Introduction to IoT

1.1 What is IoT

IoT is a technology transition in which devices will allow us to sense and control the physical world by making objects smarter and connecting them through an intelligent network.

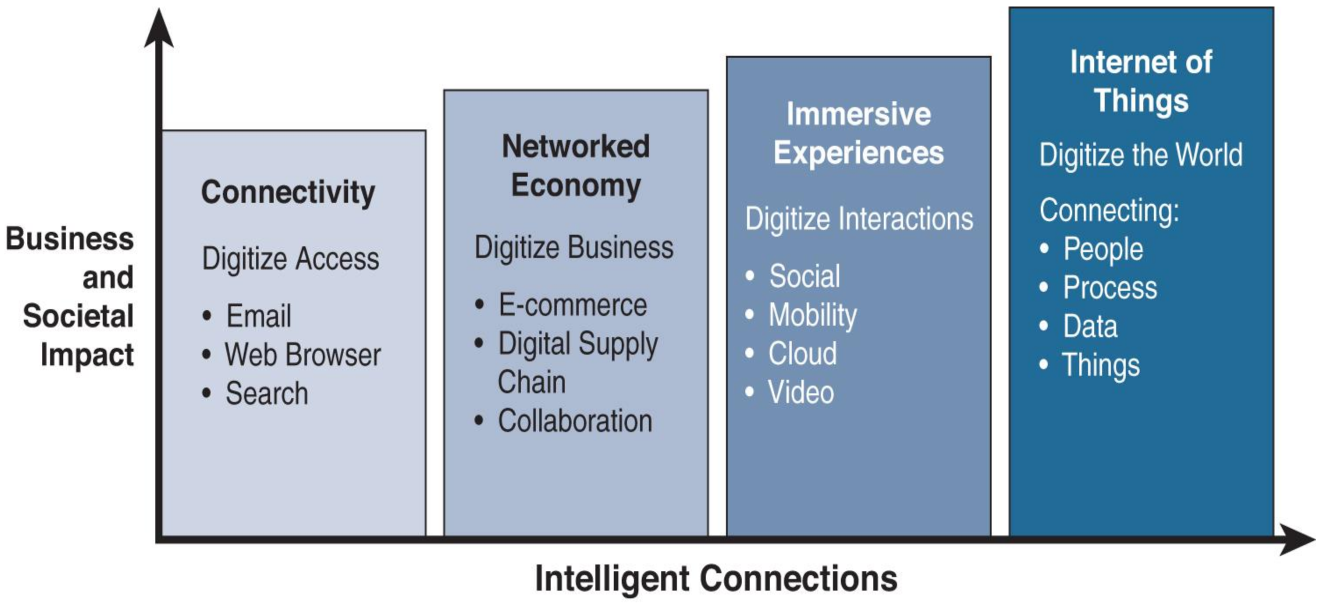
GOAL: The basic premise and goal of IoT is to “connect the unconnected.” This means that objects that are not currently joined to a computer network, namely the Internet, will be connected so that they can communicate and interact with people and other objects.

When objects and machines can be sensed and controlled remotely across a network, a tighter integration between the physical world and computers is enabled.

This allows for improvements in the areas of efficiency, accuracy, automation, and the enablement of advanced applications.

1.1.1 GENESIS OF IOT

The person credited with the creation of the term “Internet of Things” is **Kevin Ashton**. While working for Procter & Gamble in 1999, Kevin used this phrase to explain a new idea related to linking the company’s supply chain to the Internet.



the evolution of the Internet can be categorized into four phases. Each of these phases has had a profound impact on our society and our lives. These four phases are further defined in Table below.

Internet Phase	Definition
Connectivity (Digitize access)	This phase connected people to email, web services, and search so that information is easily accessed.
Networked Economy (Digitize business)	This phase enabled e-commerce and supply chain enhancements along with collaborative engagement to drive increased efficiency in business processes.
Immersive Experiences (Digitize interactions)	This phase extended the Internet experience to encompass widespread video and social media while always being connected through mobility. More and more applications are moved into the cloud.
Internet of Things (Digitize the world)	This phase is adding connectivity to objects and machines in the world around us to enable new services and experiences. It is connecting the unconnected.

1.1.2 IOT AND DIGITIZATION

IoT and digitization are terms that are often used interchangeably. In most contexts, this duality is fine, but there are key differences to be aware of.

At a high level, IoT focuses on connecting "things," such as objects and machines, to a computer network, such as the Internet. IoT is a well-understood term used across the industry. On the other hand, digitization can mean different things to different people but generally encompasses the connection of "things" with the data they generate and the business insights that result.

Digitization, as defined in its simplest form, is the conversion of information into a digital format. Digitization has been happening in one form or another for several decades. For example, the whole photography industry has been digitized. Pretty much everyone has digital cameras these days, either standalone devices or built into their mobile phones. Almost no one buys film and takes it to a retailer to get it developed. The digitization of photography has completely changed our experience when it comes to capturing images.

1.2 Characteristics of IoT

Followings are the characteristics of IoT

Dynamic & Self-Adapting: - IoT devices and systems may have the capability to dynamically adapt with the changing contexts and take actions based on their conditions, user's context, or sensed environment. For example, consider a surveillance system comprising of several surveillance cameras. The surveillance camera can adapt their modes based on whether it is day or night. Camera could switch from lower resolution to higher resolution modes when any motion is detected and alert nearby camera to do the same In this example, the surveillance system is adapting itself based on the context and changing conditions.

Self-Configuring: - IoT devices have may self-configuring capability, allowing a large number of devices to work together to provide certain functionality. These devices have ability to configure themselves, setup the networking and fetch 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 the other devices and with the infrastructure.

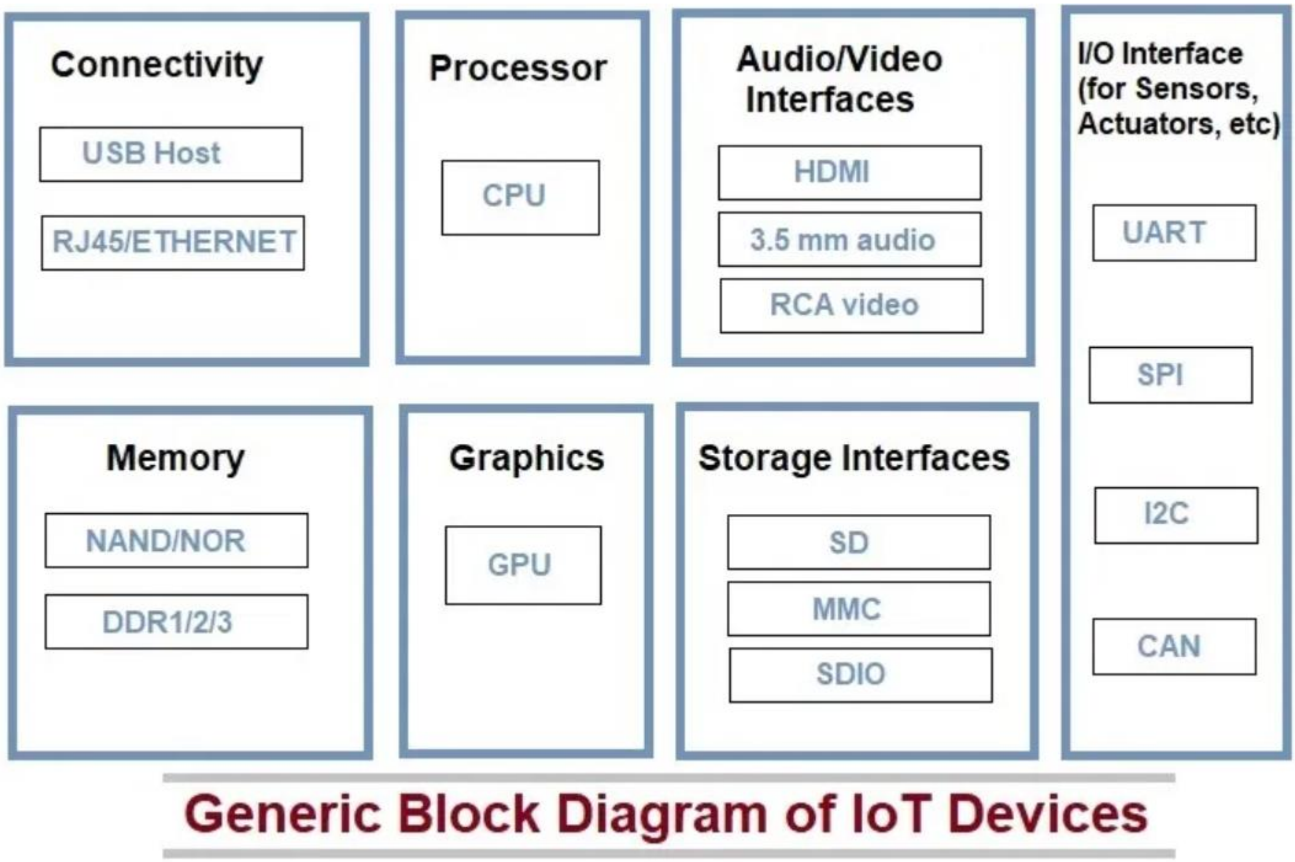
Unique Identity: - Each IoT device has a unique identity and a unique identifier. IoT systems may have intelligent interfaces which adapt based on the context, allow communicating with user and the environmental contexts. IoT device interfaces allow users to query the devices, monitor their status and control them remotely, in association with control, configuration and management infrastructure.

Integrated into Information Network: - IoT devices are usually integrated into information network which allows them to communicate and exchange data with other devices and systems. IoT devices can be dynamically discovered in the network, by other devices and/or the network, and they have capability to describe themselves to other devices or the user applications. For example, a weather monitoring node can describe its monitoring capabilities to another connected node so that they can communicate and exchange the data. Integration into the information network helps in marketing IoT systems “smarter” due to the collective intelligence of the individual devices in collaboration with the infrastructure.

1.3 PHYSICAL DESIGN OF IoT

1.3.1 Things in IoT

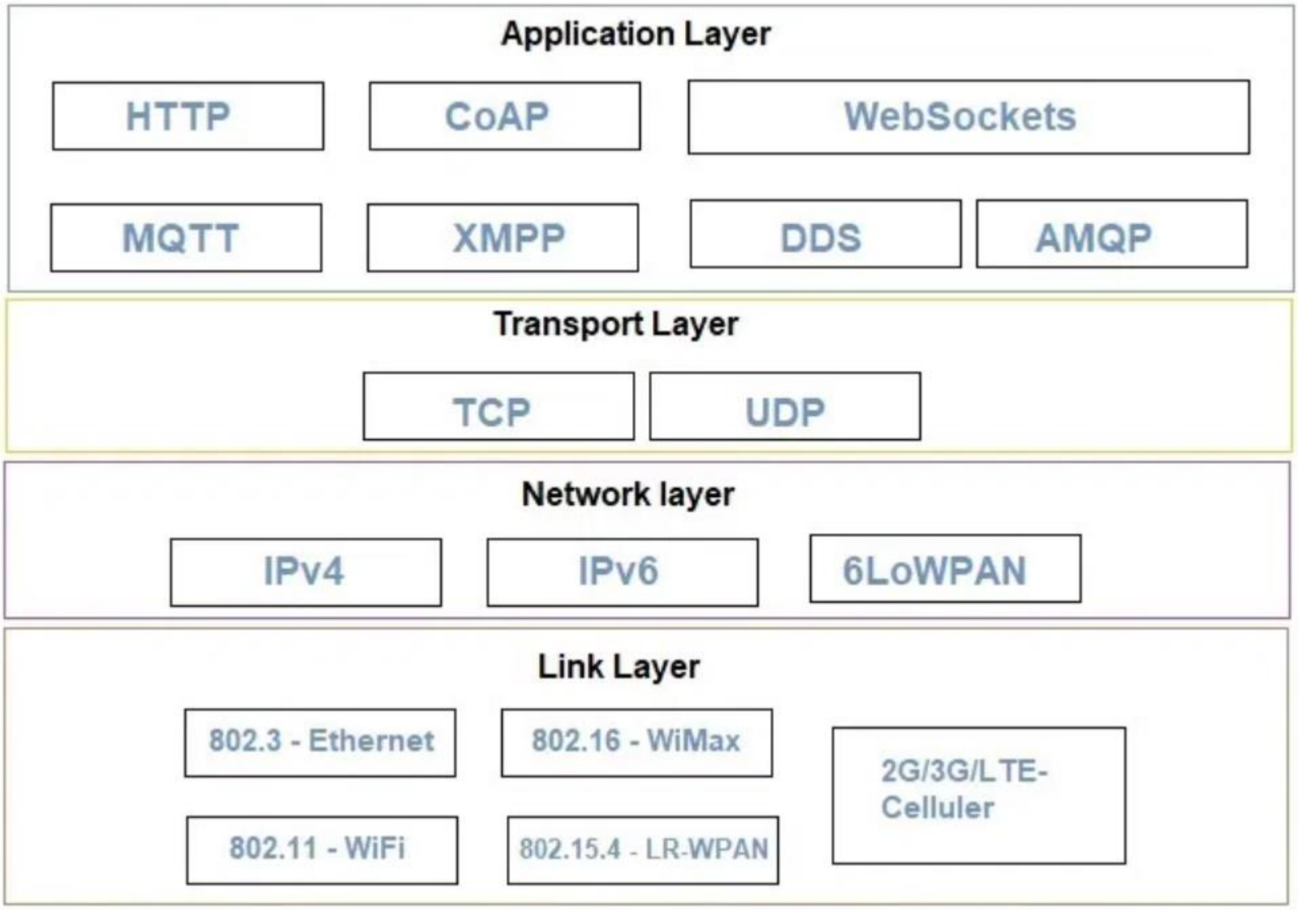
Things refers to IoT Devices which have unique identities and can perform remote sensing, actuating and monitoring capabilities. Things are is main part of IoT Application. IoT Devices can be various type, Sensing Devices, Smart Watches, Smart Electronics appliances, Wearable Sensors, Automobiles, and industrial machines. These devices generate data in some forms or the other which when processed by data analytics systems leads to useful information to guide further actions locally or remotely.



For example, Temperature data generated by a Temperature Sensor in Home or other place, when processed can help in determining temperature and take action according to users. Above picture, shows a generic block diagram of IoT device. It may consist of several interfaces for connections to other devices. IoT Device has I/O interface for Sensors, Similarly for Internet connectivity, Storage and Audio/Video. IoT Device collect data from on-board or attached Sensors and Sensed data communicated either to other device or Cloud based sever. Today many cloud servers available for especially IoT System. These Platform known as IoT Platform. These cloud especially design for IoT purpose. So here we can analysis and processed data easily.

1.3.2 IoT Protocols

IoT protocols help to establish Communication between IoT Device (Node Device) and Cloud based Server over the Internet. It helps to send commands to IoT Device and received data from an IoT device over the Internet. An image is given below. By this image you can understand which protocols used.



Link layer

Link layer protocols determine how data is physically sent over the network's physical layer or medium (Coaxial cable or other or radio wave). This Layer determines how the packets are coded and signaled by the hardware device over the medium to which the host is attached (e.g. coaxial cable).

Here we explain some Link Layer Protocols:

802.3 – Ethernet : Ethernet is a set of technologies and protocols that are used primarily in LANs. It was first standardized in 1980s by IEEE 802.3 standard. IEEE 802.3 defines the physical layer and the medium access control (MAC) sub-layer of the data link layer for wired Ethernet networks. Ethernet is classified into two categories: classic Ethernet and switched Ethernet.

802.11 – Wi-Fi : IEEE 802.11 is part of the IEEE 802 set of LAN protocols, and specifies the set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) Wi-Fi computer communication in various frequencies, including but not limited to 2.4 GHz, 5 GHz, and 60 GHz frequency bands.

802.16 – Wi-Max: The standard for WiMAX technology is a standard for Wireless Metropolitan Area Networks (WMANs) that has been developed by working group number 16 of IEEE 802, specializing in point-to-multipoint broadband wireless access.

802.15.4 -LR-WPAN : A collection of standards for Low-rate wireless personal area network. The IEEE's 802.15.4 standard defines the MAC and PHY layer used by, but not limited to, networking specifications such as Zigbee®, 6LoWPAN, Thread, WI SUN and MiWi™ protocols. The standards provide low-cost and low-speed communication for power constrained devices.

2G/3G/4G- Mobile Communication : These are different types of telecommunication generations. IoT devices are based on these standards can communicate over the cellular networks.

Network Layer

Responsible for sending of IP datagrams from the source network to the destination network. Network layer performs the host addressing and packet routing. We used IPv4 and IPv6 for Host identification. IPv4 and IPv6 are hierarchical IP addressing schemes.

IPv4 : An Internet Protocol address (IP address) is a numerical label assigned to each device connected to a computer network that uses the Internet Protocol for communication. An IP address serves two main functions: host or network interface identification and location addressing. Internet Protocol version 4 (IPv4) defines an IP address as a 32-bit number. However, because of the growth of the Internet and the depletion of available IPv4 addresses, a new version of IP (IPv6), using 128 bits for the IP address, was standardized in 1998. IPv6 deployment has been ongoing since the mid-2000s.

IPv6 : Internet Protocol version 6 (IPv6) is successor of IPv4. IPv6 was developed by the Internet Engineering Task Force (IETF) to deal with the long-anticipated problem of IPv4 address exhaustion. In December 1998, IPv6 became a Draft Standard for the IETF, who subsequently ratified it as an Internet Standard on 14 July 2017. IPv6 uses a 128-bit address, theoretically allowing 2128, or approximately 3.4×1038 addresses.

6LoWPAN : It is an acronym of IPv6 over Low-Power Wireless Personal Area Networks. 6LoWPAN is the name of a concluded working group in the Internet area of the IETF. This protocol allows for the smallest devices with limited processing ability to transmit information wirelessly using an internet protocol. 6LoWPAN can communicate with 802.15.4 devices as well as other types of devices on an IP network link like Wi-Fi.

Transport Layer

This layer provides functions such as error control, segmentation, flow control and congestion control. So, this layer protocols provide end-to-end message transfer capability independent of the underlying network.

TCP : TCP (Transmission Control Protocol) is a standard that defines how to establish and maintain a network conversation through which application programs can exchange data. TCP works with the Internet Protocol (IP), which defines how computers send packets of data to each other. Together, TCP and IP are the basic rules defining the Internet. The Internet Engineering Task Force (IETF) defines TCP in the Request for Comment (RFC) standards document number 793.

UDP: User Datagram Protocol (UDP) is a Transport Layer protocol. UDP is a part of Internet Protocol suite, referred as UDP/IP suite. Unlike TCP, it is unreliable and connectionless protocol. So, there is no need to establish connection prior to data transfer.

Application Layer

Application layer protocols define how the applications interface with the lower layer protocols to send over the network.

HTTP : *Hypertext Transfer Protocol (HTTP)* is an application-layer protocol for transmitting hypermedia documents, such as HTML. It was designed for communication between web browsers and web servers, but it can also be used for other purposes. HTTP follows a classical client-server model, with a client opening a connection to make a request, then waiting until it receives a response. HTTP is a stateless protocol, meaning that the server does not keep any data (state) between two requests.

CoAP : CoAP-Constrained Application Protocol is a specialized Internet Application Protocol for constrained devices, as defined in RFC 7252. It enables devices to communicate over the Internet. The protocol is especially targeted for constrained hardware such as 8-bits microcontrollers, low power sensors and similar devices that can't run on HTTP or TLS.

WebSocket : The WebSocket Protocol enables two-way communication between a client running untrusted code in a controlled environment to a remote host that has opted-in to communications from that code. The security model used for this is the origin-based security model commonly used by web browsers.

MQTT : MQTT is a machine-to-machine (M2M)/"Internet of Things" connectivity protocol. It was designed as an extremely lightweight publish/subscribe messaging transport and useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium.

XMPP : Extensible Messaging and Presence Protocol (XMPP) is a communication protocol for message-oriented middleware based on XML (Extensible Markup Language). It enables the near-real-time exchange of structured yet extensible data between any two or more network entities.

DDS: The Data Distribution Service (DDS™) is a middleware protocol and API standard for data-centric connectivity from the Object Management Group® (OMG®). It integrates the components of a system together, providing low-latency data connectivity, extreme reliability, and a scalable architecture that business and mission-critical Internet of Things (IoT) applications need.

AMQP : The AMQP – IoT protocols consist of a hard and fast of components that route and save messages within a broker carrier, with a set of policies for wiring the components together. The AMQP protocol enables patron programs to talk to the dealer and engage with the AMQP model.

1.4 Logical Design of IoT

Logical design of IoT system refers to an abstract representation of the entities & processes without going into the low-level specifies of the implementation. For understanding Logical Design of IoT, we describe given below terms.

- IoT Functional Blocks
- IoT Communication Models
- IoT Communication APIs

1.4.1 IoT Functional Blocks

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

Device: An IoT system comprises of devices that provide sensing, actuation, monitoring and control functions.

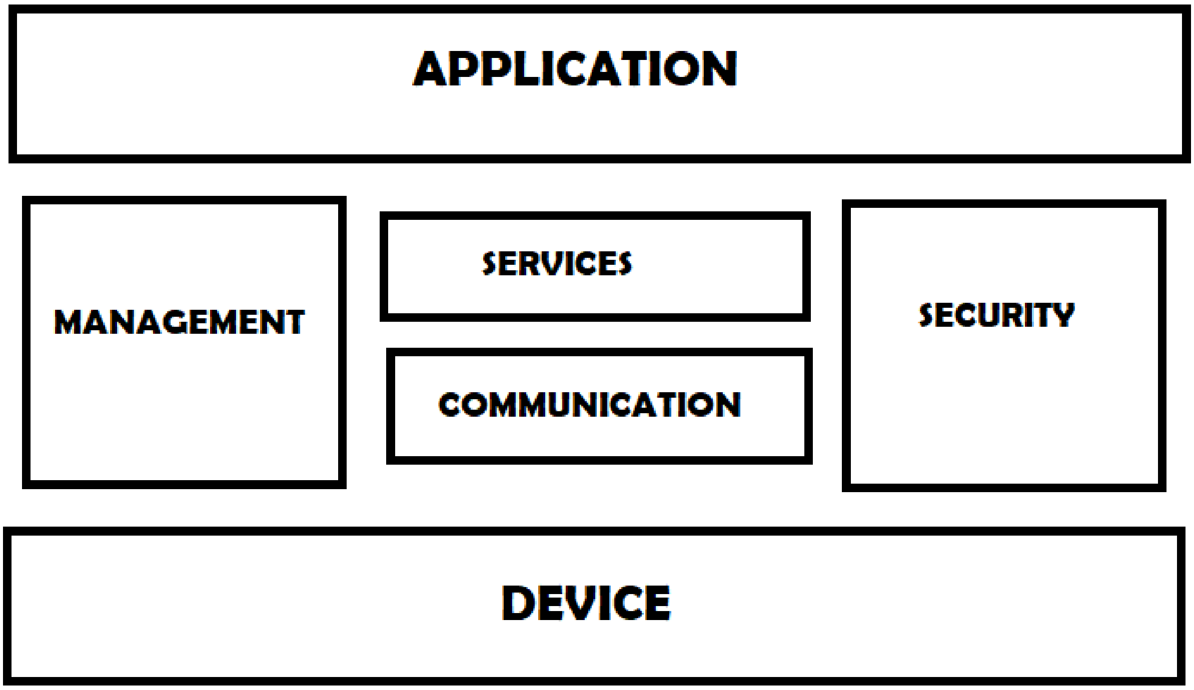
Communication: Handles the communication for the IoT system.

Services: services for device monitoring, device control service, data publishing services and services for device discovery.

Management: Provides various functions to govern the IoT system.

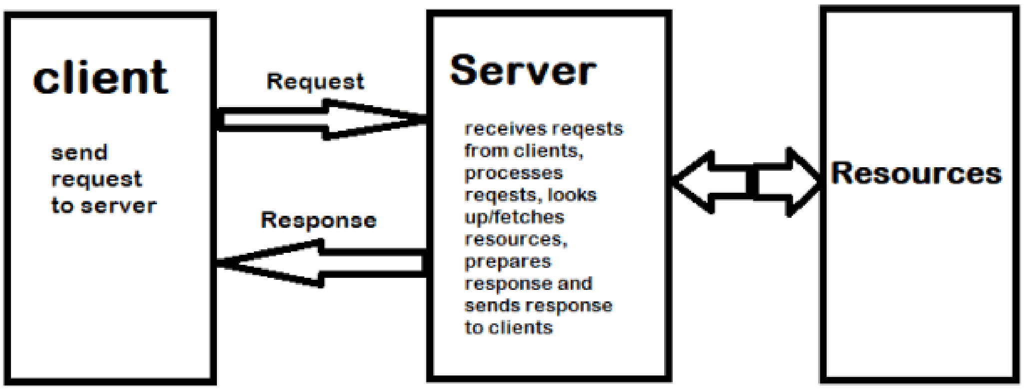
Security: this block secures the IoT system and by providing functions such as authentication , authorization, message and content integrity, and data security.

Application: This is an interface that the users can use 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 data.



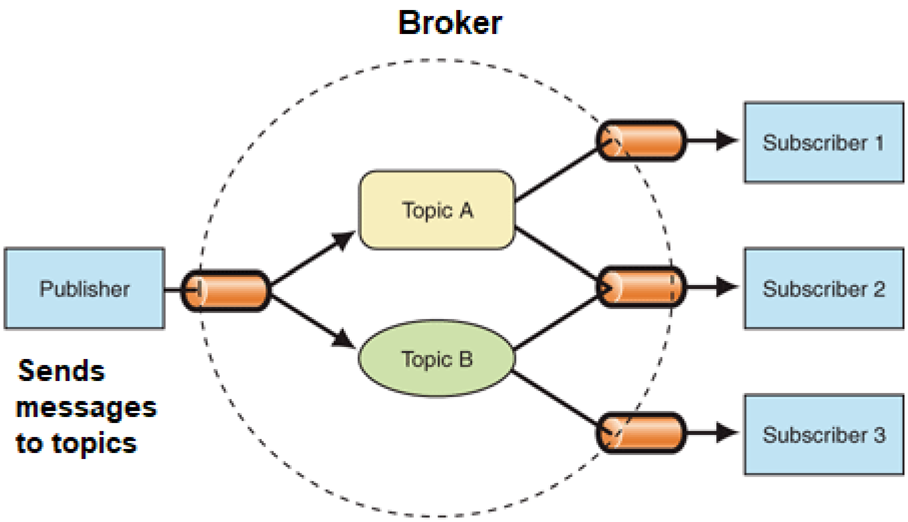
1.4.2 IoT Communication Models

Request-Response Model: - Request-response model is communication model in which the client sends requests to the server and the server responds to the requests. When the server receives a request, it decides how to respond, fetches the data, retrieves resource representation, prepares the response, and then sends the response to the client. Request-response is a stateless communication model and each request-response pair is independent of others. HTTP works as a request-response protocol between a client and server. A web browser may be the client, and an application on a computer that hosts a web site may be the server.
Example: A client (browser) submits an HTTP request to the server; then the server returns a response to the client. The response contains status information about the request and may also contain the requested content.

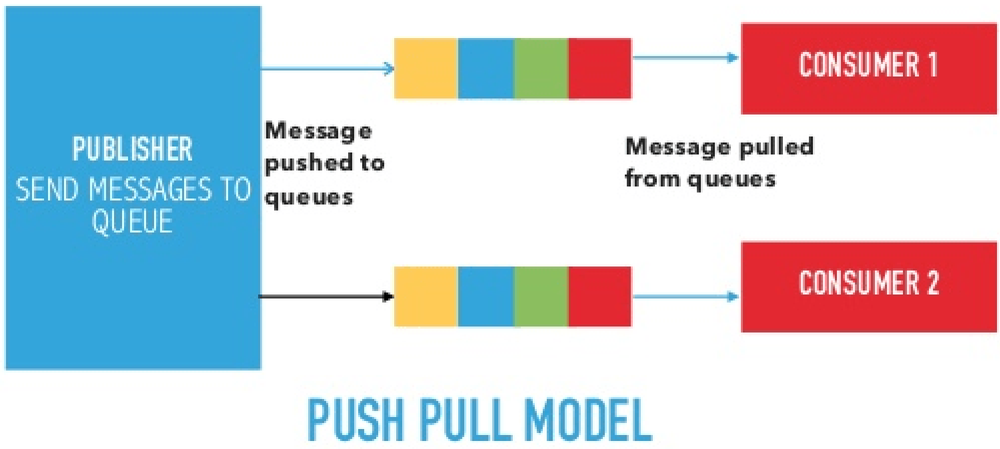


Request-Response Communication Model

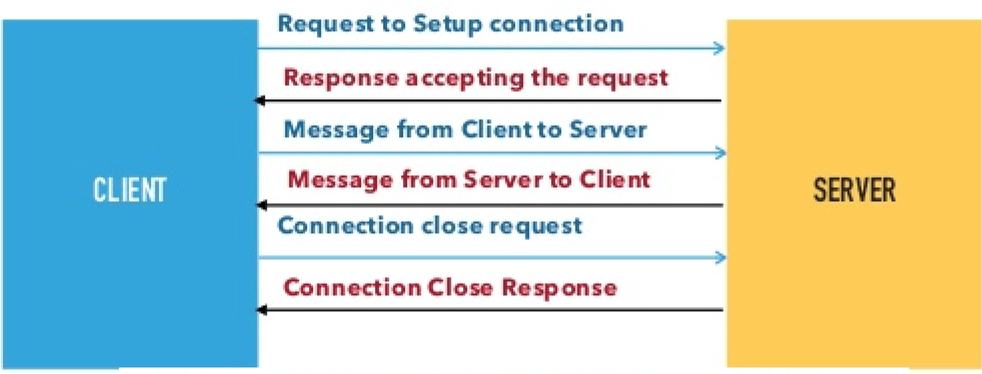
Publish-Subscribe Model: - Publish-Subscribe is a communication model that involves publishers, brokers and consumers. Publishers are the source of data. Publishers send the data to the topics which are managed by the broker. Publishers are not aware of the consumers. Consumers subscribe to the topics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



Push-Pull Model Push-Pull is a 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 consumers. Queues help in decoupling the messaging between the Producers and Consumers. Queues also act as a buffer which helps in situations when there is a mismatch between the rate at which the producers push data and the rate rate at which the consumer pull data.



Exclusive Pair Model: - Exclusive Pair is a bidirectional, fully duplex communication model that uses a persistent connection between the client and server. Connection 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 stateful communication model and the server is aware of all the open connections.



EXCLUSIVE PAIR COMMUNICATION MODEL

1.4.3 IoT Communication APIs

Generally, we used Two APIs For IoT Communication. These IoT Communication APIs are:

- REST-based Communication APIs
- WebSocket-based Communication APIs

REST-based Communication APIs

Representational state transfer (REST) is a set of architectural principles by which you can design Web services the Web APIs that focus on systems resources and how resource states are addressed and transferred. REST APIs that follow the request response communication model, the rest architectural constraint apply to the components, connector, and data elements, within a distributed hypermedia system. The rest architectural constraint are as follows:

Client-server – The principle behind the client-server constraint is the separation of concerns. for example, clients should not be concerned with the storage of data which is concern of the serve. Similarly, the server should not be concerned about the user interface, which is concern of the client. Separation allows client and server to be independently developed and updated.

Stateless – Each request from client to server must contain all the information necessary to understand the request and cannot take advantage of any stored context on the server. The session state is kept entirely on the client.

Cache-able – Cache constraints requires that the data within a response to a request be implicitly or explicitly leveled as cache-able or non cache-able. If a response is cache-able, then a client cache is given the right to reuse that repsonse data for later, equivalent requests. caching can partially or completely eliminate some instructions and improve efficiency and scalability.

Layered system – layered system constraints, constrains the behavior of components such that each component cannot see beyond the immediate layer with they are interacting. For example, the client cannot tell whether it is connected directly to the end server or two an intermediaryalong the way. System scalability can be improved by allowing intermediaries to respond to requests instead of the end server, without the client having to do anything different.

Uniform interface – uniform interface constraints requires that the method of communication between client and server must be uniform. Resources are identified in the requests (by URIs in web-based systems) and are themselves is separate from the representations of the resources data returned to the client. When a client holds a representation of resources it has all the information required to update or delete the resource you (provided the client has required permissions). Each message includes enough information to describe how to process the message.

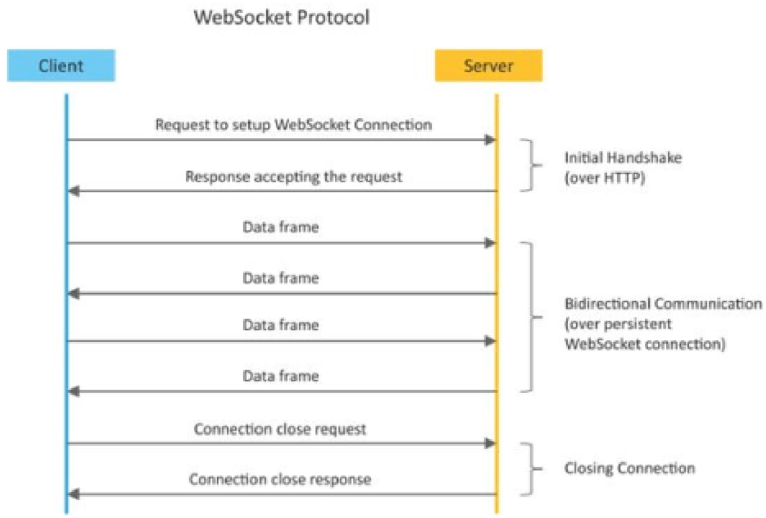
Code on demand – Servers can provide executable code or scripts for clients to execute in their context. this constraint is the only one that is optional.
A RESTful web service is a " Web API " implemented using HTTP and REST principles. REST is most popular IoT Communication APIs.

HTTP methods

Uniform Resource Identifier (URI)	GET	PUT	PATCH	POST	DELETE
Collection, such as `https://api.example.com/resources/`	*List* the URIs and perhaps other details of the collection's members.	*Replace* the entire collection with another collection.	Not generally used	*Create* a new entry in the collection. The new entry's URI is assigned automatically and is usually returned by the operation.	*Delete* the entire collection.
Element, such as `https://api.example.com/resources/item5`	*Retrieve* a representation of the addressed member of the collection, expressed in an appropriate Internet media type.	*Replace* the addressed member of the collection, or if it does not exist, create it.	*Update* the addressed member of the collection.	Not generally used. Treat the addressed member as a collection in its own right and create a new entry within it.	*Delete* the addressed member of the collection.

WebSocket based communication API

WebSocket APIs allow bi-directional, full duplex communication between clients and servers. WebSocket APIs follow the exclusive pair communication model. Unlike request-response model such as REST, the WebSocket APIs allow full duplex communication and do not require new connection to be setup for each message to be sent. WebSocket communication begins with a connection setup request sent by the client to the server. The request (called web socket handshake) is sent over HTTP and the server interprets it is an upgrade request. If the server supports websocket protocol, the server responds to the websocket handshake response. After the connection setup client and server can send data/mesages to each other in full duplex mode. Websocket API reduce the network traffic and latency as there is no overhead for connection setup and termination requests for each message. Websocket suitable for IoT applications that have low latency or high throughput requirements. So, Web socket is most suitable IoT Communication APIs for IoT System.



1.5 Domain Specific IoTs

IoT Applications for :

- Home
- Cities
- Environment
- Energy Systems
- Retail
- Logistics
- Industry
- Agriculture
- Health & Lifestyle

IoT applications for smart homes:

- Smart Lighting
- Smart Appliances
- Intrusion Detection
- Smoke / Gas Detectors

Home Automation Smart Lighting

- Smart lighting achieves energy savings by sensing the human movements and their environments and controlling the lights accordingly.
- Key enabling technologies for smart lighting include :
    - Solid state lighting (such as LED lights)
    - IP-enabled lights
- Wireless-enabled and Internet connected lights can be controlled remotely from IoT applications such as a mobile or web application.
- Paper:
  Energy-aware wireless sensor network with ambient intelligence for smart LED lighting system control [IECON, 2011]-> presented controllable LED lighting system that is embedded with ambient intelligence gathered from a distributed smart WSN to optimize and control the lighting system to be more efficient and user-oriented.

Home Automation Smart Appliances

- Smart appliances make the management easier and provide status information of appliances to the users remotely. E.g: smart washer/dryer that can be controlled remotely and notify when the washing/drying cycle is complete.
- Open Remote is an open source automation platform for smart home and building that can control various appliances using mobile and web applications.
    - It comprises of three components:
        - a Controller-> manages scheduling and runtime integration between devices.
        - a Designer -> allows to create both configuration for the controller and user interface designs.
        - Control Panel -> allows to interact with devices and control them.
- Paper:
  An IoT-based Appliance Control System for Smart Home [ICICIP, 2013] implemented an IoT based appliance control system for smart homes that uses a smart-central controller to set up a wireless sensor and actuator network and control modules for appliances

Home Automation Intrusion Detection

- Home intrusion detection systems use security cameras and sensors to detect intrusions and raise alerts.
- The form of the alerts can be in form: - SMS - Email - Image grab or a short video clip as an email attachment
- Papers:
  Could controlled intrusion detection and burglary prevention stratagems in home automation systems [BCFIC, 2012] ->present a controlled intrusion detection system that uses location-aware services, where the geo-location of each node of a home automation system is independently detected and stored in the cloud

  An Intelligent Intrusion Detection System Based on UPnP Technology for Smart Living [ISDA, 2008] -> implement an intrusion detection system that uses image processing to recognize the intrusion and extract the intrusion subject and generate Universal-Plug-and-Play (UPnP-based) instant messaging for alerts.

Home Automation Smoke / Gas Detectors

- Smoke detectors are installed in homes and buildings to detect smoke that is typically an early sign of fire.
- It uses optical detection, ionization or air sampling techniques to detect smoke
- The form of the alert can be in form :
- Signals that send to a fire alarm system
- Gas detector can detect the presence of harmful gases such as carbon monoxide (CO), liquid petroleum gas (LPG), etc.
- Paper:
  Development of Multipurpose Gas Leakage and Fire Detector with Alarm System [TIIEC, 2013]-> designed a system that can detects gas leakage and smoke and gives visual level indication.

Cities IoT applications for smart cities:

1. Smart Parking
2. Smart Lighting for Road
3. Smart Road
4. Structural Health Monitoring
5. Surveillance
6. Emergency Response

Cities Smart Parking

- Finding the parking space in the crowded city can be time consuming and frustrating
- Smart parking makes the search for parking space easier and convenient for driver.
- It can detect the number of empty parking slots and send the information over the Internet to the smart parking applications which can be accessed by the drivers using their smart phones, tablets, and in car navigation systems.
- Sensors are used for each parking slot to detect whether the slot is empty or not, and this information is aggregated by local controller and then sent over the Internet to database.
- Paper:
  Design and implementation of a prototype Smart Parking (SPARK) system using WSN [International Conference on Advanced Information Networking and Applications Workshop, 2009]-> designed and implemented a prototype smart parking system based on wireless sensor network technology with features like remote parking monitoring, automate guidance, and parking reservation mechanism.

Cities Smart Lighting for Roads

- It can help in saving energy
- Smart lighting for roads allows lighting to be dynamically controlled and also adaptive to ambient conditions.
- Smart light connected to the Internet can be controlled remotely to configure lighting schedules and lighting intensity.
- Custom lighting configurations can be set for different situations such as a foggy day, a festival, etc.

- Paper:
  Smart Lighting solutions for Smart Cities [International Conference on Advance Information Networking and Applications Workshop, 2013]-> described the need for smart lighting system in smart cities, smart lighting features and how to develop interoperable smart lighting solutions.

Cities Smart Roads

- Smart Roads provides information on driving conditions, travel time estimates and alerts in case of poor driving conditions, traffic congestions and accidents.
- Such information can help in making the roads safer and help in reducing traffic jams
- Information sensed from the roads can be communicated via internet to cloud-based applications and social media and disseminated to the drivers who subscribe to such applications.
- Paper:
  Sensor networks for smart roads [PerCom Workshop, 2006]-> proposed a distributed and autonomous system of sensor network nodes for improving driving safety on public roads, the system can provide the driver and passengers with a consistent view of the road situation a few hundred metes ahead of them or a few dozen miles away, so that they can react to potential dangers early enough.

Cities Structural Health Monitoring

- It uses a network of sensors to monitor the vibration levels in the structures such as bridges and buildings.
- The data collected from these sensors is analyzed to assess the health of the structures.
- By analyzing the data it is possible to detect cracks and mechanical breakdowns, locate the damages to a structure and also calculate the remaining life of the structure.
- Using such systems, advance warnings can be given in the case of imminent failure of the structure.
- Paper:
  Environmental Effect Removal Based Structural Health Monitoring in the Internet of Things [International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2013]-> proposed an environmental effect removal based structural health monitoring scheme in an IoT environment.
  Energy harvesting technologies for structural health monitoring applications [IEEE Conference on Technologies for Sustainability, 2013] -> Explored energy harvesting technologies of harvesting ambient energy, such as mechanical vibrations, sunlight, and wind.

Cities Surveillance

- Surveillance of infrastructure, public transport and events in cities is required to ensure safety and security.
- City wide surveillance infrastructure comprising of large number of distributed and Internet connected video surveillance cameras can be created.
- The video feeds from surveillance cameras can be aggregated in cloud-based scalable storage solutions.
- Cloud-based video analytics applications can be developed to search for patterns of specific events from the video feeds.

Cities Emergency Response

- IoT systems can be used for monitoring the critical infrastructure cities such as buildings, gas, and water pipelines, public transport and power substations.
- IoT systems for critical infrastructure monitoring enable aggregation and sharing of information collected from lager number of sensors.
- Using cloud-based architectures, multi-modal information such as sensor data, audio, video feeds can be analyzed I near real-time to detect adverse events.
- The alert can be in the form:
    - Alerts sent to the public
    - Re-rerouting of traffic
    - Evacuations of the affected areas

Environment IoT applications for smart environments:

1. Weather Monitoring
2. Air Pollution Monitoring
3. Noise Pollution Monitoring
4. Forest Fire Detection
5. River Flood Detection

Environment Weather Monitoring

- It collects data from a number of sensor attached such as temperature, humidity, pressure, etc and send the data to cloud-based applications and store back-ends.
- The data collected in the cloud can then be analyzed and visualized by cloud-based applications.
- Weather alert can be sent to the subscribed users from such applications.
- AirPi is a weather and air quality monitoring kit capable of recording and uploading information about temperature, humidity, air pressure, light levels, UV levels, carbon monoxide, nitrogen dioxide and smoke level to the Internet.
- Paper:
  PeWeMoS – Pervasive Weather Monitoring System [ICPCA, 2008]-> Presented a pervasive weather monitoring system that is integrated with buses to measure weather variables like humidity, temperature, and air quality during the bus path

Environment Air Pollution Monitoring

- IoT based air pollution monitoring system can monitor emission of harmful gases by factories and automobiles using gaseous and meteorological sensors.
- The collected data can be analyzed to make informed decisions on pollutions control approaches.
- Paper:
  Wireless sensor network for real-time air pollution monitorings [ICCSPA, 2013]-> Presented a real time air quality monitoring system that comprises of several distributed monitoring stations that communicate via wireless with a back- end server using machine-to machine communication.

Environment Noise Pollution Monitoring

- Noise pollution monitoring can help in generating noise maps for cities.
- It can help the policy maker in making policies to control noise levels near residential areas, school and parks.
- It uses a number of noise monitoring stations that are deployed at different places in a city.
- The data on noise levels from the stations is collected on servers or in the cloud and then the collected data is aggregate to generate noise maps.
- Papers:
  Noise mapping in urban environments : Applications at Suez city center [ICCIE, 2009]Presented a noise mapping study for a city which revealed that the city suffered from serious noise pollution.
  Sound Of City – Continuous noise monitoring for a health city [PerComW,2013]-> Designed a smartphone application that allows the users to continuously measure noise levels and send to a central server here all generated information is aggregated and mapped to a meaningful noise visualization map.

Environment Forest Fire Detection

- IoT based forest fire detection system use a number of monitoring nodes deployed at different location in a forest.
- Each monitoring node collects measurements on ambient condition including temperature, humidity, light levels, etc.
- Early detection of forest fires can help in minimizing the damage.
- Papers:
  A novel accurate forest fire detection system using wireless sensor networks [International Conference on Mobile Ad- hoc and Sensor Networks, 2011]-> Presented a forest fire detection system based on wireless sensor network. The system uses multi-criteria detection which is implemented by the artificial neural network. The ANN fuses sensing data corresponding to ,multiple attributes of a forest fire such as temperature, humidity, infrared and visible light to detect forest fires.

Environment River Flood Detection

- IoT based river flood monitoring system uses a number of sensor nodes that monitor the water level using ultrasonic sensors and flow rate using velocity sensors.
- Data from these sensors is aggregated in a server or in the cloud, monitoring applications raise alerts when rapid increase in water level and flow rate is detected.
- Papers:
  RFMS : Real time flood monitoring system with wireless sensor networks [MASS, 2008]-> Described a river flood monitoring system that measures river and weather conditions through wireless sensor nodes equipped with different sensors
  Urban Flash Flood Monitoring, Mapping and Forecasting via a Tailored Sensor Network System [ICNSC, 2006] -> Described a motes-based sensor network for river flood monitoring that includes a water level monitoring module, network video recorder module, and data processing module that provides floods information n the form of raw data, predict data, and video feed.

Energy IoT applications for smart energy systems:

1. Smart Grid
2. Renewable Energy Systems
3. Prognostics

Energy Smart Grids

- Smart grid technology provides predictive information and recommendation s to utilize, their suppliers, and their customers on how best to manage power.
- Smart grid collect the data regarding :
  - Electricity generation
  - Electricity consumption
  - Storage
  - Distribution and equipment health data
- By analyzing the data on power generation, transmission and consumption of smart grids can improve efficiency throughout the electric system.
- Storage collection and analysis of smarts grids data in the cloud can help in dynamic optimization of system operations, maintenance, and planning.
- Cloud-based monitoring of smart grids data can improve energy usage usage levels via energy feedback to users coupled with real-time pricing information.
- Condition monitoring data collected from power generation and transmission systems can help in detecting faults and predicting outages.

Energy Renewable Energy System

- Due to the variability in the output from renewable energy sources (such as solar and wind), integrating them into the grid can cause grid stability and reliability problems.
- IoT based systems integrated with the transformer at the point of interconnection measure the electrical variables and how much power is fed into the grid
- To ensure the grid stability, one solution is to simply cut off the overproductions.
- Paper:
  Communication systems for grid integration of renewable energy resources [IEEE Network, 2011]-> Provided the closed-loop controls for wind energy system that can be used to regulate the voltage at point of interconnection which coordinate wind turbine outputs and provides reactive power support.

Energy Prognostics

- IoT based prognostic real-time health management systems can predict performance of machines of energy systems by analyzing the extent of deviation of a system from its normal operating profiles.
- In the system such as power grids, real time information is collected using specialized electrical sensors called Phasor Measurement Units (PMU)
- Analyzing massive amounts of maintenance data collected from sensors in energy systems and equipment can provide predictions for impending failures.
- OpenPDC is a set of applications for processing of streaming time-series data collected from Phasor Measurements Units (PMUs) in real-time.

Retail IoT applications in smart retail systems:

1. Inventory Management
2. Smart Payments
3. Smart Vending Machines

Retail Inventory Management

- IoT system using Radio Frequency Identification (RFID) tags can help inventory management and maintaining the right inventory levels.
- RFID tags attached to the products allow them to be tracked in the real-time so that the inventory levels can be determined accurately and products which are low on stock can be replenished.
- Tracking can be done using RFID readers attached to the retail store shelves or in the warehouse.
- Paper:
  RFID data-based inventory management of time-sensitive materials [IECON, 2005]-> described an RFID data-based inventory management system for time-sensitive materials

Retail Smart Payments

- Smart payments solutions such as contact-less payments powered technologies such as Near field communication (NFC) and Bluetooth.
- NFC is a set of standards for smart-phones and other devices to communicate with each other by bringing them into proximity or by touching them
- Customer can store the credit card information in their NFC-enabled smart-phones and make payments by bringing the smart-phone near the point of sale terminals.
- NFC maybe used in combination with Bluetooth, where NFC initiates initial pairing of devices to establish a Bluetooth connection while the actual data transfer takes place over Bluetooth.

Retail Smart Vending Machines

- Smart vending machines connected to the Internet allow remote monitoring of inventory levels, elastic pricing of products, promotions, and contact-less payments using NFC.
- Smart-phone applications that communicate with smart vending machines allow user preferences to be remembered and learned with time. E.g: when a user moves from one vending machine to the other and pair the smart-phone, the user preference and favourite product will be saved and then that data is used for predictive maintenance.
- Smart vending machines can communicated each others, so if a product out of stock in a machine, the user can be routed to nearest machine
- For perishable items, the smart vending machines can reduce the price as the expiry date nears.

Logistic IoT applications for smart logistic systems:

1. Fleet Tracking
2. Shipment Monitoring
3. Remote Vehicle Diagnostics

Logistics Fleet Tracking

- Vehicle fleet tracking systems use GPS technology to track the locations of the vehicles in the real- time.
- Cloud-based fleet tracking systems can be scaled up on demand to handle large number of vehicles,
- The vehicle locations and routers data can be aggregated and analyzed for detecting bottlenecks I the supply chain such as traffic congestions on routes, assignments and generation of alternative routes, and supply chain optimization
- Paper:
  A Fleet Monitoring System for Advanced Tracking of commercial Vehicles [IEEE International Conference in Systems, Man and Cybernetics, 2006]-> provided a system that can analyze messages sent from the vehicles to identify unexpected incidents and discrepancies between actual and planned data, so that remedial actions can be taken.

Logistics Shipment Monitoring

- Shipment monitoring solutions for transportation systems allow monitoring the conditions inside containers.
- E.g : Containers carrying fresh food produce can be monitored to prevent spoilage of food. IoT based shipment monitoring systems use sensors such as temperature, pressure, humidity, for instance, to monitor the conditions inside the containers and send the data to the cloud, where it can be analyzed to detect food spoilage.
- Paper:
  On a Cloud-Based Information Technology Framework for Data Driven Intelligent Transportation System [Journal of Transportation Technologies, 2013]-> proposed a cloud based framework for real time fresh food supply tracking and monitoring
  Container Integrity and Condition Monitoring using RF Vibration Sensor Tags [IEEE International Conference on Automation Science and Engineering, 2007] _ Proposed a system that can monitor the vibrations patterns of a container and its contents to reveal information related to its operating environment and integrity during transport, handling, and storage.

Logistics Remote Vehicle Diagnostics

- It can detect faults in the vehicles or warn of impending faults.
- These diagnostic systems use on-board IoT devices for collecting data on vehicle operation such as speed, engine RPM, coolant temperature, fault code number and status of various vehicle sub- system.
- Modern commercial vehicles support on-board diagnostic (OBD) standard such as OBD-II
- OBD systems provide real-time data on the status of vehicle sub-systems and diagnostic trouble codes which allow rapidly identifying the faults in the vehicle.
- IoT based vehicle diagnostic systems can send the vehicle data to centralized servers or the cloud where it can be analyzed to generate alerts and suggest remedial actions.

Agriculture IoT applications for smart agriculture:

1. Smart Irrigation
2. Green House Control

Agriculture Smart Irrigation

- Smart irrigation system can improve crop yields while saving water.
- Smart irrigation systems use IoT devices with soil moisture sensors to determined the amount of moisture on the soil and release the flow of the water through the irrigation pipes only when the moisture levels go below a predefined threshold.
- It also collects moisture level measurements on the server on in the cloud where the collected data can be analyzed to plan watering schedules.
- Cultivar's Raincloud is a device for smart irrigation that uses water valves, soil sensors, and a WiFi enabled programmable computer. [http://ecultivar.com/rain-cloud-product-project/]

Agriculture Green House Control

- It controls temperature, humidity, soil, moisture, light, and carbon dioxide level that are monitored by sensors and climatological conditions that are controlled automatically using actuation devices.
- IoT systems play an importance role in green house control and help in improving productivity.
- The data collected from various sensors is stored on centralized servers or in the cloud where analysis is performed to optimize the control strategies and also correlate the productivity with different control strategies.
- Paper: -
  Wireless sensing and control for precision Greenhouse management [ICST, 2012]-> Provided a system that uses wireless sensor network to monitor and control the agricultural parameters like temperature and humidity in the real time for better management and maintenance of agricultural production.

Industry IoT applications in smart industry:

1. Machine Diagnosis & Prognosis
2. Indoor Air Quality Monitoring

Industry Machine Diagnosis & Prognosis

- Machine prognosis refers to predicting the performance of machine by analyzing the data on the current operating conditions and how much deviations exist from the normal operating condition.
- Machine diagnosis refers to determining the cause of a machine fault.
- Sensors in machine can monitor the operating conditions such as temperature and vibration levels, sensor data measurements are done on timescales of few milliseconds to few seconds which leads to generation of massive amount of data.
- Case-based reasoning (CBR) is a commonly used method that finds solutions to new problems based on past experience.
- CBR is an effective technique for problem solving in the fields in which it is hard to establish a quantitative mathematical model, such as machine diagnosis and prognosis.

Industry Indoor Air Quality Monitoring

- Harmful and toxic gases such as carbon monoxide (CO), nitrogen monoxide (NO), Nitrogen Dioxide, etc can cause serious health problem of the workers.

- IoT based gas monitoring systems can help in monitoring the indoor air quality using various gas sensors. -
- The indoor air quality can be placed for different locations
- Wireless sensor networks based IoT devices can identify the hazardous zones, so that corrective measures can be taken to ensure proper ventilation.
- Papers:
  A hybrid sensor system for indoor air quality monitoring [IEEE International Conference on Distributed Computing in Sensor System, 2013]-> presented a hybrid sensor system for indoor air quality monitoring which contains both stationary sensor and mobile sensors.

  Indoor air quality monitoring using wireless sensor network [International Conference on Sensing Technology, 2012] -> provided a wireless solution for indoor air quality monitoring that measures the environmental parameters like temperature, humidity, gaseous pollutants, aerosol and particulate matter to determine the indoor air quality.

Health & Lifestyle IoT applications in smart health & lifestyle:

1. Health & Fitness Monitoring
2. Wearable Electronics

Fitness Monitoring

- Wearable IoT devices allow to continuous monitoring of physiological parameters such as blood pressure, heart rate, body temperature, etc than can help in continuous health and fitness monitoring.
- It can analyze the collected health-care data to determine any health conditions or anomalies.
- The wearable devices may can be in various form such as:
- Belts
- Wrist-bands
- Papers:
  Toward ubiquitous mobility solutions for body sensor network health care [IEEE Communications Magazine, 2012]-> Proposed an ubiquitous mobility approach for body sensor network in health-care

  A wireless sensor network compatible wearable u-healthcare monitoring system using integrated ECG, accelerometer and SpO2 [International Conference of the IEEE Engineering in Medicine and Biology Society, 2008]-> Health & Lifestyle Health & Designed a wearable ubiquitous health-care monitoring system that uses integrated electrocardiogram (ECG), accelerometer and oxygen saturation (SpO2) sensors.

Health & Lifestyle Wearable Electronics

- Wearable electronics such as wearable gadgets (smart watch, smart glasses, wristbands, etc) provide various functions and features to assist us in our daily activities and making us lead healthy lifestyles.
- Using the smart watch, the users can search the internet, play audio/video files, make calls, play games, etc.
- Smart glasses allow users to take photos and record videos, get map directions, check flight status or search internet using voice commands

- Smart shoes can monitor the walking or running speeds and jumps with the help of embedded sensors and be paired with smart phone to visualize the data.
- Smart wristbands can tract the daily exercise and calories burnt.