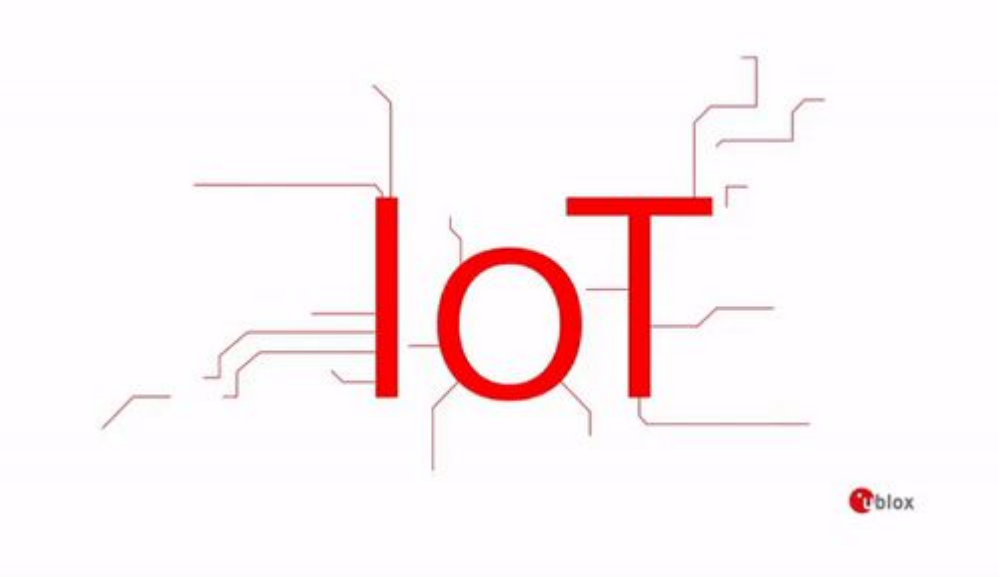
Chapter 1

Introduction to IoT



Outline

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

LETS DEFINE IOT…

"IoT refers to the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data"

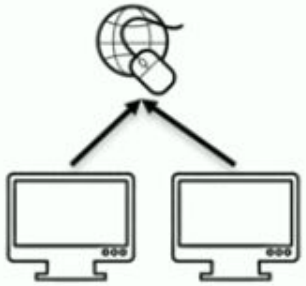
See the term, data!! Data is everything!!!

Definition source: https://wallscope.co.uk/stories/article/internet-things-0

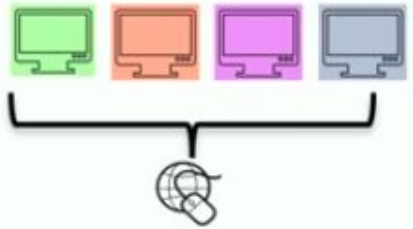
CONTD.,

- SCOPE IS NOT JUST LIMITED TO GETTING THE DEVICES CONNECTED / NETWORKED! IT IS MORE THAN THAT!
- IT IS MORE ABOUT THE EXCHANGE OF MEANINGFUL INFORMATION FROM ONE DEVICE TO ANOTHER TO GET ANOTHER MEANINGFUL ACCOMPLISHMENT. (DATA, IS THE KING / QUEEN)
- BUT, THIS DATA HAS TO BE INTERPRETED CORRECT AND IT NEEDS MANY OTHER **THINGS** COME HAND IN HAND. MANY TECHNOLOGIES TO WORK SIDE BY SIDE.
    - IF YOU JUST GET THE DATA FROM THE SENSORS WITHOUT UNDERSTANDING HOW TO USE OR WHERE TO USE, IT IS USELESS! HENCE, INTERPRETATION MATTERS A LOT!!
- **IOT IS NOT ANY ONE TECHNOLOGY! IT IS COLLECTION OF TECHNOLOGIES AND DOMAIN KNOWLEDGE!**
- **A MECHANICAL ENGINEER HAS TO WORK WITH ELECTRICAL ENGINEER AND CS ENGINEER FOR A COMPLETE IOT PRODUCT!**

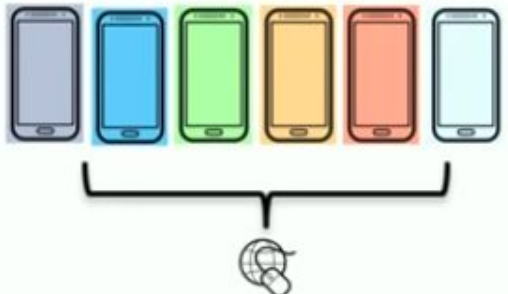
IT IS TIME TO UNDERSTAND HOW INTERNET HAS OCCUPIED OUR LIFE …



- REPORTS SUGGEST IT ALL STARTED IN 1900
  - 300,000 DESKTOP COMPUTERS WERE CONNECTED TO THE INTERNET.
- IN 2000, IT GREW TO 300 + MILLION DESKTOP COMPUTERS (LAPTOP TOO) CONNECTED TO INTERNET.



- IN 2016 (YOU GUYS CAN TELL THIS!!) – ABOUT 2.5 BILLION MOBILE PHONES ARE CONNECTED TO INTERNET!



CONTD.,
YES, IMPOSSIBLE IS NOTHING WITH IOT!

- WHEN YOU WAKE UP, THE WATER HEATER WOULD HAVE THE HOT WATER READY!
- DURING BATH, THE KETTLE WOULD HAVE COOKED YOUR FOOD, CONSUME AFTER BATH!
- WHEN YOU LOCK THE DOOR, THE CAR DOORS SHALL BE OPEN FOR YOU!
- A/C SHALL ADJUSTED BASED ON YOUR BODY TEMPERATURE.
- PARKING SLOTS SHALL BE INFORMED WHILE NEARING THE OFFICE.
- PILL BOX SHALL ALERT YOU THE TIME OF YOUR TABLET INTAKE!
- WHILE NEARING HOME, THE LIGHTS SHALL BE ON!
- YOUR WORKOUT ROOM LIGHTS/AMBIENCE SHALL BE SET. HEART BEAT/KM ALERT SHALL BE UPDATED!
- REFRIGERATOR SHALL ORDER MILK/EGG ON NEED.
- BED ROOM AC SHALL BE AUTOMATICALLY SWITCHED ON FOR YOU TO SLEEP.

SO, WHAT IOT IS?

Any time – Any device

Anyone

Any service / Any business

Any Network (Non homogenous)

Anywhere / Any location

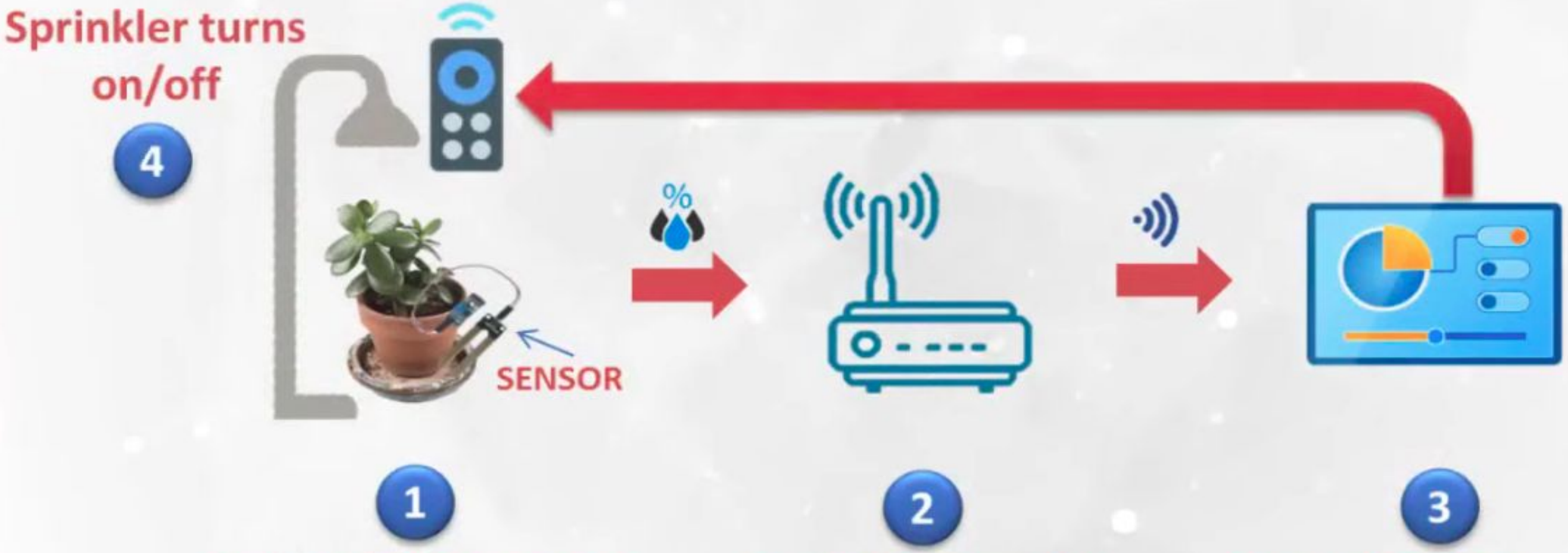
IoT enables the objects (which eventually are the things) to be sensed, while also controlling it remotely, which enables better interaction of physical world to the computers. This would improve the efficiency, accuracy with limited human intervention.

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.

Internet Of Things (IOT)

Taking everyday things, embedding them with electronics, software, sensors and then connecting them to internet and enabling them to collect and exchange data without human intervention is called as the Internet of Things (IoT)



SIMPLY CODING

IOT in Hindi

History Of IOT

1982 — Carnegie Mellon researchers connect a vending machine to Internet to remotely check for cold sodas

1990 — 1990 the first toaster was operated over the net

1999 — Term "The Internet of Things" (IoT) was coined by Kevin Ashton

2000 — LG introduce first smart fridge

2004 — First smart watch introduced

2007 — Apple smart iPhone and wearable Fitbit released

2009 — Google starts testing self-driven cars

2011 — Smart TV is introduced

2013 — Google Lens is released

2014 — Echo causes a surge in Smart Home Market

2015 — Tesla comes out with Auto Pilot drive for their cars

2:59 / 12:06

SIMPLY CODING

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.

CHARACTERISTICS OF IOT

1. **CONNECTIVITY** -- THINGS IN IOT SHOULD BE CONNECTED TO THE INFRASTRUCTURE AND CONNECTIVITY IS AN IMPORTANT CHARACTER/REQUIREMENT FOR AN IOT INFRA. ANYONE, ANYWHERE, ANYTIME – CONNECTIVITY SHOULD BE GUARANTEED IN THE IOT INFRA. WITHOUT CONNECTION, NOTHING MAKES SENSE! (I SAY THAT, THINGS ARE CONNECTED AND THEY NEED CONNECTIVITY)
2. **INTELLIGENCE AND IDENTITY** – THE EXTRACTION OF KNOWLEDGE (I.E. WHAT IS TO BE INFERENCED) FROM THE GENERATED DATA IS VERY IMPORTANT. SENSORS GENERATE DATA, THE DATA IS TO BE INTERPRETED PROPERLY! EACH IOT DEVICE HAS AN UNIQUE IDENTITY (REMEMBER IP ADDRESS). THIS IDENTITY IS HELPFUL IN TRACKING THE EQUIPMENT AND AT TIMES TO QUERY THE STATUS.
3. **SCALABILITY** – THE NUMBER OF THINGS (DEVICES) GETTING CONNECTED TO IOT INFRA IS GETTING INCREASED DAY BY DAY. HENCE, AN IOT SETUP SHALL BE CAPABLE TO HANDLE THE MASSIVE EXPANSION. ALSO, THE DATA GENERATED SHALL BE MASSIVE AND IT SHOULD BE HANDLED APPROPRIATELY.
4. **DYNAMIC AND SELF ADAPTING (COMPLEXITY)** – THE IOT DEVICES SHOULD DYNAMICALLY ADAPT ITSELF TO THE CHANGING CONTEXTS. ASSUME A CAMERA MEANT FOR SURVEILLANCE. IT MAY HAVE TO WORK IN DIFFERENT CONDITIONS AS DIFFERENT LIGHT SITUATIONS (MORNING, AFTERNOON, NIGHT)
5. **ARCHITECTURE** – ARCHITECTURE CANNOT BE HOMOGENEOUS IN NATURE. IT SHOULD BE HYBRID, SUPPORTING DIFFERENT MANUFACTURER'S PRODUCT TO BE IN THE IOT NETWORK.
6. **SAFETY** - HAVING GOT ALL THE THINGS CONNECTED TO INTERNET, THE PERSONAL DATA (IF SENSITIVE) IS UNDER THREAT. HENCE, SECURING THE DATA IS A MAJOR CHALLENGE . NOT ONLY DATA SECURITY, THE EQUIPMENT GETTING INVOLVED IN IOT NETWORK IS HUGE. HENCE, PERSONA SAFETY IS ALSO TO BE CONSIDERED. PRIVACY WITH PROTECTION! ☺

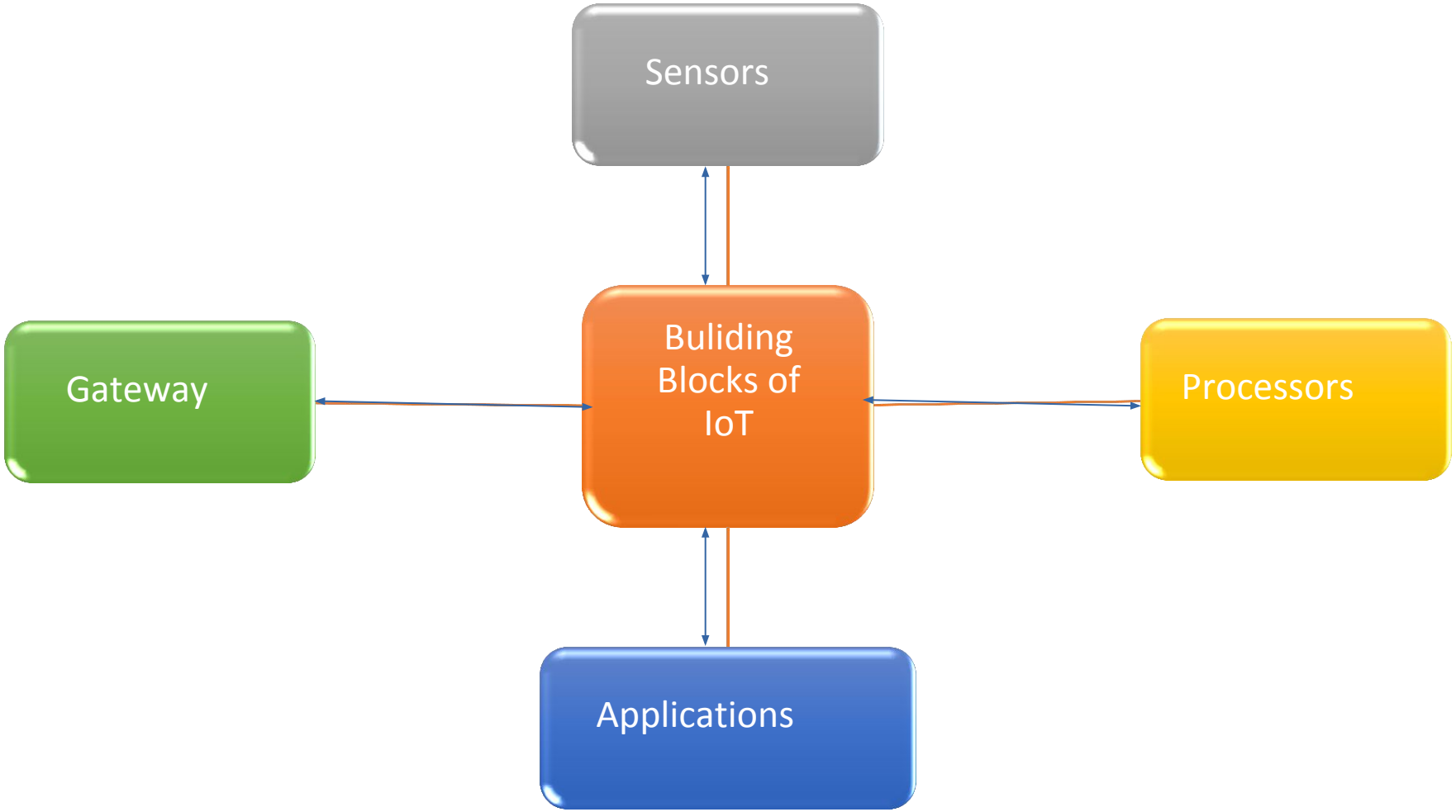
May 2020

- Q. 2 b) Why do IoT systems have to be self-adapting and self-configuring? [2]

URL

- https://www.youtube.com/watch?v=HI6XAHeX9y0

Building Blocks of IoT



Building Blocks of IoT .....Sensors

- Sensors arethefront end of theIoTdevices. They really mean "things" in IoT.
- Their main task is to get necessary data from surroundings and pass it further to database or processing systems.
- They must be uniquely findable from there IP address because they are basic front end interface in the large network of other devices.
- Sensors collect real time data and can either work autonomous or can be user controlled.
- Examples of sensors are: gassensor, water quality sensor, moisture sensor, etc.

Sensors

A sensor is a device that measures physical input from its environment and converts it into data that can be interpreted by a computer.


Touch


Speed


Motion


Position


Light


Levels


Sound


Vibration


Chemical


Moisture


Heat


Gas


Color


Flow


Pressure


Leaks


Smoke

SIMPLY CODING

Sensors

A sensor is a device that measures physical input from its environment and converts it into data that can be interpreted by a computer.

Touch
Speed
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Sound
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Moisture
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Gas
Color
Flow
Pressure
Leaks

Sensor With Microprocessor

Building Blocks of IoT ……Processors

- Processors are the brain of the IoT system.
- The main job of processors it to process raw data collected by the sensors and **transforms** them **to some meaningful information** and knowledge. In short, we can say that its job is to **give intelligence to the data.**
- Processors are easily controllable by applications and their one more important job is **to securing data**. They perform encryption and decryption of data.
- Microcontroller, embedded hardware devices, etc can process the data using processors attached within the devices.

Data Processing

In the processing stage, a computer transforms the raw data into information. The transformation is carried out by using different data manipulation techniques

Data Aggregation

Data Extraction

Data Classification

Data Analytics

Example: Show trend of rain and underwater depletion

Building Blocks of IoT …..Gateways

- Main task of gateways is to route the processed data and transfer it to proper databases or network storage for proper utilization.
- In other words, gateway helps in communication of thedata.
- Communication system and network connectivity areessentials for IoT

Examples of gateways are LAN, WAN, PAN, etc.

Connectivity

Several Communication Protocols and Technologies are used in IOT to connect to Internet cloud. Depending upon Range, Cost, Power usage, Data rate etc. the right one is used.

Building Blocks of IoT …..Applications

- Applications are another end of an IoT system. Applications **do proper utilization of all the data collected and provide interface to users to interact with that data.** These applications could be cloud based applications which are responsible for rendering data collected. Applications are user controllable and are delivery points of particular services.
- Examples of applications are: **smart home apps, security system control applications, industrial control hub applications, etc.**

User Interface

The information processed is made available to the end-user in some way, like giving Alerts, Notifications, monitoring continuous feed or controlling the system remotely

Alerts

Notifications

Live Trends

Remote Control

May 2020

- Q. 2c) Explain the steps involved in the IoT system design methodology.
- Q. 1b) With the help of diagram explain IOT functional blocks. Dec 2018
- Q 2a) List and explain different components of an IOT system. Dec 2018

PROS and CONS of IOT

Advantages	Disadvantages
• **Minimize human effort** and save time • Lead to more **automation** and technical optimization • Help in **improving the technology** • Help us to **reduce waste** and use our natural resources effectively	• **Security** of Confidential Data is a key concern • Can lead to various types of **network attacks** • Maintaining **privacy** is a challenge

Application of IOT

- Crop Monitoring
- Soil & Water Management

- SMART IDs
- SMART Board

- SMART Supply Chain
- Industrial Automation

Healthcare

SMART Homes

Retail

Agriculture

Education

Industries

- Bio Sensors
- Wearable Devices

- Centralized Monitoring
- Smart Switches

- Smart Shelves
- Digital Signage

SIMPLY CODING

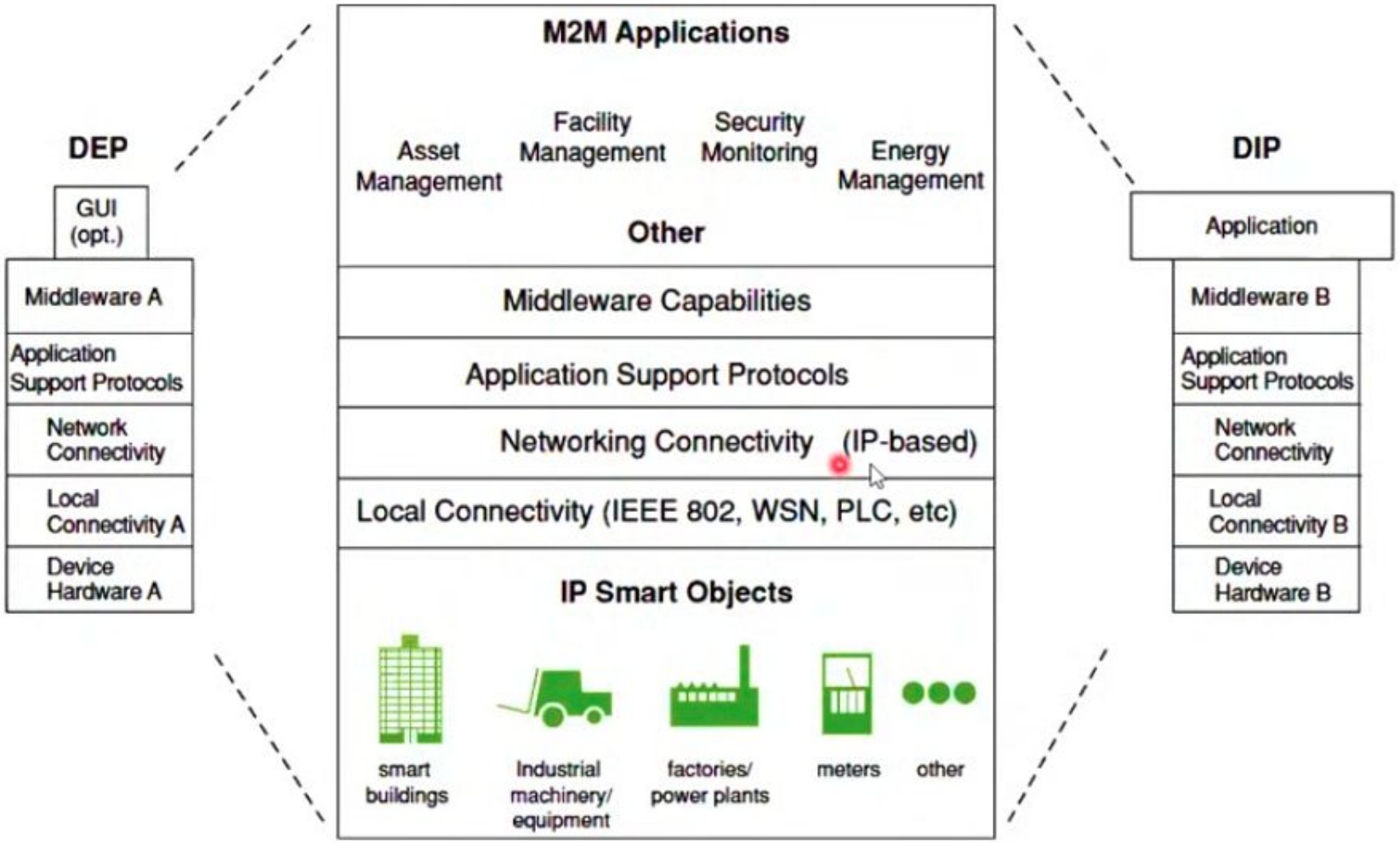
Things in IoT

- 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.

Basic Nodal Capabilities

- Remote device generally needs to have a basic protocol stack
- Basic protocol stack supports as minimum local connectivity and networking connectivity
- In addition, some higher layer application support protocols are generally needed

Basic Nodal Capabilities



Basic Protocol Stack

Basic Nodal Capabilities

- IoT devices may have capability differences such as but not limited to
  - Maximum Transmission Unit (MTU) Differences
  - COAP/UDP versus HTTP/TCP
  - Single Stack Versus Dual Stack
  - Sleep Schedule
  - Security Protocols
  - Processing and Communication Bandwidth

Basic Nodal Capabilities

- Typical requirements include following capabilities
  - Retransmission
    - Network recovers from packet loss or inform application
    - Recovery is immediate
  - Network independent of MAC/PHY
  - Scale
    - Thousands of nodes
    - Multiple link speeds

Basic Nodal Capabilities

- Typical requirements include following capabilities
  - Multicast
    - Throughout network
    - Reliable (Positive Ack)
  - Emergency messages
    - Routed and/or queued around other traffic
    - Other traffic slushed as delivered
  - Network and application versioning

Basic Nodal Capabilities

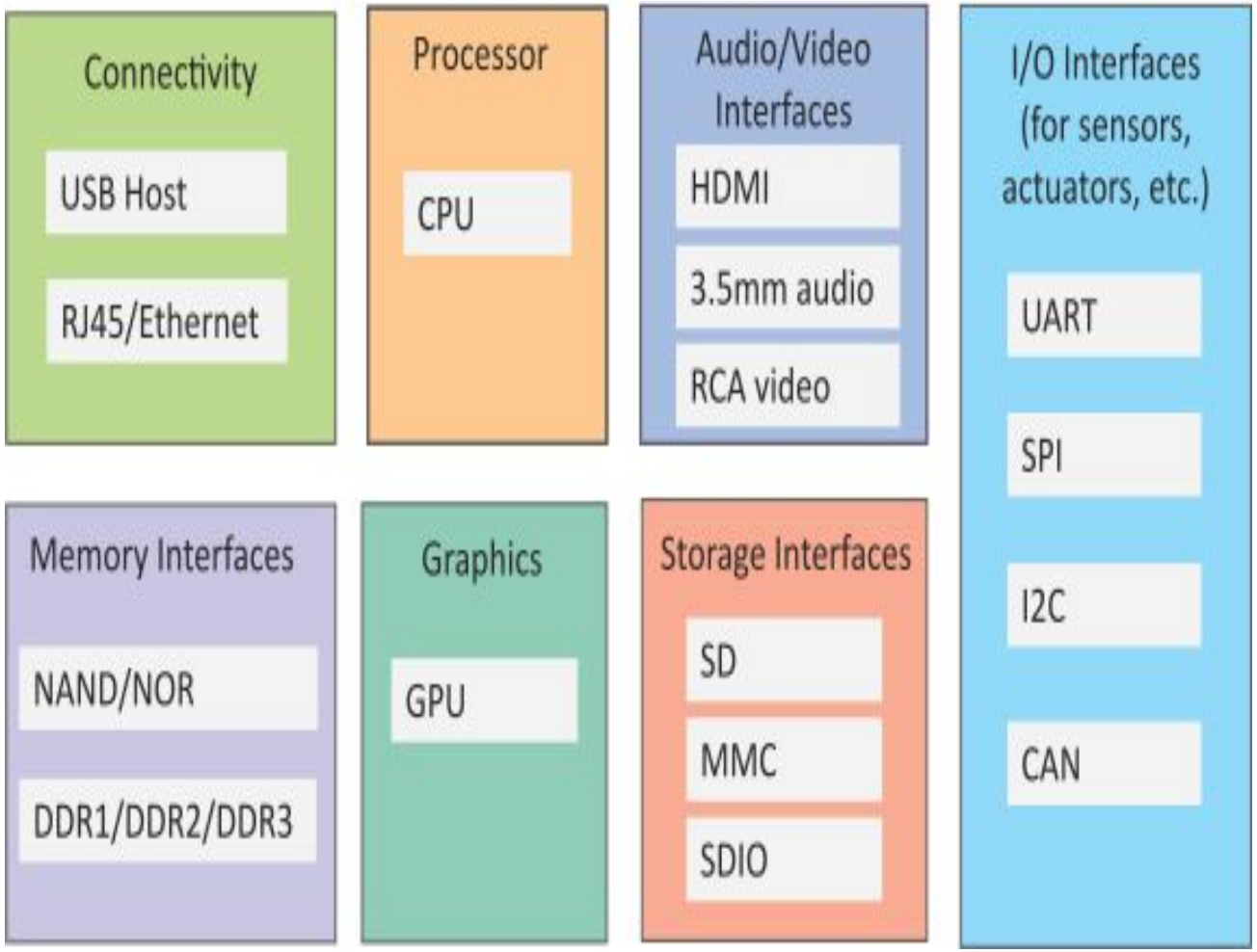
- Typical requirements include following capabilities
  - Polling of nodes
    - Sequential
    - Independent of responses
  - Security
    - Strong encryption
    - Mutual authentication
    - Protection against record/playback attacks
    - Suite B ciphers

Mar 2019

- Q.1 a) Draw and explain block diagram of an IoT device. [4]

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



https://www.youtube.com/watch?v=RurGHVOmuOM

Physical Design: IoT Protocols

- The "Things" in IoT usually refers to IoT devices which have unique identities
- They can perform remote sensing, actuating and monitoring capabilities
- IoT devices can:
  - Exchange data with other connected devices and applications
  - Collect data from other devices and process the data locally

Physical Design: IoT Protocols

- IoT devices can:
  - Send the data to centralized servers or cloud-based application back-ends for processing
  - Perform some tasks locally and other tasks within the IoT infrastructure

IoT Protocols

- **Link Layer**

802.3 – Ethernet
802.11 – WiFi
802.16 – WiMax
802.15.4 – LR-WPAN
2G/3G/4G

Network/Internet Layer

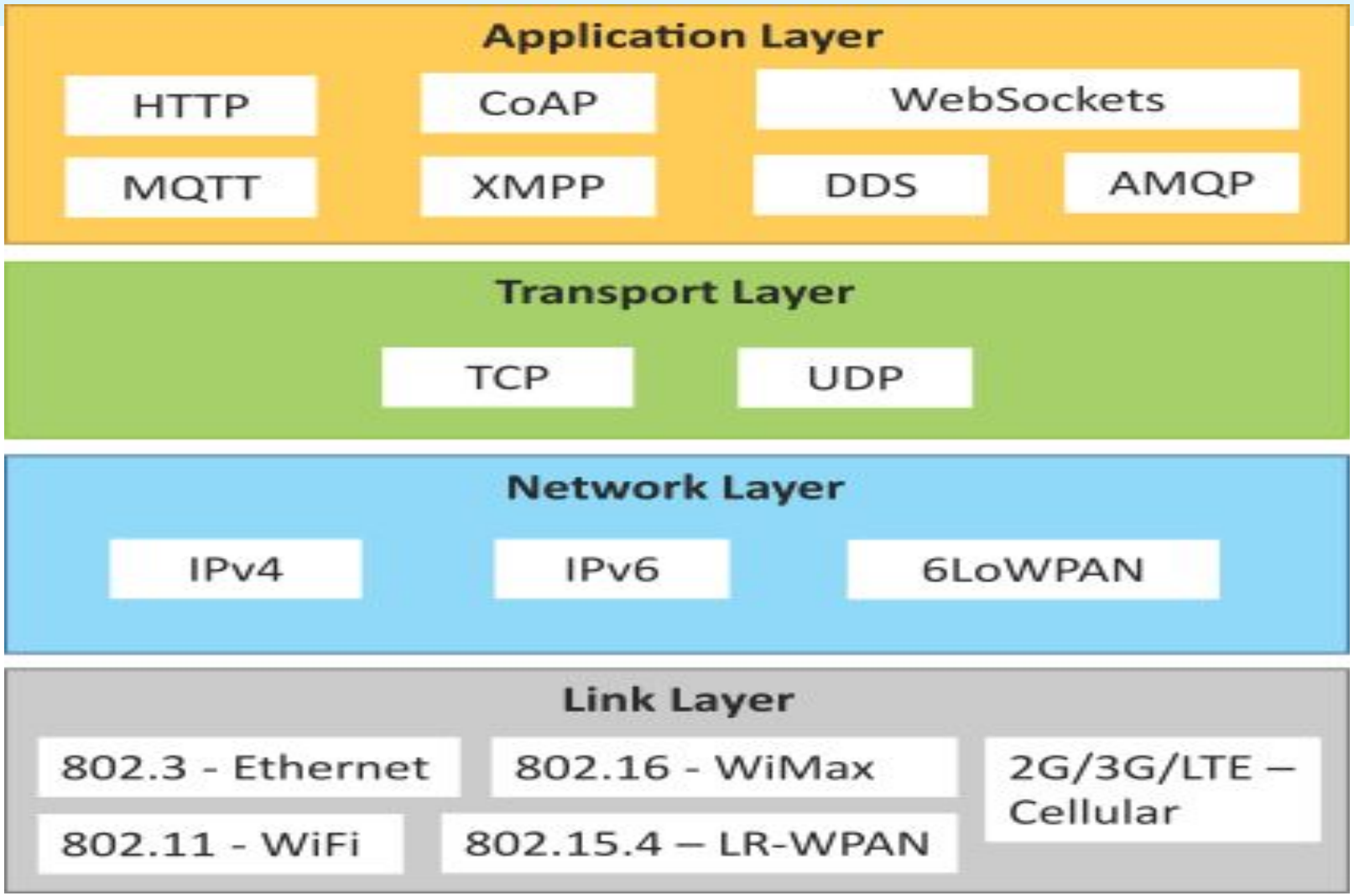
IPv4, IPv6, 6LoWPAN

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

Parameter	EtherNet	WiFi	WiMax	LR-WPAN(ZigBee)	Cellular
Used	Inside offices and houses	Outside offices and houses	Outside offices and houses	Outside offices and houses	Outside offices and houses
IEEE Standards:	802.3	802.11	802.16	802.15.4	
Range	100mtrs	100 mrts	80-90kms	10-100 mtrs	1-5kms
Data Transfer Rate	10Mbps-100Mbps	54Mbps	40Mbps	250kbit/s	100Kbps-1MBps
Application	Houses, Offices, Industries	Mobile Applications, **Video Conferencing**	MetroPolitan Area Network	Smart Metering, Home Automation (Alexa), Smart Asset Tracking	Camera on Traffic Light, Video on Demand

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 mo
- 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

Mar 2020

- Q. 2b) Compare the REST and Web Socket protocol.

REST Vs Web Socket protocol

REST	Web Socket
It is a software architectural style that defines a set of constraints used for creating Web services	It provides a point-to-point communication system
It allows no client context data stored on the server due to its Stateless property	These are persistent, meaning Stateful
Higher cost of communication	Extremely cost-effective
Using HTTP mode to relay data as it is based on HTTP protocol	IP address & Port number are required for data flow.
It received multiple timely responded requests.	Very quick, having real-time chat application.
it exhibits resource-based behavior.	Socket-based Behavior

PORT and SOCKET

- Socket and Protocols are the words one would read often while navigating the immense information available, hence defining them is also necessary.

- The **socket** is a “port” through which data goes in and out of.
- **Protocols** determine how to interpret the data transfer between the socket and the machines that are communicating with each other.

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.

Mar 2019

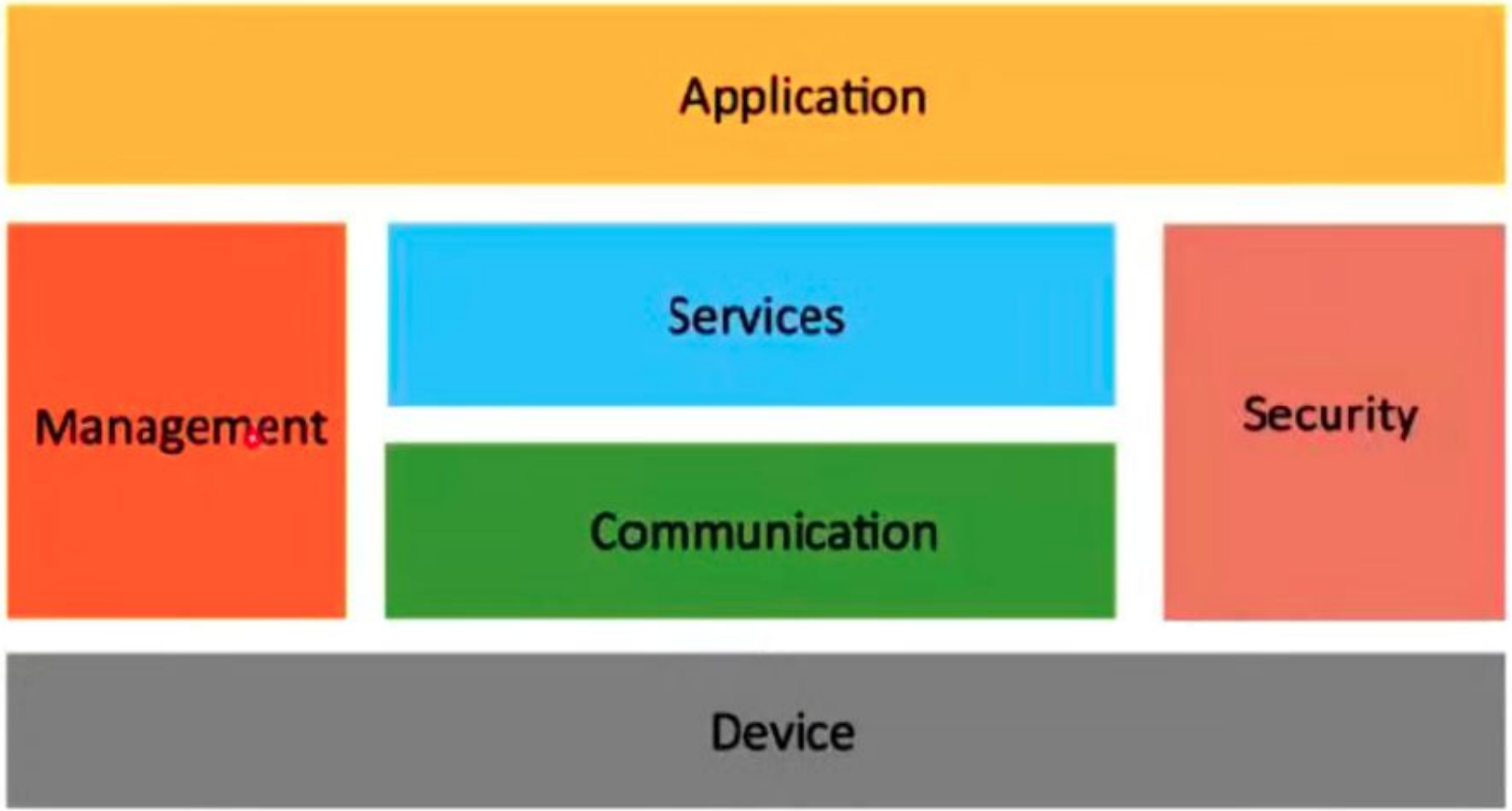
- Q.2 b) List different IoT Protocols. 2M

Parameter	HTTP	CoAP	XMPP(Ope n XML)	DDS	AMQP	MQTT
Protocol	TCP	UDP	TCP	TCP and UDP	TCP	TCP
Network Layer	IP	6LowPAN	IP	IP	IP	IP
Architecture	Client- Server	Client- Server and Publish-Subscribe	Client- Server and Publish-Subscribe	Publish-Subscribe	Client- Server	Publish-Subscribe
Synchroni zation	Needed	No Need	Needed	Sometimes Needed, Sometimes Not	Needed	Needed
Designed for	Internet	IoT/M2M	IoT/M2M	Real Time SYstems	M2M	IoT/M2M
Application	WWW	Retrieving Sensor Data	WhatsApp, Gaming, Google Talk	Volswagen Smart Cars for Video Assistance	Google Cloud	Facebook Messenger

Logical Design of 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

Logical Design of IoT: Functional Block

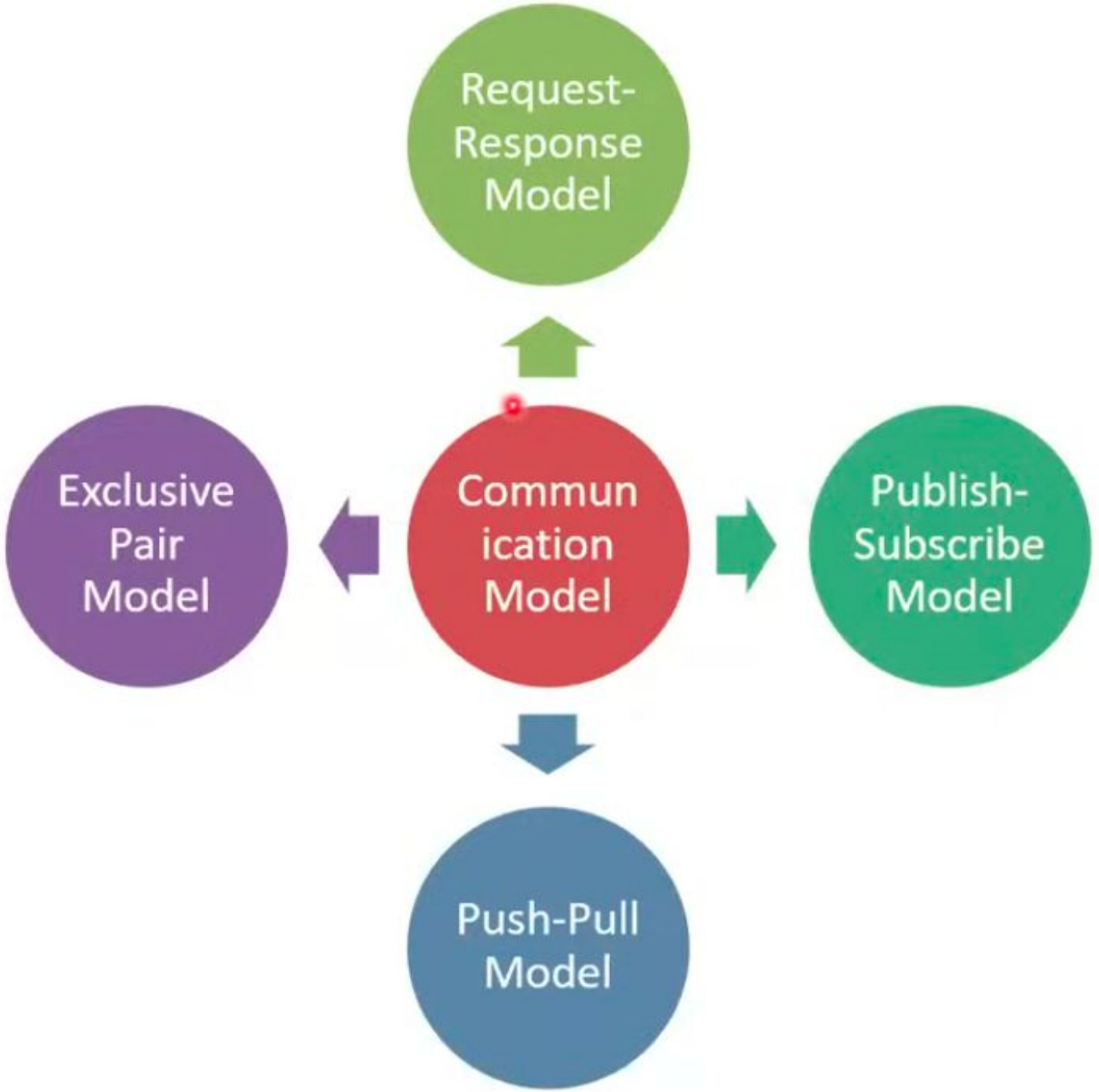


Logical Design of IoT

- 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

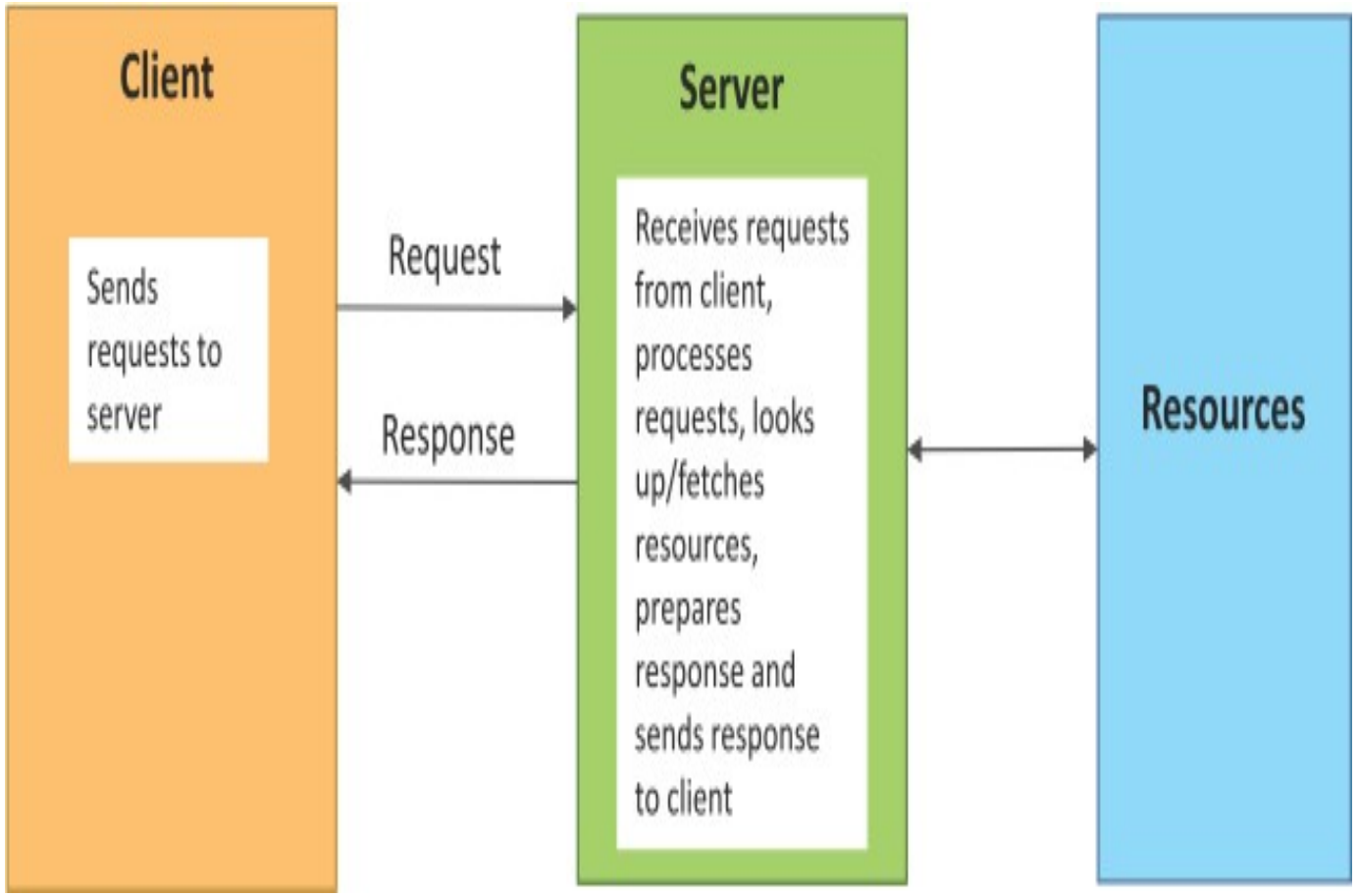
Communication Models

https://www.youtube.com/watch?v=hdJhFYS73Ig


Request-Response Model
Exclusive Pair Model
Communication Model
Publish-Subscribe Model
Push-Pull Model

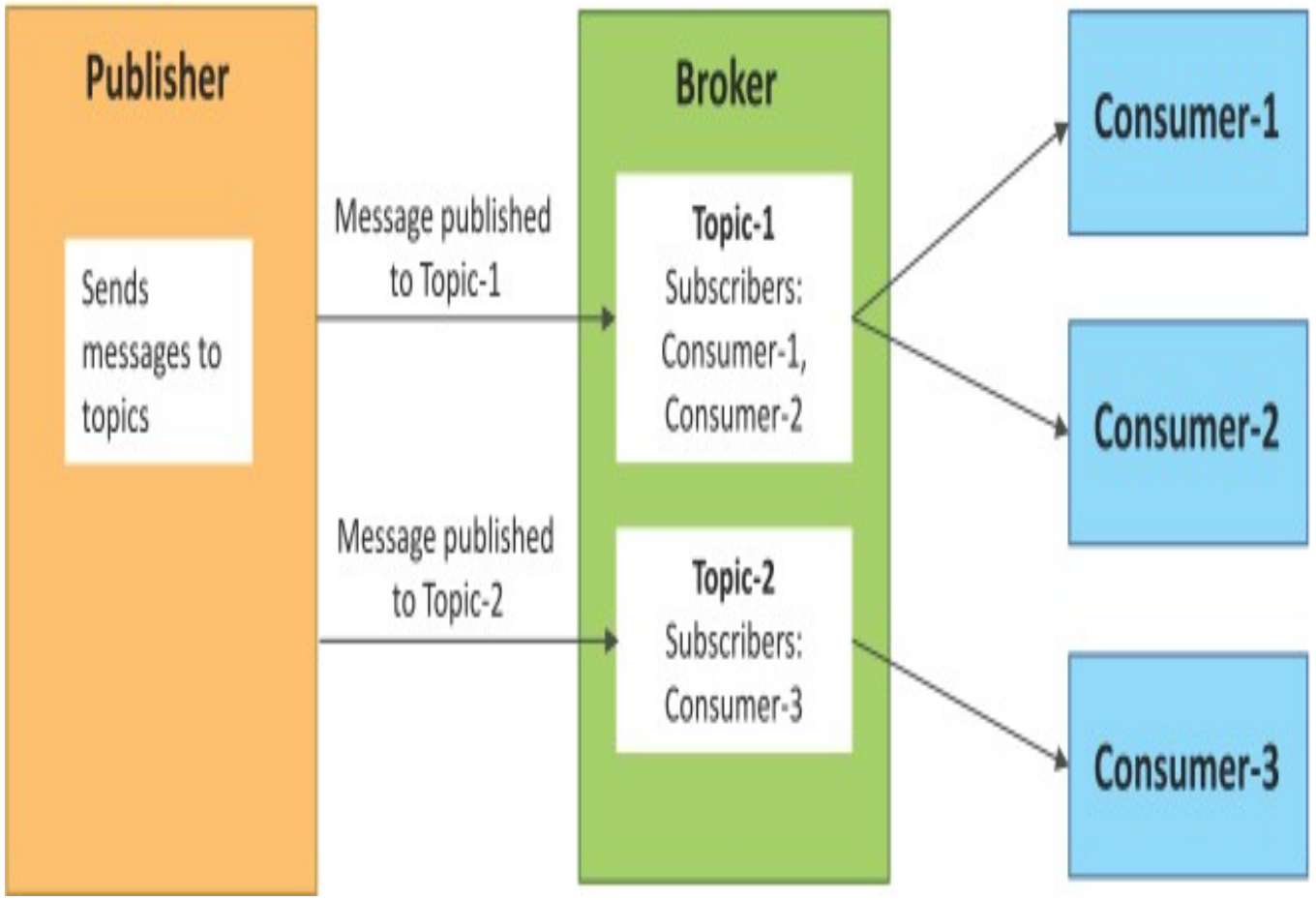
Request–Response Communication Model

- 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.
- It is 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.

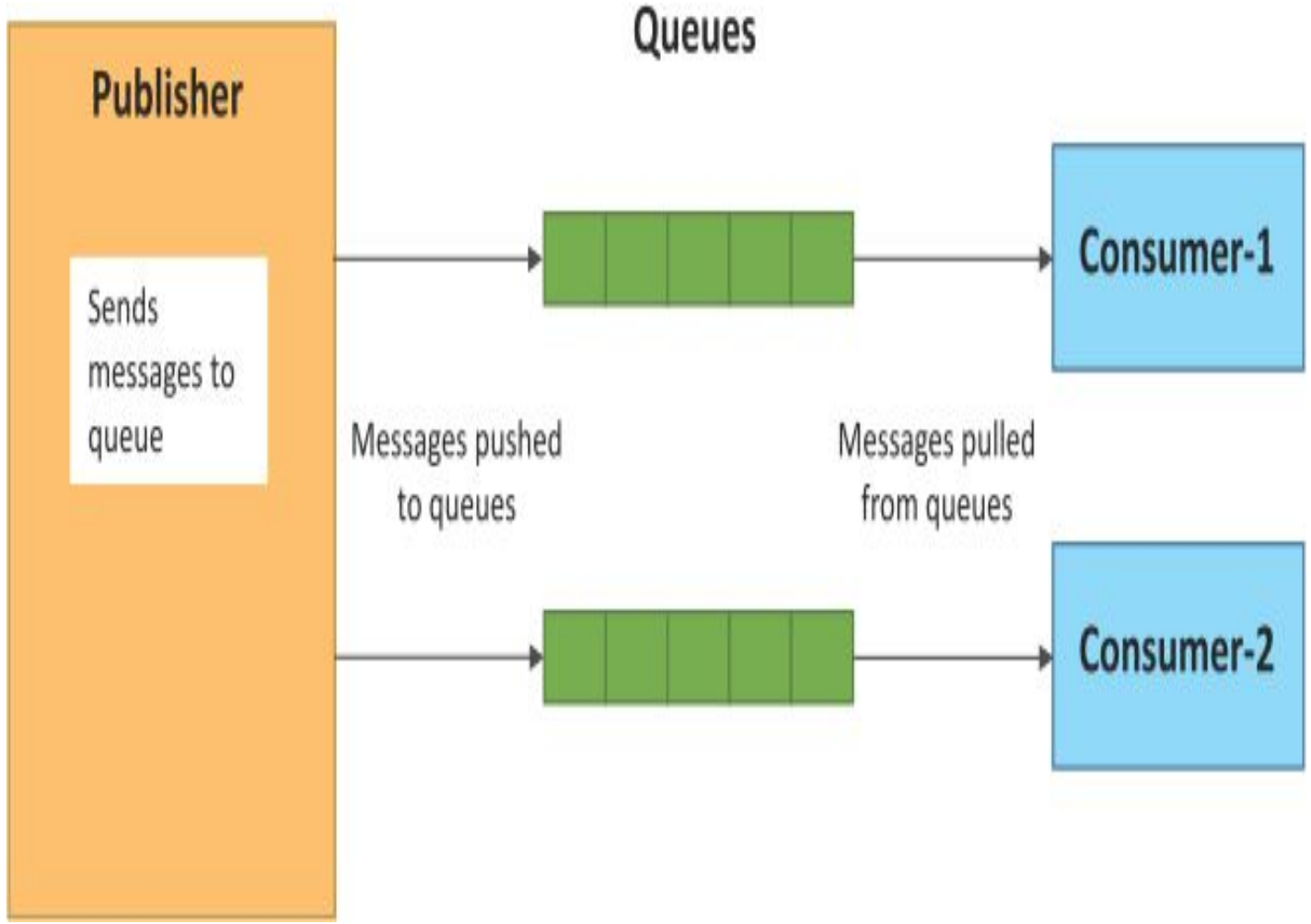


Mar 2020

- Q. 1b) Explain the Publish-Subscribe Communication Model with diagram.[5]

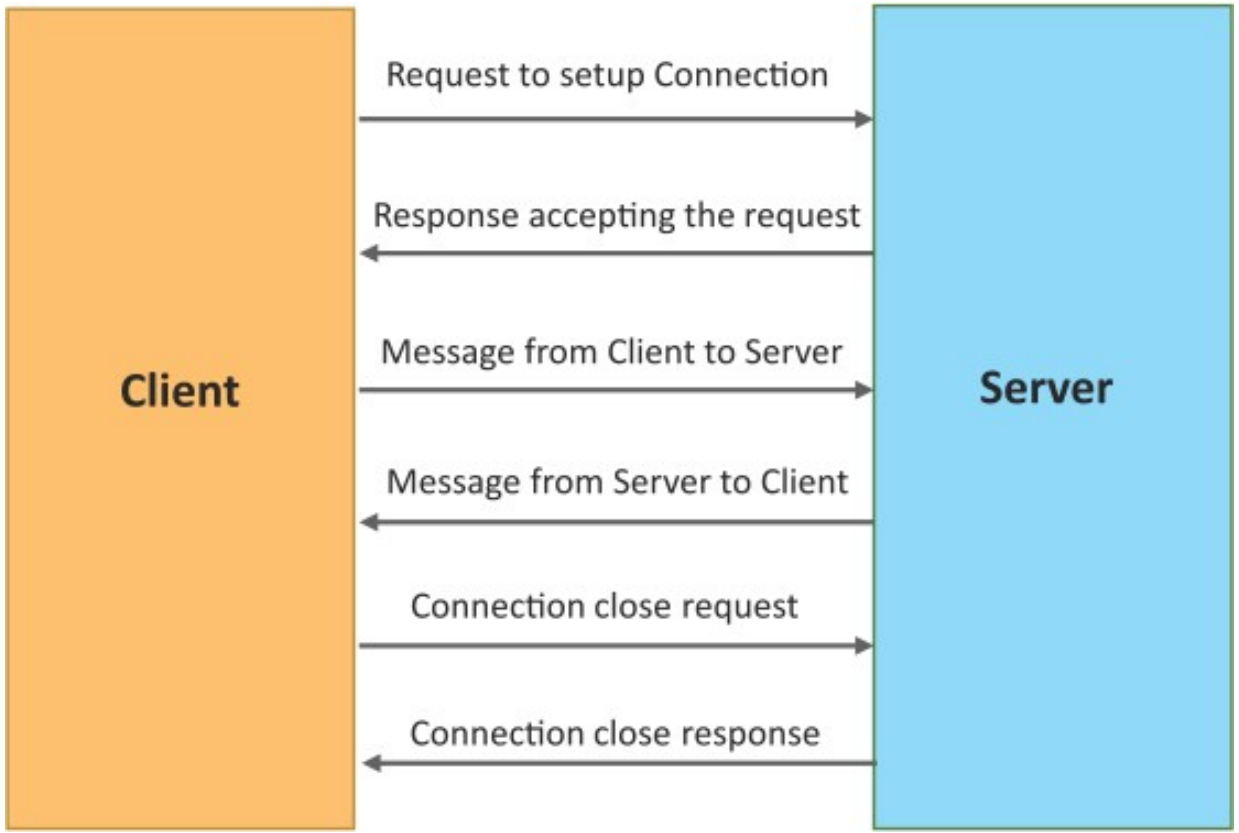
Push–Pull Communication Model

- 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.



Mar 2018

- Q. 2b) List various IoT communication models [2]

Communication APIs

https://www.youtube.com/watch?v=iuPT3rjzKHs

Communication APIs

REST-based Communication APIs

- Follows request response communication model
- Applies to components, connectors and data elements

WebSocket-based Communication APIs

- Bidirectional communication between clients and servers
- Follows exclusive pair communication model

REST-based Communication APIs

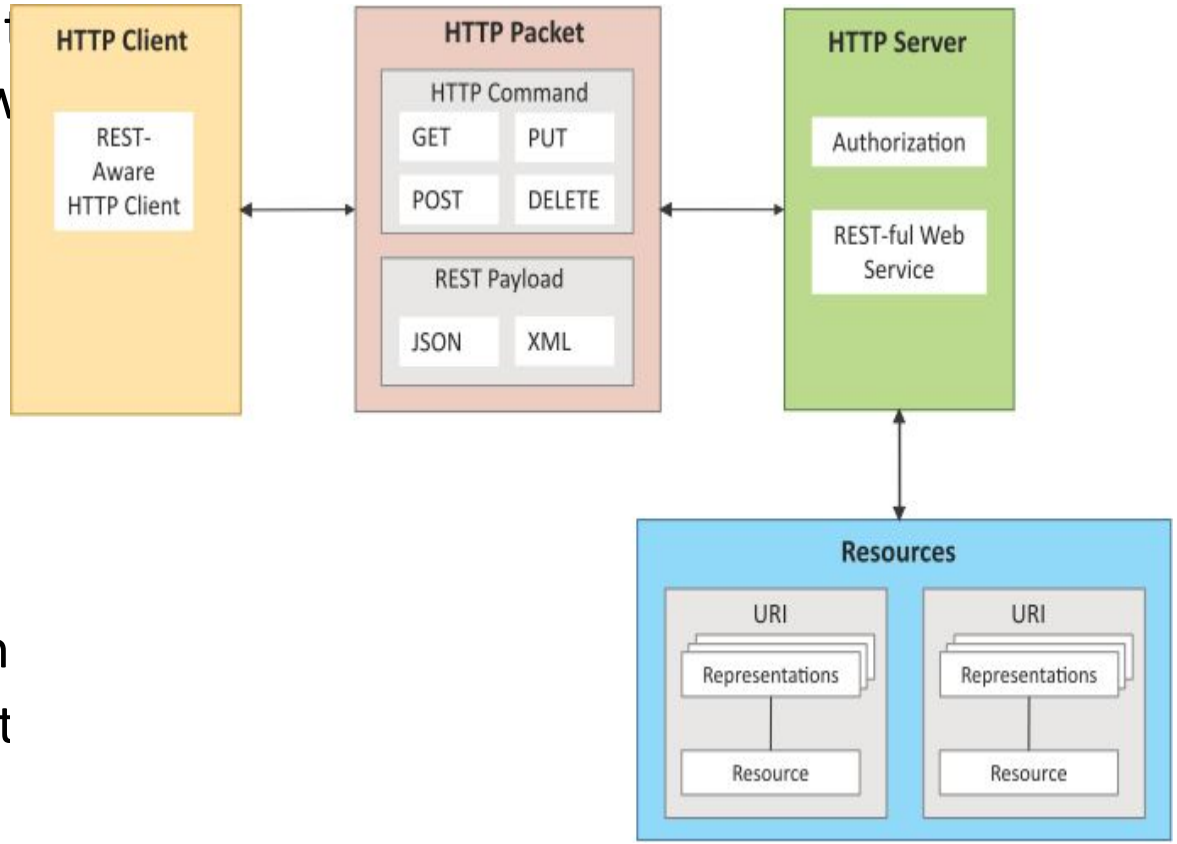
- Representational State Transfer (REST) is a set of architectural principles by which you can **design web services and web APIs** that focus on a system's resources and how resource

  states are addressed and transferred.

- REST APIs **follow the request–response communication model.**

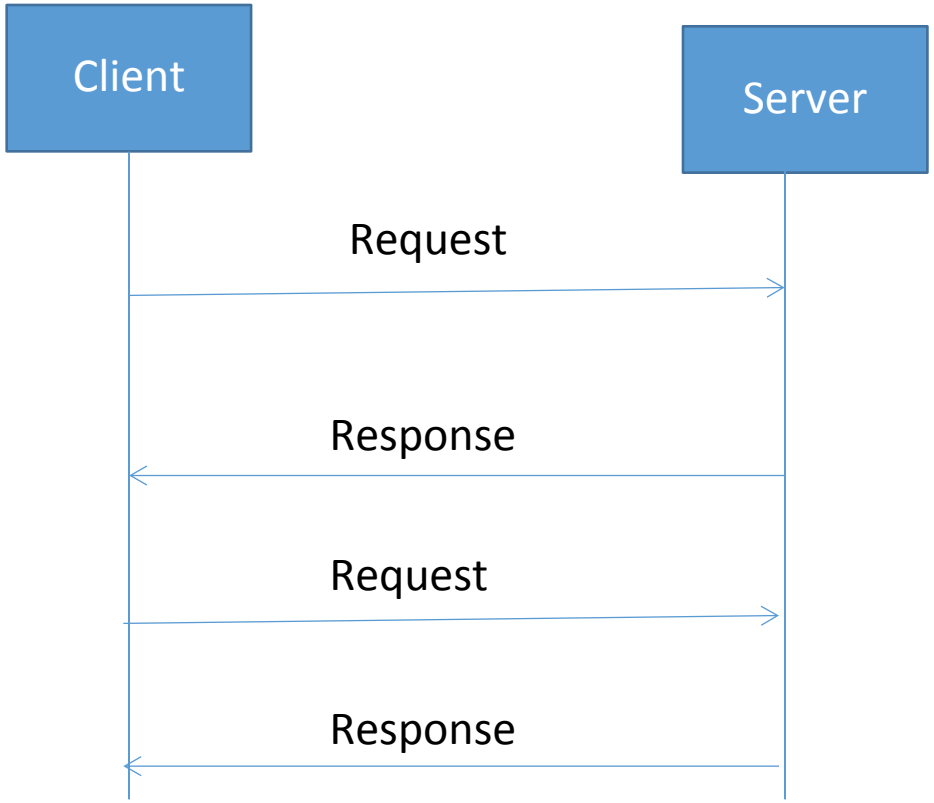
- REST architectural constraints apply to th components, connectors and data element within a distributed

  hypermedia system.



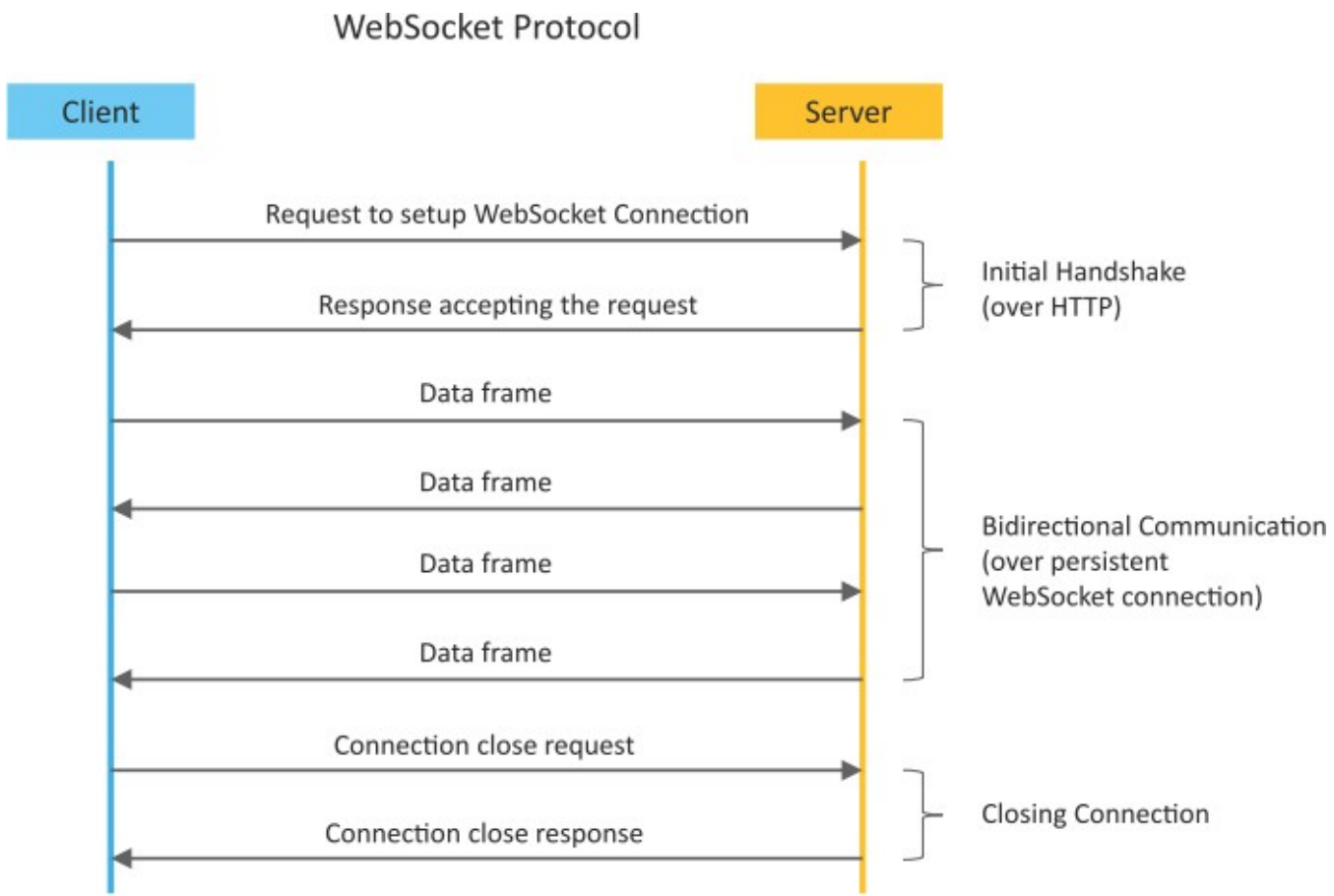
REST-based Communication APIs Constraints

- **Client – Server**
- **Stateless**
- **Cacheable**
- **Layered System**
- **Uniform Interface**
- **Code on demand**



WebSocket-based Communication APIs

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



Difference between REST and WebSocket-based Communication APIs

Comparison Based on	REST	Websocket
State	Stateless	Stateful
Directional	Unidirectional	Bidirectional
Req-Res/Full Duplex	Follow Request Response Model	Exclusive Pair Model
TCP Connections	Each HTTP request involves setting up a new TCP Connection	Involves a single TCP Connection for all requests
Header Overhead	Each request carries HTTP Headers, hence not suitable for real-time	Does not involve overhead of headers.
Scalability	Both horizontal and vertical are easier	Only Vertical is easier

IoT Enabling Technologies

- Wireless Sensor Network

- Cloud Computing

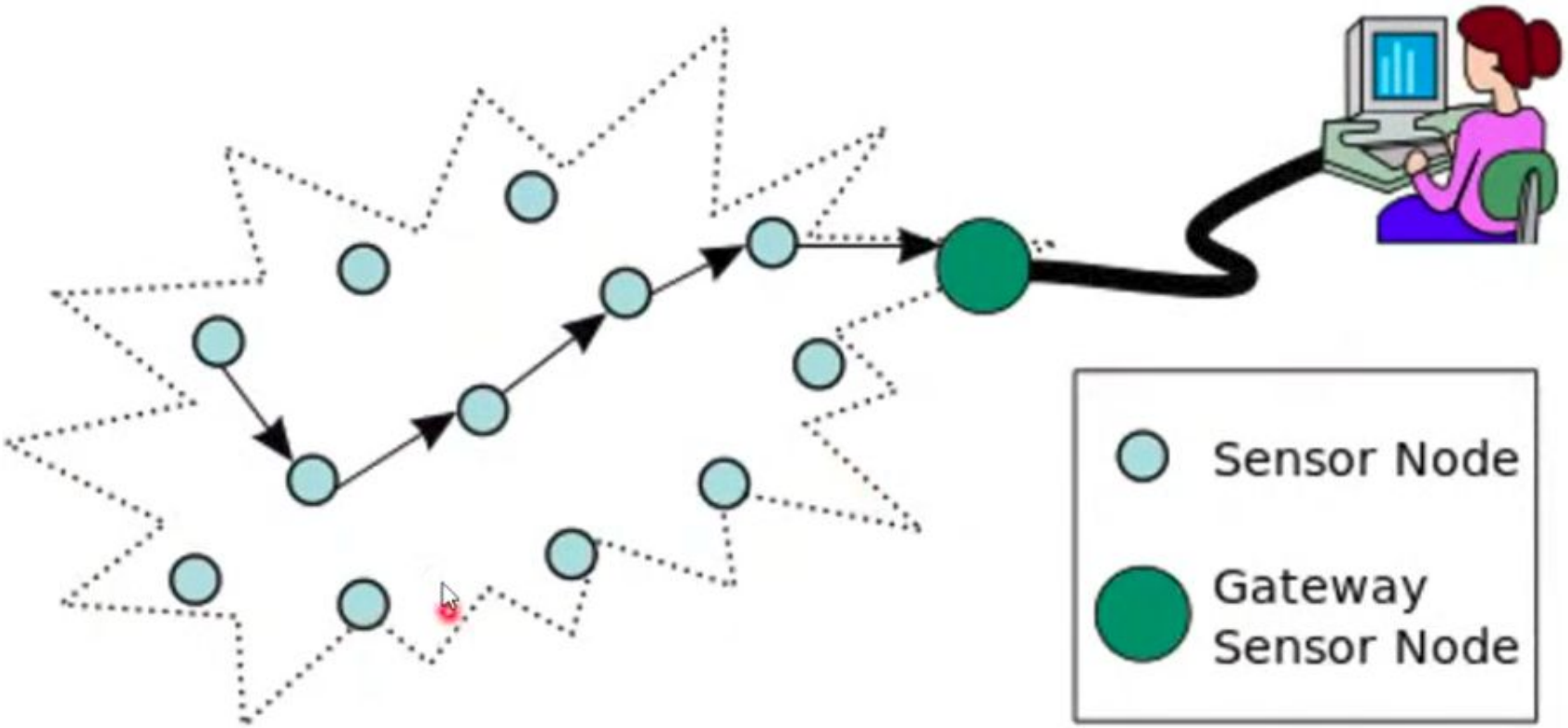
- Big Data Analytics

- Embedded Systems

WSN

- Wireless Sensor Network
- Group of sensors for monitoring and recording physical conditions of environment and
- Organizing collected data at a central location
- Measure environmental conditions like temperature, sound, pollution, humidity, etc.

WSN



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

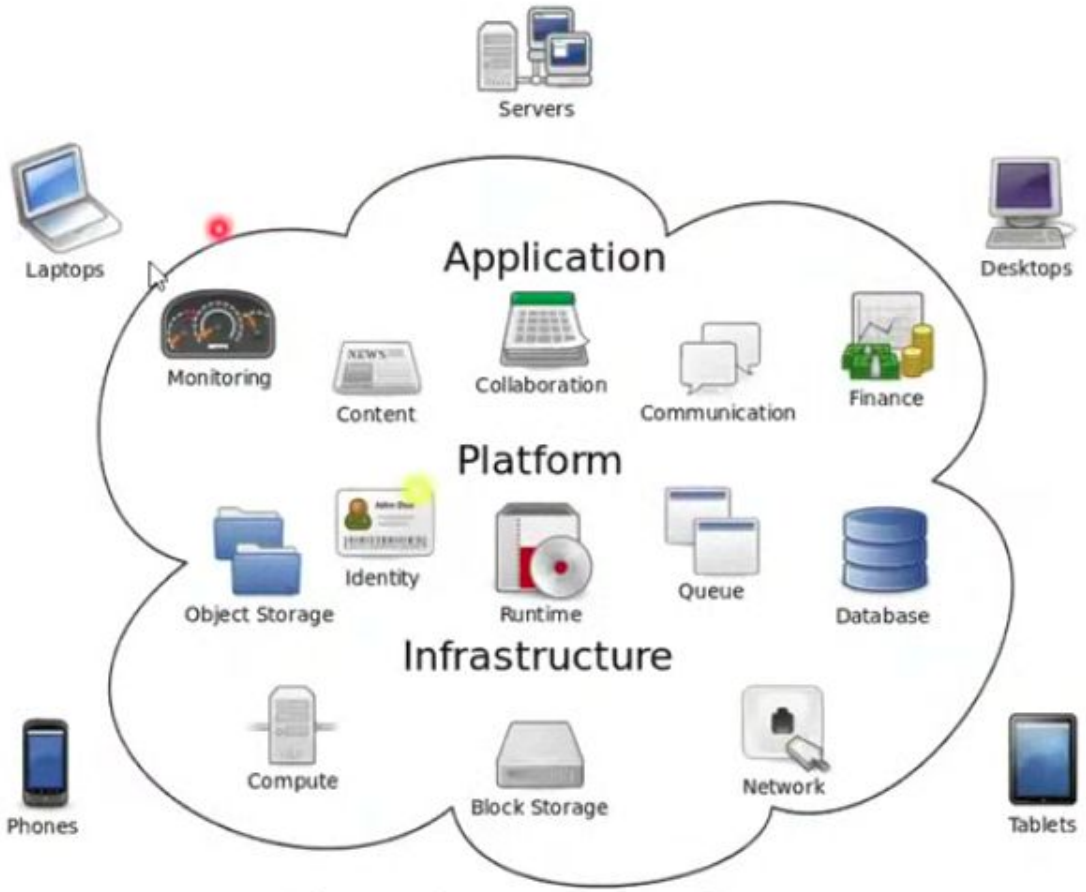
May 2020

- Q2 c) Explain WSN (the internet of transducers) pillar of IoT.

Cloud Computing

- Shared pools of configurable computer system resources and higher-level services
- Can be rapidly provisioned with minimal management effort often over the Internet
- Relies on sharing of resources to achieve consistency and economies of scale, similar to a public utility

Cloud Computing



Cloud computing

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 : Rent Infrastructure
- Paas : supply an on-demand environment for developing, testing, delivering and managing software applications.
- Saas : 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

Big Data Analytics

- Complex process of examining large and varied data sets to find information like
  - Hidden Patterns
  - Unknown Correlations
  - Market Trends
  - Customer Preferences
- Can help organizations make informed business decisions

BIG DATA ANALYTICS

Empower users of all levels with new actionable insights

Embedded Systems

- Combination of computer hardware & software
- Either fixed in capability or programmable, designed for a specific function or functions
- Computing systems but can range from having no user interface to complex GUI
- User interfaces can include buttons, LEDs, touchscreen sensing and more

Mar 2018

- Q. 2c) List different IoT enabling technologies which play a key-role and explain any of them. [4]

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

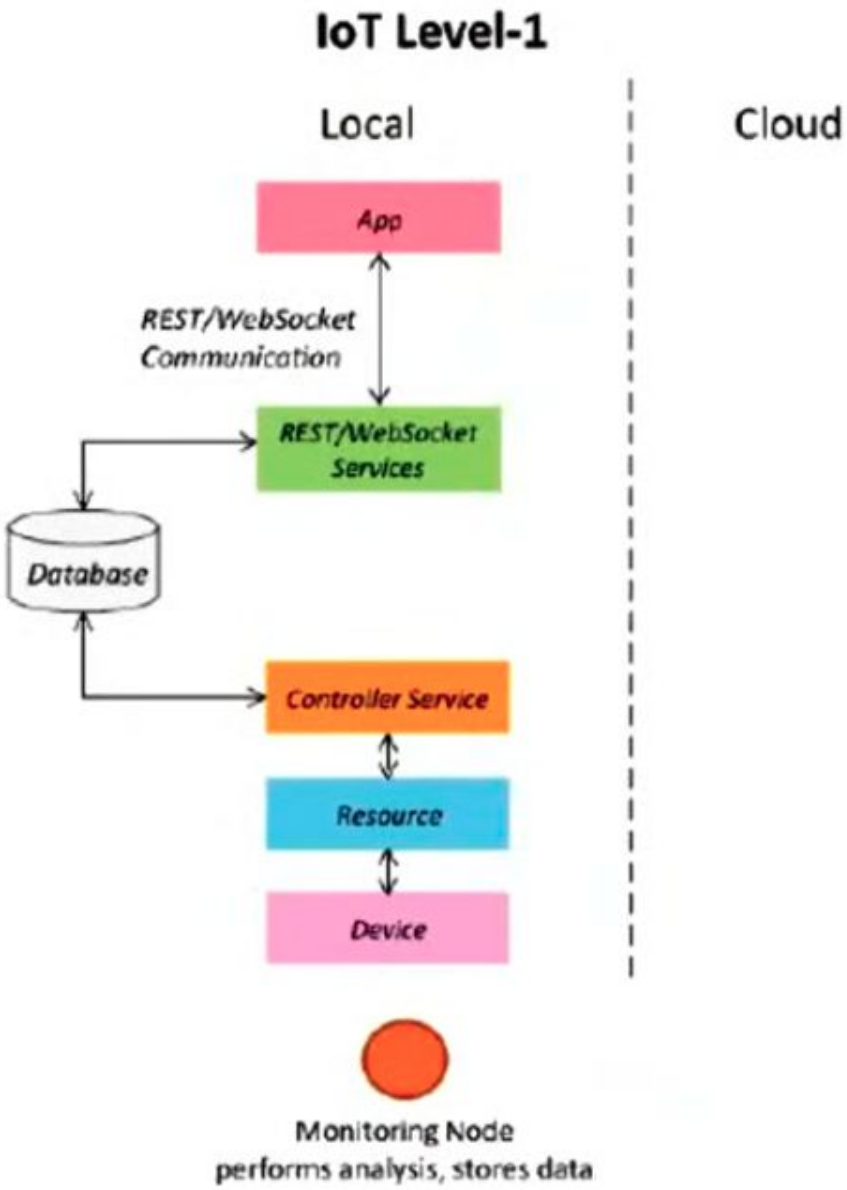
- **Database**: Database can be either local or in the cloud and stores the data generated by the IoT device.
- **Web Service**: Web services serve as a link between the IoT device, application, database and analysis components. Web service can be implemented using HTTP and REST principles (REST service) 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.

URL

https://www.youtube.com/watch?v=k_DVJlrZg20

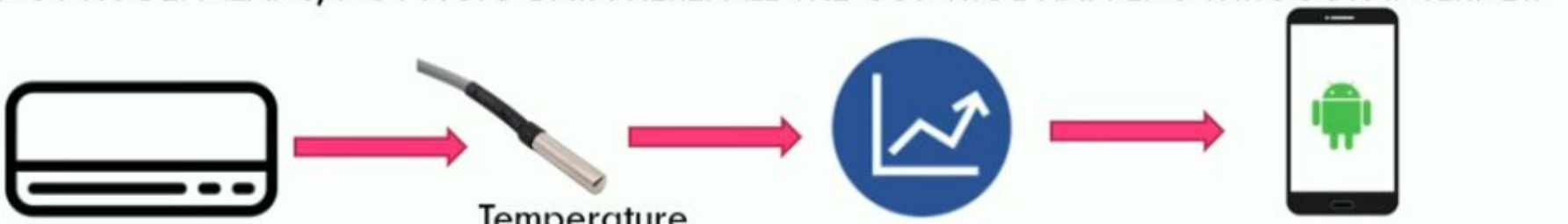
https://www.youtube.com/watch?v=rRRtYxdjwxc

- 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

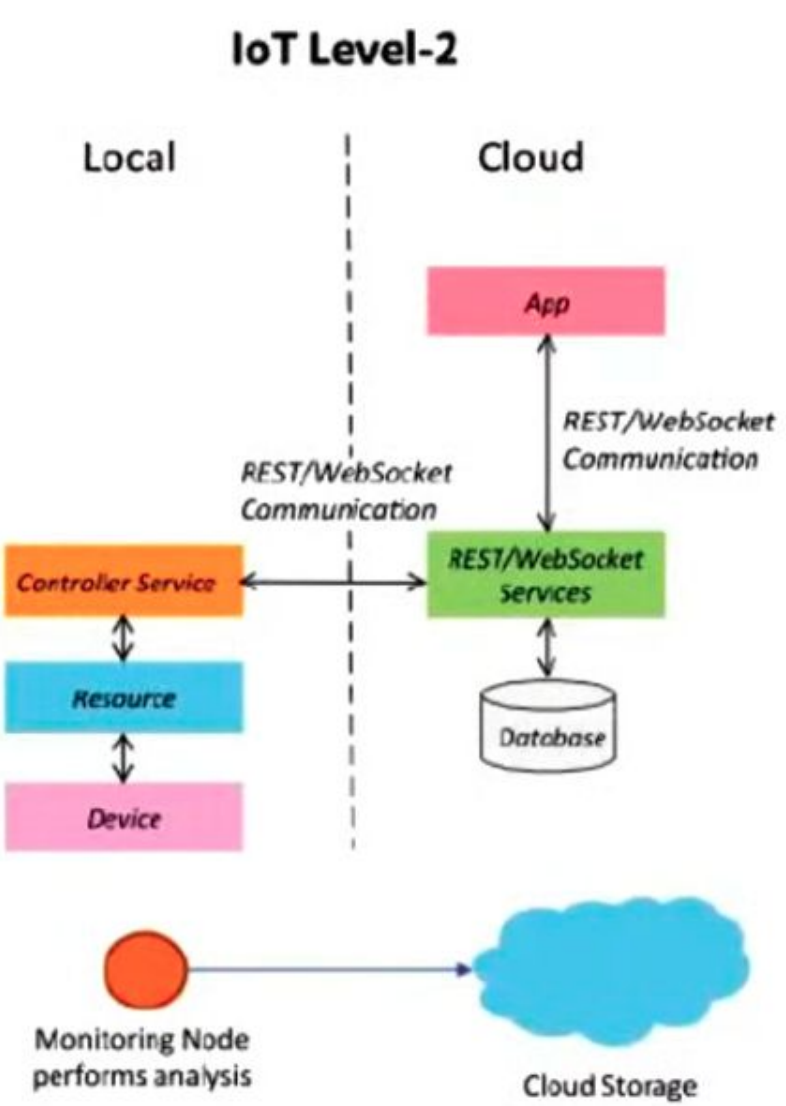


LEVEL - 1

- WITH THE AMOUNT OF COMPLEXITY INVOLVED, ONE COULD CATEGORIZE IOT AS IOT LEVEL 1/2/3/4/5/6.
- WE SHALL START WITH THE SIMPLEST OF THE LEVELS, I.E. LEVEL 1.
- WHAT CAN BE THIS?
  - HAVE ONE SENSOR / DEVICE TO SENSE. (COULD BE TEMP SENSOR/PRESSURE SENSOR ETC.)
  - THE DATA TO BE STORED IN LOCALLY.
  - DATA ANALYSIS TO BE DONE.
  - MONITORING / CONTROL CAN BE DONE THROUGH AN APPLICATION (.APK OR WEBAPP)
- THIS IS USED FOR SIMPLE APPLICATIONS WITH LIMITED COMPLEXITY OR NO COMPLEXITY
- DATA IS NOT HUGE. MEANS, NOT A BIG DATA HERE! ALL THE CONTROL HAPPENS THROUGH INTERNET.



- 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

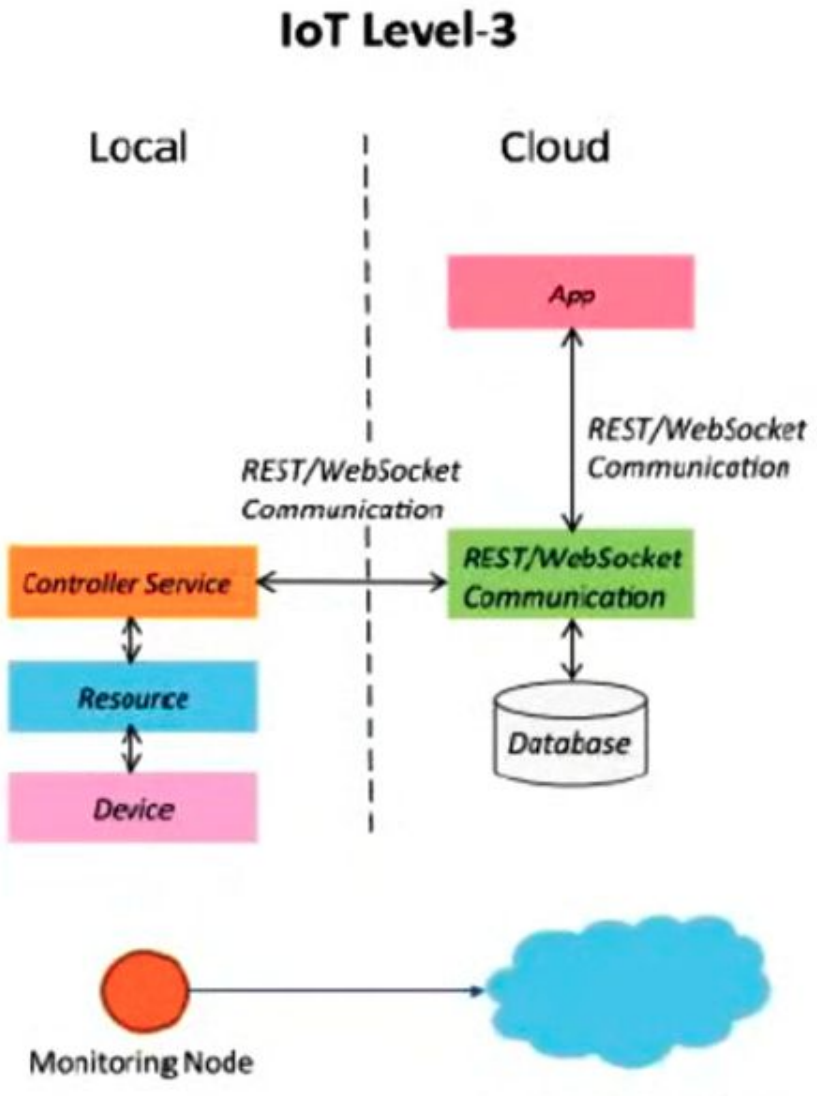


LEVEL - 2

- HERE, THE DATA IS DEFINITELY VOLUMINOUS.
- MEANS, THE FREQUENCY OF THE SENSING DONE BY SENSOR IS FASTER.
- HERE, CLOUD STORAGE IS PREFERRED AS DATA IS HUGE.
- ANALYSIS DONE LOCALLY. CLOUD MEANT FOR STORAGE ALONE.
- BASED ON THE DATA ANALYSIS, THE CONTROL ACTION CAN BE TRIGGERED THROUGH THE WEB APP OR MOBILE APPLICATION.
- SOME EXAMPLES COULD BE: AGRICULTURE APPLICATIONS, ROOM FRESHENING SOLUTIONS BASED ON ODOUR ETC.

Temperature, Moisture and Humidity

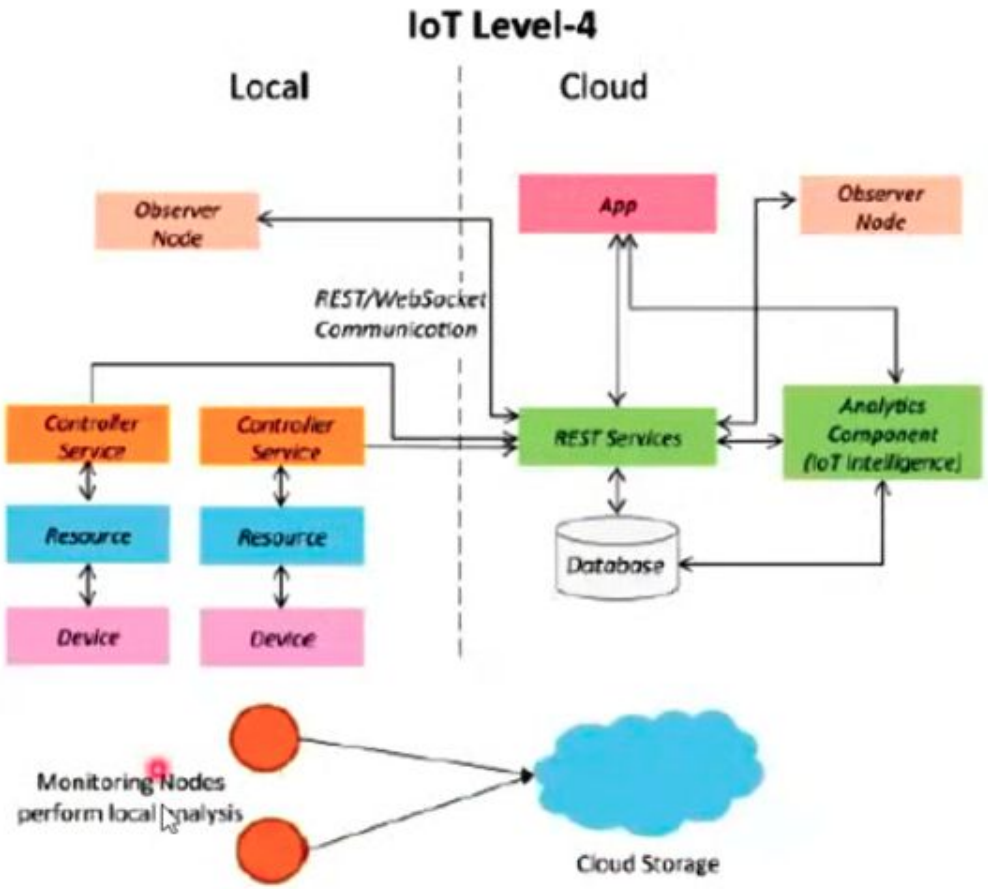
- A level-3 IoT system has a single node. Data is stored and analyzed in the cloud and application is cloud based
- Level-3 IoT systems are suitable for solutions where the data involved is big and the analysis requirements are computationally intensive



LEVEL - 3

- HERE, THE DATA IS DEFINITELY VOLUMINOUS.
- MEANS, THE FREQUENCY OF THE SENSING DONE BY SENSOR IS FASTER.
- HERE, CLOUD STORAGE IS PREFERRED AS DATA IS HUGE.
- ANALYSIS DONE IN THE CLOUD. (THIS IS A DIFFERENCE)
- BASED ON THE DATA ANALYSIS, THE CONTROL ACTION CAN BE TRIGGERED THROUGH THE WEB APP OR MOBILE APPLICATION.
- SOME EXAMPLES COULD BE: AGRICULTURE APPLICATIONS, ROOM FRESHENING SOLUTIONS BASED ON ODOUR ETC.

- 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



Temperature Sensor

MOISTURE SENSOR

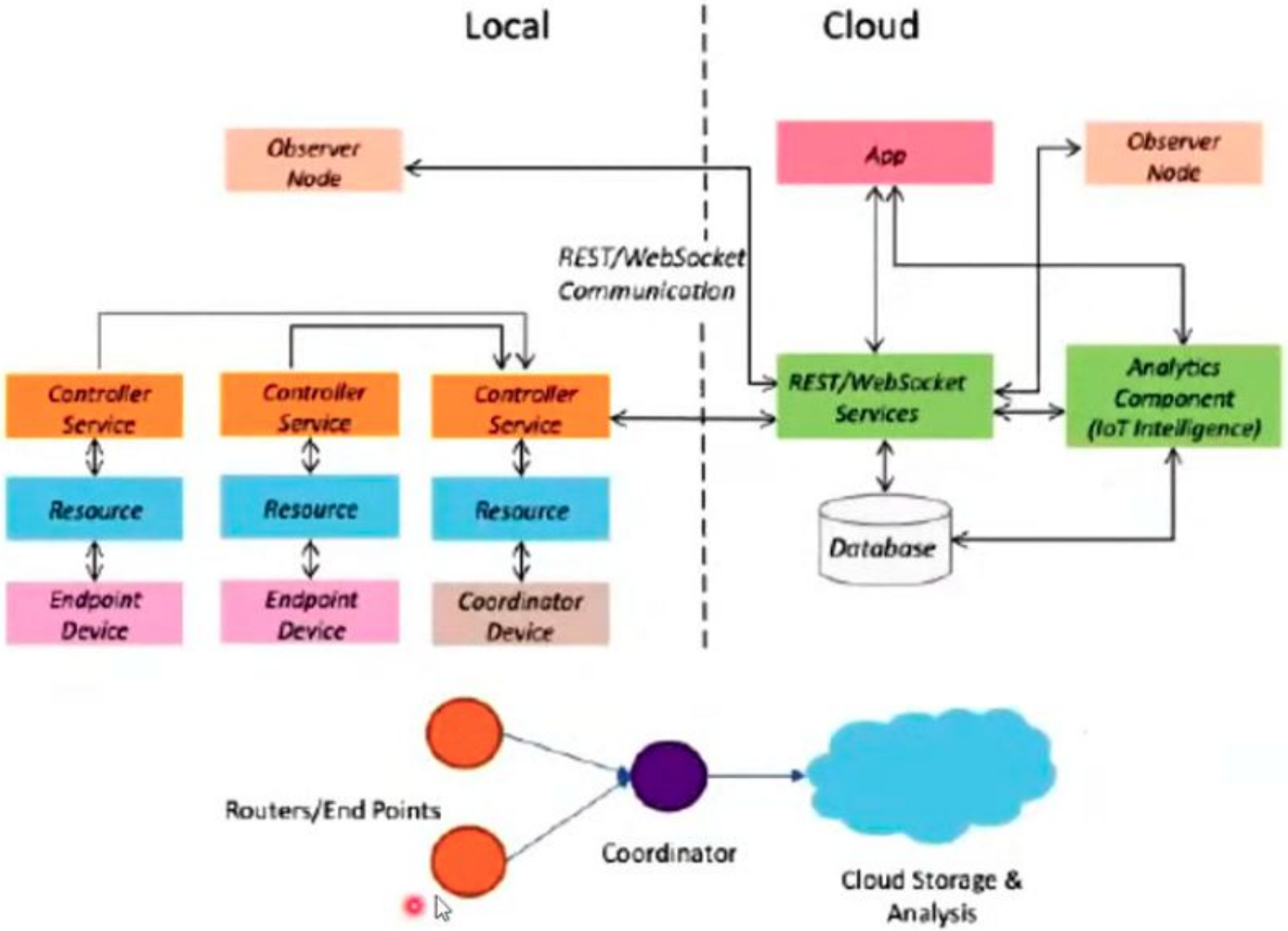
PRESSURE, TEMP, HUMIDITY – BME280

Data Collection and Analysis

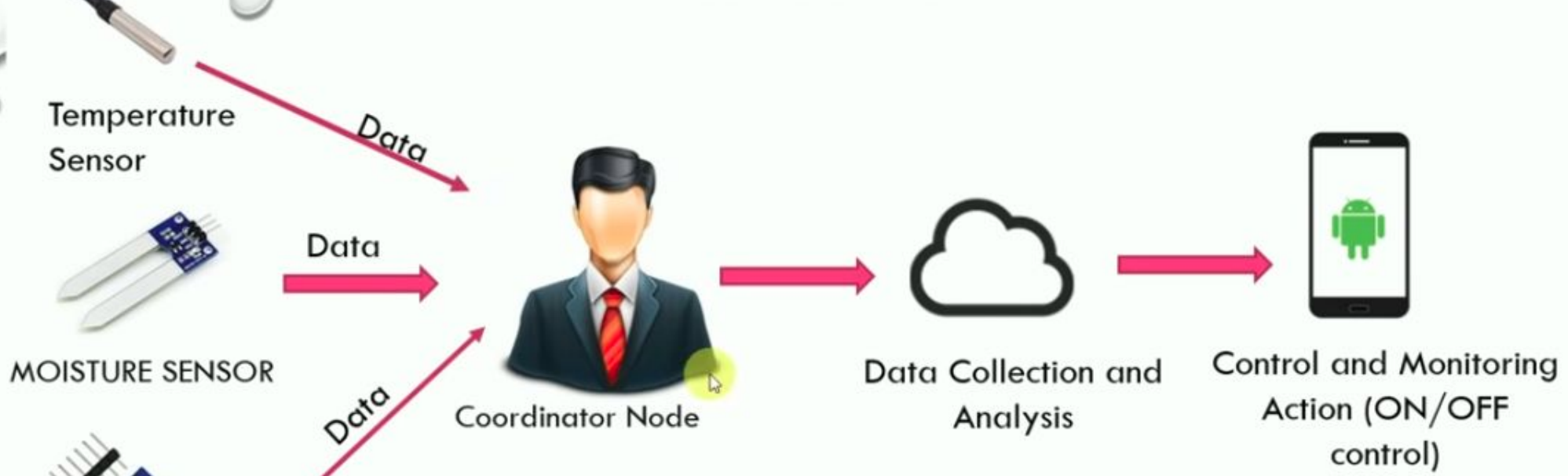
Control and Monitoring Action (ON/OFF control)

- HERE, THE DATA IS DEFINITELY VOLUMINOUS.
- MEANS, THE FREQUENCY OF THE SENSING DONE BY SENSOR IS FASTER. ALSO, MULTIPLE NODES ARE THERE AND THEY ARE INDEPENDENT OF EACH OTHER. ALSO, THEY UPLOAD DATA TO THE CLOUD. MEANS, ALL THE SENSORS AS SHOWN, SHALL UPLOAD THE READ SENSORY INPUTS.
- HERE, CLOUD STORAGE IS PREFERRED AS DATA IS HUGE.
- ANALYSIS DONE IN THE CLOUD, APPLICATION IS TOTALLY CLOUD BASED!
- BASED ON THE DATA ANALYSIS, THE CONTROL ACTION CAN BE TRIGGERED THROUGH THE WEB APP OR MOBILE APPLICATION.

IoT Level-5

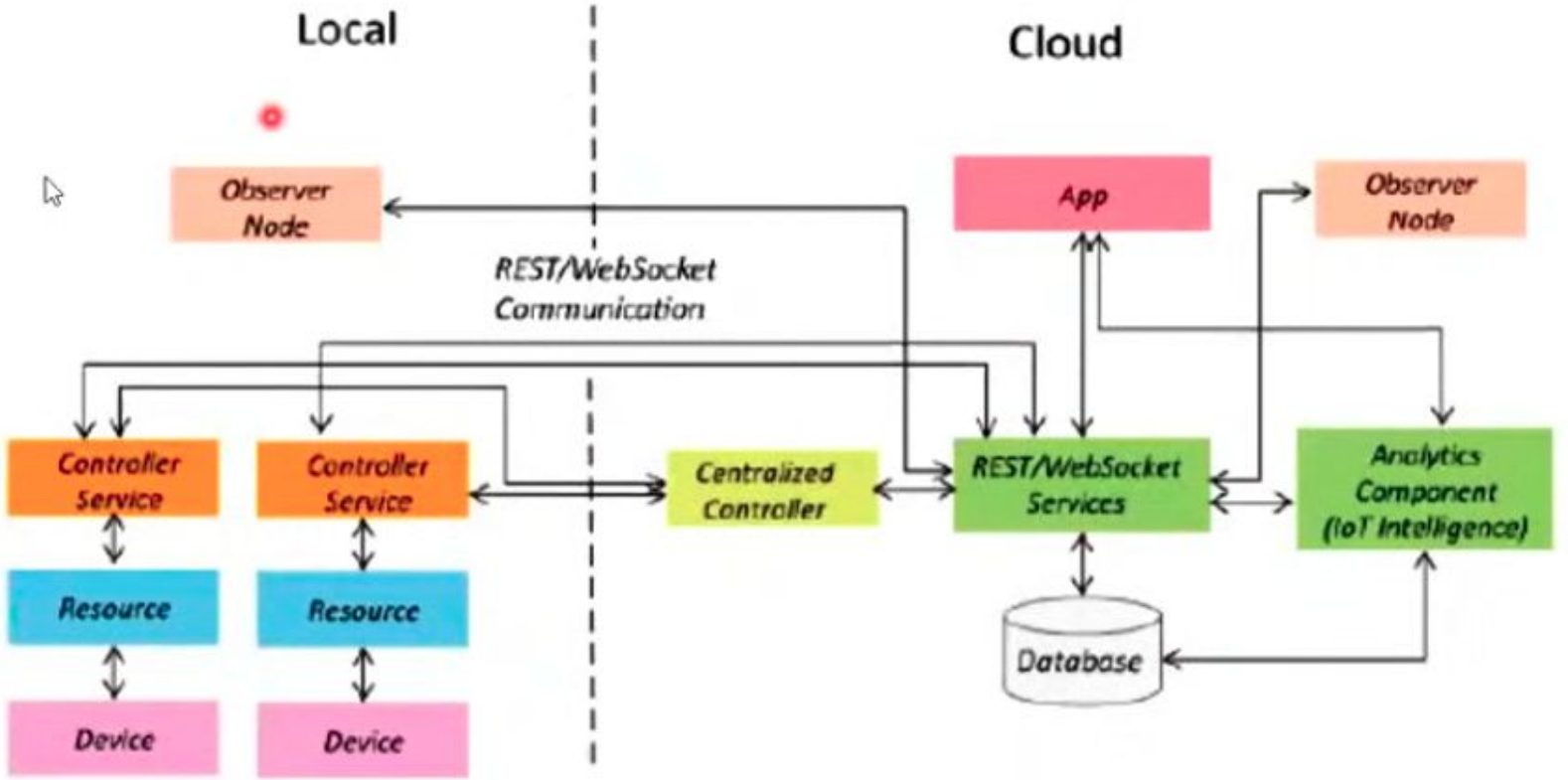

Local
Cloud
Observer Node
App
Observer Node
REST/WebSocket Communication
Controller Service
Controller Service
Controller Service
REST/WebSocket Services
Analytics Component (IoT Intelligence)
Resource
Resource
Resource
Database
Endpoint Device
Endpoint Device
Coordinator Device
Routers/End Points
Coordinator
Cloud Storage & Analysis

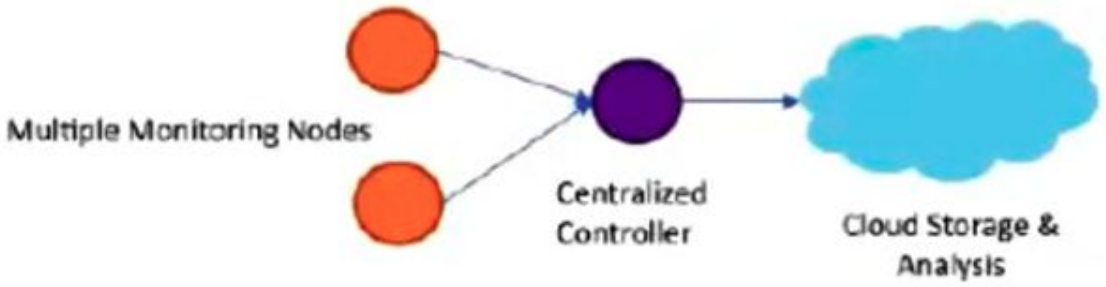
- A level-5 IoT system has multiple end nodes and one coordinator node
- The end nodes that perform sensing and/or actuation
- Coordinator node collects data from the end nodes and sends to the cloud
- Data is stored and analyzed in the cloud and application is cloud-based
- Level-5 IoT systems are suitable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



- HERE, THE DATA IS DEFINITELY VOLUMINOUS.
- MEANS, THE FREQUENCY OF THE SENSING DONE BY SENSOR IS FASTER. ALSO, MULTIPLE NODES ARE THERE AND THEY ARE INDEPENDENT OF EACH OTHER.
- THE DATA IS COLLECTED BY COORDINATOR NODE AND SENT TO THE CLOUD.
- HERE, CLOUD STORAGE IS PREFERRED AS DATA IS HUGE.
- ANALYSIS DONE IN THE CLOUD, APPLICATION IS TOTALLY CLOUD BASED!
- COMPUTATIONALLY VERY INTENSIVE.
- REAL TIME.
- BASED ON THE DATA ANALYSIS, THE CONTROL ACTION CAN BE TRIGGERED THROUGH THE WEB APP OR MOBILE APPLICATION.

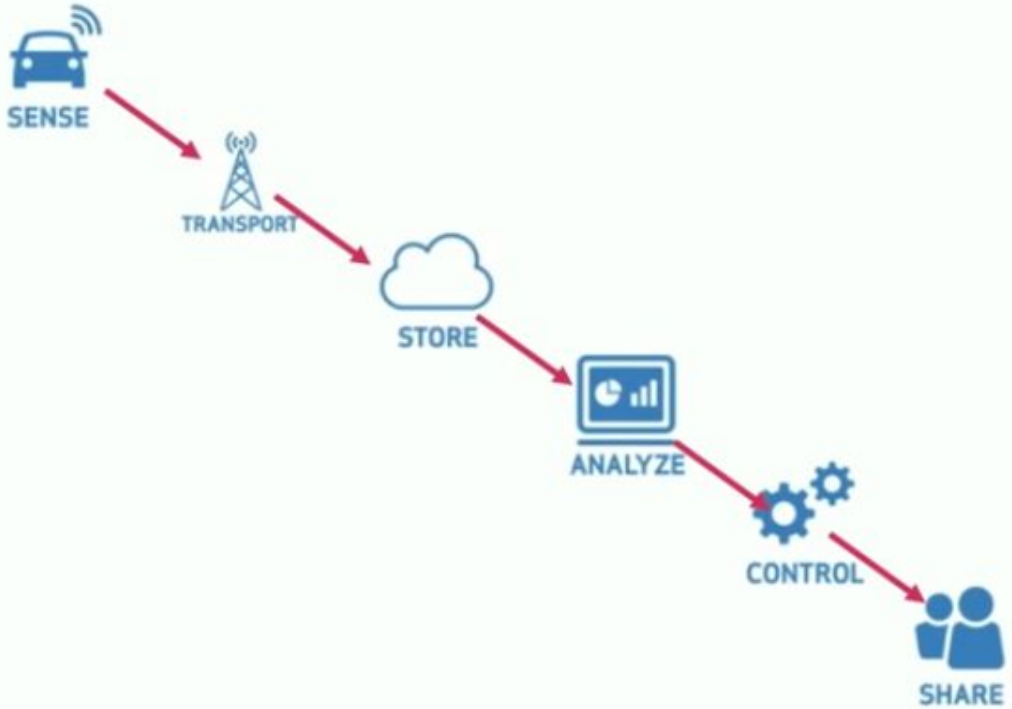
IoT Level-6


Local
Cloud
Observer Node
App
Observer Node
REST/WebSocket Communication
Controller Service
Controller Service
Centralized Controller
REST/WebSocket Services
Analytics Component (IoT Intelligence)
Resource
Resource
Database
Device
Device


Multiple Monitoring Nodes
Centralized Controller
Cloud Storage & Analysis

- 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

SO, WHAT HAVE WE UNDERSTOOD?



Mar 2019

- Q.1 c) List various levels of IoT System and explain Level 6 IoT System with diagram.[4]
- Q 1 c) List various levels of IoT system and explain Level 1 IoT system with diagram. [4] Mar 2018

IoT Issues and Challenges

Security

- Cyber Attacks, Data Theft

Privacy

- Controlling access and ownership of data.

InterOperability

- Integration Inflexibility

Legality and Rights

- Data Protection laws be followed, Data Retention and destruction policies

Economy and Development

- Investment Incentives, Technical Skill REquirement

Emerging Trends of IoT

Artificial Intelligence

Blockchain

Machine Learning

Data Analytics