

Lecture 1 : Introducing Internet of Things

Dr. Bibhas Ghoshal

Assistant Professor

Department of Information Technology

Indian Institute of Information Technology Allahabad



Internet of Things
Instructor : Dr. Bibhas Ghoshal

Spring 2022

Outline

- Internet of Things – Basic concepts, Examples
- History , Progression
- Basic Idea of the IoT Ecosystem
- IoT Architecture
- Why IoT Now?
- Summary of the course content
 - Module 1 : Enabling Technologies – Sensing, Processing, Communication
 - Module 2 : Communication Technologies
 - Module 3 : Cloud Computing for IoT
 - Module 4 : Data Analytics for IoT
 - Module 5 : Advanced Topics – Fog and Edge Computing, IoT security
- Challenges and Research Directions



Internet of Things

Internet of things

From Wikipedia, the free encyclopedia

The **Internet of things (IoT)** describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the [Internet](#).^{[1][2][3][4]}

Things have evolved due to the convergence of multiple technologies, real-time [analytics](#), [machine learning](#), [commodity sensors](#), and [embedded systems](#).^[1] Traditional fields of [embedded systems](#), [wireless sensor networks](#), control systems, [automation](#) (including [home](#) and [building automation](#)), and others all contribute to enabling the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "[smart home](#)", including devices and [appliances](#) (such as lighting fixtures, [thermostats](#), home [security systems](#) and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as [smartphones](#) and [smart speakers](#). IoT can also be used in [healthcare systems](#).^[5]

Things, People and Cloud Services
get connected via Internet to
enable new use cases and business
models

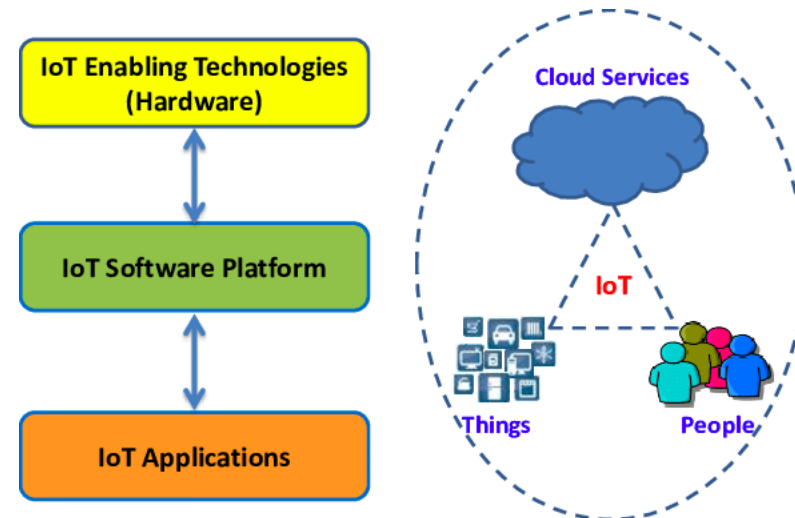
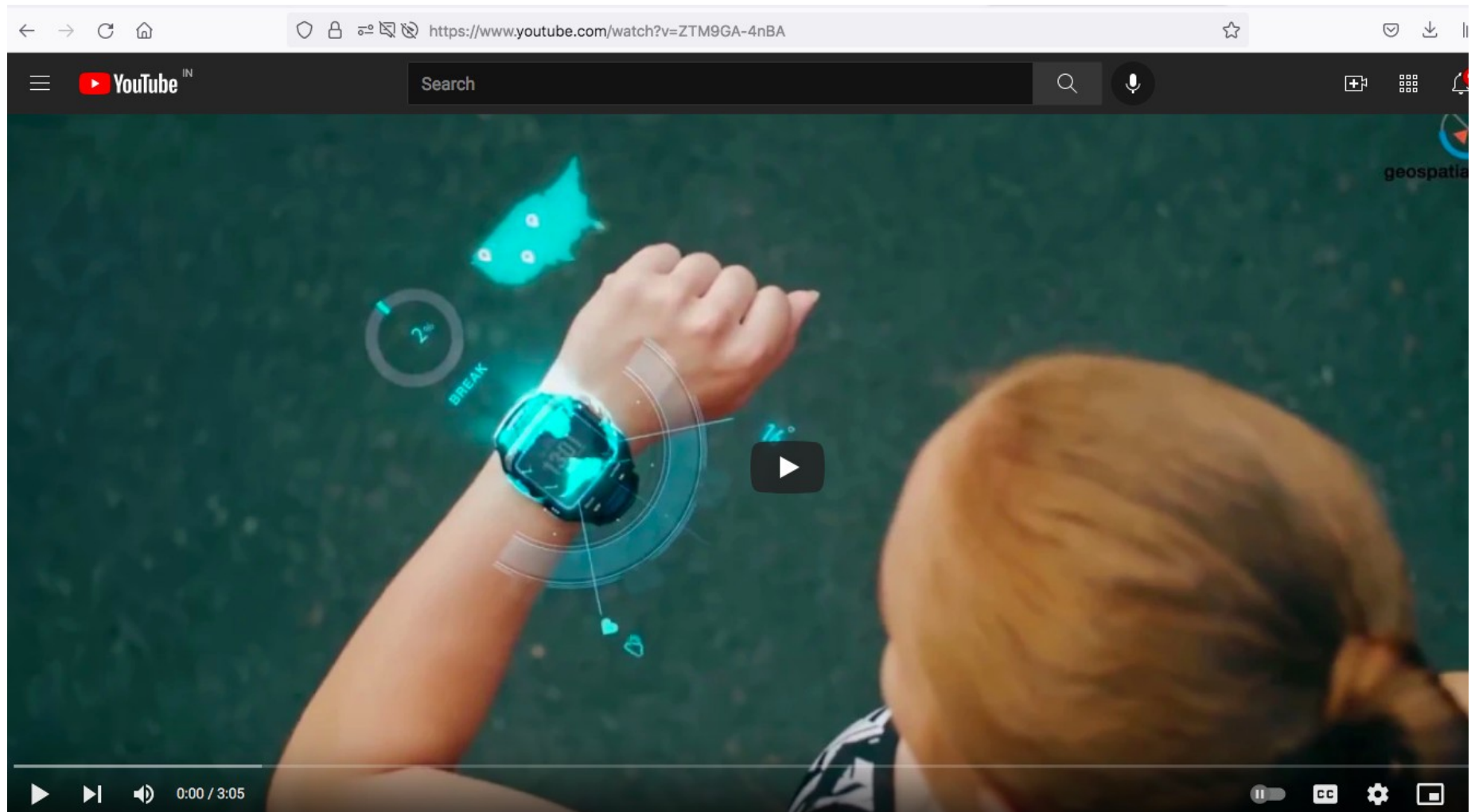


Figure source : Iman Khajenisiri et.al., A Review of Internet of Things Solution for Intelligent Energy Control in Buildings for Smart City Applications, Energy Procedia, Volume 111, 2017



Internet of Things : Applications

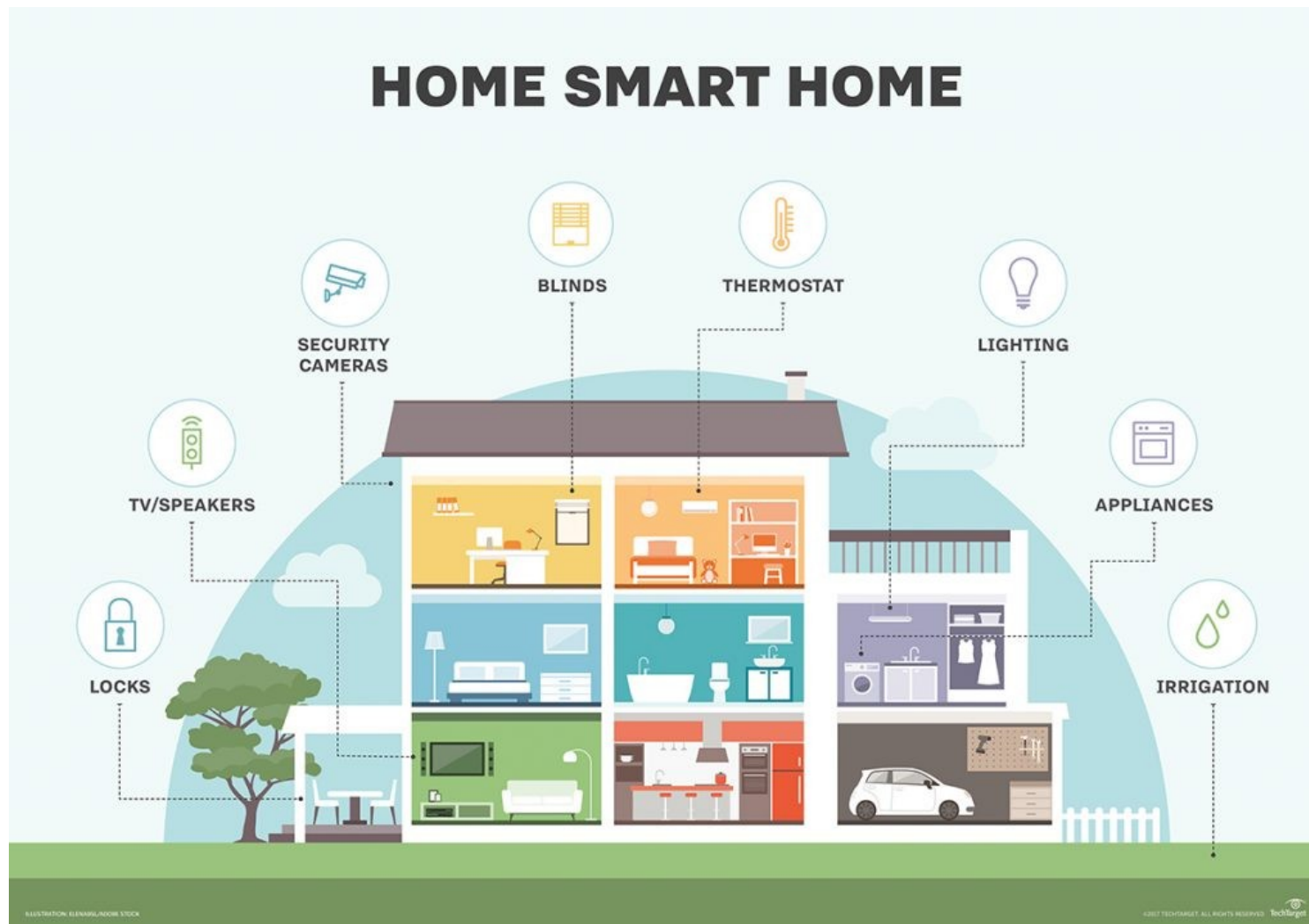
Let us Watch This !!!!!



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Internet of Things Applications

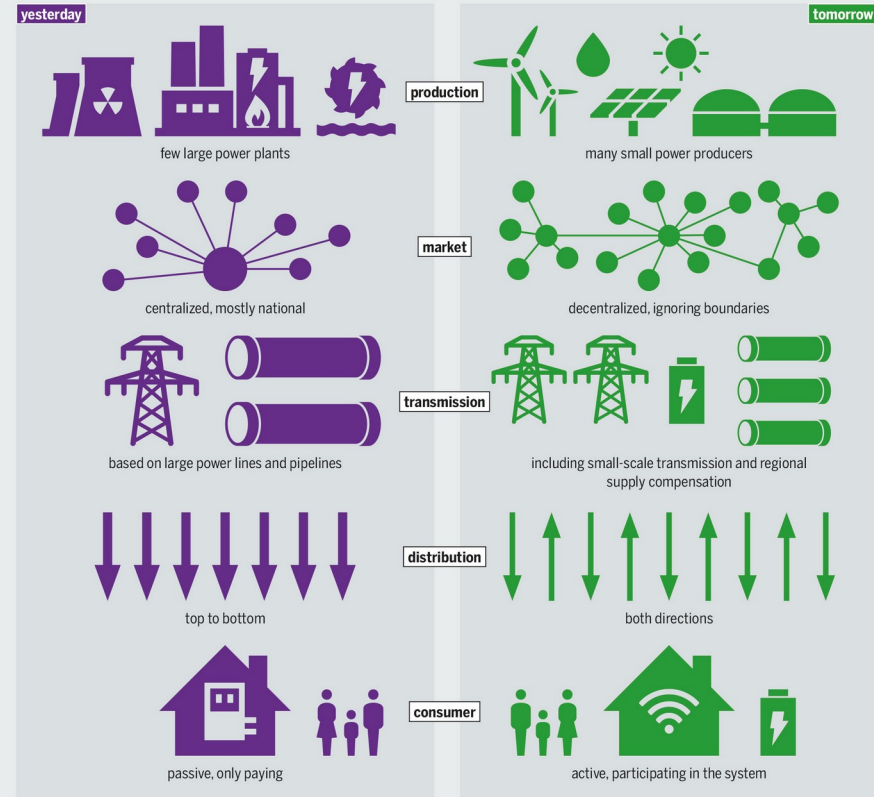


Source : TechTarget

Internet of Things Applications : Smart Grid

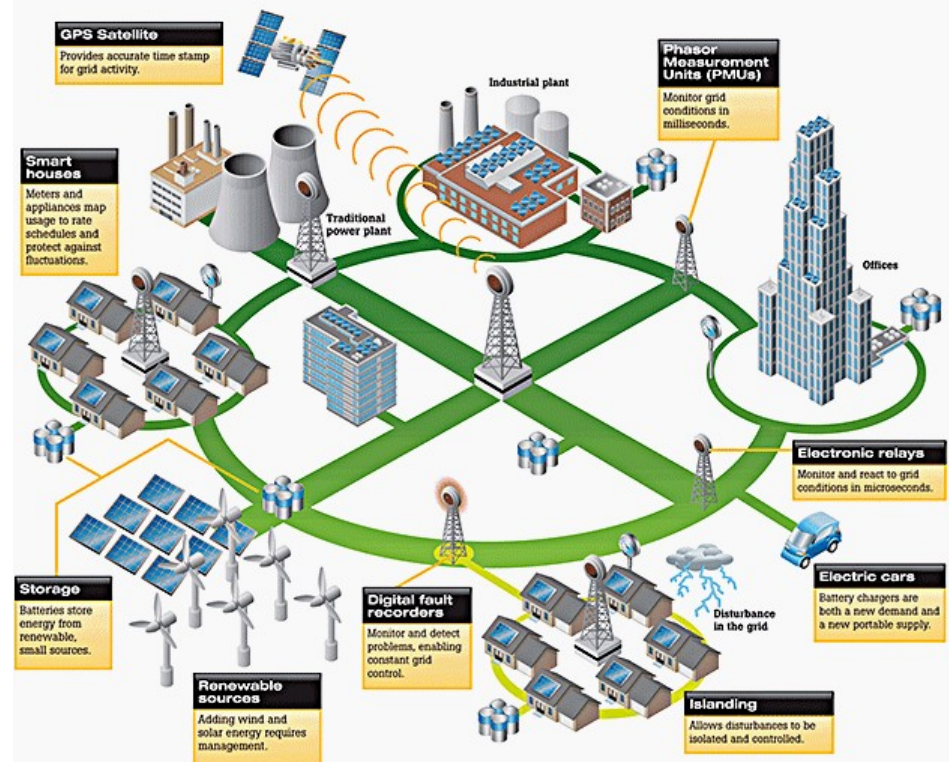
STAYING BIG OR GETTING SMALLER

Expected structural changes in the energy system made possible by the increased use of digital tools



Smart Grid

A real-time, dynamic network of electrical demand, supply, and control



Source : Internet

Watch This : [Smart Grids in India by TU Delft!](#) :



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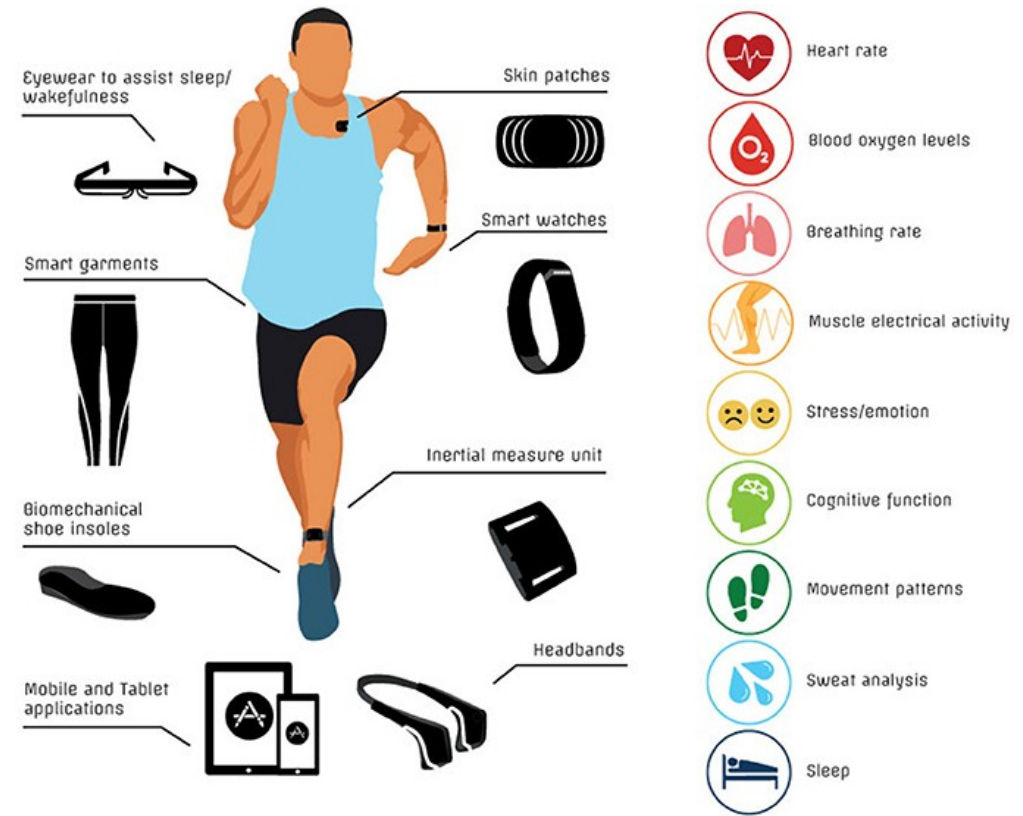
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Internet of Things Applications : Healthcare



Role of IoT in Healthcare

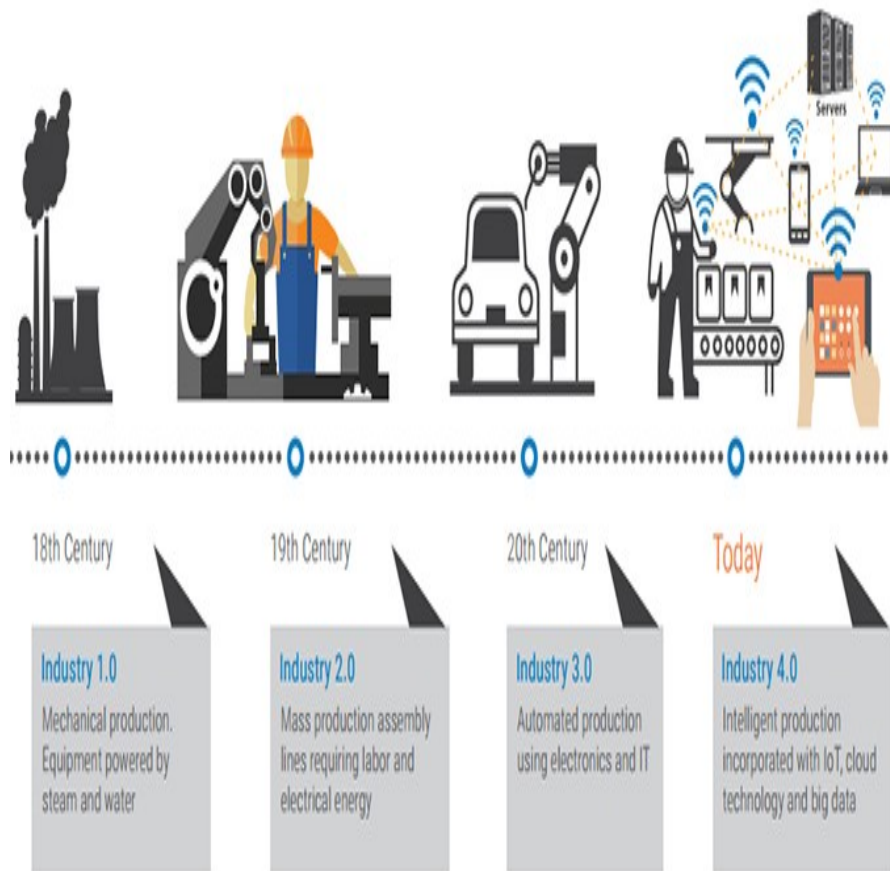
Source : Internet



Wearables

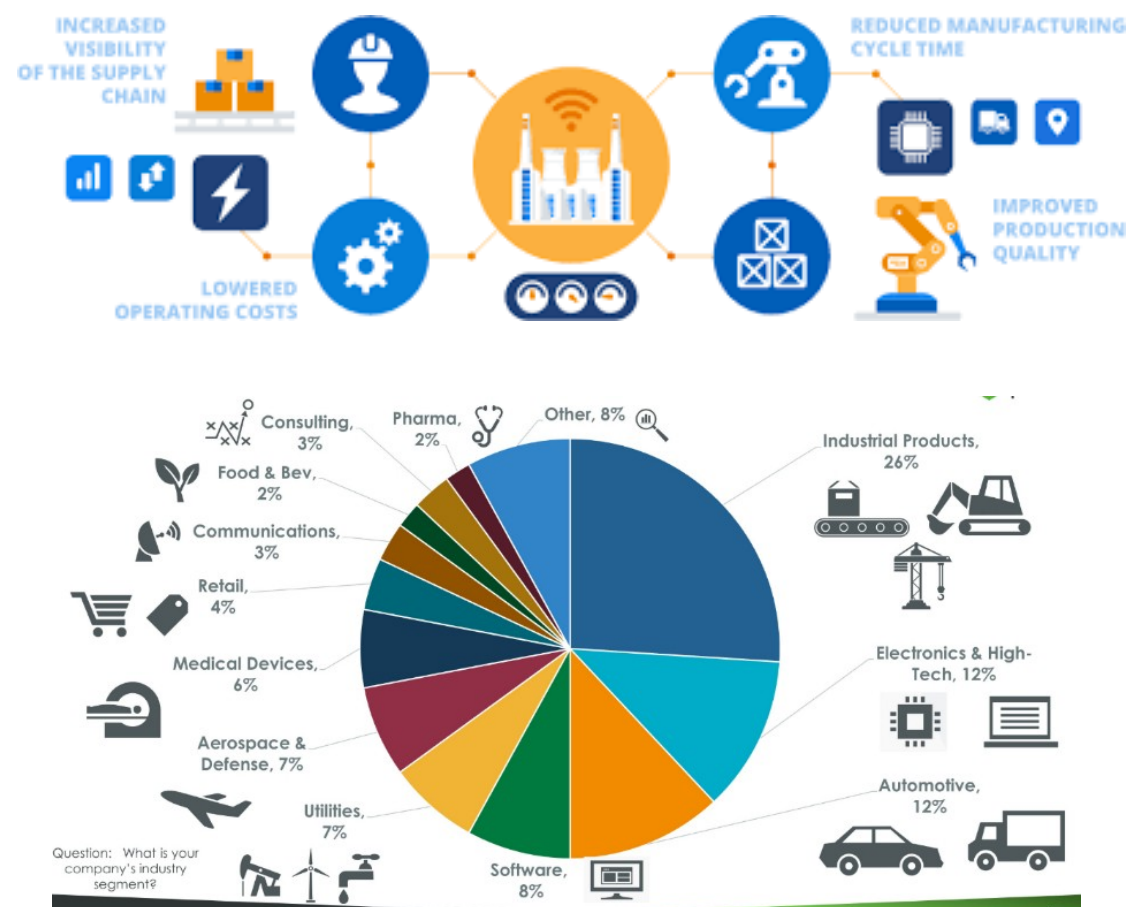
Source : Internet

Internet of Things Applications : Industry 4.0



Industrial Revolutions

Source : Internet



Source : Internet



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Internet of Things Applications : Agriculture



Source : Internet

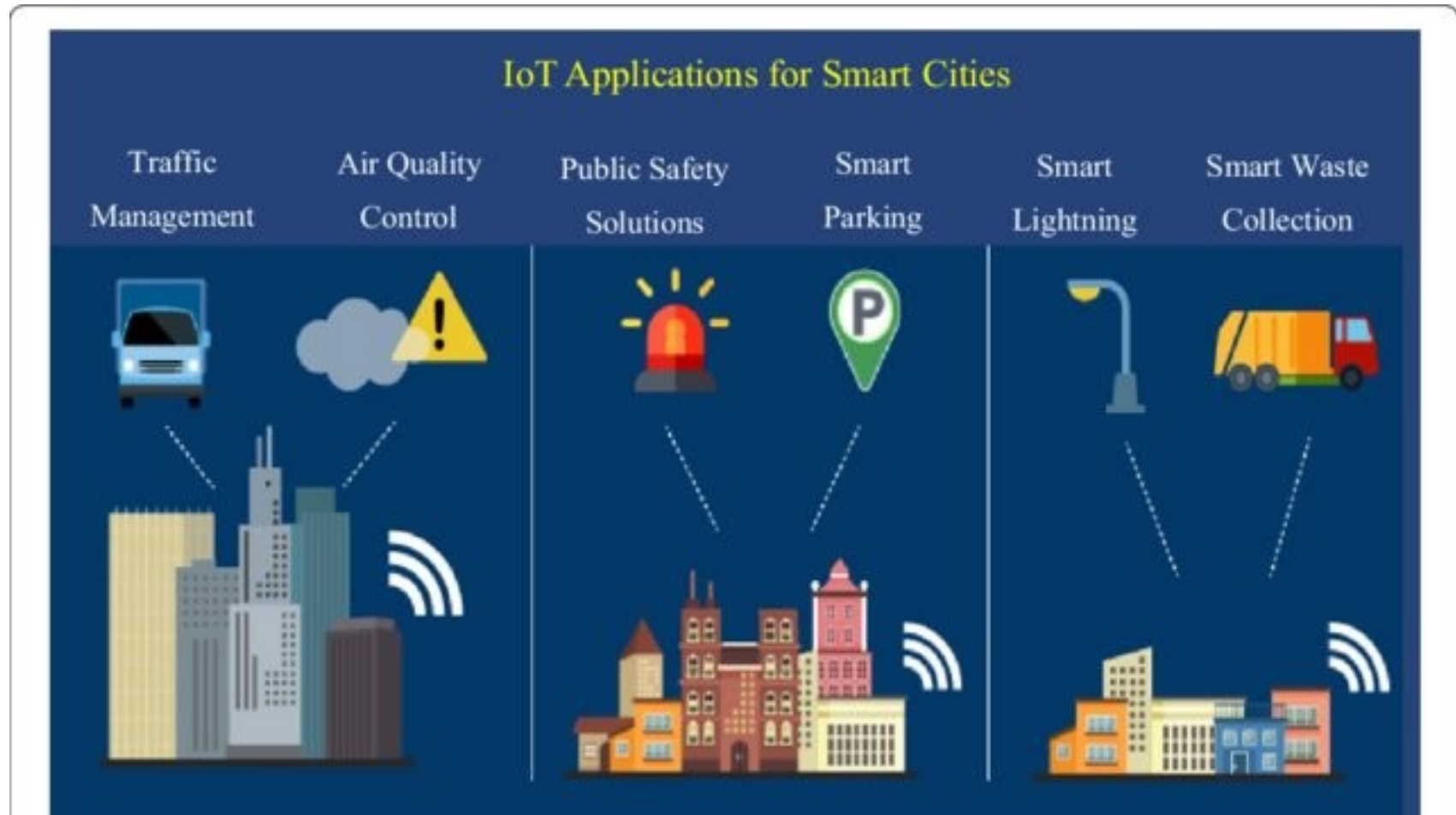
Watch This : [Smart Agriculture Solution by Infosys](#)



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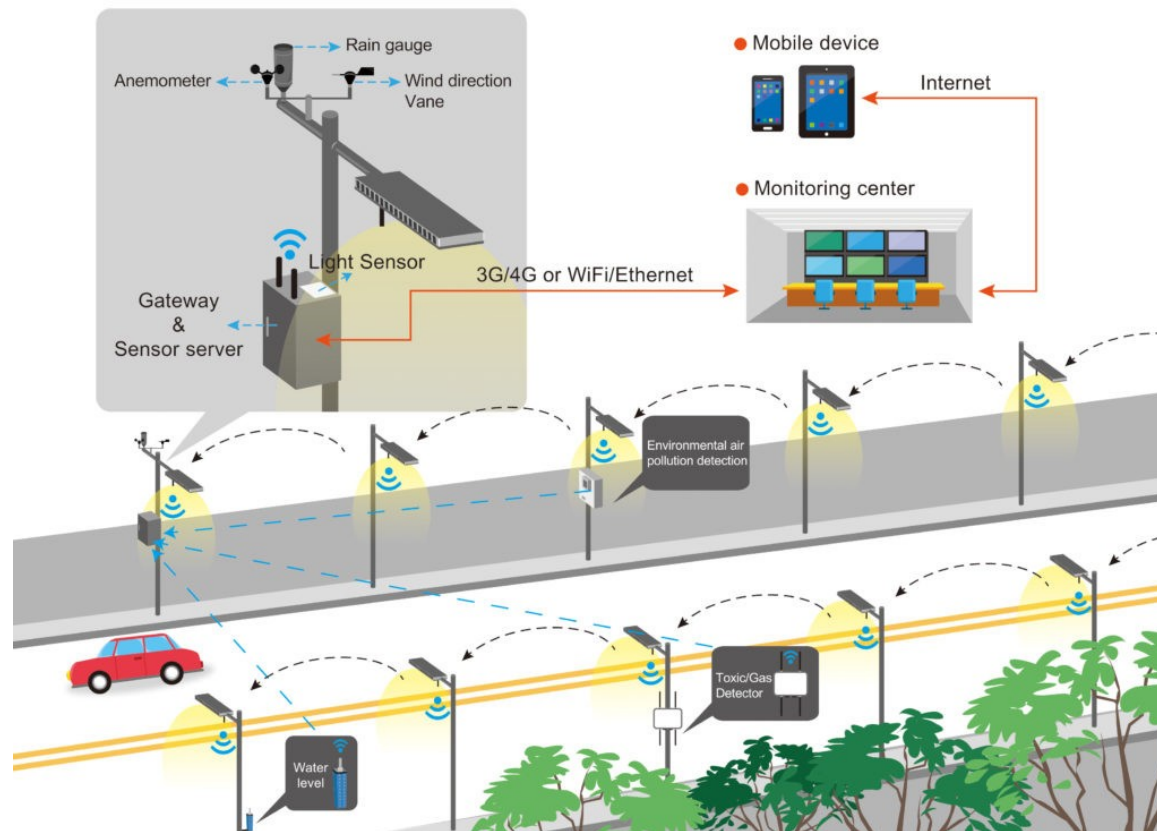
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Internet of Things Applications : Smart City



Source : Internet of Things is a revolutionary approach for future technology enhancement: a review, Sachin Kumar et al. , Journal of Big Data, Springer, 2019

Internet of Things Applications : Smart Street Lights



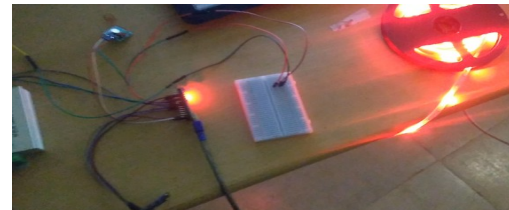
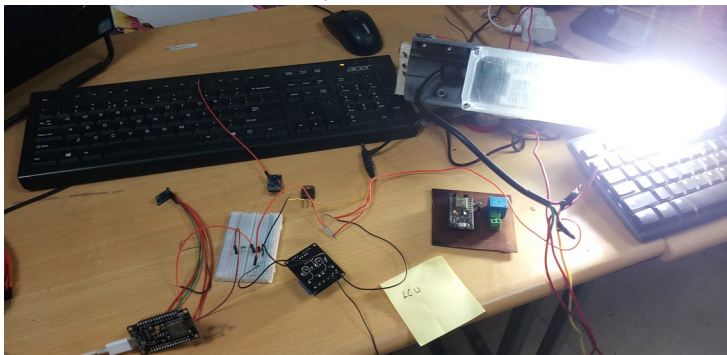
Source : Internet

Smart Street Lights Project – Systems Lab IIITA

Systems Lab IIITA aims at providing IoT based smart city infrastructure in the form of smart street lighting appending the Street Light National Program initiated by GoI in 2015 with the aim to promote energy efficiency in the country.

Objectives :

1. Energy Saving : Intelligent Lighting System which uses smart LEDs offering varying degrees of illumination based on surrounding environment (surrounding light intensity, pedestrians, vehicles, weather conditions)
2. Easy and prompt maintenance with reduced manual labour , periodic status checks of each light and automatic notification in case of fault
3. Novel, generic and scalable solution that can be implemented with any smart LED light
4. Additional services such as housing WLAN access points to deliver internet services selectively for educational content, data source for data analysis of street light consumption



Internet of Things Applications



Source : [Introduction to the Internet of Things](#), Marco Zennaro, Telecommunications/ICT4D Lab, The Abdus Salam International Centre for Theoretical Physics, [Trieste, Italy](#)

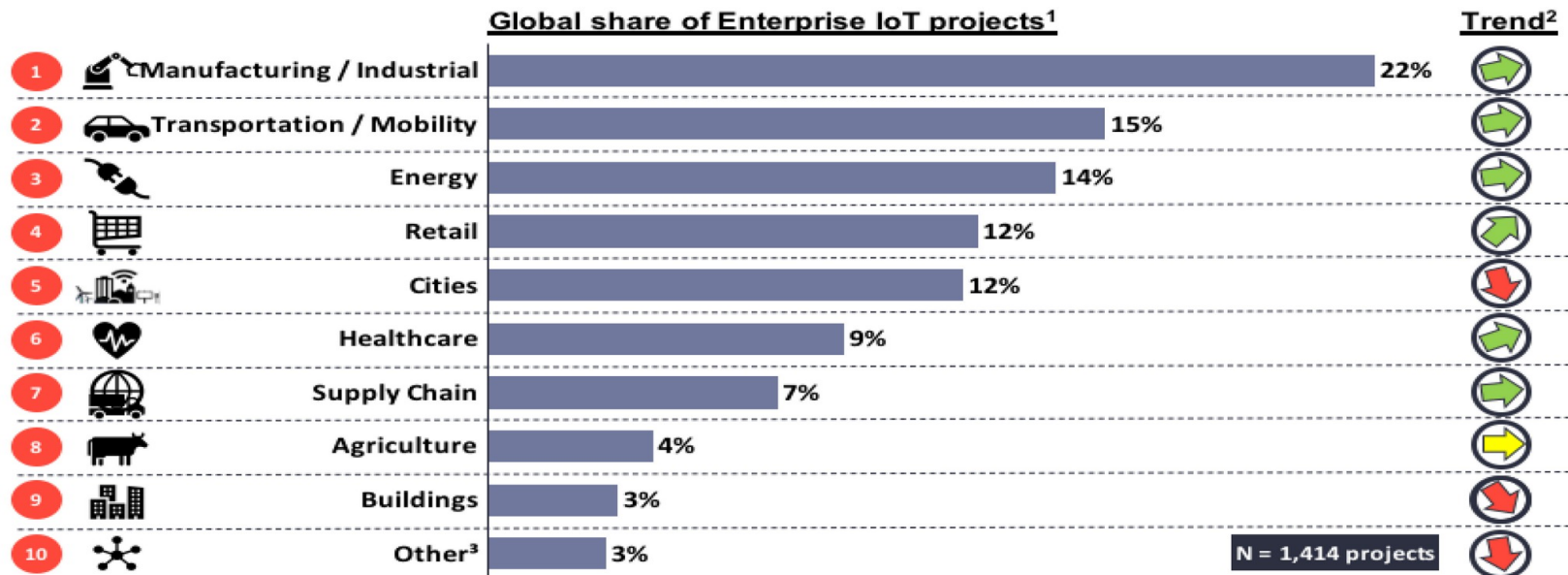


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Internet of Things Applications : Review

Top 10 IoT Application areas 2020



Top 10 IoT Applications in 2020

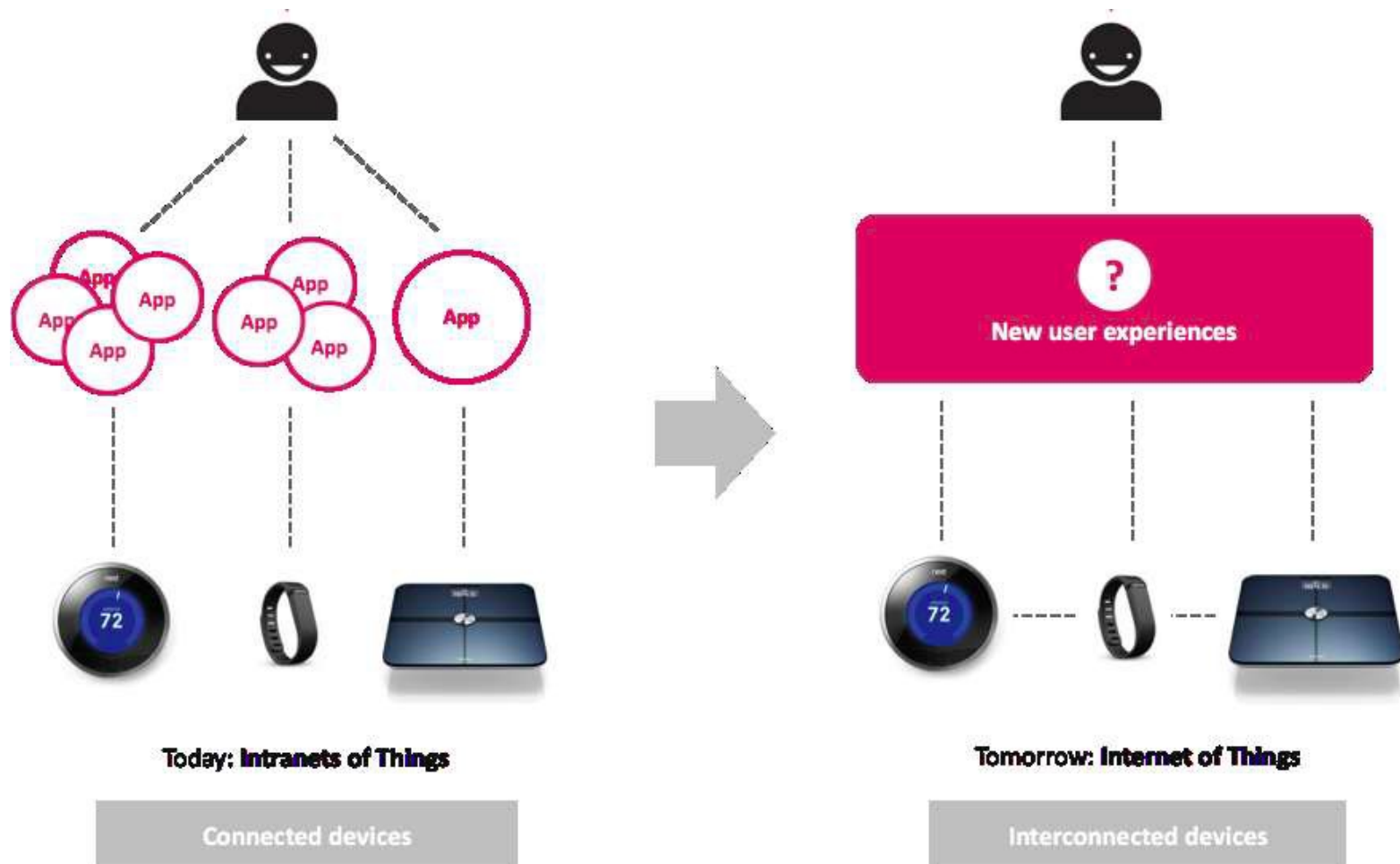
Source : IoT Analytics



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Internet of Things : Connectivity of Devices



Source : [Introduction to the Internet of Things](#), Marco Zennaro, Telecommunications/ICT4D Lab, The Abdus Salam International Centre for Theoretical Physics, [Trieste, Italy](#)



History of Internet of Things

First IoT Device : RFID (1940-1950), Major efforts in development for Tracking and identifying aircrafts in World War II (Friends or Foe)

1960 : RFID was used for monitoring nuclear and other hazardous materials, RFID companies founded

1973 : Mario W. Cadullo received the first US Patent for an active RFID tag

1980 : RFID research started, marks the beginning of transforming RFID into more widespread technology

1990 : First UHF Reader invented, RFID usage expanded to shipments, Walmart introduces their RFID program



Source : Internet

History of Internet of Things

“Machine to Machine” (M2M)
(~1970s +)



Internet of Things Beginnings



Carnegie Mellon Internet
Coke Machine (1982, 1990)



Internet Toaster
(1990)



Trojan Room Coffee
Pot
(first webcam)
(1991)

Source : [Introduction to the Internet of Things](#), Marco Zennaro, Telecommunications/ICT4D Lab, The Abdus Salam International Centre for Theoretical Physics, [Trieste, Italy](#)



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History of Internet of Things : Progression

Progression in 1980's : **Cloud and Server Space (Data moved to centralized server)**

Progression in 1990's : **Machine to Machine interaction**

- 1995 : First cellular module built, First GPS network (version 1) complete
- 1998 : IPv6 adds 2^{128} new IP addresses
- 1999 : Kevin Ashton of MIT coins a new term IoT

Progression in 2000-2010 : **Fog oriented architectures (Central Server to Regional Server located closer to Data Server subnetwork)**

- 2000 : LG announces first smart fridge
- 2007 : First iPhone released
- 2008 : First International Conference on IoT held
- 2009 : Google started testing self driving cars

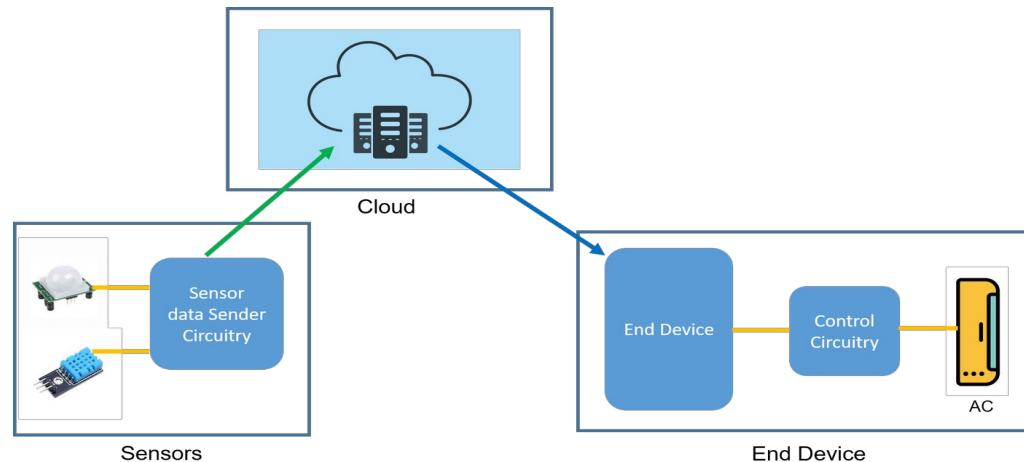
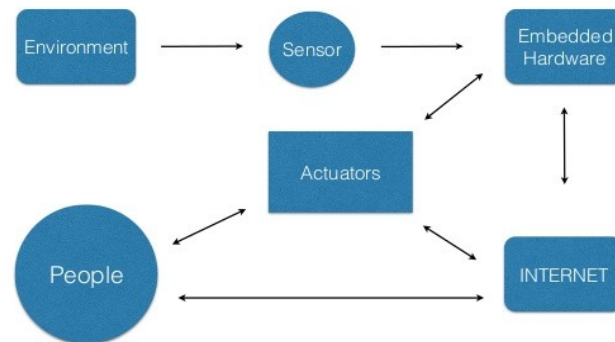
Progression in 2010-onwards : **High Processing power and Edge computing**

- 2013 : Google glass is released
- 2014 : Amazon releases Echo (smart home market opens)
- 2015 : GM, Uber, Tesla are testing self driving cars
- 2017- : IoT continues to grow,

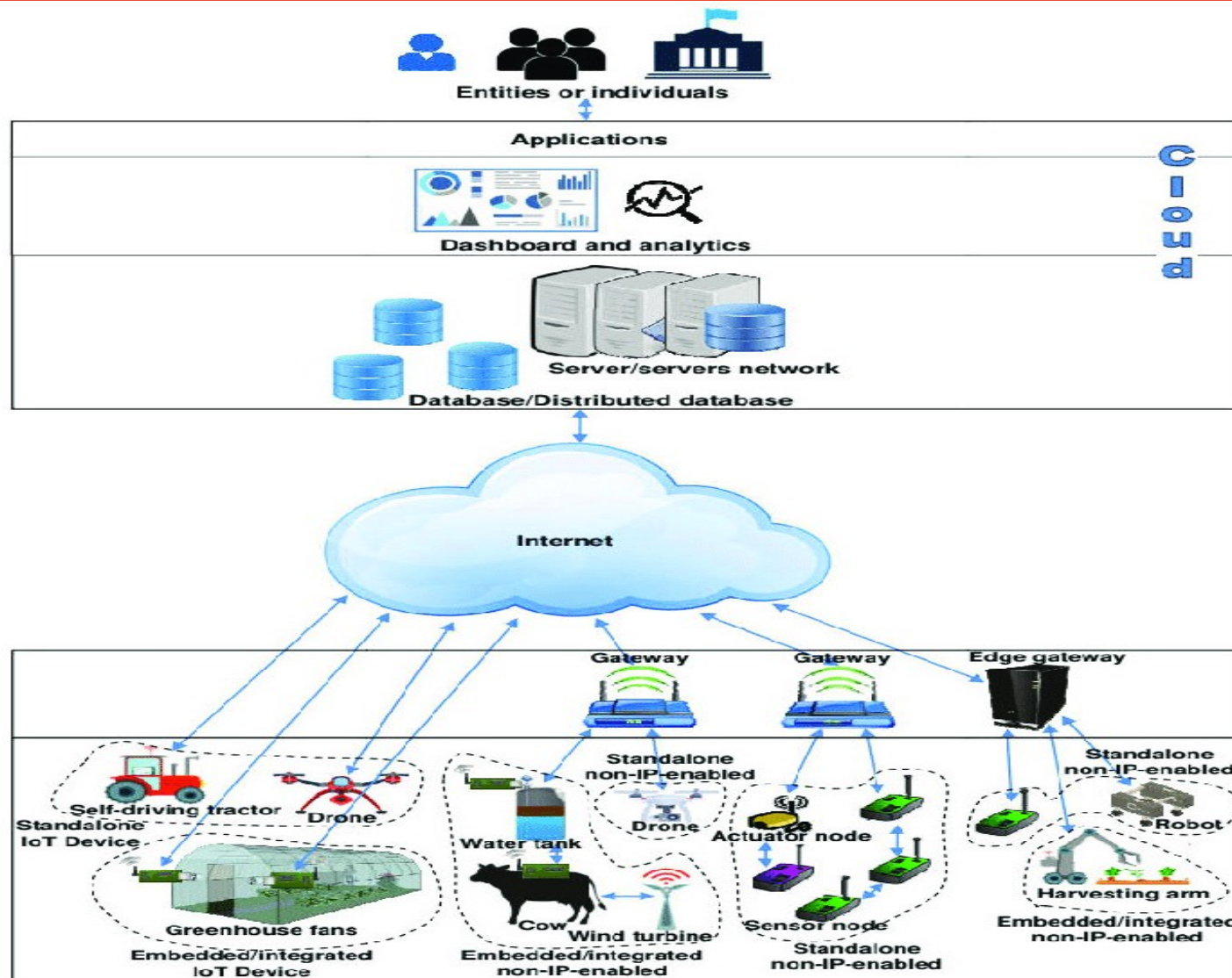


IoT – Basic Idea

How IoT works ?

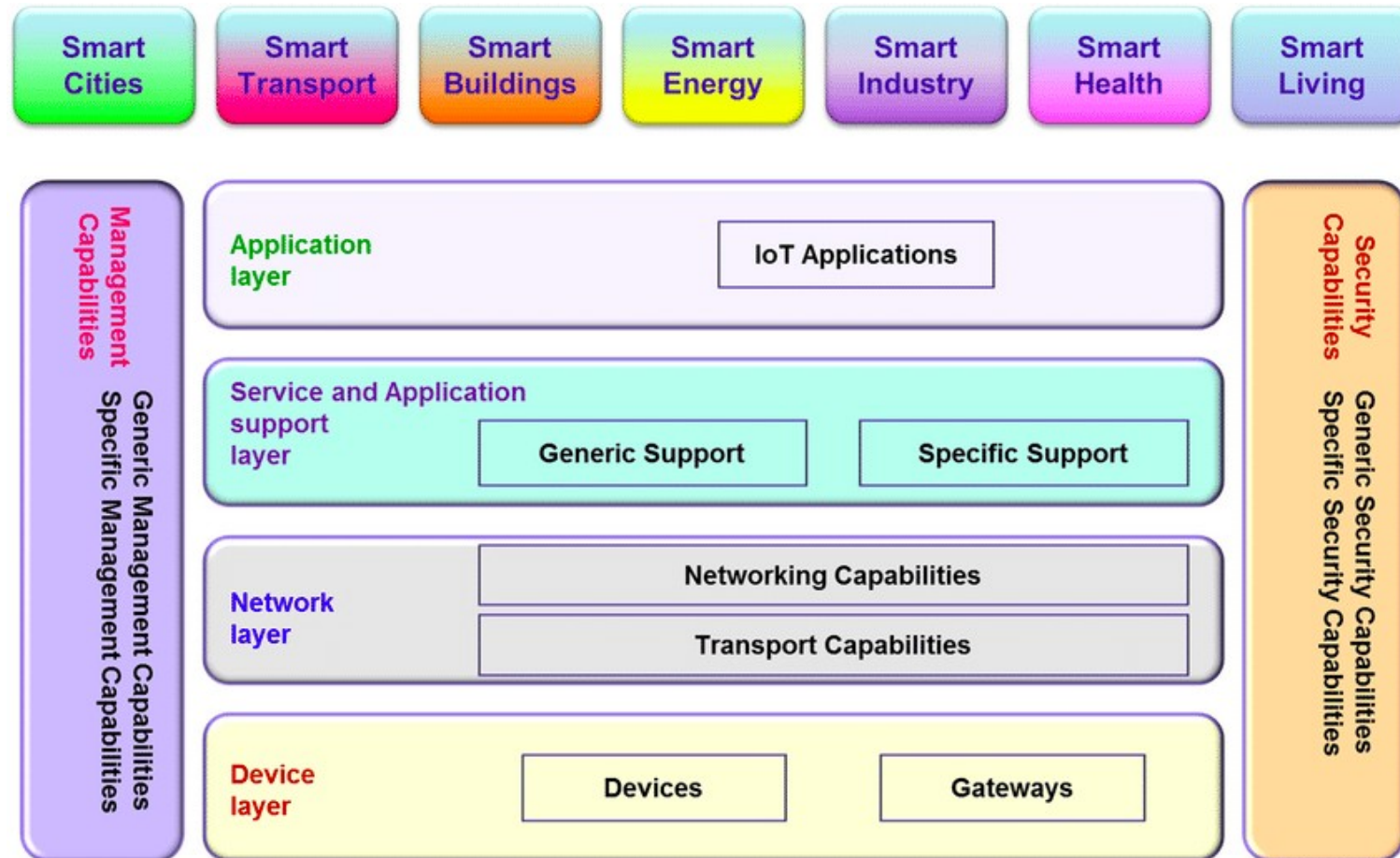


IoT Ecosystem



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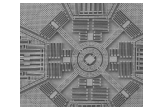
The Four Layered IoT Architecture



Source : ITU-T

Why IoT Now?

- Improved VLSI Technology – Miniaturization, MEMS Technology for Sensing

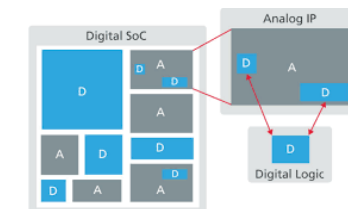


Accelerometer

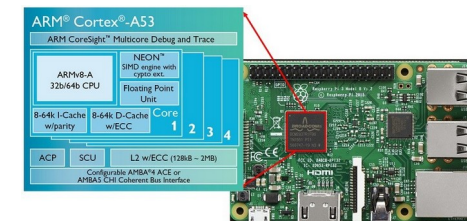


Gyroscope

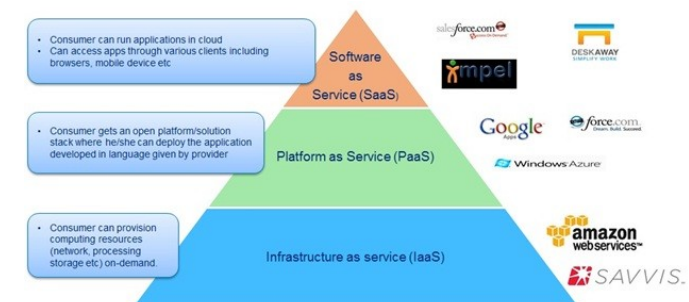
- Widespread Adoption of Intellectual Properties



- Computing Economics - Availability of System-on-Chips



- Data Analytics – Descriptive, Diagnostic, Predictive, Prescriptive
- Fast connectivity
- Rise of Cloud Computing – Provides scalability to the Big Data generated by IoT Devices



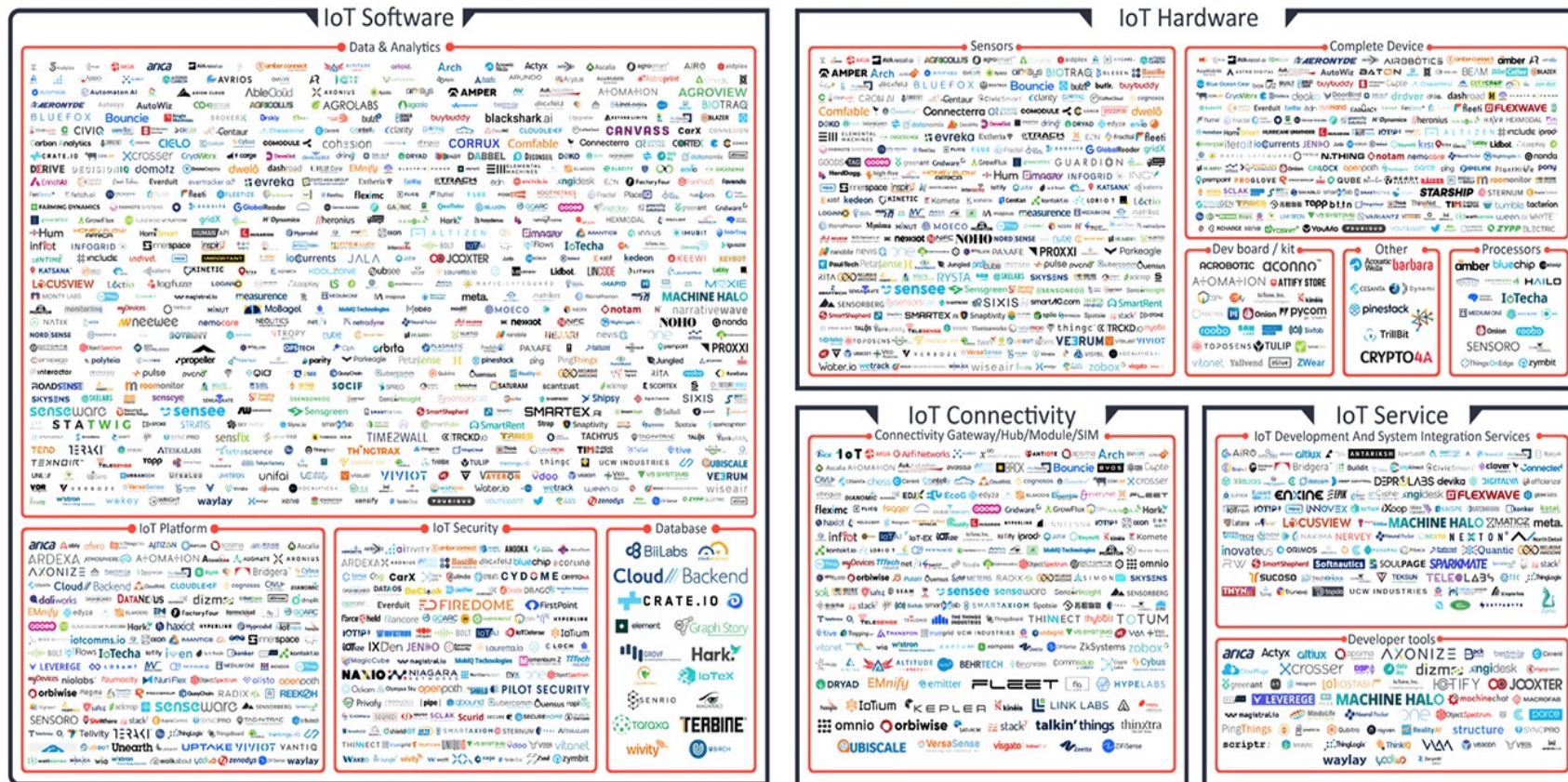
IoT Startup Landscape 2021



June 2021

Your Global IoT Market Research Partner

IoT Startup Landscape 2021 – 1,200+ companies



Note: For companies to be included in IoT Analytics IoT startups database they must be founded in or after January 2013, focus on building solutions for the Internet of Things and provide part of a solution focused on at least one area of the IoT technology stacks layers. Companies can offer more than one technology. This list represents a best effort to capture the entire landscape; however, it does not claim to be exhaustive, as some start-ups will have inevitably been missed

Source: IoT Analytics Research 2021, IoT Startups Report and Database 2021



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What do we learn in this course ?

Course Outline

Module 1 :

1. IoT Fundamentals - Architecture, Elements of IoT – Sensors, Actuators, Processing Elements, Communication modules, cloud based infrastructure
2. IoT Enabling Technologies and APIs
3. IoT Design Principles (Hands-on sessions using different IoT Platforms)

Module 2 :

1. Communications used in IoT – Device-Device, Device – Gateway, Device – Cloud, Back-end sharing model
2. IoT Communication Protocols –
Link Layer : Ethernet (802.3), Wifi(802.11), Wimax(802.16), LR-PAN(802.15.4), 2G/3G/4G
Network Layer : IPv4, IPv6, 6LoWPAN
Transport : TCP, UDP
Application : HTTP, CoAP, MQTT, XMPP
3. Tutorial sessions on different application layer protocols – MQTT, CoAP



What do we learn in this course ?

Course Outline

Module 3 :

1. Distributed Computing , Virtualization, Cloud Computing – Basic Idea, Service models – Infrastructure as a Service (I-a-a-S), Platform-as-a Service (P-a-a-S), Application/Software as a Service (S-a-a-S), Software Components, APIs, Role of Cloud in IoT
2. Software Defined Networking (SDN)
3. Social Internet of Things (SIoT) – Lysis Platform
4. Hands on session on different cloud platforms for IoT – ThinkSpeak, Google Cloud

Module 4:

1. IoT Application Development – Solution Framework for Implementation of Data Acquisition, Device Integration and Data Storage
2. Data Analytics for IoT – Summary of different Machine learning and Deep Learning models,
3. Apache Hadoop, Map-Reduce, Apache Spark
4. Tutorial sessions on Hadoop and Map-Reduce



What do we learn in this course ?

Course Outline

Module 5 :

1. Fault Tolerant in IoT based Systems
2. IoT Security
3. Challenges in Design of IoT Based Systems
4. Research problems related to IoT

Resources :

1. Pethuru Raj and Anupama C. Raman (CRC Press) , The Internet of Things : Enabling Technologies, Platforms and Use Cases
2. Arshdeep Bagha and Vijay Madisetti Internet of Things : A Hands-on Approach
3. IEEE Internet of Things Journal
4. IEEE Transactions on Mobile Computing

Web : <http://profile.iiita.ac.in/bibhas.ghoshal>



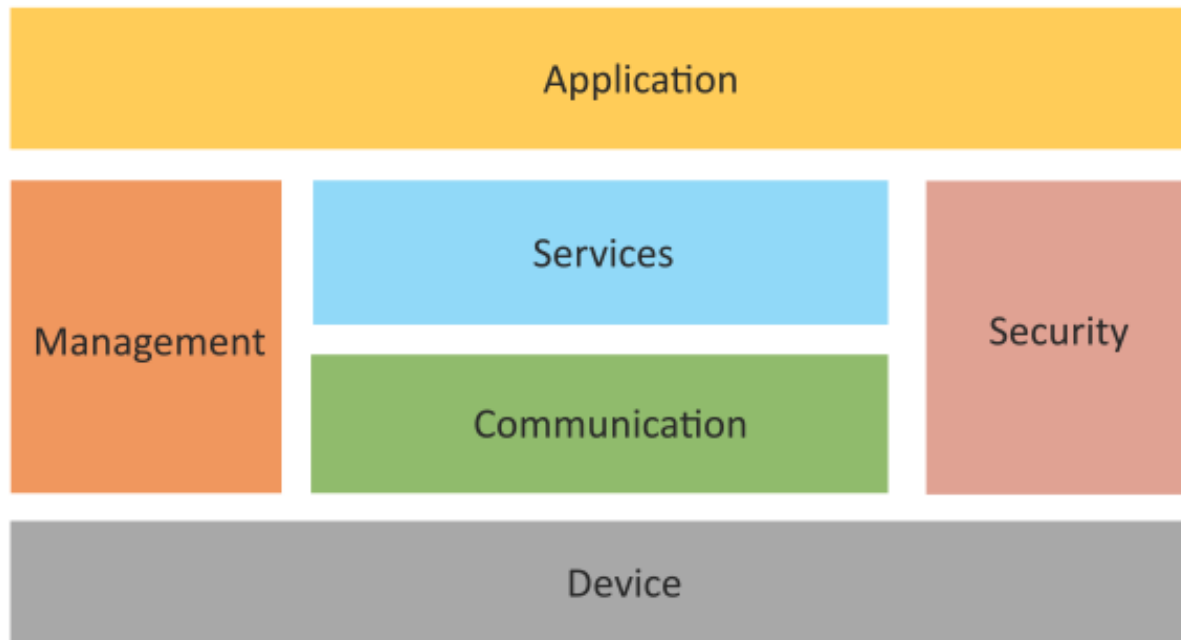
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Module 1 : Design of IoT Based Systems

Logical design of an IoT system refers to an abstract representation of the entities and processes without going into the low-level specifics of the implementation.

An IoT system comprises a number of functional blocks that provide the system the capabilities for identification, sensing, actuation, communication and management.



Logical Design of IoT

Source: Book website: <http://www.internet-of-things-book.com>



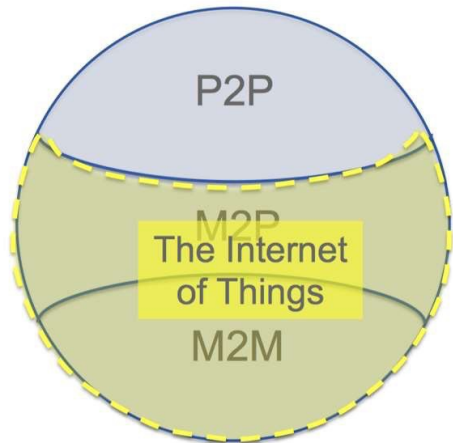
Devices

Device is a piece of equipment with the capabilities of communication and optional capabilities of sensing, actuation, data capture, data storage and data processing. The devices collect various kinds of information and provide it to the information and communication networks for further processing.

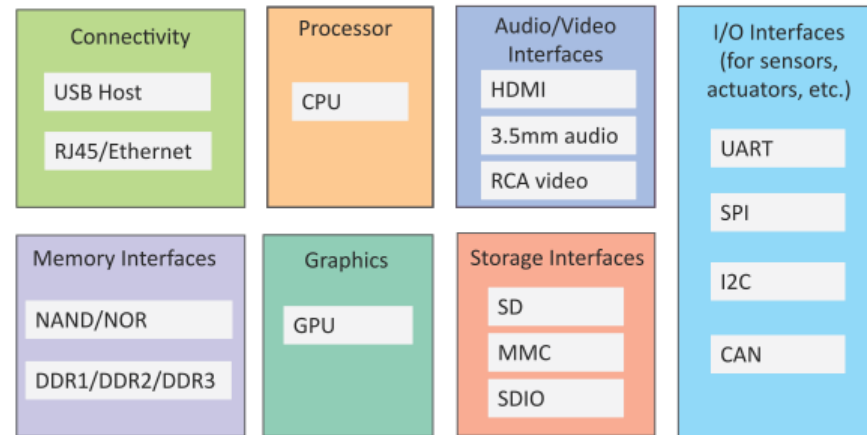
Some devices also execute operations based on information received from the information and communication networks.

An IoT device may consist of several interfaces for connections to other devices, both wired and wireless. I/O interfaces for sensors,

Interfaces for internet connectivity, Memory and storage interfaces, Audio/video interfaces



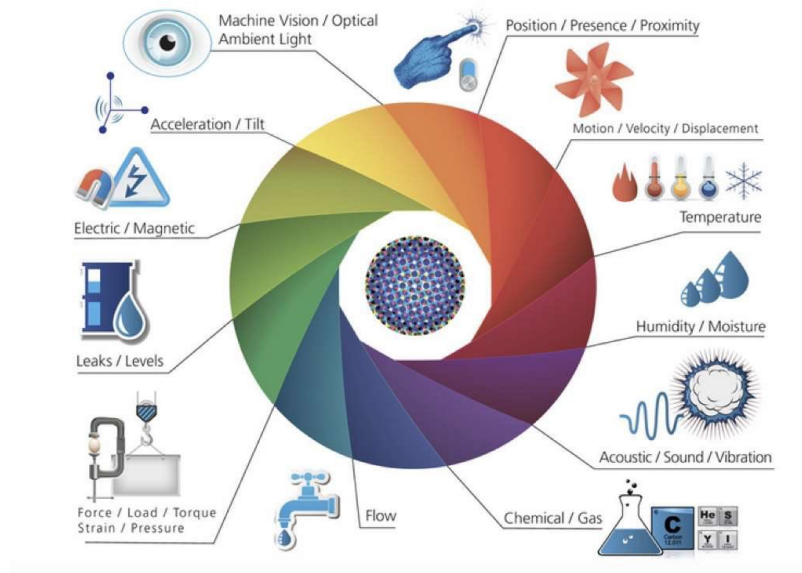
Source: ITU-T Y.2060



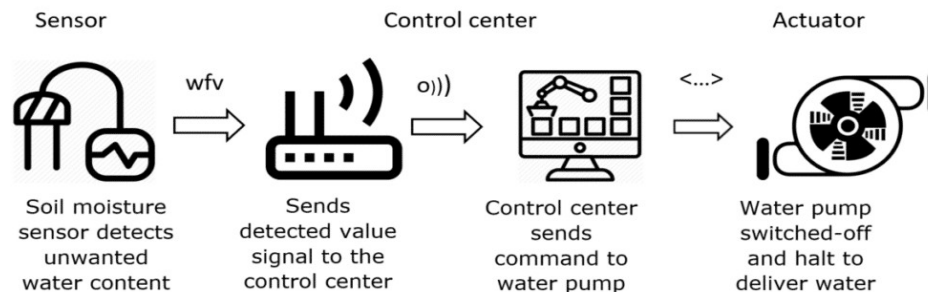
Source: Book website: <http://www.internet-of-things-book.com>

Enabling Technologies Sensors and Actuators (Usage and Calibration)

Sensors



Actuators



Source: Internet

IoT Based Soil Watering System utilizing Sensors and Actuator



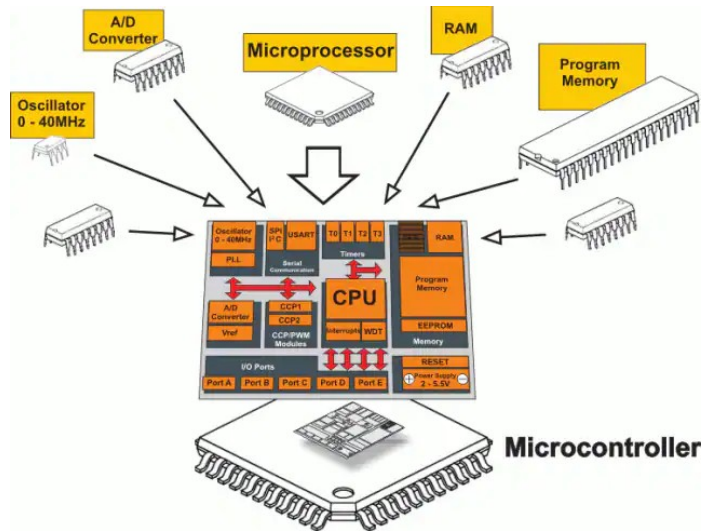
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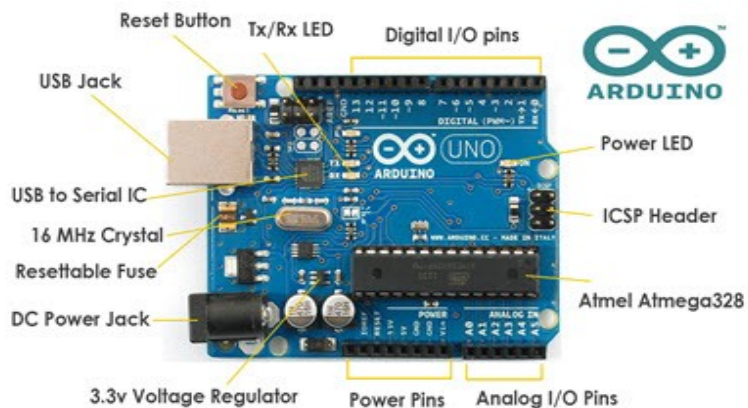
Enabling Technologies

Microcontrollers

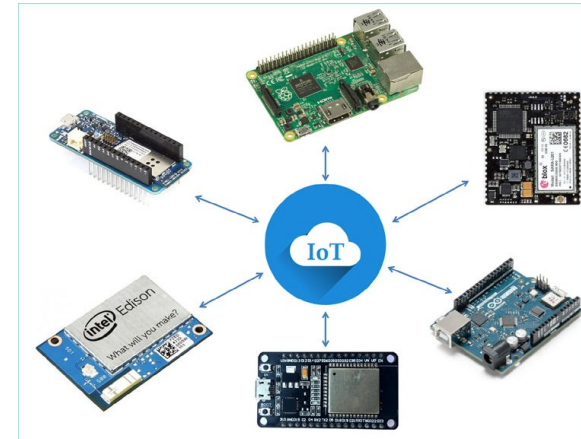
Microcontroller



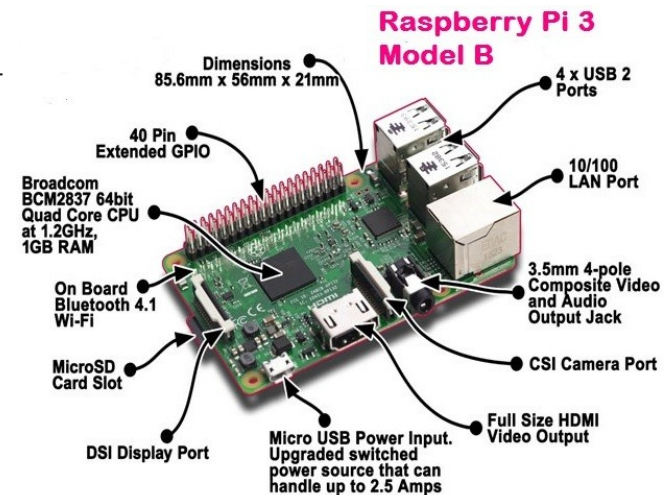
Arduino Uno



IoT Hardware Platforms



Raspberry Pi



Source: Internet



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Module 2 : Connectivity Technologies in IoT

Key aspects when considering network connectivity:

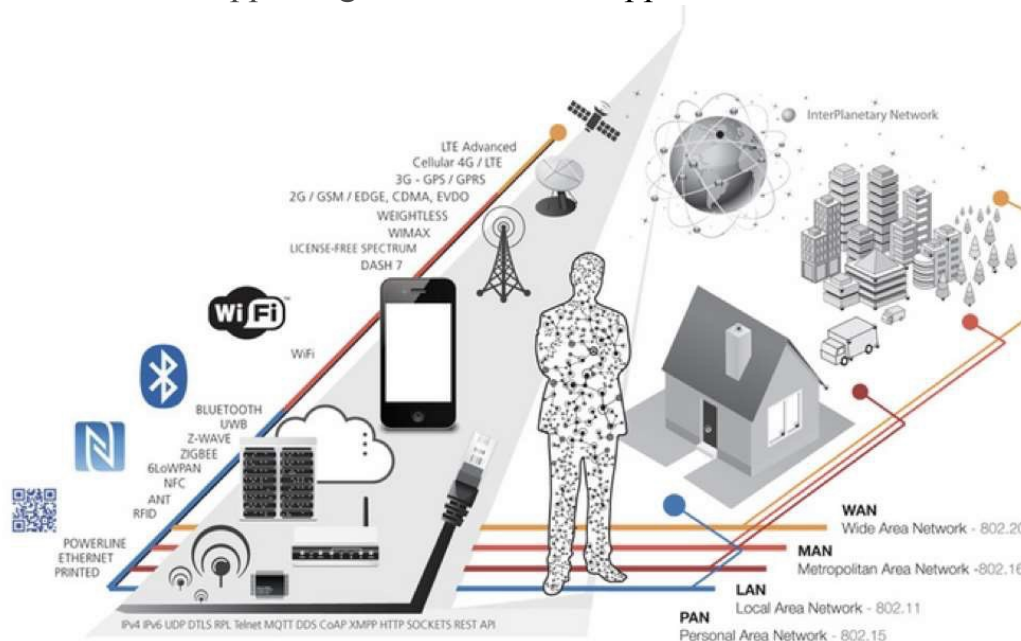
Range - are you deploying to a single office floor or an entire city?

Data Rate - how much bandwidth do you require? How often does your data change?

Power - is your sensor running on mains or battery?

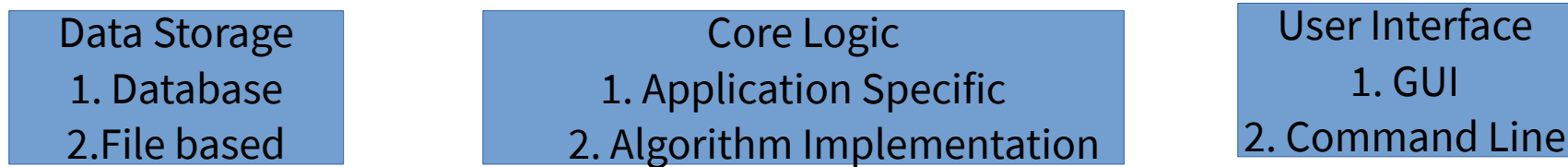
Frequency - have you considered channel blocking and signal interference?

Security - will your sensors be supporting mission critical applications?



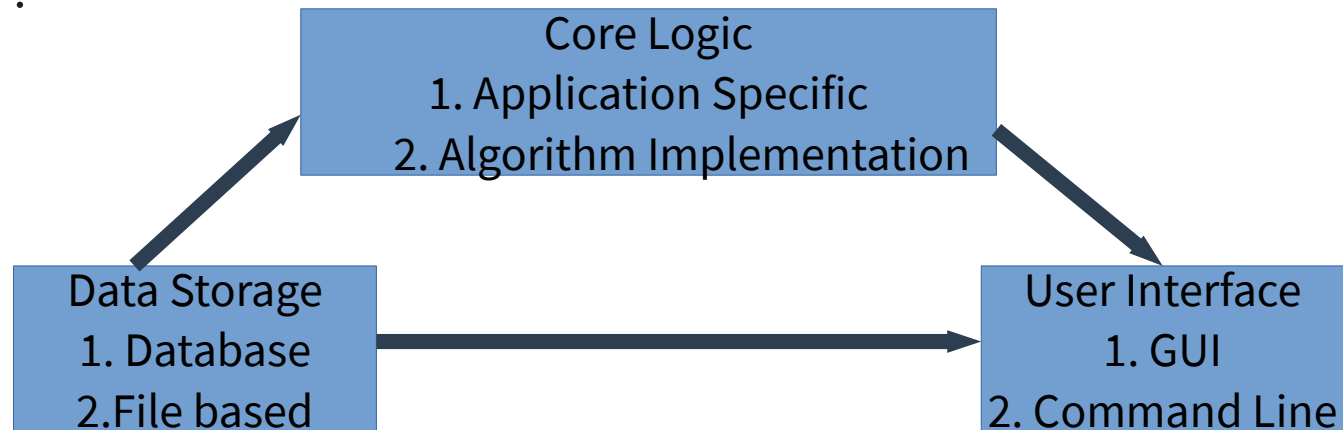
Module 3 : Distributed and Cloud Computing

Traditional Computing Components:



All Components sit on the same computer

Distributed Computing :

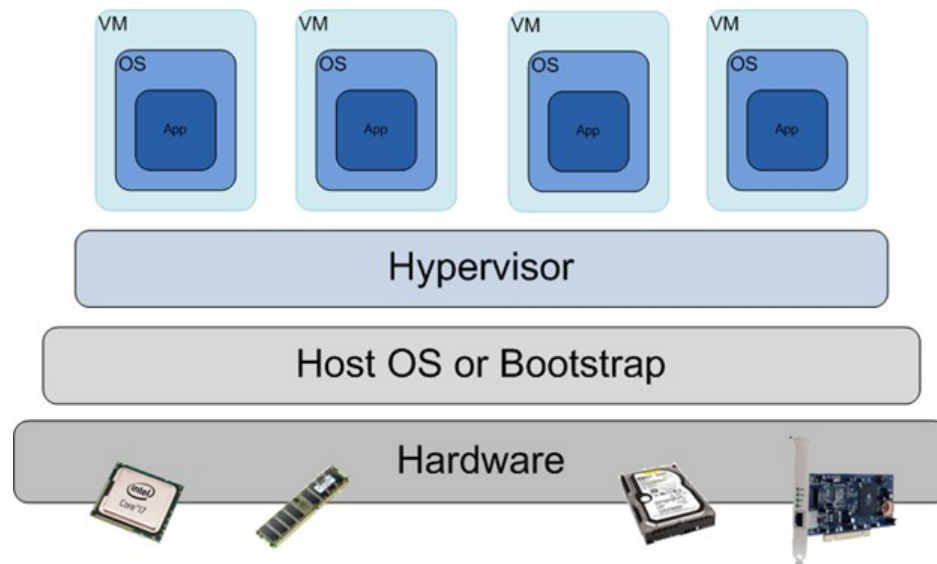
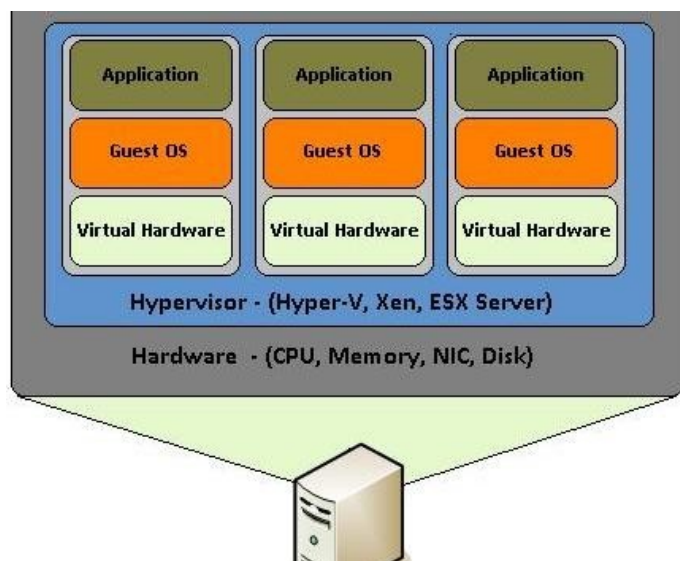


Cloud Computing = Innovative Application of Distributed Computing



Cloud Computing : Virtualization

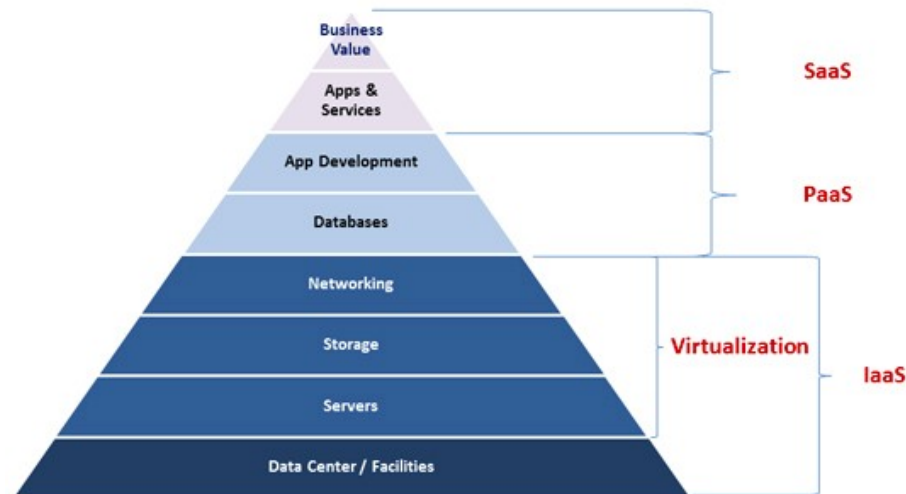
- Consists of self contained components



- Types of Virtualization : Desktop, Application, Network, Storage

Cloud Computing Service Model

- Delivers components as Services
- Pay-per-use model such as electricity, mobile network
- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)



Cloud Computing for IoT

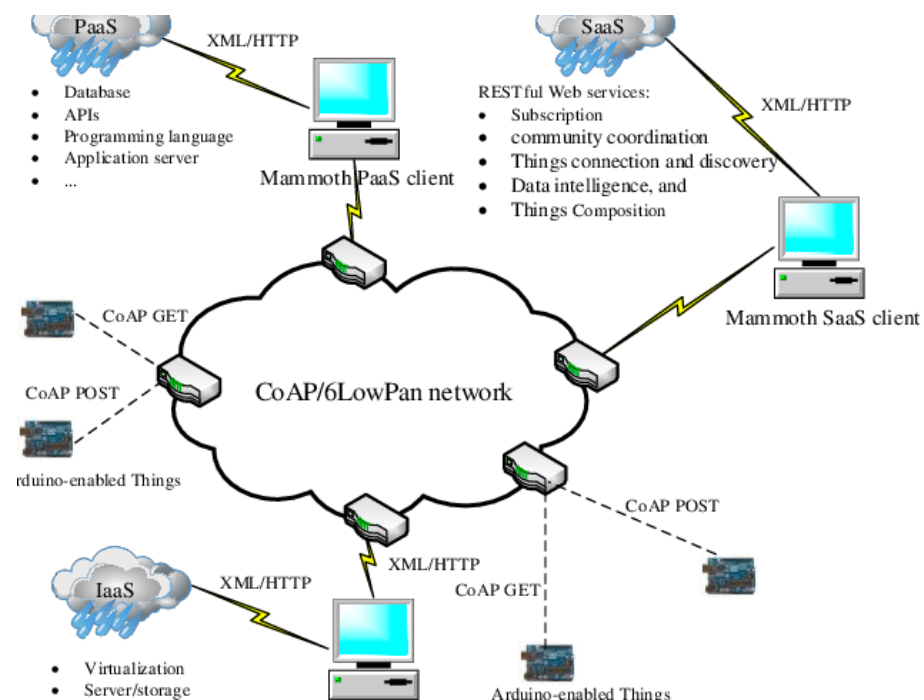
Cloud is an IoT enabler :

Huge amount of IoT Data needs storage, retrieval and management (sustained services)

Fast Analytics for Prediction and Critical Decision making

Benefits of Cloud in IoT :

Scalability ; Data Mobility; Time to Market; Security; Cost effectiveness



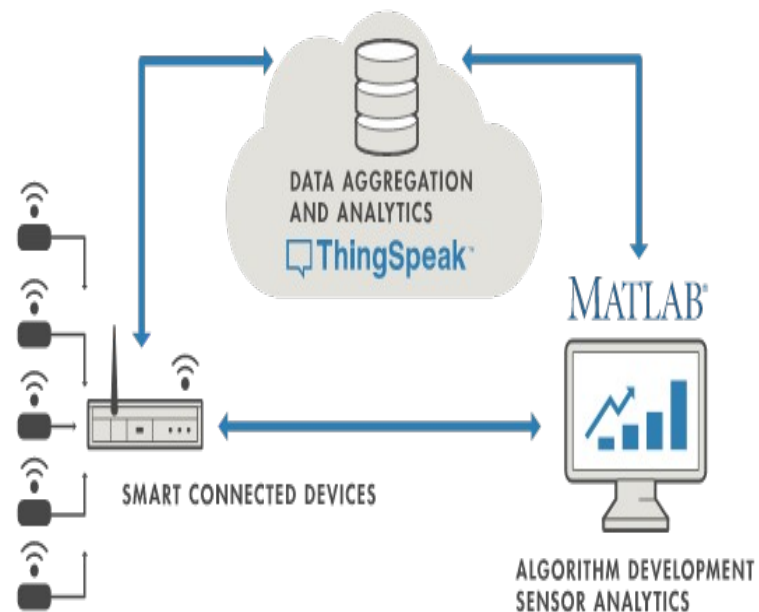
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IoT Platform Implementation

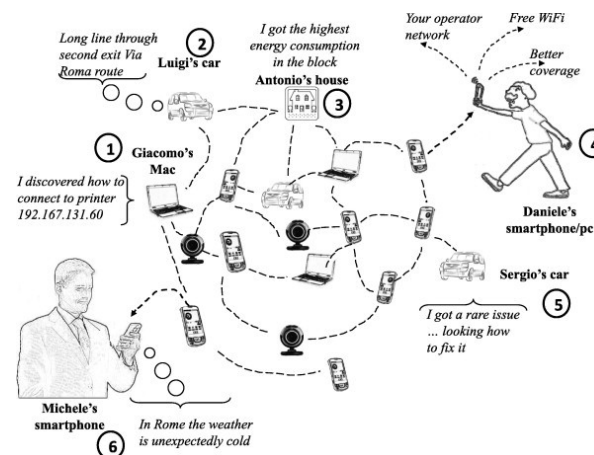
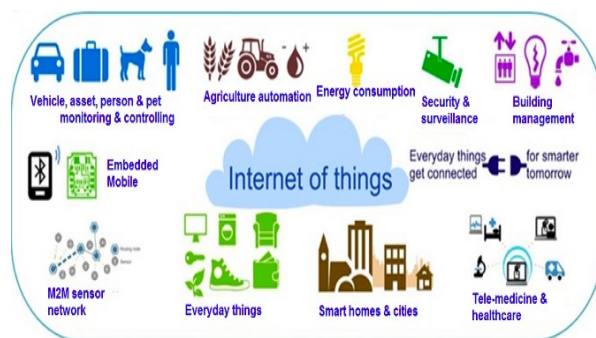


Source : <http://www.xively.com>



Source : www.thingspeak.com

Social Internet of Things (SIoT)



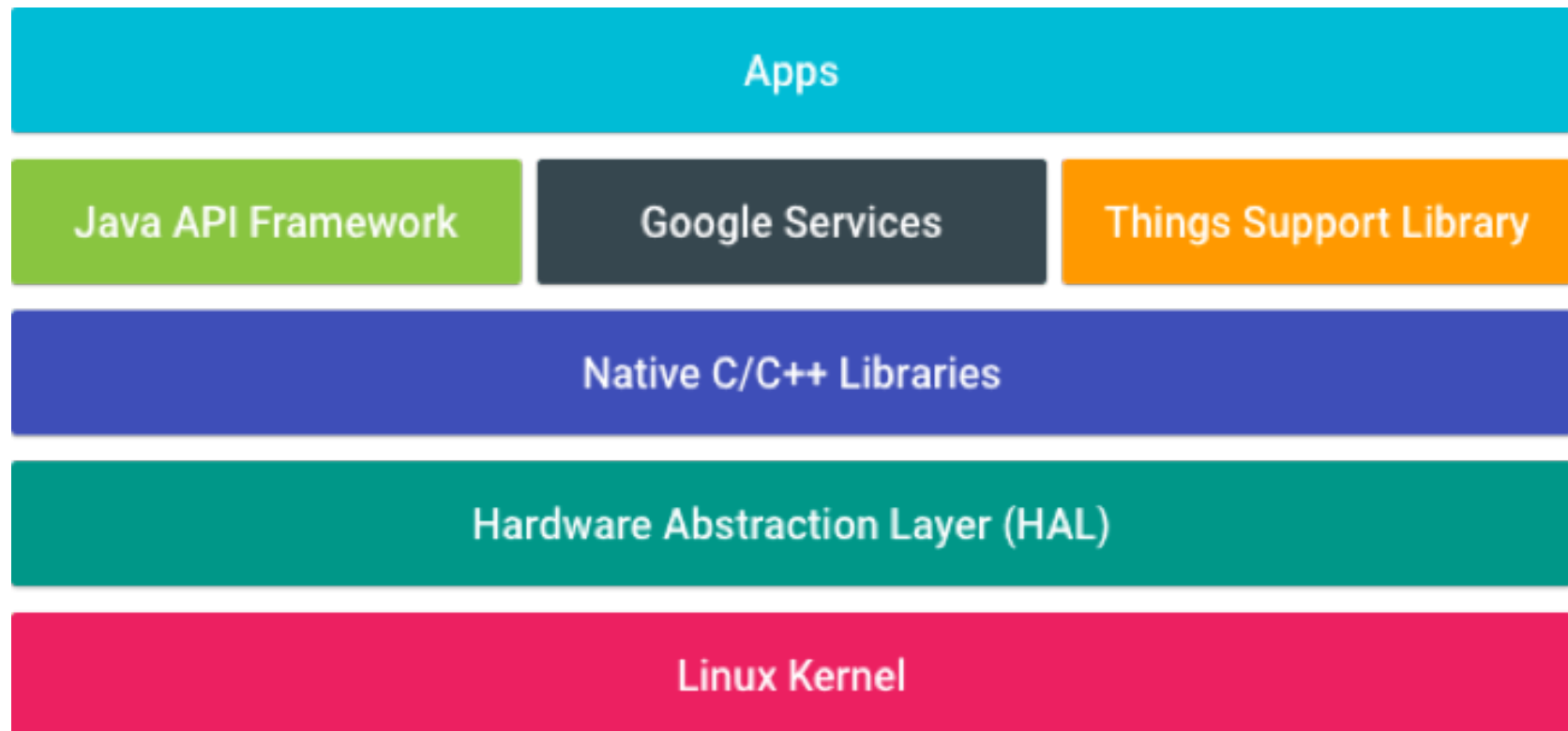
Social Networks + Intelligent Objects = Social Relation of Objects

- Example 1 : A set of mobile phones in a geographical area provide data on the radio coverage to the new visitor.
- Example 2 : PCs in the same local area establish relationship to solve common setting problem such as installing drivers
- Example 3 : Cars of the same brand, make, year share data to overcome a common electrical problem

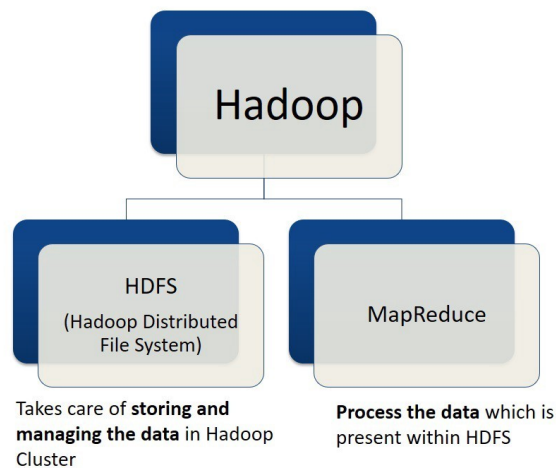
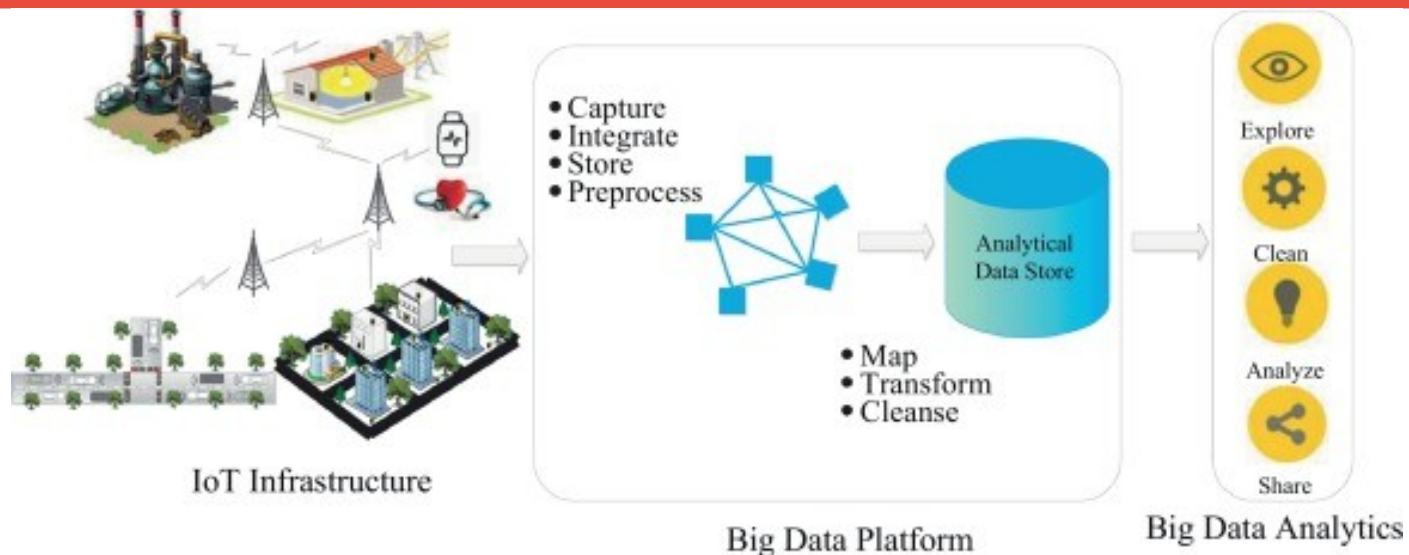


Module 4 : IoT Application Development

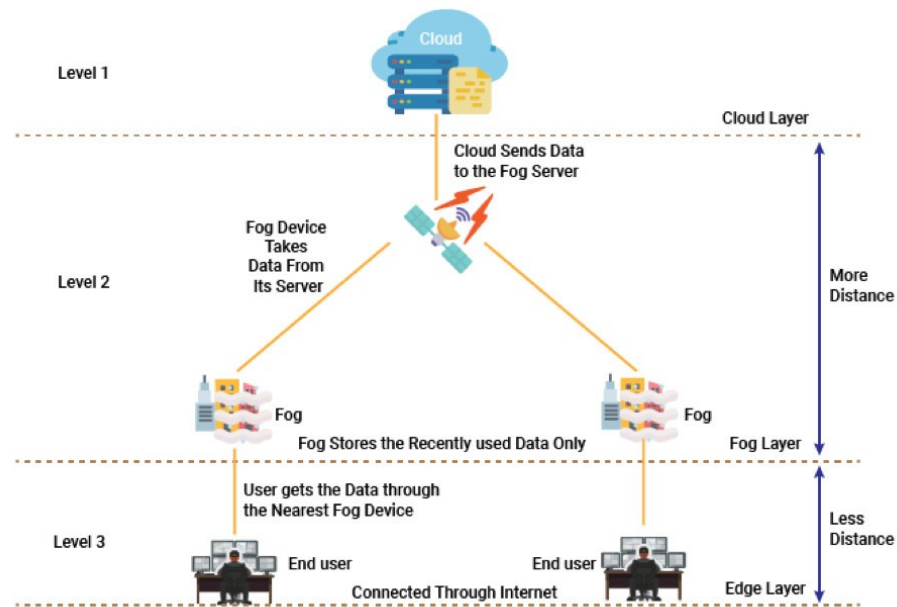
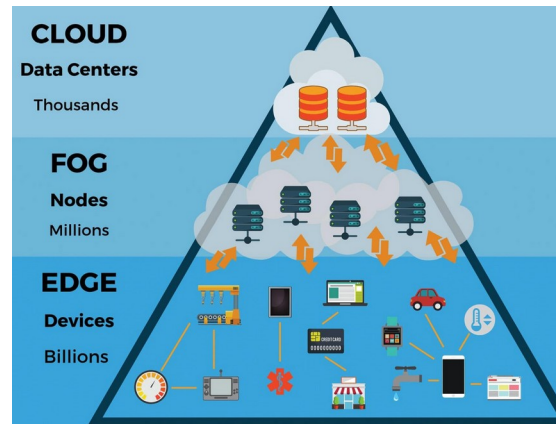
Software Stack for IoT Architecture: Software stack for devices, gateway and cloud



Module 5 : Data Analytics for IoT



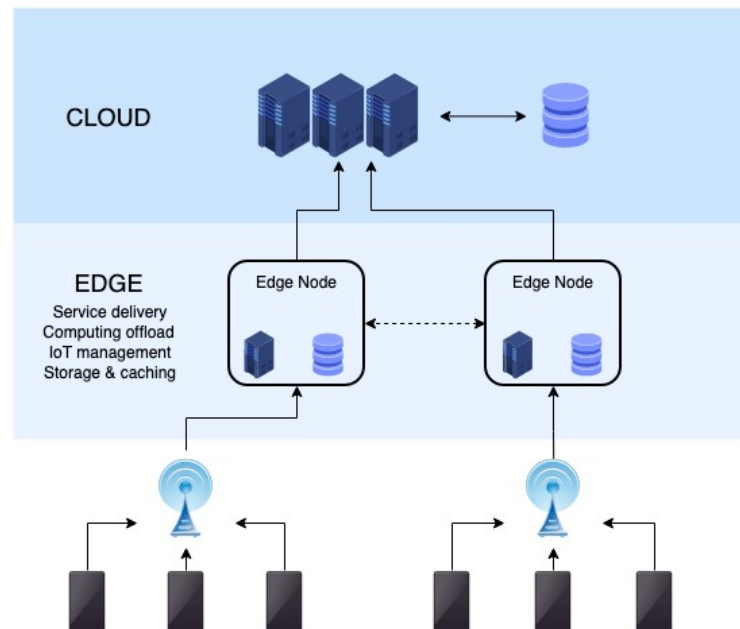
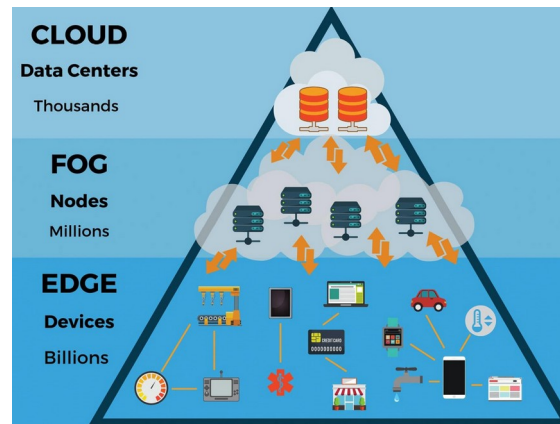
Module 5 : Advanced Topics



1. Fog Computing



Module 5 : Advanced Topics



2. Edge Computing



Module 5 : Advanced Topics

3. IoT Security

Security Principles :

a. User / Devices

Secure Devices (Hardware) – Device Intelligence, Edge processing

b. Gateway and Connection

Secure Communication - Device initiated connection, Messaging control

c. Cloud and Applications

Secure Cloud – Identification, Authentication and Encryption

d. Secure Lifecycle Management


Remote control and updates of devices



Register yourself on Google Classroom

For any queries : bibhas.ghoshal@iiita.ac.in


Web : profile.iiita.ac.in/bibhas.ghoshal











Systems Lab
IIIT Allahabad

SYSTEMS LAB

A Complex yet indispensable lab



<p>Architecture & High Performance Computing</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Current research: Machine Learning based Fault-Tolerant and secured Network-on-Chip Design</p> <p>We conduct research on all aspects of future processor technology including performance, power, multi-threading, chip- multiprocessing, security, programmability, reliability, interaction with compilers and software, interconnects and The impact of future technologies.</p> </div> </div>	<p>System Software & Optimizing Compiler</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Current research: Learning Based Power Aware compilation & Thermal Aware Scheduler for Embedded Systems</p> <p>With each new generation of devices, we expect higher performance, longer battery life, increased reliability, and greater security. These Expectations are met with the development of automatic tools that can analyse source code, optimize it for a particular platform, and catch errors and other programming flaws. These analyses and optimizations can be implemented as part of a compiler.</p> </div> </div>	<p>Embedded System & IoT</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Current research: Smart Street Lighting System (DIC Spoke Project - IIIT Allahabad)</p> <p>We build practical systems with focus on performance, low power dissipation, security, robustness, or often just for fun - Do-It-Yourself projects using Arduino & Raspberry Pi hardware. Our research projects aim not only for good publications but to come up with real programs impacting day to day software such as Firefox and Android.</p> </div> </div>	
<p>Distributed & Data Intensive Systems</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Current Research: Load Balanced Peer-to-Peer Network</p> <p>We research on topics related to distributed data intensive systems with strong emphasis on reliability, security, efficiency, and data management issues such as data mining and data analysis. We plan to work on projects including networked embedded sensors, P2Pvideo streaming, middleware for large-scale stream processing, opportunistic networking, virtualization technologies.</p> </div> </div>	<p>Security & Fault Tolerance</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Current Research: Exploring Row hammer attacks on Embedded Systems; Self Healing Embedded Systems</p> <p>Computer security deals with techniques to keep computers secure from attacks. Our research addresses fault tolerance and computer security concerns at various components of the computer system, such as at the processor micro-architecture level, memory system Architectural level, and at system software level.</p> </div> </div>	<p>VLSI Design & Testing</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Current research : Efficient Test Pattern Generation for Low Power Dissipation During test</p> <p>We at the Systems lab equipped with state-of-art tools from leading EDA (Electronic Design Automation) companies research on improvement of design quality and reduction of design and test time of VLSI circuits.</p> </div> </div>	
<div style="text-align: center;">  <p>IMPRINT INDIA</p> </div>	<p>Sponsored Project</p> <p>POWER AWARE COMPILER FOR EMBEDDED PROCESSOR (SPONSORED BY :MHRD ,Govt. of India) Under : IMPRINT INDIA Program PI: Dr. Bibhas Ghoshal</p>	<p>Team Members</p> <p>Faculty: Dr. Bibhas Ghoshal, Dr. Jagpreet Singh Research Scholar: Rakesh Kumar, Akash Sachan, Ankur Gogoi, Pravin Srivastva, Anandpreet Kaur, Akash Kumar</p>	<p>COLLABORATION</p> <div style="display: flex; align-items: center;">  </div> <p>Prof. I . SENGUPTA (IIT Kharagpur) Prof. J. JOSE (IIT Guwahati) Prof. Y.N. Srikant (IISc Bangalore)</p>



Internet of Things
Instructor : Dr. Bibhas Ghoshal

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