Introduction to IoT

Outline

- Definition of IoT
- Characteristics of IoT
- Physical design of IoT
- Logical design of IoT
- IoT protocols
- IoT levels and deployment templates

Introduction to IoT

- The term “The Internet of Things” (IoT) was coined by **Kevin Ashton** in a presentation to Proctor & Gamble in 1999.
- He is a co-founder of MIT’s Auto-ID Lab.
- “*We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory.*”

Introduction to IoT

- The ‘Thing’ in IoT can be any device with any kind of built-in-sensors with the ability to collect and transfer data over a network without manual intervention.
- The embedded technology in the object helps them **to interact** with internal states and the external environment, which in turn helps in **decisions** making process.
- IoT is a concept that **connects all the devices to the internet** and let them communicate with each other over the internet.

Introduction to IoT

- A room temperature sensor gathers the data and send it across the network, which is then used by multiple device sensors to adjust their temperatures accordingly.
- For example, refrigerator’s sensor can gather the data regarding the outside temperature and accordingly adjust the refrigerator’s temperature.
- Similarly, your air conditioners can also adjust its temperature accordingly. This is how devices can interact, contribute & collaborate.

Introduction to IoT

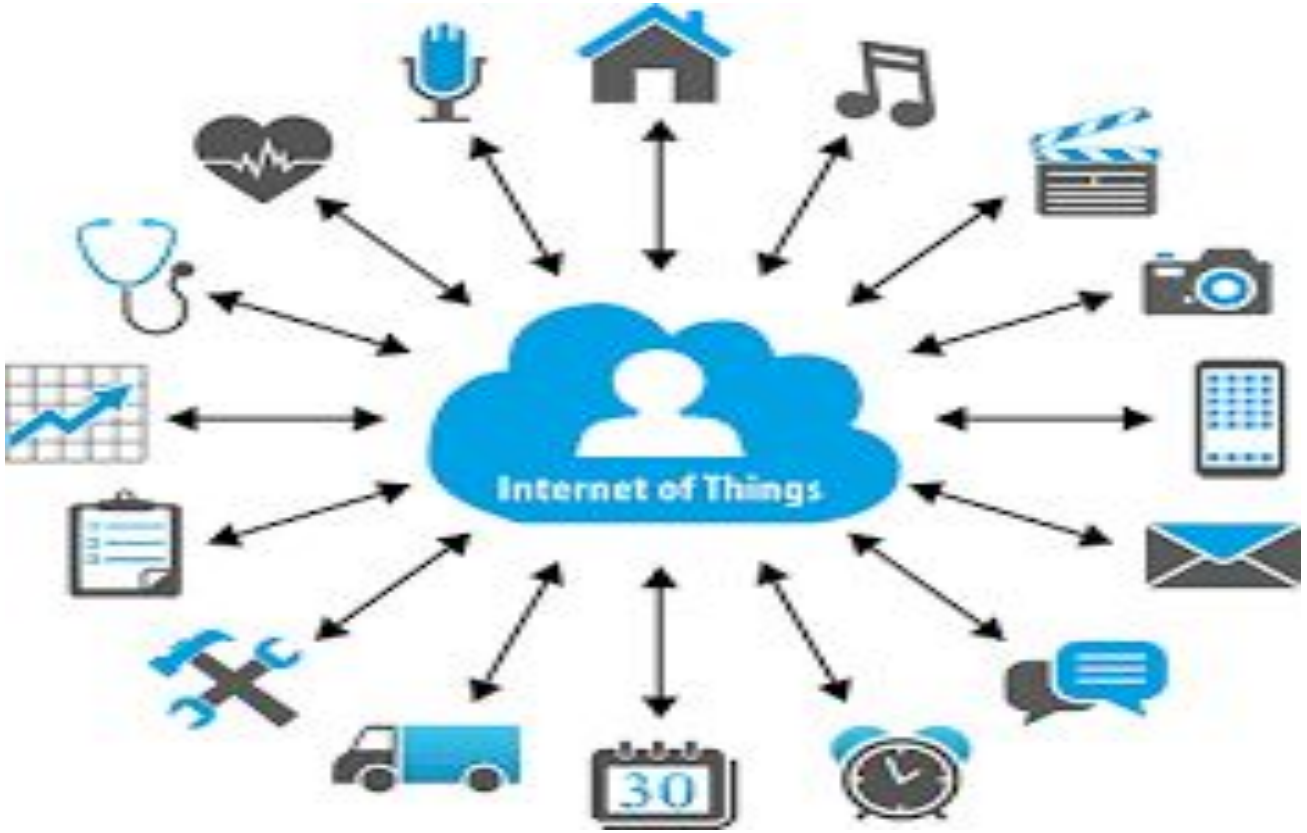
- IoT Hardware
- first require sensors that will sense the environment.
- Then you require a remote dashboard to monitor your output and display it in a clearer & conceivable form.
- At last, you will require a device with the capability of serving & routing.
- The key task of the system would be detecting specific conditions and taking actions accordingly. One thing to keep in mind is securing the communication between the devices and the dashboard.

Sensors

- Some of the common sensors that you are surrounded by are accelerometers, temperature sensors, magnetometers, proximity sensors, gyroscopes, image sensors, acoustic sensors, light sensors, pressure sensors, gas RFID sensors, humidity sensors & micro flow sensors.
- Which is the most important device which has tremendously contributed to IoT ???
- IoT **uses multiple technologies and protocols** to communicate with devices based on the requirements. The major technologies & protocols are Bluetooth, wireless, NFC, RFID, radio protocols and WiFi-Direct.

IoT

Applications of IoT



Applications of IoT

- **Energy Applications:** Smart Meters & Smart Grid are used to monitor energy consumption.
- **Healthcare Application**: Smartwatches and fitness devices have changed the frequency of health monitoring. People can monitor their own health at regular intervals.
- **Air and Water Pollution:** Through various sensors, we can detect the pollution in the air and water by frequent sampling. This helps in preventing substantial contamination and related disasters.
- **Farming:** IoT allows operations to minimize the human intervention in farming analysis and monitoring. Systems automatically detect changes in crops, soil, environment, and more.

Applications

- **Transportation**: IoT has changed the transportation sector. Now, we have self-driving cars with sensors, traffic lights that can sense the traffic and switch automatically, parking assistance, giving us the location of free parking space etc.

IoT

- https://www.youtube.com/watch?v=GIfWNtMfYvk&t=1s
- https://www.youtube.com/watch?v=Q3ur8wzzhBU

IoT

- Internet Of Things is Fully Networked and Connected Devices sending analytics data back to cloud or data center.
- The definition of Internet of things is that it is the network in which every object or **thing is provided unique identifier** and data is transferred through a network without any verbal communication.
- **Scope of IoT is not just limited to just connecting things to the internet, but it allows these things to communicate and exchange data, process them as well as control them while executing applications.**

Formal Definition of IoT

- A **dynamic global network** infrastructure with **self- configuring capabilities** based on standard and **interoperable communication protocols,** where physical and virtual “things” have **identities,** physical attributes, and use intelligent interfaces, and are seamlessly **integrated into information network** that communicate data with users and environments.

Characteristics of IoT

- **Dynamic Global network & Self-Adapting** : Adapt the changes w.r.t changing contexts
- **Self Configuring** : Eg. Fetching latest s/w updates without manual intervention.
- **Interoperable Communication Protocols** : Communicate through various protocols
- **Unique Identity** : Such as Unique IP Address or a URI
- **Integrated into Information Network** : This allows to communicate and exchange data with other devices to perform certain analysis.

Physical Design of IoT

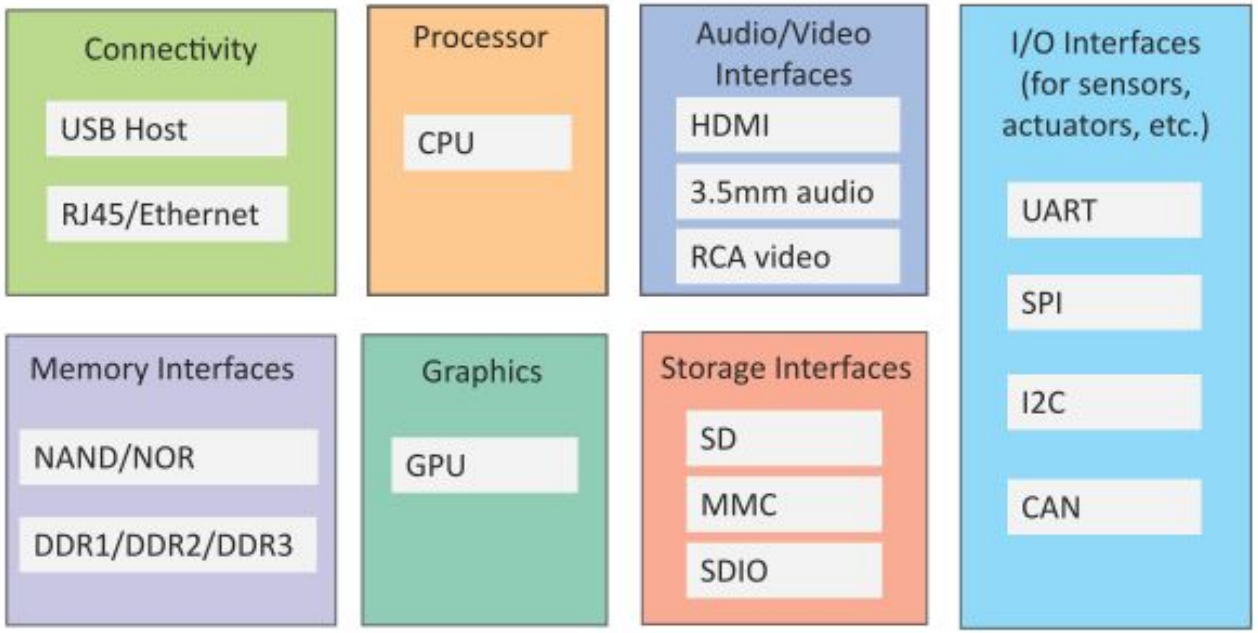
- Things in IoT
- IoT Protocols

Things in IoT

- Refers to IoT devices which have unique identities that can perform sensing, actuating and monitoring capabilities.
- IoT devices can exchange data with other connected devices or collect data from other devices and process the data either locally or send the data to centralized servers or cloud – based application back-ends for processing the data.

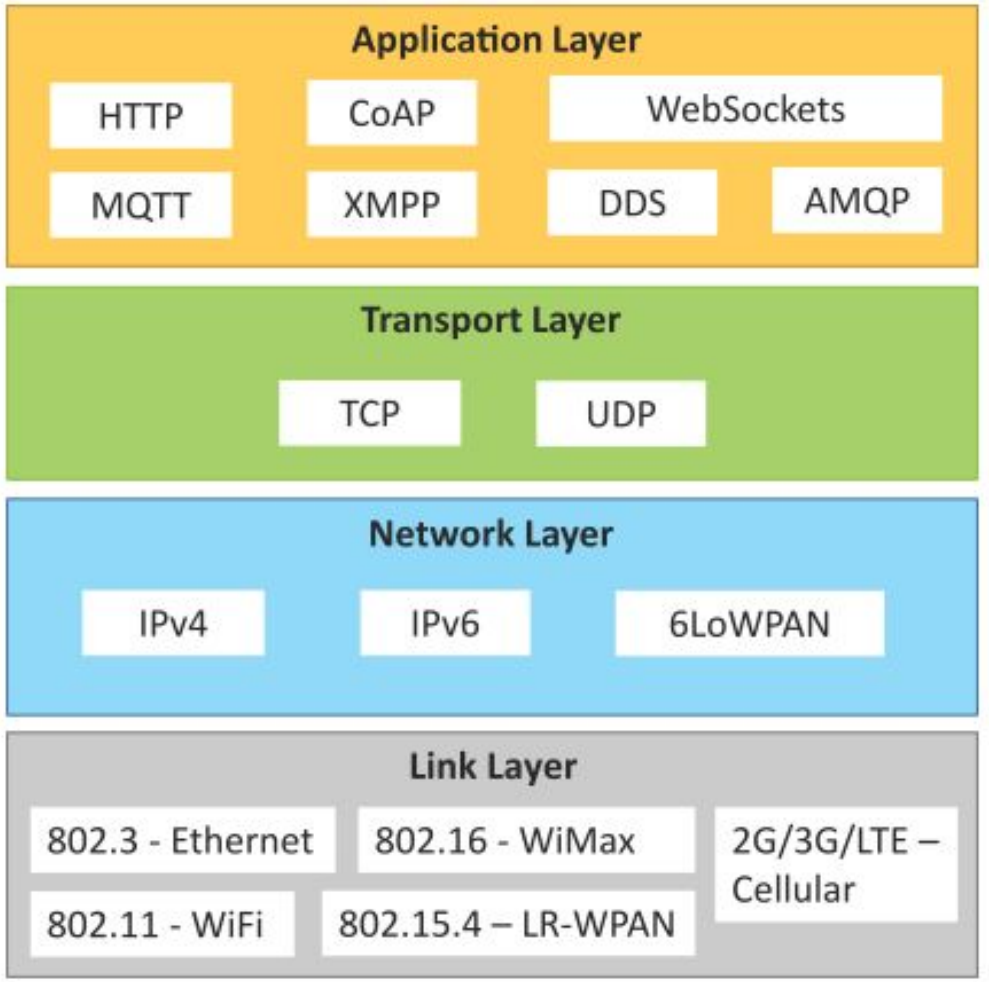
Generic Block Diagram of an IoT Device

- An IoT device may consist of several interfaces for connections to other devices, both wired and wireless.
  - I/O interfaces for sensors
  - Interfaces for internet connectivity
  - Memory and storage interfaces
  - Audio/video interfaces



IoT Protocols

- Link Layer
  - 802.3 – Ethernet
  - 802.11 – WiFi
  - 802.16 – WiMax
  - 802.15.4 – LR-WPAN
  - 2G/3G/4G
- Network/Internet Layer
  - IPv4
  - IPv6
  - 6LoWPAN
- Transport Layer
  - TCP
  - UDP
- Application Layer
  - HTTP
  - CoAP
  - WebSocket
  - MQTT
  - XMPP
  - DDS
  - AMQP



IoT Protocols…Link Layer…Ethernet

Sr.No	Standard	Shared medium
1	802.3	Coaxial Cable…10BASE5
2	802.3.i	Copper Twisted pair …..10BASE-T
3	802.3.j	Fiber Optic……10BASE-F
4	802.3.ae	Fiber…..10Gbits/s

Data Rates are provided from 10Gbit/s to 40Gb/s and higher

IoT Protocols…Link Layer…WiFi

Sr.No	Standard	Operates in
1	802.11a	5 GHz band
2	802.11b and 802.11g	2.4GHz band
3	802.11.n	2.4/5 GHz bands
4	802.11.ac	5GHz band
5	802.11.ad	60Hz band

- Collection of Wireless LAN
- Data Rates from 1Mb/s to 6.75 Gb/s

IoT Protocols…Link Layer…WiMax

Sr.No	Standard	Data Rate
1	802.16m	100Mb/s for mobile stations 1Gb/s for fixed stations

- Collection of Wireless Broadband standards
- Data Rates from 1.5Mb/s to 1 Gb/s

IoT Protocols…Link Layer…LR-WPAN

- Collection of standards for low-rate wireless personal area networks
- Basis for high level communication protocols such as Zigbee
- Data Rates from 40Kb/s to 250Kb/s
- Provide low-cost and low-speed communication for power constrained devices

IoT Protocols…Link Layer…2G/3G/4G –Mobile Communication

Sr.No	Standard	Operates in
1	2G	GSM-CDMA
2	3G	UMTS and CDMA 2000
3	4G	LTE

- Data Rates from 9.6Kb/s (for 2G) to up to 100Mb/s (for 4G)

IoT Protocols…Network/Internet Layer

- Responsible for sending of IP datagrams from source to destination network
- Performs the host addressing and packet routing
- Host identification is done using hierarchical IP addressing schemes such as IPV4 or IPV6

IoT Protocols…Network Layer

- IPV4
  - Used to identify the devices on a network using hierarchical addressing scheme
  - Uses 32-bit address scheme
- IPV6
  - Uses 128-bit address scheme
- 6LoWPAN (IPV6 over Low power Wireless Personal Area Network)
  - Used for devices with limited processing capacity
  - Operates in 2.4 Ghz
  - Data Rates of 250Kb/s

IoT Protocols…Transport Layer

- Provide end-to-end message transfer capability independent of the underlying network
- It provides functions such as error control, segmentation, flow-control and congestion control

IoT Protocols…TCP

- Transmission Control Protocol
- Connection Oriented
- Ensures Reliable transmission
- Provides Error Detection Capability to ensure no duplicacy of packets and retransmit lost packets
- Flow Control capability to ensure the sending data rate is not too high for the receiver process
- Congestion control capability helps in avoiding congestion which leads to degradation of n/w performance

IoT Protocols…UDP

- User Datagram Protocol
- Connectionless
- Does not ensures Reliable transmission
- Does not do connection before transmitting
- Does not provide proper ordering of messages
- Transaction oriented and stateless

IoT Protocols…Application Layer…Hyper Transfer Protocol

- Forms foundation of World Wide Web(WWW)
- Includes commands such as GET,PUT, POST, HEAD, OPTIONS, TRACE..etc
- Follows a request-response model
- Uses Universal Resource Identifiers(URIs) to identify HTTP resources

IoT Protocols…Application Layer…CoAP

- Constrained Application Protocol
- Used for Machine to machine (M2M) applications meant for constrained devices and n/w's
- Web transfer protocol for IoT and uses request-response model
- Uses client –server architecture
- Supports methods such as GET,POST, PUT and DELETE

IoT Protocols…Application Layer…WebSocket

- Allows full-duplex communication over single socket
- Based on TCP
- Client can be a browser, IoT device or mobile application

IoT Protocols…Application Layer…MQTT

- Message Queue Telemetry Transport , light-weight messaging protocol
- Based on publish-subscribe model
- Well suited for constrained environments where devices have limited processing, low memory and n/w bandwith requirement

IoT Protocols…Application Layer…XMPP

- Extensible messaging and presence protocol
- For Real time communication and streaming XML data between n/w entities
- Used for Applications such as Multi-party chat and voice/video calls.
- Decentralized protocol and uses client server architecture.

IoT Protocols…Application Layer…DDS

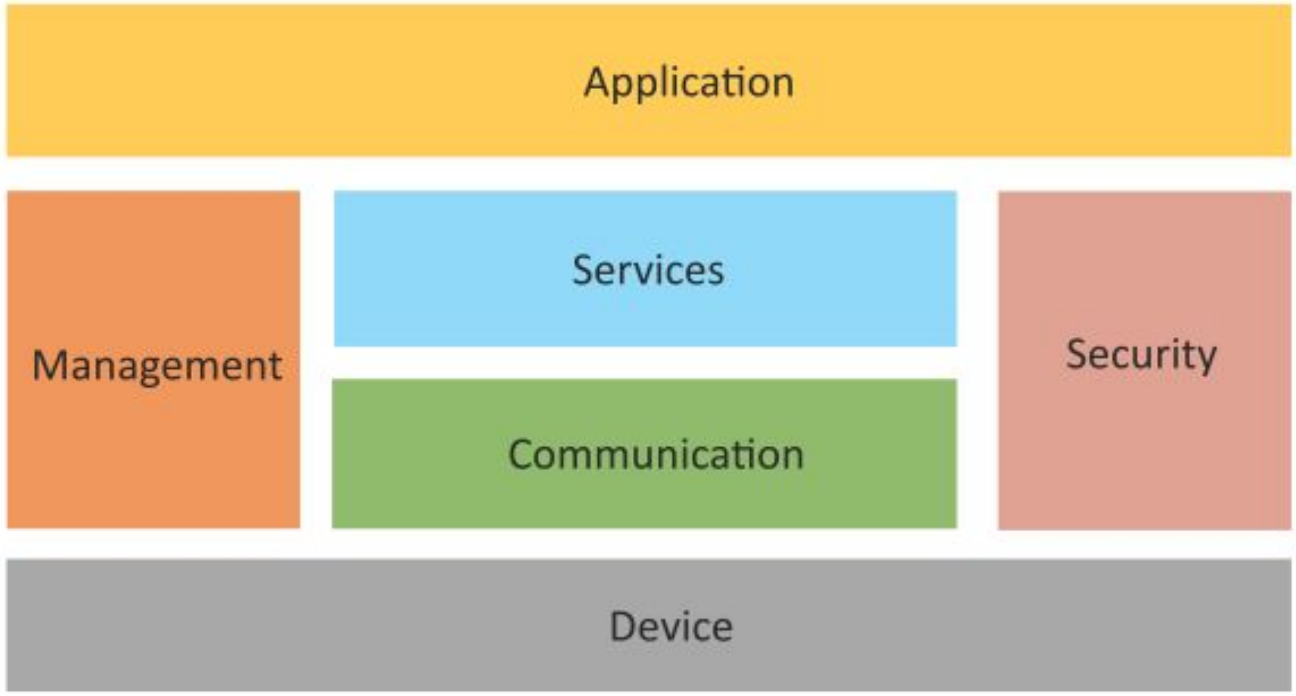
- Data Distribution service is a data-centric middleware standard for device-to-device or machine-to-machine communication.
- Publish subscribe model where publishers create topics to which subscribers can use.
- Provides Quality-of-service control and configurable reliability.

IoT Protocols…Application Layer…AMQP

- Advanced Messaging Queuing Protocol used for business messaging.
- Supports both point-to-point and publisher/subscriber models, routing and queuing
- Broker here receives messages from publishers and route them over connections to consumers through messaging queues.

Logical Design of IoT

- Logical design of an IoT system refers to an abstract representation of the entities and processes without going into the low-level specifics of the implementation.
- An IoT system comprises a number of functional blocks that provide the system the capabilities for identification, sensing, actuation, communication and management.

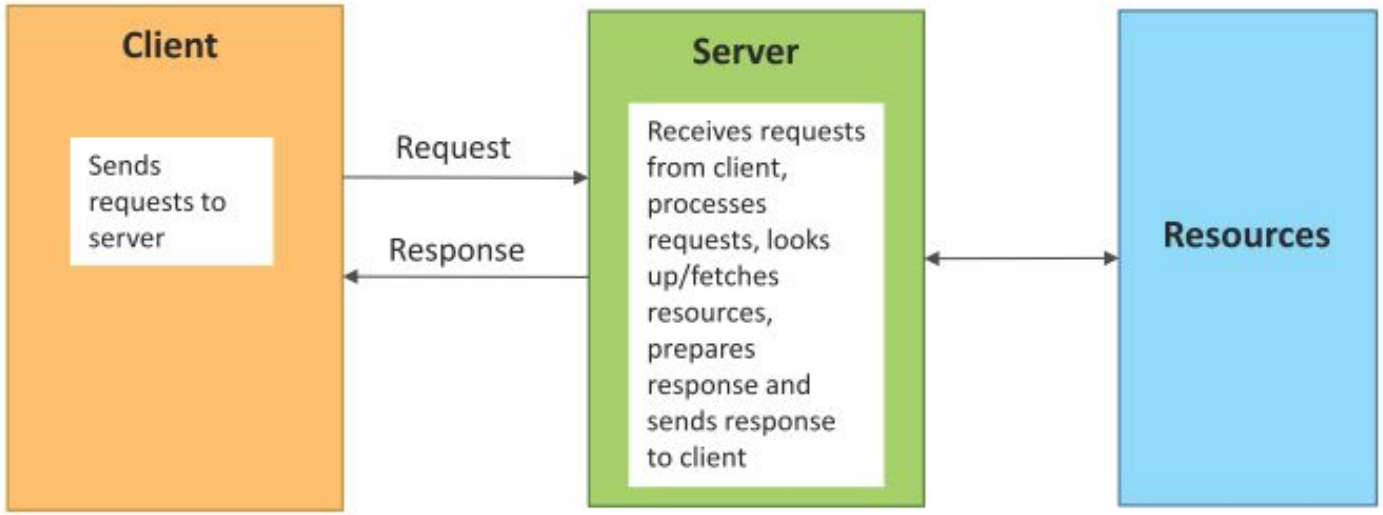


Logical Design of IoT

- Device : Devices such as sensing, actuation, monitoring and control functions.
- Communication : IoT Protocols
- Services like device monitoring, device control services, data publishing services and device discovery
- Management : Functions to govern the system
- Security : Functions as authentication, authorization, message and content integrity, and data security
- Applications

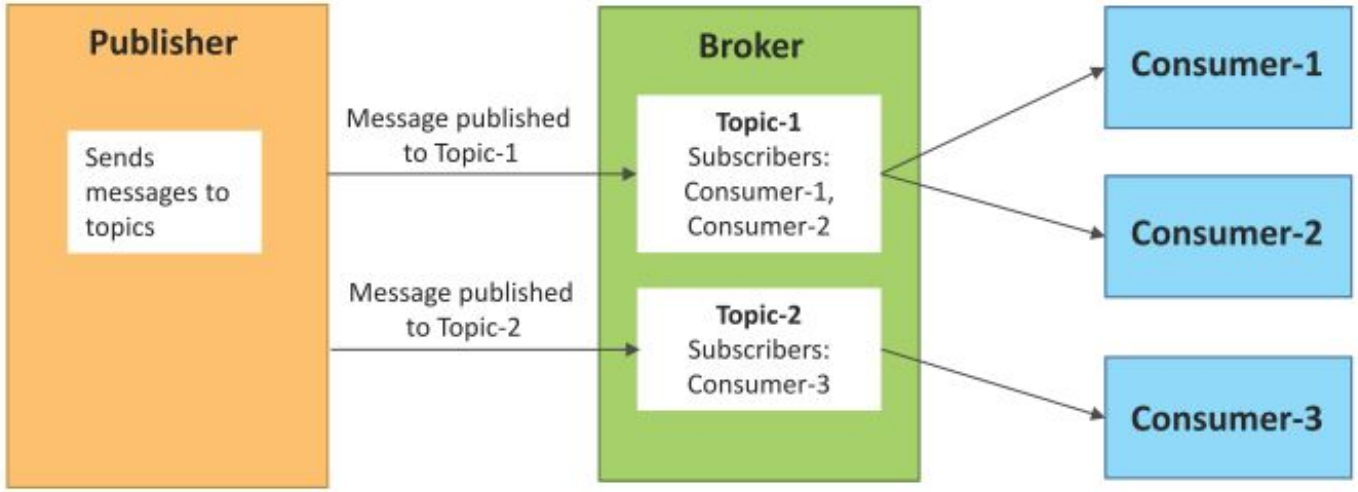
Request–Response Communication Model

- Request–Response is a 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 representations, prepares the response and then sends the response to the client.
- Stateless communication model



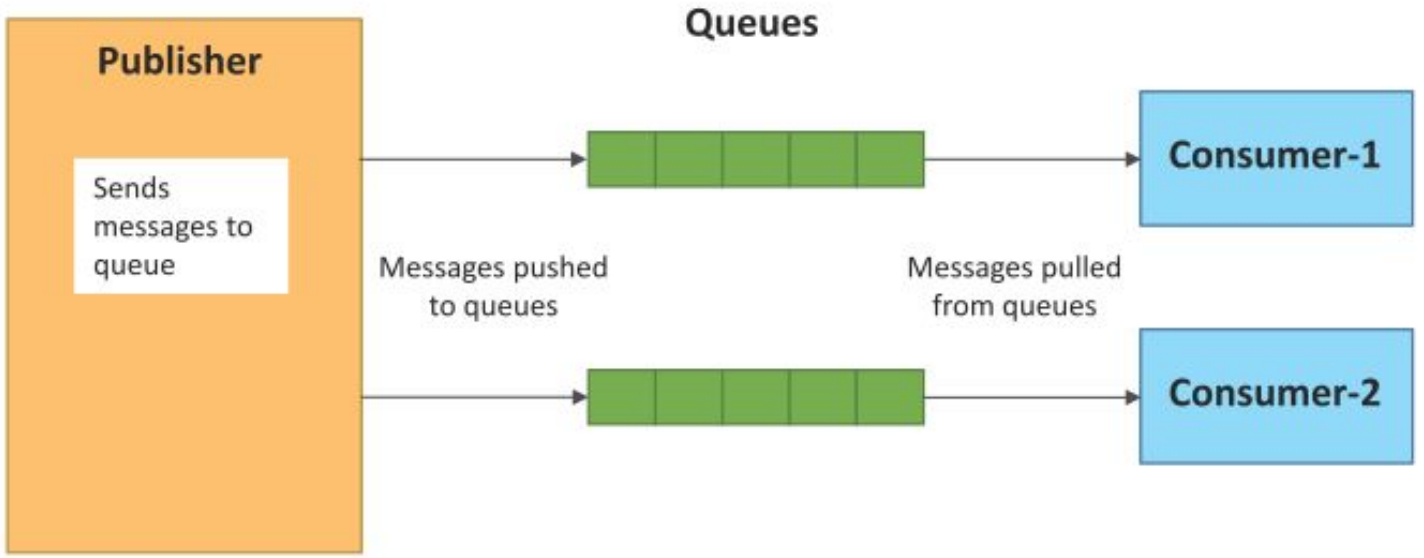
Publish–Subscribe Communication Model

- 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 receives data for a topic from the publisher, it sends the data to all the subscribed consumers.



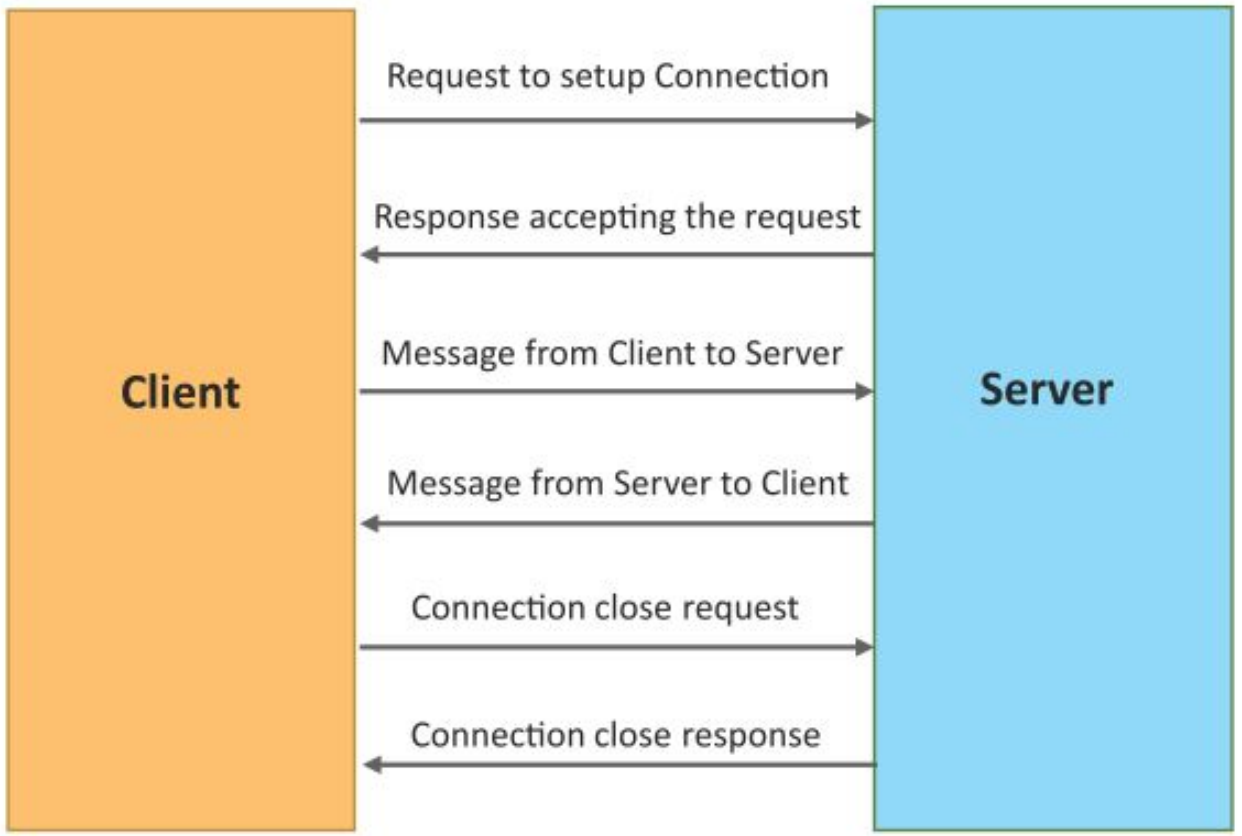
Push–Pull Communication Model

- 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 at which the consumers pull data.



Exclusive Pair Communication Model

- Exclusive Pair is a bidirectional, fully duplex communication model that uses a persistent connection between the client and the server.
- Once the connection is set up 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.



IoT Enabling Technologies

- Wireless Sensor Network

- Cloud Computing

- Big Data Analytics

- Embedded Systems

WSN

- **Distributed Devices with sensors** used to monitor the environmental and physical conditions
- Consists of several **end-nodes acting as routers or coordinators too**
- **Coordinators collects data** from all nodes / **acts as gateway** that connects WSN to internet
- **Routers route the data packets** from end nodes to coordinators.

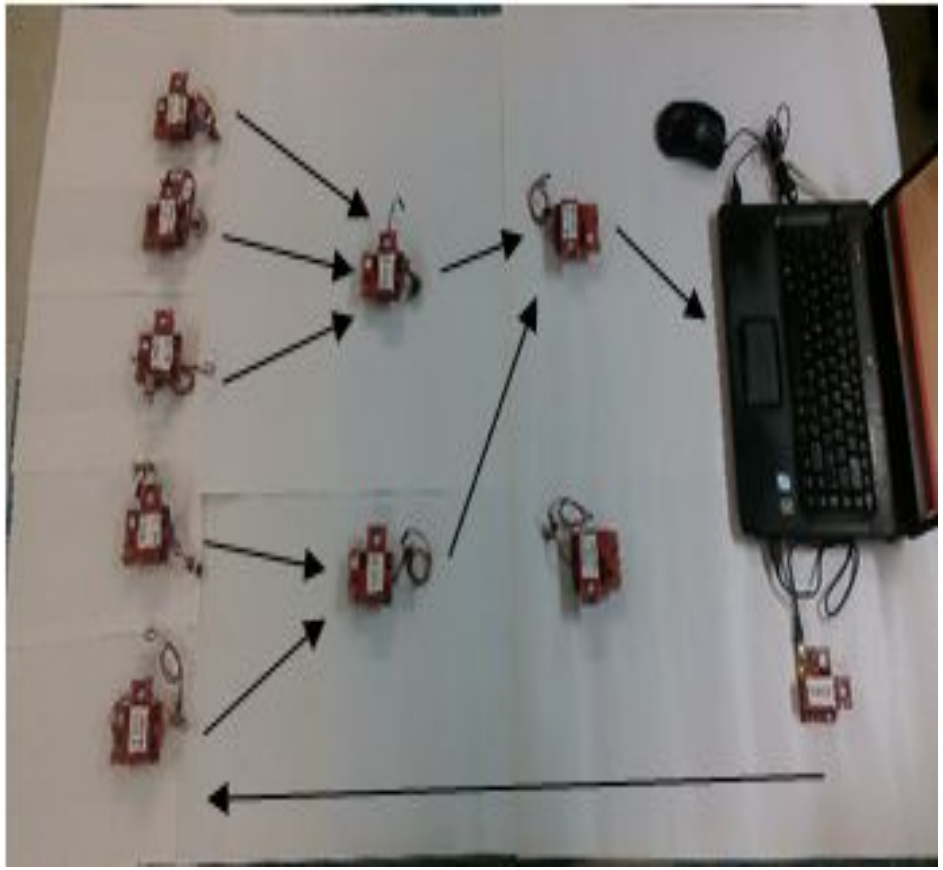
Example of WSNs in IoT & Protocols used

Example

- Weather monitoring system
- Indoor Air quality monitoring system
- Soil moisture monitoring system
- Survelliance systems
- Health monitoring systems

Protocols

- Zigbee



Cloud Computing

- **Deliver applications and services over internet**
- Provides computing, networking and storage resources on demand
- Cloud computing performs services such as Iaas, Paas and Saas
- Iaas : Infrastructure as a Service; Rent Infrastructure
- Paas : Platform as a Service; supply an on-demand environment for developing, testing, delivering and managing software applications.
- Saas : Software as a Service; method for delivering software applications over the Internet, on demand and typically on a subscription basis.

Big Data Analytics

- Collection of data whose volume, velocity or variety is too large and difficult to store, manage, process and analyze the data using traditional databases.
- It involves data cleansing, processing and visualization
- Lots of data is being collected and warehoused
  - Web data, e-commerce
  - purchases at department/ grocery stores
  - Bank/Credit Card transactions
  - Social Network

Big Data Analytics

Variety Includes different types of data

- Structured
- Unstructured
- SemiStructured
- All of above

Big Data Analytics

Velocity Refers to speed at which data is processed

- Batch
- Real-time
- Streams

Big Data Analytics

Volume refers to the amount of data

- Terabyte
- Records
- Transactions
- Files
- Tables

IoT Levels and Deployment Templates

An IoT system comprises the following components:

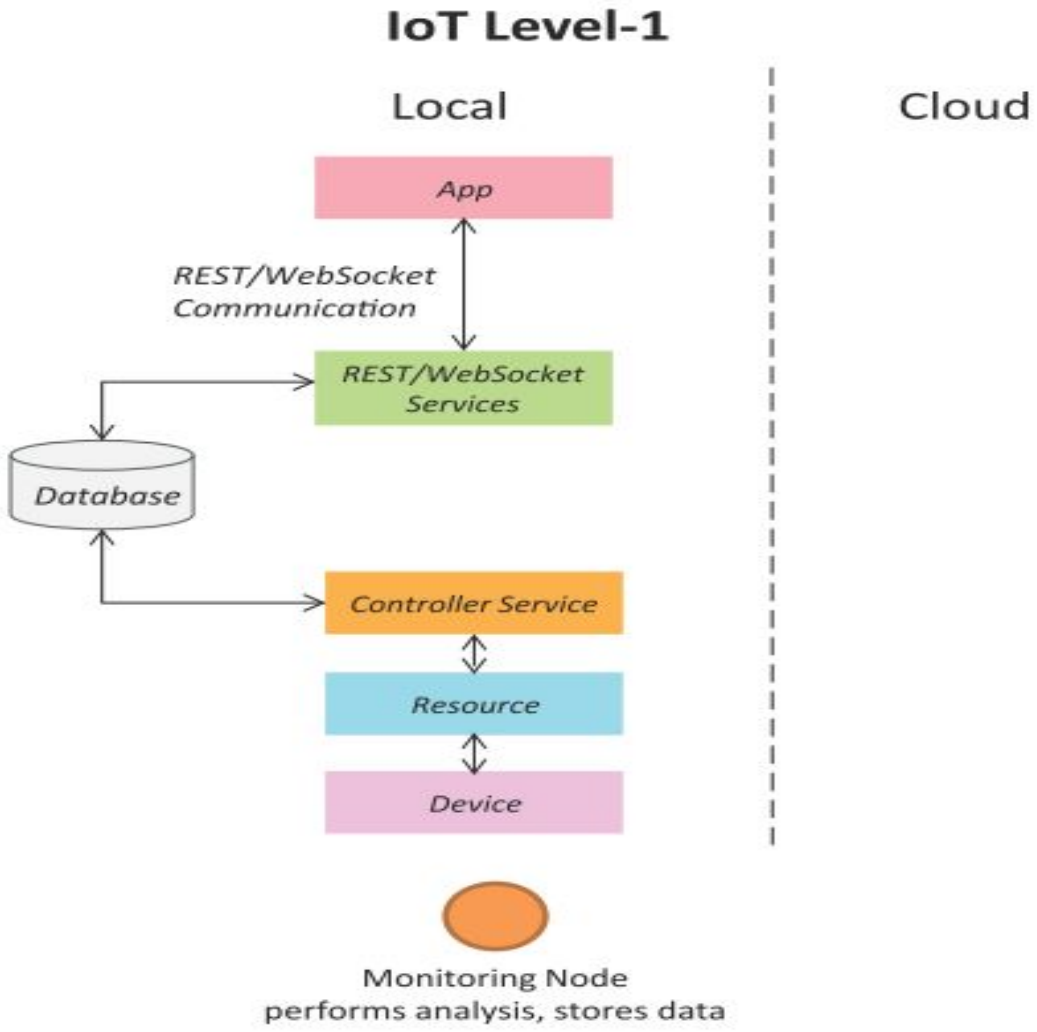
- **Device**: An IoT device allows identification, remote sensing, actuating and remote monitoring capabilities.
- **Resource**: Resources are software components on the IoT device for accessing, processing and storing sensor information, or for controlling actuators connected to the device. Resources also include the software components that enable network access for the device.
- **Controller Service**: Controller service is a native service that runs on the device and interacts with the web services. Controller service sends data from the device to the web service and receives commands from the application (via web services) for controlling the device.

IoT Levels and Deployment Templates

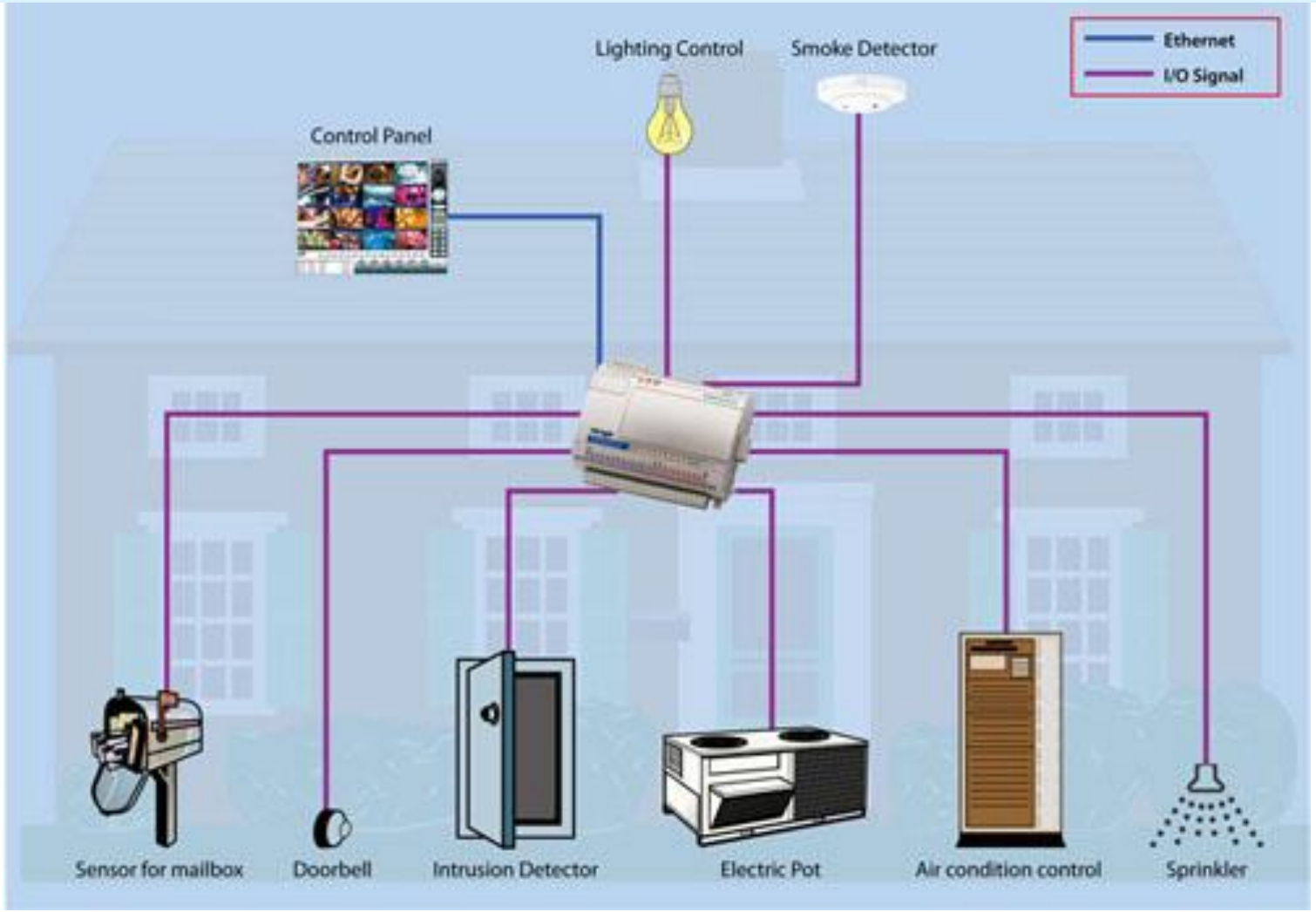
- **Database**: Database can be either local or in the cloud and stores the data generated by the IoT device.
- **Web Service**: Web services serve as a link between the IoT device, application, database and analysis components. Web service can be implemented using HTTP and REST principles (REST service) or using the WebSocket protocol (WebSocket service).
- **Analysis Component**: This is responsible for analyzing the IoT data and generating results in a form that is easy for the user to understand.
- **Application**: IoT applications provide an interface that the users can use to control and monitor various aspects of the IoT system. Applications also allow users to view the system status and the processed data.

IoT Level-1

- A level-1 IoT system **has a single node/device** that performs sensing and/or actuation, stores data, performs analysis and hosts the application.
- Level-1 IoT systems are suitable for **modelling low-cost and low-complexity solutions** where the data involved is not big and the **analysis requirements are not computationally intensive.**

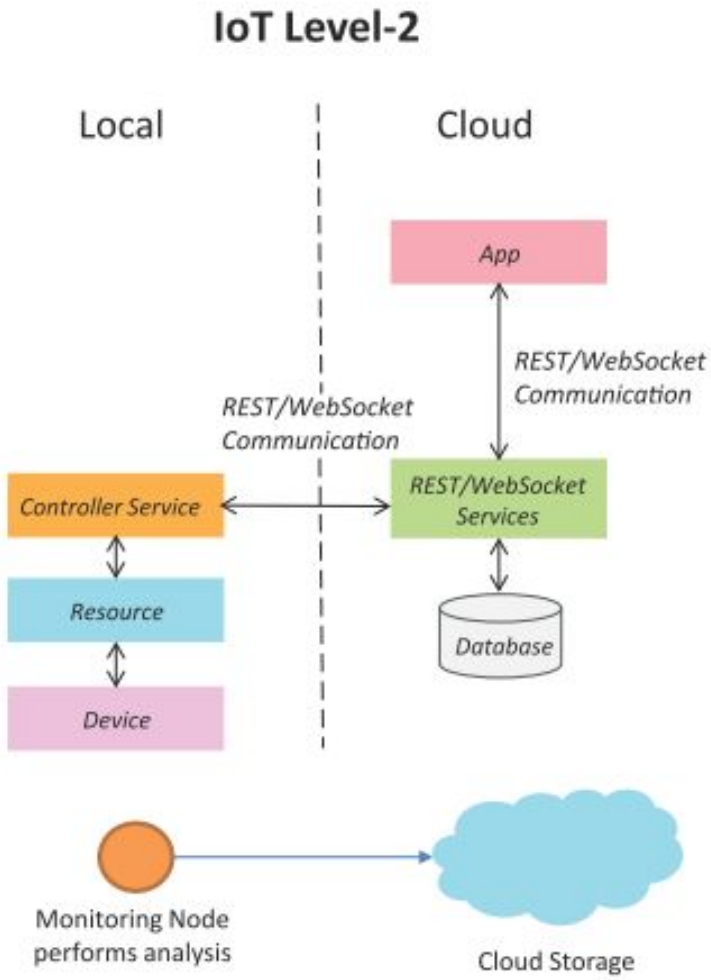


IoT – Level 1 Example …Home Automation System



IoT Level-2

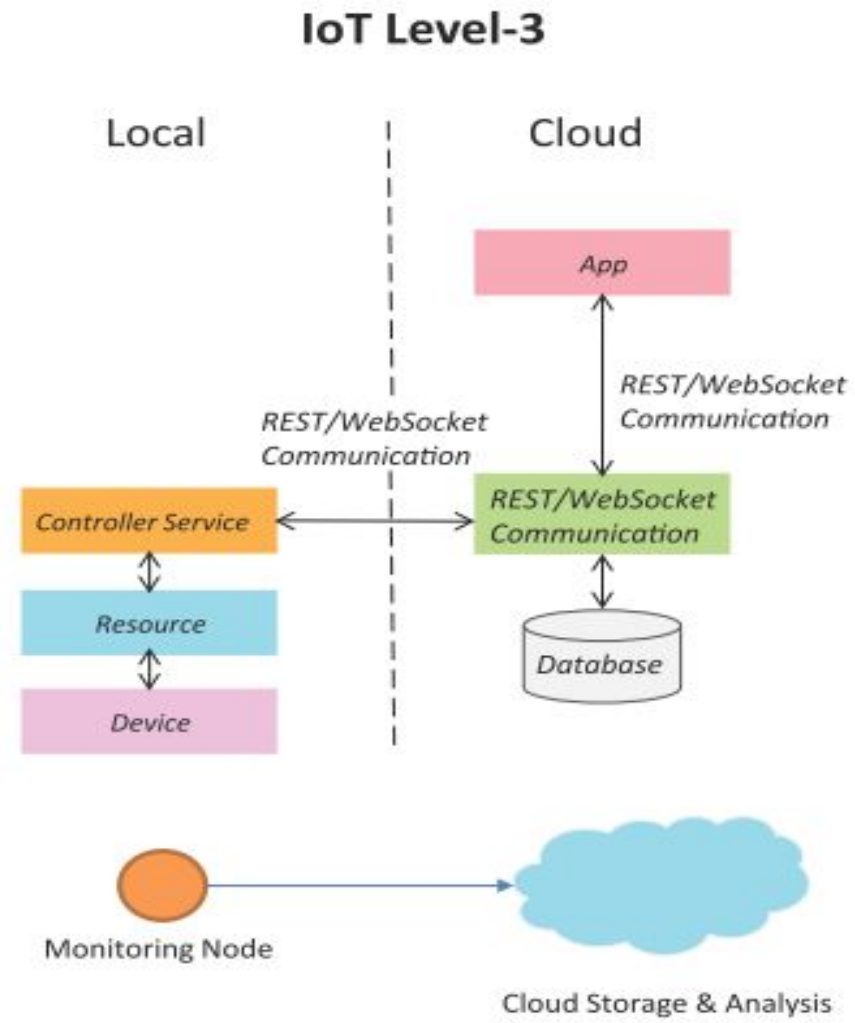
- A level-2 IoT system has a **single node that performs sensing and/or actuation and local analysis.**
- **Data is stored in the cloud** and the application is usually cloud-based.
- Level-2 IoT systems are **suitable for solutions where the data involved is big;** however, the primary **analysis requirement is not computationally intensive** and can be done locally.



IoT – Level 2 Example ...Smart Irrigation

IoT Level-3

- A level-3 IoT system has a **single node. Data is stored and analyzed in the cloud** and the application is cloud-based.
- Level-3 IoT systems are suitable for solutions **where the data involved is big and the analysis requirements are computationally intensive.**

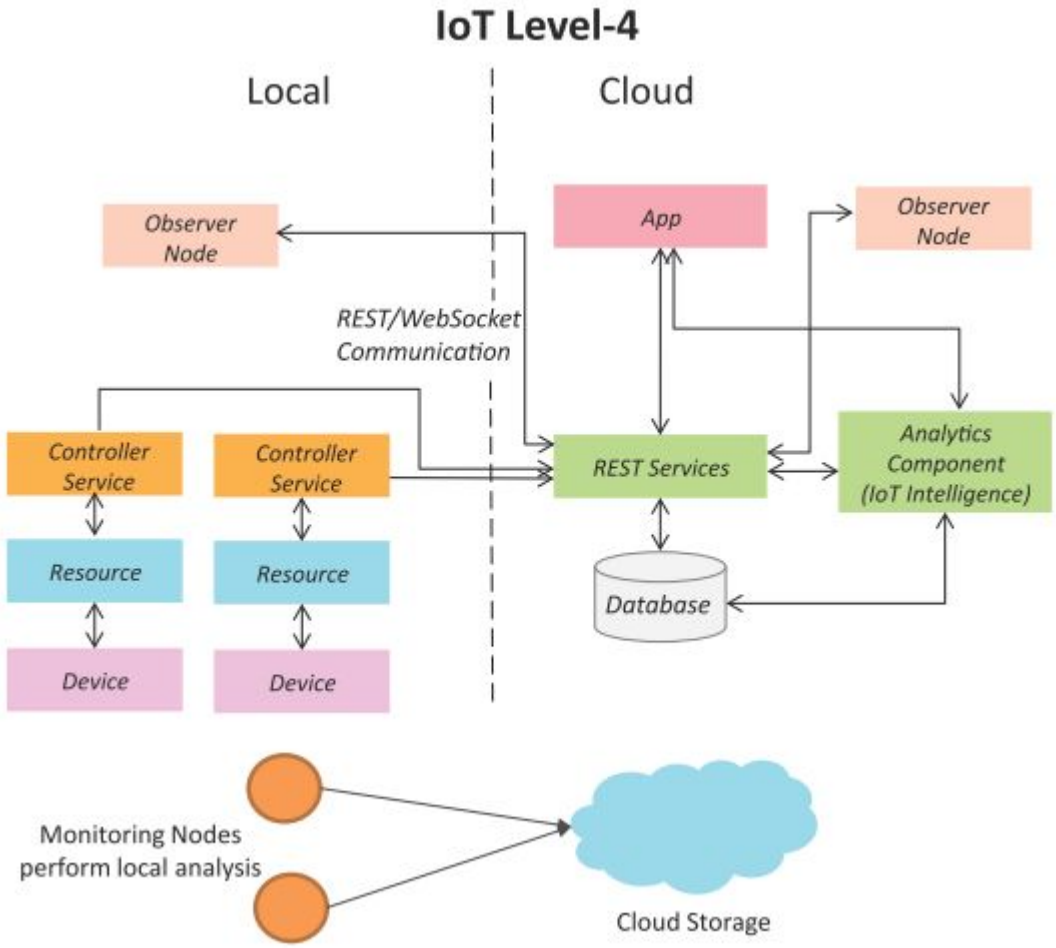


IoT – Level 3 Example …Tracking Package Handling

Sensors used accelerometer and gyroscope

IoT Level-4

- A level-4 IoT system has multiple nodes that perform local analysis. Data is stored in the cloud and the application is cloud-based.
- Level-4 contains local and cloud-based observer nodes which can subscribe to and receive information collected in the cloud from IoT devices.
- Level-4 IoT systems are suitable for solutions where multiple nodes are required, the data involved is big and the analysis requirements are computationally intensive.

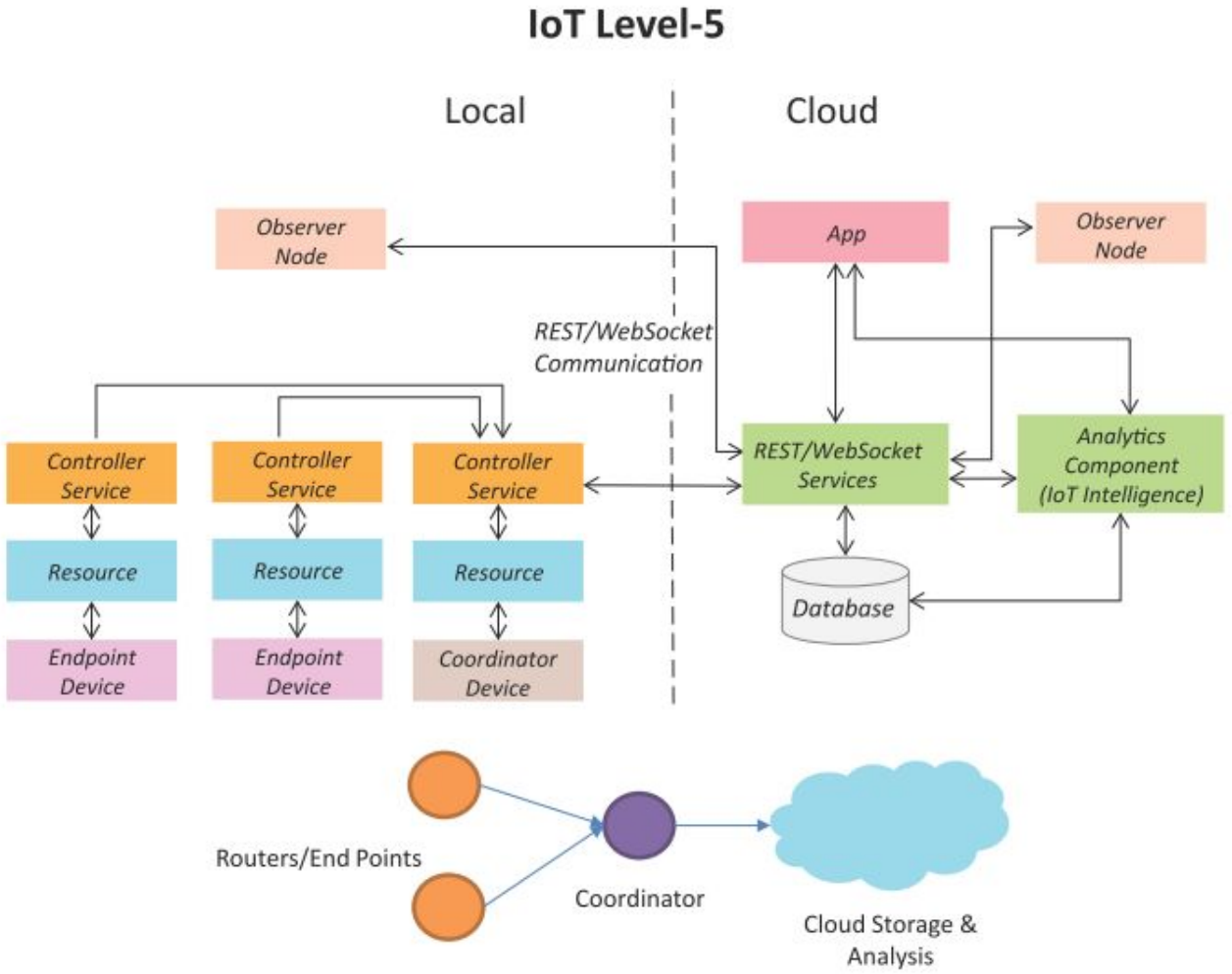


IoT – Level 3 Example …Noise Monitoring

Sound Sensors are used

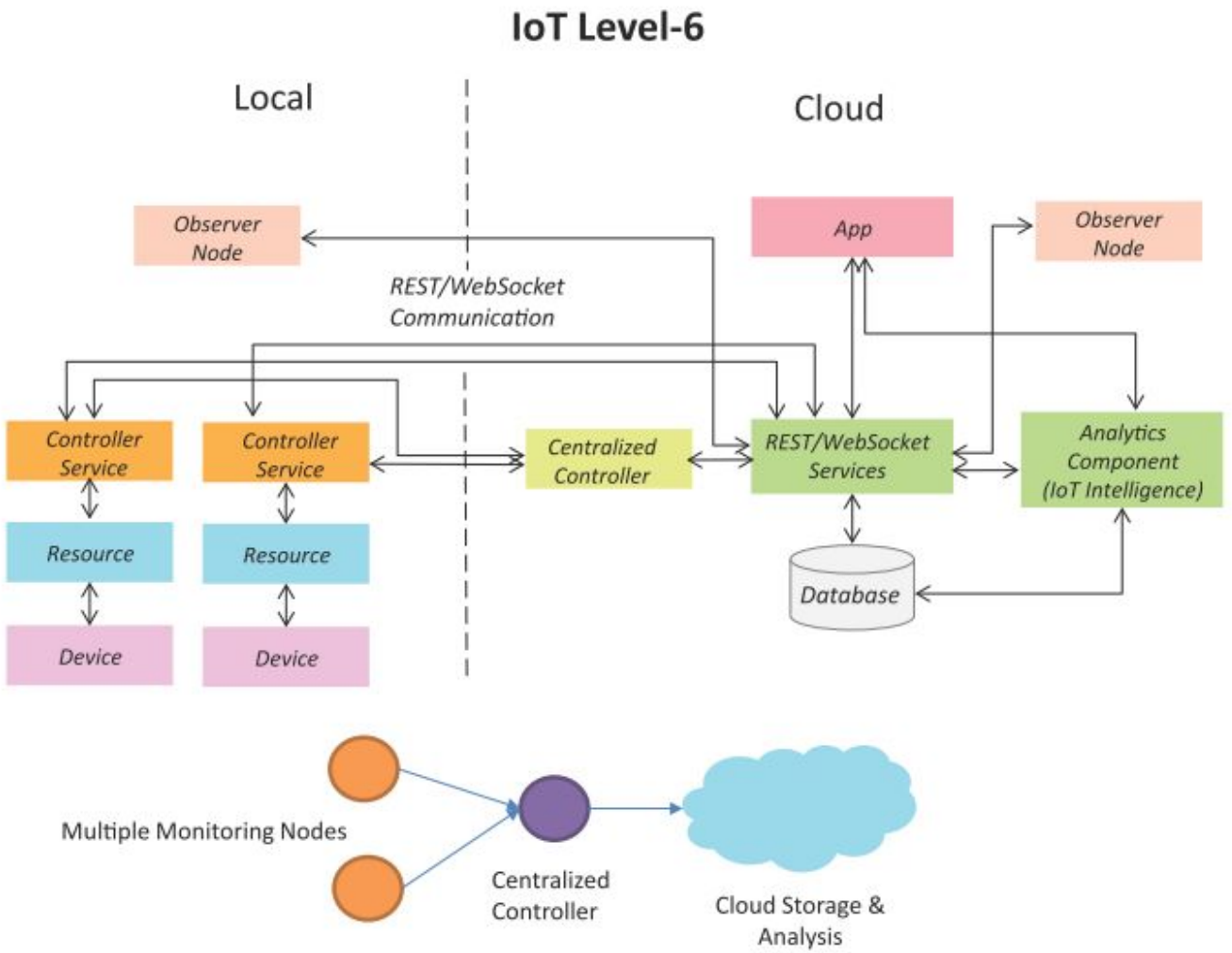
IoT Level-5

- A level-5 IoT system has multiple end nodes and one coordinator node.
- The end nodes perform sensing and/or actuation.
- The coordinator node collects data from the end nodes and sends it to the cloud.
- Data is stored and analyzed in the cloud and the application is cloud-based.
- Level-5 IoT systems are suitable for solutions based on wireless sensor networks, in which the data involved is big and the analysis requirements are computationally intensive.



IoT Level-6

- A level-6 IoT system has multiple independent end nodes that perform sensing and/or actuation and send data to the cloud.
- Data is stored in the cloud and the application is cloud-based.
- The analytics component analyzes the data and stores the results in the cloud database.
- The results are visualized with the cloud-based application.
- The centralized controller is aware of the status of all the end nodes and sends control commands to the nodes.



Sources of IoT

- Resources which enable the development of IoT prototype and product.
  - Development Boards
    - Arduino
    - Intel Galileo
    - NodeMCU
    - Raspberry Pi

Role of RFID and IoT Applications

- RFID enables tracking and inventory control, identification in supply chain systems, access to buildings and road tolls etc.
- RFID networks applications

Role of RFID and IoT Applications

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M2M to the IoT

M2M system

- Each machine in embeds a smart device
- Device senses the data or status of the machine
- Performs the computation and communication functions
- A device communicates via wired or wireless systems
- Protocols: 6LowPAN, LWM2M, MQTT, XMPP
- Each device assigned 48-bits Ipv6 addresses.

Machine-to-Machine (M2M) to IoT

- Technology closely relates to IoT which use smart devices to collect data that is transmitted via the Internet to other devices.

- Close differences lies in M2M uses for device to device communication also for coordinated monitoring and control purposes.

M2M Application Areas

- Connected Cars for Safety and Infotainment
- Remote Monitoring
- ATMs/Point of Sales Terminal Connected for centralized Security
- Remote Monitoring, Trucks Fleet Management

M2M Communication Framework

DeviceHive

- It is M2M platform and integration tool.
- Enables connecting devices to the IoTs
- Web-based management software that creates security rules based networks and monitors devices

M2M Architecture

Three domains

- M2M Device domain,
- M2M network domain
- M2M Application domain

M2M Architecture