Internet-of-Things
MCA 5036

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Outline

- IoT definition
- Characteristics of IoT
- Physical Design of IoT
- Logical Design of IoT
- IoT Protocols
- IoT Levels & Deployment Templates

Scope of IoT

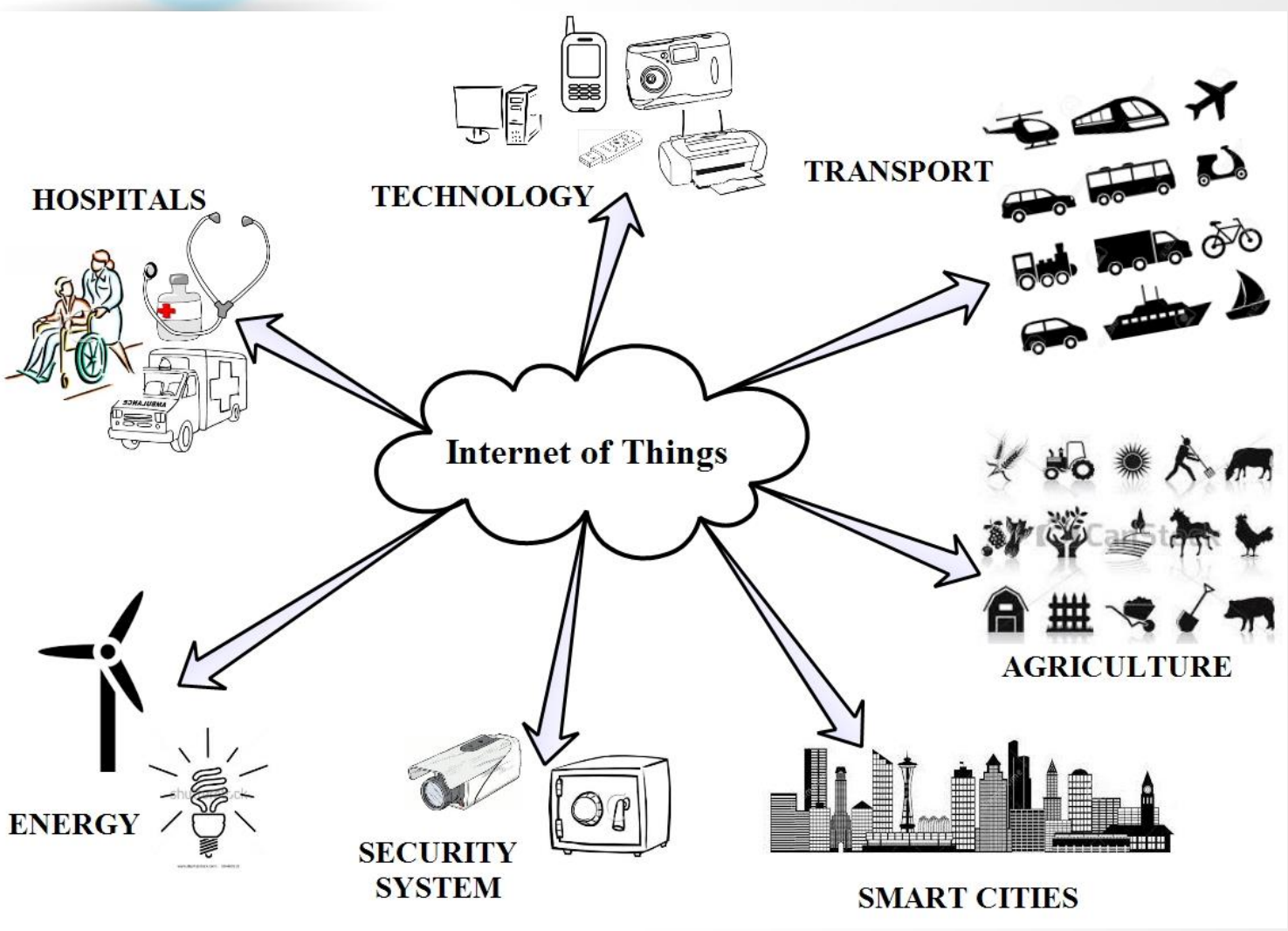
Not just limited to connecting the “things” to the Internet. It allows these things to communicate and exchange data while executing meaningful applications towards the common user

Data
Raw and unprocessed data obtained from IoT devices and systems

Information
Information is inferred from data by filtering, processing, categorizing, and contextualizing data

Knowledge
Knowledge is inferred from the information by organizing and structuring information and is put into action to achieve specific objectives

Applications of IoT



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 virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network, often communicate data associated with users and their environments.

Characteristics of IoT

- Dynamic & Self-Adapting
- Self-Configuring
- Interoperable Communication Protocols
- Unique Identity
- Integrated into Information Network

Physical Design of IoT

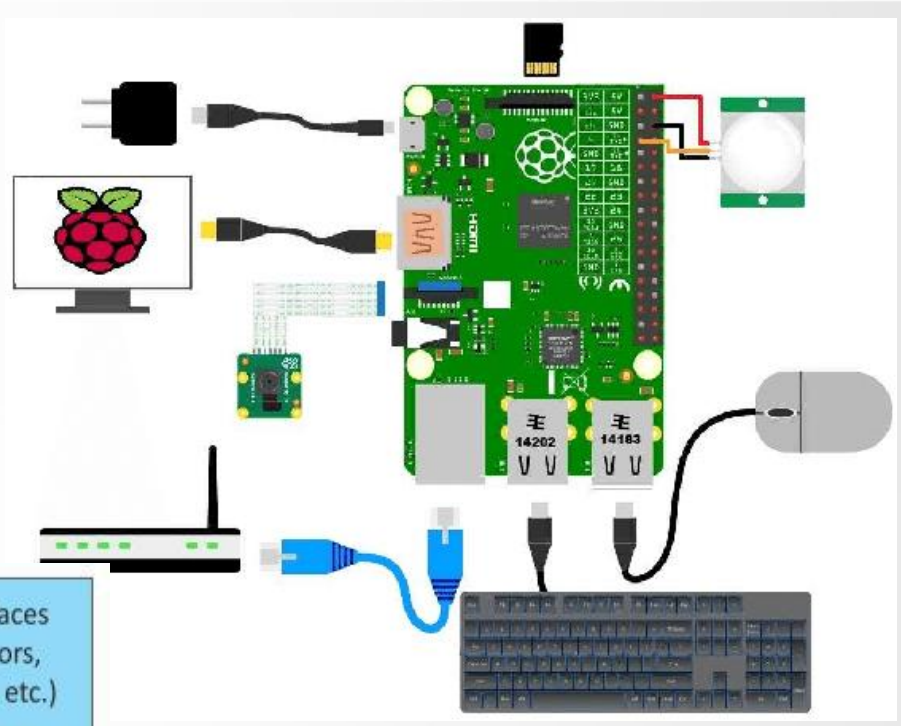
Things in IoT

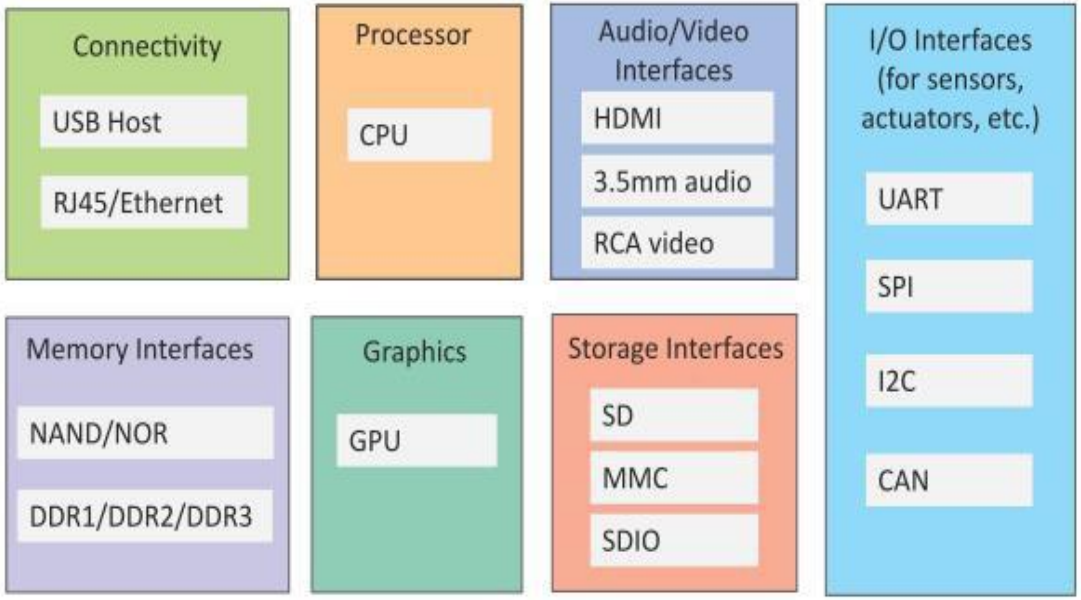
IoT Protocols

- The "Things" in IoT usually refers to IoT devices which have unique identities and can perform remote sensing, actuating and monitoring capabilities.
- IoT devices can:
  - Exchange data with other connected devices and applications (directly or indirectly),
  - Collect data from other devices and process the data locally
  - Send the data to centralized servers or cloud-based application back-ends for processing the data, or
  - Perform some tasks locally and other tasks within the IoT infrastructure, based on temporal and space constraints

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.

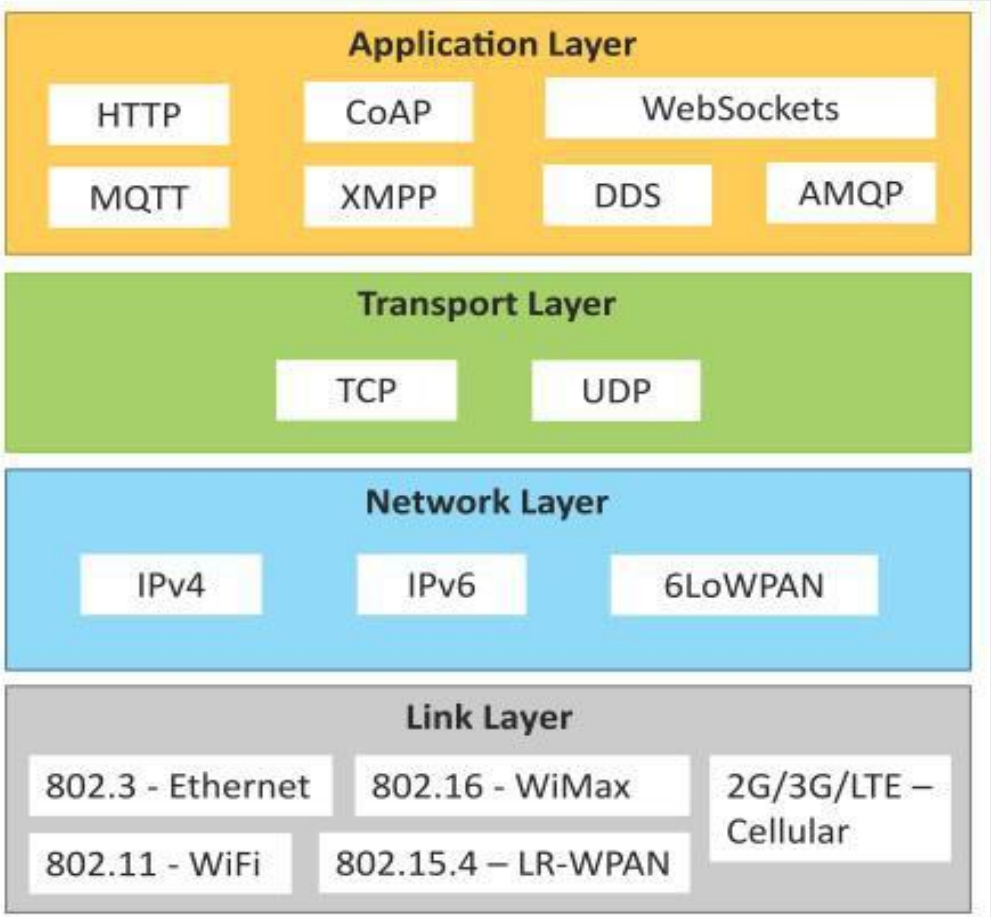




IoT Protocols

- **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
  - WebSockets
  - MQTT
  - XMPP
  - DDS
  - AMQP



Link Layer

- **Link Layer Protocols**
  - **802.3 – Ethernet**
    - Copper/coxial cable/Fiber optics
    - Data rate: 10 MBPS to 40 GBPS
  - **802.11 – WiFi**
    - Wireless Local Area Network (WLAN)
    - Data rate: 1 MBPS to 6.75 GBPS
  - **802.16 – WiMax**
    - Wireless broadband
    - Data rate: 1.5 MBPS to 1 GPBS
  - **802.15.4 – LR-WPAN**
    - Low Rate- Wireless Personal Area Network
    - Zigbee protocol
    - Data rate: 40 KBPS to 250 KBPS
  - **2G/3G/4G**
    - GSM, LTE, CSMA, CDMA
    - 9.6 KBPS for 2G to 100 MBPS for 4G

Network Layer

Sends IP Datagram	Host Addressing	Packet Routing

- **Network/Internet Layer Protocols**
  - **IPv4**
    - 32 bit addressing.
    - More number of devices added to the network so the 2011 address got exhausted.
    - No guarantee the packets reach their destination.
  - **IPv6**
    - 128-bit addressing
    - Newest version of IP addressing
  - **6LoWPAN**
    - IPv6 over Low power Wireless Personal Area Networks
    - Used for low powered devices having less processing capability
    - Operates on 2.4 GHz frequency
    - Data rate is 250 KBPS

Transport Layer

- **Transport Layer Protocols**
  - **TCP**
    - Connection oriented protocol
    - Used for web browser with HTTP/HTTPS of application layer, SMTP, and FTP
    - Ensure reliable transmission of packets with error detection and congestion control.
  - **UDP**
    - Connectionless protocol
    - Used in time-sensitive applications that hold small data units
    - No reliability of packet transmission

Application Layer

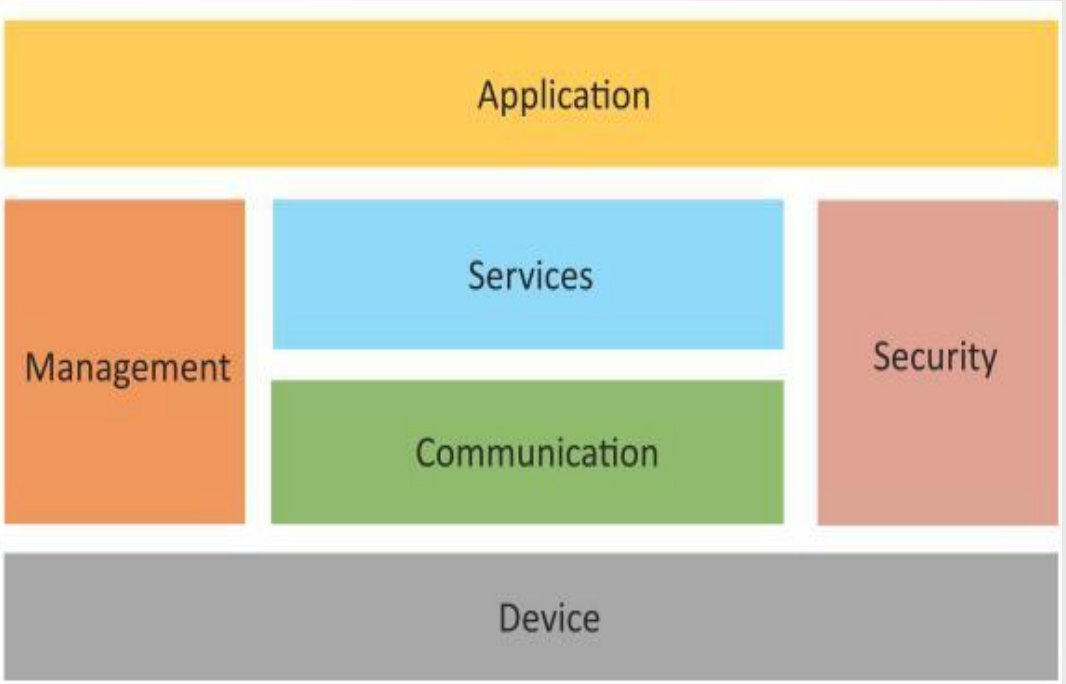
Protocol	Functions
HTTP (Hyper Text Transfer Protocol)	• **Includes commands like GET, PUT, POST, DELETE, HEAD** • **Stateless protocol – each request is independent of the previous request** • **Uses universal resource identifier (URI)**
MQTT (Message Queue Telemetry Transport)	• **Lightweight messaging protocol** • **Publish-subscribe principle (Publisher, subscriber and broker)** • **MQTT broker acts are server between MQTT client**
AMQP (Advanced Message Queuing Protocol)	• **Used for business messaging** • **Supports point-to-point, publish/subscribe, routing and queuing** • **Publisher, subscriber and broker**
CoAP (Constrained Application Protocol)	• **Is a web transfer protocol** • **Request-response is used** • **Runs on UDP**
XMPP (Extensible Messaging and Presence Protocol)	• **Realtime communication and streaming** • **Provides messaging, gaming, multi-party chat, voice/video call etc** • **Supports both client-server and sever-server communication**
DDS (Distributed Data Service)	• **Used for M2M communication** • **Publish-subscribe principle**

Logical Design of IoT

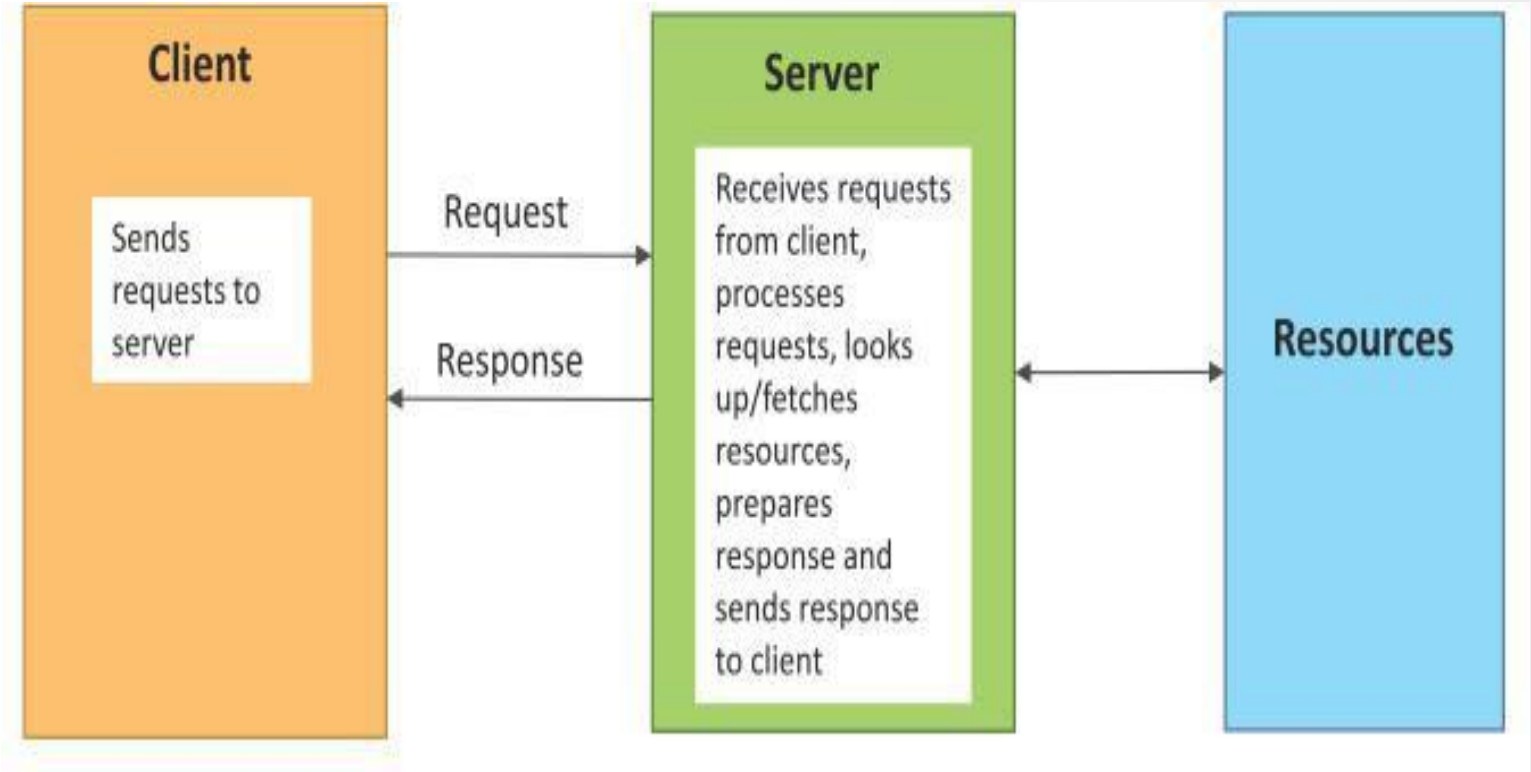
IoT Functional Block	IoT Communication Models	IoT Communication APIs
Device Communication Services Management Security Application	Request-Response Publish-Subscribe Push-Pull Exclusive Pair	REST-based Comm. Web-socket based Comm

IoT Functional Block

- 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 of a number of functional blocks that provide the system the capabilities for identification, sensing, actuation, communication, and management.

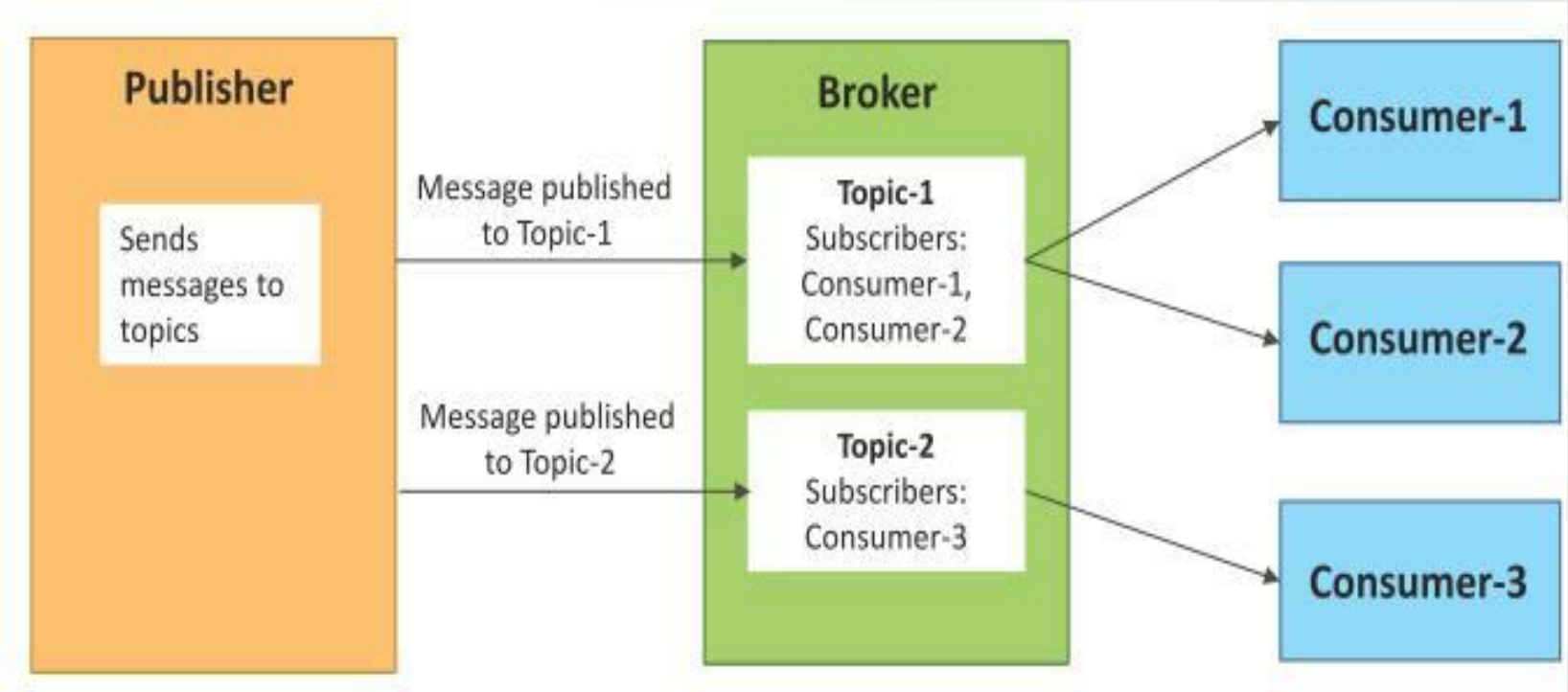


IoT Communication model



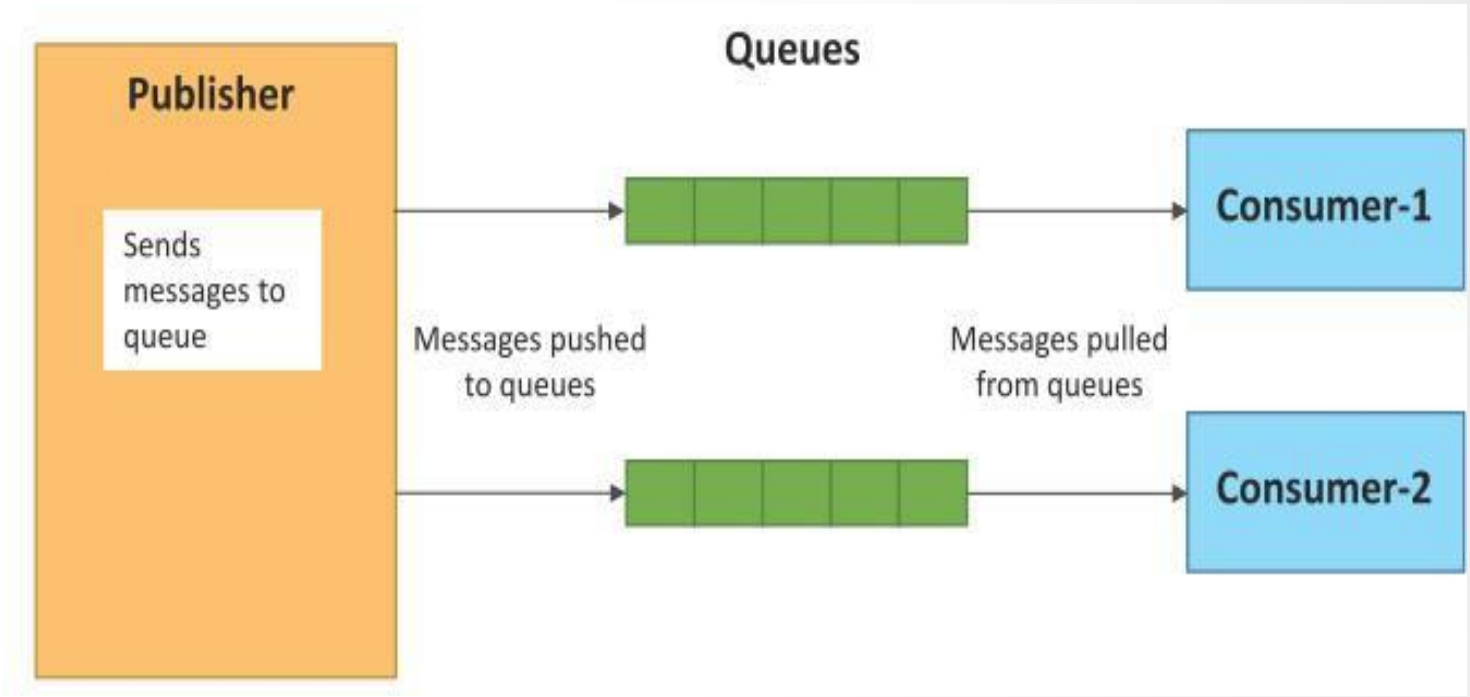
Request-Response Model

Publish-Subscribe communication model



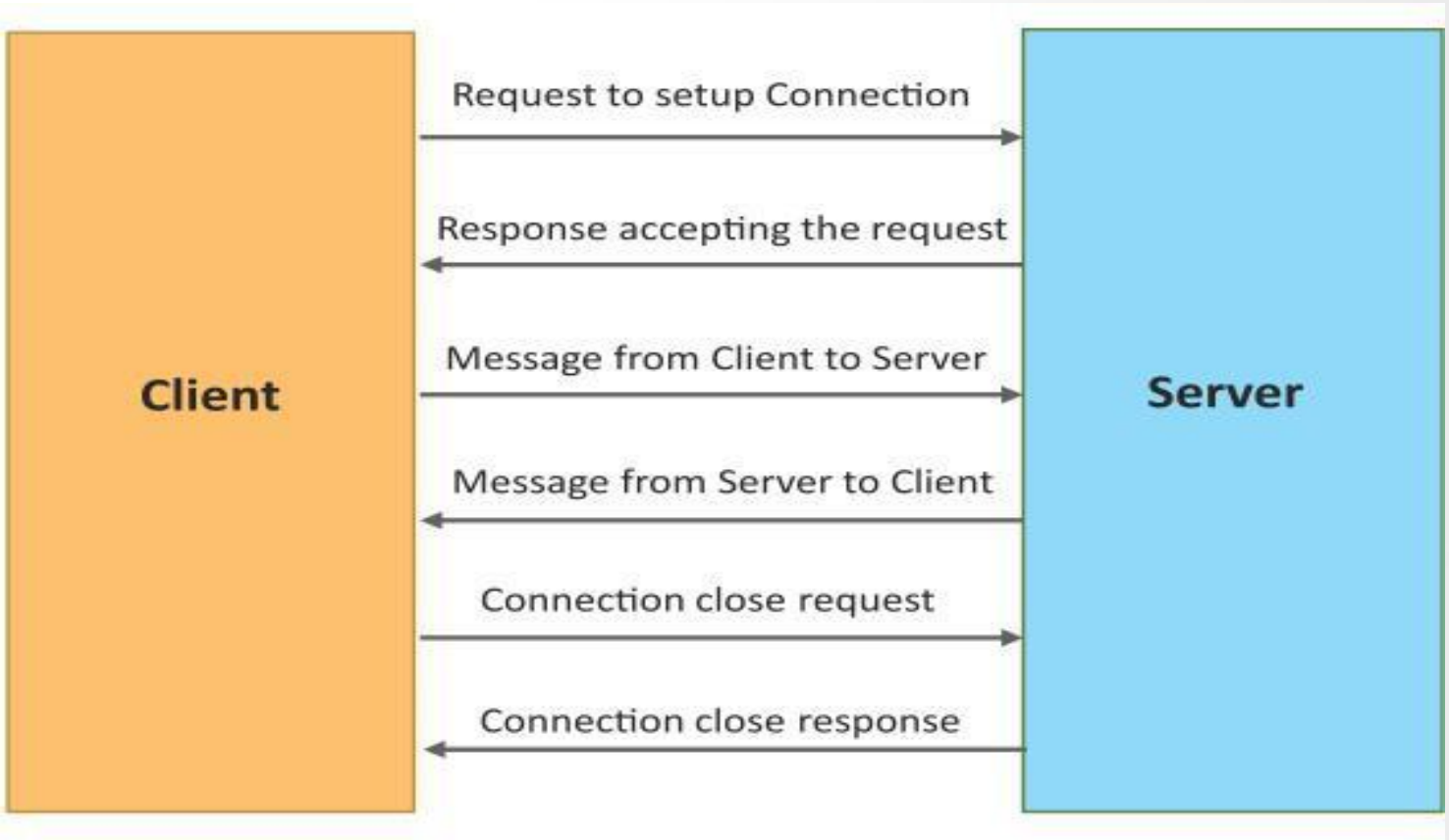
Publish-Subscribe Model

Push-Pull communication model



Push-Pull Model

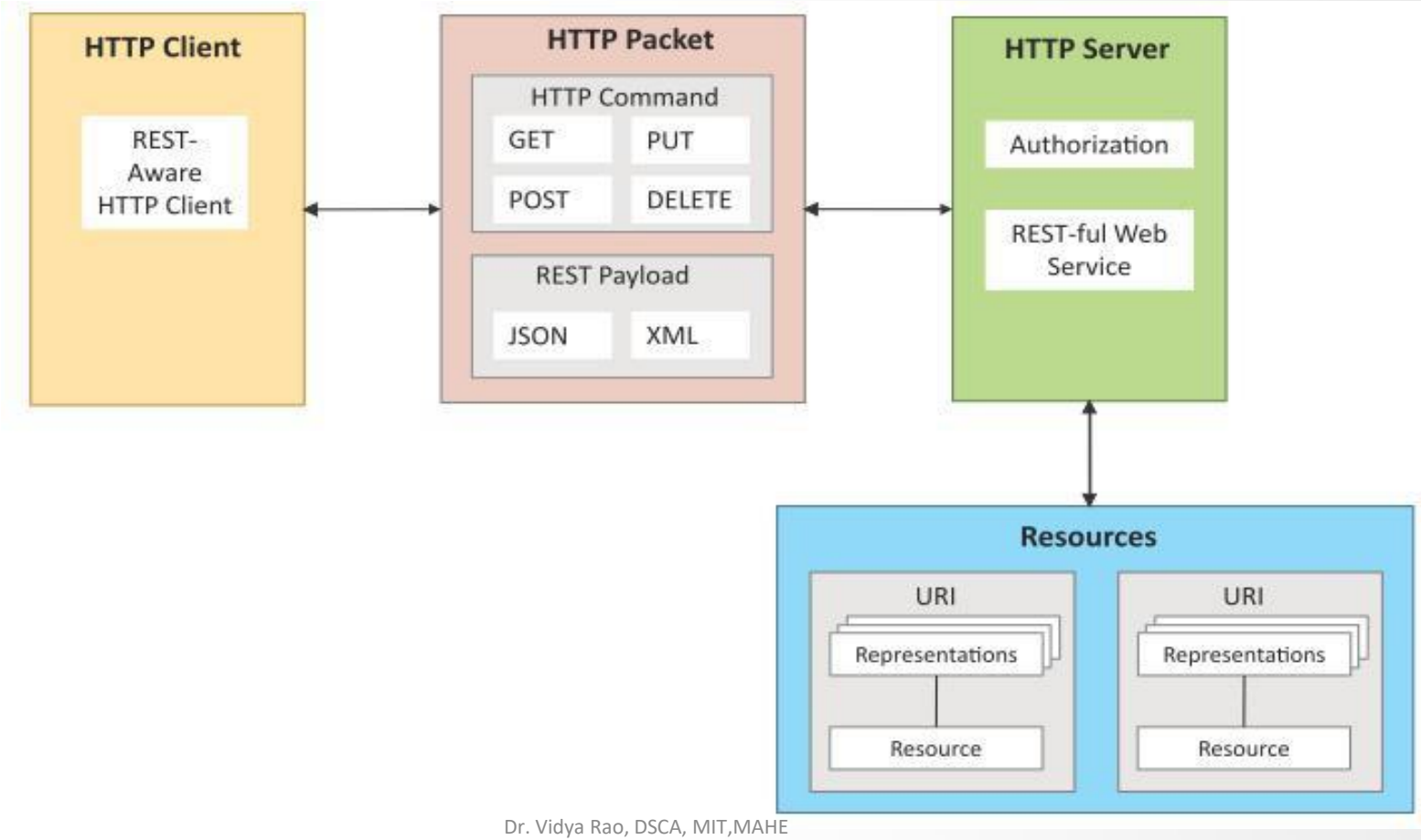
Exclusive Pair communication model



Exclusive Pair Model

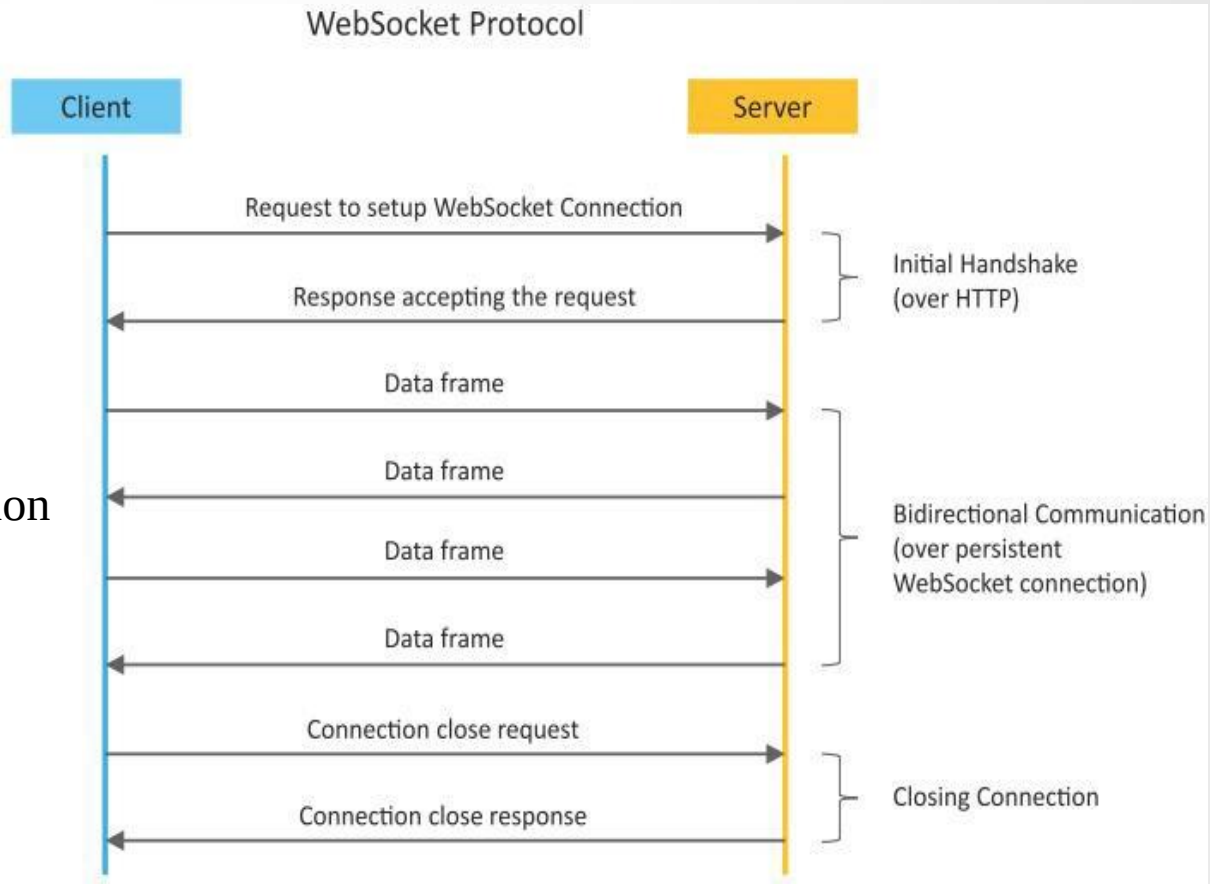
Communication APIs

Representational State Transfer (REST) API



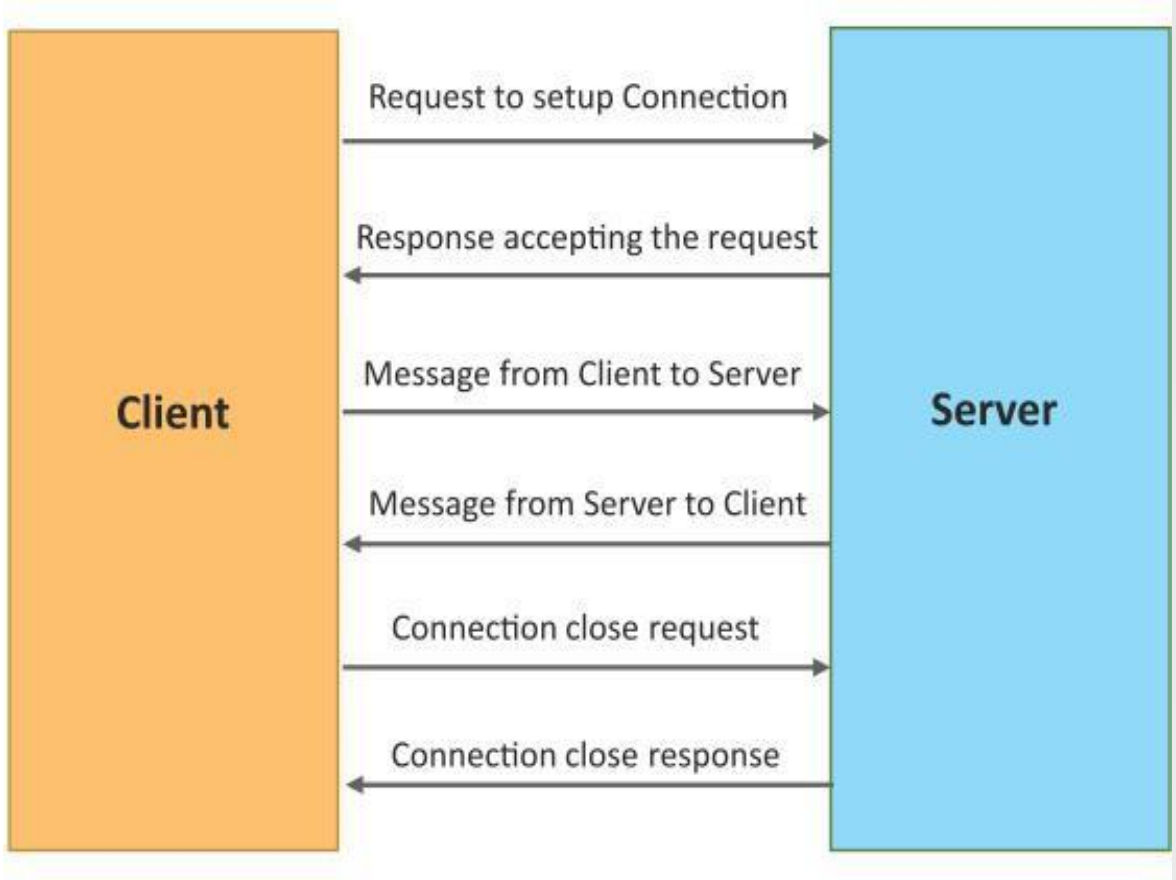
WebSocket-based Communication APIs

- WebSocket APIs allow bi-directional, full duplex communication between clients and servers.
- WebSocket APIs follow the exclusive pair communication model



Exclusive Pair communication model

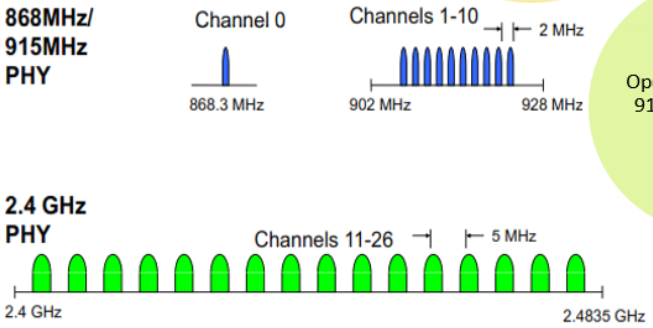
- Exclusive Pair is a bidirectional, fully duplex communication model that uses a persistent connection between the client and server.
- Once the connection is setup it remains open until the client sends a request to close the connection.
- Client and server can send messages to each other after connection setup.



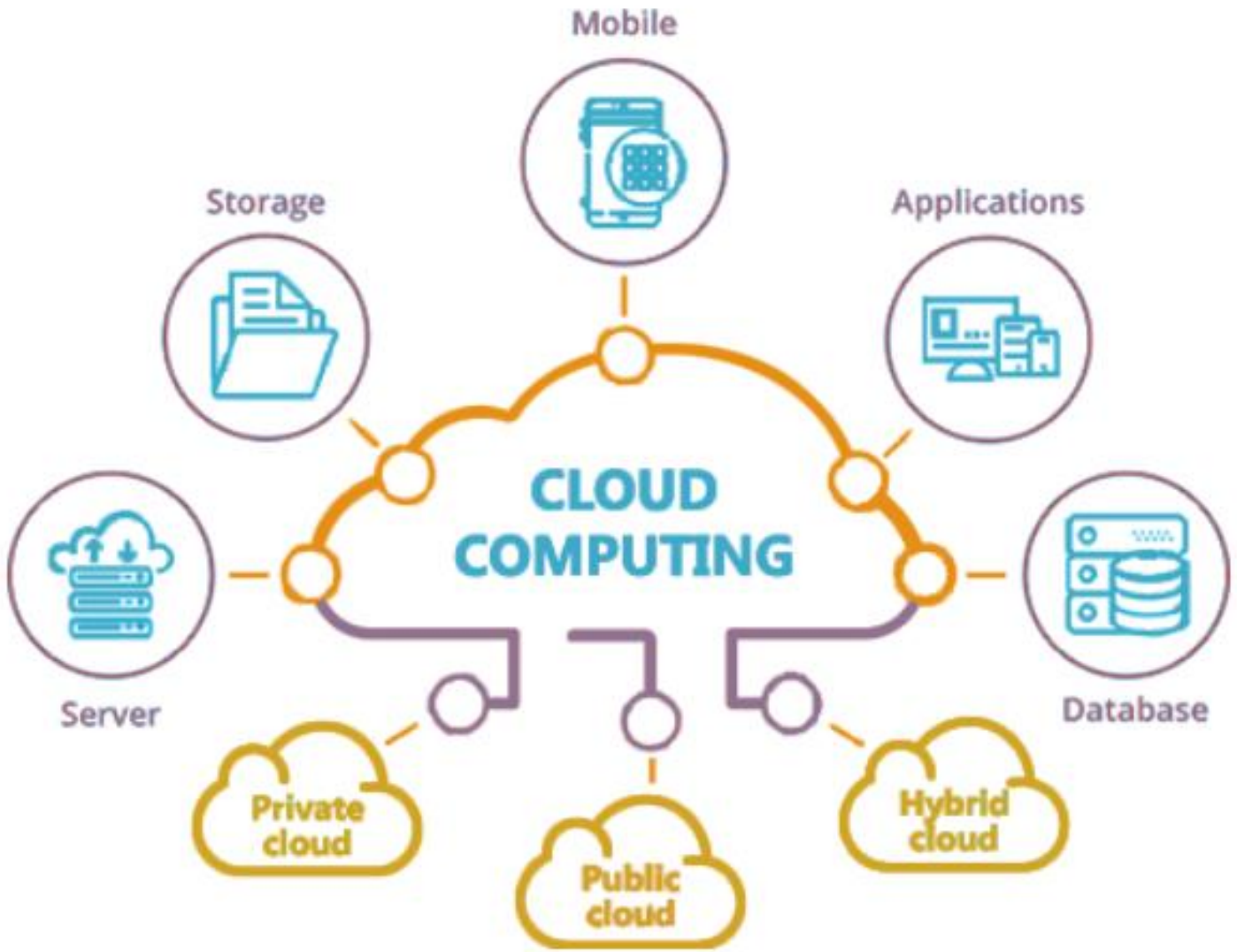
IoT Enabling Technologies

WSN

- The 2.4GHz band is free, unlicensed and available worldwide
- Small, longer lifetime – suitable for deployment in dense and inaccessible area
- Large number of sensor nodes, able to cover large area (mesh network)
- Shares the 2.4GHz band with other technologies such as WLAN, Bluetooth, cordless phone, microwave oven
- Communicate wirelessly
- Operate in 868MHz, 915MHz & 2.4GHz (worldwide)
- Operating at low data rate and low power transmission



IoT Enabling Technologies (Contd..)

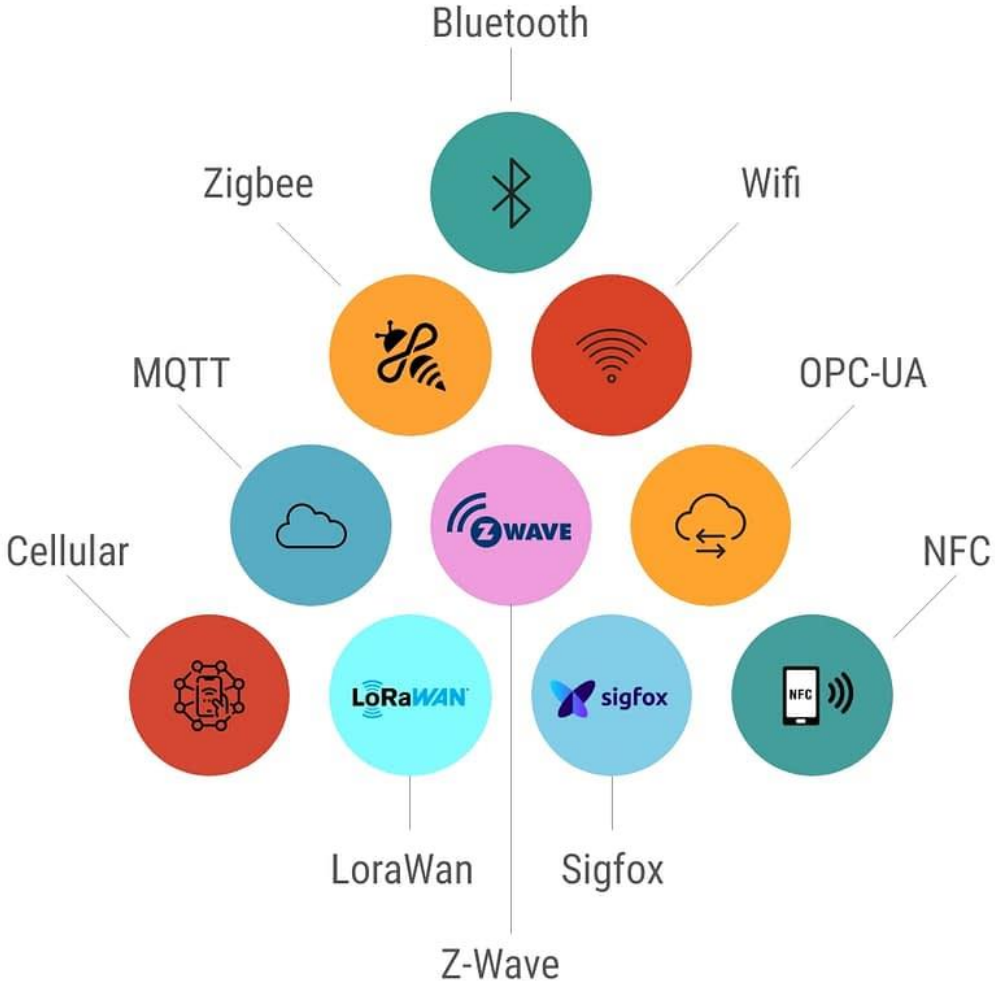


IoT Enabling Technologies (Contd..)

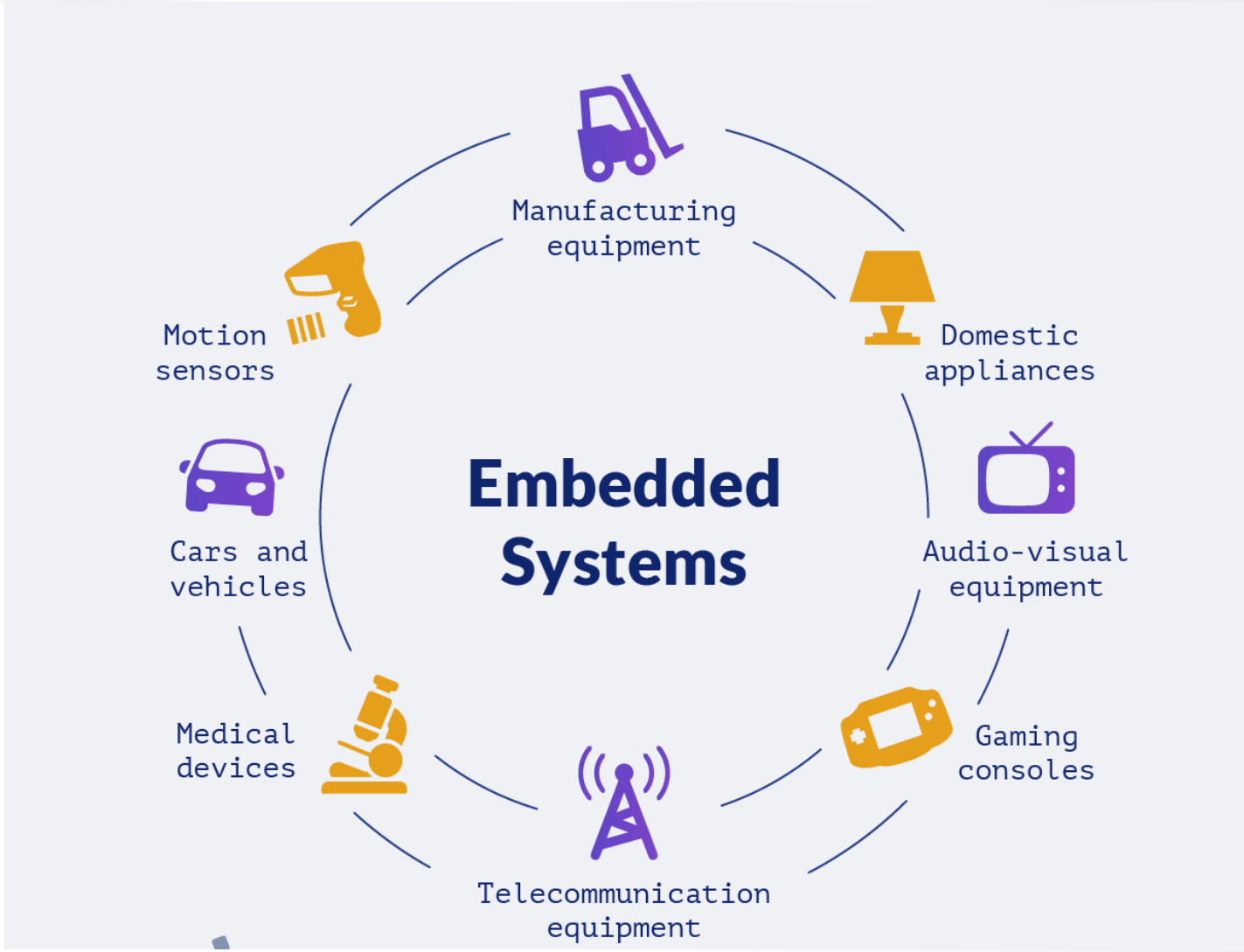
- Volume
- Velocity
- Variety

IoT Enabling Technologies (Contd..)

Communication Protocols



IoT Enabling Technologies (Contd..)



IoT Levels & Deployment Templates

An IoT system comprises of the following components:

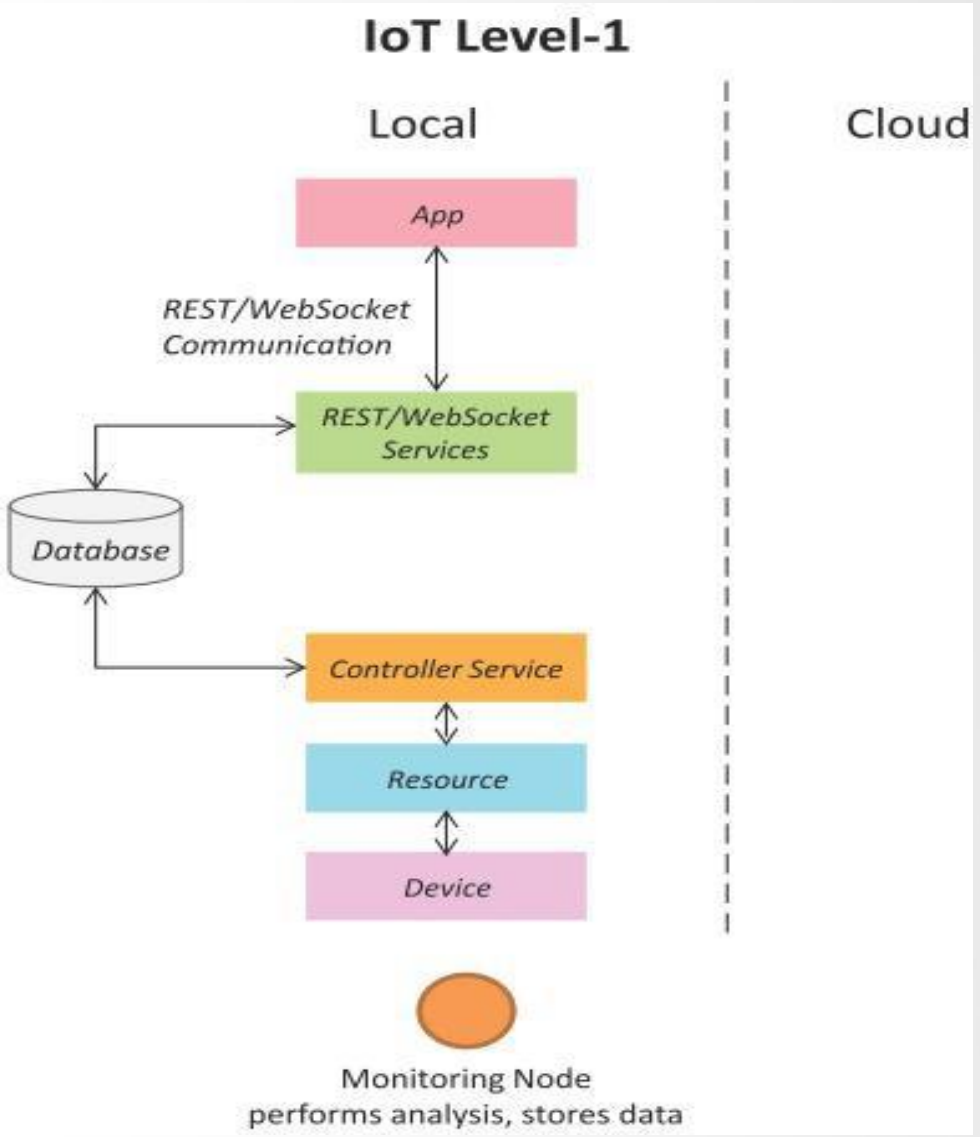
- **Device**: An IoT device allows identification, remote sensing, actuating and remote monitoring capabilities.
- **Resource**: Resources are software components on the IoT device for accessing, processing, and storing sensor information, or controlling actuators connected to the device. Resources also 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 & Deployment Templates(contd..)

- **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 either implemented using HTTP and REST principles (REST service) or using WebSocket protocol (WebSocket service).
- **Analysis Component**: The Analysis Component is responsible for analyzing the IoT data and generate results in a form which are 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 view the processed data.

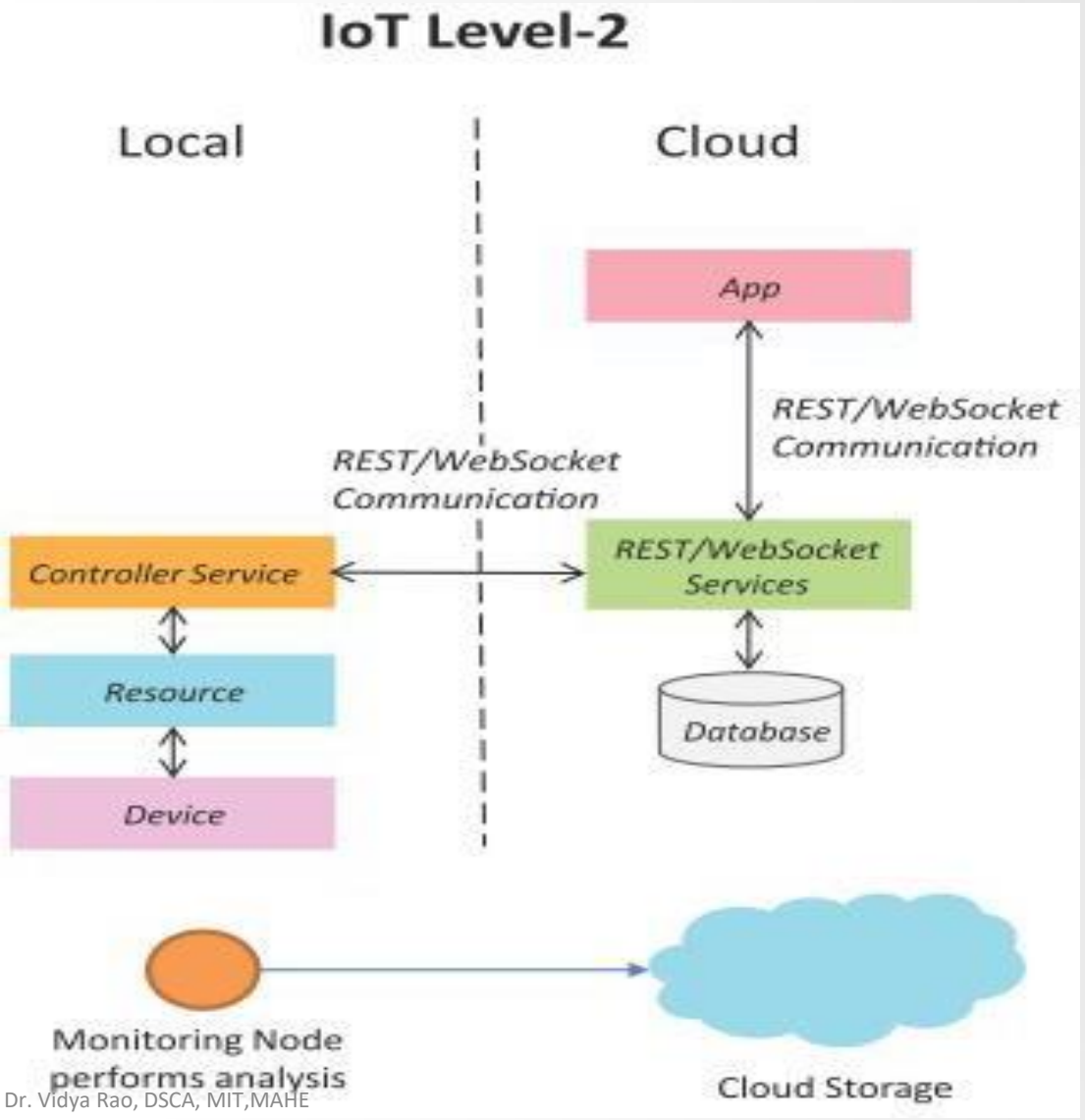
IoT Level-1

- 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 modeling low-cost and low-complexity solutions where the data involved is not big and the analysis requirements are not computationally intensive.



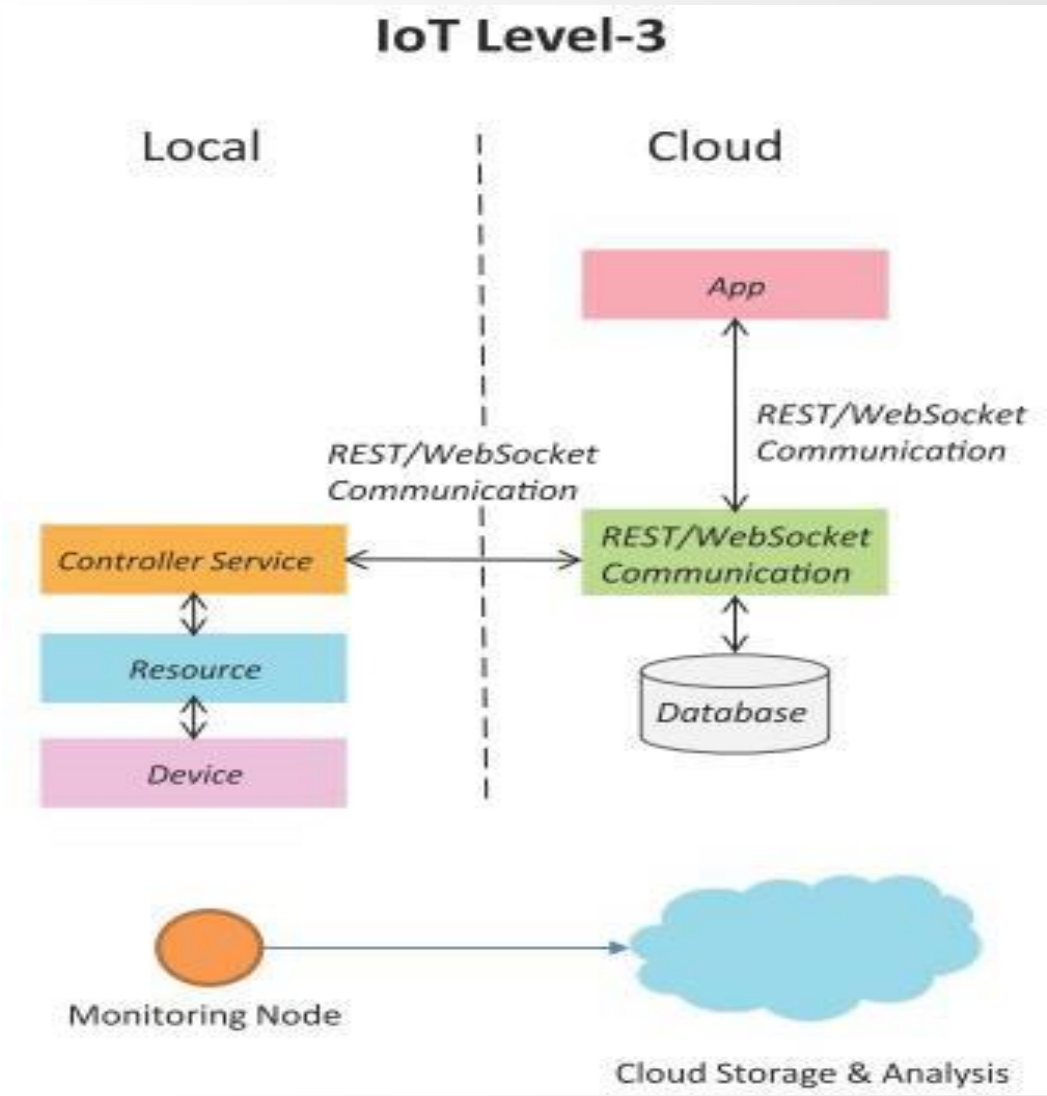
IoT Level-2

- 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 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 itself.



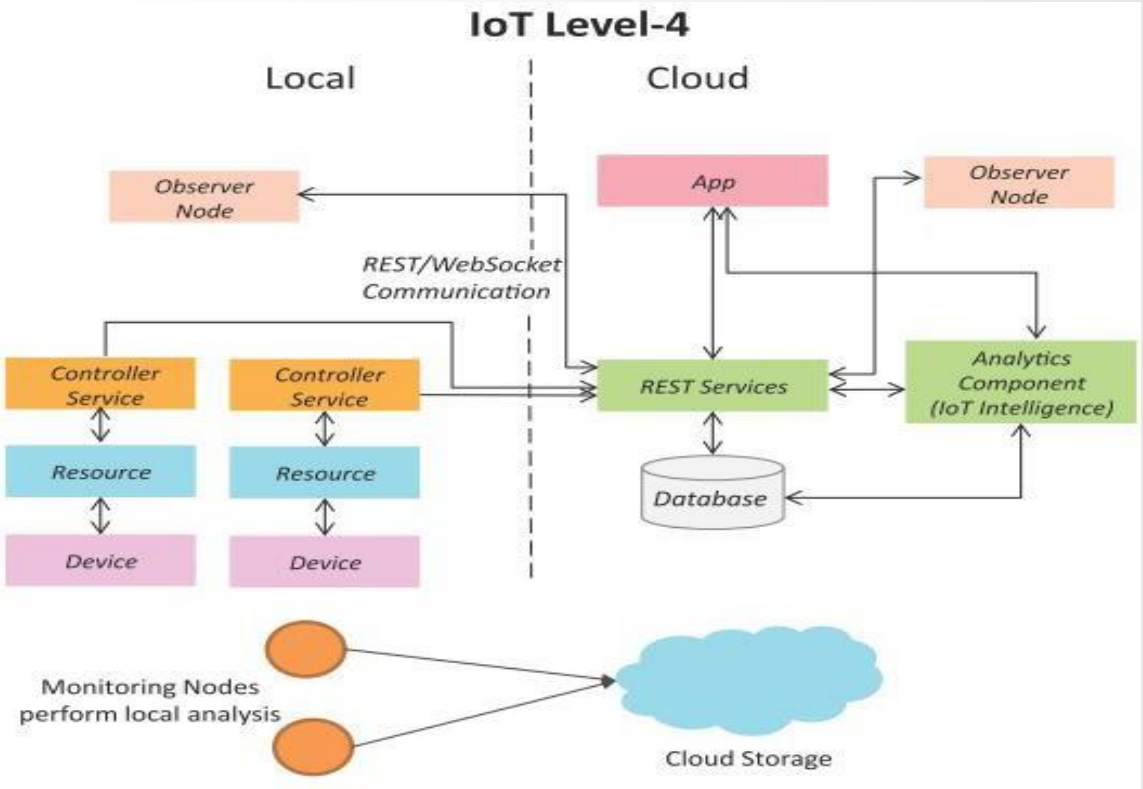
IoT Level-3

- A level-3 IoT system has a single node. Data is stored and analyzed in the cloud and 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.



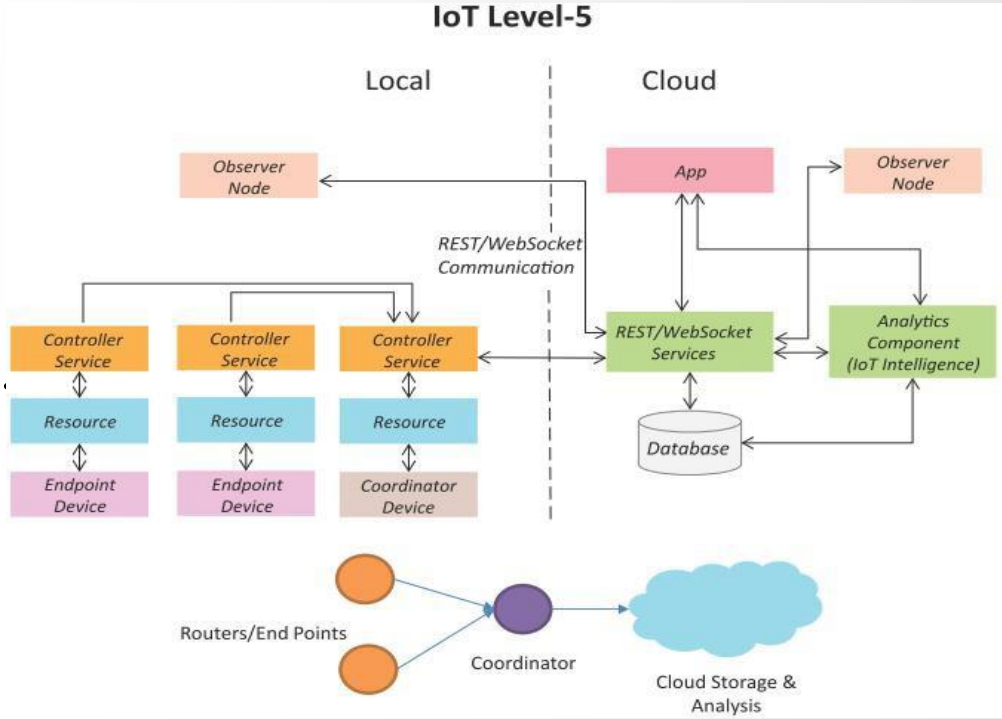
IoT Level-4

- A level-4 IoT system has multiple nodes that perform local analysis. Data is stored in the cloud and 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.



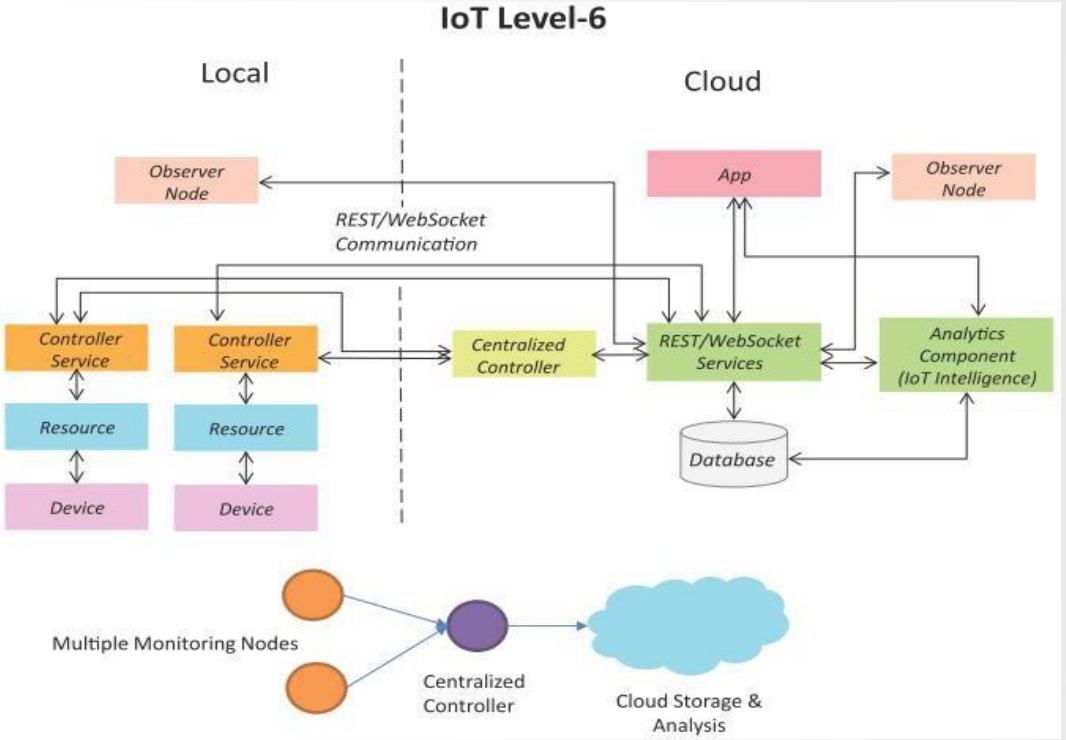
IoT Level-5

- A level-5 IoT system has multiple end nodes and one coordinator node.
- The end nodes that perform sensing and/or actuation.
- Coordinator node collects data from the end nodes and sends to the cloud.
- Data is stored and analyzed in the cloud and 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 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.



Application Domains of IoT