UNIT-I
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:

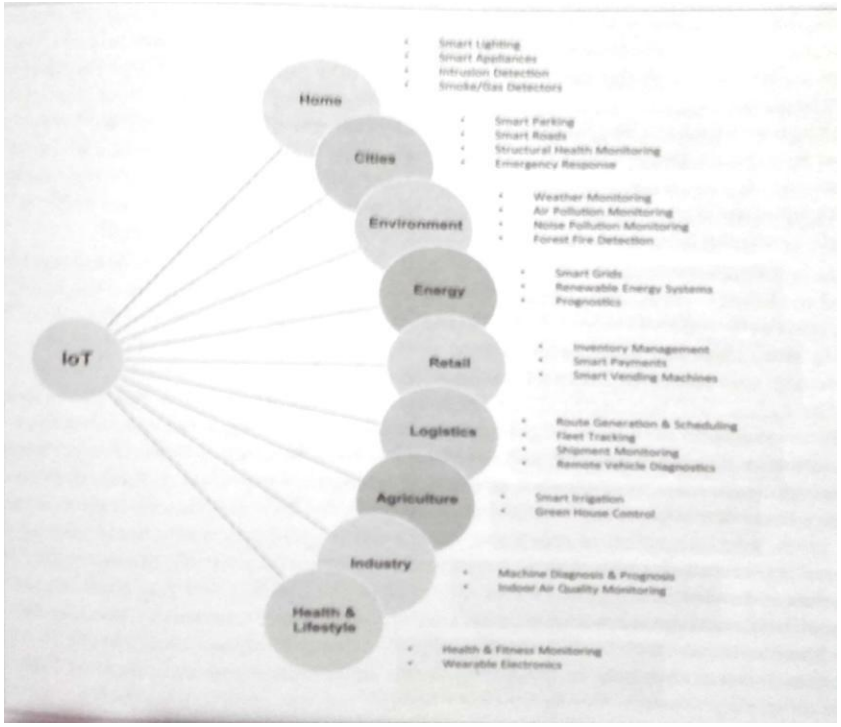
A dynamic global n/w infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual –things‖ have identities, physical attributes and virtual personalities and use intelligent interfaces, and are seamlessly integrated into information 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.

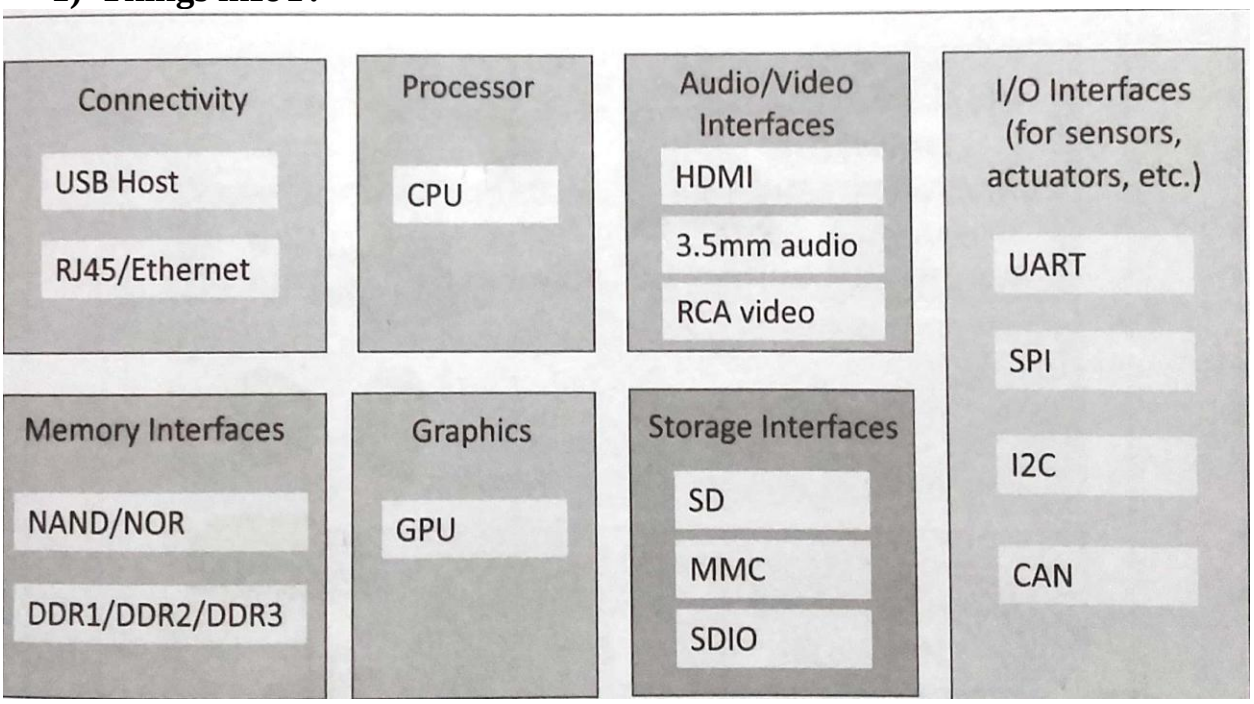
Applications of IoT:

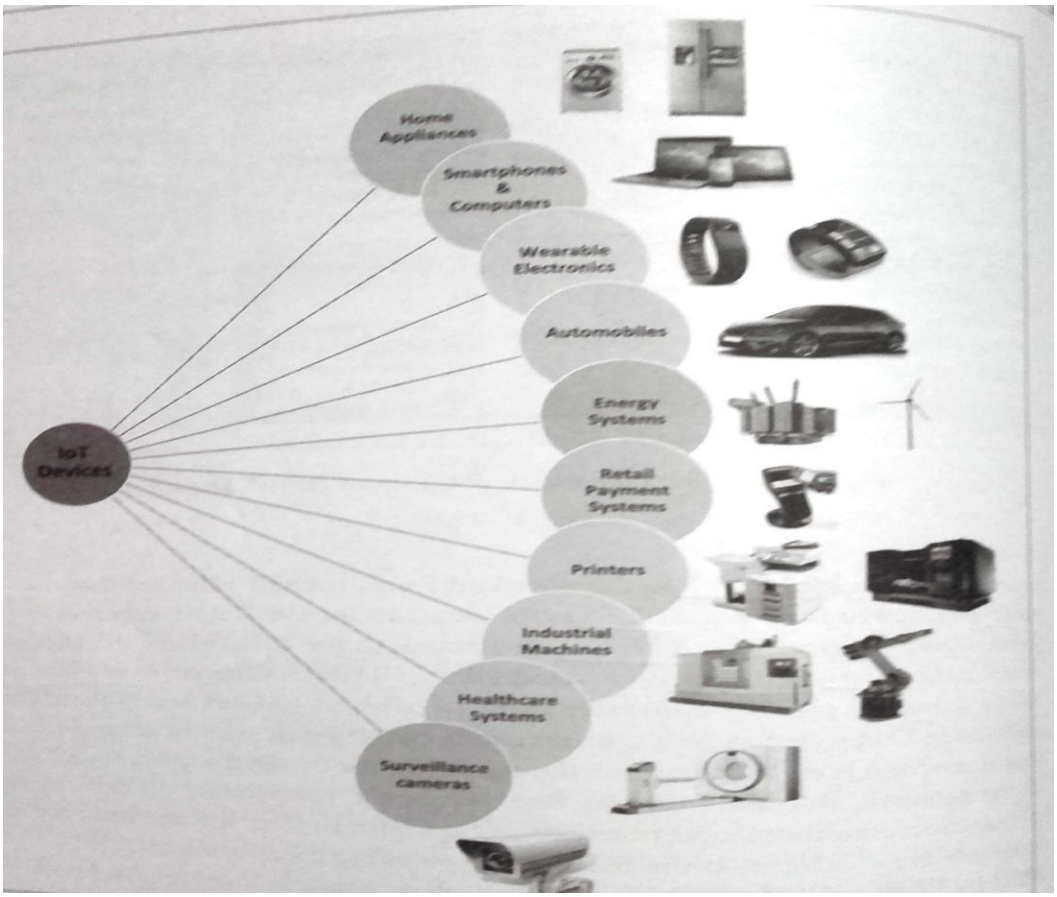
1) Home
2) Cities
3) Environment
4) Energy
5) Retail
6) Logistics
7) Agriculture
8) Industry
9) Health & LifeStyle



Physical Design Of IoT

1) Things inIoT:



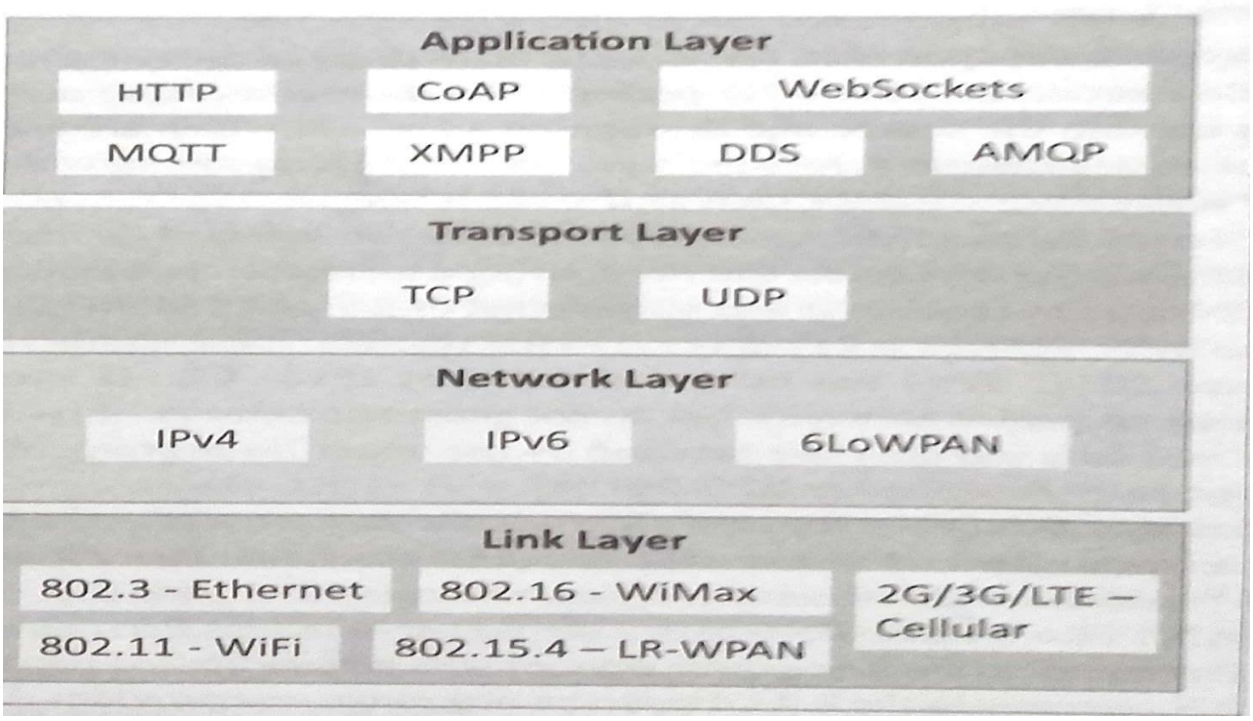


The things in IoT refers to IoT devices which have unique identities and perform remote sensing, actuating and monitoring capabilities. IoT devices can exchange dat with other connected devices applications. It collects data from other devices and process data either locally or remotely.

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 independent of the underlying n/w. Set up on connection with ACK as in TCP and without ACK as in UDP. 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:

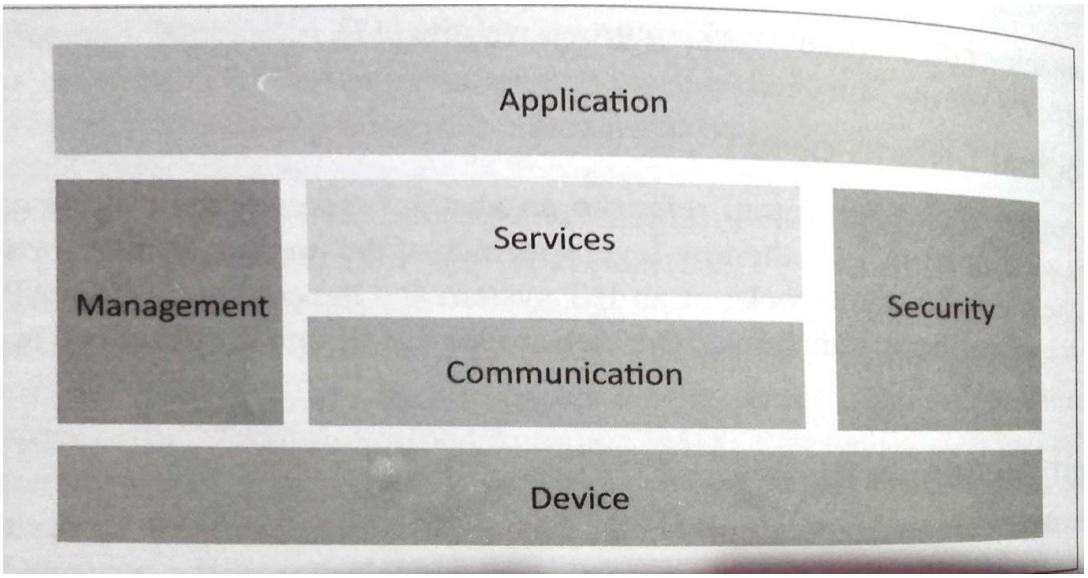
- **HTTP:** Hyper Text Transfer Protocol that forms foundation of WWW. Follow request-response model Statelessprotocol.
- **CoAP:** Constrained Application Protocol for machine-to-machine(M2M) applications with constrained devices, constrained environment and constrained n/w. Uses client-server architecture.
- **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.

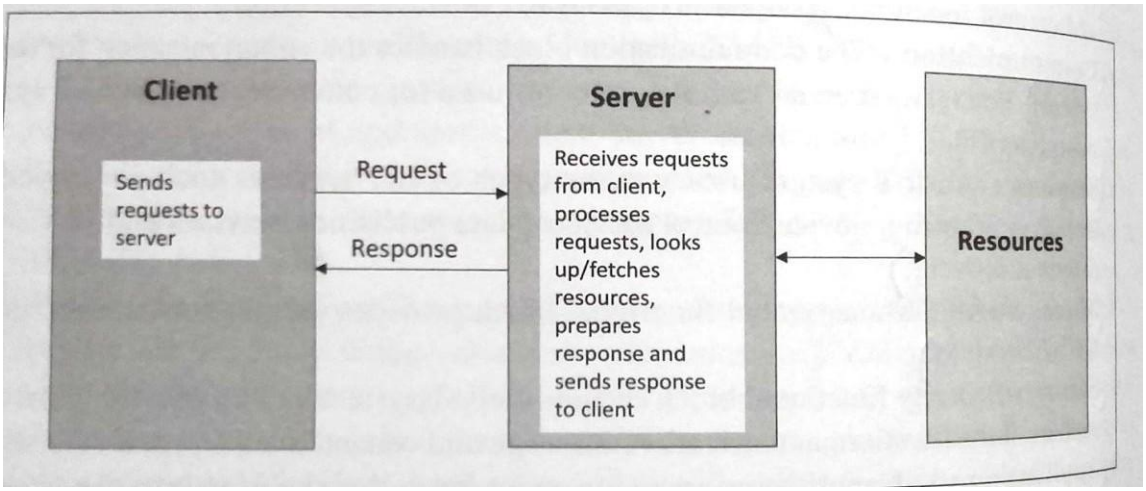


- **Device:** An IoT system comprises of devices that provide sensing, actuation, monitoring and controlfunctions.
- **Communication:** handles the communicationfor IoTsystem.
- **Services:** for device monitoring, device control services, data publishing services and services for devicediscovery.
- **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:

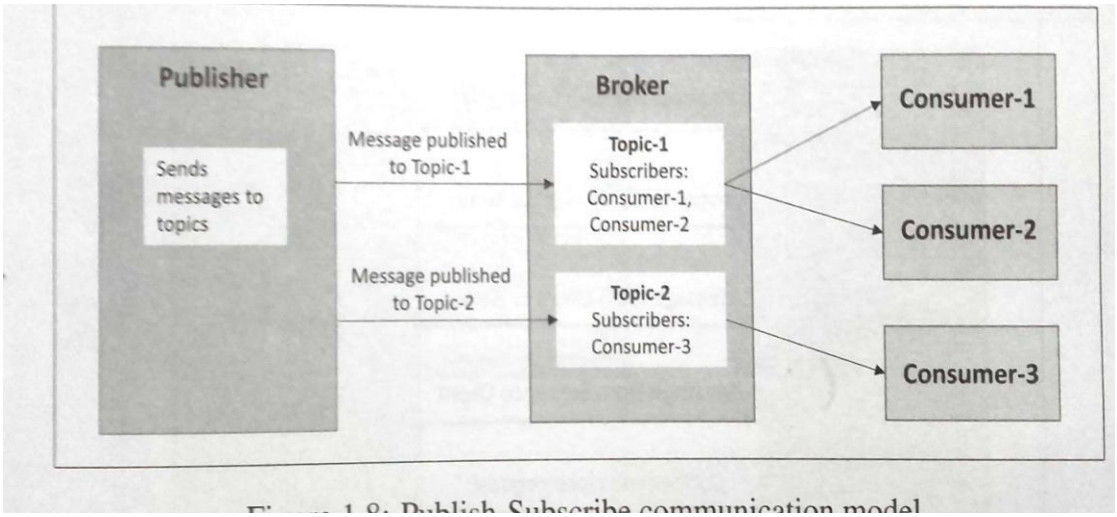
1) Request-Response 2) Publish-Subscibe 3)Push-Pull 4) ExclusivePair

1) Request-ResponseModel:



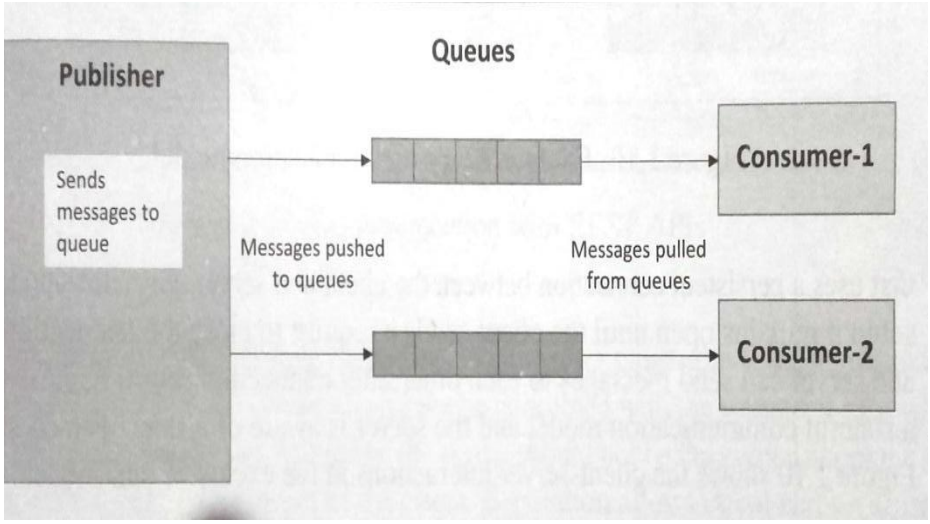
In which the client sends request to the server and the server replies to requests. Is a stateless communication model and each request-response pair is independent of others.

2) Publish-SubscibeModel:

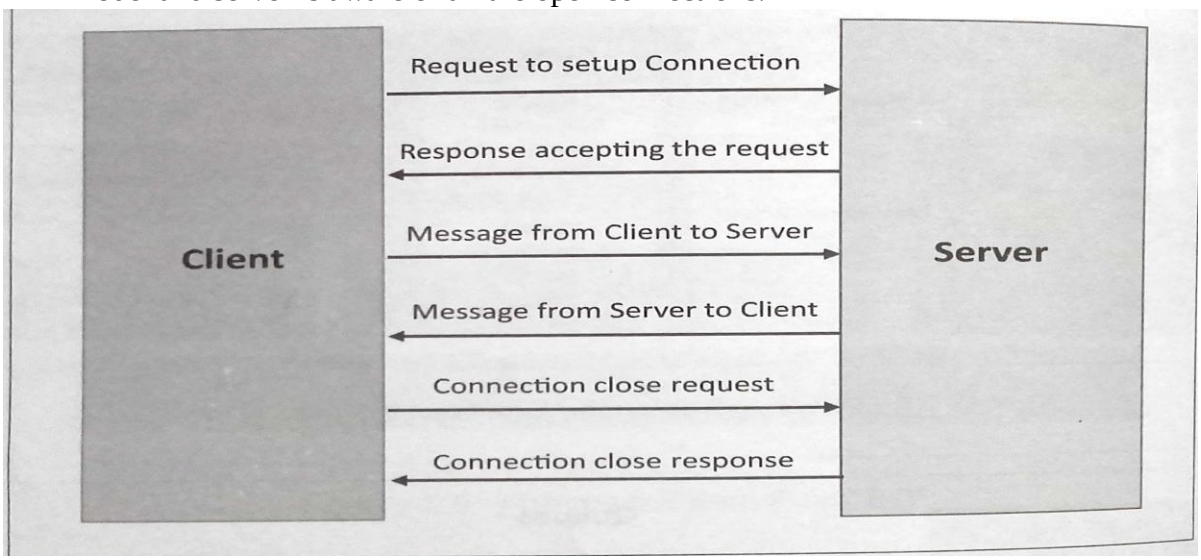


Involves publishers, brokers and consumers. Publishers are source of data. Publishers send data to the topics which are managed by the broker. Publishers are not aware of the consumers. Consumers subscribe to the topics which are managed by the broker. When the broker receives data for a topic from the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



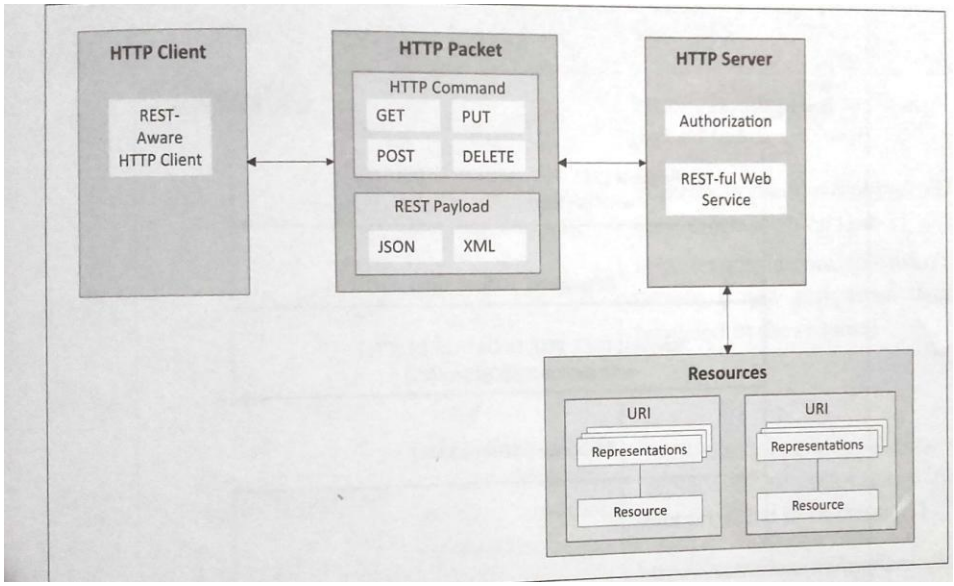
3) IoT CommunicationAPIs:

a) REST based communication APIs(Request-Response BasedModel)

b) WebSocket based Communication APIs(Exclusive PairBasedModel)

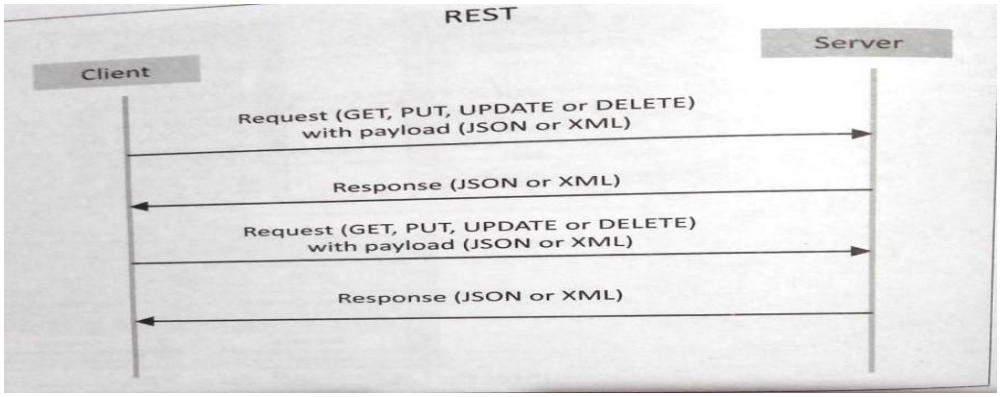
a) REST based communication APIs: Representational State Transfer(REST) is a set of architectural principles by which we can design web services and web APIs that focus on a system‘s resources and have resource states are addressed andtransferred.

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



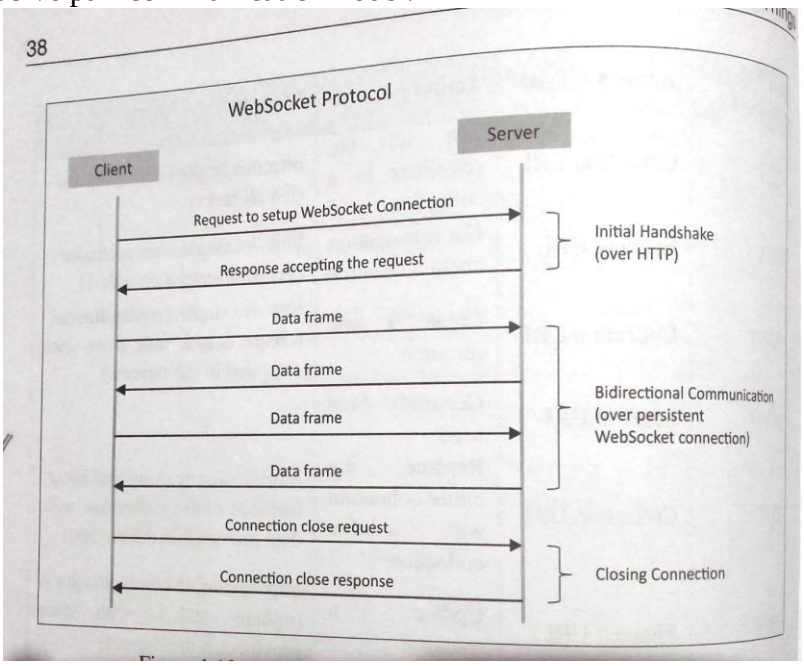
Client-Server: The principle behind client-server constraint is the separation of concerns. Separation allows client and server to be independently developed and updated.
Stateless: Each request from client to server must contain all the info. Necessary to understand the request, and cannot take advantage 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.

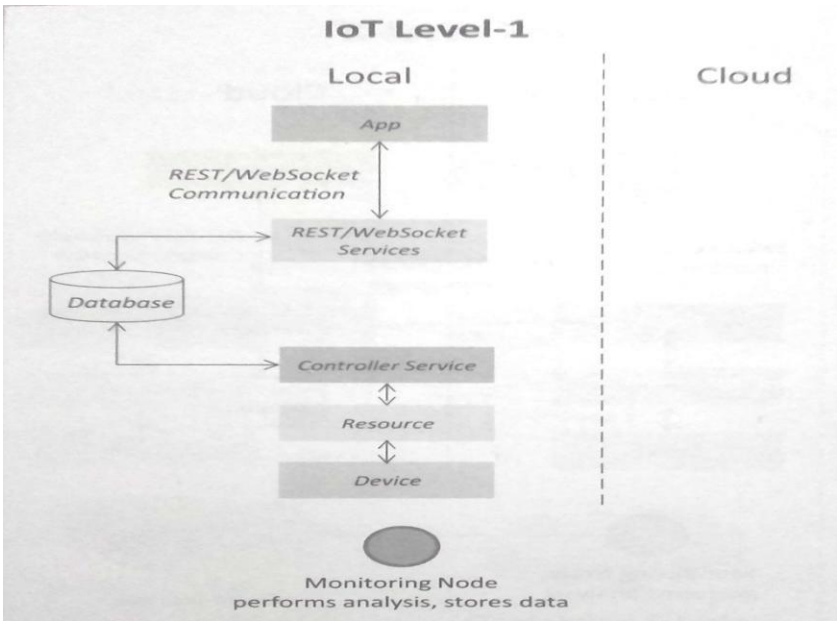
3) **Big Data Analytics:** Some examples of big data generated by IoTare
   - Sensor data generated by IoTsystems.
   - Machine sensor data collected from sensors established in industrial and energy systems.
   - Health and fitness data generated IoTdevices.
   - Data generated by IoT systems for location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

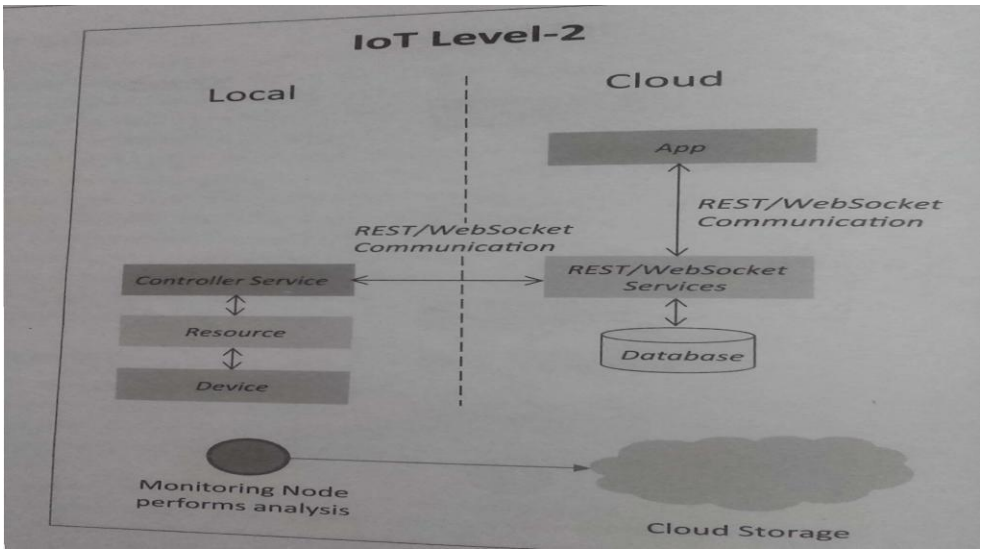
5) **Embedded Systems:** is a computer system that has computer hardware and software embedded to perform specific tasks. Embedded System range from low cost miniaturized devices such as digital watches to devices such as digital cameras, POS terminals, vending machines, appliancesetc.,

IoT Levels and Deployment Templates

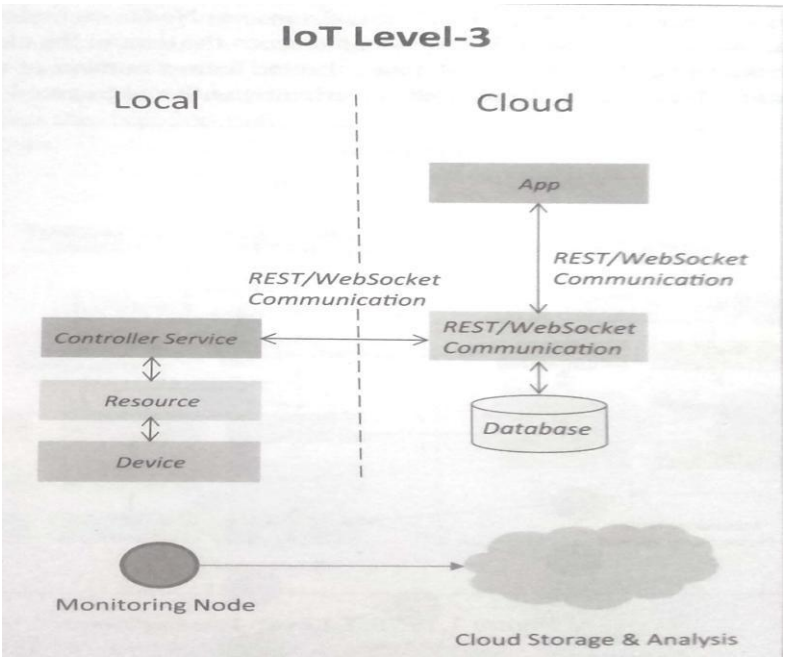
1) **IoT Level1:** System has a single node that performs sensing and/or actuation, stores data, performs analysis and host the application as shown in fig. Suitable for modeling low cost and low complexity solutions where the data involved is not big and analysis requirement are not computationally intensive. An e.g., of IoT Level1 is Home automation.



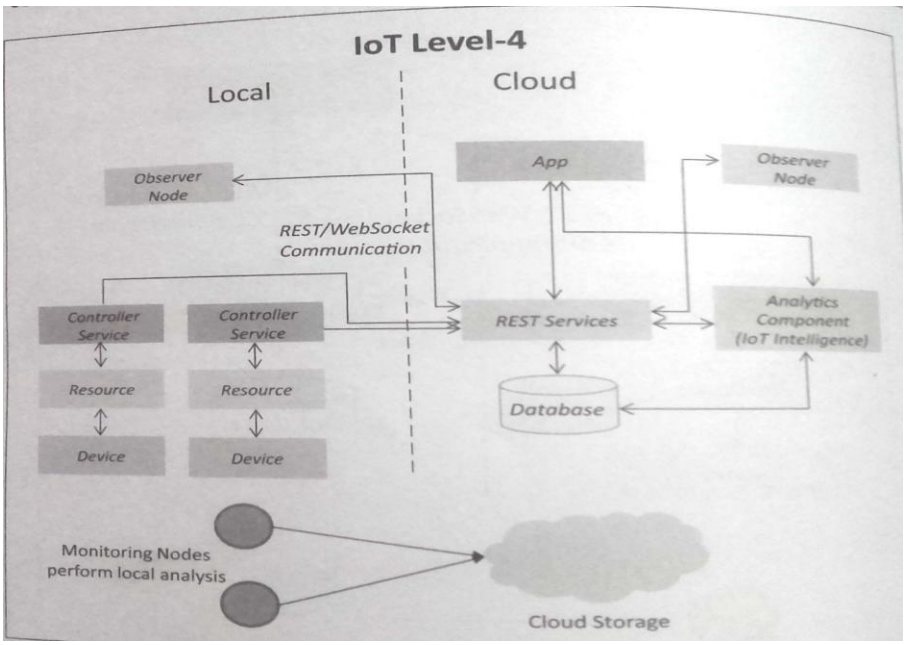
2) **IoT Level2:** has a single node that performs sensing and/or actuating and local analysis as shown in fig. Data is stored in cloud and application is usually cloud based. Level2 IoT systems are suitable for solutions where data are involved is big, however, the primary analysis requirement is not computationally intensive and can be done locally itself. An e,g.**,** of Level2 IoT system for SmartIrrigation.



3) **IoT Level3:** system has a single node. Data is stored and analyzed in the cloud application is cloud based as shown in fig. Level3 IoT systems are suitable for solutions where the data involved is big and analysis requirements are computationally intensive. An example of IoT level3 system for tracking packagehandling.

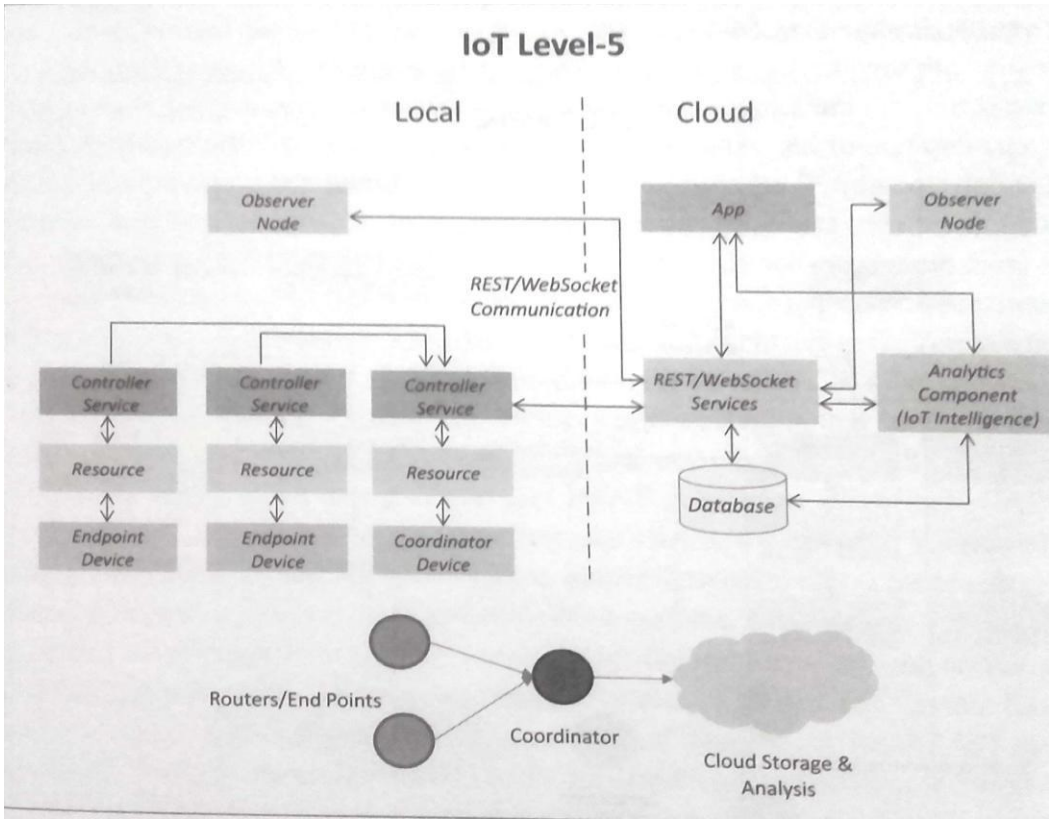


4) **IoT Level4:** System has multiple nodes that perform local analysis. Data is stored in the cloud and application is cloud based as shown in fig. Level4 contains local and cloud based observer nodes which can subscribe to and receive information collected in the cloud from IoT devices. An example of a Level4 IoT system for NoiseMonitoring.

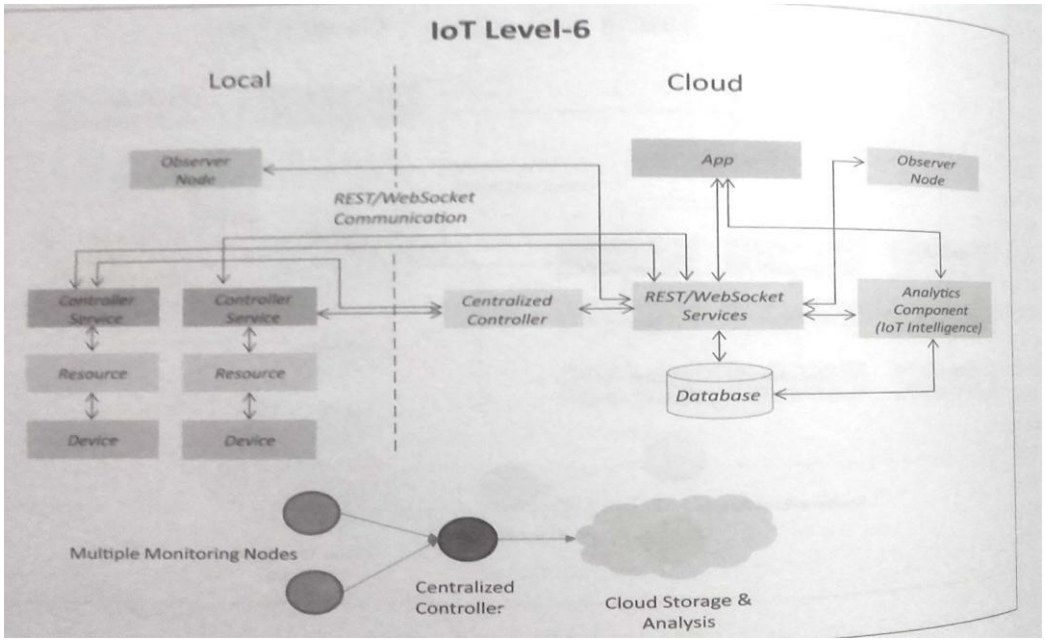


5) **IoT Level5:** System has multiple end nodes and one coordinator node as shown in fig. The end nodes that perform sensing and/or actuation. Coordinator node collects data from theendnodesandsendstothecloud.Dataisstoredandanalyzedinthecloudand

application is cloud based. Level5 IoT systems are suitable for solution based on wireless sensor network, in which data involved is big and analysis requirements are computationally intensive. An example of Level5 system for Forest Fire Detection.



6) **IoT Level6:** System has multiple independent end nodes that perform sensing and/or actuation and sensed data to the cloud. Data is stored in the cloud and application is cloud based as shown in fig. The analytics component analyses the data and stores the result in the cloud data base. The results are visualized with cloud based application. The centralized controller is aware of the status of all the end nodes and sends control commands to nodes. An example of a Level6 IoT system for Weather Monitoring System.



DOMAIN SPECIFIC IoTs

1) **Home Automation:**
   a) **Smart Lighting:** helps in saving energy by adapting the lighting to the ambient conditions and switching on/off or diming the light whenneeded.
   b) **Smart Appliances:** make the management easier and also provide status information to the usersremotely.
   c) **Intrusion Detection:** use security cameras and sensors(PIR sensors and door sensors) to detect intrusion and raise alerts. Alerts can be in the form of SMS or email sent to theuser.
   d) **Smoke/Gas Detectors:** Smoke detectors are installed in homes and buildings to detect smoke that is typically an early sign of fire. Alerts raised by smoke detectors can be in the form of signals to a fire alarm system. Gas detectors can detect the presence of harmful gases such as CO, LPGetc.,

2) **Cities:**
   a) **Smart Parking:** make the search for parking space easier and convenient for drivers. Smart parking are powered by IoT systems that detect the no. of empty parking slots and send information over internet to smart application backends.
   b) **Smart Lighting:** for roads, parks and buildings can help in savingenergy.
   c) **Smart Roads:** Equipped with sensors can provide information on driving condition, travel time estimating and alert in case of poor driving conditions, traffic condition andaccidents.
   d) **Structural Health Monitoring:** uses a network of sensors to monitor the vibration levels in the structures such as bridges and buildings.
   e) **Surveillance:** The video feeds from surveillance cameras can be aggregated in cloud based scalable storagesolution.

f) **Emergency Response:** IoT systems for fire detection, gas and water leakage detection can help in generating alerts and minimizing their effects on the critical infrastructures.

3) Environment:

a) **Weather Monitoring:** Systems collect data from a no. of sensors attached and send the data to cloud based applications and storage back ends. The data collected in cloud can then be analyzed and visualized by cloud basedapplications.

b) **Air Pollution Monitoring:** System can monitor emission of harmful gases(CO2, CO, NO, NO2 etc.,) by factories and automobiles using gaseous and meteorological sensors. The collected data can be analyzed to make informed decisions on pollutions controlapproaches.

c) **Noise Pollution Monitoring:** Due to growing urban development, noise levels in cities have increased and even become alarmingly high in some cities. IoT based noise pollution monitoring systems use a no. of noise monitoring systems that are deployed at different places in a city. The data on noise levels from the station is collected on servers or in the cloud. The collected data is then aggregated to generate noise maps.

d) **Forest Fire Detection:** Forest fire can cause damage to natural resources, property and human life. Early detection of forest fire can help in minimizingdamage.

e) **River Flood Detection:** River floods can cause damage to natural and human resources and human life. Early warnings of floods can be given by monitoring the water level and flow rate. IoT based river flood monitoring system uses a no. of sensor nodes that monitor the water level and flow ratesensors.

4) Energy:

a) **Smart Grids:** is a data communication network integrated with the electrical grids that collects and analyze data captured in near-real-time about power transmission, distribution and consumption. Smart grid technology provides predictive information and recommendations to utilities, their suppliers, and their customers on how best to manage power. By using IoT based sensing and measurement technologies, the health of equipment and integrity of the grid can beevaluated.

b) **Renewable Energy Systems:** IoT based systems integrated with the transformers at the point of interconnection measure the electrical variables and how much power is fed into the grid. For wind energy systems, closed-loop controls can be used to regulate the voltage at point of interconnection which coordinate wind turbine outputs and provides powersupport.

c) **Prognostics:** In systems such as power grids, real-time information is collected using specialized electrical sensors called Phasor Measurment Units(PMUs) at the substations. The information received from PMUs must be monitored in real-time for estimating the state of the system and for predictingfailures.

5) Retail:

a) **Inventory Management:** IoT systems enable remote monitoring of inventory using data collected by RFIDreaders.

b) **Smart Payments:** Solutions such as contact-less payments powered by technologies such as Near Field Communication(NFC) and Bluetooth.
c) **Smart Vending Machines:** Sensors in a smart vending machines monitors its operations and send the data to cloud which can be used for predictivemaintenance.

6) Logistics:

a) **Route generation & scheduling:** IoT based system backed by cloud can provide first response to the route generation queries and can be scaled upto serve a large transportationnetwork.
b) **Fleet Tracking:** Use GPS to track locations of vehicles inreal-time.
c) **Shipment Monitoring:** IoT based shipment monitoring systems use sensors such as temp, humidity, to monitor the conditions and send data to cloud, where it can be analyzed to detect foodspoilage.
d) **Remote Vehicle Diagnostics:** Systems use on-board IoT devices for collecting data on Vehicle operaions(speed, RPMetc.,) and status of various vehicle subsystems.

7) Agriculture:

a) **Smart Irrigation:** to detemine moisture amount insoil.
b) **Green House Control:** to improveproductivity.

8) Industry:

a) Machine diagnosis andprognosis
b) Indoor Air QualityMonitoring

9) Health and LifeStyle:

a) Health & FitnessMonitoring
b) WearableElectronics