Ch-1

1.1 Define Cyber Physical System (CPS).

Cyber physical Systems is a collection of computing devices that communicate with each other and interact with physical world using sensor [for collecting real-world data], Actuator [for reacting] & IoT [for connection with other devices]. in real time

1.2 Understand the Cyber Physical System in real world.

* Definition

CPS combine physical components such as sensors, actuators & machinery with cyber components. including software, network, algorithm, processors and interact with real world. CPS is closely integrated with many devices that communicate which each other & interact with physical world in real time.

In Real World, CPS systems are

1) Physical - digital Integration.

CPS combines physical hardware with software systems to monitor & control physical processes.

2) Data based decision making.

CPS systems take data from sensors & based on algorithm it takes decisions and that decisions will be passed to actuators which results in physical action

3) Real time operations:

CPS systems are Real time Systems. They uses RTOS which helps in reacting ~~for~~ to events environmental changes in real-time they can understand physical world properties & react in real time. & they are well synchronized.

4) Human interaction:

CPS systems interacts with humans when needed through human interaction interfaces to take inputs from humans in some conditions. CPS generally designed in such a way that they are easy to operate, control & maintained by humans.

5) Autonomous Applications.

CPS systems can also be operated independently without human interventions, currently world achived semiautonous CPS which need less human interaction & more autonomous work like flight-control etc but soon would can achieve Autonomous CPS with higher success in fileds like Automotive, Industrialization, urban planning etc.

: L3 know the basic principles of design & validation of CPS.

(1) Embedded Systems: CPS is a network of Embedded System & Embedded system is a system designed to perform specific task ~~&~~ but CPS system can be designed for specific task like Industry Autonomous hands, transport systems etc. / Robotic Arms etc.

(2) Close Integration of physical & cyber devices.
CPS involves close integration of physical devices like (sensors, actuators) with cyber devices like control System, Software, O.S, etc. to make decision & perform real world tasks.

(3) Human interactions:
CPS Systems involves interaction ~~of~~ with humans whenever needed in making decisions so their interface is much human friendly.

(4) Communication & networking:
CPS must connect with other devices, servers etc so to collect data from cyber world & give output if neccessary like in Robots, weather devices ~~etc~~, alexa etc

(5) Physical properties:
CPS system must understand the physical world & physical properties, characteristics of Environment
Feedback mechanisms: CPS system takes feedback ~~fr~~ & learn from past interactions & refines its behaviour to make

accurate decisions.

Industry 4.0

Industry 4.0 is the 4th Industrial revolution that focuses on making factories and industries smart by using advanced technologies like Internet, Artificial Intelligence, Robotics, IoT & CPS to make production faster, cheaper & more efficient

→ 1st Industrial Revolution: machines were powered by steam Engines
→ 2nd Industrial Revolution: machines were powered by Electricity
→ 3rd Industrial Revolution: machines were computerized & automated
→ 4th Industrial Revolution: made smart factories in which data from one machine can be transmitted to others in order to communicate & increase performance & production.

Principles

① Interoperability: Refers to ability of devices & systems to communicate with each other through Internet of Things (IoT) & workers interacting with machines using AR (Augmented Reality) or mobile apps.

② Modularity: a smart factory that adapts new market needs by analysing market trends & upgrades software or hardware components to meet desired need.

③ Service-orientation: Refers to connection of customer & devices/machines to make customized product as per customer need & specifications.

Useful technology in Industry 4.0

A-I : helps machines to make decisions

CPS : uses sensors, Actuators & controllers to collect data & react in real-time combines cyber & physical things.

IoT : Devices can work smartly by sharing data under Internet allows communication with devices & b/w devices

Cloud Computing : Allows data-to store, allows user to store & process data remotely.

Advantages of Industry 4.0

① Reduce Energy consumption & waste production through optimization

② Large production in less time.

③ cost-Reduction due to convienient & Efficient energy Consumpti

Challenges

1) Security

2) Privacy

3) Need of Resources

4) Employment : workers need to adopt new-skills.

5) proper planning & risk evaluation.

1-5 Understanding CPS platform components.

CPS needs components based on two criterias

① Physical Components

→ Sensors: sensors are used to collect data from real world which is converted into digital signal for processing

→ Actuators: Data from sensors is processed & decision made by them based on that Actuators perform actuation [physical Actions] through mechanical systems. In short they convert digital processessed signals in analog form

→ Mechanical Systems: motors, speakers, hydraulic system etc

② Cyber Components

→ Control Algorithm: for correct operation cps need to follow certain algorithm based programs.
& softwares

→ Operating System: It is a software that needs for better interaction of CPS with user. OS is nothing but hardware manager or resource manage
Ex :- RTOS.

→ Communication network: for data Exchange b/w components
Ex CAN, Wi-Fi, Automotive Ethernet, WSN etc

→ Aggregators: They need aggregators for data processing.

③ → Controlling Components: DSP, PLC, RTU are commonly

used controlling system in CPS for controlling data & Actions in a CPS System.

1.6 Understand the CPS HW Platforms

1.6.1 Processors:

Processors are basic need for any CPS system for processing data collected & for decision making etc they are many types of processors used in CPS system like CPU, microprocessor, GPU, DSP

CPU - For performing arithmetical & logical ops, I/O operation & other instructions that are passed by Operating System (O.S)

GPU - GPU is responsible in performing mathematical operations for generating meaningful image on display of specific resolution. It gives color, brightness to each pixel

DSP - Digital signal processor that processes digital signals & gives output like increase sound, remove noise etc.

1.6.2 Sensors:

Sensors are the physical component that collects data from environment, convert it in digital form.
They are of many types like heat, temp, pressure, sound, physical motion, vision. etc.

1.6.3 Actuators.

Actuators is a device that converts Electrical signals into Physical Events. It takes inputs from system & gives output to the environment ex: servo motors, heaters, hydraulic systems etc

1.6.4 CPS Wireless-Network.

WSN- wireless sensor network based CPS. CPS involves WSN as main mean to interact with physical Entities

1.6.5 Hart

Hart stands for highway addressable remote transducer is a communication protocol for industrial Automation that uses Hart protocol. It allows 2-way communication (2wc) b/w sensors etc & control Systems like PLC, DCS, RTU etc without need of new wiring.

1.6.6 CAN.

CAN - campus area network. Two or more interconnected LAN's within a geographic area like school, university military bases, co-orparate building etc.

Ex: Let two labs having 50 pc in each & are interconnected to LAN (say bluetooth) their is an e-library with intesnet & has digital Libraby & offline documents so when Lab want to access those docx we need some wiring & connection for Lab to library which allows data transfer (communication) the whole Set-up is called campus Area network (CAN).

1.6.7 Automotive Ethernet.

Automotive Ethernet is a wired communication protocol that is used to connect various components of a car in a network.

- It Ensures high speed data transfer rate (100Mbs - 1Gbs
- It is better than CAN as it has high speed data transfer.
- It has larger bandwith.
- Works with TCP/IP protocol.

1.7 Understand the CPS Software platforms.

Software is needed in CPS as to control hardware & system resource. A set of programs is designed for proper CPS

1) Operating System.

Operating system is a interface btw user & machine & also it manages resources & control the hardware & gives instruction OS handles Scheduling & a scheduler is designed in it to manage task.

Generally CPS Systems uses RTOS, TinyOS, Mantis etc

2) Control Algoriths & simulation tools

To test & simulate the system before development we use MATLAB / Gazebo softwares.

3) Security & Privacy

For Security & privacy of cyber part of System & data stored in CPS we need Encryption standards, anti-virus Authentication mechanism. for using CPS

4> Programming skills & developments

As to program the chips, microcontrollers one must need programming skills for developing a CPS

5> Cloud storage

To store data cloud storage is necessary.

6> GUI: Graphical User Interface.

mobile or web based dashboards for remote monitoring and controlling.

1.8 Know the Principles of Automated Control design.

Automated Control design focusses on creating systems that can operate & control themself without human interventions

Principles include

① Modelling: Develop mathematical representation of the system to understand its behaviour.

② Feedback: Use sensors to monitor output & adjust inputs compare the system's output to a desired reference & adjust inputs to minimize the Errors.

③ Counter Attacks: A System should handle themselve in case of attack & if not able to handle then degrade smoothly.

④

109 Automotive Case Study:

~~A Smart~~ Automotive case study typically involves a detailed analysis of real world problems related to automotive industry. These studies examines challenges, solutions, Expense, resource, safety, manufacturing of advance technology like CPS & IoT.

① Government policies: how government policies affect the automotive companies.

② Autonomous Systems: Examination of self driving car, algorithm used in it & real-life testing.

③ Cyber security measures & Risk Evaluation should be done on potential field like Vulnerabilities in smart vehicles.

Ex: A case study might analyze a cyber security breach in a connected vehicle where hackers exploit cars software to disable braking system or manipulate GPS system.

Attacks on Smart Grid.

Smart Grids are Electricity network where generator side and consumer side is connected in a network that helps in sustainable Energy system, load-balancing, pricing etc.

Consumer side sensors ~~etc~~, smart meters sends data to control Centers at generator side to send specific amount of Electricity to prevent loses.

Attacks: Attacks that can be happen are

i) DOS: Attacker may overload the network that leads to delay & disruppt in power supplies.

ii) Data manipulation: Altering the information of sensors & meters leading to incorrect decisions by automated Systems.

iii) Physical Attacks: Targeting hardware components like substations or transformers to cause blackout.

Ex: North East blackout of 2003.

It was the largest power outage of Americans history at the time that Effected north East of america.

Due to a software bug in the control room causes the Entire smart grid to disrupt resulting in power failure that affected multiple states of america & also canada.

It affected over 55M people in US & Canada.

It took nearly 2 days to fully restore the smart grid.

but more Economic damage Estimate lose of 4-10 billion $

Differences

industry 4.0	society 5.0
It is an Industrial Revolution	It is a society revolution to transfer society into advanced society
It focus on increasing Efficiency & production	It focus on Sustainability & well-being.
factory & Industries comes under application aspects	cities & public people comes under application aspects
Solves Industrial challenges like Energy consumption, time consumption, cost.	Solves society challenges like Air pollution, medical devices

Ch – 2.0 Introduction to Internet of Things

2.1 Define IoT and list the characteristics of IoT

IoT : Internet of Things is a network of physical smart devices, that are connected to the internet to share information

– (or) –

2.1 IoT : Internet of things is a network of physical devices Embedded with sensors, software & other tech that connects them to internet to share data to authorized user or admin who can monitor, analyze & control them remotely.

characteristics of IoT

(1) Scalability : New devices can be connected in the existing network so IoT is scalable.

(2) Unique identity : Each IoT device has unique identity like IP address, URL etc

(3) Remote access : IoT devices can be remotely accessed by authorized users.

(4) Interoperability : IoT device can communicate with other devices in a same network.

(5) Self Adapting : IoT devices can adapt to changes in Operating Condition & take actions.

2.2 Understand Physical design of IoT

Physical design of IoT refers to the hardware & infrastructure needed for IoT device to operate as per desired functionality.

It Involves.

1) Device (Things): physical devices ~~with~~ Embedded with Sensors, actuators that collect or act on data ex: smart lights, temperature sensors, wearables etc.

2) Microcontrollers / Processors: They are brains of device that process data from sensors & control actuators. Ex: Arduino or Raspberry Pi.

3) connectivity modules: allows devices to communicate with other devices or ~~through~~ to internet using Wi-Fi, Blutooth, zigbee or cellular network.

4) Storage & Interfaces.

2.3 Know Things in IoT and IoT protocols.

In IoT, "things" refers to physical devices that are Embedded with Sensors, software, network etc. Enable them to collect data or share them or be controlled over ~~a~~ the internet They can be consumer Electronic devices, like smart lights, cameras, temp controller AC, fans, washing machines etc or can be

vehicles that provides information of fuel, location or health of various components in car etc. or they can be healthcare devices like glucose monitor, heart rate, BP, pacemaker that collect & transmit data of patient to doctor etc. are all comes under Things in IoT.

IoT protocols

Communication protocols : MQTT, CoAP, HTTPS etc.

Network protocols : IPv6, Zigbee/z-wave, Bluetooth

Data Exchange protocols : XMPP, AMQP.

IoT Things composed of

Connectivity : USB Host RJ45 / Ethernet

Processor : CPU / GPU.

Audio/video interfaces : HDMI, 3.5mm audio, RCA Video

memory interfaces : DDR1, DDR2 / DDR3, NAND or NOR.

I/O Interface : (sensors for, actuators) UART, SPI, I2C, CAN.

IoT Protocols

IoT Protocols are rules that allow IoT devices to communicate with each other and over a internet securely.

They are generally diff protocols used by IoT devices to communicate under a network securely that Are managed by network layers like

Application, Transport, Network & Data-link layer.

Application layer: It is a input & output interface where following from protocols like HTTP, XMPP, MQTT, DDS, web sockets sender sends data & receiver receives it.

Transport layer.
manages data segmentation & Error control follow TCP & UDP protocols.

Network layer:
It adds IP addresses of sender & receiver to datagrams
It uses protocols like IPV6 & IPV4 etc.

Link layer;
convert data into signals and sends it to destination

Application	HTTP, CoAP, WebSocket, XMPP, DDS
Transport	TCD, UDP
Network	IPv4, IPV6
link	802-3 Ethernet, 2G/3G/4G cellular, WiFi 802.11 WiMax - 802-36

2.4) know about IoT Enabling Technology

2.4.1 Wireless Sensor networks.

WSN plays vital role in the Internet of Things (IoT) by Enabling devices to collect & share real-world data. WSN consist of distributed Sensor nodes that are wirelessly interconnected to monitor. These nodes transmit the collected data (like temp, light or motion) to IoT which process them & make decision.

∴ WSN helps IoT by collecting (analog or digital data) & sharing (digital) data needed for smart systems to work

Ex: Smart Agriculture, Smart Cities (Traffic, pollution sensing) Healthcare, Smart Homes.

2.4.2 Cloud Computing.

Cloud Computing also plays a critical role in IoT as it provides services like store, process & analyze the vast amount of data generated by IoT devices. IoT things & devices generally donot have Enough storage so cloud helps by storing data, analyzing it & making it available to users or systems any where.

2.4.3 Big data Analytics

Big data analytics refers to the process of examing large, massive & complex sets of data (big data). Big data analytics involves software tools & techniques to process & analyze large volumes of data that traditional data processing method can't handle. key techniques involved are.

1) Data ~~mining~~ cleaning : Remove Errors, duplicates & irrelevant info
2) Data munging : Re-arrange data & make ready for analysis
3) Data processing : process data using tools to transform it into usable format
4) Visualization : visualize data into graphs etc for Easy-Understanding

2.5.1 IoT Level - 1

2.5.2 IoT level - 2

2-5-3 IoT level - 3

2-5-4 IoT level - 4

2-5-5 IoT level - 5

IoT level

Database: It is where the data of generated by IoT device stored either local or in cloud.

Webservice: It links IoT ~~device~~ application & database & IoT device using HTTP and REST principles. or using websocket protocol.

Application: IoT app provides an interface that the users can use to control & monitor various aspects of the IoT System.

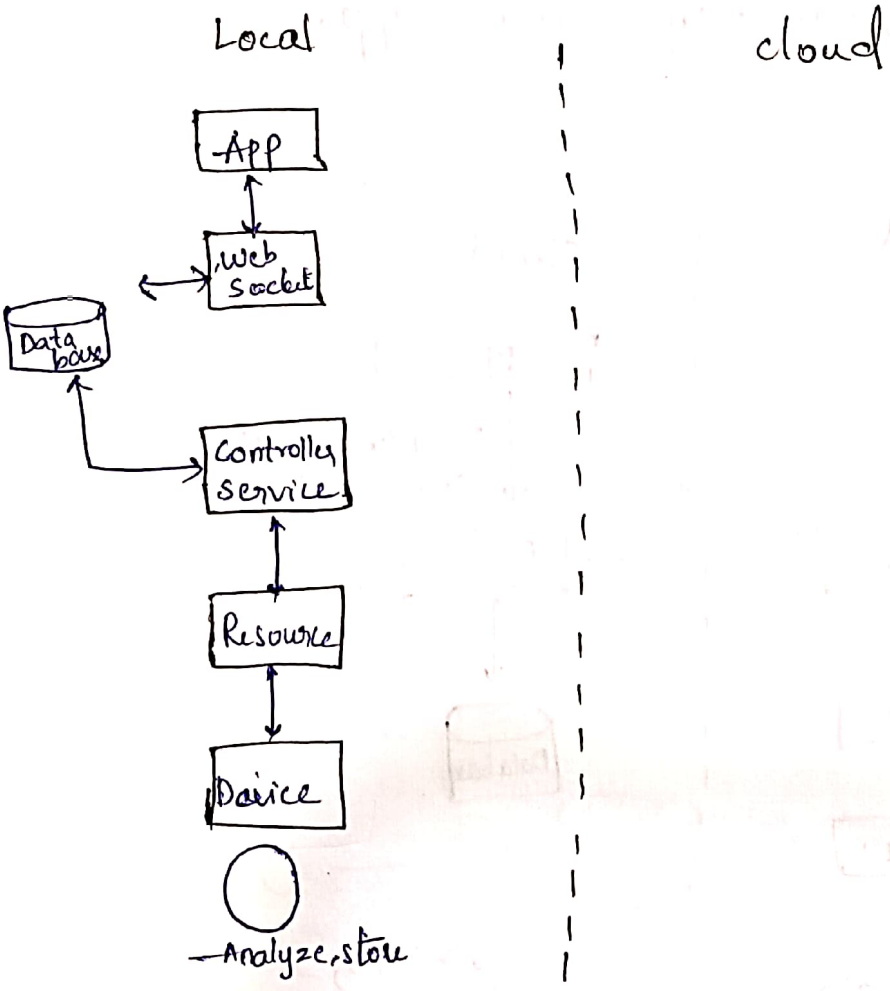
Analysis component: Analysis component responsible for

Controlling Services: manage & control IoT device remotely using various Protocols. helps IoT to actuate based on sensors data & user inputs. analying data of IoT & generate Easy form of data as a result.

Resources: Software & Hardware that processes, stores the data make decisions based on data from sensors & control actuations.

Controller Services: link web services with IoT device like link IoT device with cloud, application & control action of IoT device

Level-1



① IoT level 1 is basic & fundamental level of IoT technology.

② here their is only single ~~sed~~ node (device) that senses & performs processing based on available resource & perform actuation and send all the result data to local database through communication protocol & user can monitor & control device

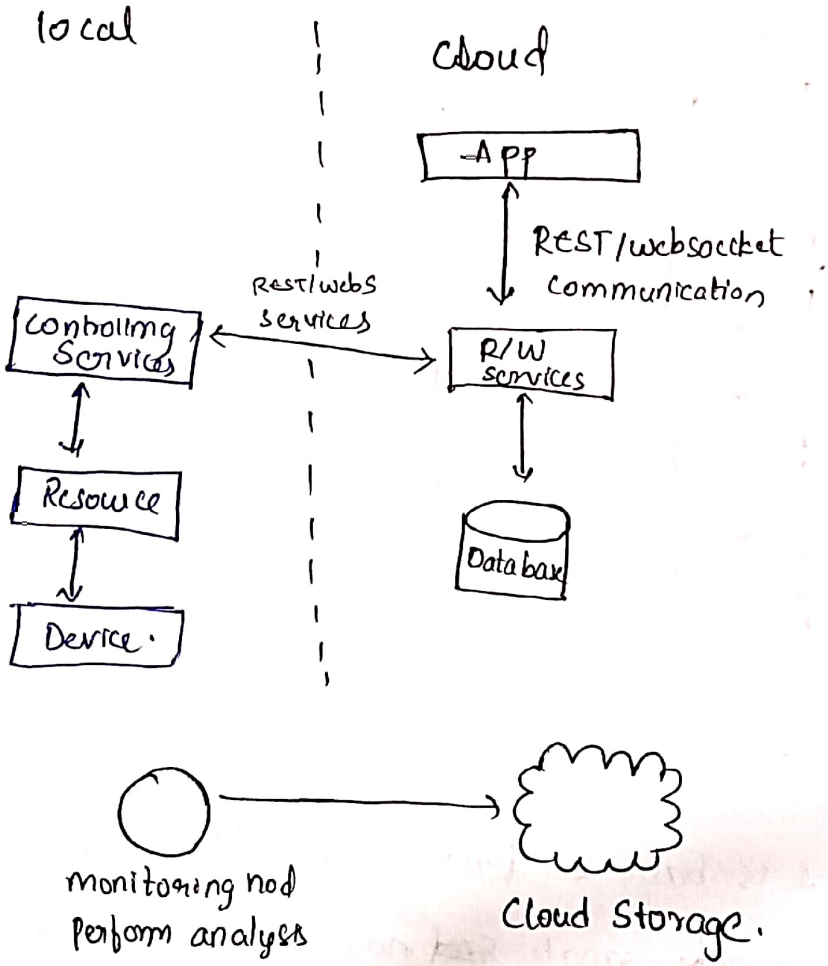
through Application & user get feedback or data stored in DB through Application at local

③ Everything in LV-1 is at local side no cloud is used

④ At LV-1 data involved is not so big & not computationally intensive so no need of cloud for storage & analysis.

Ex: Room temperature is monitored using a temperature sensor & data is stored / analyzed locally & based on analysis control action is triggered using a mobile app.

IOT Level-2



① IoT level 2 has single node / device that is used for sensing, Actuating, processing and analysis.

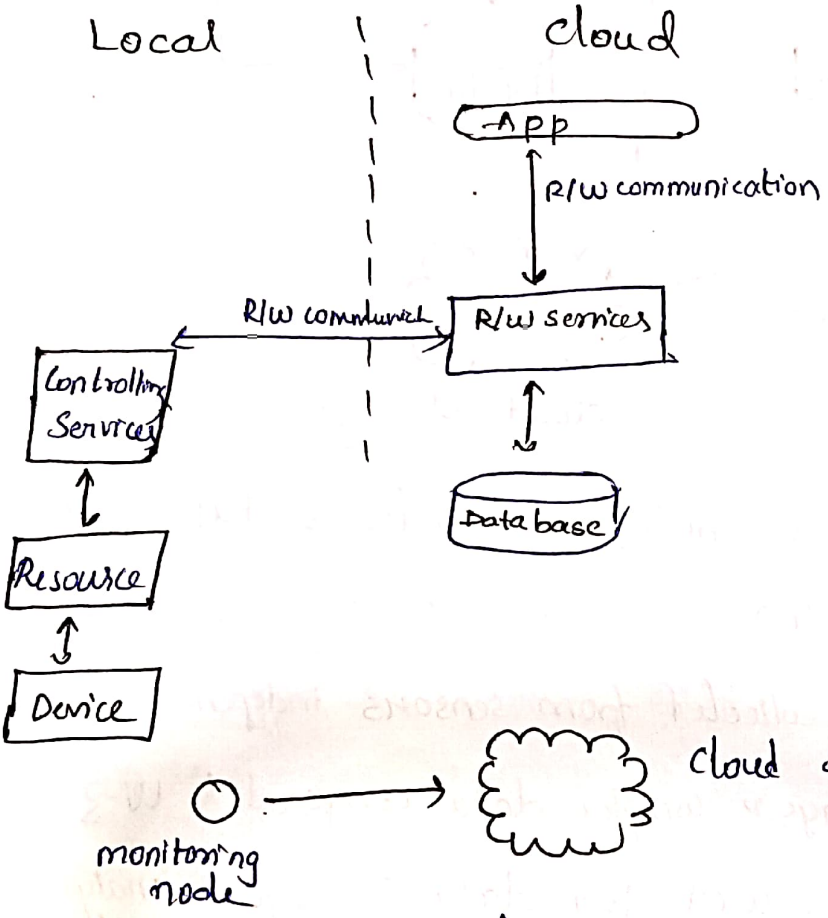
② But It produces large amount of data compared to LV 1

③ So It uses cloud for storage of data produced & locally analyz

④ Both IoT device & user can access data ~~usin~~ from D.B using websocket / REST communication.

⑤ Application is cloud based & user can monitor & control IoT device.

IoT Level-3



① IoT LV-3 uses single node / device that is used for sensing actuating, processing based on collected data & user inputs.

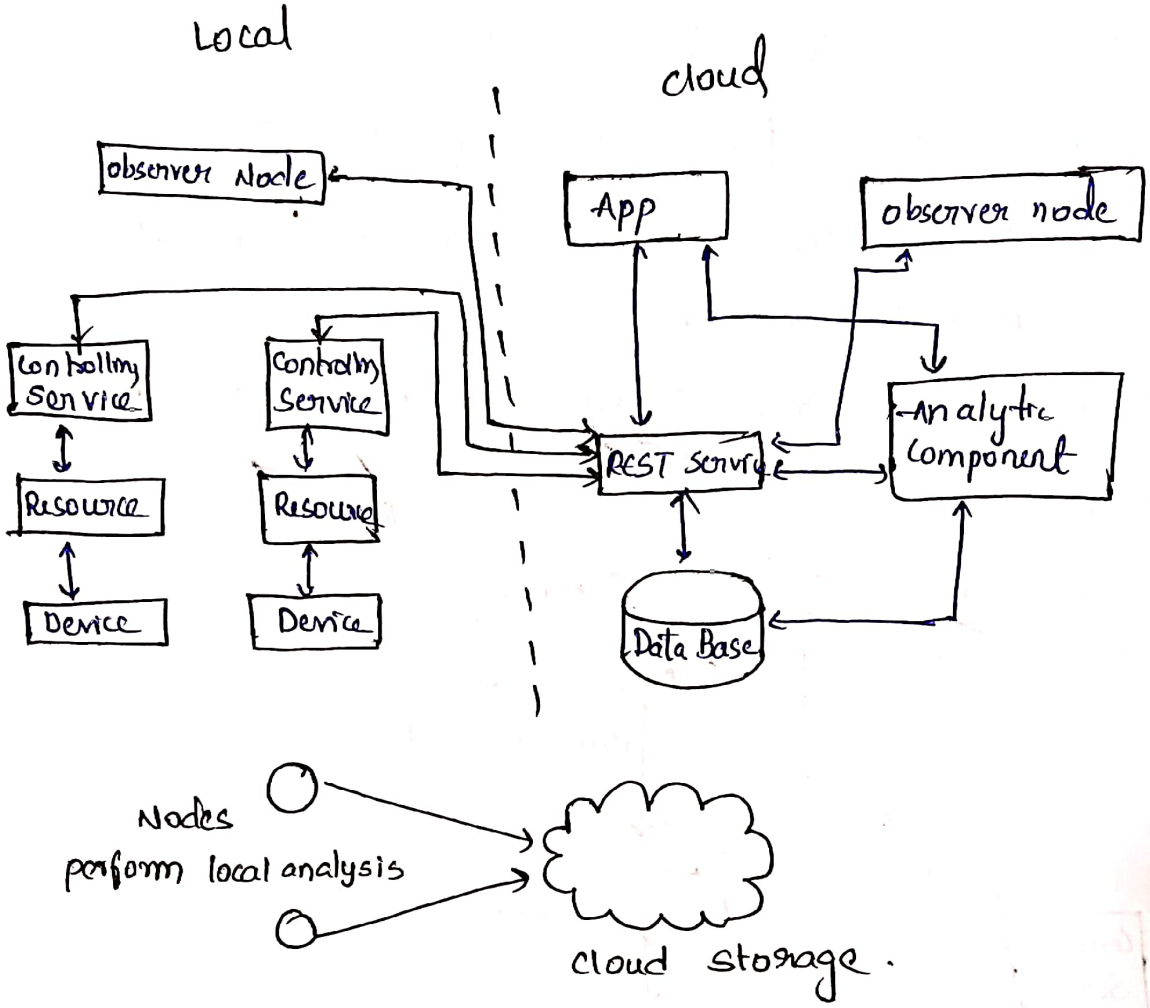
② But It produces large & complex data compared to LV-2

③ So here cloud is used for data storage & analysis.

④ Both IoT device & user can access data from DB using commu- protocol

(5) Cloud based app is used for user inputs & monitoring & controlling IoT

IoT Level-4



(1) IoT Level-4 uses multiple node/devices that is used for sensing different/same quantity, actuating & processing inputs of users & data collected from sensors independently.

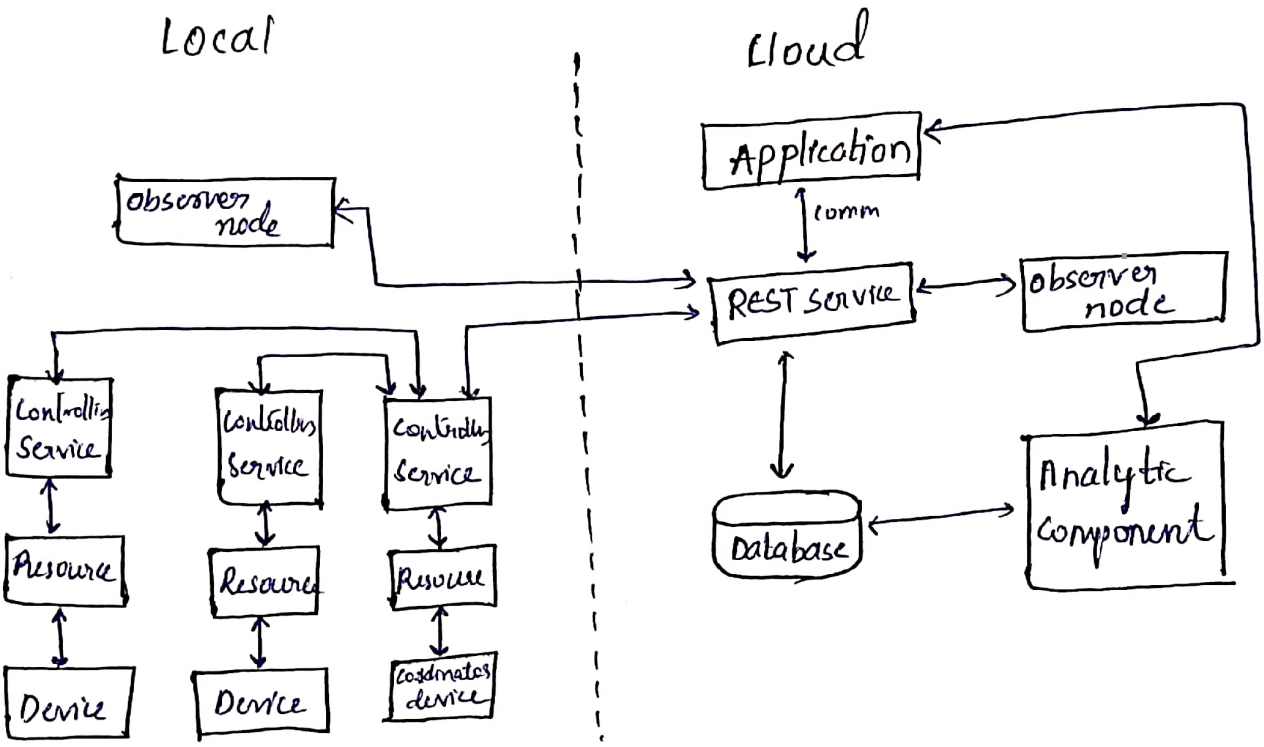
(2) It provides large & complex data compared to LV-3

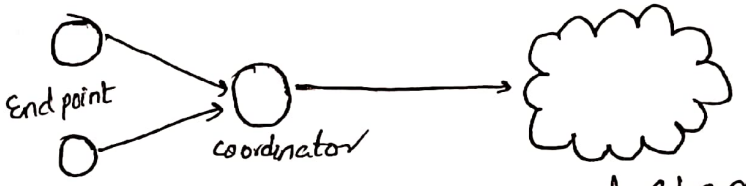
(3) So cloud here is used for data storage & analysis is done locally

(4) All the nodes / IoT devices are connected with database of cloud & application using REST communication.

(5) Cloud based app is used for user inputs & also for monitoring & controlling IoT.

IoT Level-5





Cloud Storage & Analysis.

(1) IoT Level-5 uses multiple nodes/devices that performs sensing, processing user inputs & sensors data, actuation using resources independently & their is one co-ordinator node

(2) It provides large & complex data compared to LV-4

(3) Cordinator takes the data from all nodes & sends to cloud

(4) So cloud here is used to store the data & also to analyze big data using analytic component.

(5) All nodes are connected with database & application using REST communication

(6) Cloud based app used to monitor & control IoT devices (nodes).