05/02/2024

*IOT: Self-configuring capability.

→ Network of physical objects that are embedded with sensors, software and other technologies for the purpose of connecting and exchanging data.

→ Allows objects to be sensed & controlled remotely across network infrastructure.

→ Things: Variety of devices which collect useful data.
  ↳ consists of communication protocol; processing elements and controllers.

→ RFID: Radio frequency identification used to identify the devices.

→ IOT works with the help of communication & cooperation, addressability, identification Sensing, actuation, embedding info. processing, localization, user interfaces.

→ Working depends.
*RFID. : identification
*Sensor : Sensing
*Smart Tech: Enhancing
*Nano Tech: Small materials can be used to connect.

* Benefits of IOT:

→ Monitoring
→ Improve customer experience.
→ Save time & money.
→ Enhance employee productivity
→ Integrate and adapt business models.
→ Generate more revenue.

08/02/2024

* Characteristics:

→ Self - adapting & dynamic.
→ self- configuring
→ Interoperable Communication protocols.
→ unique identity
→ Integrated Information Network:

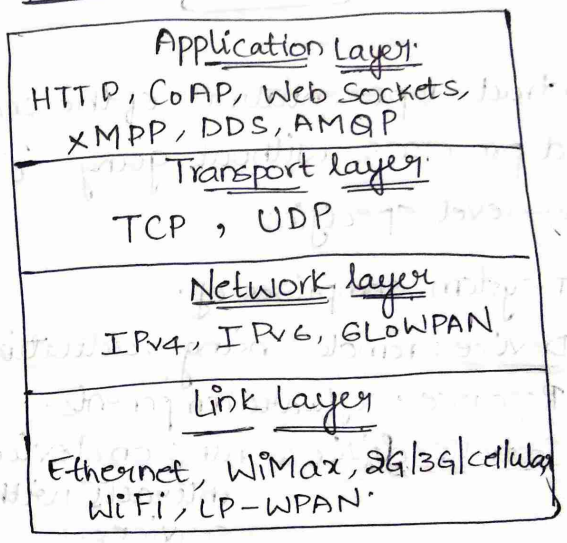
* Physical design of IOT:
  - → Exchange data.
  - → Collect data.
  - → Send data
  - → perform some tasks locally and other tasks based on time & space constraints.

  - → remote sensing
  - → actuating
  - → monitoring

→ Components:
  - → connectivity: Ethernet / USB host.
  - → processor: CPU.
  - → Audio/Video interfaces.
  - → Memory interfaces: NAND/NOR.
  - → Graphics.
  - → Storage Interfaces: SD, MMC.
  - → I/O interfaces: UART, SPI, I2C, CAN

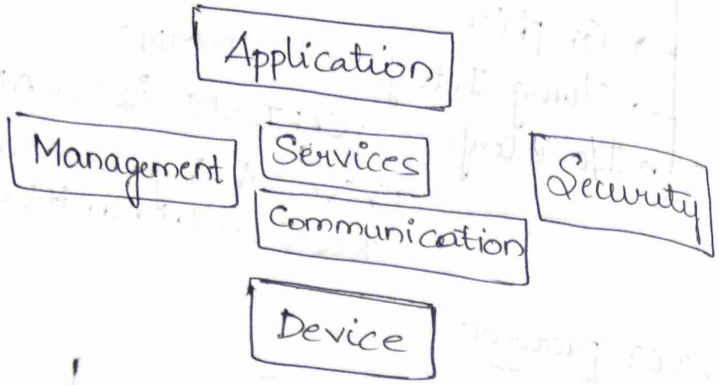
UART: Universal Asynchronous Receiver-Transmitter.

→ IOT protocols:



CoAP: Constrained App. protocol.
AMQP: Advanced Message Queuing Protocol
DDS: Data distribution service.
XMPP: Extensible Messaging presence protocol.

→ Logical Design:



→ abstract representation of the entities and processes without going into low-level specifics.

* IOT system comprises of:
  - Device: remote sensing, actuation, ID
  - Resource: software components.
  - Controller service: runs on device & interacts with web services.
  - Database: storing
  - Web service: REST APIs, works on other servers.
  - Analysis Component: analyze the data using ML algorithms.
  - Application: display interface.

→ IOT Level-1 systems are suitable for modelling

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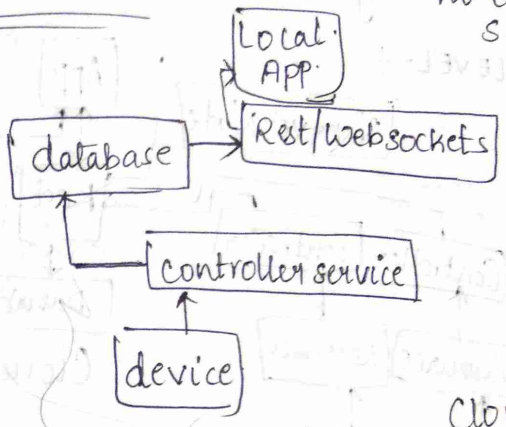
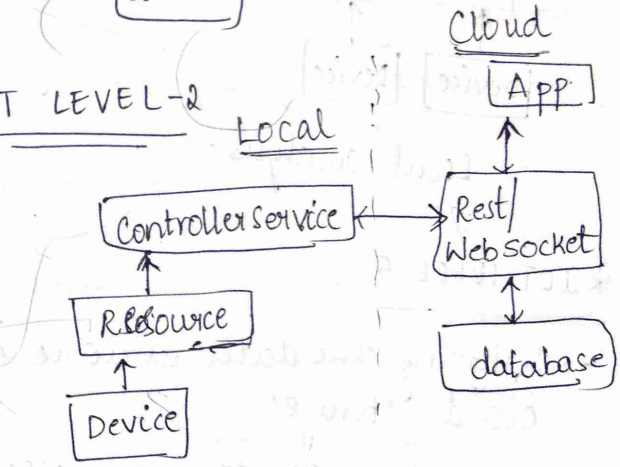
* IOT LEVEL-1 → Less complex and no cloud services.



* IOT LEVEL-2



○ Monitoring & analysis → Cloud Storage.

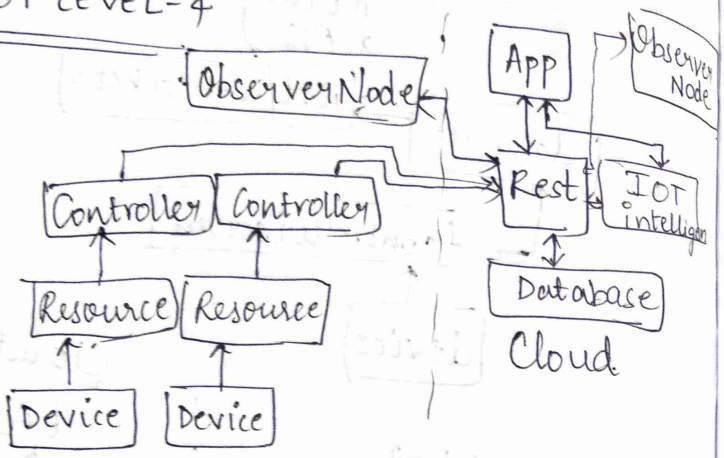
→ Analysing the data using cloud in Local storage.

SIVANI

* IOT LEVEL-3

→ Analyzing the data is done in cloud storage.

* IOT LEVEL-4



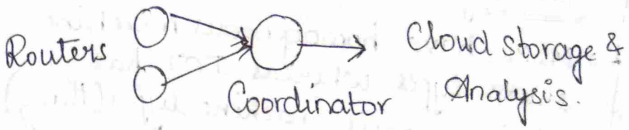
Local analysis.

* IOT LEVEL-5

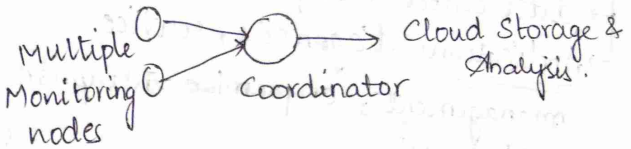
→ Analyzing the data is done in cloud storage.

→ Routers are used for monitoring where coordinator is used to connect routers & cloud.

* IOT LEVEL-5



* IOT LEVEL-6



* → M2M : Machine to Machine

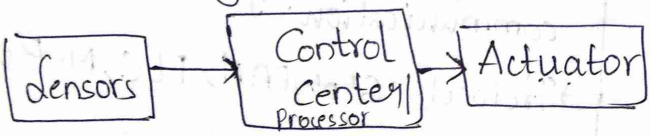
- → refers to networking of machines for the purpose of remote monitoring and control and data exchange.
- → which have embedded hardware modules for sensing, actuation & communication.
- → Protocols : 6LOWPAN, PLC, M-Bus.
- → M2M area networks use either proprietary or) non IP-based communication protocols; IOT uses standardized communication protocols.

- Gateway: Protocol conversion.
- M2M have homogeneous machine types whereas IOT has heterogeneous machine types (thing)
- M2M has more emphasis on hardware.
- data collected in point solutions.
- Applications: diagonosis, service management, on premise enterprise applications.

* IOT emphasizes on software.

Sensors: physical gestures → Sensors → Electrical Signal.

Actuators: Electrical signal → Actuators → Physical actions.



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Characteristics of Sensors:

- Range
- Resolution
- Sensitivity
- Error → Bias, Precision
- Accuracy.
- Precision.
- Repeatability
- Impedance
- Response time.

* Sensor Classification
  - Passive & Active
  - Analog & digital
  - Scalar & Vector

* Actuators Examples: Solenoid, electric motors, hard drive stepper motor, hydraulic cylinders, piezoelectric actuator.

* Classification of Actuators
  - Electric Linear
  - Electric Rotary
  - Fluid Power Linear
  - Fluid Power Rotary.
  - Linear Chain

* SDN (Software Defined Network).

** data plane ⇒ carry data
** contrd plane ⇒ carry control info. (router table).

→ controlling networking devices using software so that VM's can be used instead of purchasing a network devices

Flow program helps to do role of router with VM's data management plane - reading data.

NFV allows VM's to act as router.
Network Function Virtualization.

* Key elements of SDN:
  - Centralized Network Controller.
  - Programmable Open APIs.
  - Standard communication Interface.

. OpenFlow is an SDN protocol for southboard interface.

→ software implemented on NFV infrastructure is VNF (Virtual Network Function).

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* RaspberryPi

- mini-computer model.
- credit card sized.
- plugs into TV (or) monitor.

→ Kit: Board, OS card, USB keyboard, display (HDMI, DVI etc), power supply.

** BCM 2835.

17/02/24

→ Flavours of IOT
  - Cognitive IOT
  - Social IOT

→ SAAS → software as a service.
PAAS → platform as a service → Ex: Vscode etc.
IAAS → infrastructure as a service
  - physical devices

→ Cyber Physical System:
  - Device Management
  - Data Management
  - Control Management

** Sending feedback
** focusses more on device control
** control is within device.

→ Industry 4.0:
  - 4th generation → currently using
  - 1st generation : steam engine industrial revolution

2nd generation : Assembly line (pipelining)

3rd generation : computers were used machines using computerized technology

4th generation : IOT (used efficiency : reduced time & cost
Cyber Security ; AIML techniques.

→ Ultrasonic Sensor: (HC-SR04)
- range (10 feet max)
- distance is measured with the help of ultrasonic way.
- with the help of reflection; these waves transmit & receive.
- 2 points
  - trigger point (start)
  - echo point (end) (receiver)

→ PIR Sensor: Passive Infrared Sensor.
- Infra red signals are sensed in their field of view.
- Pins: Vcc, Gnd, Out.
- used in security alarms & automatic lighting applications.
- produces digital signal as O/P.

19/02/2024

*ARDUINO (C++)
- Program
  - setup (I/P & O/P)
  - loop (execution)

16 digital I/O pins

→ Digital IO is binary valued ⇒ 1(ON) & 0(OFF)

→ Functions:
- pinMode(pin, Mode): I/P / O/P
- digitalRead(pin): High / Low
- digitalWrite(pin, value): High/Low.

→ Arduino uses 1024 states (10 bits)

→ Smallest measurable voltage change = 5V/1024 (or) 4.8mV

→ Max. sample rate is 10,000 times a second.

→ Resolution values range from 2^8 states to 2^{32} states.

→ Analog O/P is simulated using pulse width modulation.

→ On Arduino board; pins 3, 5, 6, 9, 10 & 11 were used for PWM process.

→ 16MHz frequency: clock frequency

→ Pulse Width Modulation: digital to analog

LPWAN ⇒ Low Power Wide Area Network

→ Serial Communication / UART:

- → bit by bit the data is sent over the wire.
- → Commands:
  - → Serial.begin()
  - → serial.print()
  - → serial.read()
  - → serial.available()
  - → serial.write().

Evolution of Mobile Systems:

→ 1G: Analog systems.

→ 2G: Voice Communication
Circuit Switched.

→ 3G: Packet switching for voice & data.
High speed. (UMTS)

18/03/2024

→ Bluetooth: → small range (10m)
↳ low power devices.

→ Range of zigbee is more than wifi and bluetooth. ⇓ used in complete building (cheaper) (automation). ⇓ for a flat.

→ LORA: long distances, small amount of data; low power consumption.
↓ Ex: Smart lighting (street light monitoring)
not a good protocol for on & off.

→ LORA is used in smart meters (water / electricity meters) where only small amount of data can be transferred.

* Companies: developing smart street lights.
Echelon, Ubicquia, Senicity system, Lightricity.

* Sensors used smart street lights.
- → Brightness sensor, humidity / temperature
- → Motion sensor.
- → ambient light sensor

* UNIT-2

19/03/2024

→ Raspberry Pi:

* Board Components:
- → CPU: ARM processor.
- → RAM: for running programs.
- → GPIO pins: I/O pins for interfacing with external hardware.
- → USB ports: for connecting peripherals
- → Ethernetport / WiFi: for network connectivity.
- → HDMI port: for connecting displays.
- → MicroSD card slot: for storing OS & data.

→* Linux provides a familiar environment for developers and users, offering access to a wide range of tools & software.

→*
```
import RPi.GPIO as GPIO
import time
LED_PIN = 18
GPIO.setmode(GPIO.BCM)
GPIO.setup(LED_PIN, GPIO.OUT)
try:
    while True:
        GPIO.output(LED_PIN, GPIO.HIGH)
        time.sleep(1)
```

```
        GPIO.output(LED_PIN, GPIO.LOW)
        time.sleep(1)
except KeyboardInterrupt:
        GPIO.cleanup()
```

* Arduino Uno Platform:

→ Micro-controller board based on ATmega328P.

→ programmed using ~~C/C++~~ Arduino IDE typically in C/C++.

→ has digital and analog pins for interfacing with sensors, actuators & other devices.

→ Code:

```
const int ledPin = 13;
void setup()
{ pinMode(ledPin, OUTPUT); }
void loop()
{ digitalWrite(ledPin, High);
  delay(1000);
  digitalWrite(ledPin, Low);
  delay(1000); }
```

* Architecture for IoT using Mobile Devices:

→ 3 layers:
- Perception layer
- Network layer
- Application layer.

→ Mobile devices acts as gateways/endpoints for collecting data from sensors; process it & communicate it to the cloud (or) other devices.

→ Mobile Technologies:

* Bluetooth: used for short range communications such as connecting smartphones to IoT sensors.
* Wifi: provides high speed internet connectivity over short to medium ranges.
* Cellular Networks: Enable IoT devices to connect to the internet over long distances using 4G & 5G.

→ 5G:
- higher data speeds; lower latency.
- increased capacity to previous generations.
- higher bandwidth, real-time communication

Ex: autonomous vehicles, smart cities etc.

* Software - Defined Networking:
  - separates control plane from data plane in network devices.
  - allowing centralized management & programmability of network infrastructure.
  - In IoT, SDN can dynamically allocate network resources based on application requirements, optimize traffic routing & enhance security.

* Ultra Wide Band Technology:
  - high speed, short-range wireless communication with precise positioning capabilities.
  - Suitable for indoor asset tracking, location-based services.
  - proximity detection.

* Near Field Communication (NFC) Technology:
  - allows devices to communicate over short distances.
  - used for contactless payments, access control systems and pairing IoT devices with smartphones.

* Low Power Wide Area Networking Technology:
  - designed for low-power, long-range communication with IoT devices.
  - enable battery-powered devices to operate for years on a single charge while transmitting small amounts of data.
  - * Sigfox: long range comm. with low power consumption, Suitable for asset tracking & smart metering.
  - * Weightless: optimized for low-power, wide area IoT applications, providing connectivity over long distances with low infrastructure costs.
  - * LoRa: based on spread spectrum modulation, offering long range communication & high interference immunity. Used in smart agriculture, environmental monitoring & industrial automation.

UNIT-3

→ Layered Architecture of IoT:
  - Perception layer: collects data.
  - Network layer: comm. b/w devices & cloud/other services
  - Middleware layer: services like data processing, Security & device management
  - Application layer: implements specific IoT apps.

→ Protocol Architecture of IoT:

- Application layer: MQTT, CoAP, HTTP.
- Transport layer: TCP, UDP.
- Network layer: IPv6, 6LoWPAN
- Data link layer: IEEE 802.15.4; Bluetooth
- Physical layer: Zigbee, Z-wave.

*→ IEEE 802.15.4:

- low rate wireless personal area networks.
- providing physical & MAC layer for short range communications.
- used in Zigbee & 6LOWPAN

*→ IPv6 over 6LoWPAN:

- 6LOWPAN enables the transmission of IPv6 packets over low-power wirless networks.
- suitable for resource-constrained devices.

*→ Parallel Redundancy Protocol:

- fault-tolerant networking protocol used in industrial automation.
- provides high availability & reliability by sending duplicate packets over independent paths.

*→ Bluetooth low energy:

- low-power wireless communication technology designed for short-range communication between devices.
- used for smart home devices, wearables etc.

*→ Long Term Evolution Advanced (LTE-A):

- provides high speed mobile broadband connectivity with improved performance and efficiency.
- enables IoT applications requiring high bandwidth & low latency

*→ Radio Frequency Identification (RFID):

- uses radio waves to identify & track objects equipped with RFID tags (or) transponders.
- used in logistics, supply chain management, asset tracking applications.

*→ Z-wave:

- wireless communication protocol used for short range networking apps
- home automation, industrial control

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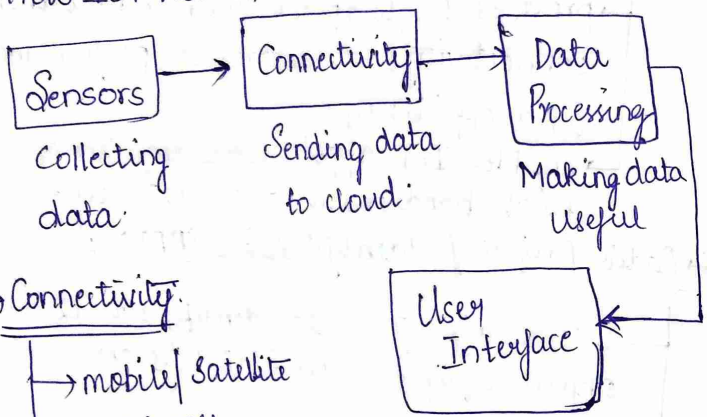
→ UNIT-1 (INTERNET OF THINGS)

* IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers & ability to transfer data over a network.

* How IoT works?



* → Connectivity
  - → mobile/satellite networks
  - → Bluetooth, Wifi, LoRa, WAN etc

* Benefits of IoT:
  - → monitor business processes
  - → improve the customer experience
  - → save time & money
  - → make better business decisions
  - → generate more revenue

→ IoT helps in collecting and sharing data easily with the help of low-cost computing, big data, analytics with minimal human intervention.

* Applications of IoT:
  - → Smart Thermostats
  - → Connected cars
  - → Activity Trackers
  - → Parking sensors
  - → Connect Health
  - → Smart city

* Challenges of IoT:
  - → Insufficient testing & updating
  - → Concern regarding data security & privacy
  - → software complexity
  - → data volumes & interpretation
  - → Integration with AI and automation
  - → Interaction & short range communication

* Advantages of IoT:

- Access info from anywhere
- improved communication b/w connected electronic devices.
- transferring packets over internet and saving time & money
- improved quality of business

* Disadvantages of IoT:

- Stealing of confidential info.
- Millions of IoT devices ⇒ maintainence would be difficult.
- Bugs would lead to corruption.
- compatibility issues

* Characteristics of IoT:

- Unique Identity
- Dynamic Nature
- Self-adopting
- Self-configuring
- Scalability
- Safety.

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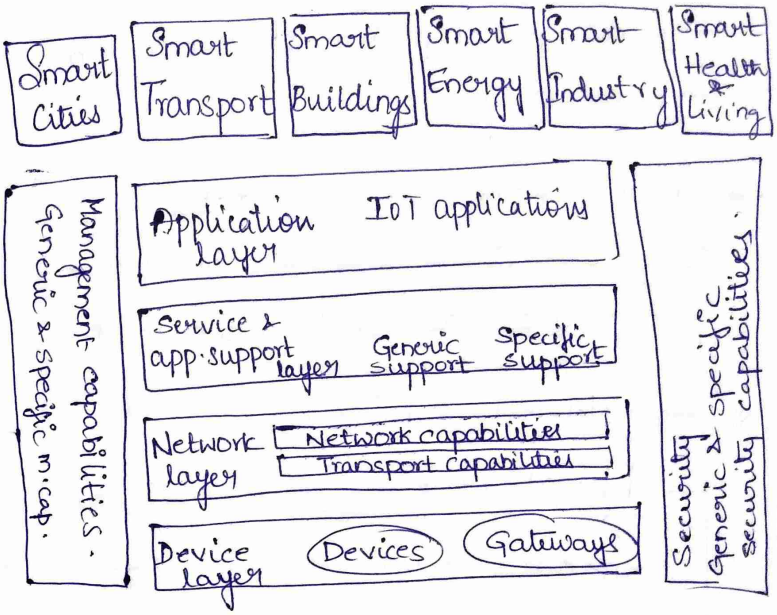
→ IoT reference architecture:



→ Sensor and Actuator Network (S2AN)

* Sensor gateways, middleware, brokers, adaptors, connectors, drivers and controller are being leveraged which use sensor data fusion algorithms.
* Actuators accomplish the execution based on sensor findings.

* Sensor to Cloud Network (S2CN)

→ Combines a WSN and cloud computing, extending the capacity of traditional networks for computing, storage, comm. and scalability.

→ Sensor network collects the data, and complex functions like data analysis & processing are also sent to the cloud.

* Sensor Network consists of
  - → physical node layer: sensors take the data from surrounding.
  - → Virtual node layer: data collected on the sensor is virtualized on the cloud computing platform. Provide real-time info from their physical counterparts.
  - → user interface layer: Users view the stored data from the cloud. Multiple users can view the data on the cloud.

* Cloud Storage improves the data management.

  It stores, analyzes, visualize, store and share large quantities of data.

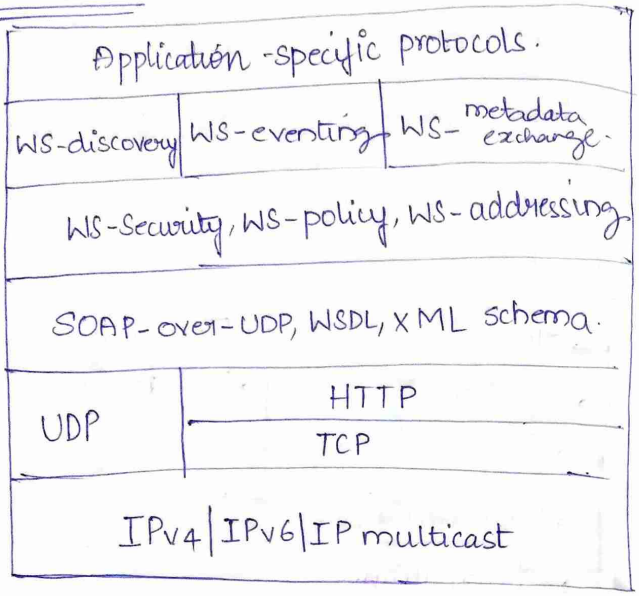
* Advantages:
  - → Analysis.
  - → Scalability
  - → Collaboration
  - → Visualization
  - → Automation
  - → Flexibility
  - → Multitenancy
  - → Security
  - → Cost
  - → Installation.

* IoT device integration:
  - → M2M: 5G, UWB, NFC etc.
  - → SODA for device integration:
    - ↳ service based device integration
  - → Device Profile for Web Services:
    - ↳ REST - less (or SOAP messages.

* Device Profile Web Service: (DPWS)
  - ↳ Standard for service design, development deployment & integration

for all kinds of devices.

* OSI model:



* Open Gateway System Interconnect (OGSi).

→ OSGi framework sits on top of a JVM and is execution environment for services.

→ consists of following parts.

- Standard for building modular components called bundles (or) plugins.
- JVM.

OSGI: Open Service Gateway Initiative.

→ Services need to be executed as Java bundles on the central gateway.

→ The topology, which describes the network setup of a device-centric SOA is star topology.

* Environments to Explore:

→ Eclipse: platform for building IoT gateways.

- remote management of gateways
- provides wide range of APIs.

→ OpenHAB: software to integrate different home automation systems & technology into a single sol^{n}.

* Device Integration protocols & middleware:

→ MQTT: collecting device data & sending it to the server.

→ XMPP: best protocol for connecting devices to ppl.

→ AMQP: queuing system designed to connect servers.

→ CoAP: optimized protocol.

* Message Queue Telemetry Transport (MQTT)

→ Publish/Subscribe based light-weight messaging protocol used along with TCP/IP protocol.

→ Provides connectivity b/w applications on one side and networks on other side.

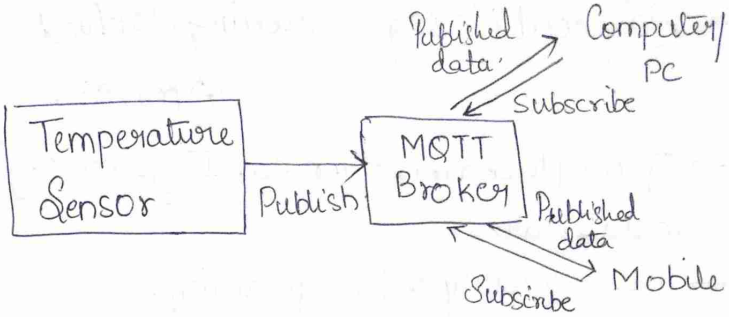
→ Components:

① Publisher: lightweight sensors.
② Subscriber: Applications waiting for sensor data.
③ Broker: Interface.

→ Methods:

* Connect ; Disconnect (Connection to server)
* Subscribe ; unsubscribe (Client → topics)
* Publish (Update)

Ex: +, #, $ → wild cards



→ myhome/groundfloor/living room/temp.
topic topic
topic level Separator

myhome/GF/+/temp
↓
single level wildcard.

myhome/groundF/#
↓
multi-level wildcard.

→ MQTT using Node-Red:

- MOSCA : Nodejs MQTT Broker & Server
- useful for simple testing & automation.
- Simple.

(*)
- MOSCA : Node-Red as a Pallet node.
- Configure MQTT broker – Publish & Subscribe
- Include the inject & debug nodes.

• Deploy & see the comm.

→ MQTT is used as an M2M protocol

* Advanced Message Queuing Protocol (AMQP).

→ Open replacement for existing messaging middleware.

→ uses: reliability & interoperability

→ binary wire protocol

→ Applications:

- → JP Morgan use it to process billion messages
- → NASA: Nebula cloud computing
- → Google: complex event processing
- → India: Messaging platform for Aadhar project

AMQP	MQTT
→ wide range messaging systems.	→ used in embedded systems.
→ uses TCP for asynchronous transfer with use of intra & N/w	→ uses TCP for asynchronous transfer with min. ~~band~~ BW over N/w
→ Uses Buffering for performance improvement of servers.	→ Executes frames for min. memory devices.
→ Supports diff transactions use cases along with message queues.	→ Doesn't support any kind of transaction & provide only acks.
→ Supports SASL for authentication	→ Supports basic authentication ~~with~~

* Representational State Transfer (REST):

→ uniformly accessing & modifying a resource.

→ uses: URIs: identify objects
HTTP verbs: specify an action
JSON: represent the object

→ loosely coupled systems and stateless.

→ compared to SOAP:

- → less overhead
- → low parsing complexity
- → statelessness
- → integration with HTTP

* RESTful Web Service	RESTless Web Service
→ provides interoperability	→ based on REST principles
→ REST	→ SOAP
→ data formats: HTML, JSON etc.	→ XML format.
→ use URL to expose business logic.	→ use service interface to expose business logic.
→ less BW & resource.	→ More BW & resource.
→ Easy & flexible	→ Not

* Constrained Application Protocol (CoAP)

→ Web transfer protocol for use with constrained nodes & network.

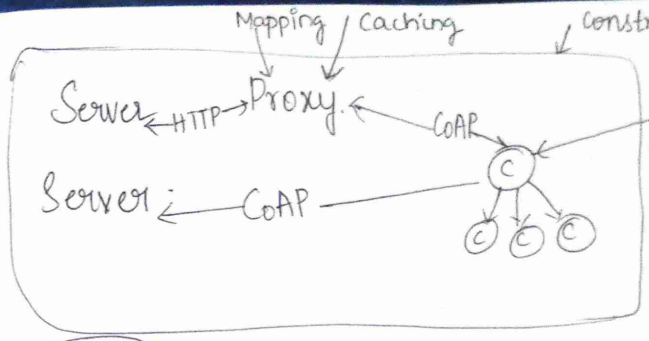
→ M2M appli = Smart energy & building automation

→ Request-Response Model

→ Client-server interaction is asynchronous over a datagram oriented transport protocol (UDP)

→ Session layer protocol to provide lightweight RESTful HTTP interface.

→ enables low power sensors to use REST services



Slide 25

→ Architecture divided into 2 parts:

- → Messaging: reliability & duplication of messages.
- → Req/Res: Communication
- → 4 messaging modes.
  - → Confirmable
  - → Separate
  - → Non-confirmable
  - → Piggyback

IoT Middleware.

Slide 29