Chapter Four: Internet of Things (IoT)

- This chapter covers:
  - Overview of the Internet of Things (IoT)
  - Architecture of IoT
  - IoT tools and platforms
  - Applications of IOT

Overview of IOT

- The most important features of IoT include artificial intelligence, connectivity, sensors, active engagement, and small device use. A brief review of these features is given below-
  - AI − IoT essentially makes virtually anything “smart”, meaning it enhances every aspect of life with the power of data collection, artificial intelligence algorithms, and networks.
  - Connectivity − New enabling technologies for networking and specifically IoT networking, mean networks are no longer exclusively tied to major providers.
  - Sensors − IoT loses its distinction without sensors.
    - Sensors are devices that can measure a physical quantity(like temperature, humidity, etc.) and convert it into signal, which can be read and interpreted by the microcontroller unit.

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- **Active Engagement − Much of today's interaction with connected technology happens through passive engagement. IoT introduces a new paradigm for active content, product, or service engagement.**
- **Small Devices − Devices, as predicted, have become smaller, cheaper, and more powerful over time. IoT exploits purpose-built small devices to deliver its precision, scalability, and versatility.**

What is IOT?

- IoT is the networking of smart objects, meaning a huge number of devices intelligently communicating in the presence of internet protocol that cannot be directly operated by human beings but exist as components in buildings, vehicles or the environment. (Internet Architecture Board's (IAB))
- IoT is the networking of smart objects in which smart objects have some constraints such as limited bandwidth, power, and processing accessibility for achieving interoperability among smart objects. (Internet Engineering Task Force (IETF) organization's)
- IoT is a framework of all things that have a representation in the presence of the internet in such a way that new applications and services enable the interaction in the physical and virtual$_4$ world in the form of Machine-to-Machine (M2M) communication in

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- **IoT is the interaction of everyday object's computing devices through the Internet that enables the sending and receiving of useful data. (Oxford dictionary's)**
- **The term Internet of Things (IoT) according to the 2020 conceptual framework is expressed through a simple formula such as:**

IoT= Services+ Data+ Networks + Sensors

Generally, IoT is a network of devices that can sense, accumulate and transfer data over the internet without any human intervention.

IoT is "Smart Object Networking".

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- **The internet of things (IoT) has found its application in several areas such as**
  - **Connected industry,**
  - **smart-city,**
  - **smart-home,**
  - **smart-energy,**
  - **Connected car,**
  - **smart agriculture,**
  - **Connected building and campus,**
  - **health care,**
  - **Logistics and etc.**


IoT
Internet of Things



Figure 4.1 IoT in different domains

- **IoT utilizes existing and emerging technology for sensing, networking, and robotics.**

History of IoT

- **Evolution of Internet (1995-2015)**



- **Internet of Things term was first coined by British pioneer Kevin Ashton in 1999.**

IoT – Advantages

- **Improved Customer Engagement**
- **Technology Optimization**
- **Reduced Waste**
- **Enhanced Data Collection**

IoT – Disadvantages

Here is a list of some of the disadvantages of IoT. these are:

- **As the number of connected devices increases and more information is shared between devices, the potential that a hacker could steal confidential information also increases.**
- **If there's a bug in the system, it's likely that every connected device will become corrupted.**
- **Since there's no international standard of compatibility for IoT, it's difficult for devices from different manufacturers to communicate with each other.**
- **Enterprises may eventually have to deal with massive numbers maybe even millions of IoT devices and collecting and managing the data from all those devices will be challenging.**

How does it work?

- An IoT ecosystem consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments.
- IoT devices share the sensor data they collect by connecting to an IoT gateway or another edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another.
- The devices do most of the work without human intervention, although people can interact with the devices.

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- Most likely the communication between IOT devices and internet is performed in two ways:
  - There is an internet-enabled intermediate node acting as a gateway.
  - The IOT device has direct communication to the internet.
- In the first case, the device is commonly connected to the computer and sends data to it using e.g. a USB port. The computer receives the data and using appropriate software it forwards it to the internet.
- In the second case, things are much simpler and devices can function and communicate more autonomously.

Three types of Interactions in IoT

1. **Device to Device communication.**
   - **Device-to-device communication model is generally used in home automation.**
   - **Low data rate requirement.**
   - **Example : Lights, bulbs, locks and thermostat send small amount of information to [illegible]er.**



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2. Device to Cloud communication.

- **Device-to-cloud communication model is used to extend the capability of device by sending data to cloud for analysis.**
- **Example 1: Nest Lab Learning Thermostat: Device sends data to cloud to analyze the home energy consumption.**
- **Example2 : Samsung Smart TV: Sends user viewing information to Samsung and enable interactive voice recognition system.**



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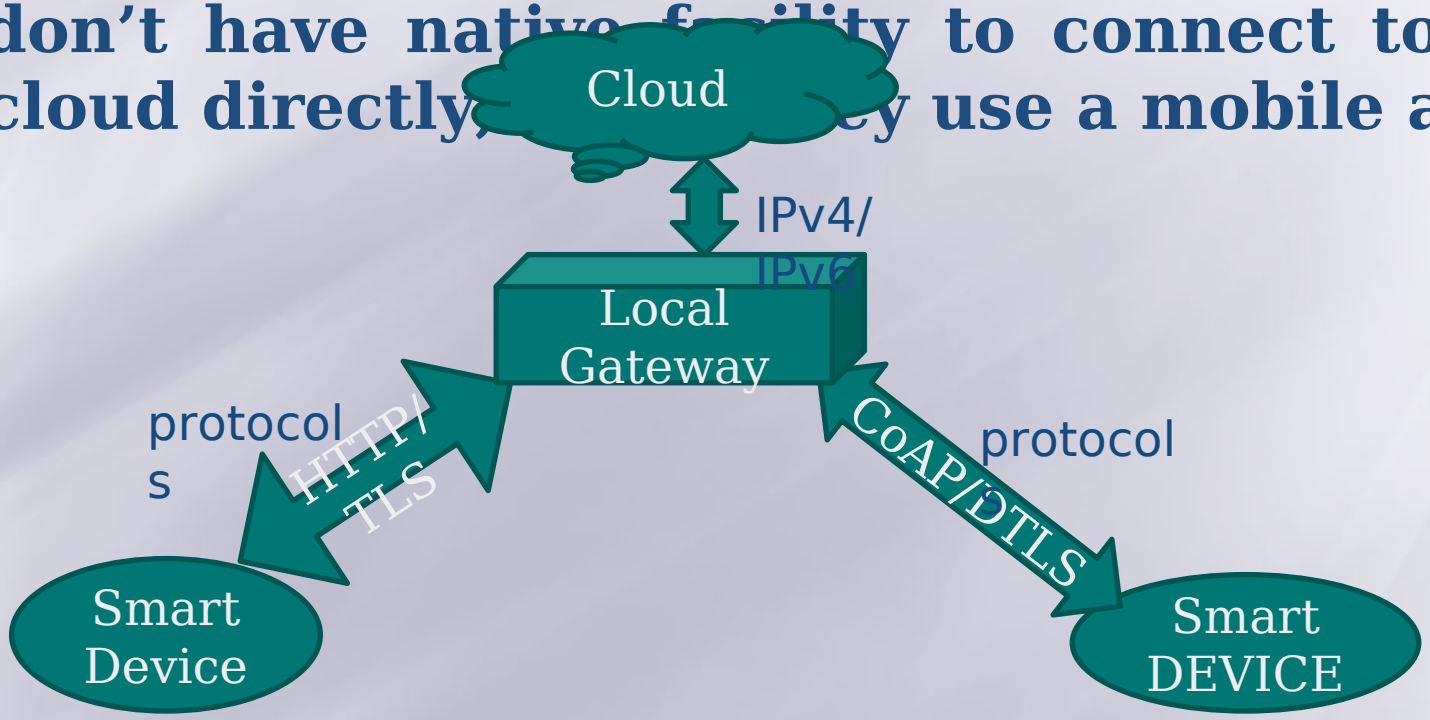
3. Device to Gateway communication

- A gateway device is used between device and cloud in the device-to-gateway communication model.
- **Example: Fitness tracker.** These devices don't have native facility to connect to the cloud directly, they use a mobile app.



Architecture of IoT

- In general, an IoT device can be explained as a network of things that consists of hardware, software, network connectivity, and sensors. Hence, the architecture of IoT devices comprises four major components: sensing, network, data processing, and application layers

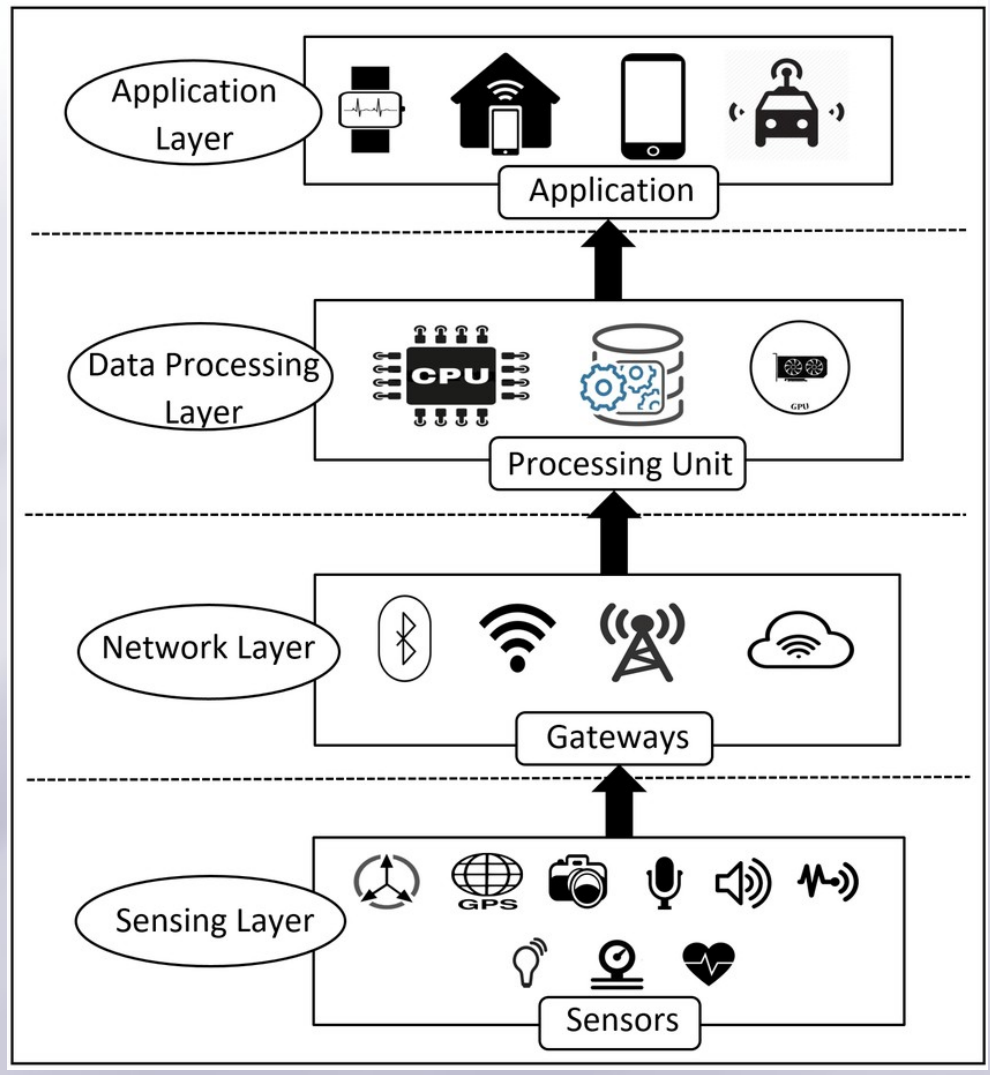


Fig 4.2. Architecture of IoT

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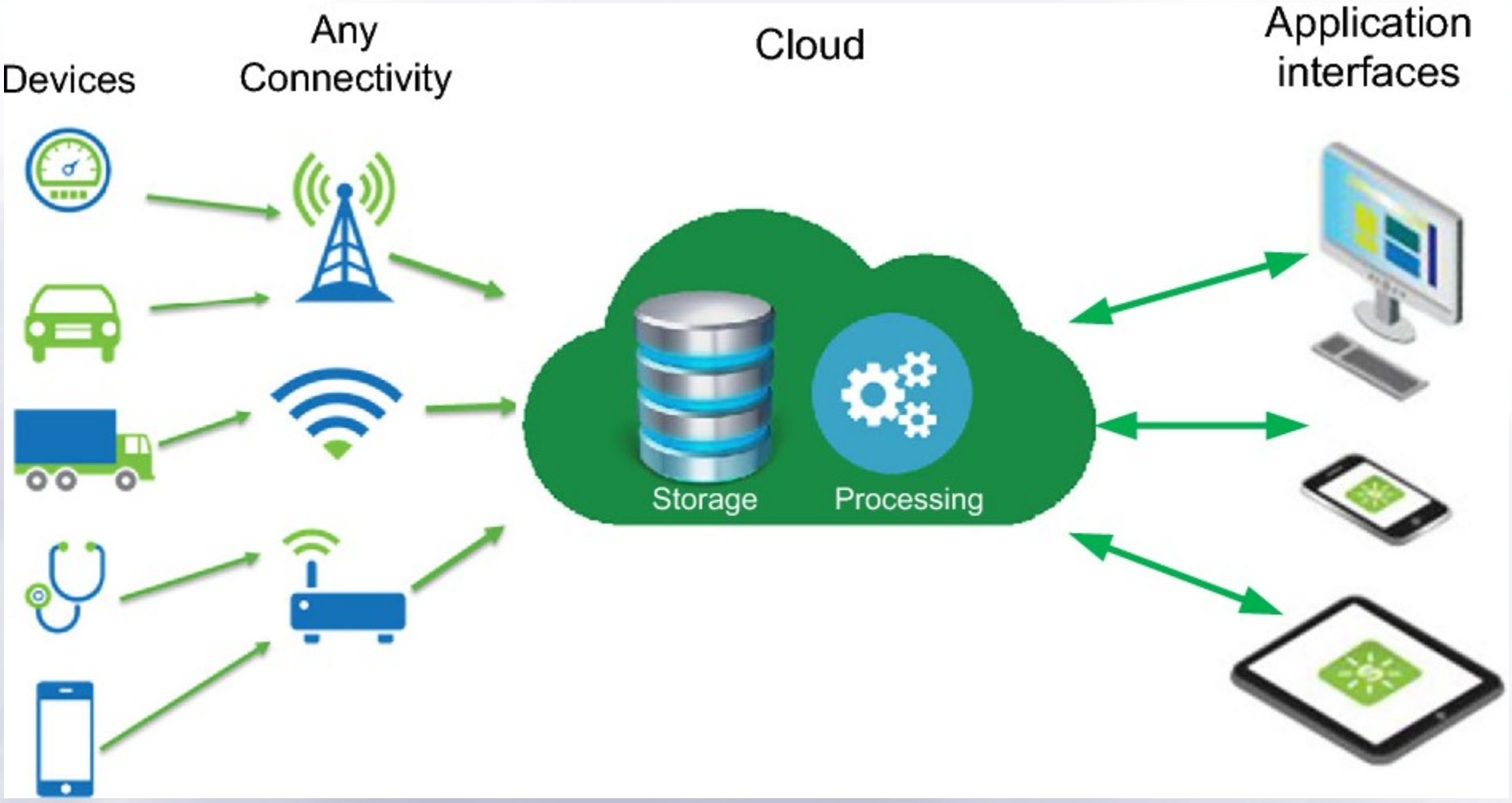

Fig 4.2. Architecture of IoT

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. Using multiple sensors for applications is one of the primary features of IoT devices.
- These are the small, memory-constrained, often battery-operated electronics devices with onboard sensors and actuators. These could either function as standalone sensing devices or be embedded as part of a bigger machinery for sensing and control. Three main capabilities of a typical IOT device are:
  - being able to sense and record data
  - being able to perform light computing and finally
  - being able to connect to a network and communicate the data

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- Sensors in IoT devices can be classified into three broad categories as described below:

A. **Motion Sensor-** Motion sensors measure the change in motion as well as the orientation of the devices. There are two types of motions one can observe in a device:

- Linear motion : refers to the linear displacement of an IoT device.
- Angular motion: refers to the rotational displacement of the device.

- **What is the role of motion Sensors?**

Example of Home security

- **Motion sensors** stand guard, ready to react to various situations, such as movement in your living room, windows or doors being opened or closed, or a broken window.

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Motion sensors can:

- Trigger a doorbell when someone approaches the front door
- Alert you when kids enter restricted areas in the home, like the basement, workout room, or medicine cabinet
- Save energy by using motion sensor lighting in unoccupied spaces
- Notify you if animals enter areas where they’re not supposed to be



Fig 4

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B. Environmental Sensors: Sensors such as Light sensors, Pressure sensors, etc. are embedded in IoT devices to sense the change in environmental parameters in the device's peripheral.

- The primary purpose of using environmental sensors in IoT devices is to help the devices to take autonomous decisions according to the changes of a device's peripheral.
- Environmental sensors are used to sense parameters in the physical environment such as temperature, humidity, pressure, water pollution, and air pollution.
- For instance, environment sensors are used in many applications to improve user experience (e.g., home automation systems, smart locks, smart lights, etc.).

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What is the role of Environmental Sensors?

Example of Environmental monitoring

- Monitoring water for quality, pollutants, thermal contaminants, chemical leakages, the presence of lead, and flood water levels.
- Monitoring soil for moisture and vibration levels in order to detect and prevent landslides.
- Monitoring forests and protected land for forest fires.
- Monitoring for natural disasters like earthquake and tsunami warnings
- Monitoring data centers for air température and humidity
- Monitoring Air pollution, Soil moisture, Water quality.

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C. Position sensors: Position sensors of IoT devices deal with the physical position and location of the device.

- The most common position sensors used in IoT devices are
  - Magnetic sensors and Global Positioning System (GPS) sensors.
    - Magnetic sensors are usually used as digital compass and help to fix the orientation of the device display.
    - GPS is used for navigation purposes in IoT devices.
- A position sensor is any device used for measuring the distance traveled by a body starting from its reference position.
- This type of sensor can also be used to detect the presence or absence of an object.

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, ZWave, LoRa, cellular network, etc.) to allow data flow between other devices within the same network.

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 make 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.

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 that executes various tasks for the users.
- There exist diverse IoT applications, which include smart transportation, smart home, personal care, healthcare, etc.

IoT Tools and Platforms

- There are many vendors in the industrial IoT platform marketplace, offering remarkably similar capabilities and methods of deployment.
- These IoT Platform Solutions are based on the Internet of Things and cloud technology.
- They can be used in areas of smart home, city, enterprise, home automation, healthcare or automotive, just to name a few.

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- **KAA**
  - **Manage an unlimited number of connected devices**
  - **Set up cross-device interoperability**
  - **Perform real-time device monitoring**
  - **Perform remote device provisioning and configuration**
  - **Collect and analyze sensor data**
  - **Analyze user behavior and deliver targeted notifications**
  - **Create cloud services for smart products**

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- **SiteWhere**
  - **Run any number of IoT applications on a single SiteWhere instance**
  - **Spring delivers the core configuration framework**
  - **Add devices through self-registration**
  - **Integrates with third-party integration frameworks such as Mule any point**
  - **Default database storage is MongoDB**
  - **Eclipse Californium for CoAP messaging**
  - **InfluxDB for event data storage**
  - **Grafana to visualize SiteWhere data**

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- **ThingSpeak**
  - **Collect data in private channels**
  - **Share data with public channels**
  - **MATLAB analytics and visualizations**
  - **Alerts**
  - **Event scheduling**
  - **App integrations**
  - **Worldwide community**

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DeviceHive

- Directly integrate with Alexa
- Visualization dashboard of your choice
- It supports Big data solutions such as ElasticSearch, Apache Spark, Cassandra and Kafka for real-time and batch processing.
- Connect any device
- It comes with Apache Spark and Spark Streaming support.
- Supports libraries written in various programming languages, including Android and iOS libraries
- It allows running batch analytics and machine learning on top of your device data

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- **Zetta**
  - Supports a wide range of hacker boards
  - Zetta allows you to assemble smartphone apps, device apps, and cloud apps
- **ThingsBoard**
  - Real-time data visualization and remote device control.
  - Customizable rules, plugins, widgets and transport implementations. Allows monitoring client-side and provision server-side device attributes.
  - Support multi-tenant installations out-of-the-box.
  - Supports transport encryption for both MQTT and HTTP(s) protocols.

Applications of IoT

- The versatile nature of IoT makes it an attractive option for so many businesses, organizations, and government branches, that it doesn’t make sense to ignore it. Here’s a sample of various industries, and how IoT can be best applied.
- Agriculture
  - For indoor planting, IoT makes monitoring and management of microclimate conditions a reality, which in turn increases production.
  - For outside planting, devices using IoT technology can sense soil moisture and nutrients, in conjunction with weather data, better control smart irrigation and fertilizer systems.

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Applications of IoT in Agriculure

- Monitoring quality of soil in real time
- Regulating water supply and controlling usgae of water
- Monitoring and measuring humidity, temperature etc.
- Warehouse monitoring for fire hazards or pests - a lot of crop is damanged in storage.
- It helps identify sick animals so they can be pulled from the herd, preventing the spread of disease.



Fig 4.4. IoT in Agriculture

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Fig 4.5 Technical farmer use wifi computer control agricultural drone

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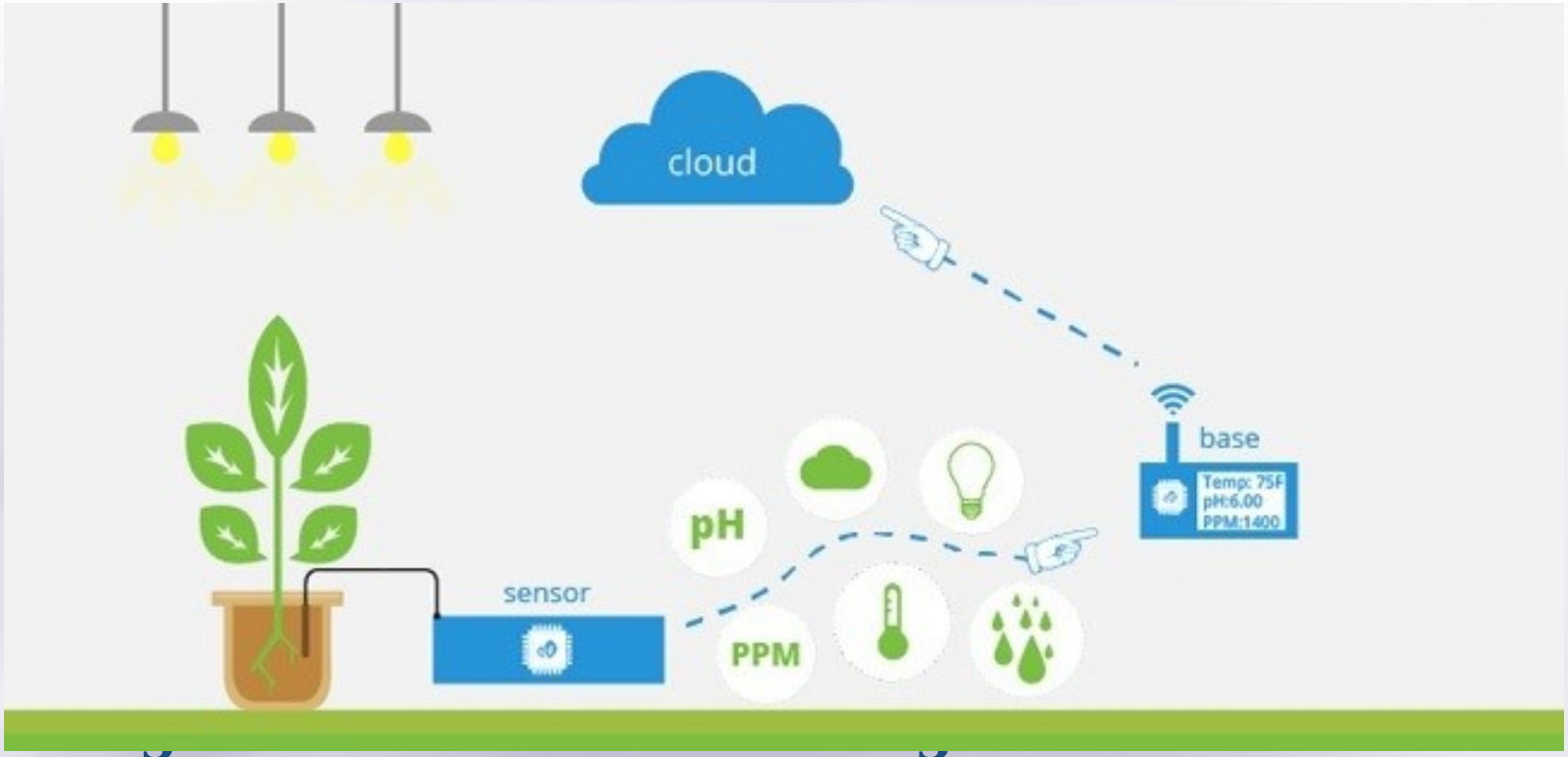

- **Temperature, humidity, light intensity, and soil moisture can be monitored through various sensors.**

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Consumer Use

- For private citizens, IoT devices in the form of wearables and smart homes make life easier. Wearables cover accessories such as smartphones, Apple watches, health monitors, to name a few. These devices improve entertainment, network connectivity, health, and fitness.
- Security is made more accessible as well, with the consumer having the ability to control appliances and lights remotely, as well as activating a smart lock to allow the appropriate people to enter the house even if they don’t have a key.

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Healthcare

- Wearable IoT devices let hospitals monitor their patients' health at home, thereby reducing hospital stays while still providing up to the minute realtime information that could save lives.
- In hospitals, smart beds keep the staff informed as to the availability, thereby cutting wait time for free space.
- Sensors can also determine if a patient has fallen or is suffering a heart attack.

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Insurance

- Insurance companies can offer their policyholders discounts for IoT wearables such as Fitbit. By employing fitness tracking, the insurer can offer customized policies and encourage healthier habits, which in the long run benefits everyone, insurer, and customer alike.

Manufacturing

- RFID and GPS technology can help a manufacturer track a product from its start on the factory floor to its placement in the destination store, the whole supply chain from start to finish. These sensors can gather information on travel time, product condition, and environmental conditions that the product was subjected to.
- Sensors attached to factory equipment:
  - To identify bottlenecks in the production line, thereby reducing lost time and waste.
  - To track the performance of the machine, predicting when the unit will require maintenance, thereby preventing costly breakdowns.

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Retail

- Online and in-store shopping sales figures can control warehouse automation and robotics, information gleaned from IoT sensors. Much of this relies on RFIDs, which are already in heavy use worldwide.

IoT Based Smart Home

- **Smart Home initiative allows subscribers to remotely manage and monitor different home devices from anywhere via smartphones or over the web with no physical distance limitations.**
- **The concept of a Smart Home has become a reality where all devices are integrated and interconnected via the wireless network.**
- **These “smart” devices have the potential to share information with each other given the permanent availability to access the broadband internet connection.**

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- **Remote Control Appliances:** Switching on and off remotely appliances to avoid accidents and save energy.
- **Weather**: Displays outdoor weather conditions such as humidity, temperature, pressure, wind speed and rain levels with the ability to transmit data over long distances.
- **Smart Home Appliances:**
  - Refrigerators with LCD screen telling what's inside, food that's about to expire, ingredients you need to buy and with all the information available on a smartphone app.
  - Washing machines allowing you to monitor the laundry remotely.
  - The kitchen ranges with the interface to a Smartphone app allowing remotely adjustable temperature control and monitoring the oven's self-cleaning feature.

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- **Safety Monitoring:** cameras, and home alarm systems making people feel safe in their daily life at home.
- **Intrusion Detection Systems:** Detection of window and door openings and violations to prevent intruders.
- **Energy and Water Use:** Energy and water supply consumption monitoring to obtain advice on how to save cost and resources, & many more.

IoT Based Smart City

- **Structural Health:** Monitoring of vibrations and material conditions in buildings, bridges





Future trends: Using sensors and drones for monitoring Bridge



Building collapsed in Thane, August 5, 2015

Recent train accident in M.P. on August 4, 2015

Poor structural monitoring

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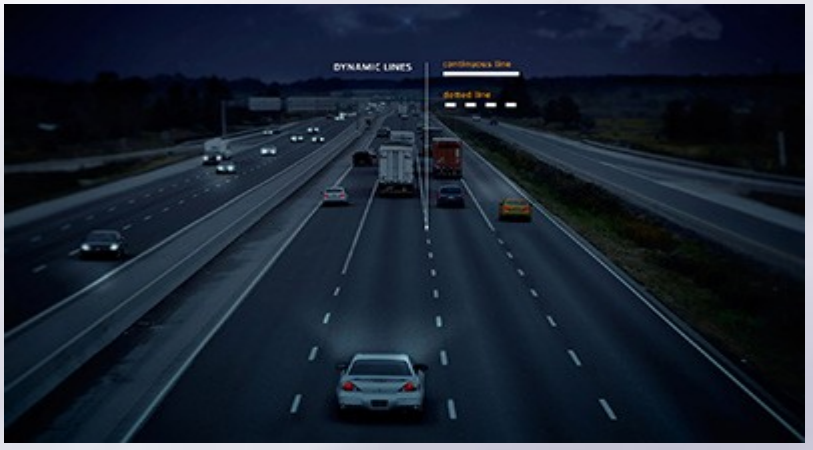
- **Lightning:** intelligent and weather adaptive lighting in street lights.







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- **Smart Parking: Real-time monitoring of parking spaces available in the city making residents able to identify and reserve the closest available spaces.**



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- **Safety:** Digital video monitoring, fire control management, public announcement systems.
- **Transportation:** Smart Roads and Intelligent High-ways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.
- **Waste Management:** Detection of rubbish levels in containers to optimize the trash collection routes. Garbage cans and recycle bins with RFID tags allow the sanitation staff to see when garbage has been put out.

IoT Based Smart Farming

- **Green Houses:** Control micro-climate conditions to maximize the production of fruits and vegetables and its quality.
- **Compost:** Control of humidity and temperature levels in alfalfa, hay, straw, etc. to prevent fungus and other microbial contaminants.
- **Offspring Care:** Control of growing conditions of the offspring in animal farms to ensure its survival and health.
- **Field Monitoring:** Reducing spoilage and crop waste with better monitoring, accurate ongoing data obtaining, and management of the agriculture fields, including better control of fertilizing, electricity and watering.

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- **Animal Farming/Tracking:** Location and identification of animals grazing in open pastures or location in big stables, Study of ventilation and air quality in farms and detection of harmful gases from excrements.
  - **Cattle monitoring and management:** there are IoT agriculture sensors that can be attached to the animals on a farm to monitor their health and log performance.
    - It helps identify sick animals so they can be pulled from the



Examples of Smart Farming




5 Smart Building
9 Intelligent Retail
4 Smart Parking
3 Factory Warehouse
2 Logistics
6 Structural Healthcare
8 Home Automation