CHAPTER 6

AUTOMATION

6.1 Introduction to Automation

The concept of Automation has evolved from the term mechanization, which had its beginnings during the Industrial Revolution. Mechanization meant the replacement of human power with some form of mechanical power. Mechanization resulted in series of inventions such as Steam Engine by Watt, mechanical loom invented by Jacquard, Power loom by Edmund Cartwright, etc. Another historical development was the analytical engine by Charles Babbage which sowed the seeds for development of the modern computer. Though Mechanization reduced human efforts, it did not replace human with its technologies. Then came the need for automation.

In 1946, the term automation was first coined by Delmar S. Harder of the Ford Motor Company to describe the increased use of automatic devices and controls in mechanized production lines. When initially coined by Harder, the term Automation was used to describe automatic transfer of parts from one metalworking machine to another. But, Automation is now used in both manufacturing and non-manufacturing context to describe a variety of systems where the human effort and intelligence are substantially substituted by mechanical, electrical, or computerized action.

In a general sense, automation is a technology of executing a process by way of programmed commands along with automatic feedback control to ensure proper execution of the instructions thereby resulting in a system that is capable of operating without human intervention.

With constant technological improvements, automated systems have become advanced to a level of capability and performance that far surpasses the human abilities to accomplish similar activities. Automation has given birth to other technologies that are widely popular on their own today. Example: Robotics. Robotics has been explained in detail in the previous chapter.

6.2 Definition of Automation

The word 'Automation' is derived from Greek words "Auto"(self) and "Matos" (moving). Automation can be defined as *the set of technologies of carrying out a process or procedure without human assistance and achieves performance superior to manual operation.*

6.3 Types of Automation

The automation of production systems can be classified into three basic types:

1. Fixed Automation or Hard Automation
2. Programmable Automation or Soft Automation
3. Flexible Automation

1. **Fixed automation:** *Fixed automation or hard automation* is a type of automation which uses special purpose equipment in order to automate a fixed sequence of processing or assembly operations. The programmed commands are contained in the equipment in the form of cams, gears, wiring etc. The equipment is designed to be efficient for the fixed set of operations. Usually each of the operation in the sequence is simple involving a plain linear or rotational motion or both. But integration and co-ordination of one or more operations can introduce complexity in the hard automated system. This type of automation is highly recommended for mass production systems that require high rate of production. Examples are transfer lines found in the automotive industry, paint shops, distillation process, automatic assembly processes, chemical processes, etc.

Advantages of Fixed Automation:

1. The production rates realized are high
2. Since goods are mass produced, the unit cost will be low.
3. Material handling is automated by the specialized equipment and thus special robot intervention is not required

Disadvantages of Fixed Automation:

1. High initial investment for the special purpose equipment
2. Not flexible to accommodate product variety / product changes.

2. **Programmable automation:** The *Programmable automation or soft automation* is chosen in production systems where the volume of production is relatively low and there are a number of variety of products to be produced. Here, the equipment for production is designed to be adaptable to variations in the product styles/configuration.

The step by step instructions in the form of a program controls the sequence of operations and these programs are read and interpreted by the system.

For every new batch, the production equipment must be re-programmed and changed over to as per the new product configuration.

Advantages of Programmable Automation:

1. Very much suitable for batch production
2. Flexible to adapt to the changes in the product configuration since sequences can be programmed and re-programmed.

Disadvantages of Programmable Automation:

1. The cost of the general purpose equipment is high
2. Production time is lost due to frequent setup changes, loading of fixtures and also due to reprogramming. This reduces production rate compared to fixed automation

Examples of Programmable automation include Numerically Controlled (NC) machine tools, industrial robots, and Programmable Logic Controllers (PLC). In industries programmable automation is found in production of brackets, hinges, locks, door knobs, musical instruments, weaving, etc.

3. Flexible automation: This type of automation is used for mid production size and combines the features of both fixed automation and programmable automation. The flexible automated system is built in a way such that it can both produce a variety of products and with almost no time lost for setup changes from one configuration to another. Even reprogramming does not cause lost production time. This is because programming is done off-line at a computer terminal without using the production equipment itself. The system is therefore capable of producing many varieties in the product mix under various schedules without need for batch changes.

Advantages of Flexible Automation:

1. For the variety of product configurations, continuous production is possible
2. Flexible to adapt to the changes in the product configuration in very less time using an off-line computer terminal for programming and re-programming.
3. Improved quality of the product

Disadvantages of Flexible Automation:

1. The cost of investment is huge since the equipment is custom-built
2. Only medium production rates can be achieved unlike fixed automation
3. Compared to fixed automation, unit cost of the product is higher.

Example of a Flexible Automation System is the use of CNC Machine Tools along with Robots and Automated Guided Vehicles (AGV). In industries, flexible automation systems are used in fabrication, assembly and machining processes.

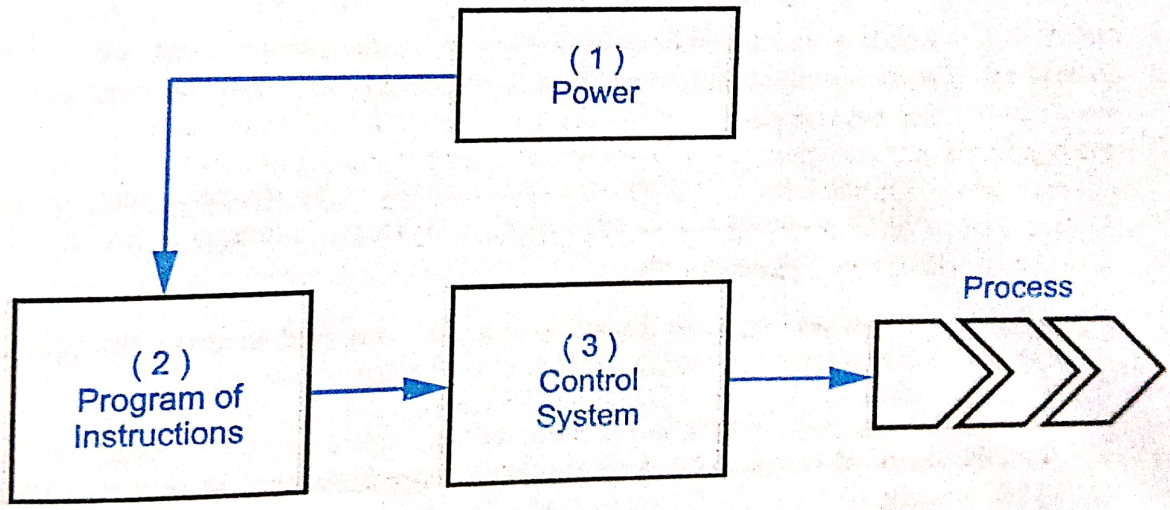
6.4 Basic Elements of an Automated System

An Automated system is the system that is used to realize automation.

As shown in Fig 6.1 there are three basic elements of an automated system. The three basic elements of an automated system are

1. A Power source
2. A program of instructions
3. A control system

Principally in an automated system, the program of instructions are fed to the control system where these instructions are executed and a power source is used to provide power to drive the process as well as operate the control system. The process then becomes an "**automated process**".



Basic elements of an automated system
Fig. 6.1

1. **Power Source:** An automated system is used to automatically complete the tasks in a process. To accomplish this, a power source has to drive both the process and the controls. The commonly used power source in an automated system is electric power.

   Electric power is widely preferred power source for an automated system due to its wide availability at reasonable cost, its ease of conversion into other forms of energy like

mechanical, thermal, hydraulic, pneumatic, etc, its easy storage in long life high performance batteries which makes it conveniently available at any place and its usage at lower levels to carryout signal transmission, information processing, data storage and communication.

Other power sources can be conventional sources such as fossil fuels, or non-conventional sources such as solar energy, wind energy, etc. These are generally used in combination with electrical power. Example: Fossil fuels are used to heat the furnace in casting, but electricity is used in the control system to regulate temperature and time cycle.

Even other energy sources can be converted to electrical energy and used to operate the process and its automation. Example: Conversion of Solar energy to electricity to operate an automated system.

As mentioned earlier, a power source is used to drive both process and for the automation.

a) **Power for the process:** Power is required to drive various manufacturing processes such as casting, injection moulding, machining, forging, welding, etc. In a manufacturing process, some form of power is employed to accomplish some action. For example: In sheet metal punching and blanking process, the form of energy used is mechanical and the action accomplished is the mechanical power to shear metal sheets.

   Apart from driving the manufacturing process, power is also used for material handling functions such as

   1. Loading and unloading the work unit, where power is required for moving the parts into the required position & orientation and after the process is completed, unload the parts.

   2. Transporting work units between operations by transport technologies such as AGVS (Automated Guided Vehicle System), automated storage and retrieval system, conveyors, etc.

b) **Power for the automation:** Power is not only required to drive the process but also required for automation which includes power for:

   i. Controller unit: Power is required for the controller unit to read and interpret the program of instructions, execute these instructions and send the commands to the actuator.

   ii. Power to actuate control signals: The controller unit sends the commands in the form of low voltage signals which is amplified to provide the required power for the actuator (which are electromechanical devices such as motors, valves, cylinder, switches, etc) to carry-out the commands.

   iii. Data acquisition and information processing: Power in small amount is needed to collect data from the process to use as input to control algorithm and upkeep of the

records of process performance.

2. **Program of Instructions:** The set of actions that is accomplished by an automated system are determined by the program of instructions. Each part produced in a manufacturing operation requires following of sequential processing steps within a work cycle. These processing steps for the work cycle are specified in a *work cycle program*. In NC machines, we call these as *Part Programs*.

The Work Cycle Programs in an automated system must include the following features:

a. Distinct number of steps involved in the work cycle. Example: Simple steps of load, process and unload.

b. Number of Process parameters (which are the inputs to the process), are the process parameters continuous or discrete? How are these parameters actuated? Will the parameters change during the step?

c. Is the work cycle completely automated or is there any human involvement?

d. Does the production style remain the same throughout the cycle (as in fixed automation) or does it changes across batches (as in programmable automation) or does it require processing different product styles or models in each cycle (as in flexible automation)?

e. Does the start dimensions vary? If so adjustments are required in the work cycle.

f. Does it require the operator to enter processing data for each cycle of work?

3. **Control System:** The function of the Control System is to execute the program of instructions and make the process to carry out a manufacturing operation.

There are basically two types of Control systems:

1. Closed loop Control system
2. Open loop Control system

1. *Closed loop Control System (Feedback Control System):* In this control system, the output variable is compared to an input parameter and the difference between the output variable (which is the actual condition) and input parameter (which is the input condition) is sensed and fed back to drive the output according to input requirements.

The basic elements of a feedback control system shown in Fig. 6.2 above are:

a. *Input parameter*: This is the set point which defines what must be the output value.

b. *Process*: Process is the operation that is being controlled.

c. *Output variable*: The output variable is the actual value of the parameter.

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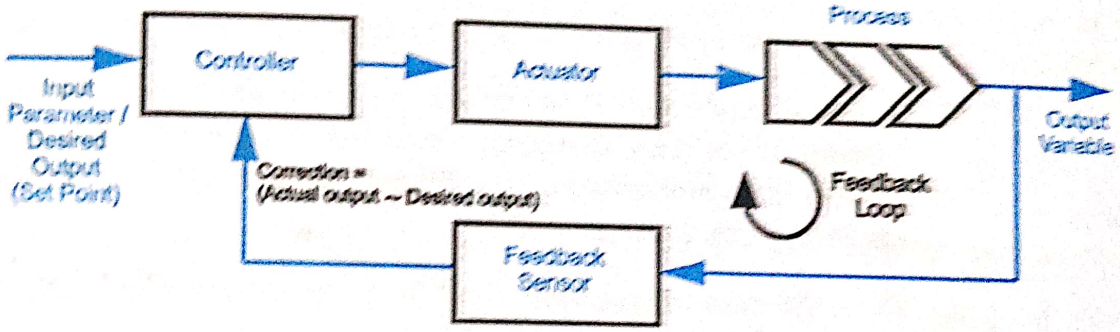
b. *Process:* Process is the operation that is being controlled.

c. *Output variable:* The output variable is the actual value of the parameter.

d. *Feedback Sensors:* Sensors measure the output variable and feeds it back to the control system. Thus, a feedback loop is created between input and output.

e. *Controller:* The function of the controller is to compare the actual output with the desired input, compute the difference and make suitable process adjustments that reduces the difference between output and input.

f. *Actuators:* The adjustments made in the process are actuated by hardware devices called Actuators that uses hardware devices like motor or valve to physically control the actions.



A feedback control system

Fig. 6.2

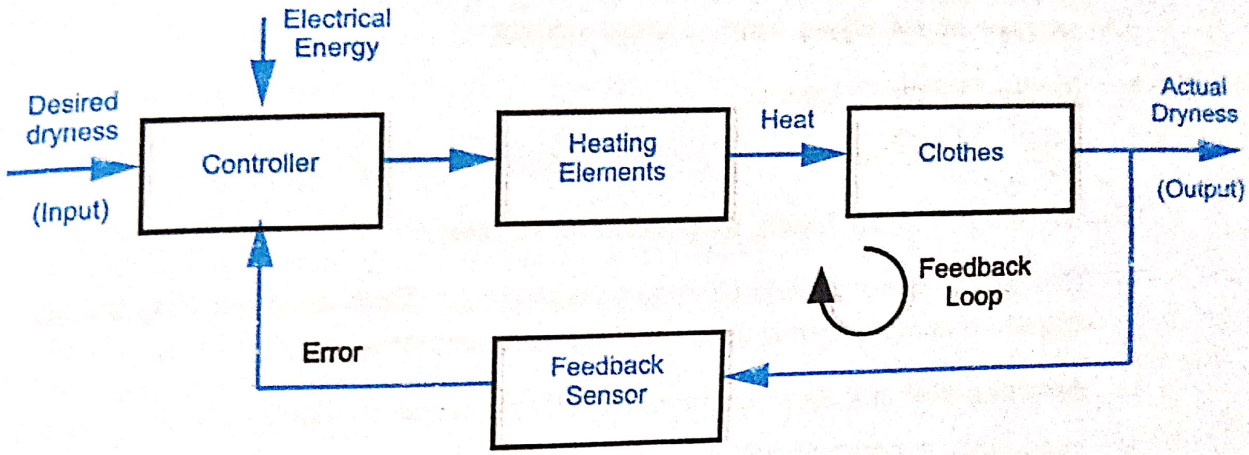
Advantages of Closed loop Control system:

1. The response to an input signal is faster
2. Can be used to stabilize systems that are inherently unstable in the open-loop form.
3. Closed loop systems are more accurate since the feedback ensures that the difference between the actual output and desired input is minimal. Thus errors are also minimal.
4. Closed loop systems are less affected by disturbances.

Disadvantages of Closed loop Control system:

1. The use of sensors for feedback increases the system cost.
2. More complex than open loop system since more number of components are used.
3. Since stability is the main concern in a closed loop control system, more care must be taken to design such a system

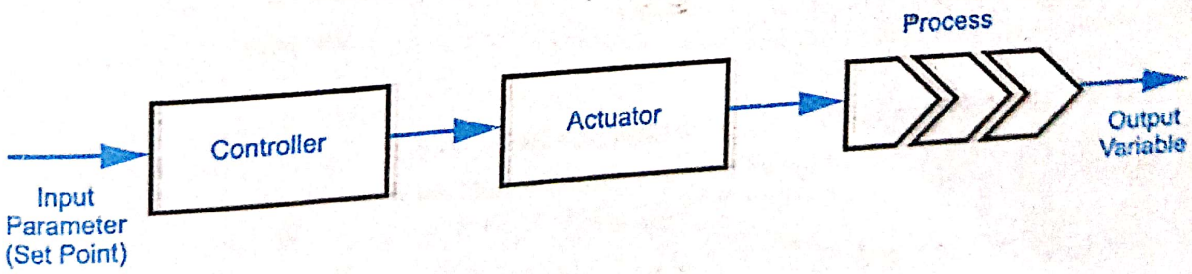
An example of a closed control system is the clothes dryer with a feedback sensor shown below in *Fig. 6.3.*



Example of feedback control system

Fig. 6.3

2. *Open loop Control System*: In this control system, there is no comparison of the output variable to the input parameter since feedback element is missing here. The Open loop control system is given below in terms of a simple block diagram (Fig. 6.4)



An open loop control system

Fig. 6.4

The open loop control system is chosen when the actions performed by the control system are simple, the reliability of the actuator is very high and the reaction forces counteracting the actuator are so negligible that they do not have any effect on the actuator.

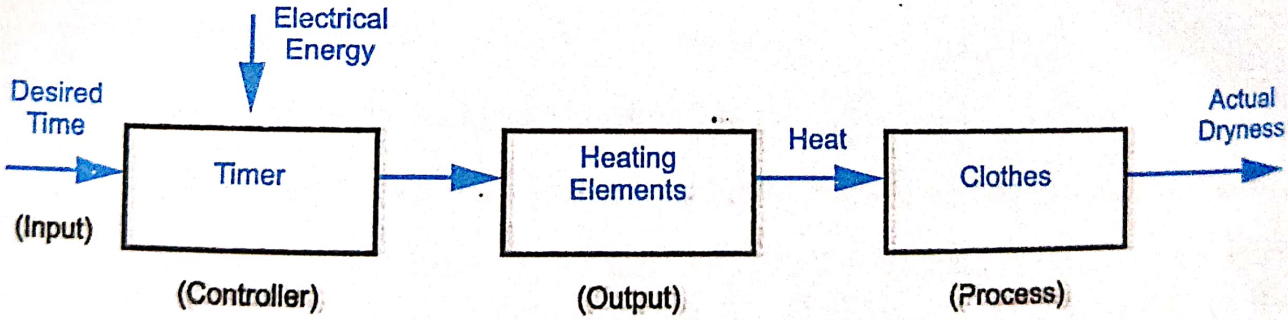
Advantages of an Open loop control system:

1. Simple system to operate
2. Does not involve much cost since feedback is not present

Disadvantages of an Open loop control system:

1. There is no measurement of output versus input. Thus we cannot say that the system output is achieving the desired input requirements.
2. Actuator will not have its intended effect on the process.
3. Open loop systems are more affected by disturbances.

Going by the same example of Electric dryer, we can image it to be an open-loop control system without the sensor as shown in Fig. 6.5.



Example of an open loop control system

Fig. 6.5

6.5 Advantages of Automation

The main advantages of automation are:

1. Automation results in increase of productivity: Use of automated systems can increase the

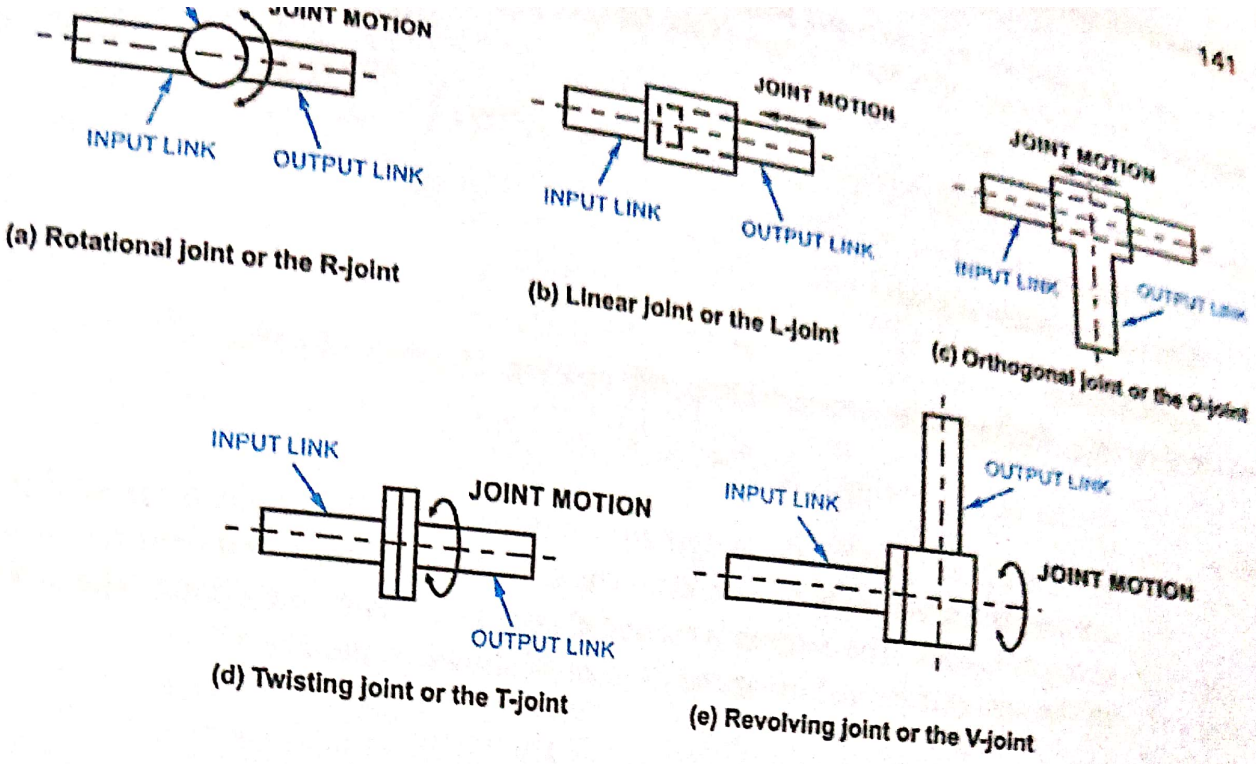
efficiency in performing tasks which results in higher productivity.

2. Improvement in Product Quality: Automated systems perform the manufacturing process with less variability compared to human workers and hence product quality is improved.
3. Increase in accuracy and repeatability: When an automated system is programmed to carry out a task over and over again, the accuracy and repeatability compared to a human worker is far greater.
4. Improved safety at the workplace: Automated systems can perform tasks in hazardous and unfriendly environment which when done by humans would be prone to injuries and accidents. This improves workplace safety.
5. Reduction in manufacturing lead time: Automated Systems can reduce the lead time for manufacturing due to speed, consistency and less/zero defects.
6. Reduced direct human labour costs and expenses: Using automated systems implies less number of employees are required to get the job done. By having less number of employees, there are numerous costs that are directly reduced such as payroll, benefits, sick days, etc.
7. Mitigation of Potential Labour Shortages: Automation can mitigate the effects of potential labour shortages. It decreases dependency on skilled labour and fills the void created due to a skilled worker retirement.
8. Automated Systems can carry out processes that cannot be done manually. Example, automated systems can carry out certain processes in a nuclear radiation environment which is not possible by human labour.
9. Automation can reduce or eliminate day-to-day manual and clerical jobs.

6.6 Disadvantages of Automation

Though automation has a bright future, it has got its downside. The main disadvantages of automation are:

1. Though automation effectively replaces human labour in performing various tasks, it results in increased unemployment and poverty which counters job creation efforts.
2. High initial cost: The initial investment involved in the automation of a new product or plant is very large. Though the cost of automation may be amortized or spread among many units of products over some time period, the unit cost of the product manufactured using automation will still be higher compared to the product manufactured without automation. This may be at competitive disadvantage.
3. Automated systems can pose Security Threats since with a limited level of intelligence it is more susceptible to committing errors outside of its immediate scope of knowledge (Example, lack of application of simple rules of logic to general propositions).
4. Additional Costs: Other than a high investment cost, automated systems also involve excessive development costs due to research and development, preventive maintenance and cost of training personnel to operate automated systems. These costs offset the costs supposed to have been saved by automation.
5. With excessive automation, humans become slaves of automated machines creating too much dependency on machines rather than human intelligence.



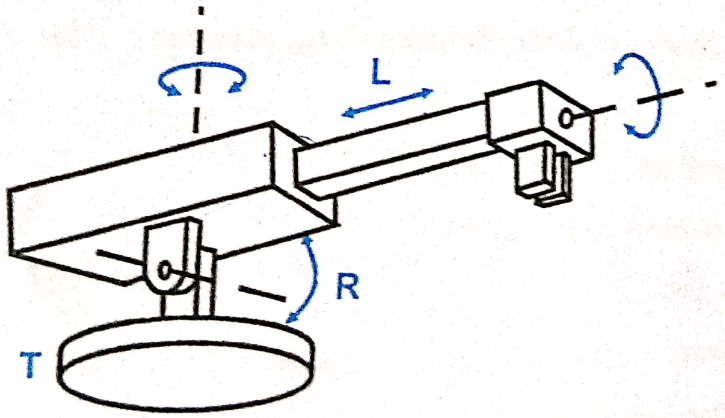
Types of Robot joints

Fig. 5.3

5.7 Classification of Robot based on Robot Configurations

Though there are various ways to classify robots, in this section we take up the classification based on robot configurations. The robot types can be classified based on the robot configurations as:

1. **Polar Configuration (Spherical Configuration):**
The Polar configuration robots also called as the spherical configuration robots consists of a sliding arm (L-joint) that is actuated relative to the body and a rotational base along with a pivot, which can rotate about a horizontal axis (R joint) and the vertical axis (T Joint). This is shown in the *Fig.5.4*.



Polar Configuration Robot

Fig. 5.4

The one linear and the two rotary joints creates a spherical work volume in which the robot operates. Example: The Unimate 2000 series robot. *(Courtesy: Unimation Inc.)*

Advantage:

Long reach capability is realized in the horizontal position

Disadvantage:

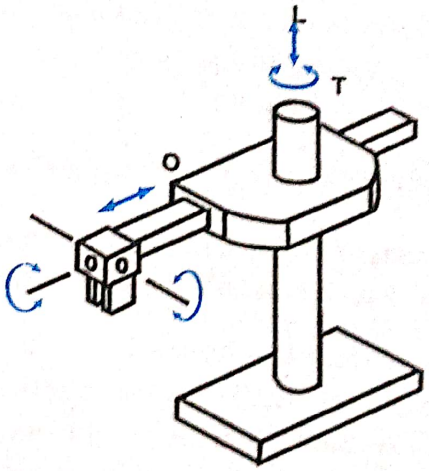
The vertical reach is low.

Applications:

Die casting, forging, injection moulding, dip coating, cleaning of parts, etc.

2. **Cylindrical Configuration:**

Robots of the cylindrical configuration consists of a slide in the horizontal position and a column in the vertical position. The arm assembly moves up or down relative to the column using as L-joint. The column is rotated about its axis using the T-joint. The radial movement of the arm is achieved using the O-joint as shown in the *Fig 5.5.*



Cylindrical Configuration Robot

Fig. 5.5

Example: Model 1A Robot of GMF Robotics Corp. *(Courtesy: GMF Robotics Corp.)*

Advantages:

1. Rigidity is increased and is quite robust.
2. Has the capacity to carry high payloads.

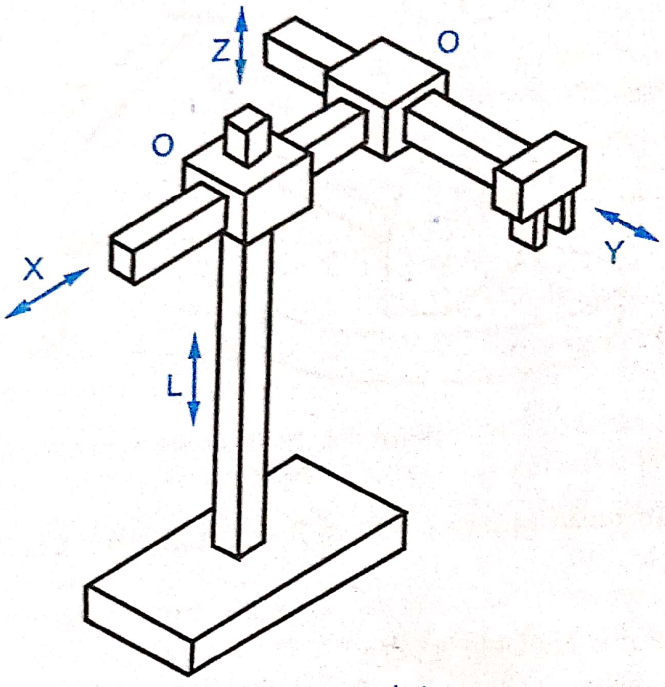
Disadvantages:

1. Work volume is less.
2. Occupies more floor space.

Applications: Foundry and forging applications, investment casting, conveyor pallet transfers, machine loading and unloading

3. Cartesian Co-ordinate Robot:

It is also called as a rectilinear robot or a XYZ Robot. It consists of three sliding joints along the X, Y and Z directions in three dimensional space. There are two orthogonal joints. Since movement can stop and start simultaneously along the X, Y and Z axes, the motion of the tool tip is smoother. A typical Cartesian co-ordinate Robot is shown in the *Fig. 5.6*.



Cartesian Co-ordinate Robot

Fig. 5.6

Example: The IBM 7565 Robot *(Courtesy: IBM)*

Advantages:

- Allows for simpler controls.
- Possess a high degree of mechanical rigidity, accuracy and repeatability.
- They can carry heavy loads and the weight lifting capacity do not vary within the work envelope.

Disadvantages:

- Limited in their movement to a small and rectangular work space.
- Reduced flexibility.

Applications:

To perform pick and place tasks, material handling, loading/unloading and machining operations

INTRODUCTION OF IOT

IoT comprises things that have unique identities and are connected to internet. By 2020 there will be a total of 50 billion devices /things connected to internet. IoT is not limited to just connecting things to the internet but also allow things to communicate and exchange data.

Definition:

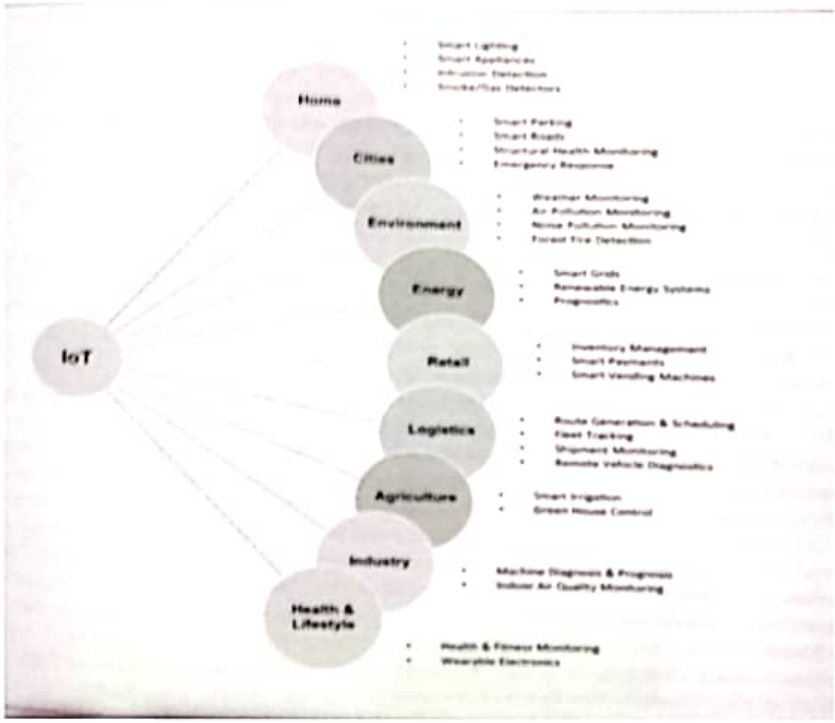
A dynamic global n/w infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual –thingsl have identities, physical attributes and virtual personalities and use intelligent interfaces, and are seamlessly integrated into information n/w, often communicate data associated with users and their environments.

Characteristics:

1) **Dynamic & Self Adapting**: IoT devices and systems may have the capability to dynamically adapt with the changing contexts and take actions based on their operating conditions, user's context or sensedenvironment.
   Eg: the surveillance system is adapting itself based on context and changing conditions.
2) **Self Configuring:** allowing a large number of devices to work together to provide certain functionality.
3) **Inter Operable Communication Protocols:** support a number of interoperable communication protocols ans can communicate with other devices and also with infrastructure.
4) **Unique Identity:** Each IoT device has a unique identity and a unique identifier(IP address).
5) **Integrated into Information Network:** that allow them to communicate and exchange data with other devices andsystems.

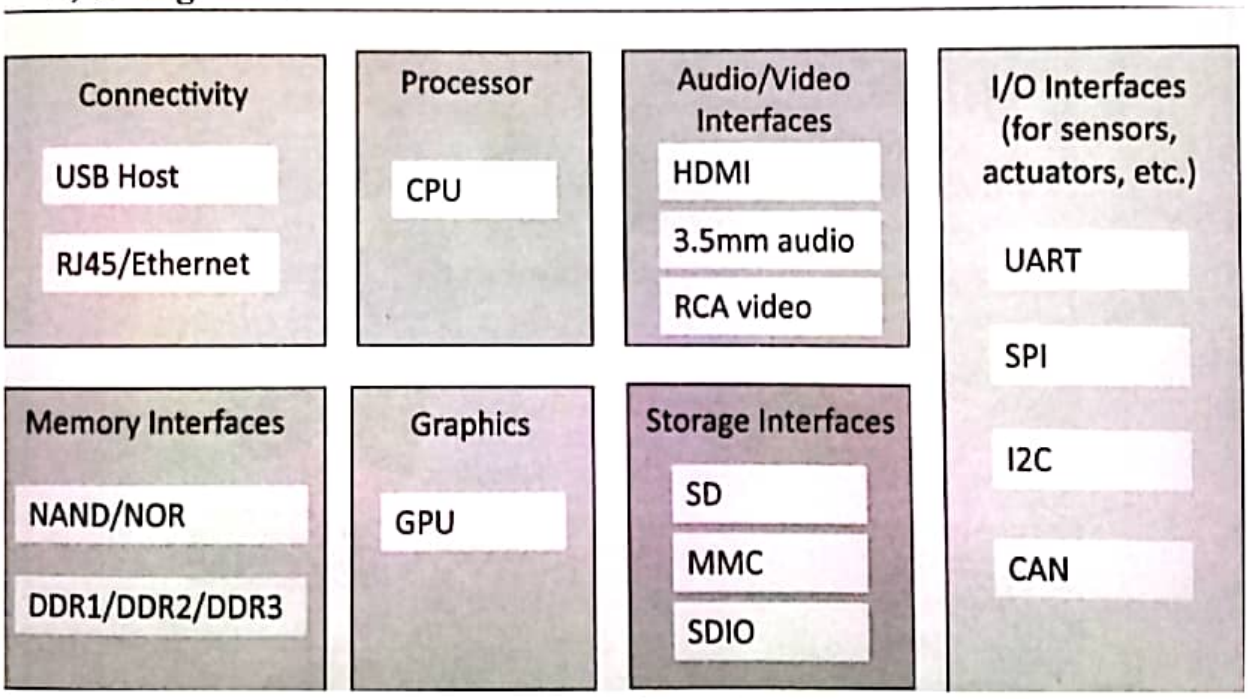
Applications of IoT:

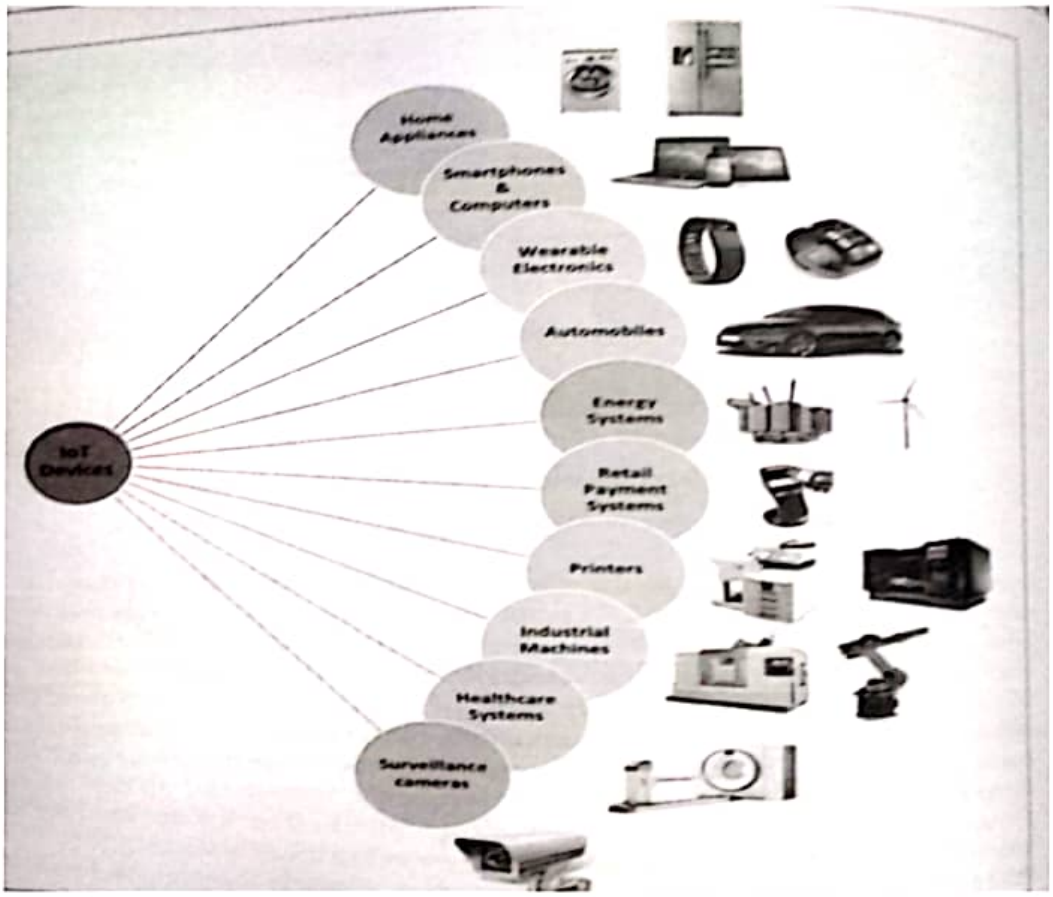
1) Home
2) Cities
3) Environment
4) Energy
5) Retail
6) Logistics
7) Agriculture
8) Industry
9) Health & LifeStyle



Physical Design Of IoT

1) Things inIoT:



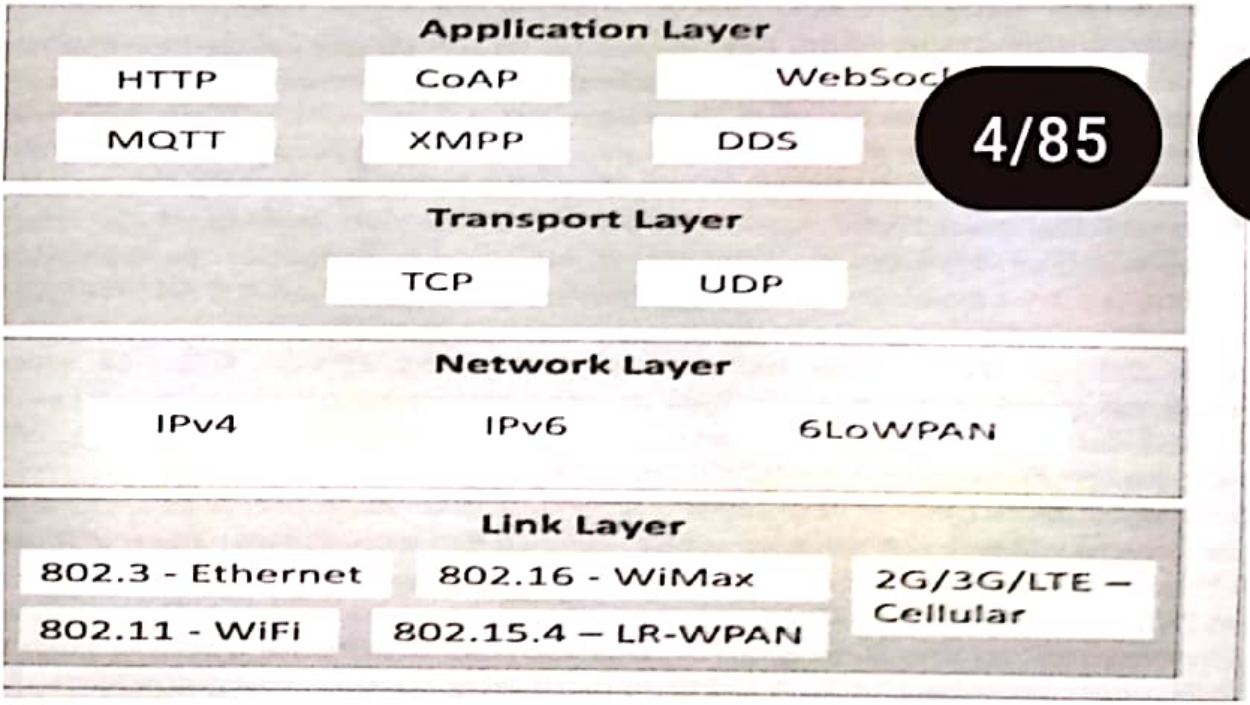


The things in IoT refers to IoT devices which have unique identities and perform remote sensing, actuating and monitoring capabilities. IoT devices can exchange dat with other connected devices applications. It collects data from other devices and process data either locally or remotely.

An IoT device may consist of several interfaces for communication to other devices both wired and wireless. These includes (i) I/O interfaces for sensors, (ii) Interfaces for internet connectivity (iii) memory and storage interfaces and (iv) audio/videointerfaces.

2) IoTProtocols:

a) Link Layer : Protocols determine how data is physically sent over the network's physical layer or medium. Local network connect to which host is attached. Hosts on the same link exchange data packets over the link layer using link layer protocols. Link layer determines how packets are coded and signaled by the h/w device over the medium to which the host isattached.



Protocols:

- 802.3-Ethernet: IEEE802.3 is collection of wired Ethernet standards for the link layer. Eg: 802.3 uses co-axial cable; 802.3i uses copper twisted pair connection; 802.3j uses fiber optic connection; 802.3ae uses Ethernet overfiber.
- 802.11-WiFi: IEEE802.11 is a collection of wireless LAN(WLAN) communication standards including extensive description of link layer. Eg: 802.11a operates in 5GHz band, 802.11b and 802.11g operates in 2.4GHz band, 802.11n operates in 2.4/5GHz band, 802.11ac operates in 5GHz band, 802.11ad operates in 60Ghzband.
- 802.16 - WiMax: IEEE802.16 is a collection of wireless broadband standards including exclusive description of link layer. WiMax provide data rates from 1.5 Mb/s to 1Gb/s.
- 802.15.4-LR-WPAN: IEEE802.15.4 is a collection of standards for low rate wireless personal area network(LR-WPAN). Basis for high level communication protocols such as ZigBee. Provides data rate from 40kb/s to250kb/s.
- 2G/3G/4G-Mobile Communication: Data rates from 9.6kb/s(2G) to up to100Mb/s(4G).

B) **Network/Internet Layer:** Responsible for sending IP datagrams from source n/w to destination n/w. Performs the host addressing and packet routing. Datagrams contains source and destinationaddress.

Protocols:

- **IPv4:** Internet Protocol version4 is used to identify the devices on a n/w using a hierarchical addressing scheme. 32 bit address. Allows total of 2**32addresses.
- **IPv6:** Internet Protocol version6 uses 128 bit address scheme and allows 2**128 addresses.

- **6LOWPAN:**(IPv6overLowpowerWirelessPersonalAreaNetwork)operatesin 2.4 GHz frequency range and data transfer 250 kb/s.

C) Transport Layer: Provides end-to-end message transfer capability ind underlying n/w. Set up on connection with ACK as in TCP and without ACK as Provides functions such as error control, segmentation, flow control and congestion control.

Protocols:

- **TCP:** Transmission Control Protocol used by web browsers(along with HTTP and HTTPS), email(along with SMTP, FTP). Connection oriented and stateless protocol. IP Protocol deals with sending packets, TCP ensures reliable transmission of protocols in order. Avoids n/w congestion and congestioncollapse.
- **UDP:** User Datagram Protocol is connectionless protocol. Useful in time sensitive applications, very small data units to exchange. Transaction oriented and stateless protocol. Does not provide guaranteeddelivery.

D) **Application Layer:** Defines how the applications interface with lower layer protocols to send data over the n/w. Enables process-to-process communication usingports.

Protocols:

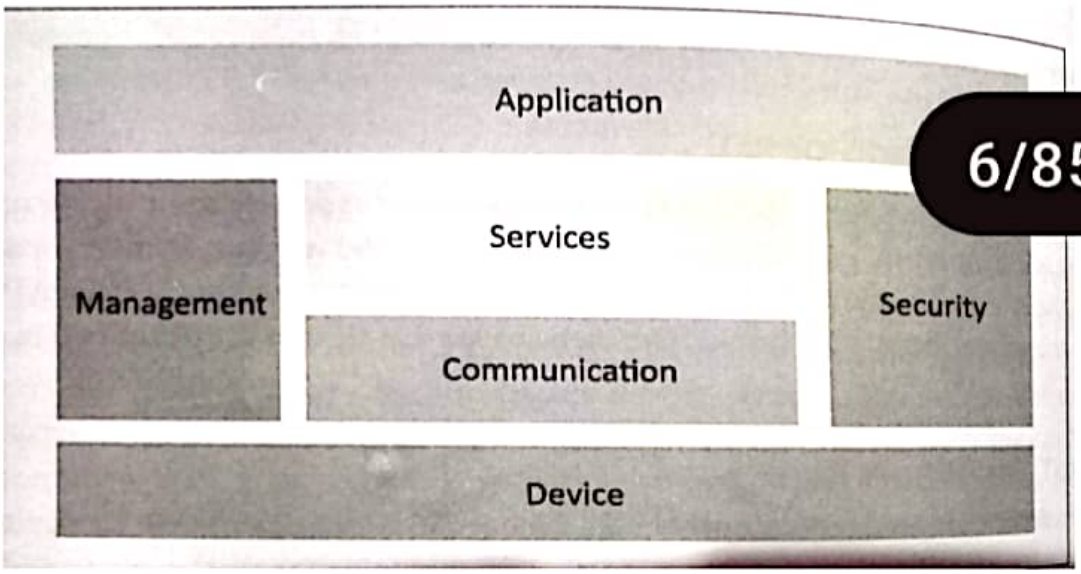
- **HTTP:** Hyper Text Transfer Protocol that forms foundation of WWW. Follow request-response model Statelessprotocol.
- **CoAP:** Constrained Application Protocol for machine-to-machine(M2M) applications with constrained devices, constrained environment and constrained n/w. Uses client-server architecture.
- **WebSocket:** allows full duplex communication over a single socketconnection.
- **MQTT:** Message Queue Telemetry Transport is light weight messaging protocol based on publish-subscribe model. Uses client server architecture. Well suited for constrained environment.
- **XMPP:** Extensible Message and Presence Protocol for real time communication and streaming XML data between network entities. Support client-server and server-server communication.
- **DDS:** Data Distribution Service is data centric middleware standards for device-to-device or machine-to-machine communication. Uses publish-subscribemodel.
- **AMQP:** Advanced Message Queuing Protocol is open application layer protocol for business messaging. Supports both point-to-point and publish-subscribemodel.

LOGICAL DESIGN of IoT

Refers to an abstract represent of entities and processes without going into the low level specifies of implementation.

1) IoT Functional Blocks 2) IoT Communication Models 3) IoT Comm. APIs

1) **IoT Functional Blocks:** Provide the system the capabilities for identification, sensing, actuation, communication andmanagement.

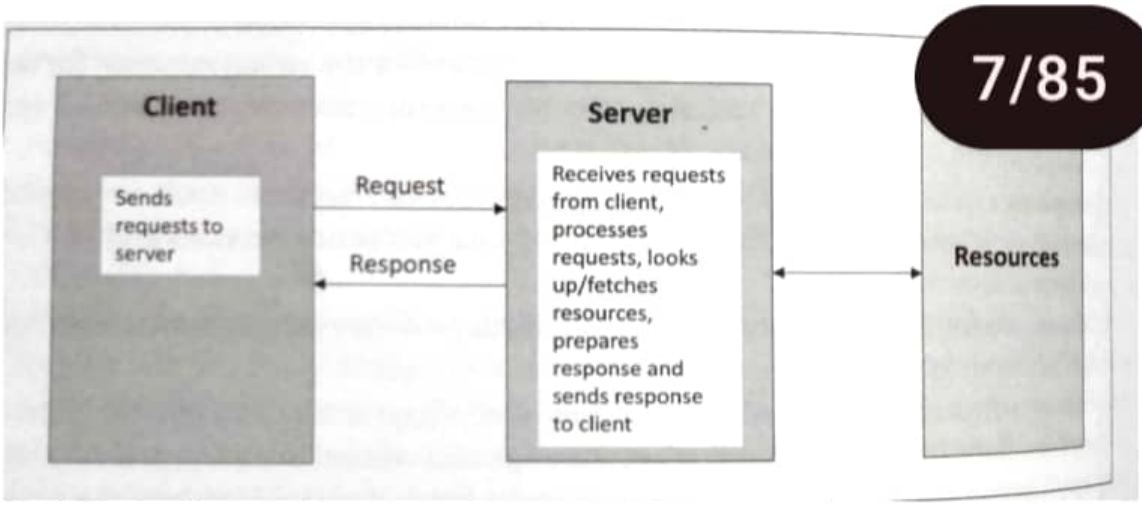


- **Device:** An IoT system comprises of devices that provide sensing, actuation, monitoring and controlfunctions.
- **Communication:** handles the communicationfor IoTsystem.
- **Services:** for device monitoring, device control services, data publishing services and services for devicediscovery.
- **Management:** Provides various functions to govern the IoTsystem.
- **Security:** Secures IoT system and priority functions such as authentication,authorization, message and context integrity and datasecurity.
- **Application:** IoT application provide an interface that the users can use to control and monitor various aspects of IoTsystem.

2) IoT CommunicationModels:

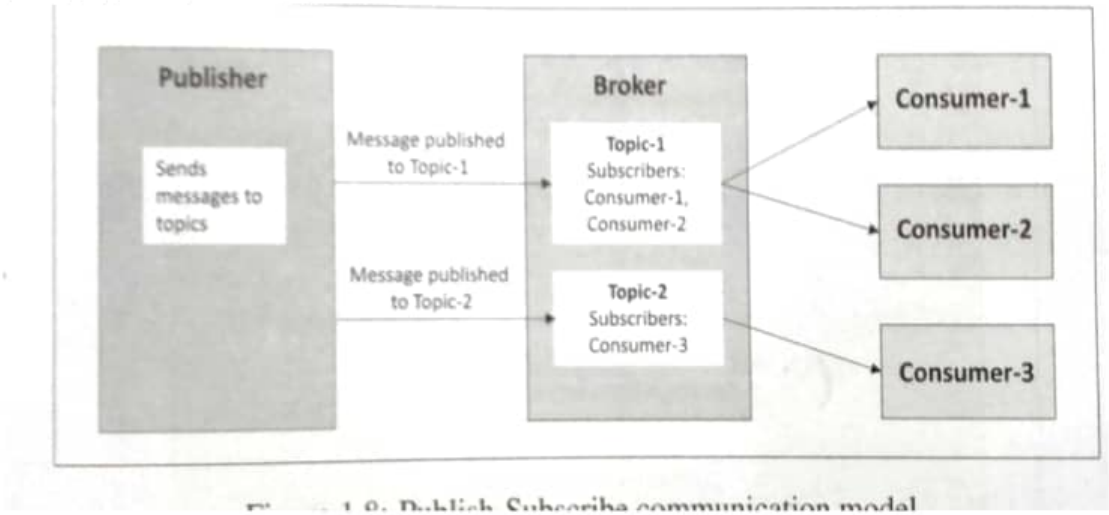
1) Request-Response 2) Publish-Subscibe 3)Push-Pull 4) ExclusivePair

1) Request-ResponseModel:



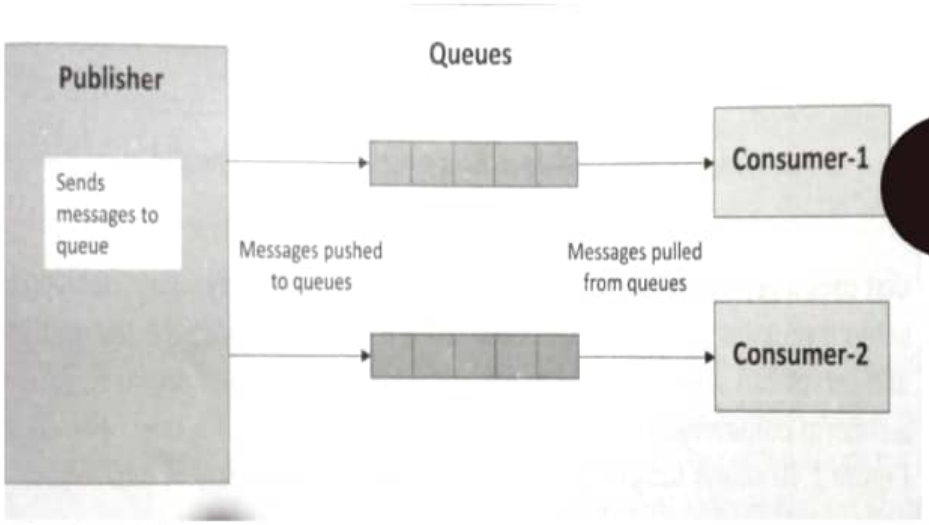
In which the client sends request to the server and the server replies to requests. Is a stateless communication model and each request-response pair is independent of others.

2) Publish-SubscibeModel:

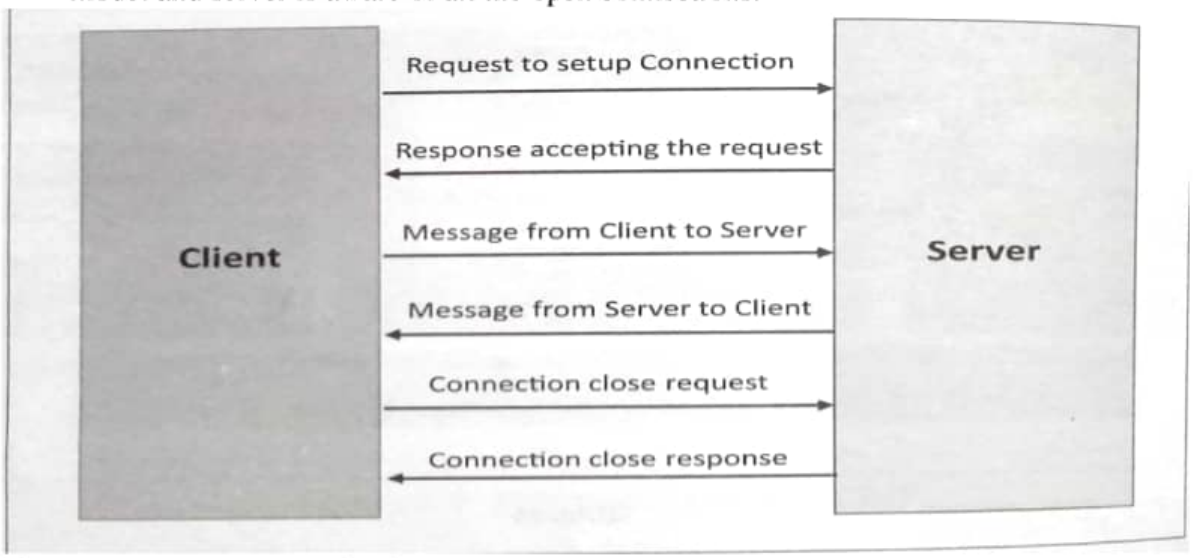


Involves publishers, brokers and consumers. Publishers are source of data. Publishers send data to the topics which are managed by the broker. Publishers are not aware of the consumers. Consumers subscribe to the topics which are managed by the broker. When the broker receives data for a topic from the publisher, it sends the data to all the subscribedconsumers.

3) **Push-Pull Model:** in which data producers push data to queues and consumers pull data from the queues. Producers do not need to aware of the consumers. Queues help in decoupling the message between the producers andconsumers.



4) **Exclusive Pair:** is bi-directional, fully duplex communication model that uses a persistent connection between the client and server. Once connection is set up it remains open until the client send a request to close the connection. Is a stateful communication model and server is aware of all the open connections.

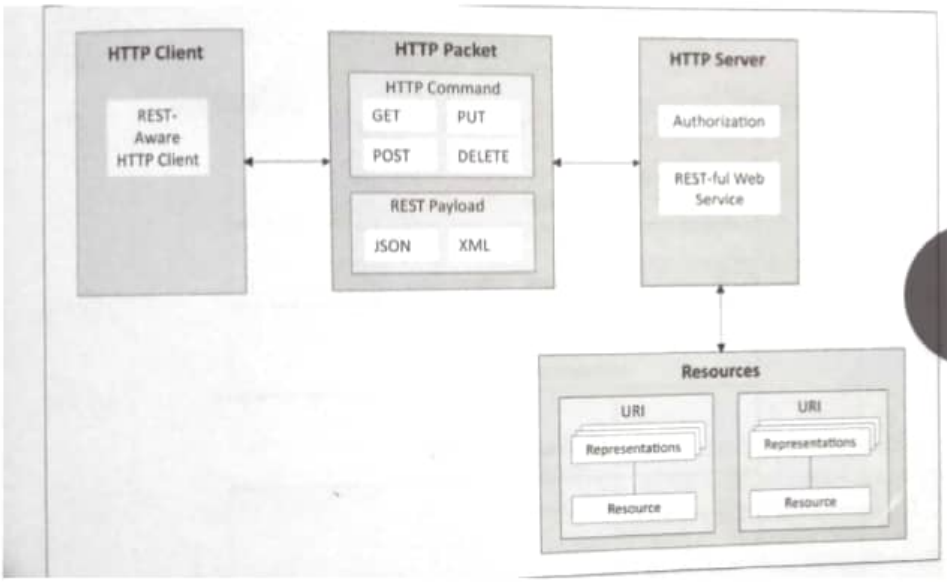


3)IoT CommunicationAPIs:

a) REST based communication APIs(Request-Response BasedModel)
b) WebSocket based Communication APIs(Exclusive PairBasedModel)

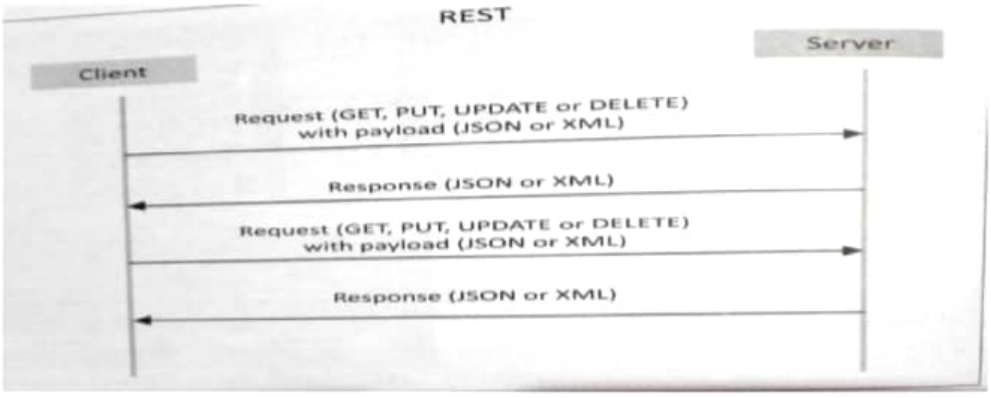
a) REST based communication APIs: Representational State Transfer(REST) is a set of architectural principles by which we can design web services and web APIs that focus on a system's resources and have resource states are addressed andtransferred.

The REST architectural constraints: Fig. shows communication between client server with REST APIs.



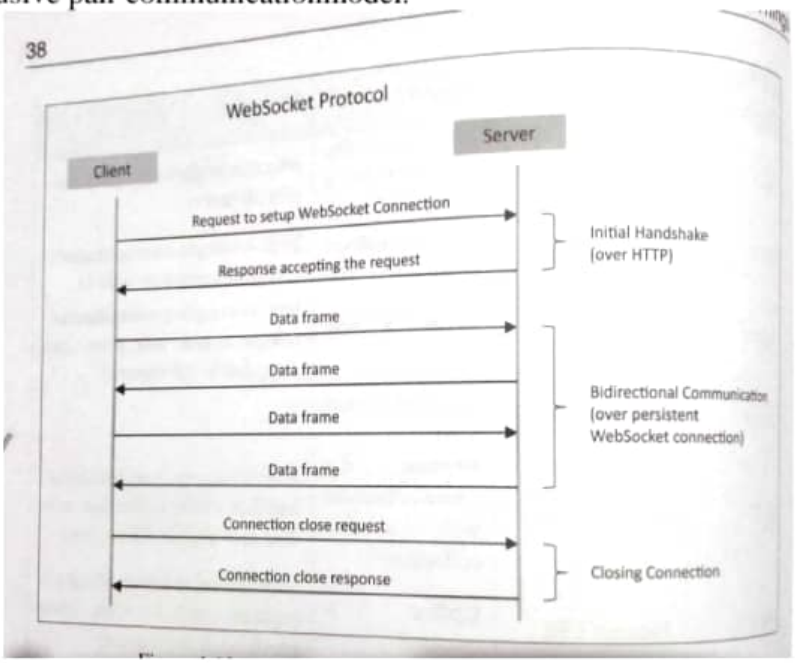
Client-Server: The principle behind client-server constraint is the separation of concerns. Separation allows client and server to be independently developed and updated.
Stateless: Each request from client to server must contain all the info. Necessary to understand the request, and cannot take advantage of any stored context on the server.
Cache-able: Cache constraint requires that the data within a response to a request be implicitly or explicitly labeled as cache-able or non-cacheable. If a response is cache-able, then a client cache is given the right to reuse that response data for later, equivalentrequests.
Layered System: constraints the behavior of components such that each component cannot see beyond the immediate layer with which they are interacting.
User Interface: constraint requires that the method of communication between a client and a server must be uniform.
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.

Request-Response model used by REST:



RESTful webservice is a collection of resources which are represented by URIs. RESTful web API has a base URI(e.g: http://example.com/api/tasks/). The clients and requests to these URIs using the methods defined by the HTTP protocol(e.g: GET, PUT, POST or DELETE). A RESTful web service can support various internet media types.

b) WebSocket Based Communication APIs: WebSocket APIs allow bi-directional, full duplex communication between clients and servers. WebSocket APIs follow the exclusive pair communicationmodel.



IoT Enabling Technologies

IoT is enabled by several technologies including Wireless Sensor Networks, Cloud Computing, Big Data Analytics, Embedded Systems, Security Protocols and architectures, Communication Protocols, Web Services, Mobile internet and semantic search engines.

1) **Wireless Sensor Network(WSN):** Comprises of distributed devices with sensors which are used to monitor the environmental and physical conditions. Zig Bee is one of the most popular wireless technologies used byWSNs.
   WSNs used in IoT systems are described as follows:
   - Weather Monitoring System: in which nodes collect temp, humidity and other data, which is aggregated and analyzed.
   - Indoor air quality monitoring systems: to collect data on the indoor air quality and concentration of various gases.
   - Soil Moisture Monitoring Systems: to monitor soil moisture at variouslocations.
   - Surveillance Systems: use WSNs for collecting surveillance data(motiondata detection).
   - Smart Grids : use WSNs for monitoring grids at variouspoints.

- Structural Health Monitoring Systems: Use WSNs to monitor the health of structures(building, bridges) by collecting vibrations from sensor nodes deployed at various points in thestructure.

2) **Cloud Computing:** Services are offered to users in differentforms.
   - Infrastructure-as-a-service(IaaS):provides users the ability to provision computing and storage resources. These resources are provided to the users as a virtual machine instances and virtualstorage.
   - Platform-as-a-Service(PaaS): provides users the ability to develop and deploy application in cloud using the development tools, APIs, software libraries and services provided by the cloud serviceprovider.
   - Software-as-a-Service(SaaS): provides the user a complete software application or the user interface to the applicationitself.

3) **Big Data Analytics:** Some examples of big data generated by IoTare
   - Sensor data generated by IoTsystems.
   - Machine sensor data collected from sensors established in industrial and energy systems.
   - Health and fitness data generated IoTdevices.
   - Data generated by IoT systems for location and trackingvehicles.
   - Data generated by retail inventory monitoringsystems.

4) **Communication Protocols:** form the back-bone of IoT systems and enable network connectivity and coupling toapplications.
   - Allow devices to exchange data overnetwork.
   - Define the exchange formats, data encoding addressing schemes for device and routing of packets from source todestination.
   - It includes sequence control, flow control and retransmission of lostpackets.

5) **Embedded Systems:** is a computer system that has computer hardware and software embedded to perform specific tasks. Embedded System range from low cost miniaturized devices such as digital watches to devices such as digital cameras, POS terminals, vending machines, appliancesetc.,