# Unit-1

## Introduction to IoT

# Introduction to IoT

## Emergence of IoT

- Introduction
- Evolution of IoT Versus (M2M, CPS, WoT)
- Enabling IoT and the Complex Interdependence of Technologies
- IoT Networking Components

## IoT Sensing and Actuation

- Introduction
- Sensors
- Sensor Characteristics
- Sensorial Deviations
- Sensing Types
- Sensing Considerations
- Actuators
- Actuator Types
- Actuator Characteristics

**The Internet of Things (IoT) refers to the network of physical objects devices, vehicles, buildings, and other items embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet.**


Introduction to
IOT
IOT
NGS

# Introduction to IoT

- IoT is also known as the Internet of Things.
- It is a way of connecting physical objects through the internet to other devices.
- The things in IoT are defined as objects that can be a person or automobile with a built-in sensor having IP addresses with the ability to collect and transfer the data over the Internet.
- It has generally evolved from microservices, wireless, and MEMS technology (Micro-Electro Mechanical Systems).

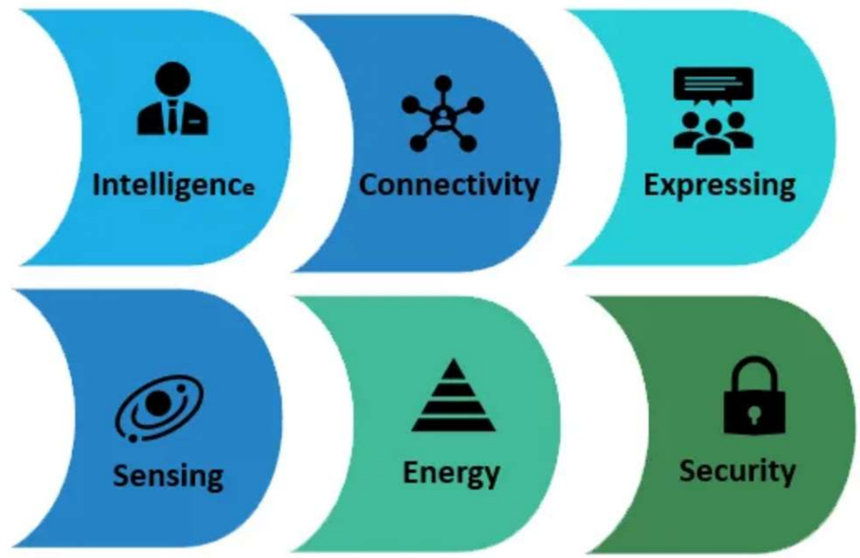
- It is being evolved from M2M communication when machines connect to each other network without any human interference or interaction
- When separate devices are attached to the Internet, sending and receiving the data and sending the data to make things intelligent.

IoT has three categories based on the devices that connect over the internet

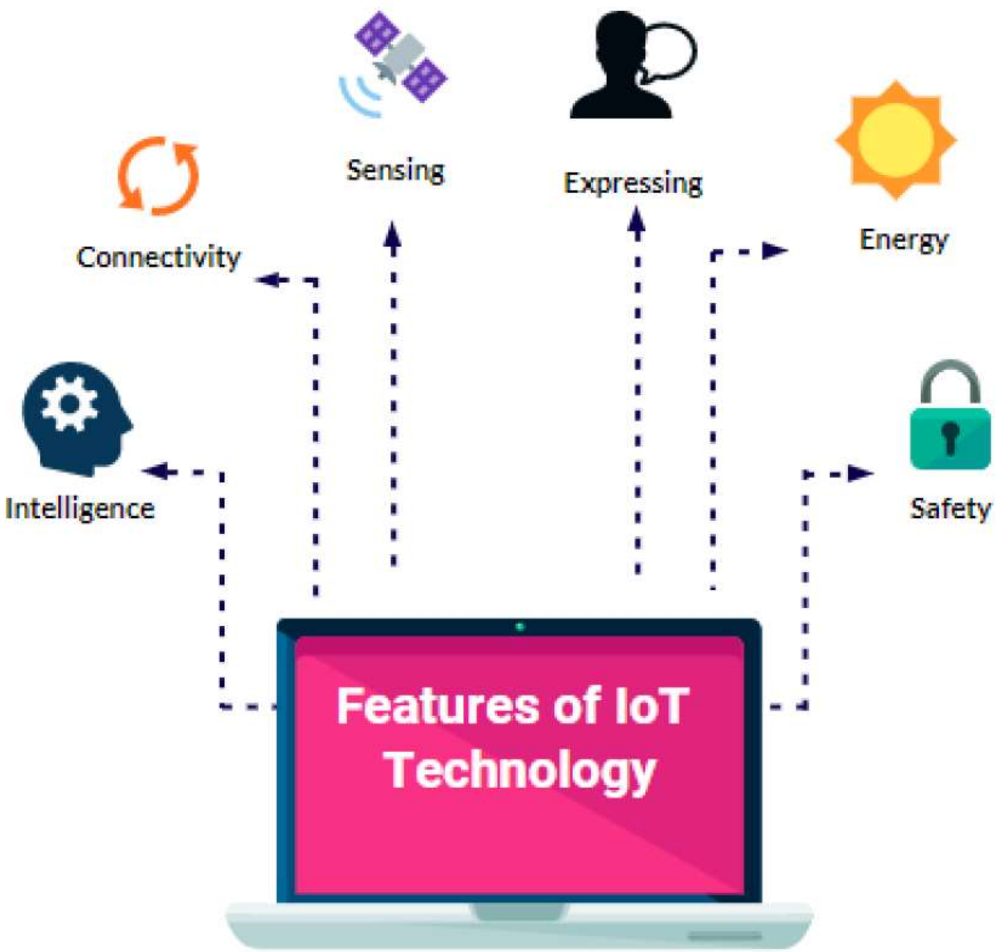
1) The devices that can **collect** and **send** the information.
2) The devices that **collect** and **respond** to the information.
3) The devices that can equip **both** of the above features.

## Components of IoT


## Characteristics of IoT



# Features of IoT




**Intelligence:** This will be essential for smart products.

**Connectivity:** This feature will be responsible for network accessibility and compatibility features of the devices, hence one of the prime characteristics.

**Sensing:** Like collecting the information basing the retrieval capacity and providing it for an intelligent decision.

**Expressing:** This will enable interactivity with humans and the world.

**Energy:** Energy harvesting and proper infrastructure to charge will be important features for our IoT devices.

**Safety:** The prime feature on which customers rely and use the product.


1. **Communication Protocols**
2. **Networking**
3. **Data Formats**
4. **Security**
5. **Interoperability**
6. **Device Management**
7. **Application Layer**

IoT standards refer to the set of guidelines, protocols, and frameworks established to ensure the interoperability, security, and efficiency of Internet of Things (IoT) devices and systems. These standards are crucial because they enable different IoT devices and systems to work together seamlessly, regardless of the manufacturer or platform

**Communication Protocols**: Standards like MQTT, CoAP, and HTTP are used for communication between IoT devices and servers.

**Networking**: Standards for network connectivity, such as IPv6, 6LoWPAN, and Zigbee, ensure devices can connect to networks efficiently.

**Data Formats**: Standards like JSON, XML, and CBOR are used for structuring data to ensure it can be easily interpreted by different systems.

**Security**: Standards like TLS/SSL, DTLS, and IoT-specific frameworks like the IoT Security Foundation guidelines ensure data integrity, confidentiality, and authentication.

**Interoperability**: Organizations like the Open Connectivity Foundation (OCF) and the All Seen Alliance work on standards to ensure different IoT devices and ecosystems can interoperate.

**Device Management**: Standards like the Lightweight M2M (LwM2M) protocol help in the remote management of IoT devices.

**Application Layer**: Standards like OMA LwM2M and oneM2M provide frameworks for developing IoT applications.


IoT
Connectivity
Ethernet
Wi-Fi
LPWAN
Cellular
Satellite
Bluetooth

# Architecture of IoT

**4.Application layer**

Smart application
and management

Smart application

**3.Data processing layer**

Processing unit
Decisions – analytics

Information processing

**2.Network layer**

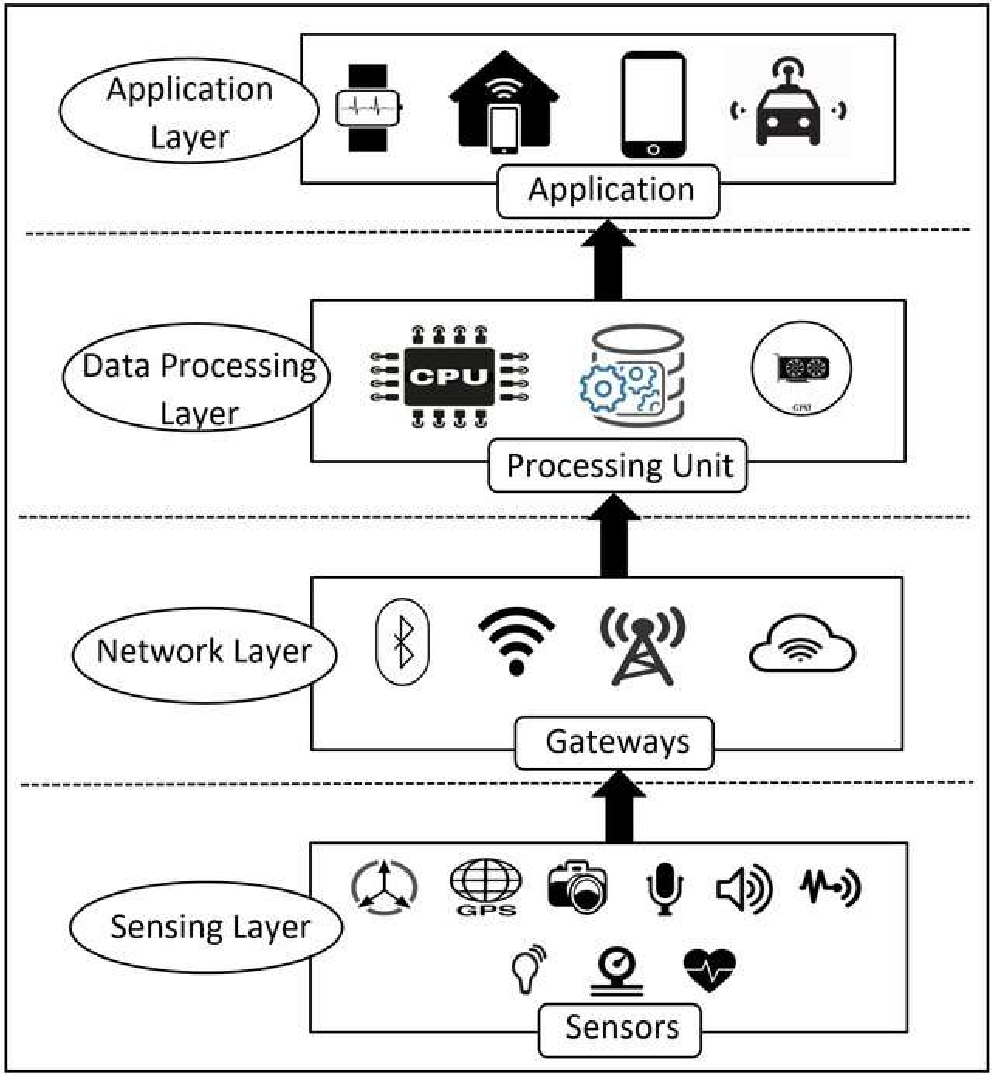
Internet gateways
Network technologies

Data transmission

**1.Sensing layer**

Physical object
Sensors and actuators

Data gathering



# IoT Architectures

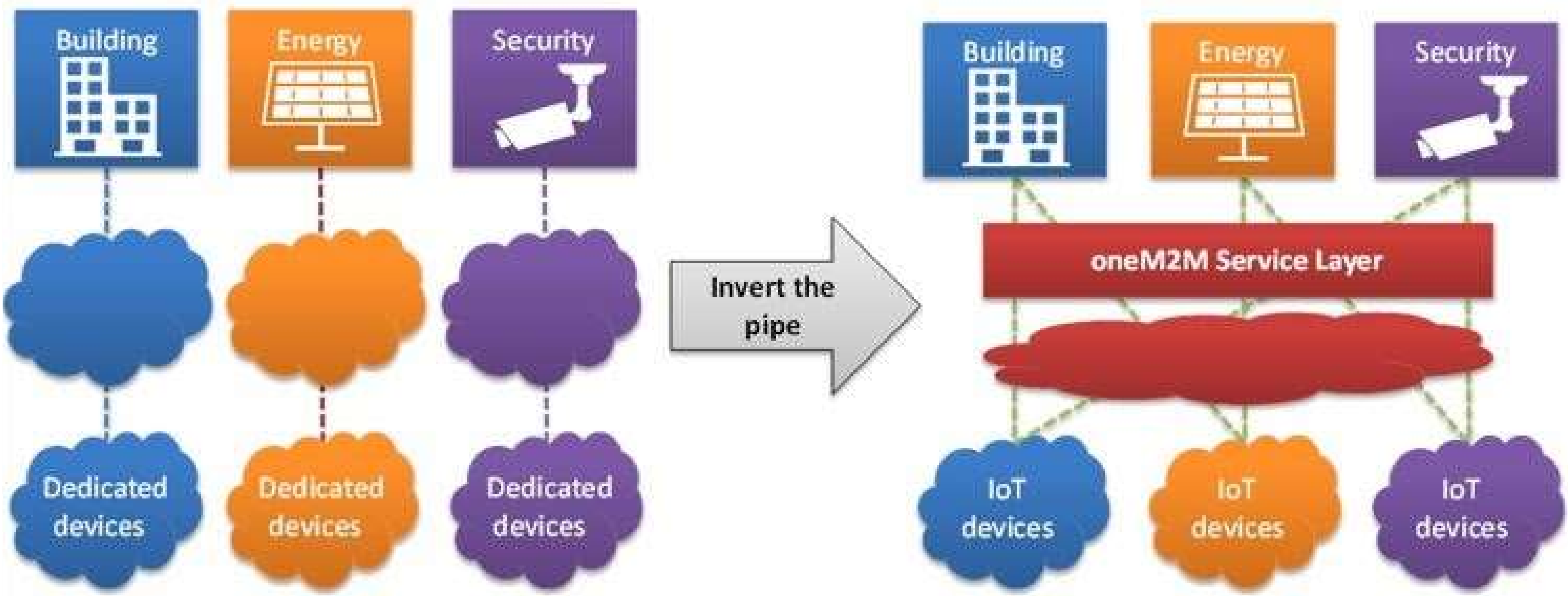
The Foundational concept in all the IoT Architectures is supporting data, process, and the functions that endpoint devices perform.

Two of the best known architectures

1) **OneM2M**

2) **IoT World Forum (IoTWF)**

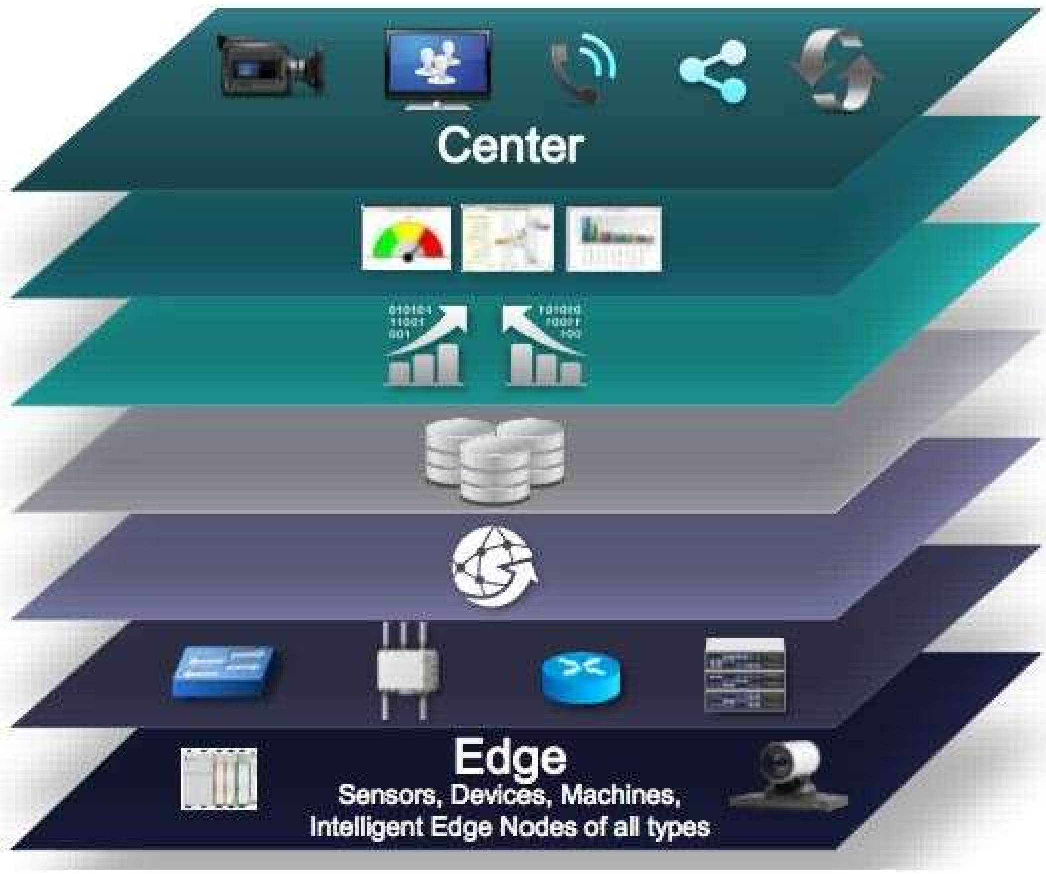
# oneM2M IoT Architecture



# The IoT World Forum (IoTWF) Standardized Architecture

Levels

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



# Stages of IoT Architecture

## 1. Sensors and Actuators

**Sensors** are physical devices that collect information from the real-world environment, such as temperature, air quality, people flow, etc.

**Actuators** are devices that can take electrical input and turn it into physical action.

## 2. IoT Gateway and Data Acquisition Systems

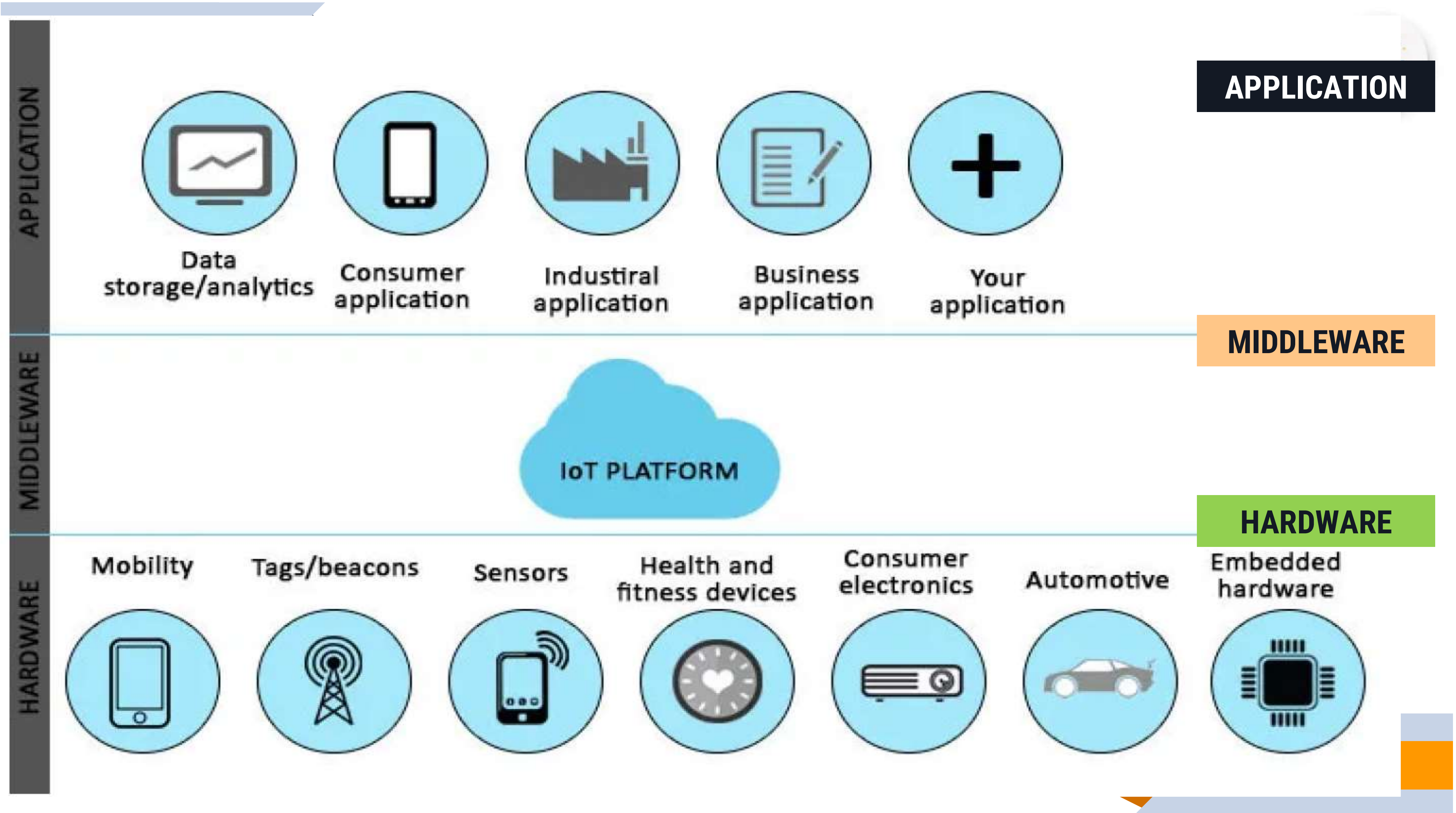
A **data acquisition system (DAS)** collects raw data from sensors, aggregates, and stores it before transferring to an IoT gateway

## 3. Edge IT: fog computing

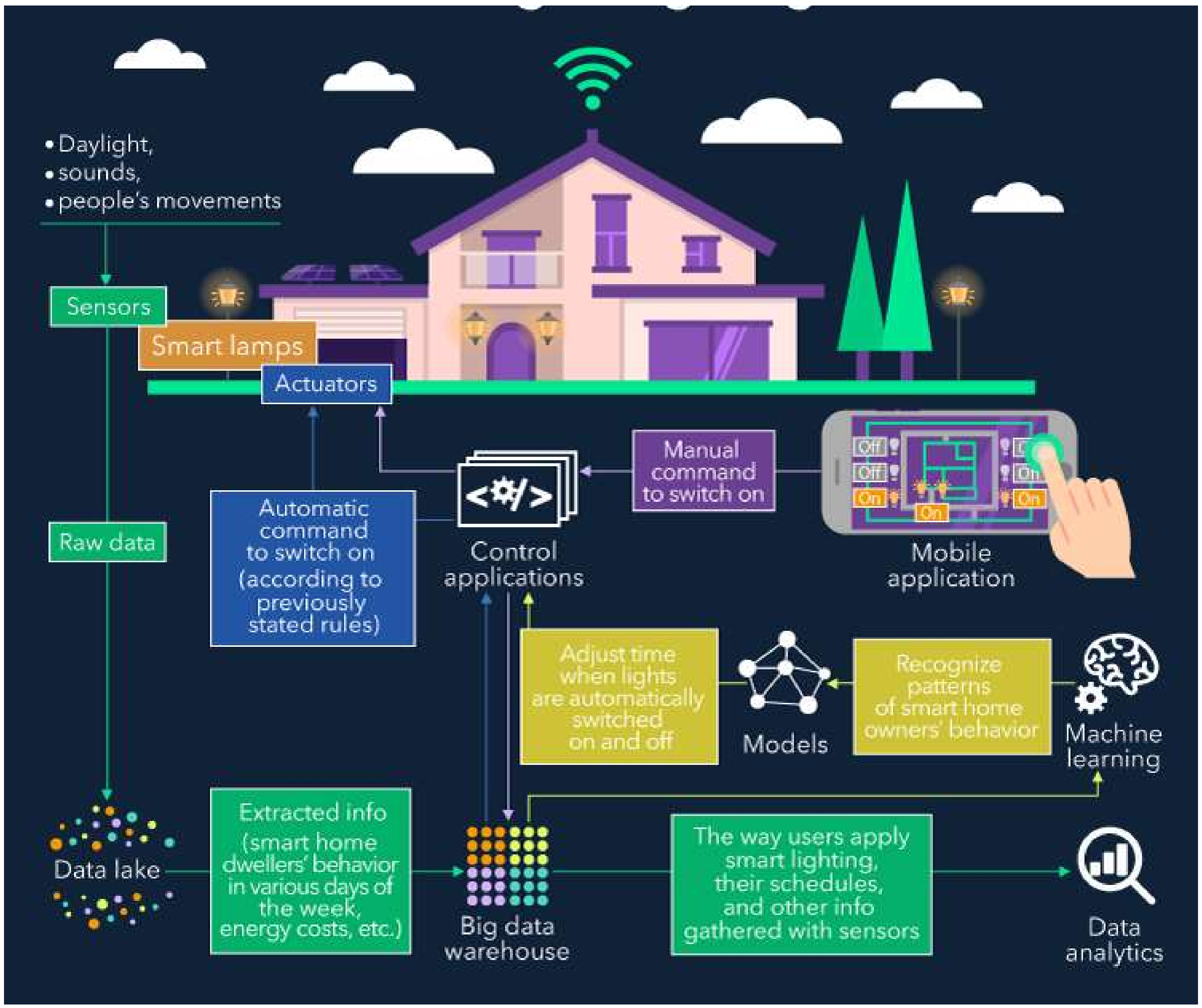
An **edge IT system** is a platform that filters and pre-processes incoming data from the IoT gateway to minimize the volume of information that will be transferred to the cloud.

## 4. The cloud: in-depth analysis

**The cloud** is a cloud-based system (less often - a corporate data center) that provides the processing power for the data that was transferred from an edge platform or an IoT gateway.


APPLICATION
MIDDLEWARE
HARDWARE
Data storage/analytics
Consumer application
Industrial application
Business application
Your application
IoT PLATFORM
Mobility
Tags/beacons
Sensors
Health and fitness devices
Consumer electronics
Automotive
Embedded hardware
APPLICATION
MIDDLEWARE
HARDWARE

## IoT architecture example – Intelligent lighting




**1. Sensors**

**2. Smart Lamps:**

**3. Control Applications**

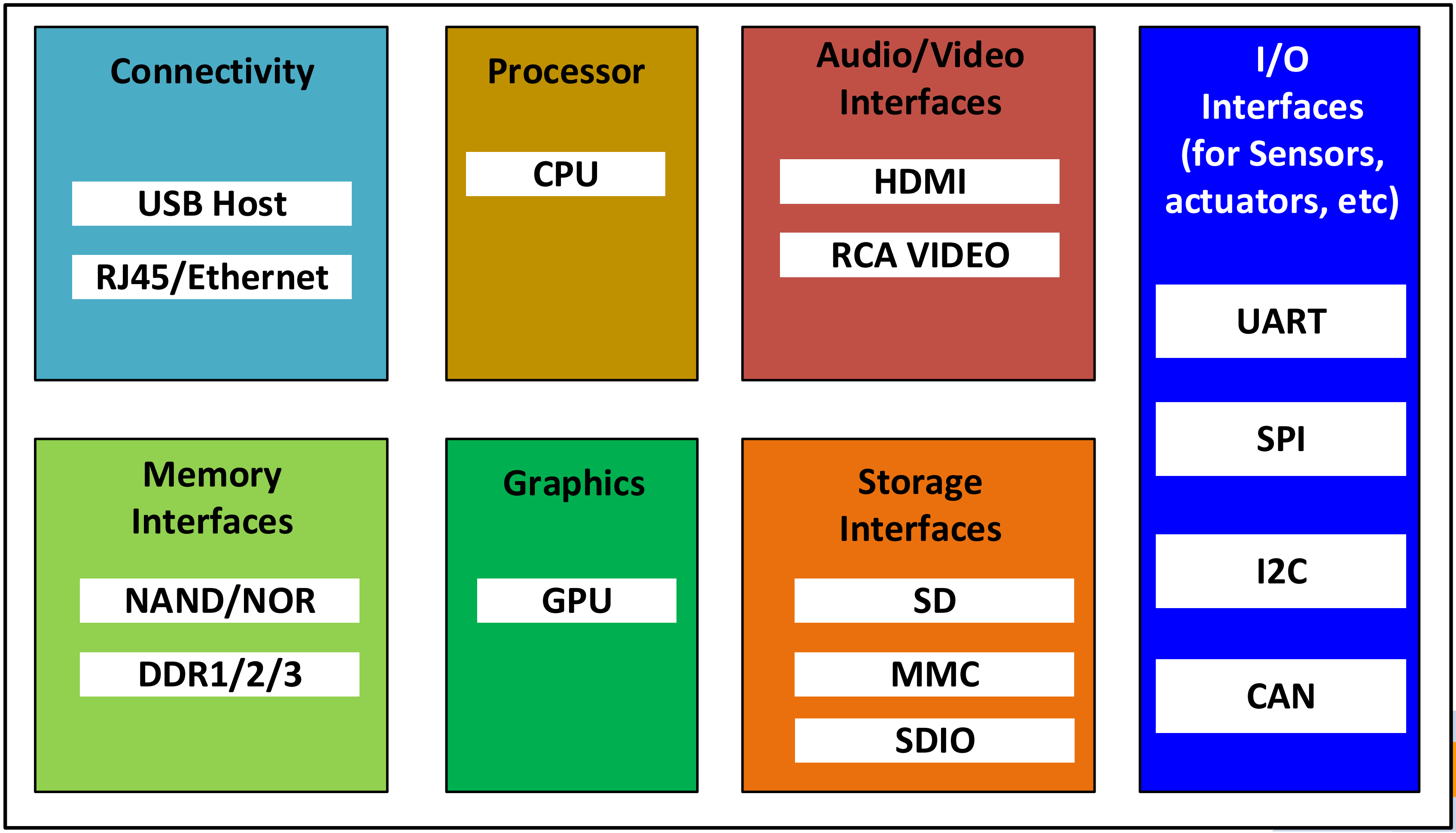
**4. Data Lake**

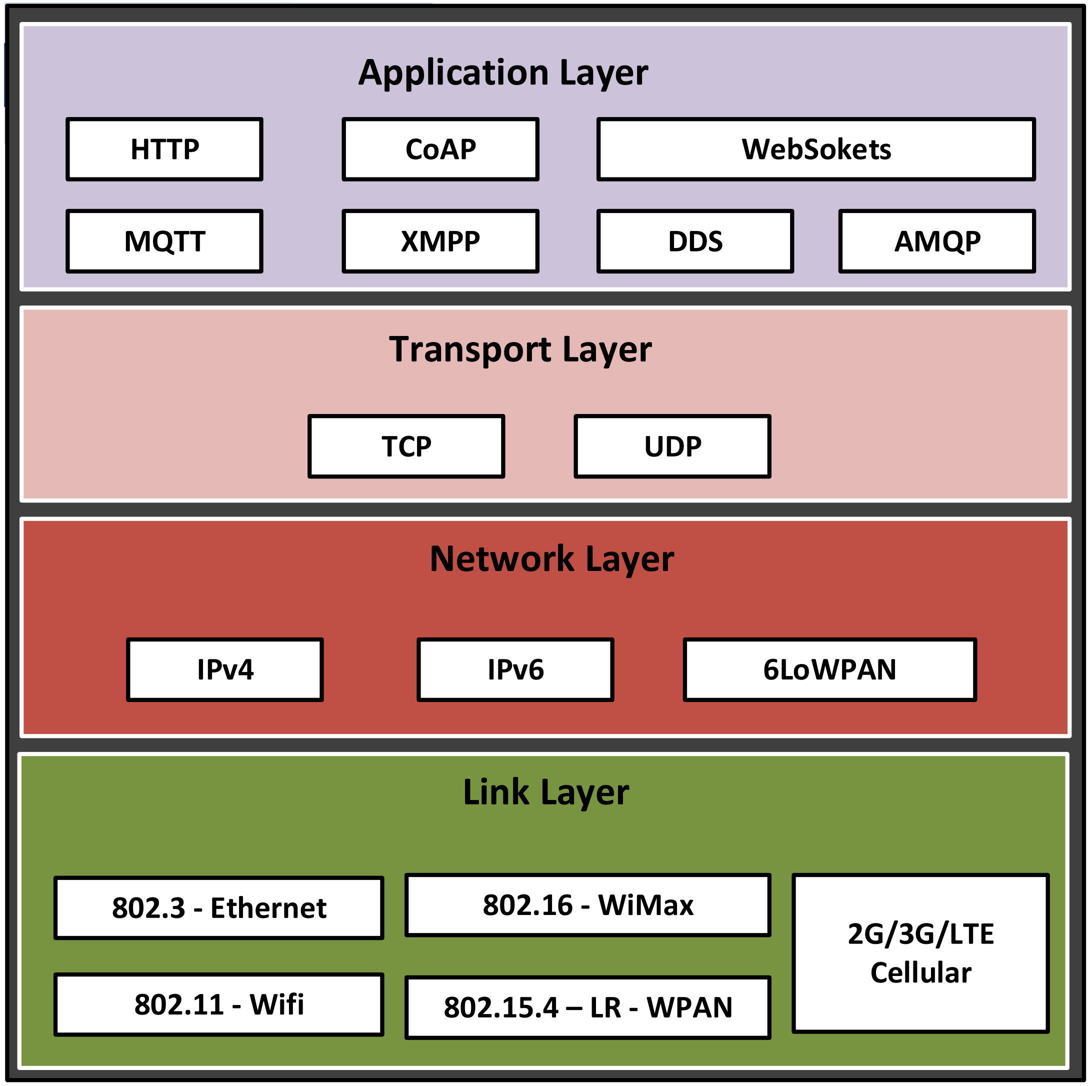
**5. Big Data Warehouse**

**6. Data Analytics**

**7. Machine Learning Models**

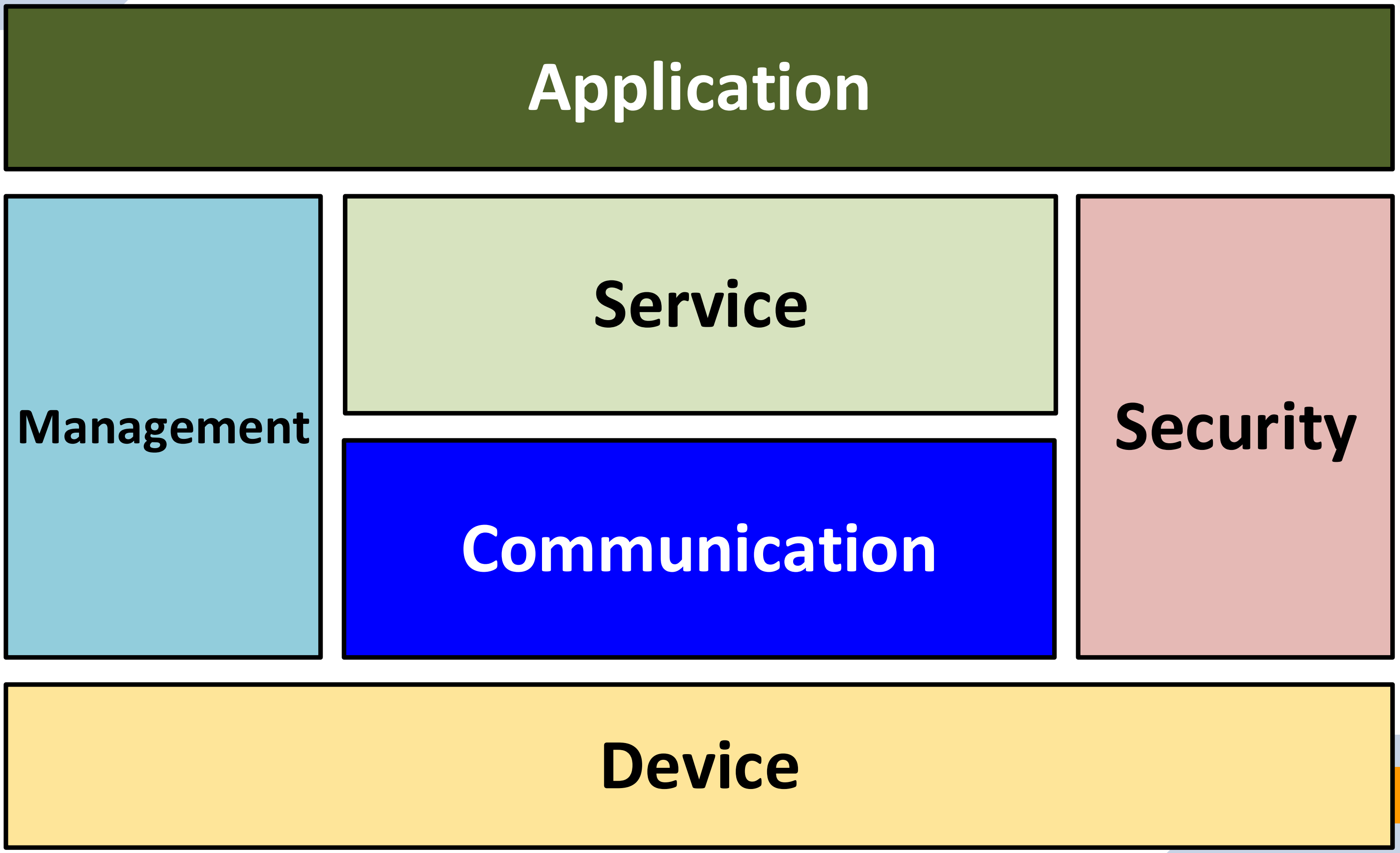
# Physical Design of IoT – Generic Block Diagram

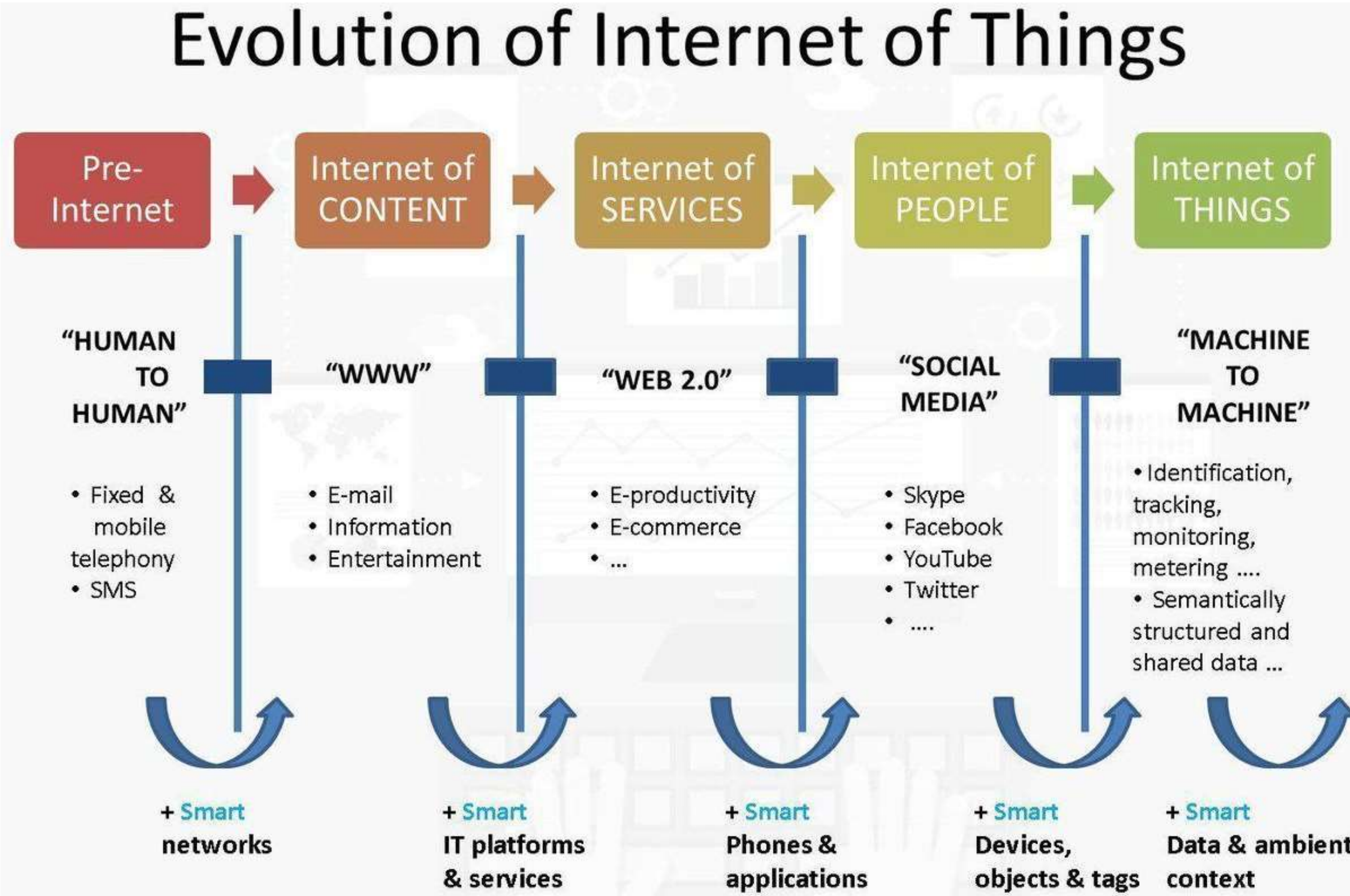


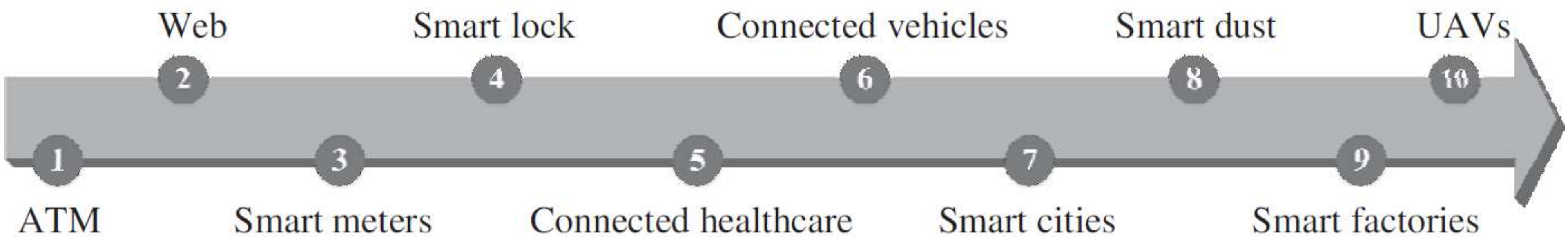



# IoT - Protocols

# Functional Blocks of IoT



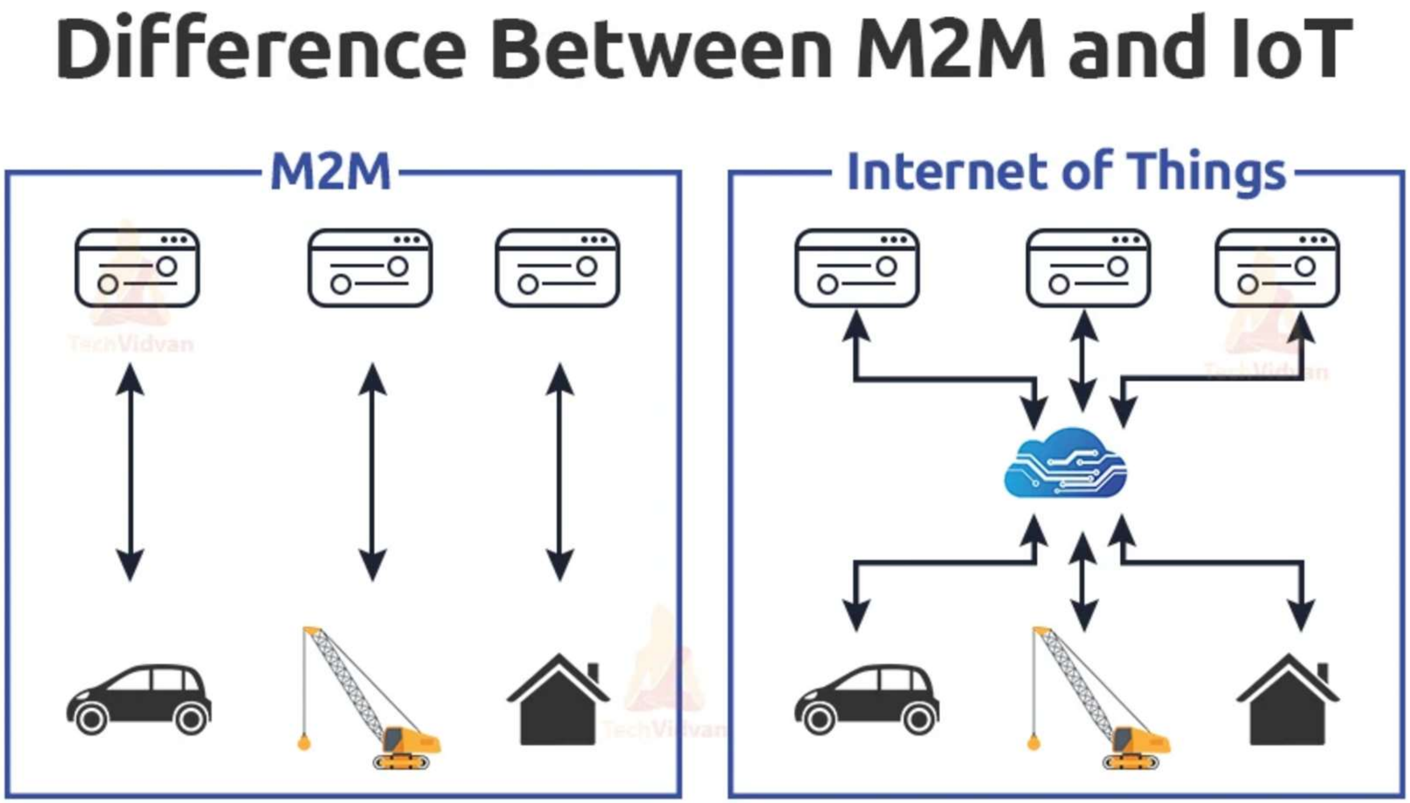

Evolution of Internet of Things
Pre-Internet
Internet of CONTENT
Internet of SERVICES
Internet of PEOPLE
Internet of THINGS
"HUMAN TO HUMAN"
• Fixed & mobile telephony
• SMS
"WWW"
• E-mail
• Information
• Entertainment
"WEB 2.0"
• E-productivity
• E-commerce
• ...
"SOCIAL MEDIA"
• Skype
• Facebook
• YouTube
• Twitter
• ....
"MACHINE TO MACHINE"
• Identification, tracking, monitoring, metering ....
• Semantically structured and shared data ...
+ Smart networks
+ Smart IT platforms & services
+ Smart Phones & applications
+ Smart Devices, objects & tags
+ Smart Data & ambient context


Web
Smart lock
Connected vehicles
Smart dust
UAVs
2
4
6
8
10
1
3
5
7
9
ATM
Smart meters
Connected healthcare
Smart cities
Smart factories

# IoT Versus M2M

- IoT and M2M share similarities in connecting devices and enabling automation.
- IoT represents a broader, more integrated, and internet-centric approach with a focus on data analytics and smart decision-making across various domains.
- **M2M**, on the other hand, is more specific to industrial applications, focusing on direct **device-to-device** communication and automation **with less reliance on the internet**.
- Both technologies continue to evolve, with IoT building on the foundational concepts of M2M to create more sophisticated and interconnected systems

# IoT Versus M2M



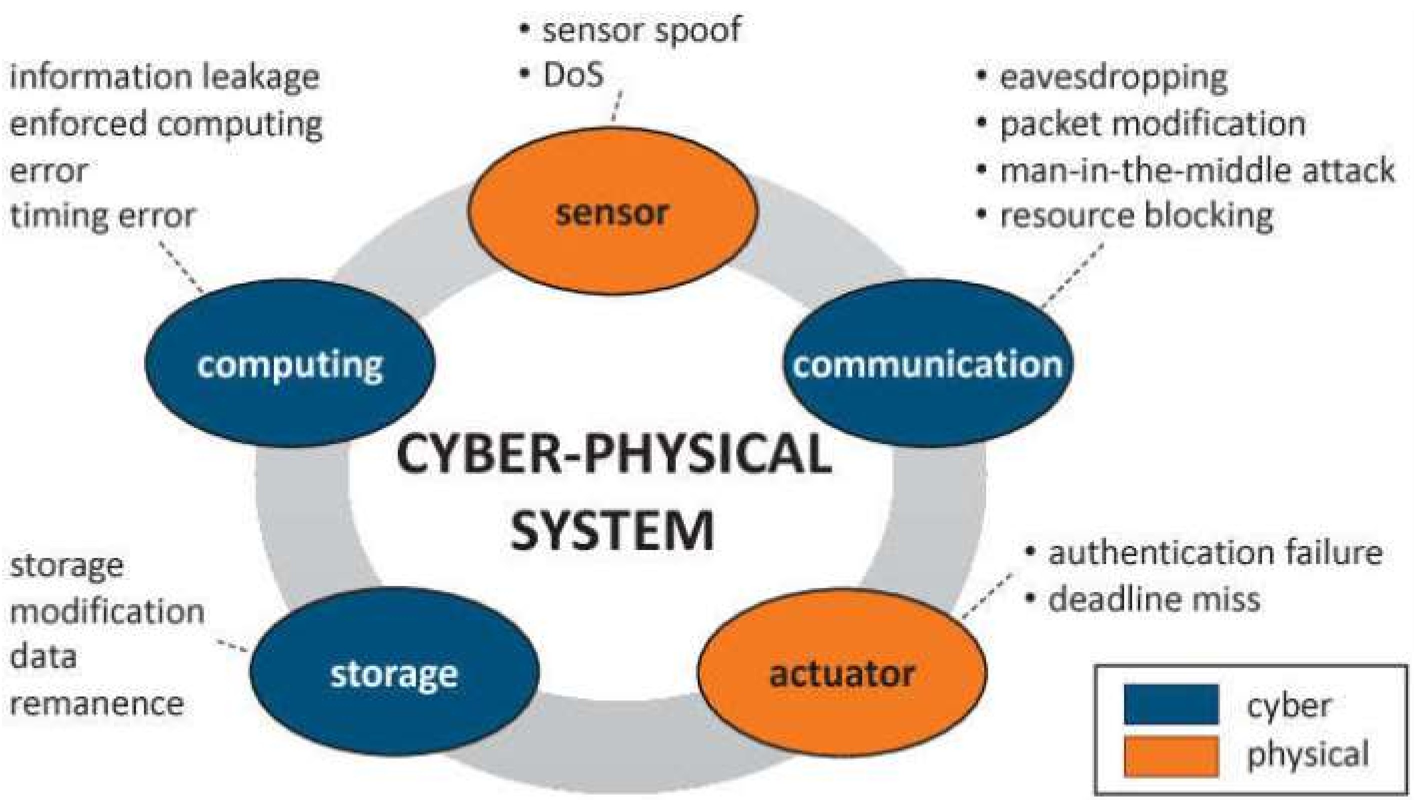
| Feature | IoT | M2M |
| --- | --- | --- |
| Scope | Broad, multi-industry (consumer, industrial, healthcare) | Narrow, mainly industrial and utility sectors |
| Communication | Internet-based, various protocols | Point-to-point, often cellular or wired |
| Architecture | Complex, hierarchical (devices, edge, cloud) | Simpler, direct device-to-device or device-to-server |
| Data Processing | Cloud and edge computing | Centralized processing |
| Connectivity | Wi-Fi, Bluetooth, Zigbee, LoRa, Sigfox, 4G/5G | Cellular networks, wired connections |
| Applications | Smart homes, cities, healthcare, industrial automation | Industrial automation, remote monitoring, telematics |
| Technologies | Advanced analytics, machine learning, cloud services | SCADA, telematics, basic monitoring and control |

# IoT Versus CPS

| |
|---|
| Cyber + Physics (Physical devices(world)<br>=<br>CPS (Cyber Physical System) |
| Internet (connectivity) + Things (IoT devices)<br>=<br>IoT (internet of things) |

- IoT and CPS both involve in the integration of the physical and digital worlds, they differ in focus, scope, and architecture.
- IoT is broader and more diverse, emphasizing **data collection**, **connectivity**, and **cloud-based analytics** across various domains.
- CPS, on the other hand, is more specialized, focusing on the **tight integration** and **real-time control of computational and physical processes** in critical applications.

# IoT Versus CPS



## IoT Versus CPS

| Feature | IoT | CPS |
|---|---|---|
| Definition | Network of interconnected devices for data exchange | Integration of computation, networking, and physical processes |
| Scope | Broad (consumer, industrial, healthcare, smart cities) | Focused (industrial, critical infrastructure, real-time control) |
| Architecture | Layered (sensors, connectivity, cloud) | Tightly integrated with real-time control and feedback loops |
| Communication | Internet-based protocols (MQTT, HTTP, etc.) | Real-time communication with a mix of wired/wireless networks |
| Data Processing | Cloud-centric | Embedded systems with real-time processing |
| Applications | Smart homes, wearables, industrial IoT, healthcare | Manufacturing, robotics, aerospace, automotive, smart grids |
| Technologies | Sensors, connectivity, cloud computing, big data, AI | Embedded systems, control systems, real-time networking, safety-critical systems |

# IoT Versus WoT

The Internet of Things (IoT) provides the foundational technology and infrastructure for **connecting physical devices** and enabling data-driven insights and automation across various domains.

The Web of Things (WoT) builds on top of IoT by standardizing how these **devices are integrated and interact using web technologies**, aiming to simplify and enhance interoperability and accessibility.

- The IoT connects physical devices and sensors to the Internet.
- WoT connects IoT to web architecture.
- IoT primarily focuses on data collection and device communication
- WoT ensures device interoperability and access to the web.

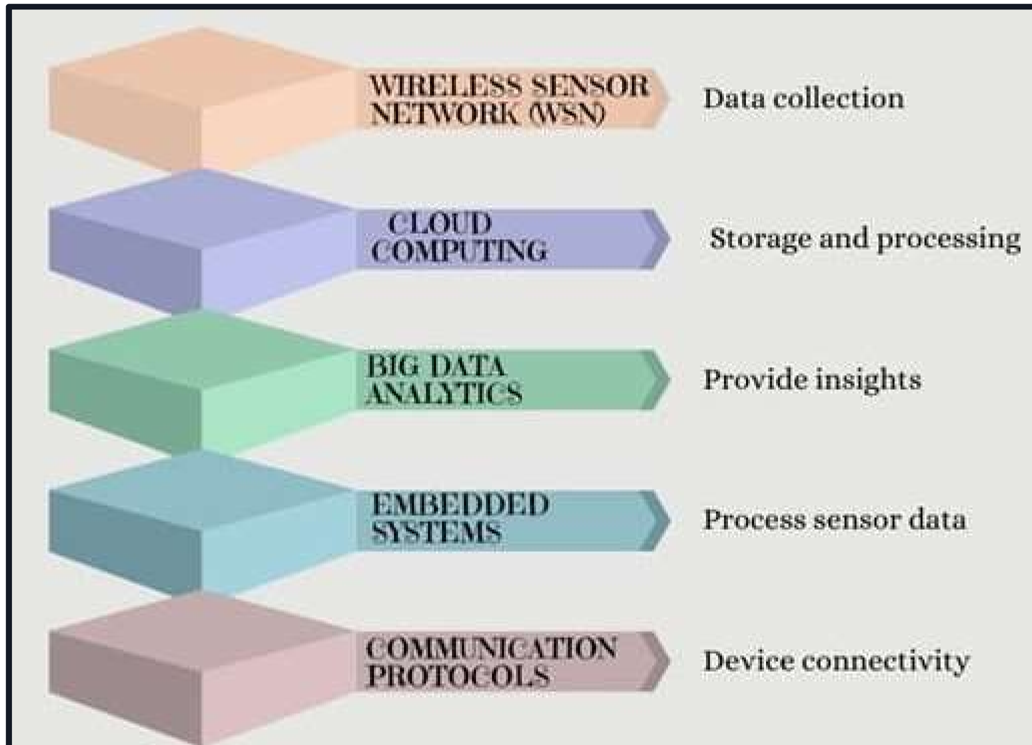
## IoT Versus WoT

| Feature | IoT | WoT |
|---|---|---|
| **Definition** | Network of interconnected physical devices | Standardized web-based integration of IoT devices |
| **Scope** | Broad, multi-industry (consumer, industrial, healthcare) | Web-based interoperability and accessibility |
| **Architecture** | Layered (devices, connectivity, cloud) | Web standards-based (HTTP, WebSockets, Thing Description) |
| **Communication** | Various protocols (MQTT, CoAP, HTTP) | Web protocols (HTTP, WebSockets, RESTful APIs) |
| **Connectivity** | Wi-Fi, Bluetooth, Zigbee, LoRa, 4G/5G | Internet/Web-based connectivity |
| **Data Utilization** | Cloud and edge computing, big data, analytics | Standardized data interaction via web technologies |
| **Interoperability** | Diverse ecosystem, often proprietary protocols | High interoperability using web standards |
| **Key Technologies** | Sensors, connectivity, cloud computing, edge computing | Thing Description, web protocols, semantic interoperability |
| **Security** | IoT-specific security measures | Web security standards (HTTPS, OAuth) |

# IoT Enabling Technologies

IoT(internet of things) enabling technologies are

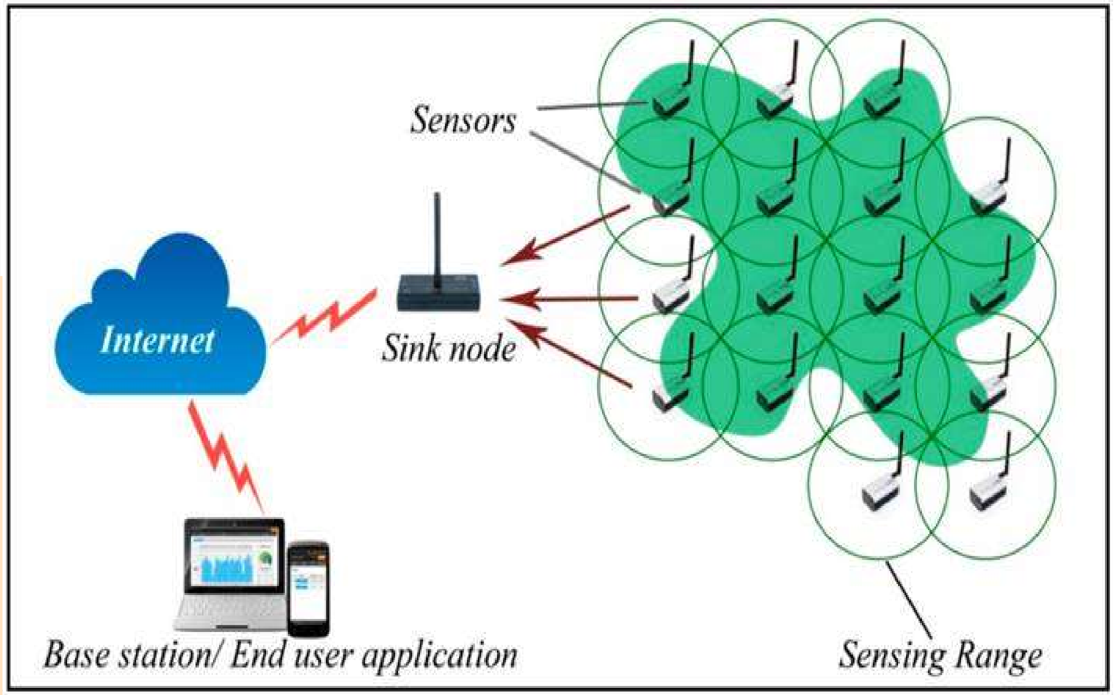
1. Wireless Sensor Network
2. Cloud Computing
3. Big Data Analytics
4. Communications Protocols
5. Embedded System



Enabling Technologies

## 1. Wireless Sensor Network

- A Wireless Sensor Network (WSN) is a collection of devices which communicate through wireless channels.
- A WSN consists of distributed devices with sensors which are used to monitor the environmental and physical conditions.
- A WSN consists of a number of end nodes, routers and coordinators.
- End nodes can also act as routers. A coordinator collects data from all the nodes and is connected to Internet.



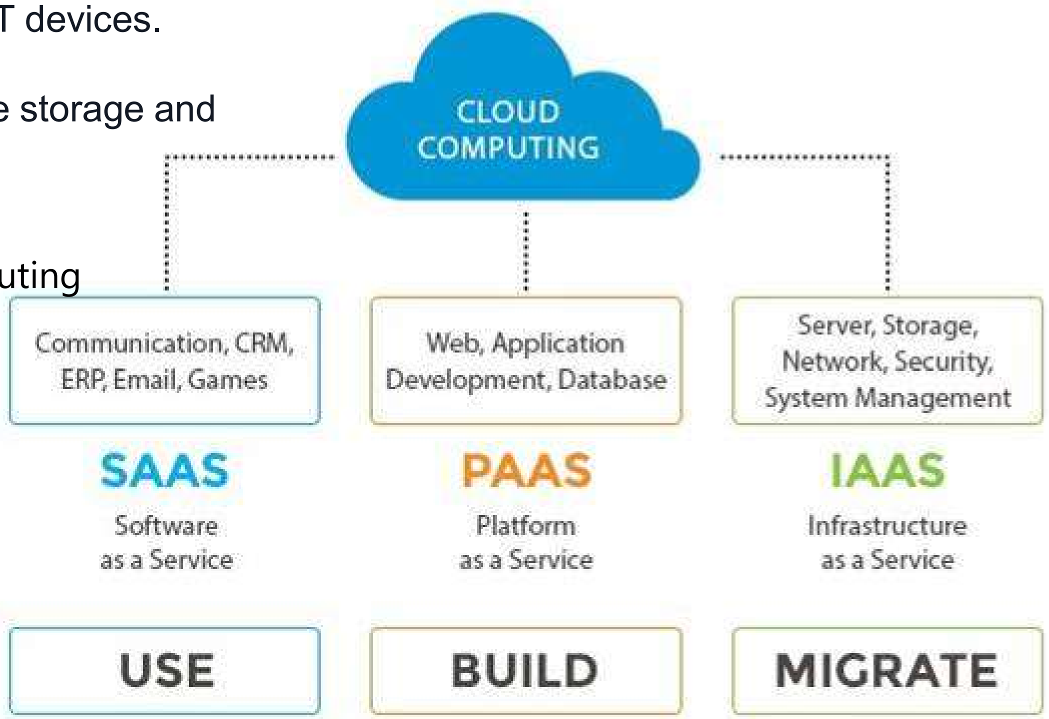

Examples of WSNs used in IoT systems:
- Weather monitoring systems
- Indoor air quality monitoring systems
- Soil moisture monitoring systems
- Surveillance systems
- Smart grids
- Structural health monitoring systems

## 2. Cloud Computing

- Cloud Computing is another important IoT-enabling technology.
- Massive amounts of data are generated by IoT devices.
- Cloud solutions offer scalable and dependable storage and processing for this data.

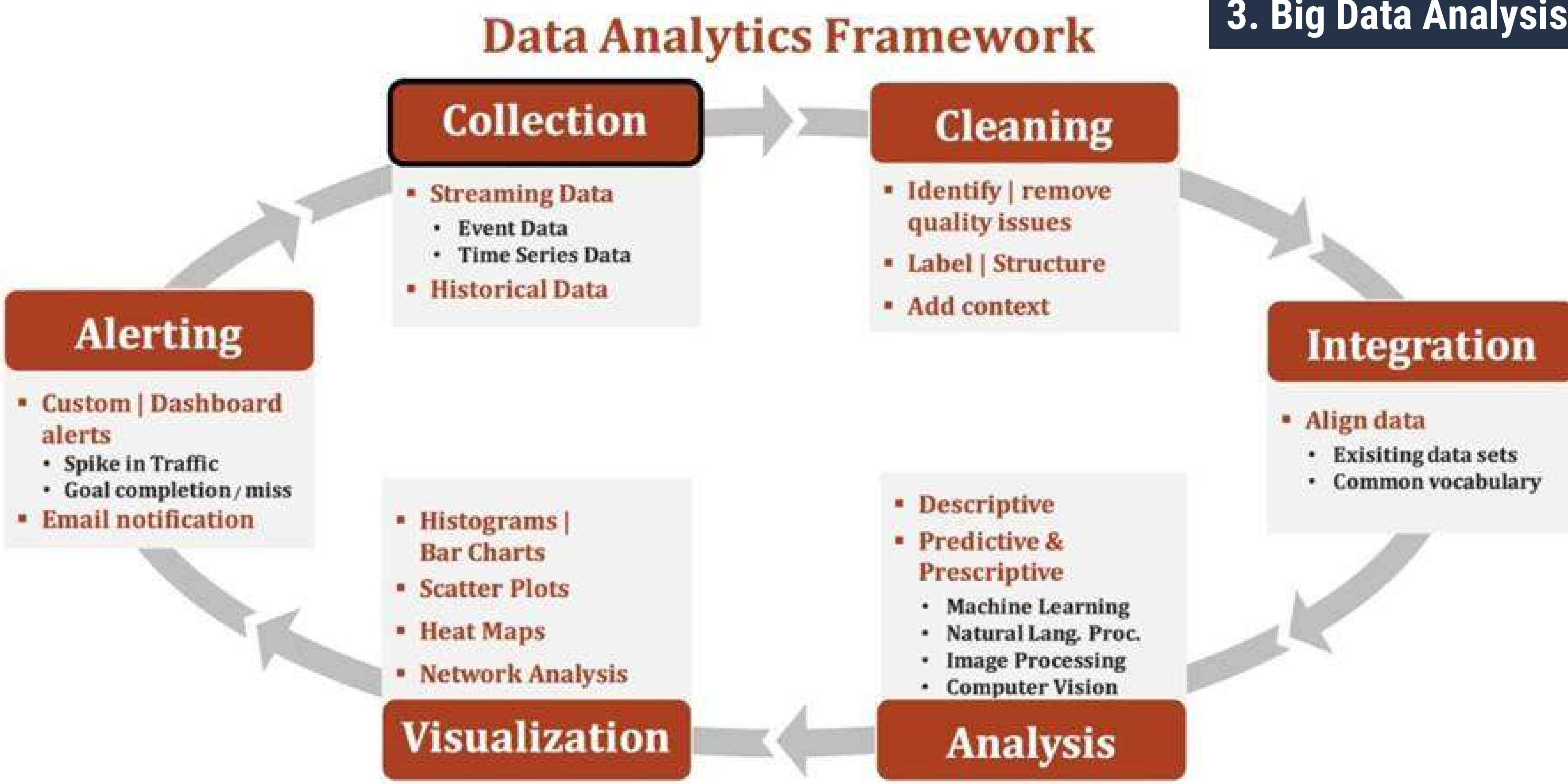
There are mainly three main types of cloud computing

- Infrastructure-As-A-Service (IAAS)
- Platform-As-A-Service (PAAS)
- Software-As-A-Service (SAAS)



BigData is a collection of data coming from various types of sources. The data is often huge which cannot be handled by the traditional databases and data warehouses.

## 3. Big Data Analysis



# 4. Communication Protocols

- IoT devices **communicate with each other** and with the central systems **via communication protocols**.
- These protocols enable efficient and secure data transfer in IoT networks.
- IoT (Internet of Things) communication protocols are required for devices to connect and share data in the IoT ecosystem.
- There are several popular IoT communication protocols, each with unique advantages and applications.
- Several important IoT communication protocols are
  - ✓ **Message Queue Telemetry Transport (MQTT)**
  - ✓ **Hypertext Transfer Protocol (HTTP)**
  - ✓ **Constrained Application Protocol (CoAP)**
  - ✓ **Bluetooth**
  - ✓ **Zigbee**
  - ✓ **Bluetooth Low Energy (BLE)**
  - ✓ **Wi-Fi**
  - ✓ **Z-Wave**

# 5. Embedded system

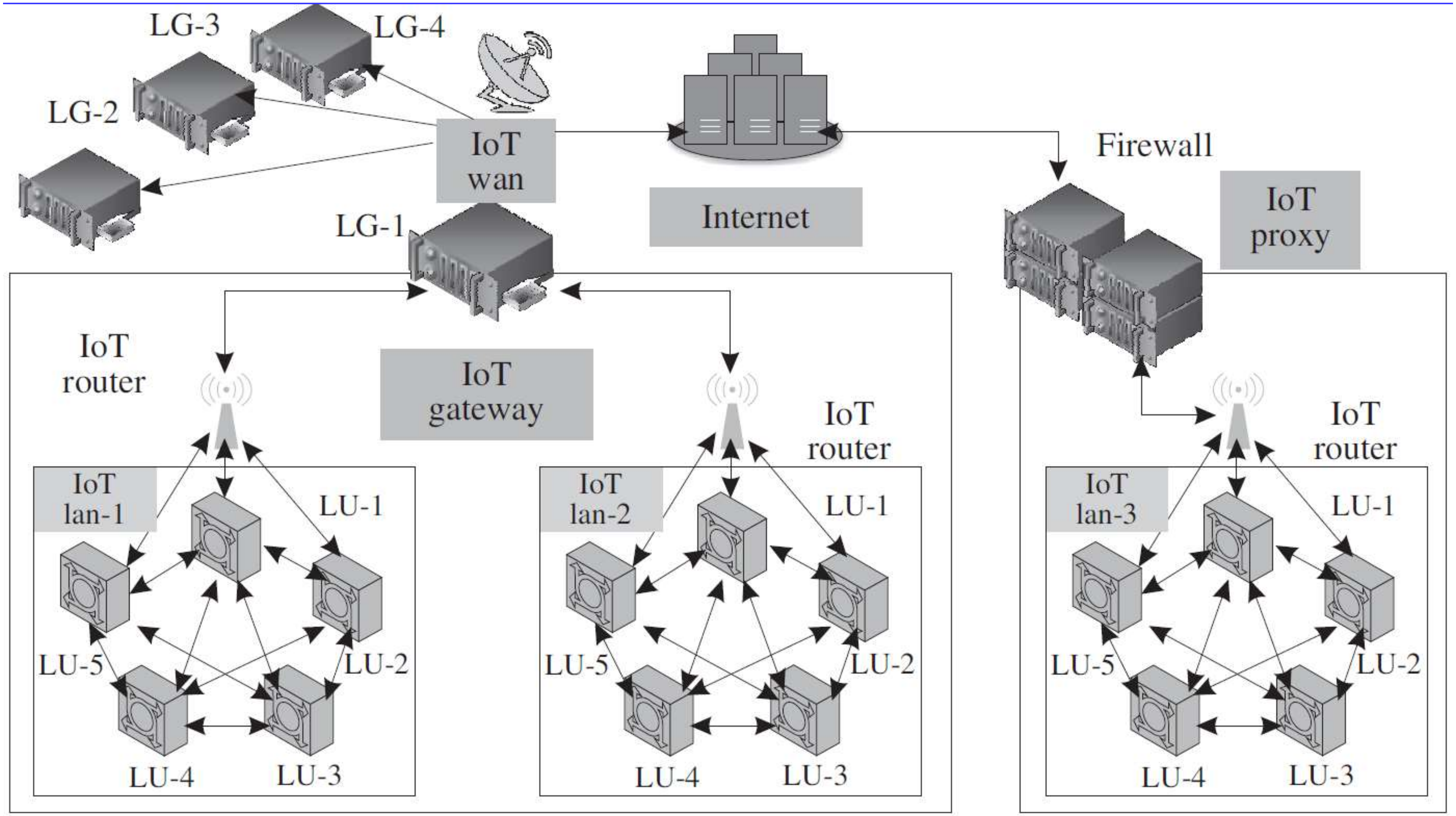
- It is a combination of **hardware and software** used to perform special tasks.
- It includes microcontroller and microprocessor memory, networking units (Ethernet Wi-Fi adapters), input output units (display keyword etc. ) and storage devices (flash memory).
- It collects the data and sends it to the internet.
- Some Embedded systems Examples are

1. **Digital camera** 3. **DVD player, music player**
2. **Industrial robots** 4. **Wireless Routers etc.**

# IoT Networking Components

IoT networking components

1) **IoT node**
2) **IoT router**
3) **IoT LAN**
4) **IoT WAN**
5) **IoT gateway**
6) **IoT proxy**


LG-3
LG-4
LG-2
IoT
wan
LG-1
Internet
Firewall
IoT
proxy
IoT
router
IoT
gateway
IoT
router
IoT
router
IoT
lan-1
LU-1
LU-5
LU-2
LU-4
LU-3
IoT
lan-2
LU-1
LU-5
LU-2
LU-4
LU-3
IoT
lan-3
LU-1
LU-5
LU-2
LU-4
LU-3

## IoT Networking Components

**IoT Node:** These are the devices that **collect data or perform tasks**. Examples include sensors, actuators, and smart devices.

**IoT Router:** A device that forwards data packets between different networks, ensuring that data from IoT nodes reaches its intended destination within the network.

**IoT LAN (Local Area Network):** A network that **connects IoT devices within a limited area**, such as a home or office. It enables communication between devices and local data processing.

**IoT WAN (Wide Area Network):** A broader network that connects **IoT LANs over large geographical areas**. It enables communication between devices and data centers or cloud services that are not in the same physical location.

**IoT Gateway:** A device that **bridges different networks, protocols, and data formats**. It acts as a translator and mediator between IoT nodes and the cloud or central data processing systems.

**IoT Proxy:** An intermediary that handles requests from IoT nodes to other servers or services. It can provide additional security, manage traffic, and perform caching.

## IoT Networking Components

**1.IoT Node:** These are the networking devices within an IoT LAN. Each of these devices is typically made up of a sensor, a processor, and a radio, which communicates with the network infrastructure (either within the LAN or outside it). The nodes may be connected to other nodes inside a LAN directly or by means of a common gateway for that LAN. Connections outside the LAN are through gateways and proxies.

**2. IoT Router:** An IoT router is a piece of networking equipment that is primarily tasked with the routing of packets between various entities in the IoT network; it keeps the traffic flowing correctly within the network. A router can be repurposed as a gateway by enhancing its functionalities.

**3. IoT LAN:** The local area network (LAN) enables local connectivity within the **purview of a single gateway**. Typically, they consist of **short-range connectivity technologies**. IoT LANs may or may not be connected to the Internet. Generally, they are localized within a building or an organization.

**4. IoT WAN:** The wide area network (WAN) connects various network segments such as LANs. They are typically **organizationally and geographically wide**, with their operational range lying between a few kilometers to hundreds of kilometers. **IoT WANs connect to the Internet** and enable Internet access to the segments they are connecting.

**5. IoT Gateway**: An IoT gateway is simply a **router connecting the IoT LAN to a WAN or the Internet**. Gateways can implement several LANs and WANs. Their primary task is to forward packets between LANs and WANs, and the IP layer using only layer 3.

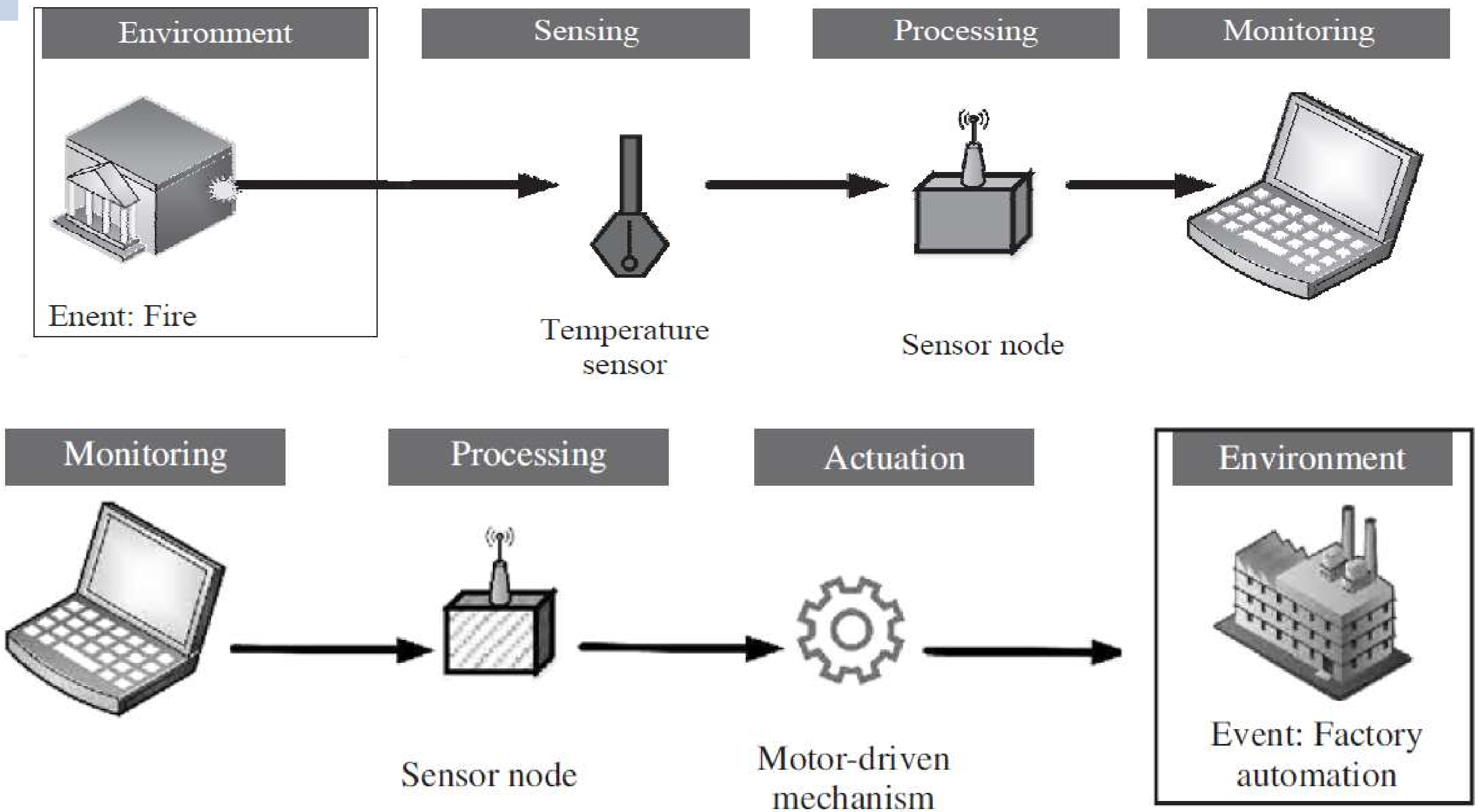
**6. IoT Proxy:** Proxies actively lie on the application layer and performs application layer functions between IoT nodes and other entities. Typically, application layer proxies are a means of providing security to the network entities under it ; it helps to extend the addressing range of its network.

# Sensors

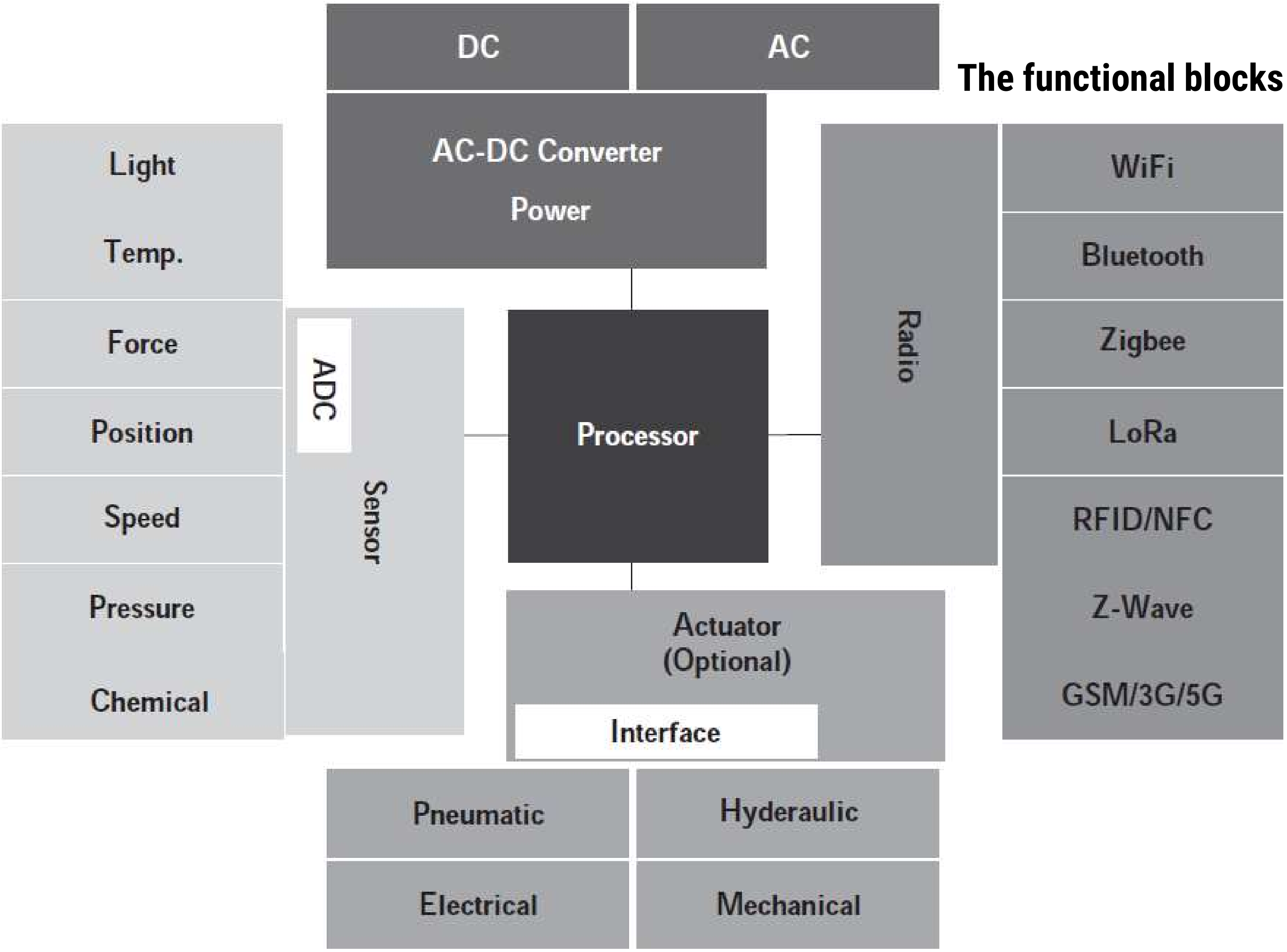
1. Infrared Sensor(IR Sensor)
2. Temperature & Thermocouple Sensors
3. Proximity Sensor
4. Ultrasonic sensor
5. Accelerometers Sensor
6. Gyroscope Sensor
7. Pressure Sensor
8. Hall Effect Sensor
9. Load cell
10. Light Sensor & Color Sensor
11. Touch Sensor
12. Tilt Sensor
13. PIR Motion Detector
14. Vibration Sensor
15. Metal detector Sensor
16. Water Flow Sensor
17. Heartbeat Sensor
18. Flow and Level Sensor
19. Smoke, Fog, Gas, Ethanol & Alcohol Sensor
20. Humidity Sensor
21. Soil Moisture Sensor
22. Rain Sensor

| Parameters | Transducers | Sensors | Actuators |
|---|---|---|---|
| Definition | Converts energy from one form to another. | Converts various forms of energy into electrical signals. | Converts electrical signals into various forms of energy, typically mechanical energy. |
| Domain | Can be used to represent a sensor as well as an actuator. | It is an input transducer. | It is an output transducer. |
| Function | Can work as a sensor or an actuator but not simultaneously. | Used for quantifying environmental stimuli into signals. | Used for converting signals into proportional mechanical or electrical outputs. |
| Examples | Any sensor or actuator | Humidity sensors, Temperature sensors, Anemometers (measures flow velocity), Manometers (measures fluid pressure), Accelerometers (measures the acceleration of a body), Gas sensors (measures concentration of specific gas or gases), and others | Motors (convert electrical energy to rotary motion), Force heads (which impose a force), Pumps (which convert rotary motion of shafts into either a pressure or a fluid velocity). |

# The outline of a simple sensing & actuation operation



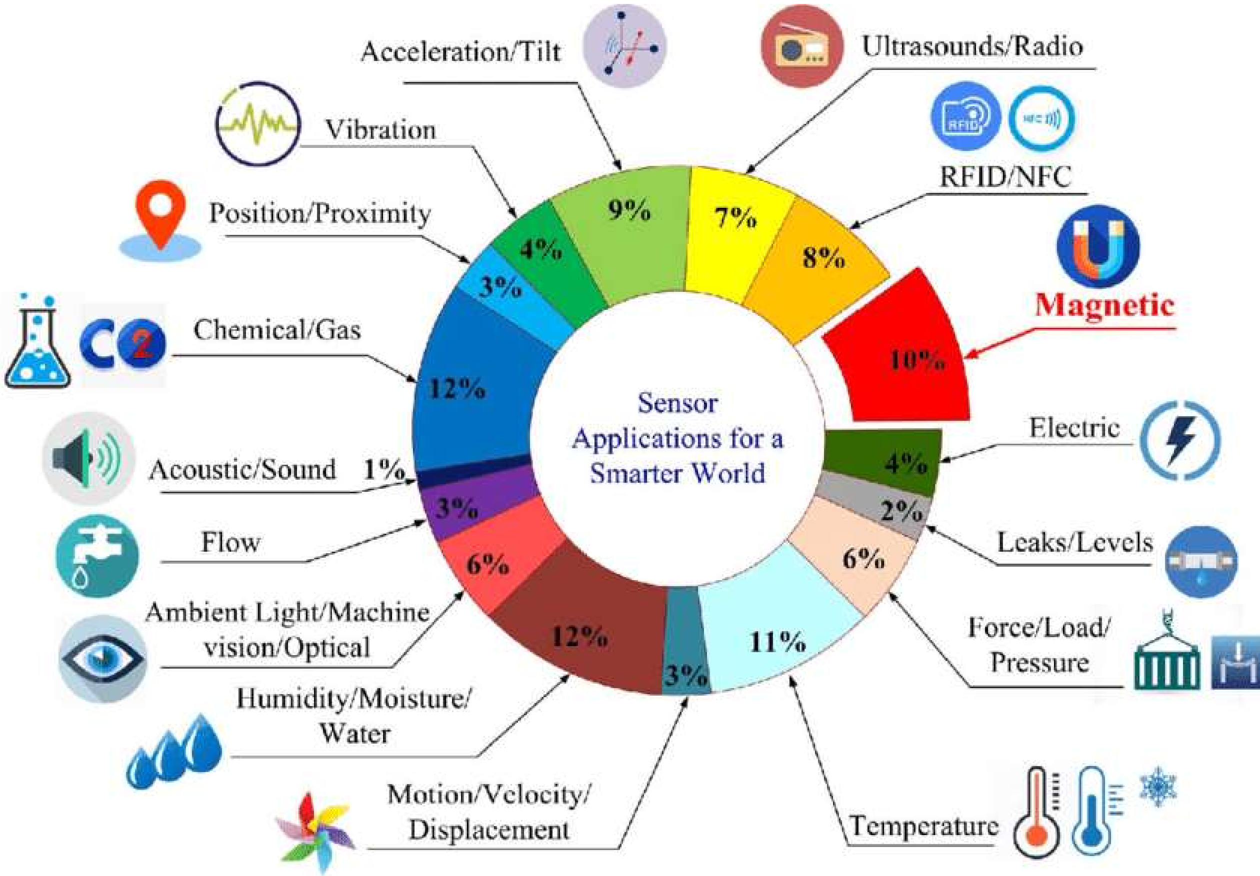
## The functional blocks of a typical sensor node in IoT



# Sensors

**A Sensor is a transducer device that converts energy from one form to another for any measurement or control purpose.**

- Temperature Sensor
- *Light intensity sensors*
- *Humidity sensor*
- *Gas sensor*
- *Ultrasound sensor*
- *Infrared sensors*

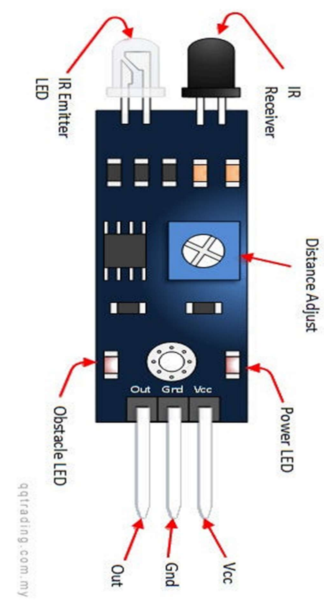


# Criteria to choose a Sensor

- ✓ Accuracy.
- ✓ Environmental condition- usually has limits for temperature/ humidity
- ✓ Range - Measurement limit of sensor.
- ✓ Calibration Essential for most of the measuring devices as the readings changes with time.
- ✓ Resolution Smallest increment detected by the sensor.
- ✓ Cost.
- ✓ Repeatability The reading that varies is repeatedly measured under the same environment.

# Infrared Sensor(IR Sensor)

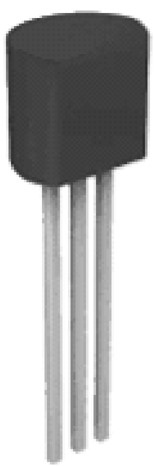
- An infrared sensor is an electronic instrument which is used to sense certain characteristics of its surrounding by either emitting and/or detecting motion.
- Infrared sensors are also capable of measuring the heat being emitted by an object and detecting motion.
- Infrared waves are not visible to human eye. In the electromagnetic spectrum, infrared radiations can be found between the visible and microwave regions.
- The Infrared waves typically have wavelengths range from 780nm to 1mm
- IR LED keeps transmitting infrared rays up to some range.
- When some objects comes in the IR range the IR wave hits the object and comes back at some angle
- The photodiode next to IR led detects the IR rays which got reflected from the object.



# Temperature Sensors

- It is a type of temperature sensor, which is made by joining two dissimilar metals at one end. The joined end is referred to as the HOT JUNCTION. The other end of these dissimilar metals is referred to as the COLD JUNCTION.

- The cold junction is formed at the last point of thermocouple material. If there is a difference in temperature between the hot junction and cold junction, a small voltage is created. This voltage is referred to as an EMF (electro-motive force) and can be measured and in turn used to indicate temperature.



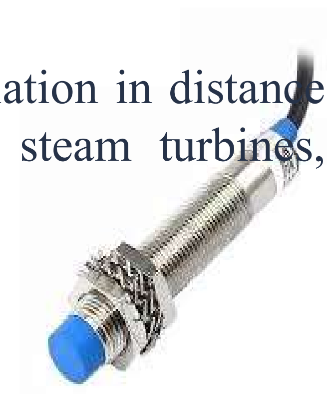
- CPU temperature

- Battery temperature

- Ambient temperature

# Proximity Sensor

- A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.
- A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared), and looks for changes in the field.
- There is no contact between the sensors and sensed object and lack of mechanical parts, these sensors have long functional life and high reliability.
- Proximity sensors are commonly used on smartphones to detect (and skip) accidental touchscreen taps when held to the ear during a call.
- They are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines, compressors, and motors that use sleeve-type bearings.



# Smoke, Fog, Gas Sensors

- This sensor is also used for Air quality monitoring, Gas leak alarm and for maintaining environmental standards in hospitals. In industries, these are used to detect the leakage of harmful gases.
- This sensor contains a sensing element, mainly aluminum-oxide based ceramic, coated with Tin dioxide, enclosed in a stainless steel mesh. Oxygen gets adsorbed on the surface of sensing material when it is heated in air at high temperature. Then donor electrons present in tin oxide are attracted towards this oxygen, thus preventing the current flow.
- When reducing gases are present, these oxygen atoms react with the reducing gases thereby decreasing the surface density of the adsorbed oxygen. Now current can flow through the sensor, which generated analog voltage values.

- These voltage values are measured to know the concentration of gas. Voltage values are higher when the concentration of gas is high.

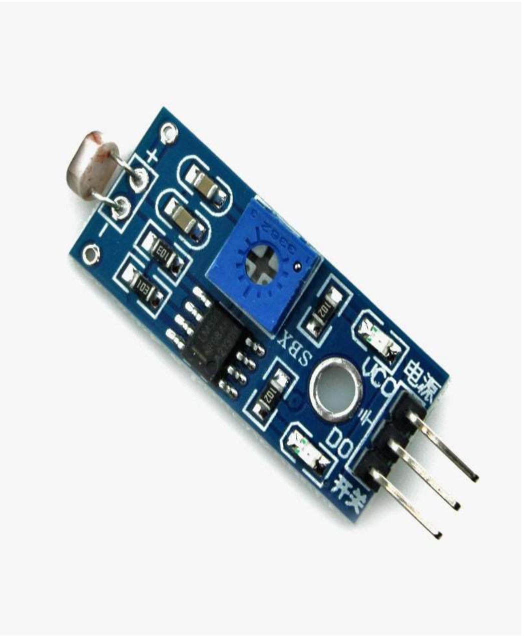
# Soil Moisture Sensor

- The fork-shaped probe with two exposed conductors acts as a variable resistor (similar to a potentiometer) whose resistance varies with the soil's moisture content.
- This resistance varies inversely with soil moisture:
- The more water in the soil, the better the conductivity and the lower the resistance.
- The less water in the soil, the lower the conductivity and thus the higher the resistance.
- The sensor produces an output voltage according to the resistance, which by measuring we can determine the soil moisture level.

# Light Sensor & Color Sensor

- Light sensors are a type of photodetector (also called photosensors) that detect light. Different types of light sensors can be used to measure illuminance, respond to changes in the amount of light received, or convert light to electricity.

- Light sensors work by the photoelectric effect. Light can behave as a particle, referred to as a photon. When a photon hits the metal surface of the light sensor, the energy of the light is absorbed by the electrons, increasing their kinetic energy and allowing them to be emitted from the material. This movement of electrons, and therefore charge, is electrical current.



# Ultra Sonic Sensor

- An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves.
- It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back.
- By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object.

➢Since it is known that sound travels through air at about 344 m/s, you can take the time for the sound wave to return and multiply it by 344meters to find the total round-trip distance of the sound wave.

➢Round-trip means that the sound wave traveled 2 times the distance to the object before it was detected by the sensor; it includes the 'trip' from the sonar sensor to the object AND the 'trip' from the object to the Ultrasonic sensor (after the soundwave bounced off the object).

# PIR Motion Detector

- PIR sensors allow you to sense motion, almost always used to detect whether a human has moved in or out of the sensors range.
- They are small, inexpensive, low-power, easy to use and don't wear out.
- For that reason they are commonly found in appliances and gadgets used in homes or businesses.

- They are often referred to as PIR, "Passive Infrared“ "Pyroelectric", or "IR motion" sensors.
- PIRs are basically made of a pyroelectric sensor (the round metal can with a rectangular crystal in the center), which can detect levels of infrared radiation.
- Everything emits some low level radiation, and the hotter something is, the more radiation is emitted.

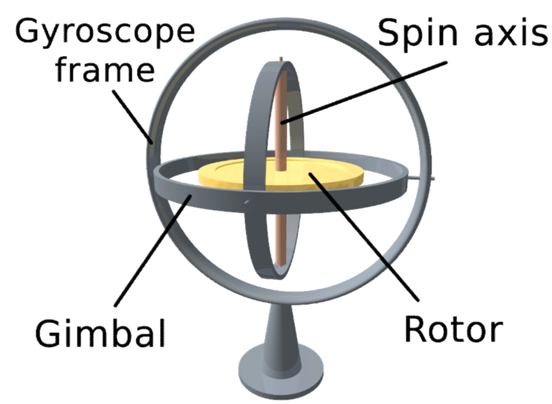
# Metal detector Sensor

- Metal detector is a device that can detect metal, the basics can make a sound when it is near some metal.
- Metal detectors work on the principle of transmitting a magnetic field and analyzing a return signal from the target and environment.
- when some metals are coming close to the coil the amplitude of the reflective pulse is getting little lower and a duration of the pulse a little longer.
- The need for detection is very clear to protect our self from any kind of danger.
- Metal detectors contain one or more inductor coils. When metal is placed in a close proximity to a varying magnetic field (generated by the coil or coils), currents are induced in the metallic part.
- These fields act in such a direction as to oppose that generated by the coils. The resultant field and using a specially designed electronic circuit can indicate the type of material being magnetize.

# Gyroscope Sensor

- Gyroscopes sensors is a micro-electromechanical device which is small, with inexpensive sensors which are used to measure angular velocity or rotational motion or displacement.


- The unit of angular velocity is measured in revolutions per second (RPS) or degrees per second. It simply measures the speed of rotation.




- Mechanically, Gyroscopes is a spinning wheel or disc mounted on an axle and the axle is free to assume directions.

- They rely on the same principle that is vibrating objects undergoing rotation.

# Actuators

- An Actuator is a part of a device or machine that helps it to achieve **physical movements** by converting energy, often electrical, air or hydraulic, into mechanical force.
- **Types of Actuators:**
  - Pneumatic (air pressure)
  - Hydraulic (fluid pressure)
  - Electric
    - Electro Mechanical
    - Electro Magnetic
  - Thermal actuators
  - Piezo actuator

# Sensor Characteristics

All sensors can be defined by their ability to measure or capture a certain phenomenon and report them as output signals to various other systems. However, even within the same sensor type and class, sensors can be characterized by their ability to sense the phenomenon based on the following three fundamental properties.

- **Sensor Resolution**: The smallest change in the measurable quantity that a sensor can detect is referred to as the resolution of a sensor. For digital sensors, the smallest change in the digital output that the sensor is capable of quantifying is its sensor resolution. The more the resolution of a sensor, the more accurate is the precision. A sensor's accuracy does not depend upon its resolution. For example, a temperature sensor **A** can detect up to 0.5 C changes in temperature; whereas another sensor **B** can detect up to 0.25 C changes in temperature. Therefore, the resolution of sensor **B** is higher than the resolution of sensor **A**.
- **Sensor Accuracy**: The accuracy of a sensor is the ability of that sensor to measure the environment of a system as close to its true measure as possible. For example, a weight sensor detects the weight of a 100 kg mass as 99.98 kg. We can say that this sensor is 99.98% accurate, with an error rate of 0.02%.
- **Sensor Precision**: The principle of repeatability governs the precision of a sensor. Only if, upon multiple repetitions, the sensor is found to have the same error rate, can it be deemed as highly precise. For example, consider if the same weight sensor described earlier reports measurements of 98.28 kg, 100.34 kg, and 101.11 kg upon three repeat measurements for a mass of actual weight of 100 kg. Here, the sensor precision is not deemed high because of significant variations in the temporal measurements for the same object under the same conditions.

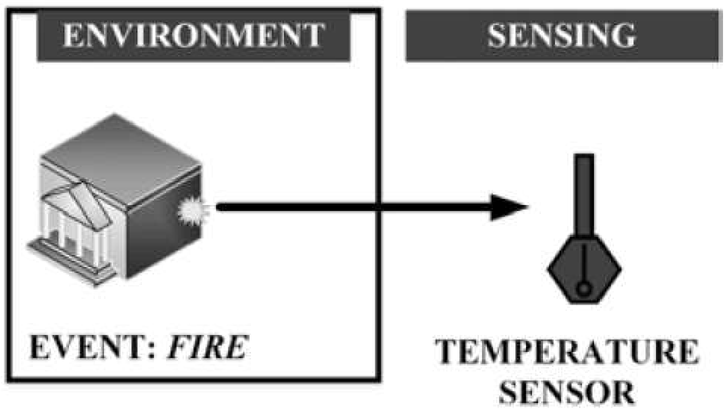
# Sensorial Deviations

- Sensor's output signal going beyond its designed maximum and minimum capacity for measurement, the sensor output is truncated to its maximum or minimum value, which is also the sensor's limits. The measurement range between a sensor's characterized minimum and maximum values is also referred to as the full-scale range of that sensor. In Real time the sensitivity of a sensor may differ from the value specified for that sensor leading to sensitivity error. This deviation is mostly attributed to sensor fabrication errors and its calibration.
- If the output of a sensor differs from the actual value to be measured by a constant, the sensor is said to have an **offset error or bias**. For example, while measuring an actual temperature of 0 C, a temperature sensor outputs 1.1 C every time. In this case, the sensor is said to have an offset error or bias of 1.1 C
- some sensors have a non-linear behavior. If a sensor's transfer function (TF) deviates from a straight line transfer function, it is referred to as its **non-linearity.**
- If the output signal of a sensor changes slowly and independently of the measured property, this behavior of the sensor's output is termed as **drift.** Physical changes in the sensor or its material may result in long-term drift.

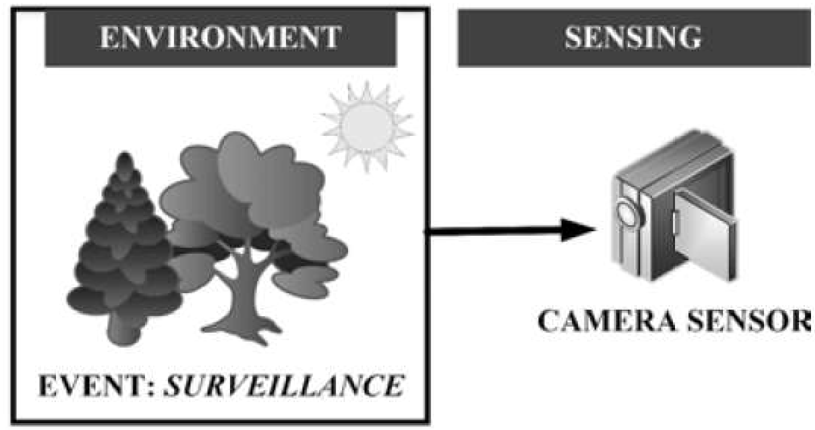
# Sensing Types

Sensing can be broadly divided into four different categories based on the nature of the environment being sensed and the physical sensors being used to do so

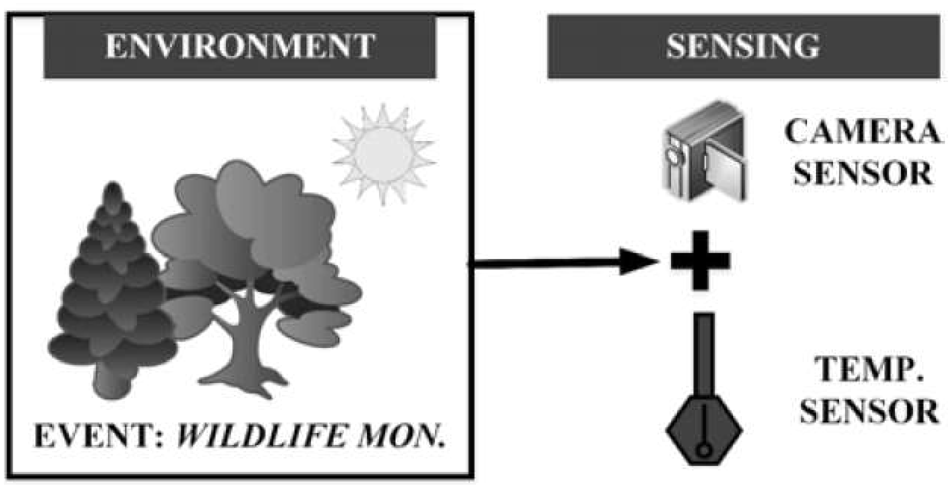
1) **scalar sensing**
2) Multimedia sensing
3) hybrid sensing
4) **virtual sensing**



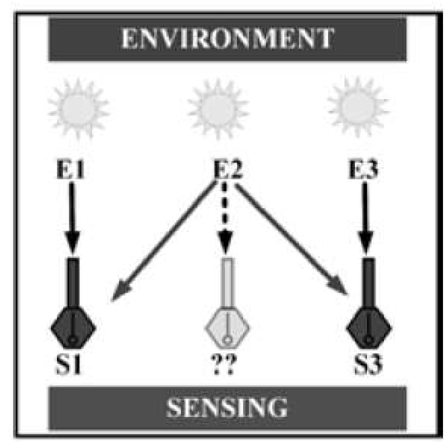

(a) Scalar sensing




(b) Multimedia sensing




(c) Hybrid sensing




(d) Virtual sensing

## Sensing Types

- **Scalar sensing** refers to the measurement of physical quantities that can be represented by a single value, or scalar, without direction. Scalars include temperature, pressure, humidity, and other parameters that have a magnitude but no direction.

  **Examples of Scalar Quantities:**
  Temperature (measured in degrees Celsius, Fahrenheit, etc.)
  Pressure (measured in Pascals, bar, etc.)
  Humidity (measured as a percentage)

- **Multimedia sensing** refers to the collection, processing, and analysis of data from multiple types of media, such as audio, video, images, and text, using various sensors and technologies. This approach is increasingly used in applications where understanding complex environments or events requires integrating and interpreting data from different sources.

## Sensing Types

**Hybrid sensor** is a device that combines multiple sensing technologies or types of sensors into a single unit to enhance performance, increase measurement accuracy, or enable the detection of multiple parameters simultaneously. Hybrid sensors can integrate different types of sensors, such as scalar sensors, vector sensors, virtual sensors, and even other advanced sensing technologies like optical, acoustic, or electromagnetic sensors.

**Virtual sensing** refers to the use of mathematical models, algorithms, and data from physical sensors to estimate or predict the value of a quantity that is not directly measurable with a physical sensor

**Examples of Virtual Sensing:**

Estimating the internal temperature of an engine by using external temperature sensors, engine speed, and other related data.

# Sensing Considerations

The choice of sensors in an IoT sensor node is critical and can either make or break the feasibility of an IoT deployment. The following major factors influence the choice of sensors in IoT-based sensing solutions:

1) Sensing range

2) Accuracy and Precision

3) Energy

4) Device size

# Actuator Types

Broadly, actuators can be divided into seven classes:

1) Hydraulic
2) Pneumatic
3) Electrical
4) Thermal/magnetic
5) Mechanical
6) Soft
7) Shape memory polymers.

# Actuator Characteristics

The choice or selection of actuators is crucial in an IoT deployment, where a control mechanism is required after sensing and processing of the information obtained from the sensed environment. Actuators perform the physically heavier tasks in an IoT deployment

- Weight
- Power Rating
- Torque to Weight Ratio
- Stiffness and Compliance