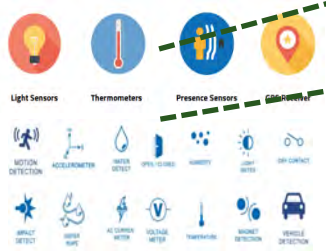


System-on-Chip (SoC)

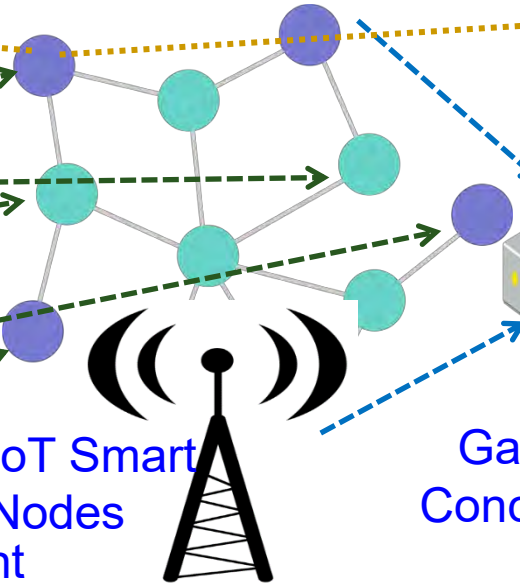
Trans-receiver

Provides security while consuming only 22μW power due to harvesting.

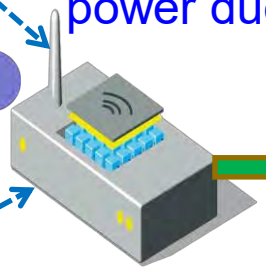




Edge Devices and their deployment



IoT Smart Nodes



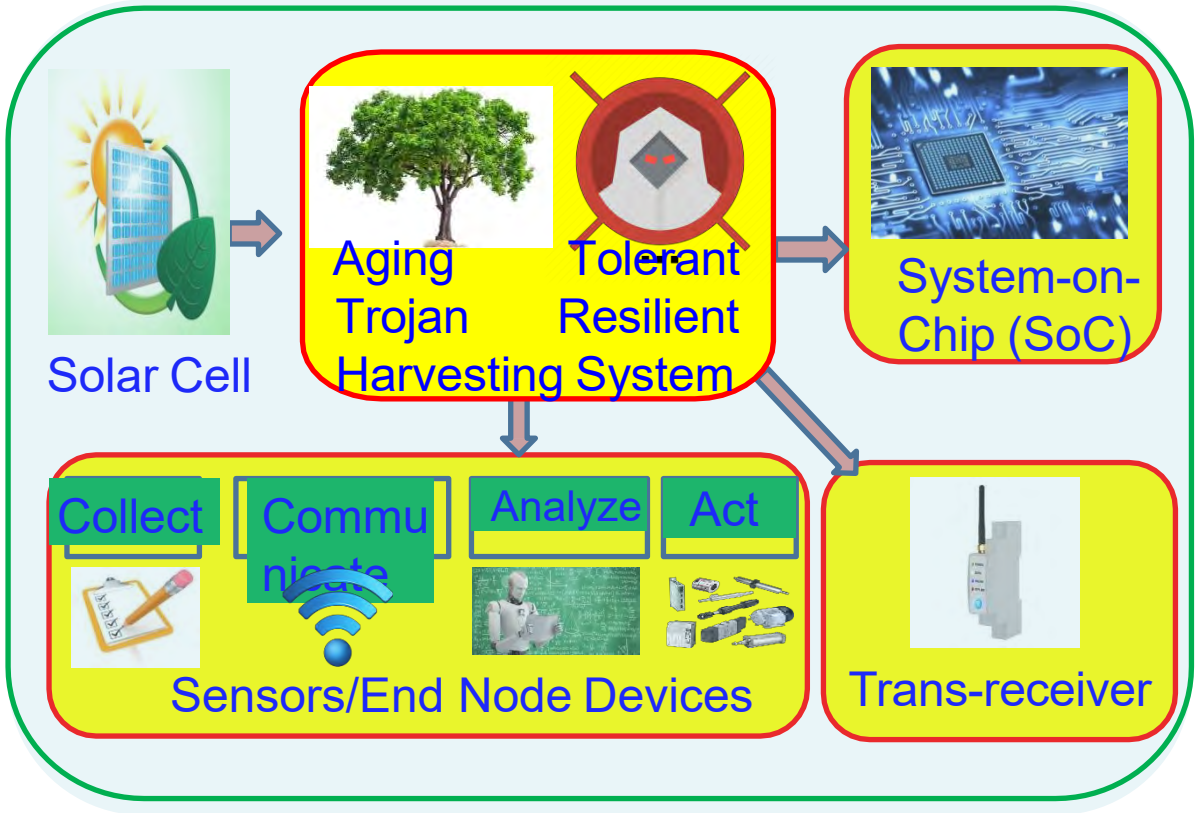
Gateways/ Concentrators

Cloud

Eternal-Thing: Combines Security and Energy Harvesting at the IoT-Edge

Source: S. K. Ram, S. R. Sahoo, Banee, B.Das, K. K. Mahapatra, and S. P. Mohanty, "Eternal-Thing: A Secure Aging-Aware Solar-Energy Harvester Thing for Sustainable IoT", *IEEE Transactions on Sustainable Computing*, Vol. XX, No. YY, ZZ 2021, pp. Accepted on 08 April 2020, DOI: 10.1109/TSUSC.2020.2987616.

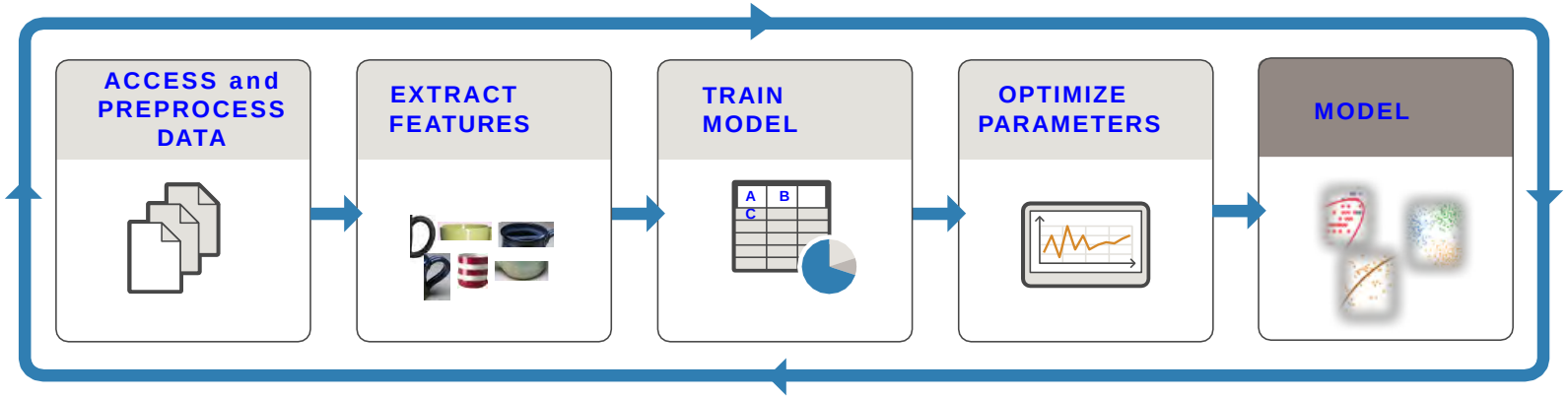
Eternal-Thing 2.0: Combines Analog-Trojan Resilience and Energy Harvesting at the Edge



Source: S. K. Ram, B. B. Das, K. K. Mahapatra, **S. P. Mohanty**, and U. Choppali, "Energy Perspectives in IoT Driven Smart Villages and Smart Cities", *IEEE Consumer Electronics Magazine (MCE)*, Vol. XX, No. YY, ZZ 2021, pp. Accepted on 08 Sep 2020, DOI: 10.1109/MCE.2020.3023293.

TinyML - Key for Smart Cities and Smart Villages

TRAIN: Iterate until you achieve satisfactory performance.

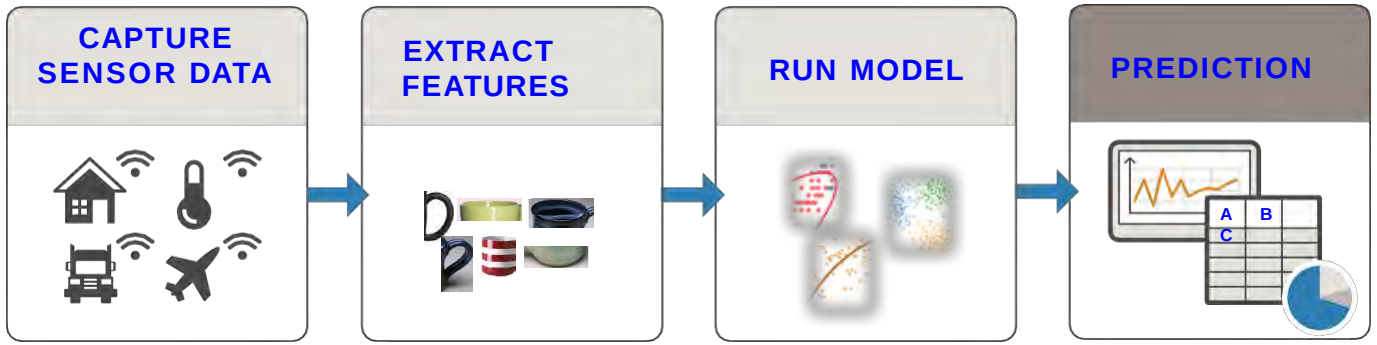


Needs Significant:

- Computational Resource
- Computation Energy

Solution: Reduce Training Time and/or Computational Resource

PREDICT: Integrate trained models into applications.



Source: https://www.mathworks.com/campaigns/offers/mastering-machine-learning-with-matlab.html

Needs:

- Computational Resource
- Computation Energy

Solution: TinyML

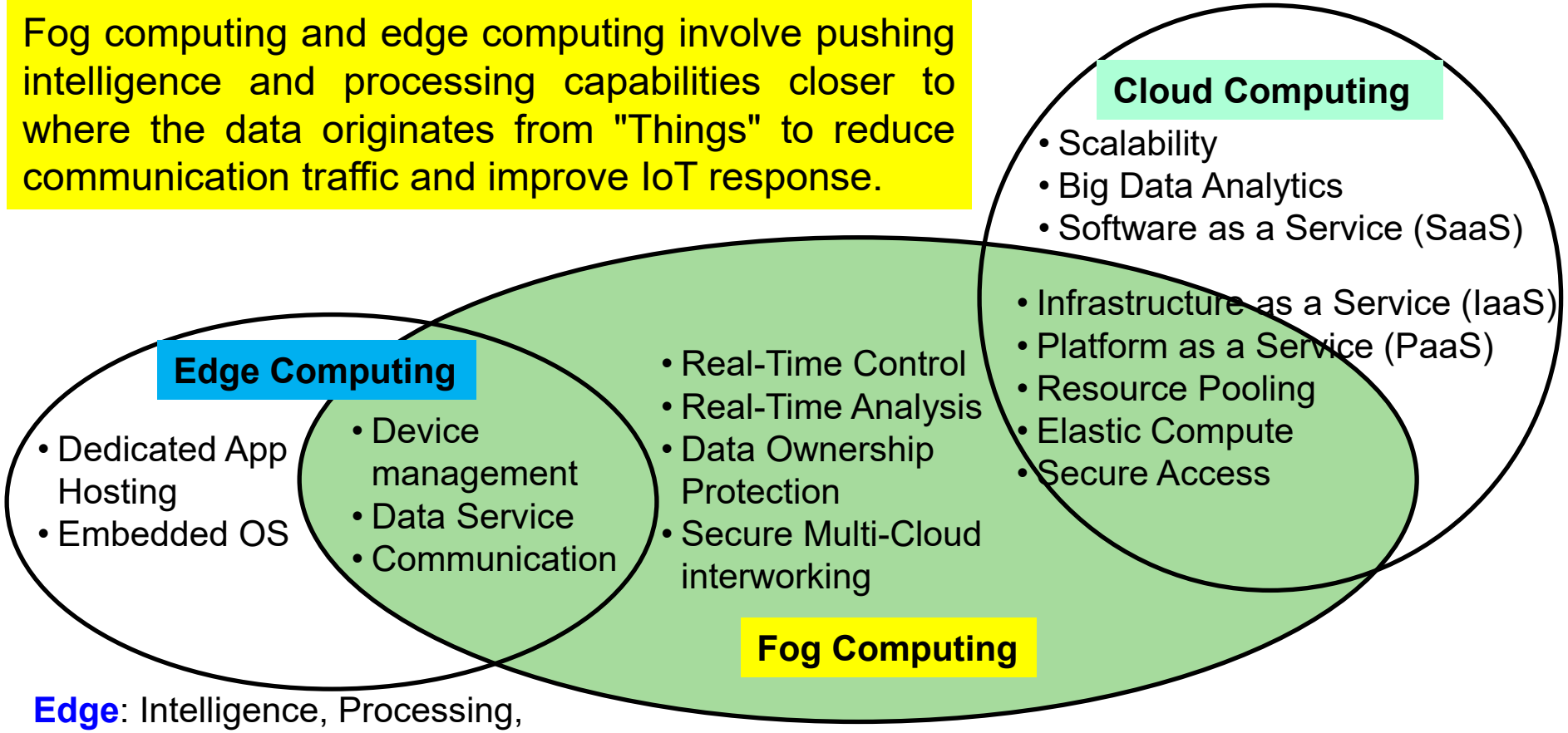
Where to Store and Process Data for ML Modeling, and where to Execute ML models?

Sensor, Edge, Fog, Cloud?

ASIC, FGPA, SoC, FP-SoC, GPU, Neuromorphic, Quantum?

Fog Vs Edge Vs Cloud Computing

Fog computing and edge computing involve pushing intelligence and processing capabilities closer to where the data originates from "Things" to reduce communication traffic and improve IoT response.



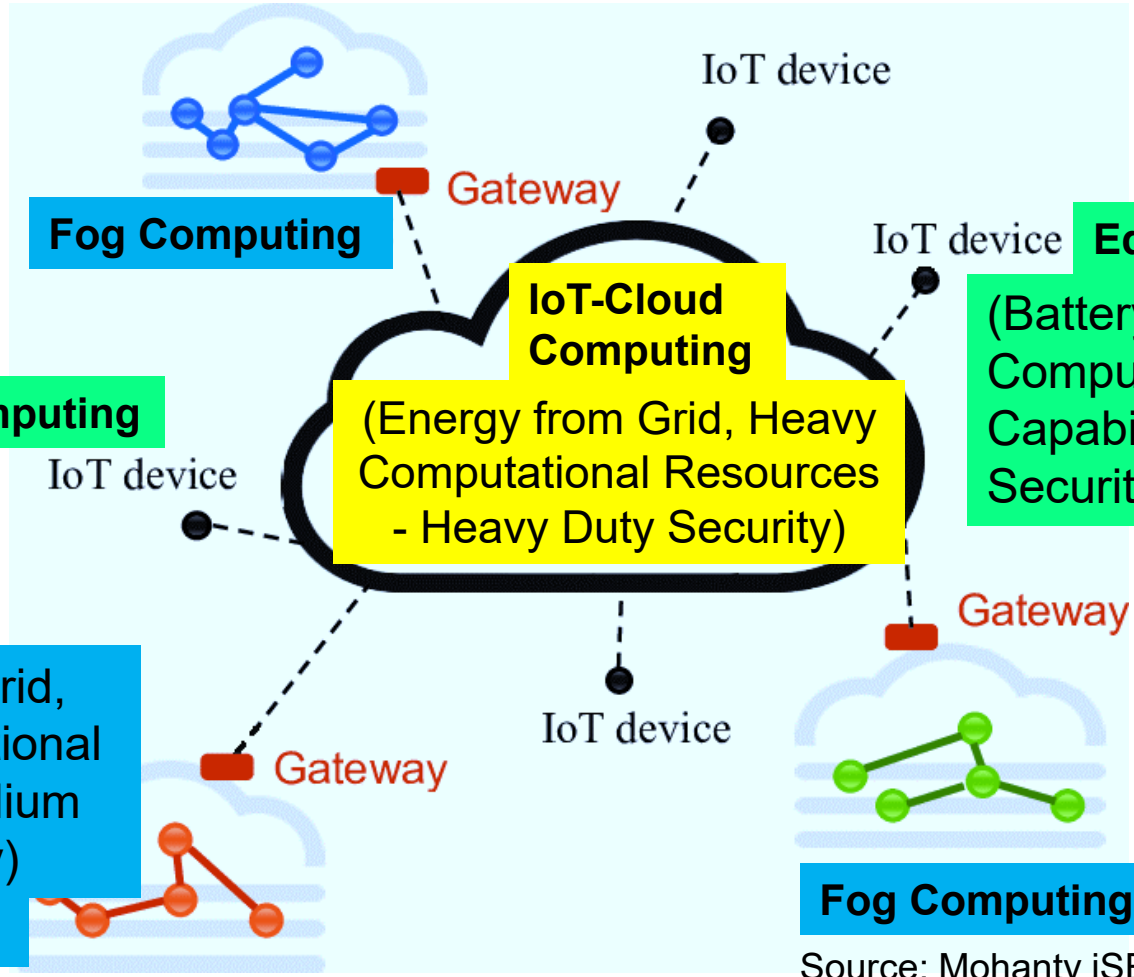
Edge: Intelligence, Processing, and Communication - Devices like Programmable Automation Controllers (PACs)

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

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

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

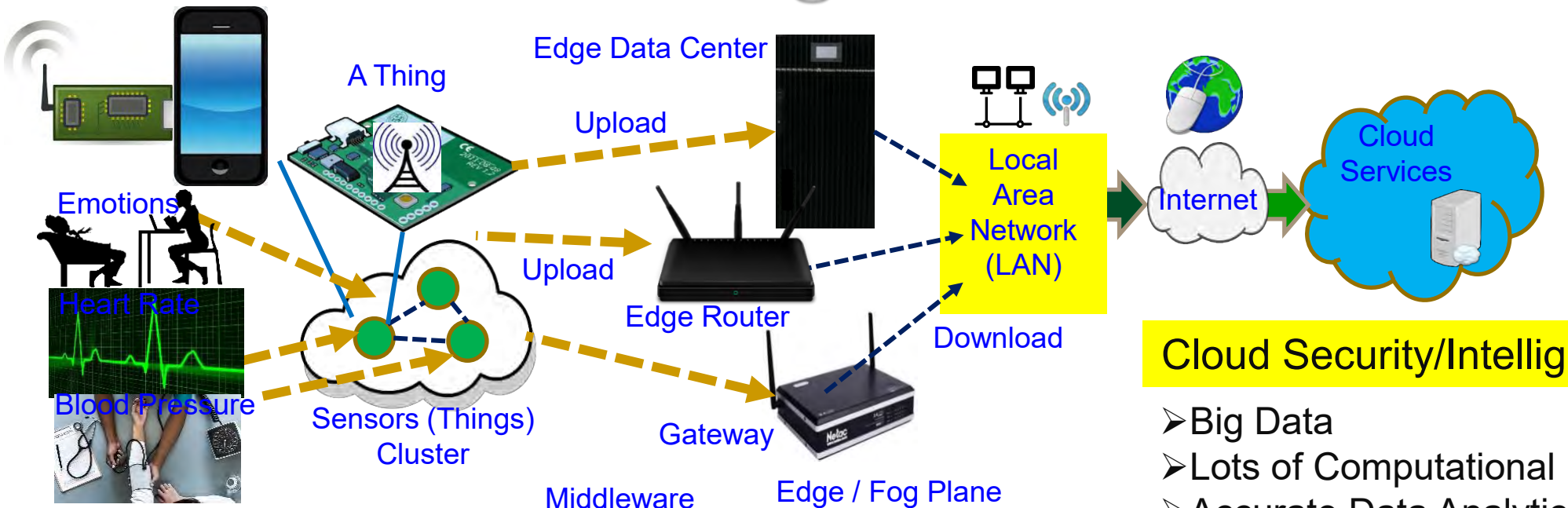
IoT Vs Fog Vs Edge Computing – Energy, Security, Response Tradeoffs



Source: Mohanty iSES 2018 Keynote

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

CPS – IoT-Edge Vs IoT-Cloud



End Security/Intelligence

- Minimal Data
- Minimal Computational Resource
- Least Accurate Data Analytics
- Very Rapid Response

Edge Security/Intelligence

- Less Data
- Less Computational Resource
- Less Accurate Data Analytics
- Rapid Response

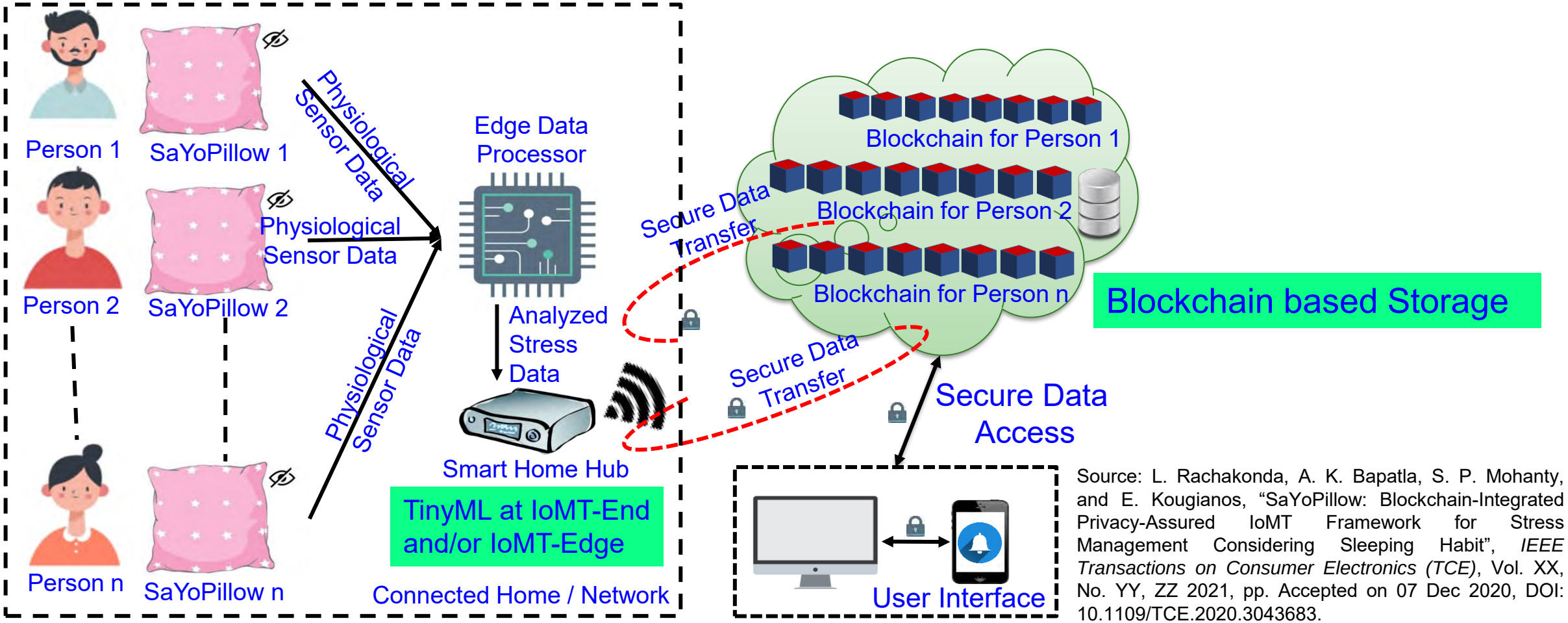
Cloud Security/Intelligence

- Big Data
- Lots of Computational Resource
- Accurate Data Analytics
- Latency in Network
- Energy overhead in Communications

TinyML at End and/or Edge is key for smart villages.

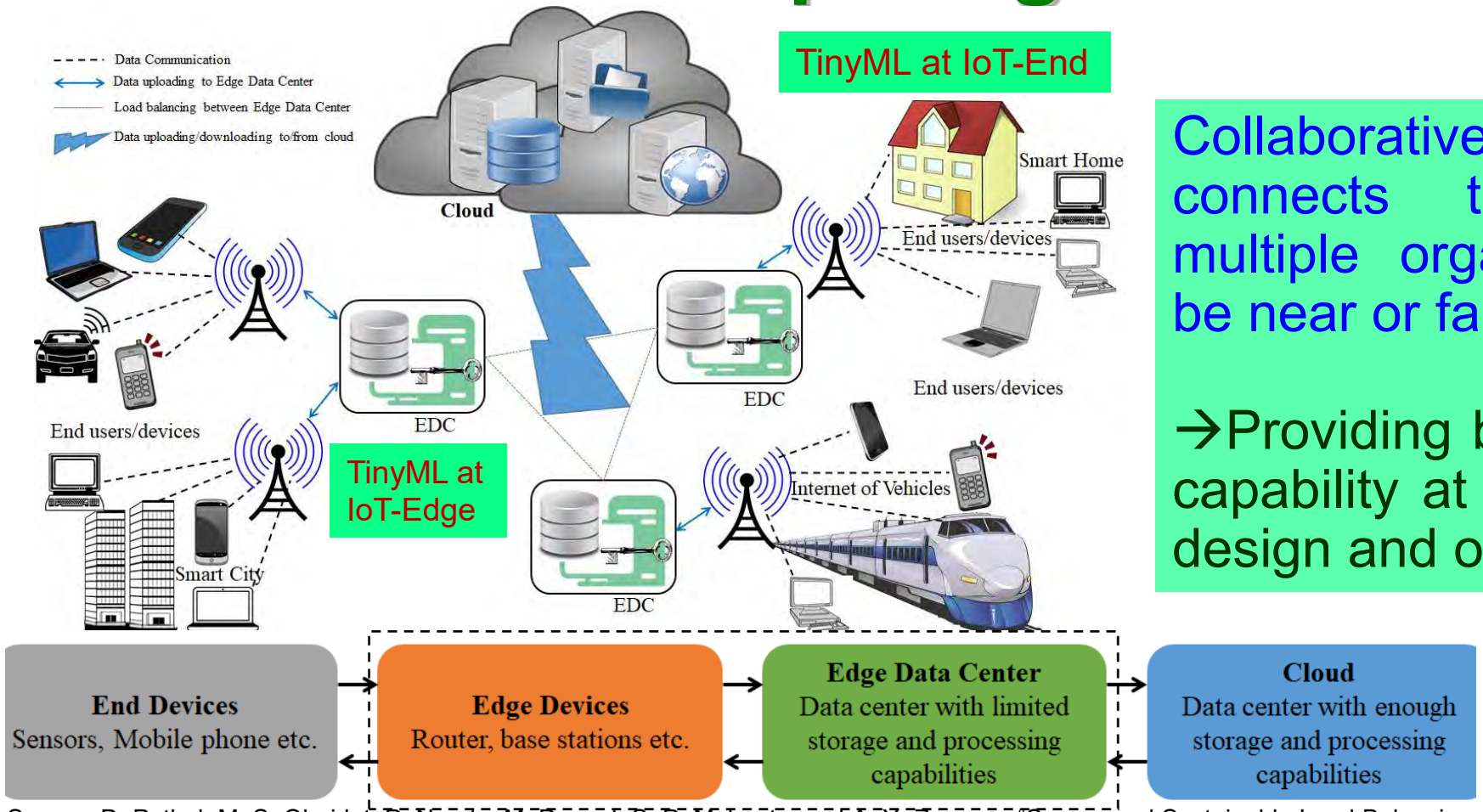
Heavy-Duty ML is more suitable for smart cities

Our Smart-Yoga Pillow (SaYoPillow) with TinyML and Blockchain based Security



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: Blockchain-Integrated Privacy-Assured IoMT Framework for Stress Management Considering Sleeping Habit", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. XX, No. YY, ZZ 2021, pp. Accepted on 07 Dec 2020, DOI: 10.1109/TCE.2020.3043683.

Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages



Collaborative edge computing connects the IoT-edges of multiple organizations that can be near or far from each other

→Providing bigger computational capability at the edge with lower design and operation cost.

Source: D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya, "Secure and Sustainable Load Balancing of Edge Data Centers in Fog Computing", *IEEE Communications Mag*, Vol. 56, No 5, May 2018, pp. 60--65.

Tools and Solutions

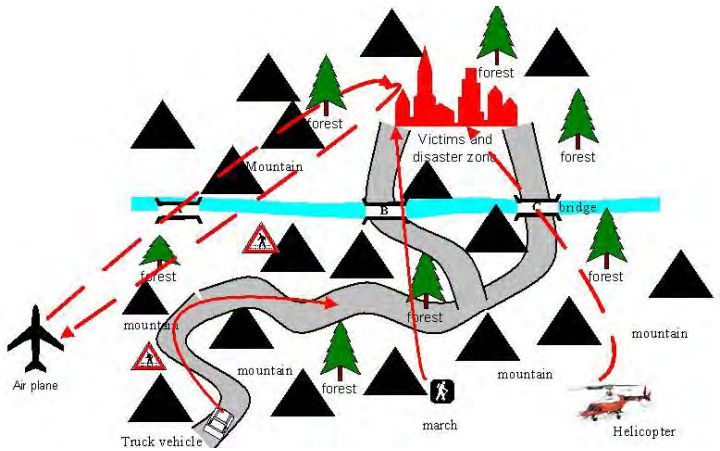
Market Opportunities

- "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/

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.



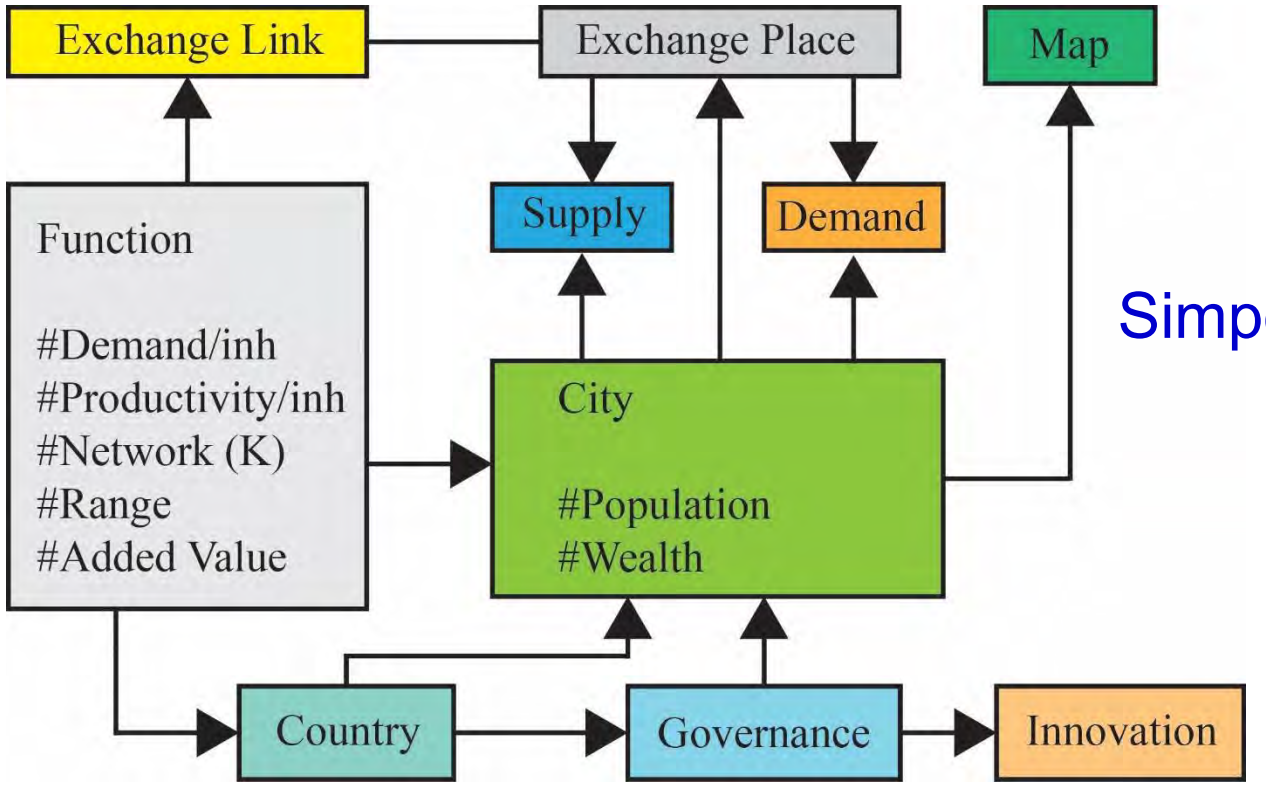
Smart Cities Simulator - CUPCARBON

- **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 - Simpop

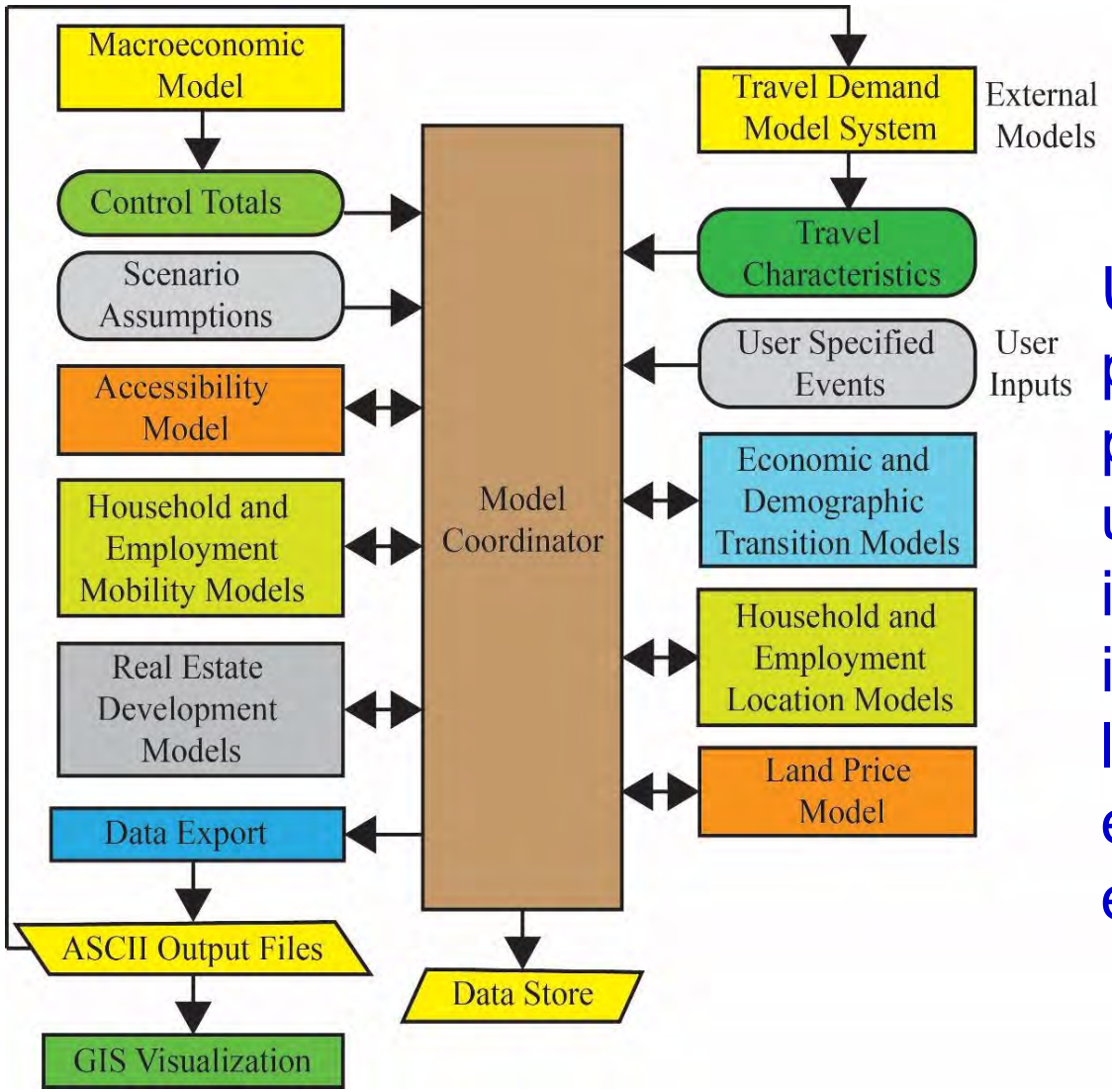


Simpop2

- SIMPOP is a geosimulation tool for exploring smart cities.
- Common features in the genesis and long-term evolution of cities help in understanding and predicting their future dynamics.

Source: http://www.simpop.parisgeo.cnrs.fr/models/simpop2

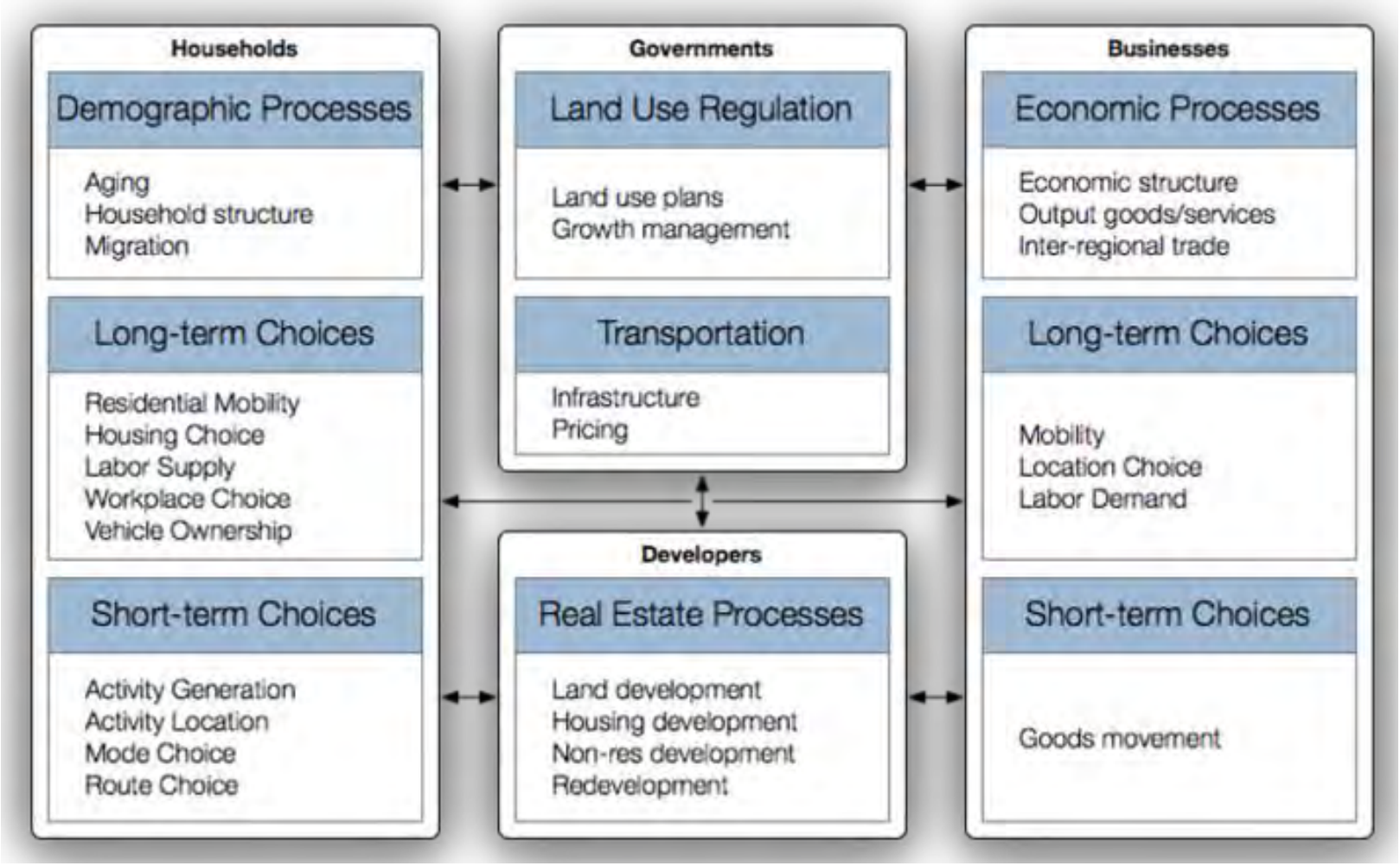
Smart Cities Simulator - UrbanSim



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

Smart Cities Simulator - UrbanSim



Source: http://datasmart.ash.harvard.edu/news/article/simcities-designing-smart-cities-through-data-driven-simulation-893

Industry Solutions - IBM

IBM has tools to:

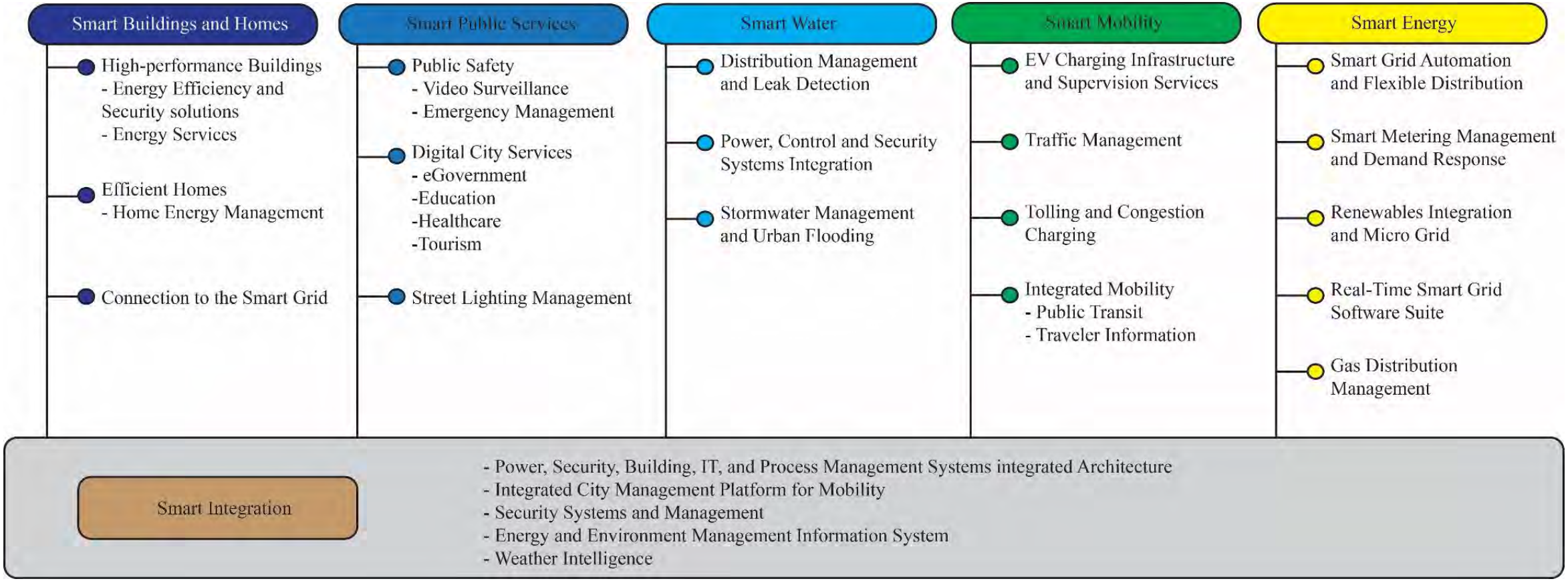
- Determine top goals and objectives
- Understand the relationships among systems
- Compare the performance of cities to each other
- Evaluate operational maturity
- Develop actionable roadmaps

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

Industry Solutions - Schneider Electric



Source: http://www.digital21.gov.hk/sc/relatedDoc/download/2013/079%20SchneiderElectric%20(Annex).pdf

Standards

Standards - Why

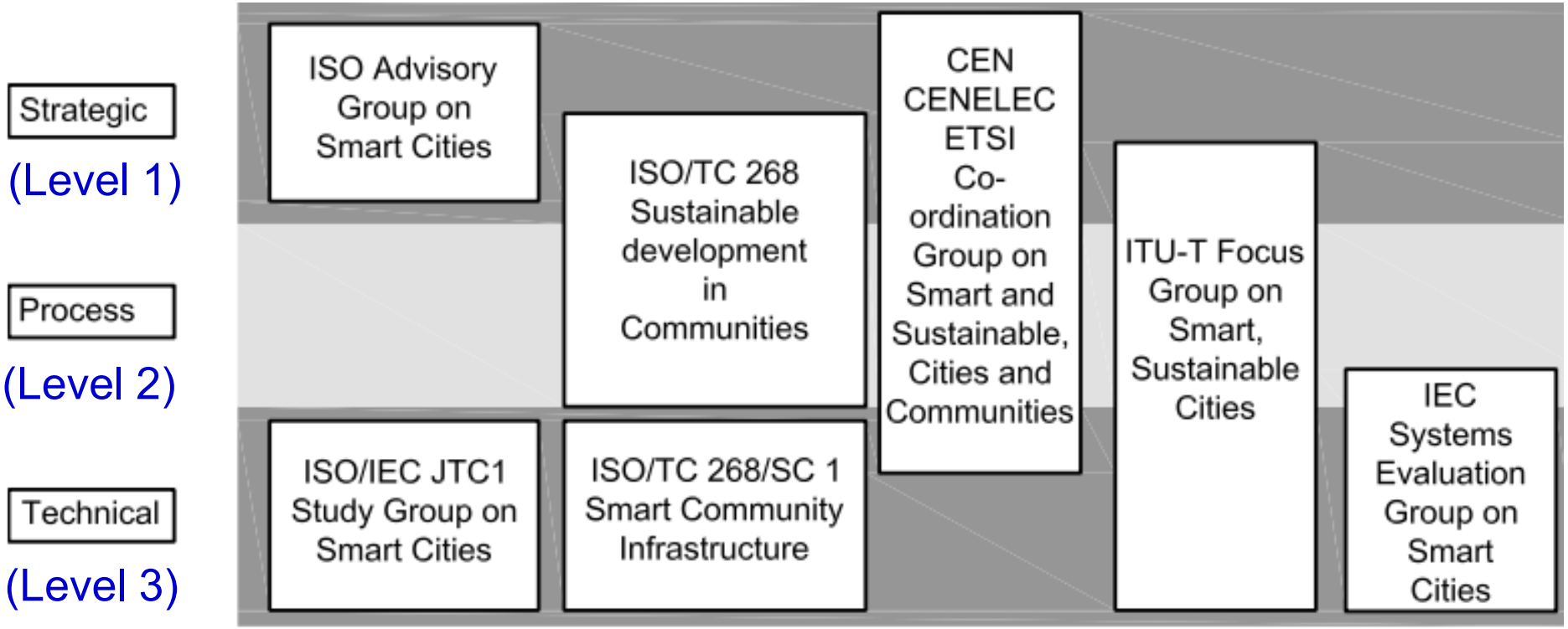
- To determine entry points for investment in city markets and make informed decisions through data analysis
- To benchmark investments and monitor progress
- To evaluate the “impact” of infrastructure projects on the sustainability and efficiency of the city
- To build smart and sustainable cities
-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

Standards - What

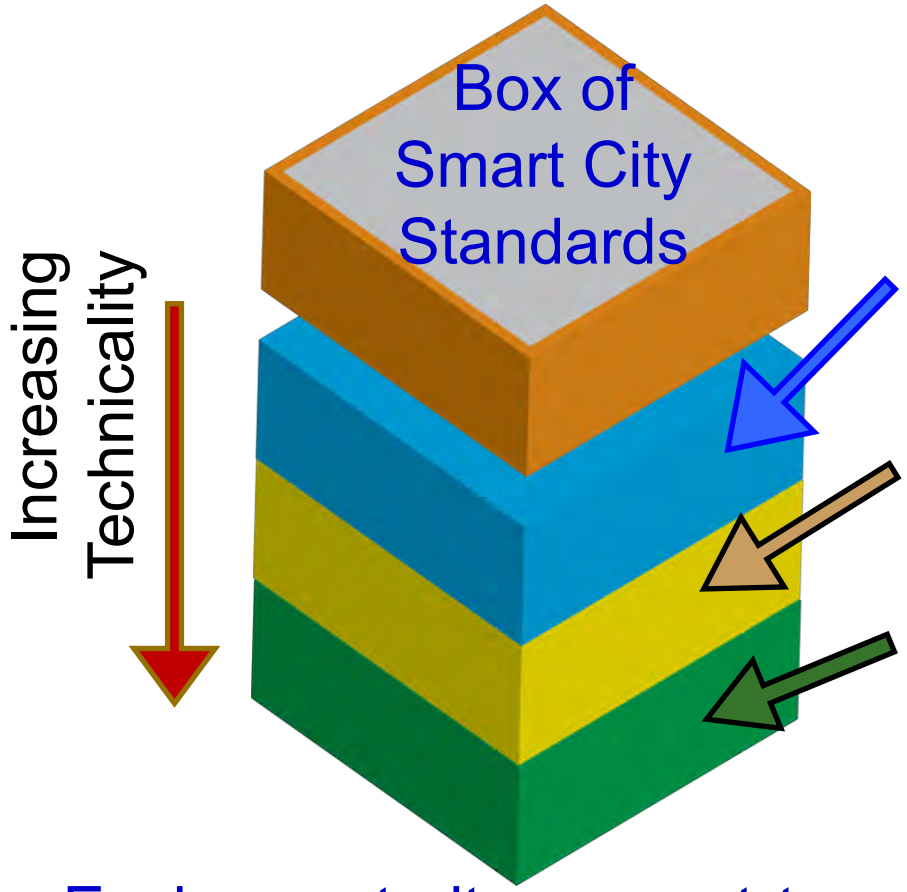
- International Organization for Standards (ISO) initiatives.
- International Telecommunication Union (ITU), United Nations specialized agency on ICT has been working.
- International Electrotechnical Commission (IEC) has initiatives.
- IEEE has been developing standards for smart cities for its different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

Standards – Major Bodies



Source: http://urbanopus.net/smart-city-standards-an-overview/

Standards - Levels



Level 1 – Strategic: Developing a clear and effective overall smart city strategy

Level 2 – Process: Procuring and managing smart city projects

Level 3 – Technical Specifications: Technical specifications that are needed to actually implement

Each smart city can put together a particular combination of standards which are needed to fulfil in its vision in a block by block fashion.

Source: http://urbanopus.net/smart-city-standards-an-overview/

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 - ISO 37120

- ISO 37120 defines 100 city performance indicators which include 46 core and 54 supporting indicators.
- 2 Core Indicators for Transportation:
  - Kilometers of high capacity public transportation per 100,000 population
  - Annual number of public transport trips per capita
- 2 Core Indicators for Economy:
  - City's unemployment rate
  - Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties
- 2 Core Indicators for Energy:
  - Total electrical energy use per capita (kWh / year)
  - Average number of electrical interruptions per customer per year

Source: http://smartcitiescouncil.com/article/dissecting-iso-37120-why-new-smart-city-standard-good-news-cities

Initiatives

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 & 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 United States 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-

Smart Cities - Case Study - Singapore

- Smart transport with traffic lights/management, smart parking
- Visible Light Communication (VLC) or LiFi for indoor positioning in malls
- Smart waste management.

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

UN Initiative - United 4 Smart Sustainable Citie (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
- 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 Mission – Livability Index

Institutional	Social	Economic	Physical
			
Governance	- Health - Education - Identity and Culture - Safety and Security	- Economy and Employment	- Housing and Inclusiveness - Public Open Spaces - Mixed Land Use and Compactness - Power Supply - Transportation and Mobility - Assured Water Supply - Waste Water Management - Reduced Pollution - Solid Waste Management

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

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

- Accurate and scalable smart city simulator
- Energy-efficient, accurate sensors
- Security
- Privacy
- IP or content protection
- Energy efficiency
- Big data processing
- Efficient, Safer Battery
- Larger, cheaper, faster memory