Welcoming and Course Introduction

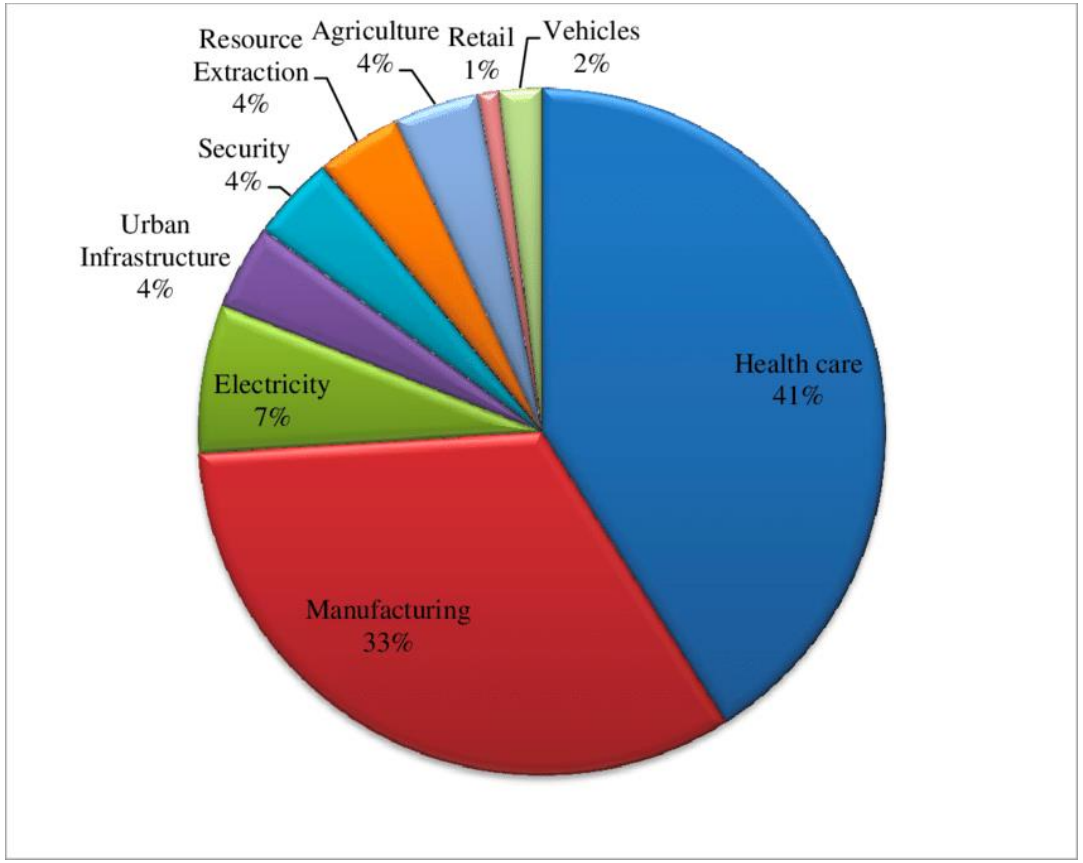
Motivation

Indian IoT market is expected to reach US$9.28 billion by 2025

IoT solution deployment for manufacturing industries, including

- automotive,
- energy and utilities,
- smart cities (government),
- retail, and
- other industries such as logistics,

Drive investments for enterprise IoT products and services



Projected market share of dominant IoT applications by 2025.

Image sources: https://futureiot.tech/wp-content/uploads/2022/01/Frost-India-IoT-market-set-to-grow-to-US9.28-billion-in-2025-resized.jpg
https://www.researchgate.net/publication/301887107/figure/fig42/AS:630058028892171@1527228948844/Projected-market-share-of-dominant-IoT-applications-by-2025.png

Course Overview

Week 1: Introduction to IoT and IoT Devices Selection & Configuration

Week 2: IoT Communication Protocols and 5G Fundamentals

Week 3: Data Management in IoT and Industry-specific IoT Applications

Week 4: Capstone Project and Course Conclusion

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SANKALP
Ministry of Skill Development
& Entrepreneurship

Introduction to IoT

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Recommended Book

https://www.amazon.in/Internet-Things-Surya-Durbha/dp/0190121092/ref=cm_cr_arp_d_bdcrb_top?ie=UTF8

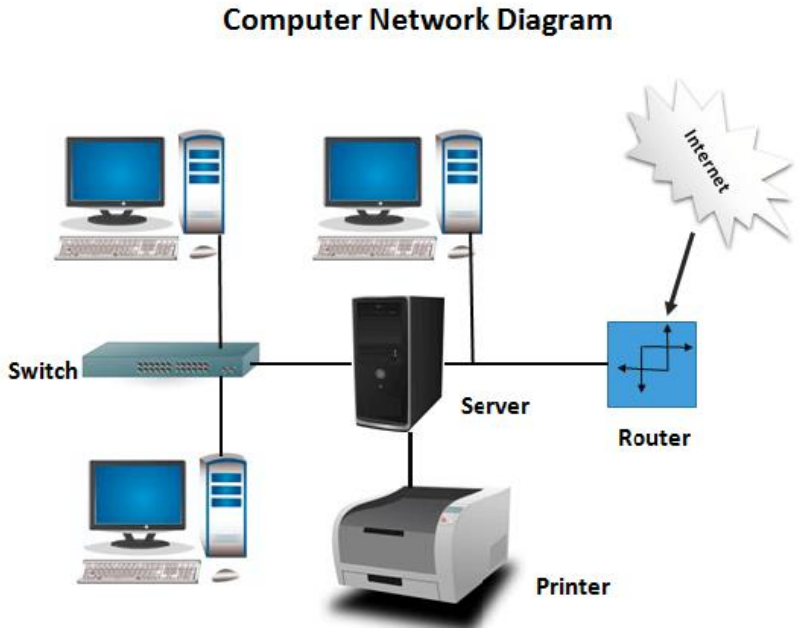
OBJECTIVES

- Basics of Internet and Networks
- Define IoT and Its Evolution
- Overview of the IoT Ecosystem and Key Components
- IoT Technology Stack
- Icebreaker Activity - IoT Conceptual Understanding (with real-time use cases)

Basics of Internet and Networks

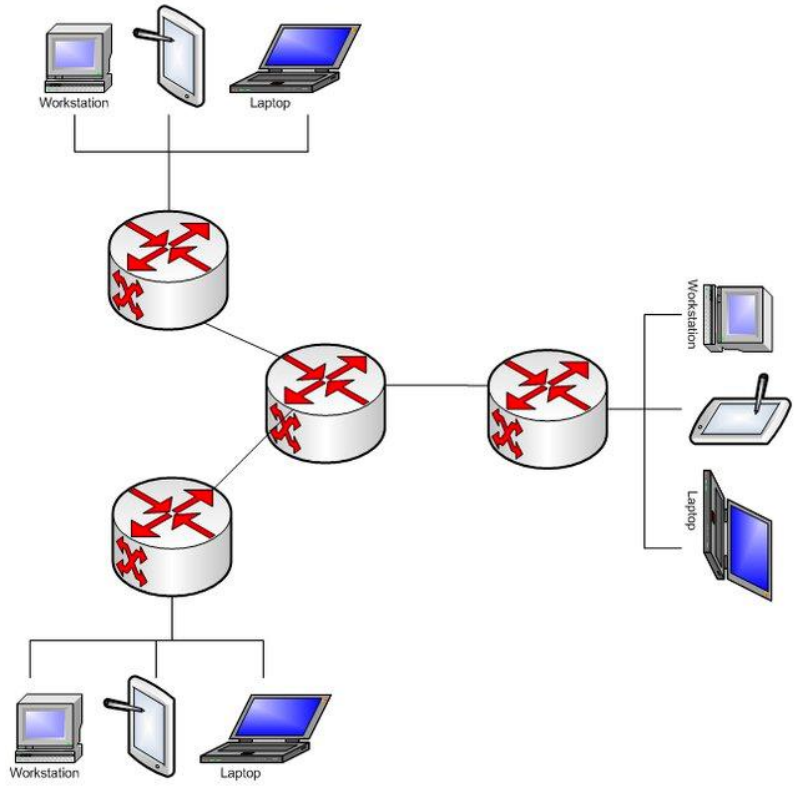
Network

- Network is two or more connected computers
- They can share resource like a printer, an internet connection, application, etc.
- It is a collection of computer systems and devices which are linked together using a wireless network or via communication devices and transmission media.



Internet

- Internet (**Interconnected Network**) is a worldwide telecommunications system that provides connectivity for millions of other, smaller networks;
- Internet is often referred to as a **network of networks**.
- It allows computer users to communicate with each other across **distance** and computer platforms.



Internet: Network of Networks

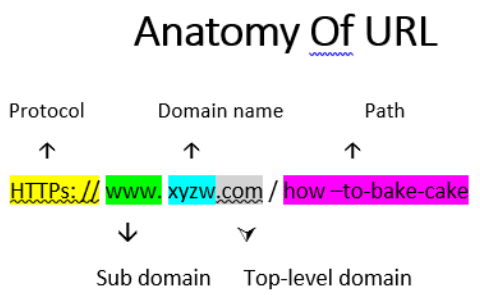
Internet Terminology

WWW: World Wide Web. This is what we call the web. It is a collection of information, data, videos, pictures, multimedia etc on the internet. It is all linked together through the world wide web.

URL: It stands for Universal Resource Locator. This is the link that connects the user to the remote locator on the world wide web. It is basically a link to a website, which opens when you click on the URL.

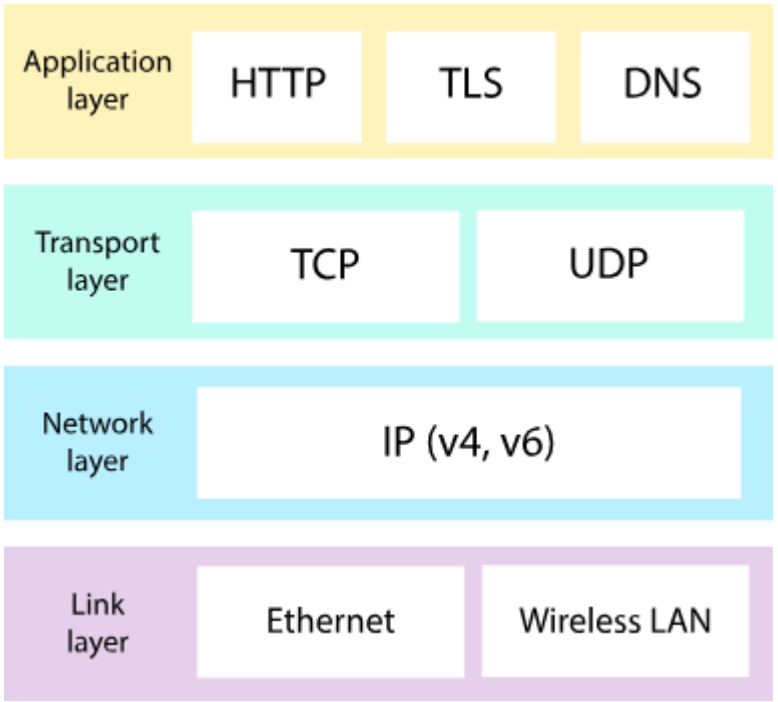
Host: Any computer or device that is used to transfer the data

IP Address: IP Address is a unique code for each computer or device that connects to the internet. It is four numbers between 0 and 255 separated by a dot. Example 21.177.07.59



Internet Protocols

- The internet is a **massive networking infrastructure**.
- There are rules that **regulate** such a network.
- Internet protocols are a set of regulations and protocols that define and govern the format of the data that is sent via the internet.
- It is the method by which the data is sent over from one host to another.

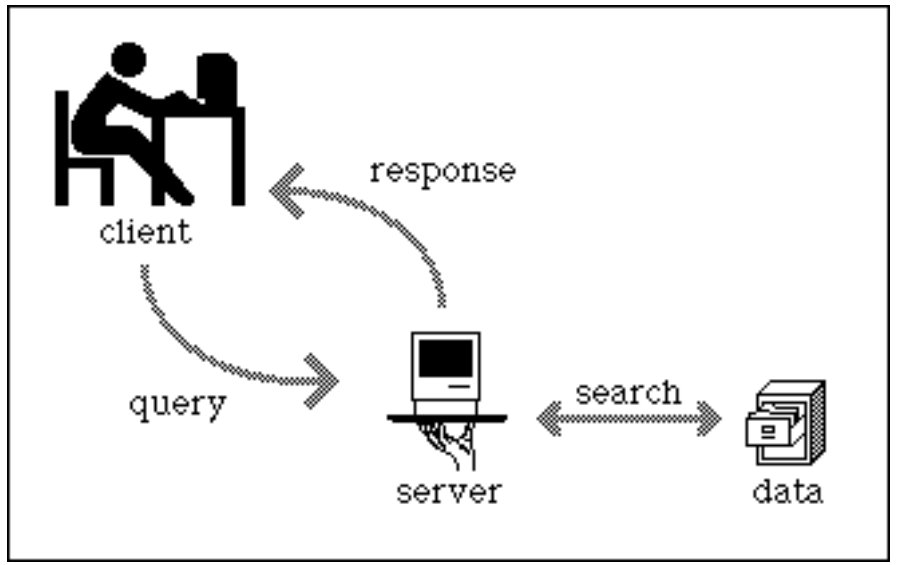


Terminology

TCP: Transmission Control Protocol. This is the protocol for communicating over a network. The data is broken down into smaller packets, identifiable by their IP address.

FTP: File Transfer Protocol. Used for transferring files over the internet. This includes text and multimedia files as well. It is faster than the other methods.

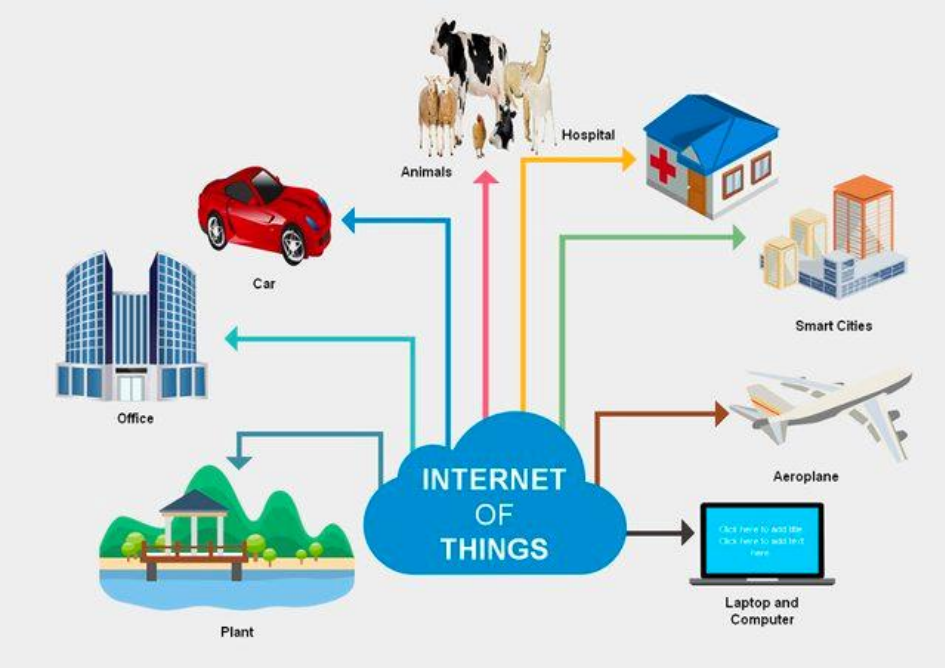
HTTP: Hypertext Transfer Protocol. It follows the client and server model. It facilitates the connection between web client and web server.



Definition of IoT and Its Evolution

BACKGROUND AND VISION

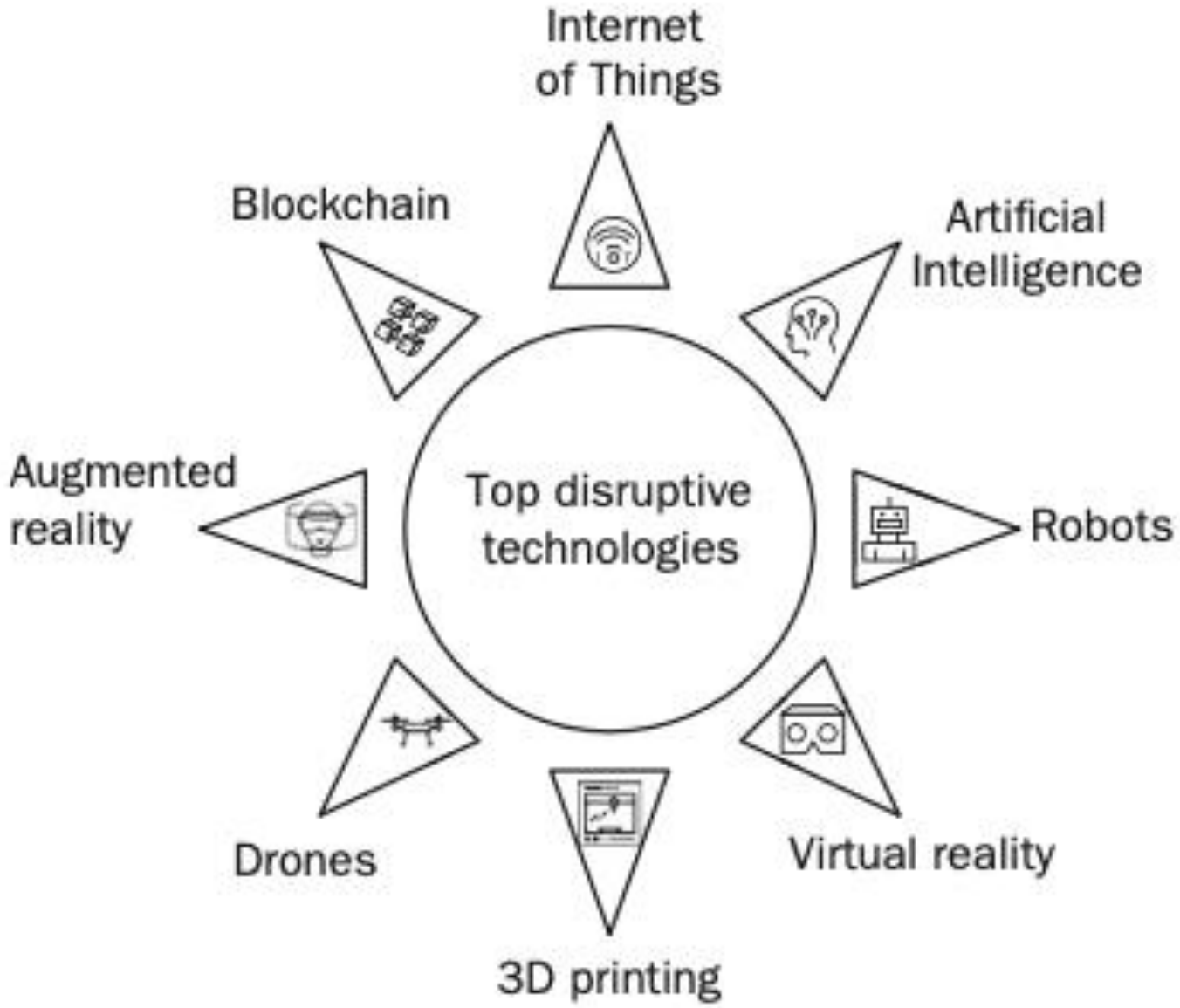
- Internet has dramatically changed the way we conduct our daily life
- De facto way of communication.
  - Spread deeply in our society
  - routine activities are now driven by technology and are highly dependent on the Internet
- IoT has revolutionized many domains and brought in many new applications to the forefront
- Last decade has seen an accelerated synthesis of research in several path-breaking technologies,
  - Areas of semiconductors, networking, and information processing.
- significant drop in the prices of sensors, transmitters, processors, and computing infrastructure.
- Revolutionized both the information and communication technologies (ICT) and non-ICT areas.



IoT AS A DISRUPTIVE TECHNOLOGY

- A disruptive technology (a hardware, software, networking, etc.) has the potential to replace an existing technology or a well working system that is already in place.
- **Product perspective:** something that begins small and steadily moves up the market and eventually becomes a threatening competitor to the existing products, and may eventually replace them.

IOT AS A DISRUPTIVE TECHNOLOGY



Internet of Things (IoT) Along with Other Disruptive Technologies

Source: Internet of Things, Durbha et.al.

Number of Devices Connected to the Internet by 2023

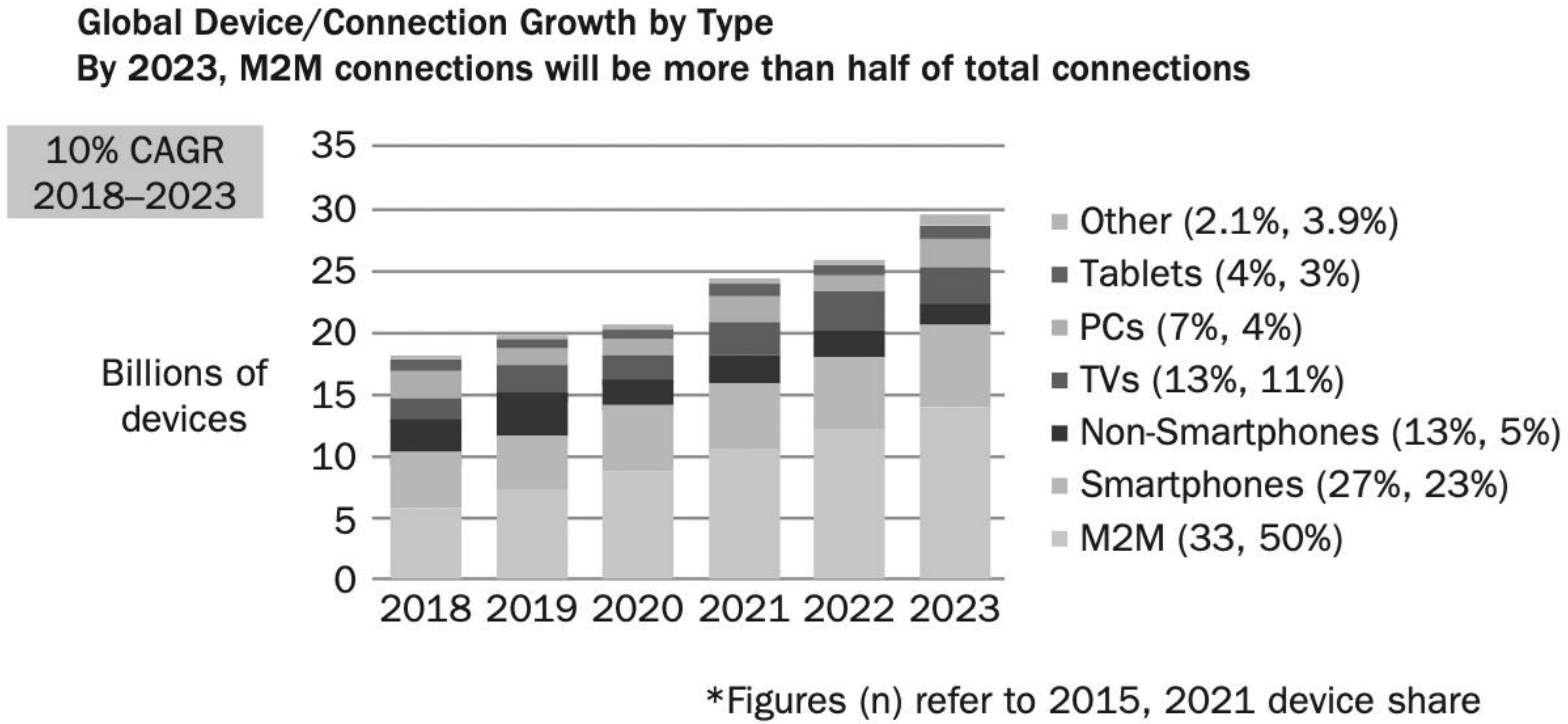


Fig. 1.1 Number of Devices Connected to the Internet by 2023; Half (51%) of Them are IoT Devices

(Source credit: Cisco)

Gartner, predicts that by 2020, there will be 20.8 billion IoT devices connected around the world, overtaking the number of personal computers and smartphones.

Another estimate by Cisco projects that nearly half of the devices connected to the Internet by 2023 are IoT devices

IoT definition

- The Internet of Things (IoT)
  - aims to make things (physical objects) smart using sensors/actuators and digitally identifiable over the Internet.
  - seamlessly accessed and controlled remotely.
- Things have the ability to
  - react in real time to the events in the environment that they exist
  - send information to humans as well as other things autonomously
  - enable them to contextually respond for decision-making.

Various Definitions of IoT

IEEE Definition

IEEE led an initiative in 2015 on developing a definition for IoT. In the special issue of IEEE on Internet of Things, IoT is defined as:

"A network of items, each embedded with sensors, which are connected to the internet."

ITU Definition

The international Telecom Union (ITU) defines IoT as:

"A global infrastructure for the information society, enabling advanced services by interconnecting

(physical and virtual) things based on, existing and evolving, interoperable information and communication technologies."

Various Definitions of IoT(Cont.)

IETF Definition

The Internet Engineering Task Force (IETF) is playing a crucial role in the development of several standards for IoT. They define IoT as:

"IoT will connect objects around us (electronic, electrical, non-electrical) to provide seamless communication and contextual services provided by them. Development of RFID tags, sensors, actuators, mobile phones make it possible to materialize IoT which interact and cooperate each other to make the service better and accessible anytime, from anywhere."

Working Definition

Based on the aforementioned definitions, it is useful to have a working definition whose spirit will be used as the foundation for the rest of the topics

IoT = Sensing + Communication + Computation + Web Application

“Making things (objects) to sense the environment in which they exist, communicate, access, actuate, and process data autonomously with other things in a network, and also with humans via web applications.”

Evolution of IoT Technology

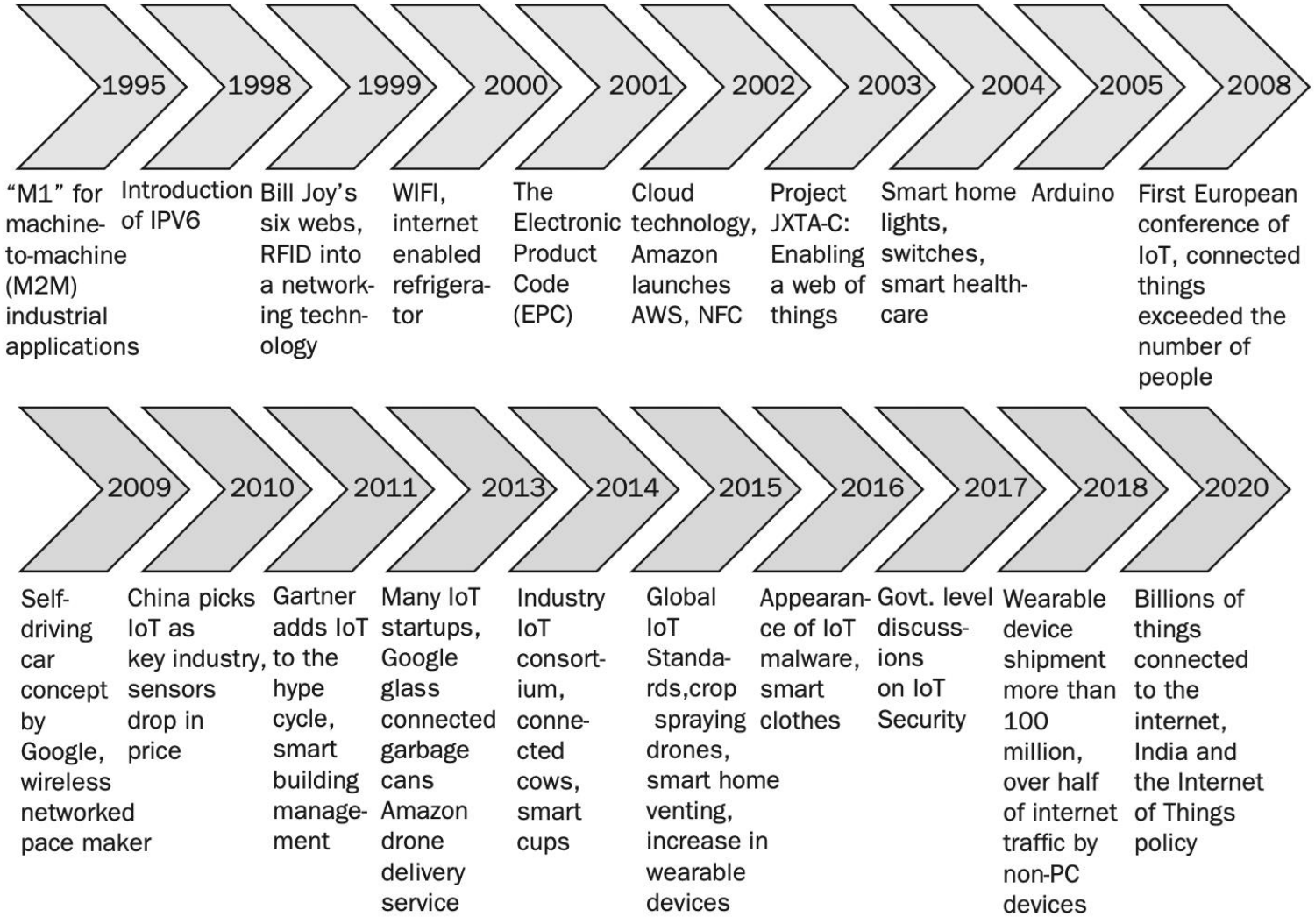
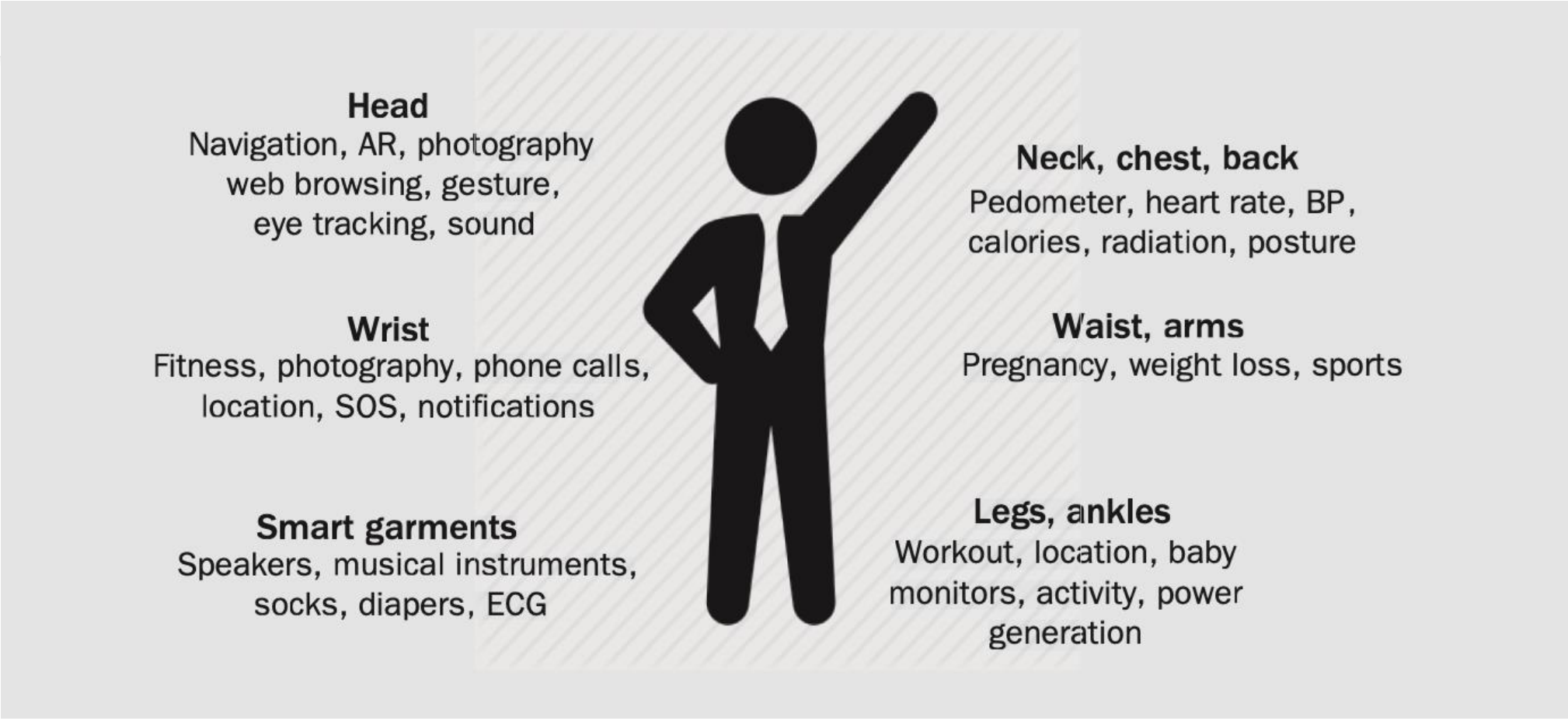


Fig. 1.2 Timeline of IoT Technology Maturity

Source: [Internet of Things, Durbha et.al.]

Wearable Devices



Source: Internet of Things, Durbha et.al.

Vision of IoT

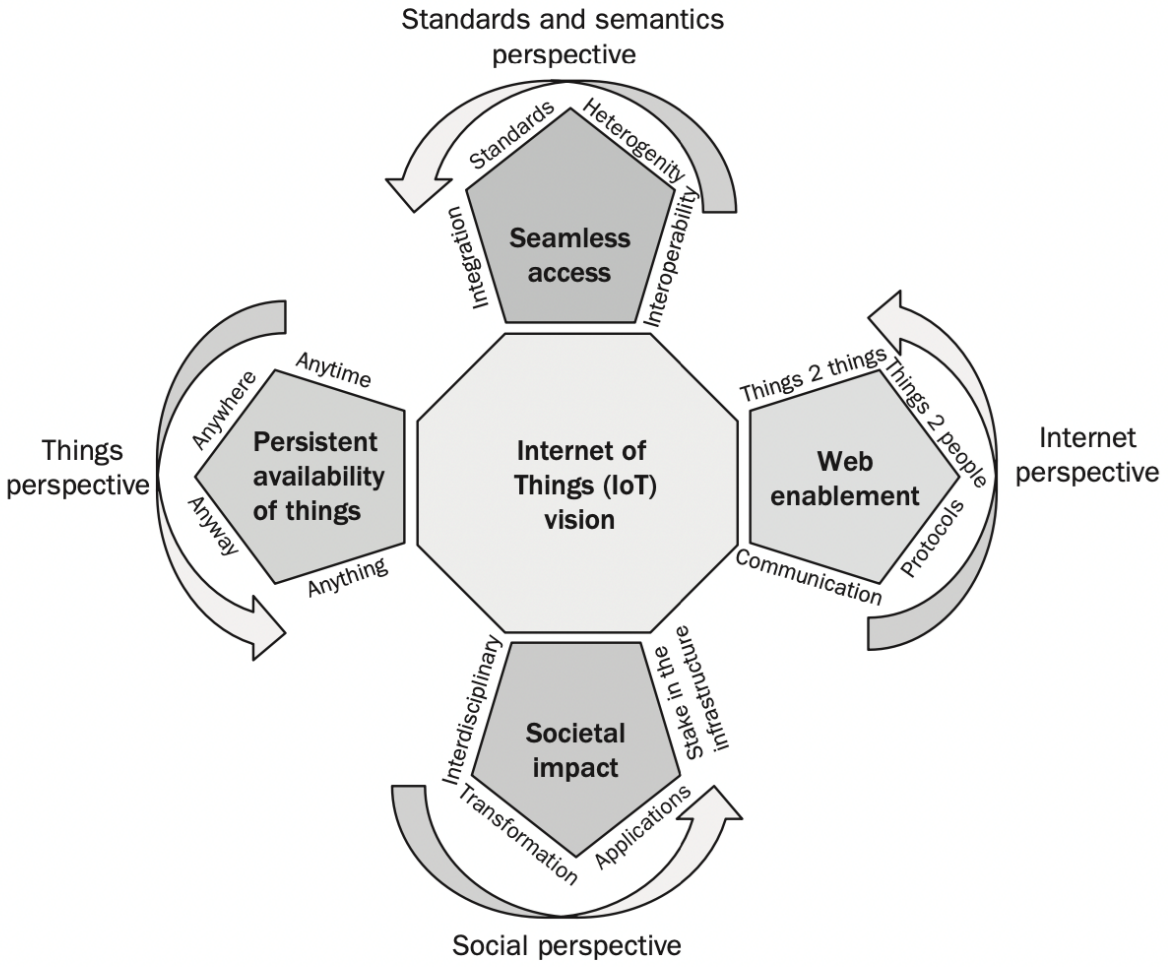


Fig. 1.4 The Vision of IoT from Four Different Perspectives

Source: [Internet of Things, Durbha et.al.]

Vision of IoT

Four major perspectives:

Things perspective:

- The persistent and reliable availability of anything that is of interest to the user
- connected in anyway using a variety of technologies.
- connected things should be available to be accessed at anytime and from any location.

Standards and semantics perspective

- Access of the things should be seamless,
  - well-defined standards are adhered to by the providers of these things as they are highly heterogeneous in nature.
- things should be interoperable,
    - ability to integrate data from heterogeneous IoT devices is a must,
    - standards are necessary in every component of the IoT architecture.

Vision of IoT (Contd.)

Internet perspective

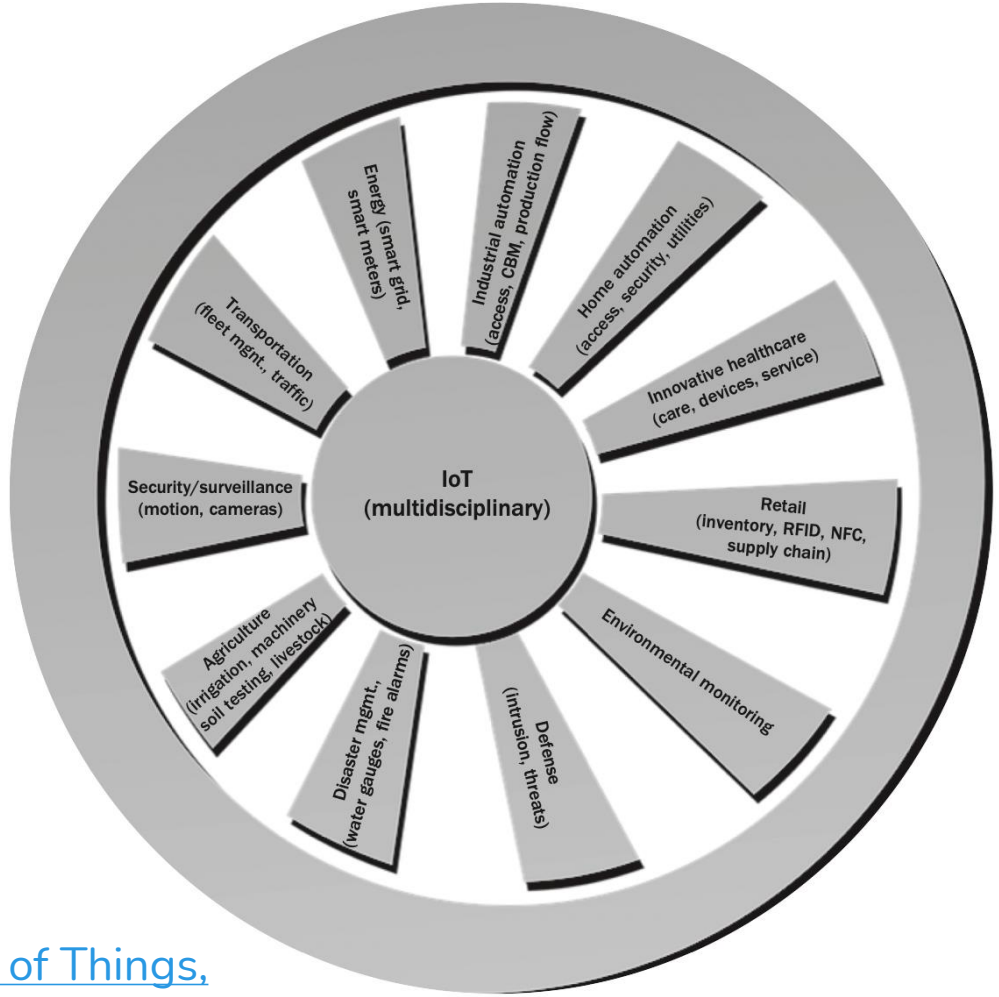
- Things are able to communicate with people and people with things (people 2 things, i.e., P2T),
- Among things themselves (things 2 things, i.e., T2T),
- Certain level of autonomous decision making is achieved.
- Web enablement or web addressability is one of the prime goals of IoT.

Vision of IoT (Contd.)

Social perspective

- The societal impact of the IoT is primarily driven by the acceptance of the users and their perceived value that it would bring to their lives.
- IoT infrastructure will be owned by the stakeholders in some form of democratic process, who will develop, maintain, and take in directions that are congenial for their growth
- The society will be benefited by a spectacular transformation of traditional services into IoT-based smart services that provides applications that are much easier to use and provides far-reaching benefits.
    - Several applications such as monitoring air pollution, improved water conservation, and increased production of food grains.

Multidisciplinary Nature of IoT



Source: Internet of Things, Durbha et.al.

multi-domain research and development teams are currently preferred in the development of IoT system.

Key Enabling Technologies

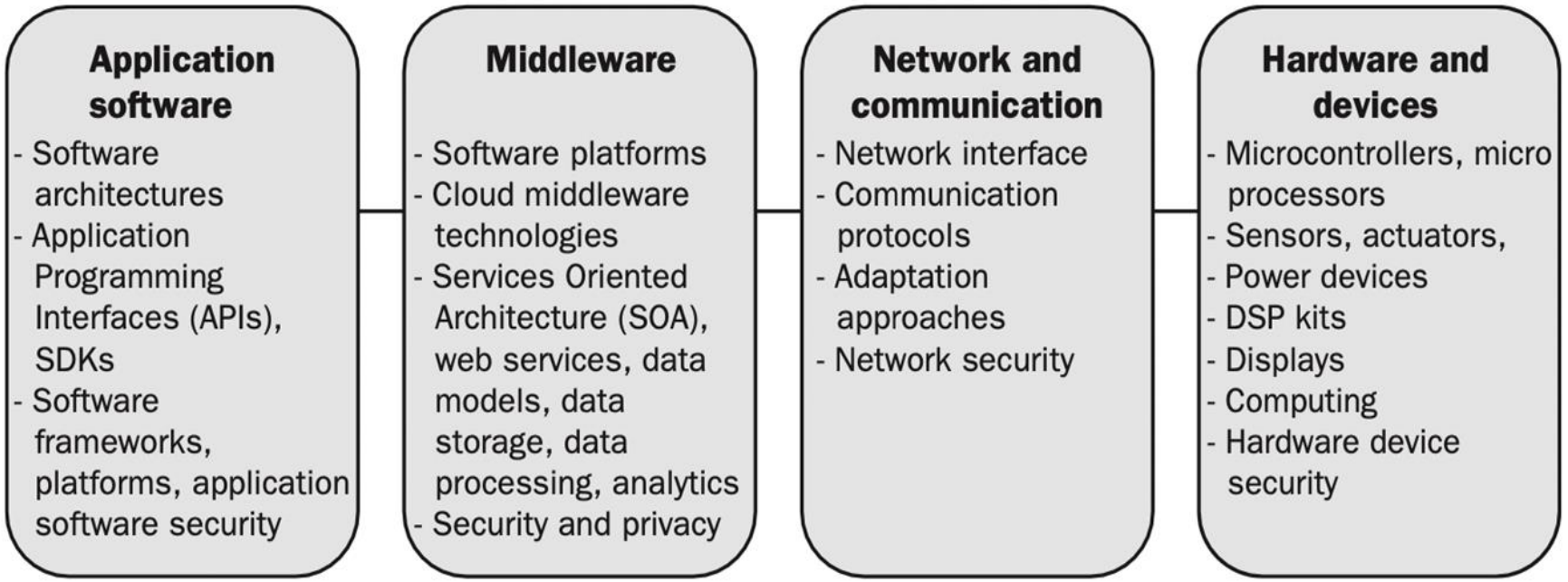
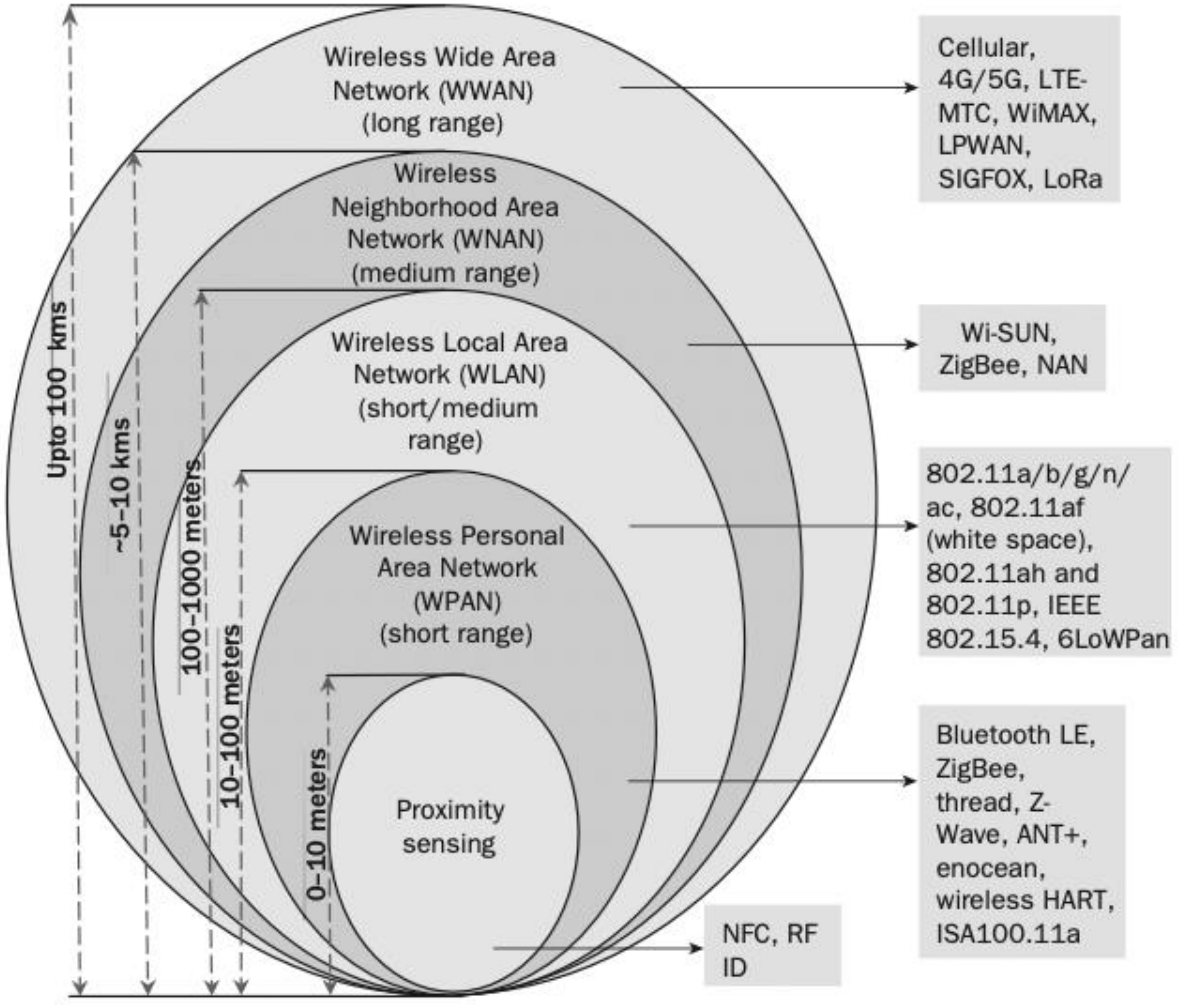


Fig. 1.5 Major Categories of Enabling Technologies for IoT

Source: Internet of Things, Durbha et.al.

The enabling technologies of IoT are distributed in several layers of the IoT systems. The technologies at each of these layers are specialized and serves some key purposes for the functioning of that layer.

Various Types of Short-, Medium-, and Long-range Connectivity in IoT



Source: Internet of Things, Durbha et.al.

Key Enabling Technologies (Contd.)

Hardware and Devices

Miniaturization and composability

- Novel hardware developments are enabling the development of ultra-compact wireless.
- Advancements in the miniaturization of the hardware mainly through the use of the microelectromechanical systems (MEMS) technology is enabling the development of a new generation of devices that are ultra-compact and have high computing ability.
- nano-electromechanical systems (NEMS)-based sensors are miniaturizing the sensors to nanometres size.
- the increased ability to put together complex systems from simpler components is enabling the development of revolutionary products in many areas.

Key Enabling Technologies (Contd.)

Hardware and Devices

High durability

- The IoT sensors are expected to work in harsh situations.
- n many field-based applications, these sensors are deployed in open environments, exposing them to the elements of weather for years.
- Some of these sensors are explicitly required to withstand harsh extreme environments such as extreme temperatures, vibration ratings, and dust and liquid resistance. Hence, durability of these sensors is of great concern.

Key Enabling Technologies (Contd.)

Improvements in System on Chip (SOC) architectures

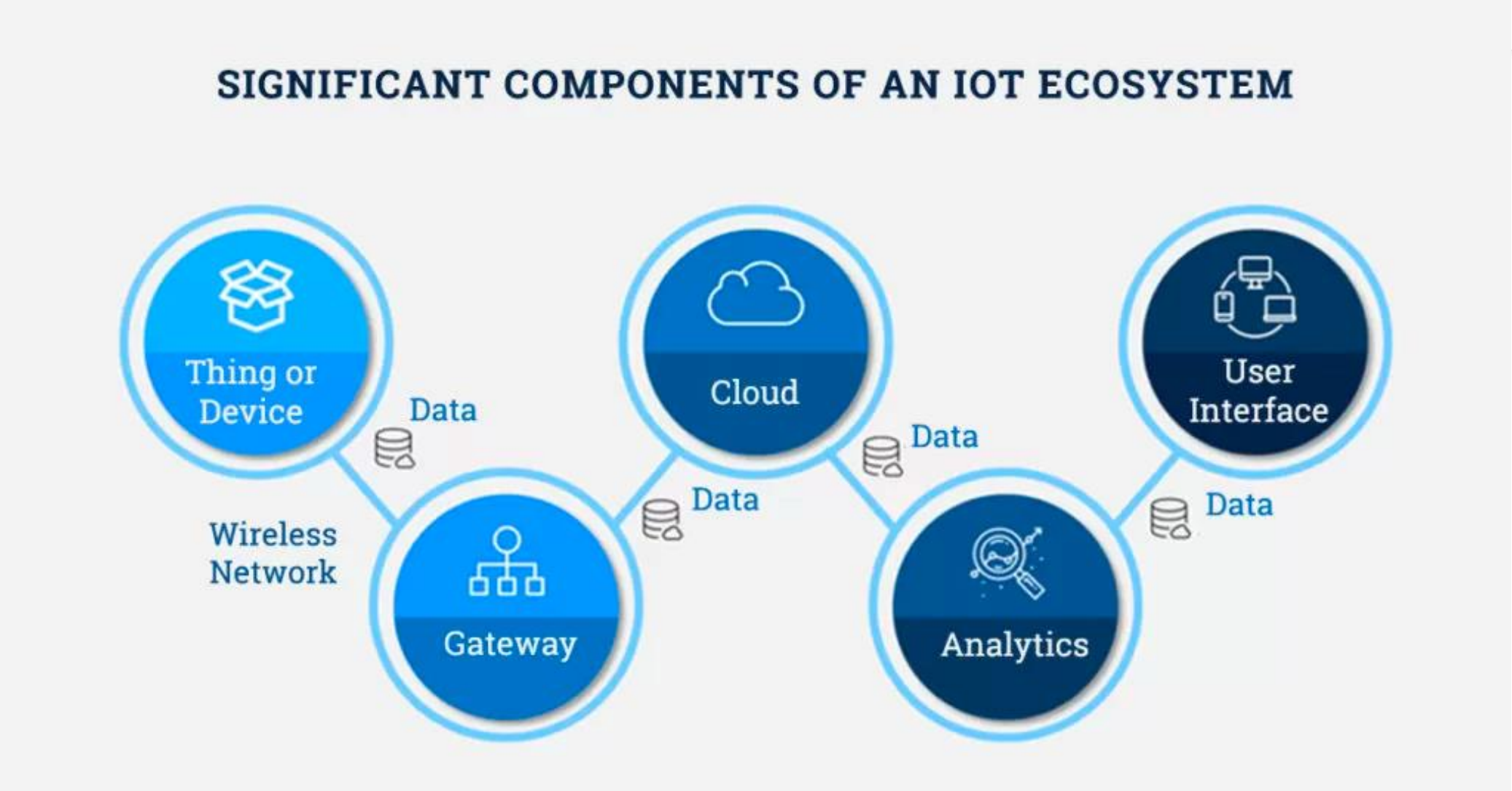
- key advancements happened in the area of SOC architectures specifically designed for IoT devices
  - application processors (high end) (are usually based on technologies adapted from mobile phone/tablet architectures) microcontrollers (low end), and smart analogue.

Lower costs

- One trend that is driving greater adoption of IoT is the lowering of the cost of the sensors.
  - It is estimated that the average cost of the sensors will drop to $0.38 by 2020, down by $0.92 as compared to 2004.
- Helping to sense and acquire more data from a variety of environments and develop more data-driven intelligent applications than before.

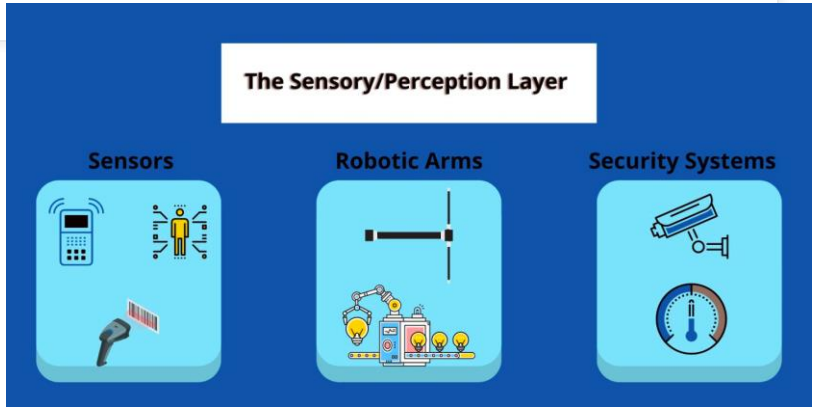
Overview of IoT Ecosystem and Key Components

Key Components of IoT Ecosystem

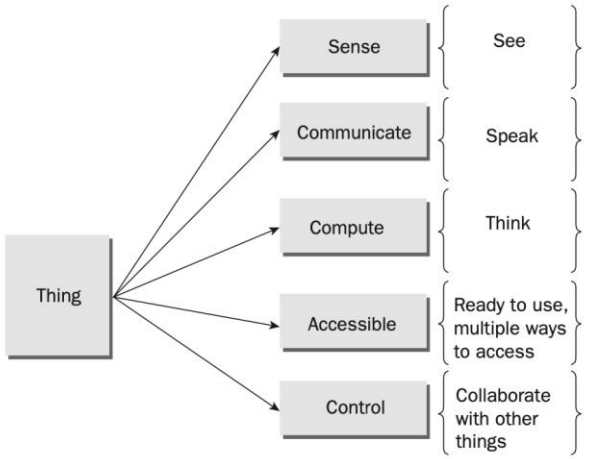


Device or Thing

- In the IoT architecture, physical layer is also known as perception layer which consists of sensor devices for sensing and collecting information from the environment. Physical parameters are sensed by these sensors. The task of perception layer is to identify other smart objects in the environment.
- Sensors and actuators are at the key components of the whole IoT network.
- The sensors are associated with resources in the form of a physical micro appliance embedded in the IoT device.The actuator responds to the signal or command by responding or causing something to happen based on this signal.

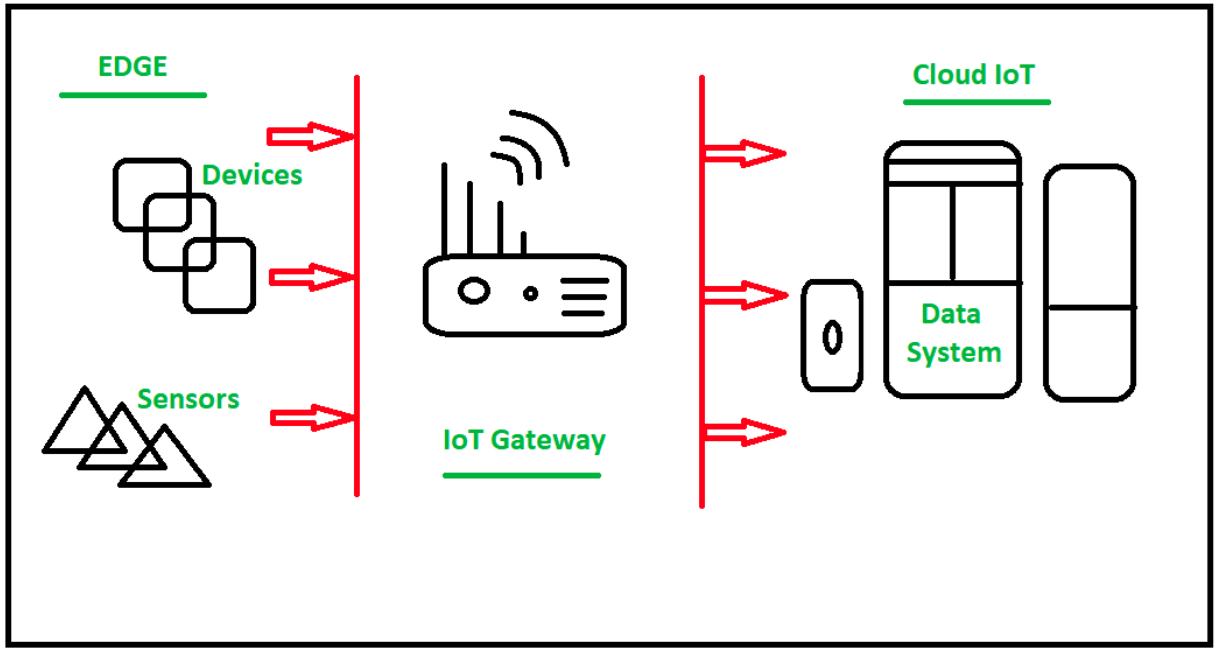


Concept of Smart Things/Object



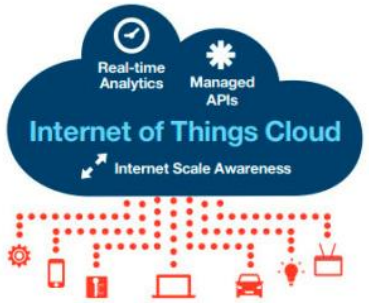
Gateway

Gateway provides a bridge between different communication technologies which means we can say that a Gateway acts as a medium to open up connections between the cloud and controller(sensors/devices)



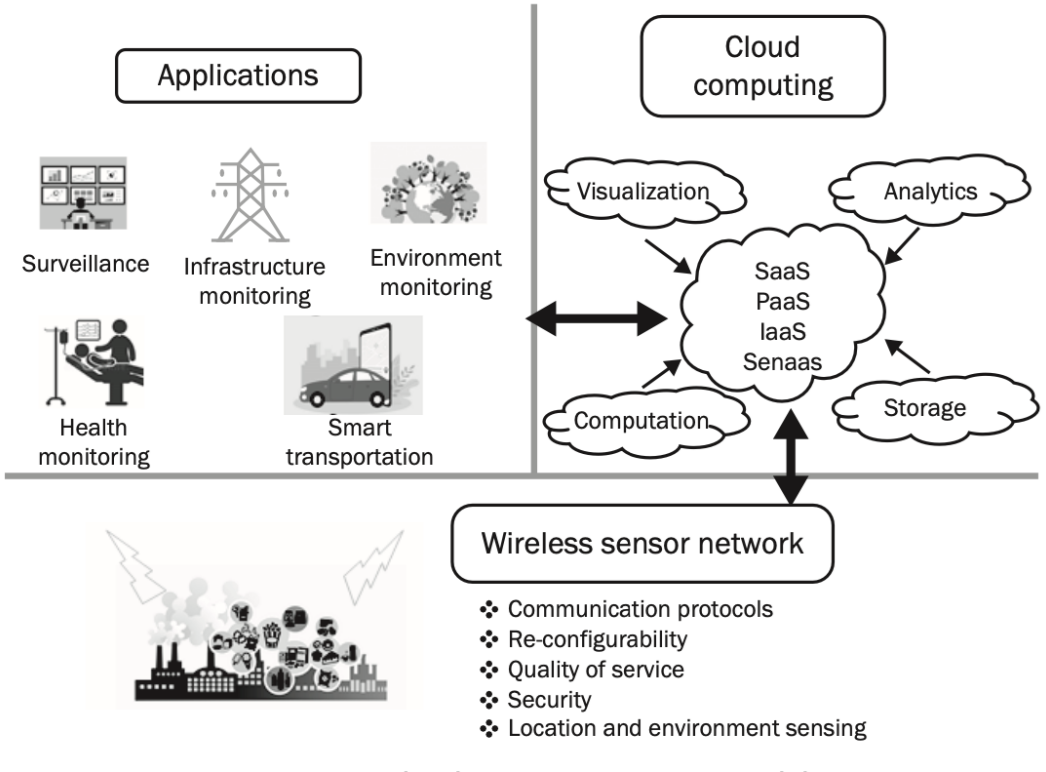
https://media.geeksforgeeks.org/wp-content/uploads/20200605164922/gateway.png

IoT Cloud



Majority of IoT applications produce high frequency and volume of data. These data are processed at various levels such as:

- **Edge/fog computing,** where streaming raw data from IoT sensors is processed for real/ near real- time applications. These computations usually happen on an specialised edge device integrated with an IoT gateway or on nearby available servers.
- **Cloud computing** where the data is further sent to a remote location hosting a large network of servers and capable of providing various services such as hardware, software, storage, processing, security, etc.



Source: Internet of Things, Durbha et.al.

Advantages of using cloud for IoT

- On demand processing of high volumes of data
- Availability of latest computing hardware and software that enables more efficient processing
- High scalability and availability that allows aggregation and processing of data from multiple IoT applications and distributed IoT sensors
- Payment of the cloud services such as data storage, processing, etc. on the basis of "pay as you go" approach
- No maintenance is required at the user end for the computing infrastructure as it is managed by the cloud service provider
- Several options for choosing off-the-shelf (commercial and open source) IoT platforms to quickly setup the required infrastructures for integrating the IoT sensors with the processing hardware/ software and begin gaining useful insights in a particular domain.

IoT Analytics

- IoT Big data analytics provides a means for analyzing and visualizing data from IoT sensors, actuators, devices, and other connected components of the IoT system.
- The analytics are useful to understand, summarize, and obtain useful insights from large volumes of data coming at very high speed in the form of streams.

https://www.kaaiot.com/img/iot/dash1.png

Uses of IoT data analytics

• Automating many decision-making processes so that human intervention is minimized and IoT devices and applications can autonomously perform actions.

• Increasing the efficiency with which processes can be executed. For example, supply chain operations can be made highly efficient by deploying IoT-based solutions.

• Condition-based monitoring and predictive maintenance of equipment, which is critical in many areas such as industries, manufacturing, healthcare, and transportation.

• Service efficiency that encompasses remote management, service chain, material management, etc.

• Analysis of the product usage by customers and accordingly customize the product thus enabling

competitive advantage in the market.

• Reducing overall operational expenditure and increasing revenue.

IoT User Interface

- The user interface is an effectively accessible and visible component that can be used by the IoT user
- User can control the system and set their choices.
- A user can communicate with the system through a device or this communication can be done remotely via smartphones, laptops and tablets.
- Touch screens, colors, text styles, voice and a lot more are some of the elements.

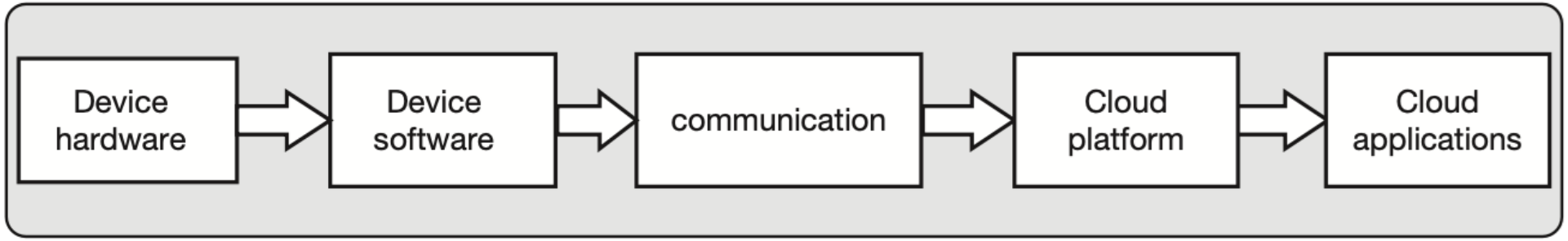
https://softengi.com/wp-content/uploads/1_2-light.png

Source: https://www.enlightenmed.com.hk/images/gallery/iot%20ui.png

IoT Technology Stack

IoT Technology Stack

The IoT technology stack consists of both the hardware and software.



Source: Internet of Things, Durbha et.al.

Layer

5 Cloud Applications
The customer interface for dashboards, settings and devices

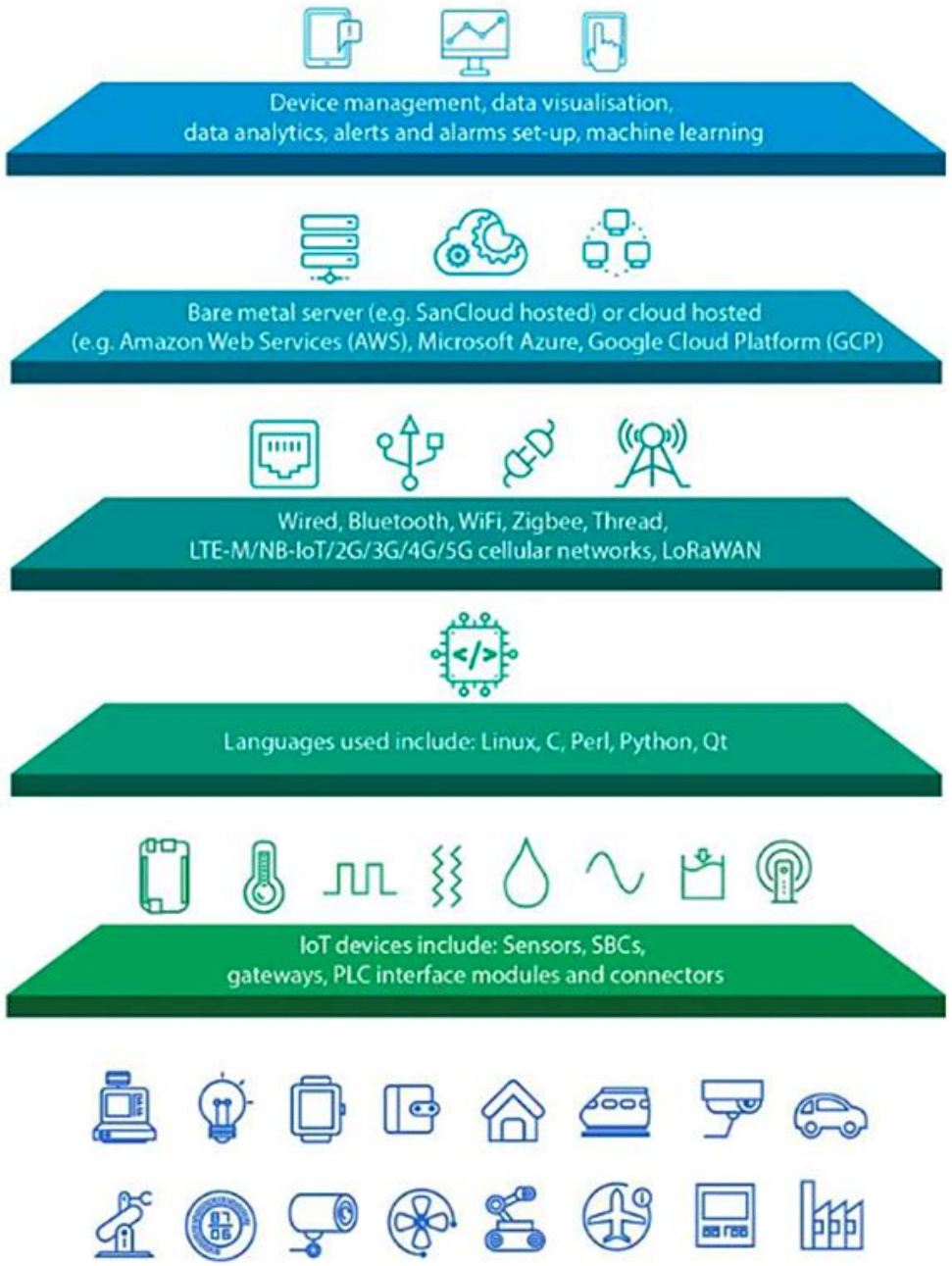
4 Cloud Platform
Where data from IoT devices is captured, processed and stored

3 Communications
How devices connect to the internet and transfer data

2 Device Software
Runs on the device's processor and controls its functionality

1 Device Hardware
Embedded into 'Things' in the IoT

Things
Physical objects found in your home, workplace and everyday life



Source: https://iotbusinessnews.com/WordPress/wp-content/uploads/2022/07/IoT-technology-stack-diagram.jpg

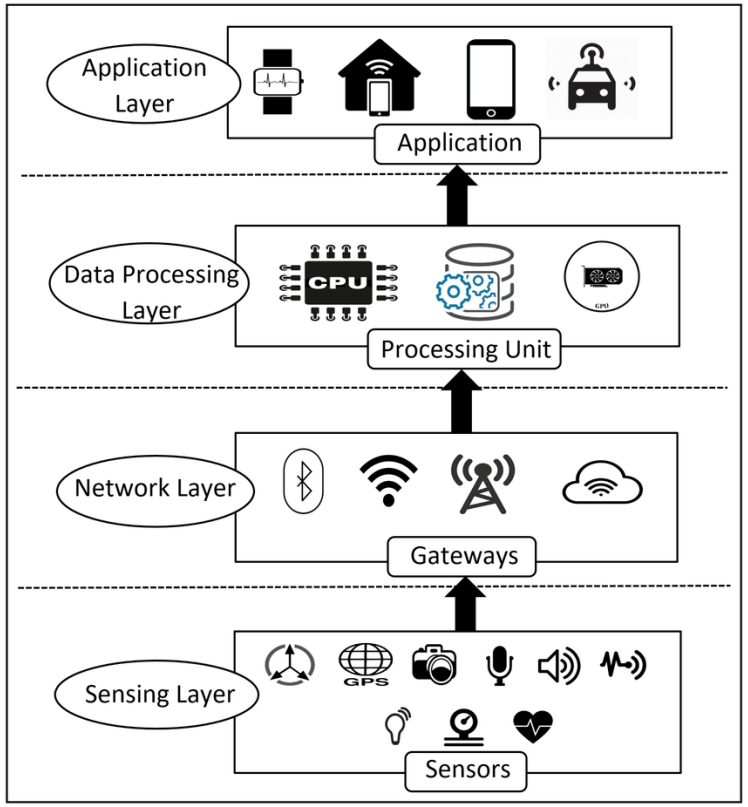
IoT Architecture Layers and Components

A. Sensing Layer: The main purpose of the sensing layer is to identify any phenomena in the devices' peripheral and obtain data from the real world. This layer consists of several sensors. Using multiple sensors for applications is one of the primary features of IoT devices

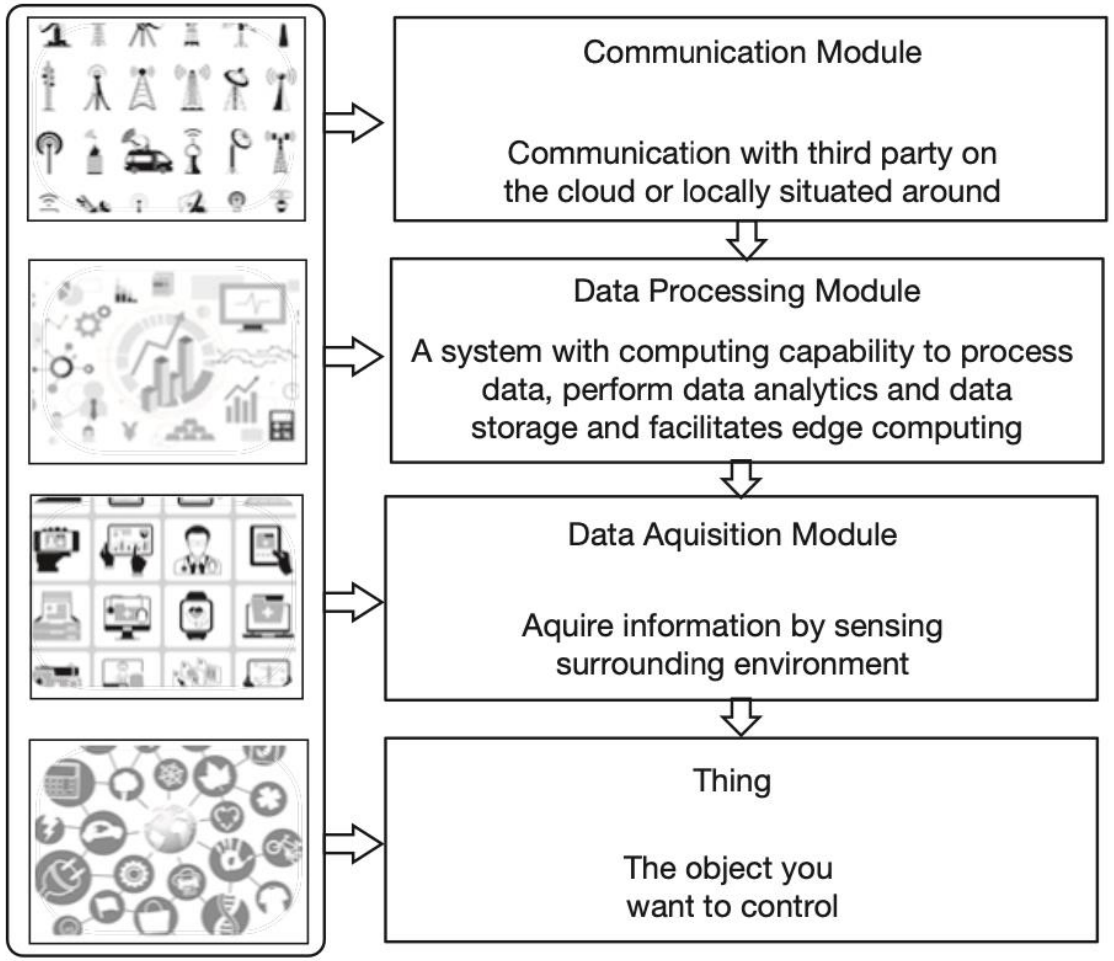
B. Network Layer The network layer acts as a communication channel to transfer data, collected in the sensing layer, to other connected devices. In IoT devices, the network layer is implemented by using diverse communication technologies (e.g., Wi-Fi, Bluetooth, Zigbee, Z-Wave, LoRa, cellular network, etc.) to allow data flow between other devices within the same network.

C. Data Processing Layer The data processing layer consists of the main data processing unit of IoT devices. The data processing layer takes data collected in the sensing layer and analyses the data to take decisions based on the result. In some IoT devices (e.g., smartwatch, smart home hub, etc.), the data processing layer also saves the result of the previous analysis to improve the user experience. This layer may share the result of data processing with other connected devices via the network layer.

D. Application Layer The application layer implements and presents the results of the data processing layer to accomplish disparate applications of IoT devices. The application layer is a user-centric layer which executes various tasks for the users. There exist diverse IoT applications, which include smart transportation, smart home, personal care, healthcare, etc



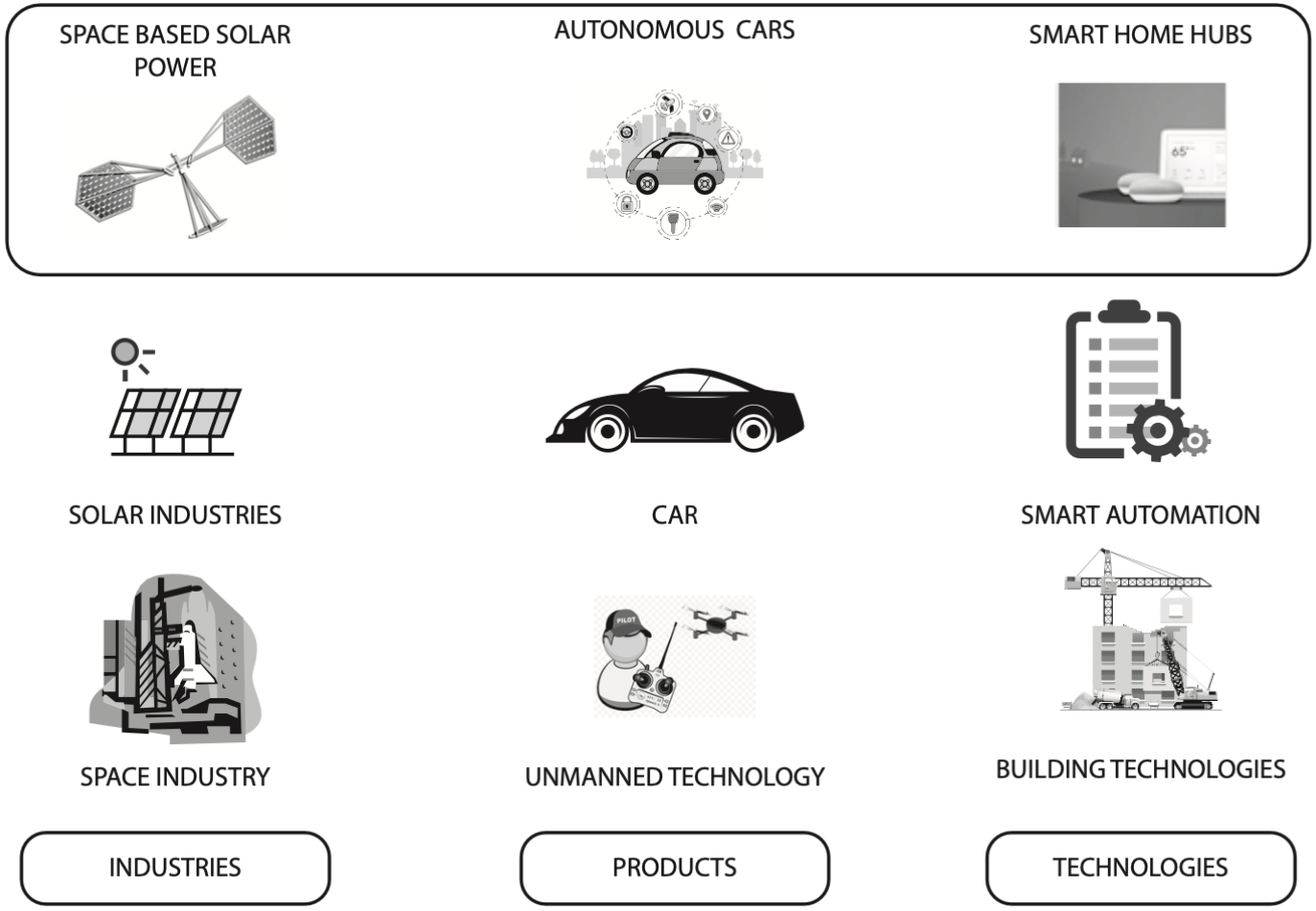
IoT Device Framework



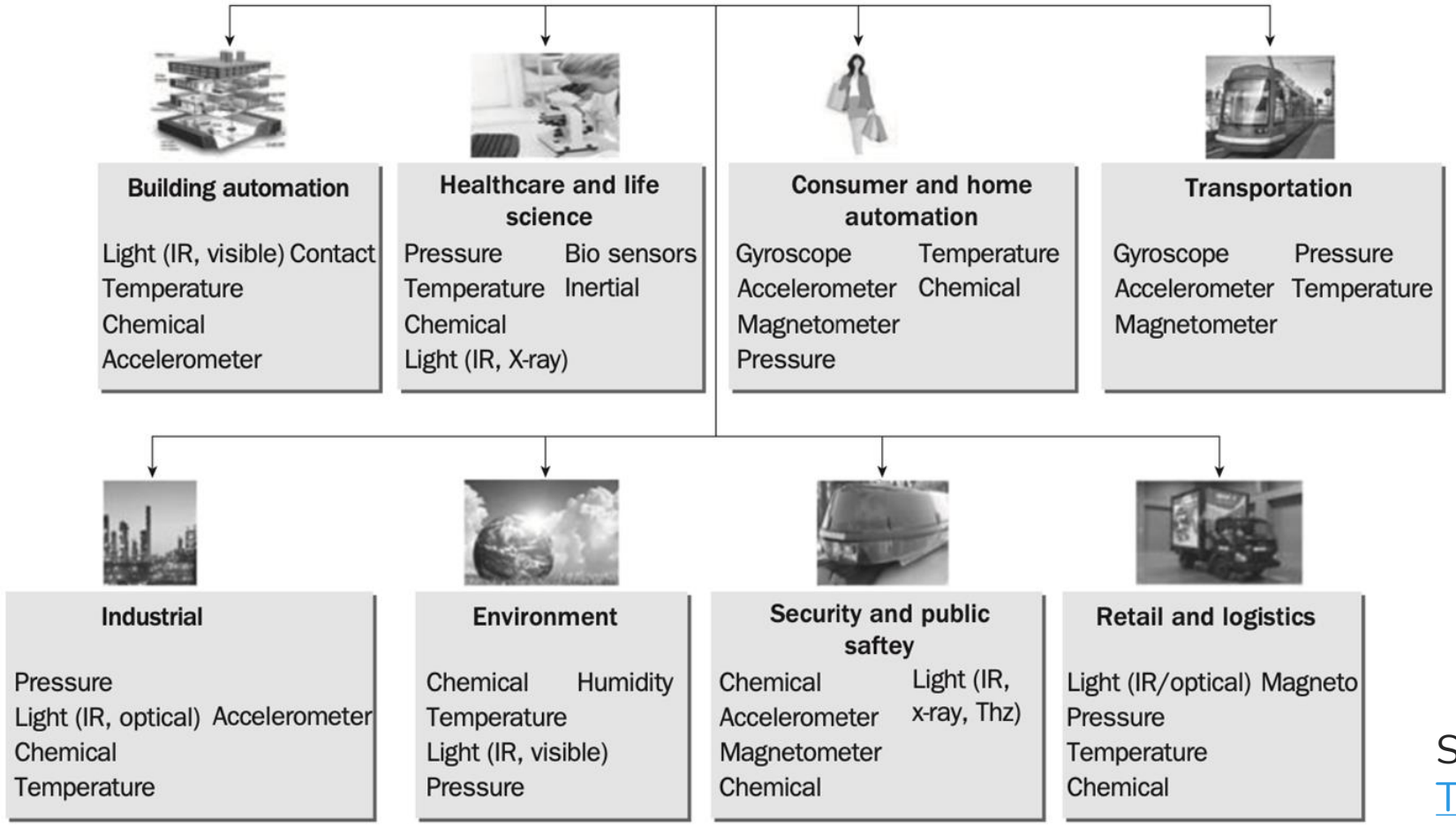
Source: Internet of Things, Durbha et.al.

Icebreaker Activity - IoT Conceptual Understanding (Use Cases)

IoT Application Domains

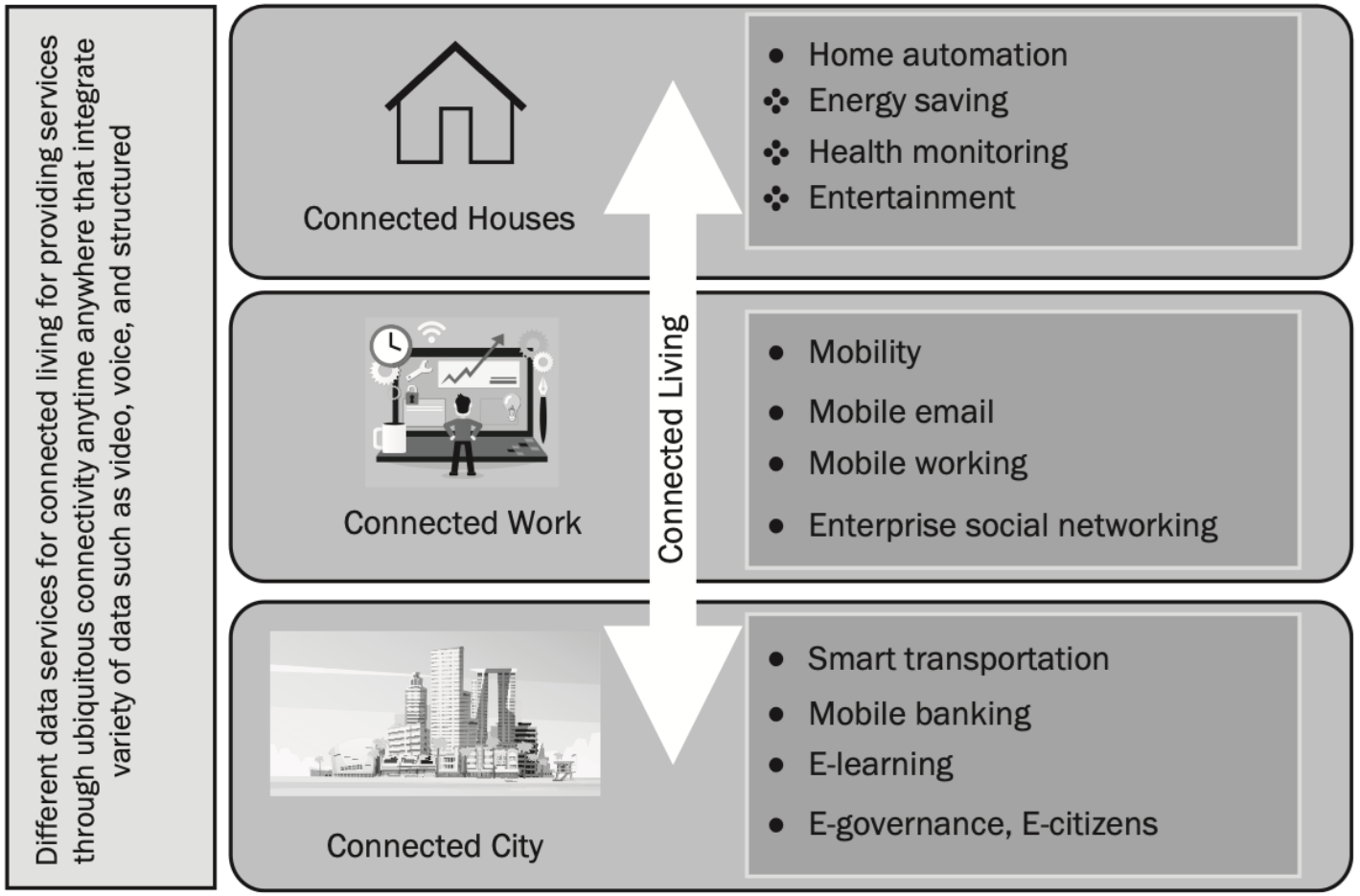


Example IoT Domains and Sensors



Source: Internet of Things, Durbha et.al.

Creating IoT Driven Solutions



Source: Internet of Things, Durbha et.al.

Home and Personal Space

The **personal space IoT** centres on a person's space. It includes all objects implanted or wearable by the person such as implanted sensors, smartwatches, Google glasses, ECG sensors, and smartphones. It also includes all fixed or mobile objects and devices that come into contact (or reachable) with wearable objects on the person. Devices are reachable when they are within the wireless transmission radius of one another.

Smart buildings IBM is building a solution with the Watson IoT platform and IoT-enabled sensors for tracking every asset in the building using that information in their IoT platform. This will facilitate the owners of the building to understand, monitor, and control of installations such as Heating, Ventilation, Air Conditioning (HVAC) systems, to enable to monitor remotely. The burden of facility management is overtaken by smart sensors that capture every pulse of this infrastructure and to enable remote diagnostics and analysis.

Smart elevators **KONE,** the elevator company, is trying to understand how people are using the elevators. By using sensors, they are assessing how people move through buildings and estimating how much time can be reduced for the elevator wait. They conclude that even 2 or 3 minutes reduction in the waiting time will make a huge difference in moving people to their relevant floor.

Water ATM

Peeth is a village in the heart of the Aravallis in Rajasthan. It is one of the most backward districts of the country and faces a serious water shortage. In Peeth, 84% of the population gets its drinking water from the local well, polluted with dangerously high levels of fluoride and other heavy minerals. Surveys showed that although the locals were aware of hazards of drinking polluted water, but the only alternative was a single private drinking water supplier, who charged ₹2 per litre and only catered to 40 families. Thus, the villagers welcomed the Sarvajal Kendra, as a much-needed solution. Today, the facility serves more than 200 families daily, ensuring they get safe water delivered at their doorstep.

Adapted from www.sarvajal.com; www.downtoearth.com; www.thehindu.com

Water ATM Piramal Sarvajal, a mission-driven social enterprise, is committed to leveraging technology to bring community-level safe drinking water to the underserved. The organization has developed and implemented innovative market-based drinking water solutions in 16 states in India. Their infrastructure includes remotely monitored water purification units and solar powered, cloud connected water kiosks called water ATMs

Connected medical devices

- Remote diagnosis and follow up monitoring
- Memory disabilities monitoring
- Early intervention for detection of critical signs
- Monitoring patient fall
- Timely medicine alerts and enhanced drug management
- Healthcare assets monitoring and tracking

Improving water conservation

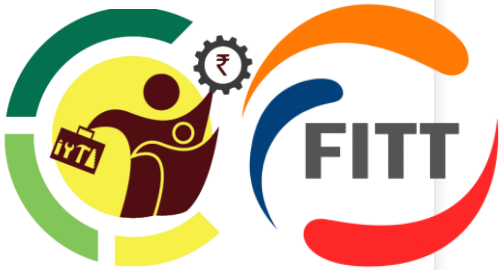
Water conservation and management is essential in many facets of human lives. The various current practices are time consuming and lack real-time tracking and alerts for timely intervention to reduce wastage of water. Out of many applications of IoT in this area, two applications are described as follows:

- Smart water meters that can be used to detect leakage of pipes in the water delivery infrastructure (e.g., water grid). It also can help to precisely understand the water consumption behaviour of the users through data analytics and make and send alerts in real time. Further, by analysing the requirement of water in an area, adjustments to the optimal supply of water can be achieved.

- Water quality aspects can be studied by the deployment of IoT sensors in the water supply network to measure various water quality parameters to quickly react to those conditions when the water quality is deemed below the safe level.

Introduction to Python Programming

Python



Introduction to Google Colab

https://mcgrawect.princeton.edu/guides/Google-Colab-Introduction.pdf

Homework Assignment

Homework

- Describe Internet Protocols
- Give your own definition of IoT. How is it different from other definitions?
- What is an enabling technology? Describe the key enabling technologies of IoT.
- Why is IoT considered as a disruptive technology?
- What makes commonly used things to become smart? Explain with real-world examples.
- Explain various layers of IoT technology stack