# Introduction of IoT

# Internet Of Things

- IOT comprises of things that have unique identities and are connected to the Internet.

- While many existing devices such as 4G enables mobile phones are also connected to the Internet, the focus on IOT is in the configuration, control and networking of devices that are traditionally not associated with the Internet.

# Internet Of Things

- These devices may include
  - Thermostat (A thermostat is a regulating device component which senses the temperature of a physical system and performs actions so that the system's temperature is maintained near a desired setpoint),
  - Utility meter (Electricity meter, gas meter, water meter, heat meter),
  - Irrigation pumps (An irrigation pump is a pump used for providing water to a section of land),
  - Sensors (a device which detects or measures a physical property and records, indicates, or otherwise responds to it), etc.

# Internet Of Things

- IOT is advancements in capabilities in sensor networks, mobile devices, wireless communication, networking and cloud technologies.

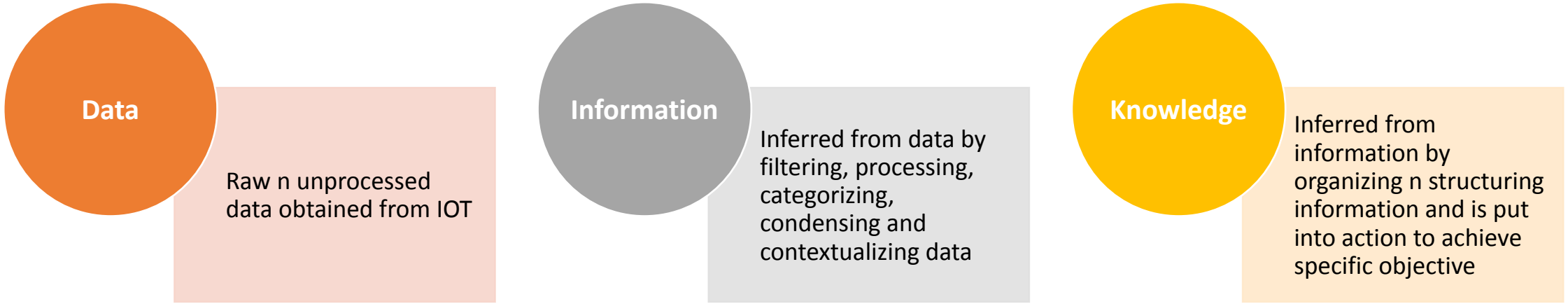
- The scope of IOT is not just limited to connecting things/devices to the Internet.

- It also allows these things to communicate and exchange data while executing meaningful applications towards a common user.

# Internet Of Things

- Data itself doesn't have a meaning unless processed or contextualized.

- It needs to be processed and structured to be converted into knowledge.




- This knowledge inferred allows for a smart performance of the system.

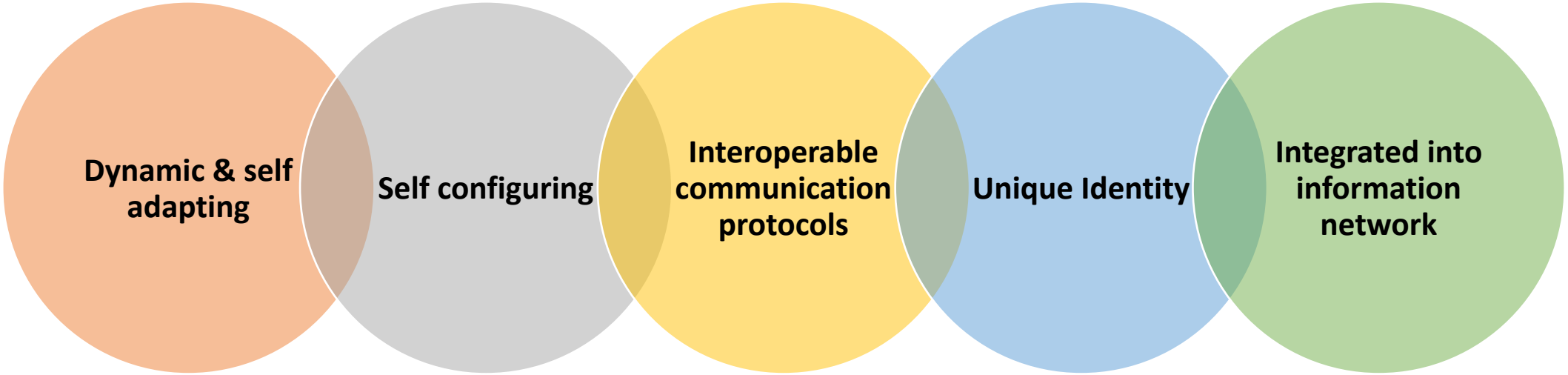
# Internet Of Things

- Consider the following data
  - (72,45) ; (84,56) ; (75,55)
  - These are sensor measurements generated by weather monitoring system.
- These measurements by themselves don’t have any meaning unless the context is added.
- Context: each tuple in the data measures temperature and humidity at second. This context provides some meaning to the data.
- Further, the data can be processed to calculate average temperature and humidity. This converts the data into information.
- This information can be further organized to understand relationships and infer knowledge.
- In this example, an alert can be raised if the average temp in last 5 min exceeds 120F considering the user’s location.

# IOT Definition

- A dynamic **global network** infrastructure with **self configuring** capabilities based on standard and **interoperable** communication **protocols** where physical and virtual "**things**" have **identities**, physical attributes, and virtual personalities and use intelligent **interfaces**, and ae seamlessly **integrated** into the **information network**, often **communicate** data associated with **users** and their **environment**.

# IOT Characteristics



# IOT Characteristics

## Dynamic & self adapting

IOT devices have the capability to dynamically adapt and take actions based on their operating conditions, user's context, or sensed environment.

Consider a surveillance system comprising of multiple cameras.

These cameras can adapt their mode (normal or infra-red) based on whether it is day or night.

Also they can switch from lower resolution to higher resolution when any motion is detected & alert nearby cameras to do the same.

Thereby, the surveillance system is adapting itself based on the context and the changing conditions.

# IOT Characteristics

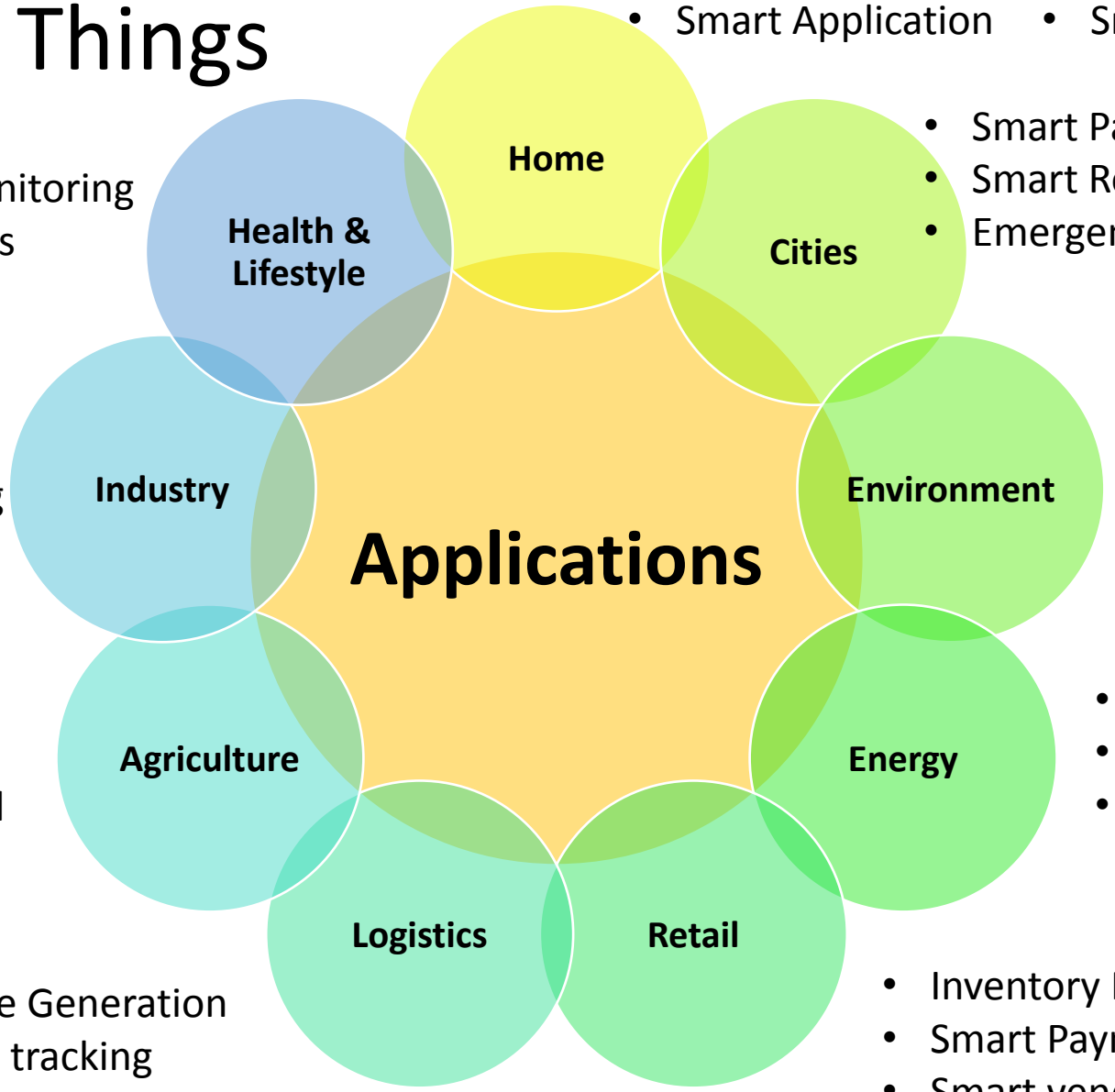
| | |
|---|---|
| Self configuring | IOT devices can configure themselves and allow a large number of devices to work together to provide a certain functionality. |
| | These devices have the ability to set up the networking and fetch the latest software upgrades with minimal manual or user intervention. |
| Interoperable communication protocols | IoT Devices may support a number of interoperable communication protocols and can communicate with other devices and also with the infrastructure. |
| | E.g. an MI phone can control a smart AC or smart TV from different manufacturer. |

# IOT Characteristics

| | |
|---|---|
| Unique Identity | Each IoT devices has a unique identity and a unique identifier (IPaddress, URI). |
| | IoT systems may have intelligent interfaces which adapt based on the context, allow communication with users and the environment contexts. |
| | IOT device interfaces allow users to query the device, monitor their status, and control them remotely. |
| Integrated into information network | IoT devices are usually integrated into the information network that allows them to communicate and exchange data with other devices and systems. |
| | E.g. in weather monitoring systems, one node can describe its monitoring capabilities to another connected node, and they may communicate and exchange data. |
| | The data from large number of nodes can be aggregated and analyzed to predict weather. |

# IoT Applications

# Internet Of Things




- Smart Lighting
- Smart Application
- Intrusion Detection
- Smoke Detectors

- Smart Parking
- Smart Roads
- Emergency response
- Structural Health Monitoring

- Health & fitness monitoring
- Wearable electronics

- Weather monitoring
- Air pollution monitoring
- Noise pollution monitoring
- Forest fire detection

- Machine diagnosis
- Indoor air quality monitoring

- Smart Grids
- Renewable Energy Systems
- Prognostics

- Smart irrigation
- Green house control

- Inventory Management
- Smart Payments
- Smart vending machines

- Route Generation
- Fleet tracking
- Shipment monitoring
- Remote vehicle diagnostics

# IOT Applications (Home)

| | |
|---|---|
| Smart Lighting | • Lighting technology designed for energy efficiency, convenience and security. |
| Smart Application | • Application used to remotely control and manage connected non-computing devices in the home, typically from a smartphone or tablet. |
| Intrusion Detection | • Systems that use security cameras and sensors to detect intrusion and raise alerts. Alert can we inform of an SMS or an email sent to the user. |
| Smoke Detectors | • Detect smoke and rings fire alarm and sends message for fire alert. |

# IOT Applications (City)

| | |
|---|---|
| Smart Parking | • Utilizes smartphones and other sensing devices to ascertain the occupancy of a parking structure or level. |
| Smart Roads | • Specially engineered roadways fitted with smart features and sensors that monitor and report changing road conditions. |
| Emergency response | • If a gas pipeline reaches a high pressure in a particular location, for example, an IoT device could detect this and inform a remote-control system to address the situation, before it reaches the point of an explosion. |
| Structural Health Monitoring | • identify the possible existence of a risk or opportunity in an infrastructural asset. |

# IOT Applications (Environment)

| | |
|---|---|
| Weather monitoring | • Uses sensors to monitor weather conditions like temperature, humidity etc. |
| Air pollution monitoring | • Monitors the constituents which results in pollution like aerosol, CO, CO2, and temperature-humidity. An alarm is triggered when the air quality goes down beyond a certain level. |
| Noise pollution monitoring | • Monitors the sound levels with the help of microphone based sound sensor and takes action accordingly. |
| Forest fire detection | • Fire detection and alert/message generation |

# IOT Applications (Energy)

| | |
|---|---|
| Smart Grids | • System that enables communication between the supplier and the consumer.<br>• E.g. to solve regional issues like detect power failures and repair without interruption |
| Renewable Energy Systems | • monitoring and efficient working of wind turbines.<br>• The direction of the wind turbine can be altered for gaining maximum efficiency by analyzing the data generated by IoT sensors. |
| Prognostics | • prognostic analytics give a foresight on what is going to happen when and with which probability by assessing the extent of deviation or degradation of a system from its expected normal operating conditions. |

# IOT Applications (Retail)

**Inventory Management**

- Allows micro-tracking of items, touchless data collection etc.
- Overstocking of products results in additional storage expense while understocking results in loss of revenue.
- Using RFID tags, products can be tracked in real time, thereby enabling the remote monitoring of inventory.

**Smart Payments**

- Systems that make fully automated payments based on real-time data analysis.
- For example, technologies such as near field payments(NFC) or Bluetooth can be used for making payments by bringing the smart phones in the proximity of point of sale terminals.

**Smart vending machine**

- Provides real time usage reporting to vendors which helps them to keep sufficient items in the machine by monitoring inventory all the time.
- Sensors from the vending machine send the data to cloud which can be used for predictive maintenance

# IOT Applications (Logistics)

| | |
|---|---|
| Route Generation | • Finding which route is the most cost-effective with the help of sensor given data.<br>• Real time notifications can be sent to the personnel to inform about change in route. |
| Fleet tracking | • Fleet is a group of ships sailing together, engaged in the same activity, or under the same ownership.<br>• Fleet tracking helps in collecting data about trip history, fuel levels, location, mileage, speed, direction etc. |
| Shipment monitoring | • To ensure timely delivery of shipments.<br>• Safety and security of the shipments especially the high-value assets or sensitive substances that need regular monitoring. |
| Remote vehicle diagnostic | • Allows an expert to obtain an insight into the vehicle's state and localize the problem without being physically present on-site. |

# IOT Applications (Agriculture)

## Smart irrigation

- Collects real-time water usage data through remote sensing technologies.
- This allows the farmer to make smarter decisions about water usage.
- It can Trigger actions based on sensor data to switch water on and off, depending on irrigation needs and level of resources.

## Green house control

- Provide real-time information on critical climate factors including, temperature, humidity, light exposure and carbon dioxide across the greenhouse.
- Depending on the values, appropriate actions can be triggered.

# IOT Applications (Industry)

## Machine diagnosis

- Monitoring of mechanical wear and tear needs to be done in order to avoid sudden breakdown in the machines and unexpected shutdown in the plant.
- This results in decrease in the frequency of unscheduled repairs, minimizes downtime and hence, guarantees reliability, and sustainability of machines.
- This monitoring can be done by sensing Current, Vibration, Acoustic emission from the machines.

## Indoor air quality monitoring

- Collect data about the concentration of aerosol, CO, $CO_2$, and temperature-humidity to monitor the air quality using various sensors.
- This data can be further analyzed to take appropriate measures.

# IOT Applications (Health & Lifestyle)

## Health & fitness monitoring

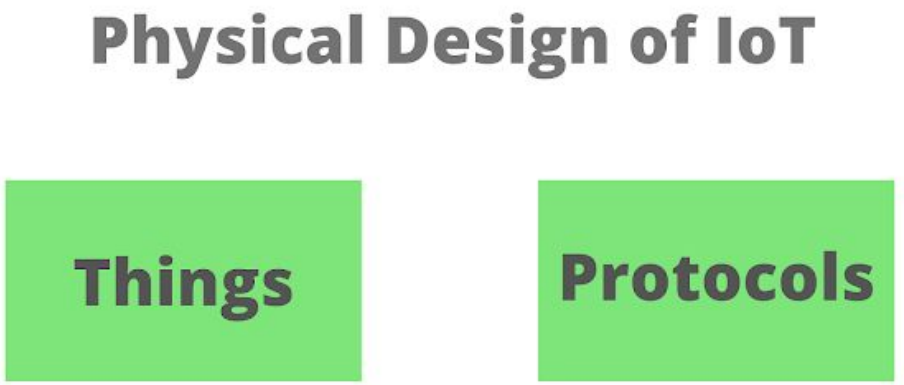
- useful for the rapid and accurate diagnosis and treatment of diseases.
- Help in patient monitoring, emergency services, health suggestions, health information storage etc.

## Wearable electronics

- allow the follow-up of patients outside the hospital.
- It is now possible to analyze assay samples, health status and various data.
- Sports movements and exercises can be detected with the help of sensors.
- As a result of the analysis of these data, individual training plans or training programs can be created.
- Wearable devices can be used to control all these data.

# Physical Design of IOT

- The **physical design** of an **IoT** system is referred to the **Things/Devices** and **protocols** that used to build an IoT system.
- All these things/Devices are called Node Devices and every device has a unique identity that performs remote sensing, actuating, and monitoring work and the protocols that used to established communication between the Node devices and server over the internet.



# Things in IOT

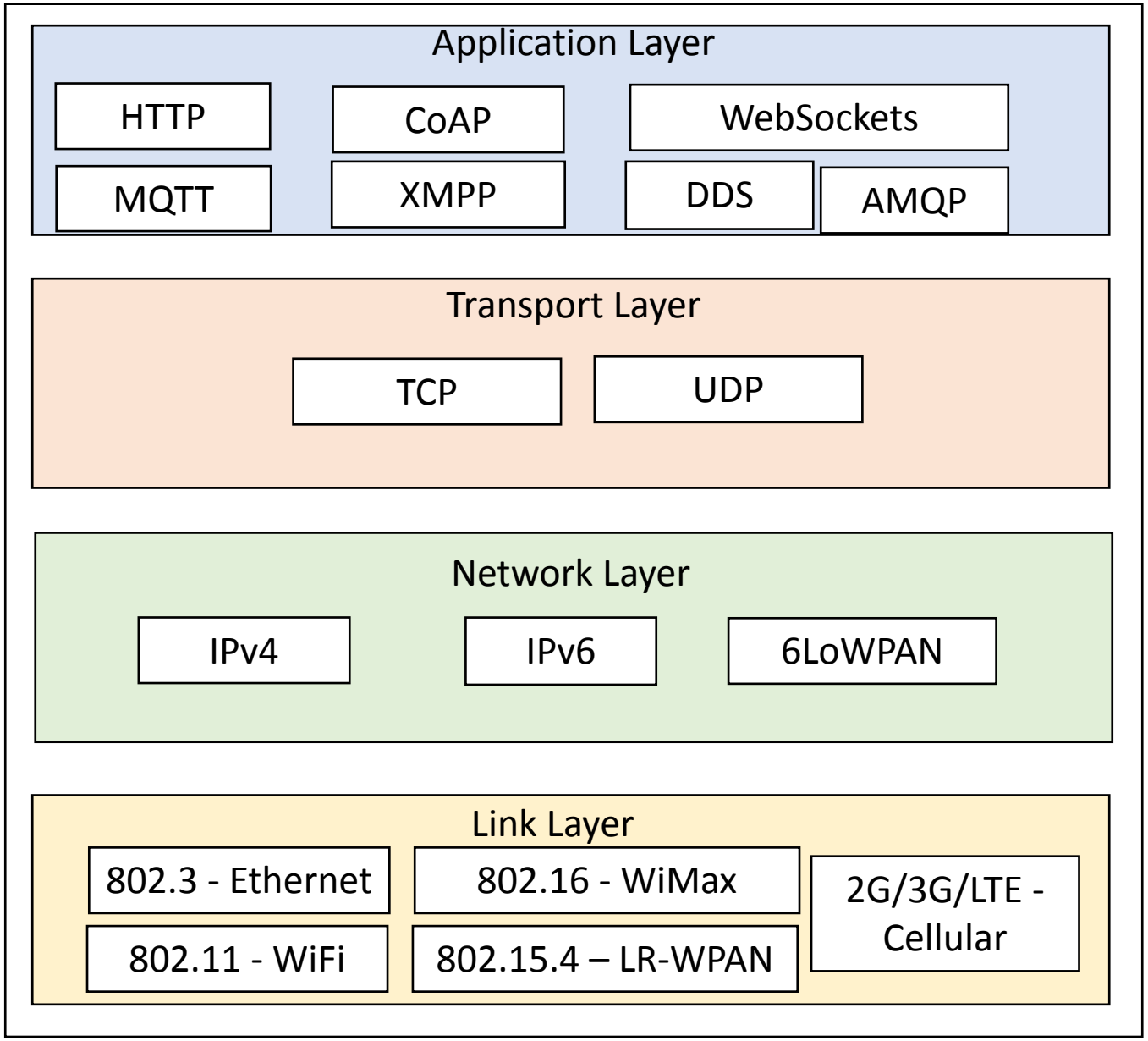
- Things/Devices are used to build a connection, process data, provide interfaces, provide storage, and provide graphics interfaces in an IoT system.
- All these generate data in a form that can be analysed by an analytical system and program to perform operations and used to improve the system.
- for example temperature sensor that is used to analyse the temperature, generates the data from a location and either processes it locally or sends it to the centralized servers and cloud based applications.

An IoT device may consist of several interfaces connections to other devices, both wired and wireless. These include:

- **Connectivity**
  - Devices like USB host and ETHERNET are used for connectivity between the devices and server.
- **Processor**
  - A processor like a CPU and other units are used to process the data.
  - These data are further used to improve the decision quality of an IoT system.
- **Audio/Video Interfaces**
  - An interface like HDMI and RCA devices is used to record audio and videos in a system.
- **Input/Output interface**
  - To giving input and output signals to sensors, and actuators we use things like UART, SPI, CAN, etc.
- **Storage Interfaces**
  - Things like SD, MMC, SDIO are used to store the data generated from an IoT device.
- Other things like DDR, GPU are used to control the activity of an IoT system.

# IOT Protocols

- These protocols are used to establish communication between a node device and server over the internet.
- It helps to send commands to an IoT device and receive data from an IoT device over the internet.
- We use different types of protocols that are present on both the server and client-side and these protocols are managed by network layers like application, transport, network, and link layer



## Application Layer protocol

- In this layer, protocols define how the data can be sent over the network with the lower layer protocols using the application interface.
- These protocols include HTTP, WebSocket, XMPP, MQTT, DDS, and AMQP protocols.

- **HTTP**
  - Hypertext transfer protocol is a protocol that presents in an application layer for transmitting media documents.
  - It is used to communicate between web browsers and servers.
  - It makes a request to a server and then waits till it receives a response and in between the request server does not keep any data between two requests.

## Application Layer protocol

- **WebSocket**
  - This protocol enables two-way communication between a client and a host that can be run on an untrusted code in a controlled environment.
  - This protocol is commonly used by web browsers.

- **MQTT**
  - It is a machine-to-machine connectivity protocol that was designed as a publish/subscribe messaging transport.
  - It is used for remote locations where a small code footprint is required.

## Transport Layer protocol

- This layer is used to control the flow of data segments and handle the error control.
- Also, these layer protocols provide end-to-end message transfer capability independent of the underlying network.
- **TCP**
  - The transmission control protocol is a connection oriented protocol that defines how to establish and maintain a network that can exchange data in a proper manner using the internet protocol.
- **UDP**
  - User datagram protocol is a part of internet protocol called the connectionless protocol.
  - This protocol does not require to establish the connection to transfer data.

## Network Layer

- This layer is used to send datagrams from the source network to the destination network.
- We use IPv4 and IPv6 protocols as a host identification that transfers data in packets.
- **IPv4**
  - This is a protocol address that is a unique and numerical label assigned to each device connected with the network.
  - An IP address performs two main functions host and location addressing.
  - IPv4 is an IP address that is 32 bit long.
- **IPv6**
  - It is a successor of IPv4 that uses 128 bits for an IP address.
  - It is developed by the IETF task force to deal with the long-anticipated problems.

## Link Layer

- Link-layer protocols are used to send data over the network's physical layer.
- It also determines how the packets are coded and signalled by the devices.

- **Ethernet**
  - It is a set of technologies and protocols that are used primarily in LANs.
  - It defines the physical layer and the medium access control for wired ethernet networks.
- **WiFi**
  - It is a set of LAN protocols and specifies the set of media access control and physical layer protocols for implementing wireless local area networks.

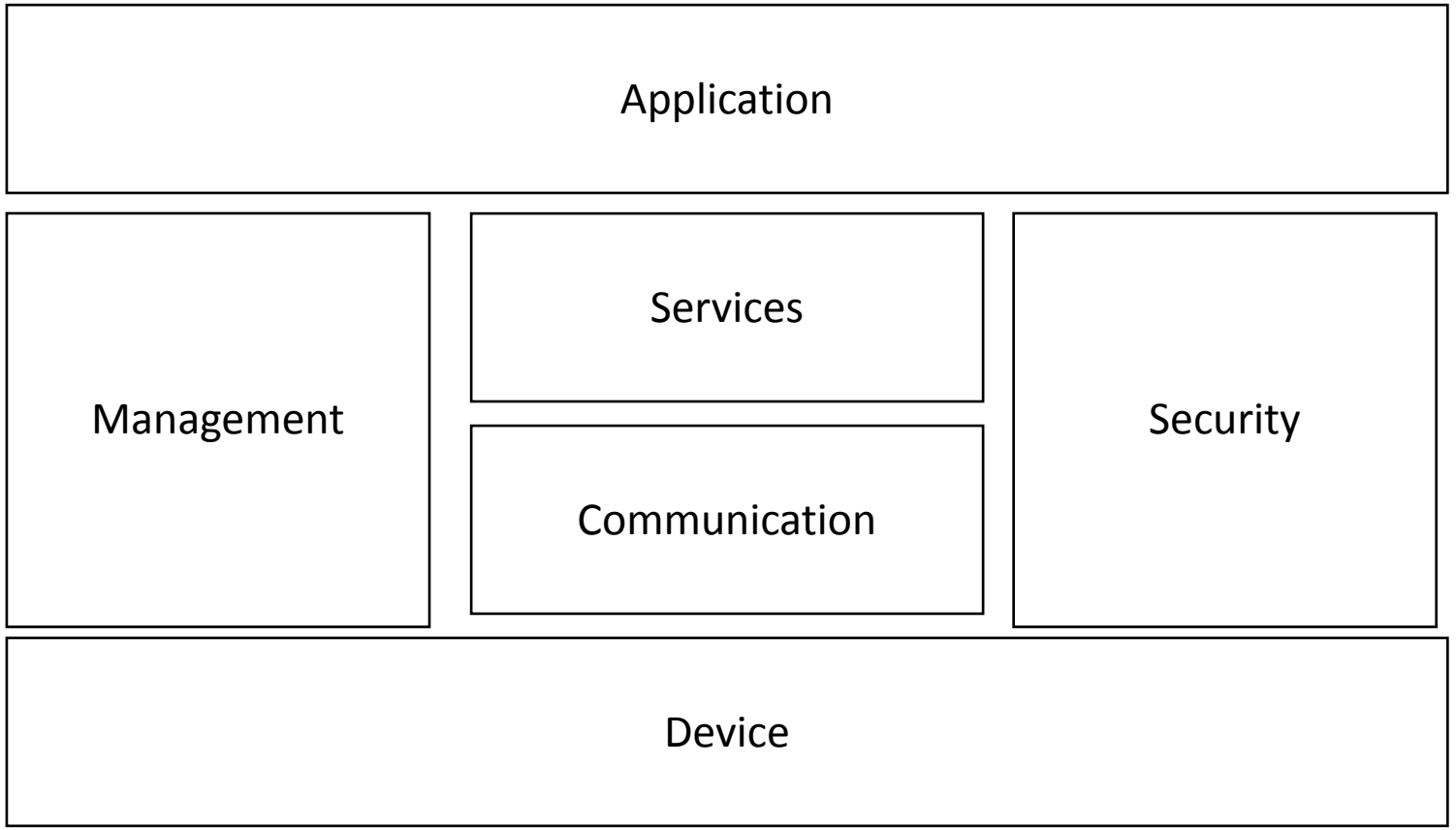
# Logical Design of IOT

# IoT Functional Blocks

Logical design of an IoT system refers to an abstract representation of the entities and process without going into low level specification of the implementations.

An IoT system comprises of a number of functional blocks that provide the system the capabilities for

- identification
- sensing
- actuation
- communication and
- Management.



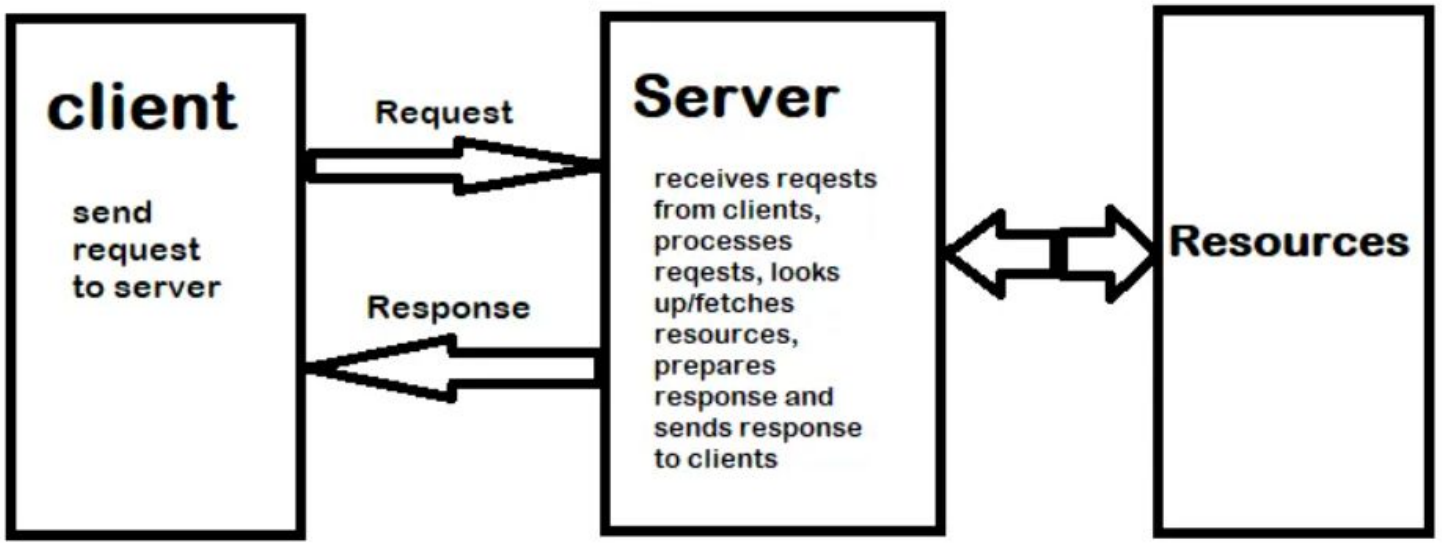
# IoT Functional Blocks

- **Devices:** An IoT system comprises of the devices that provide sensing, actuation, monitoring and control function.
- **Communication:** communication block handle the communication systems. It allows interoperability among devices. (Protocols)
- **Services :** An IoT system uses various types of IoT services such as services for device monitoring, device control services, data publishing services and services for device Discovery. (authenticating, configuring, maintaining, adding new device etc)
- **Management:** Functional blocks provide various functions to govern the IoT system
- **Security:** Security functional block security IoT system and by providing functions such as application authorization message and content integrity and data security.
- **Application:** IoT application provides an interface that the user can used to control and monitor various aspects of the IoT system. Application also allow users to view the system status and view or analyze the processed to data.

# IoT Communication Models

**Request response**

- A communications model in which the client sends request to the server and the server responds to the requests.
- When the server receives a request it decides how to respond, fetches the data, prepares the response and then sends the response.
- It is a stateless communication model and each request response pair is independent of the others.




Request-Response Communication Model

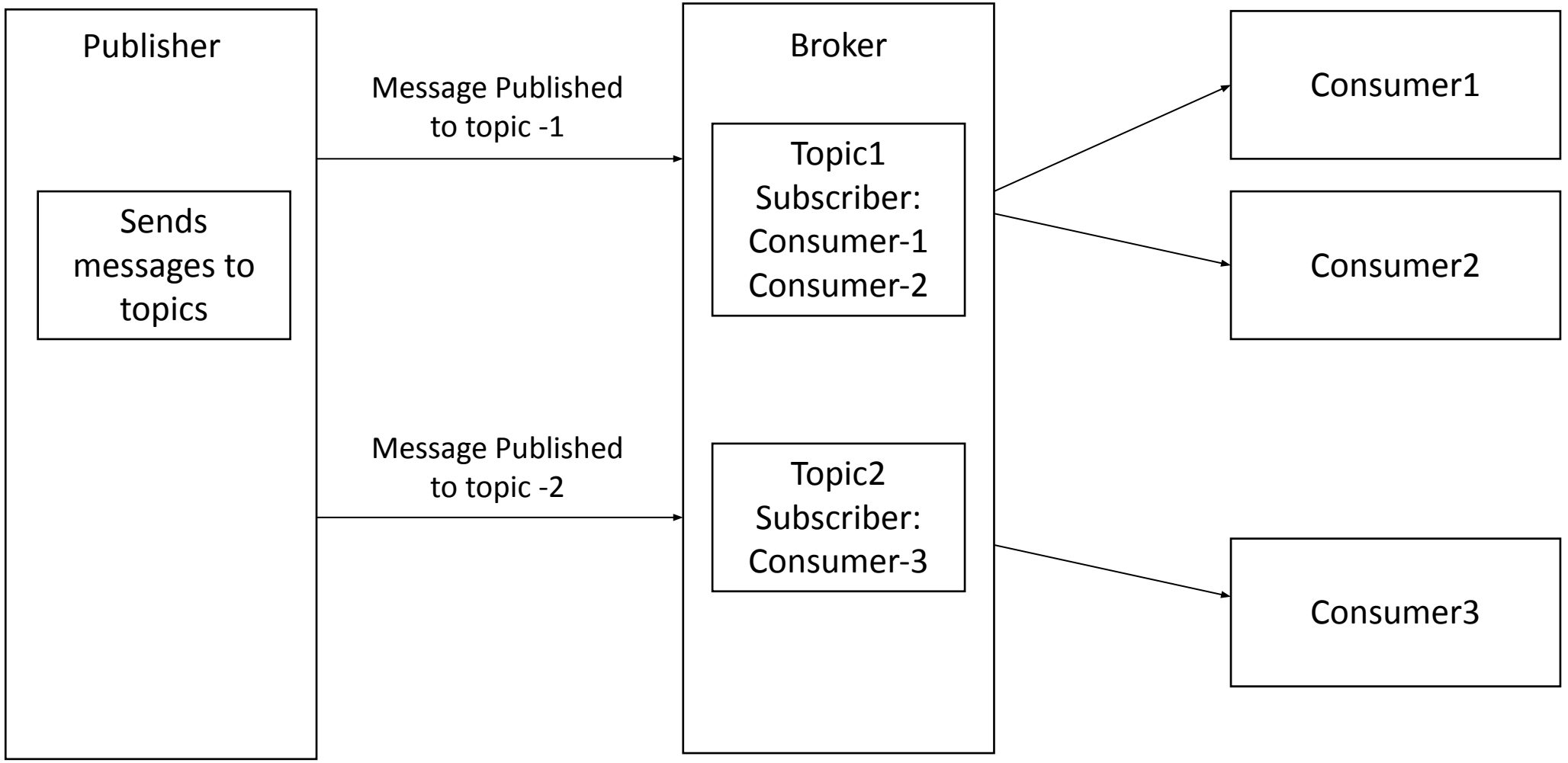
# IoT Communication Models

**Publish-Subscribe**

- A communication model that involves publishers, brokers and consumers.
- Publishers are the source of data.
- Publishers send the data to the topics which are managed by the broker.
- Publishers are not aware of the consumer.
- Consumers Subscribe to the topic which are managed by the broker.
- When the broker receives the data for a topic from the publisher, it sends the data to all the subscribed consumers.

# IoT Communication Models

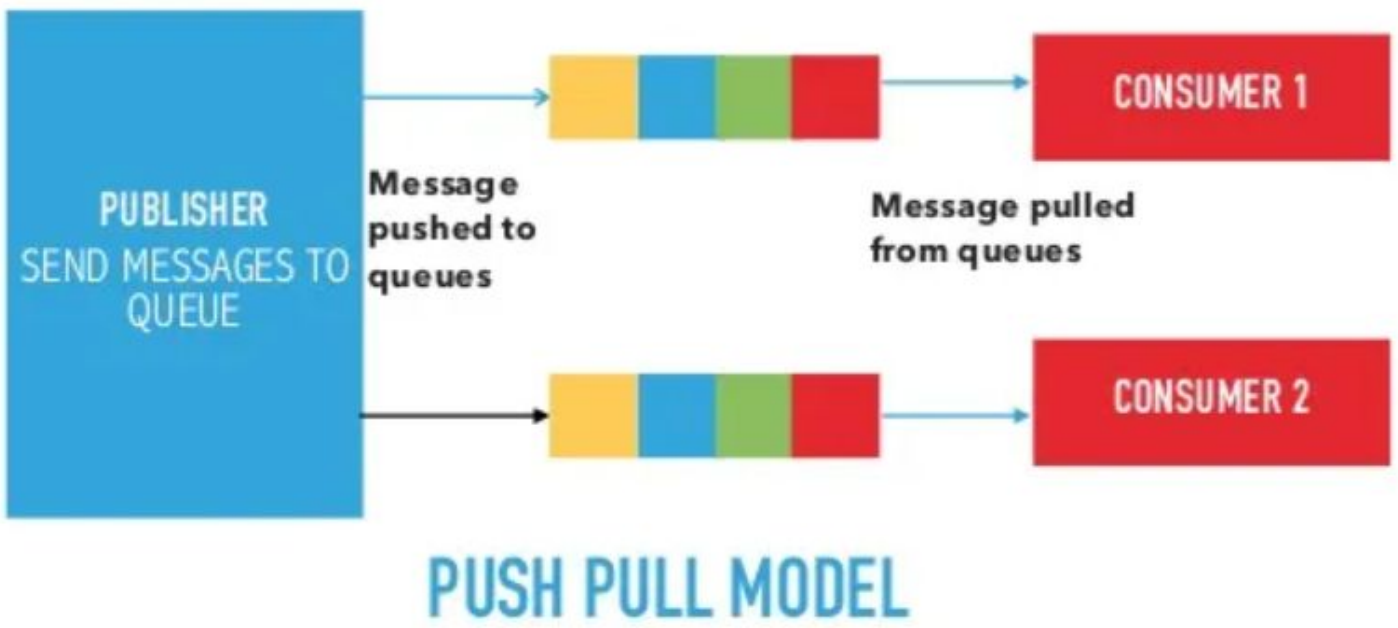
## Publish-Subscribe



# IoT Communication Models

## Push-Pull

- Push pull is communication model in which the data producers push the data to queues and the consumers pull the data from the queues.
- Producers do not need to be aware of the consumer.
- Queues help in decoupling the messaging between the Producers and Consumers .
- It also act as a buffer which helps in situations when there is a mismatch between the rate at which the produces push data and the rate at which the consumers full the data



# IoT Communication Models

## Exclusive Pair

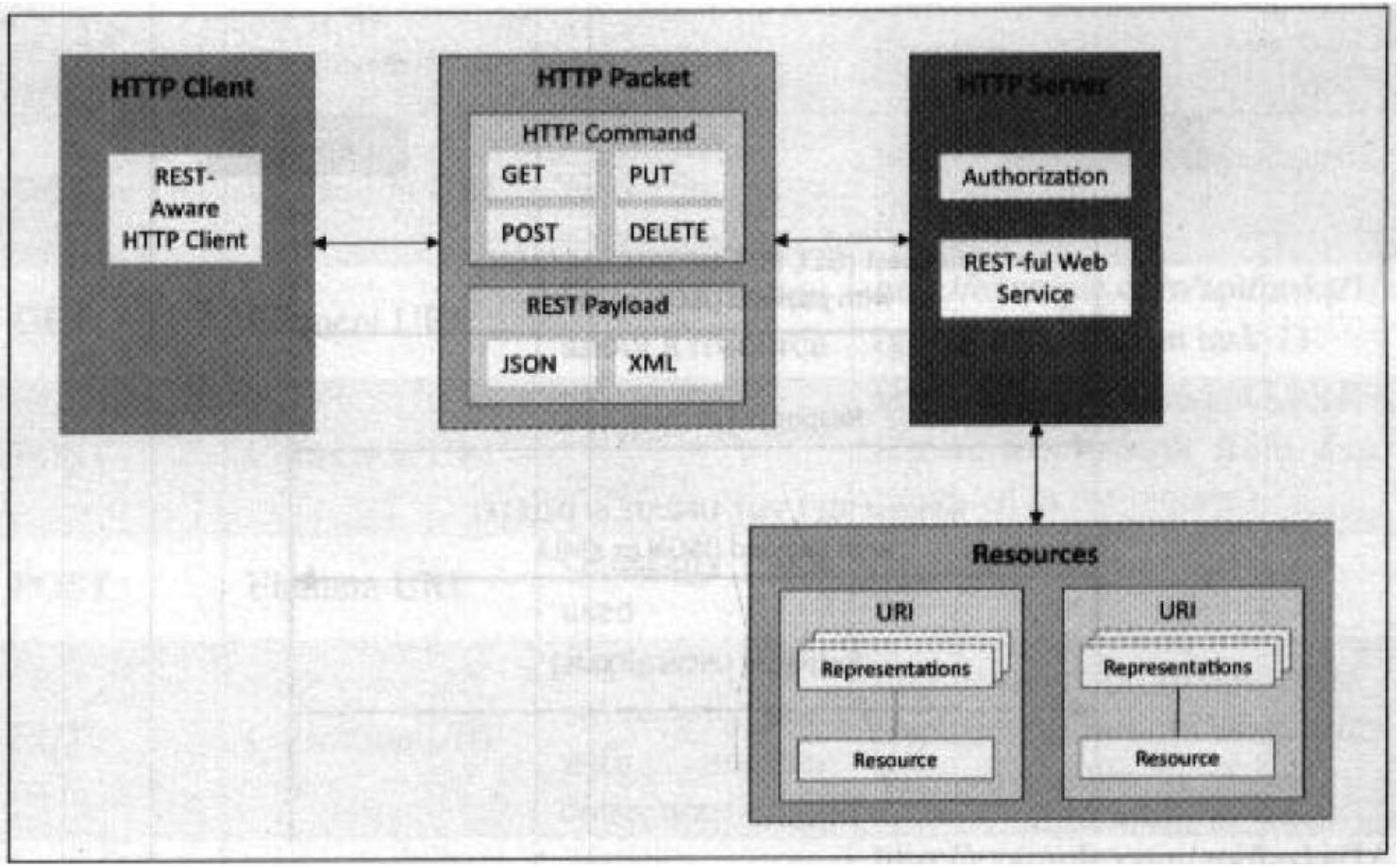
- Exclusive pair is a bi directional, fully duplex communication model that uses a persistent connections between the client and the server.
- Once the condition is setup it remains open until the client sends a request to close the connection.
- Client and server can send messages to each other after connection setup.
- Exclusive pair is a stateful Communications model and the server is aware of all the open connections

# IoT Communication APIs

## 1) REST-based APIs

- Representational state transfer is a set of architectural principles to design Web API that focus on a system resources and how resources states and addressed the transferred.
- A RESTful web service is a web API implemented using HTTP and REST principles.
- It is a collection of resources represented by URIs.
- The clients send requests to these URIs using methods defined by HTTP protocol (GET, PUT, POST etc).
- A RESTful web service can support various internet media types such as JSON.

# IoT Communication APIs (**REST-based APIs**)



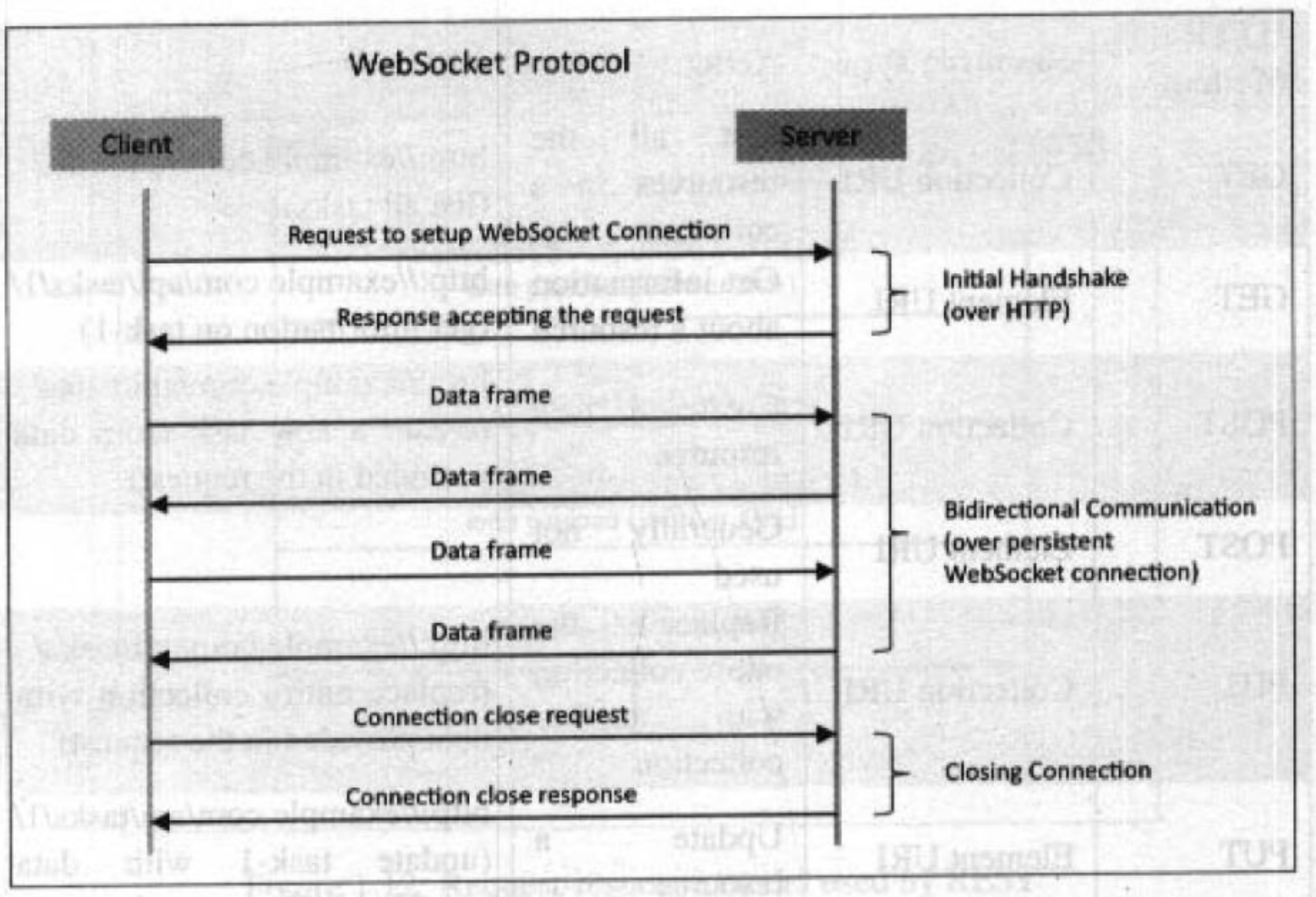

Communication with REST APIs

# IoT Communication APIs

**2) WebSocket based communication API:**

- WebSocket API allow bi directional, full duplex communication between client and server.
- Unlike request-response API, this API allows full duplex communication and do not require new connection to be set up for each message to be sent.
- WebSocket communication begins with connection setup request send by the client to the server.
- This request is sent over http and the server interprets it as an upgrade request.
- If the server supports WebSocket protocol, the server responds to the website handshake response.
- After the connection is setup the client and the server can send data or messages to each other in full duplex model.
- WebSocket API reduce network traffic and latency as there is no overhead for connection setup and termination requests for each message.
- It is suitable for IOT applications that have low latency or high throughput requirements

# IoT Communication APIs (**WebSocket based)**




Exclusive pair model used by WebSocket based APIs

# Baseline technologies

# Baseline technologies - M2M

- M2M stands for **Machine to Machine** communication.
- It is a direct communication system between the devices using wired or wireless communications channels without any human interaction.
- It collects the data and shares it with other connected devices.
- It is a technology that allows devices without the use of the internet to connect between devices.
- Various applications, such as defense, monitoring and tracking, production and facility management, are provided by M2M communications.
- A common example of a machine to machine is controlling electrical devices like fans and bulbs using Bluetooth from the smartphone. Here, the smartphone and electrical devices are the two interacting devices with each other.

# Baseline technologies - M2M
## (Difference between IoT and M2M)

**IOT**

- Devices include objects that are responsible for decision-making processes.
- IoT has used internet protocols like FTP, Telnet, and HTTP.
- The connection of IoT is through the network and using various types of communication.
- In IoT, data sharing depends on the Internet protocol network.
- IoT technology supports Open API integrations.

**M2M**

- In M2M, there is a limited amount of intelligence observed.
- Communication technology and Traditional protocols are uses in M2M technology.
- M2M uses a point to point connection.
- In M2M, devices may be connected through mobile or any other network.
- In M2M technology, there is no Open API support.

# Baseline technologies - WoT

- Utilizing current technologies and techniques used on the web and applying them in the creation of IoT systems is known as the Web of Things.
- The WoT seeks to empower the IoT in a flexible and scalable way by using the web as its application layer.
- IoT aims to create a network of objects, things, people, services, and applications, whereas WoT integrates them into the web.
- WoT is closely related to IoT; it's an additional application layer added to IoT's network layer to maximize connectivity.
- WoT allows access and control over IoT applications using web technologies such as HTML, JavaScript.
- It reuses already existing web protocols to create a global ecosystem of things for seamless communication.
- The prominent limitation of IoT is the integration of devices from various manufacturers into a single application or system.
- WoT assists in establishing effective communication between different machines of different manufacturers.

# Baseline technologies - WoT

## (Difference between IoT and WoT)

| IoT | WoT |
| --- | --- |
| • IoT is a network of Things, which are anything that can be connected in some form to the Internet | • WoT is web network created for proper handling and using the potential of IoT platforms to provide better future |
| • IoT is a hardware layer to connect everything to the Internet | • WoT is a software layer to connect everything to the web |
| • IoT deals with sensors, actuators, computation and communication interfaces. From a box of oranges with an RFID tag, to a smart city and to everyThing in between, all these digitally augmented objects make up the IoT | • WoT deals with protocols and web servers. All those applications for IoT devices make up the WoT |
| • There is a different protocol for each and every IoT devices | • WoT makes it easy by using single protocol for multiple IoT devices |
| • IoT platforms are hard to program due to multiple protocols | • Due to common API's to handle the protocol WoT programming is easier |
| • IoT standards and prototypes are not public. They are privately funded and are not publicly accessible Insecure data transmission | • WoT is free for everyone and can be accessed anywhere, anytime |
| • IoT is tightly coupled between the applications and networks | • whereas WoT in application layer is loosely coupled |

# IOT categories

# IOT categories - Consumer

- Consumer IoT is a term used to refer to connected devices personally used by a consumer, that collect and share data through an Internet connection.
- These interrelated devices are provided with unique identifiers (UIDs) to recognize and access various entities for many purposes.
- Consumer IoT doesn’t just add convenience to the consumer’s home and daily tasks, but it helps them get comfortable and stay connected on the go.
- There are several real-life applications of Consumer IoT and device categories such as, wearables, connected car applications, voice-command systems, home control devices and all types of smart watches.
- Consumer IoT devices and applications are broadly subdivided into two types namely Personal IoT and Smart Home IoT

# IOT categories – Consumer (Personal IoT)

## Smart Clothing

- Examples –smart shirts

## Smart Watch

- Examples – Apple Watch, Fitbit.

## Battery power-sharing between two smartphones

- Examples – Donor Cable bracelets by NAR Mobile.

## Hearable

- Examples – AirPods, Google Pixel Buds.

## Smart glass

- Examples – Vuzix Smart Glasses.

# IOT categories – Consumer (Smart Home IoT)

## Voice Assistance

- Examples – Amazon Echo and Google Home Smart Voice-Activated Speaker

## Security

- Examples – Bitdefender BOX.

## Lighting fixtures

- Examples – Philips Hue Smart Bulbs

## Smart Energy Savings

- Examples – Ambi Climate, Rachio Smart Sprinkler Controller, etc.

## Family Entertainment

- Examples – Keepon social robot, Kuri home robot, Singlecue gesture control.

## Smart Kitchen Gadgets

- Examples – iGrill Smart grill thermometer, Samsung Family Hub, Birdi monitors

# IOT categories - Industrial

- Industrial IoT (IIoT) is the use of network-connected sensors and other monitoring devices to improve the manufacturing and quality of an organization's products and product parts.
- IIoT devices are used primarily for insights on machine health, causes for defective parts, and general data collection.
- Connected sensors and actuators enable companies to pick up on inefficiencies and problems sooner and save time and money, while supporting business intelligence efforts.
- Some of the industries which use IIoT are:
  - Automotive industry, which uses IIoT devices in the manufacturing process. IIoT can help proactively maintain the industrial robots used in the automotive industry and spot potential problems before they can disrupt production.
  - Agriculture industry makes extensive use of IIoT devices. Industrial sensors collect data about soil nutrients, moisture and more, enabling farmers to produce an optimal crop.

# IOT Components

# IOT Components

**Sensors/ Devices**

- Sensors or devices help in collecting very minute data from the surrounding environment.
- This data can have various degrees of complexities ranging from a simple temperature monitoring sensor or a complex full video feed.
- A device can have multiple sensors that can do more than just sense things.
- For example, our phone is a device that has multiple sensors such as GPS, accelerometer, camera but our phone does not simply sense things.

**Connectivity**

- The collected data is sent to a cloud infrastructure but it needs a medium for transport.
- The sensors can be connected to the cloud through various mediums of communication and transports such as cellular networks, satellite networks, Wi-Fi, Bluetooth, wide-area networks (WAN), low power wide area network and many more.

# IOT Components

## Data Processing

- Once the data is collected and it gets to the cloud, the software performs processing on the acquired data.
- This can be simple , such as checking that the temperature reading on devices is within an acceptable range.
- It can sometimes also be very complex, such as identifying objects (such as intruders in your house) using computer vision on video.
- There might be a situation when a user interaction is required, example- when the temperature is too high or if there is an intruder in the house?

## User Interface

- Next, the information is  made available to the end-user in some way.
- This can be achieved by triggering alarms on their phones or notifying through texts or emails.
- Also, a user sometimes might have an interface through which they can actively check in on their IOT system.
- For example, a user has a camera installed in his house, he might want to check the video recordings and all the feeds through a web server.