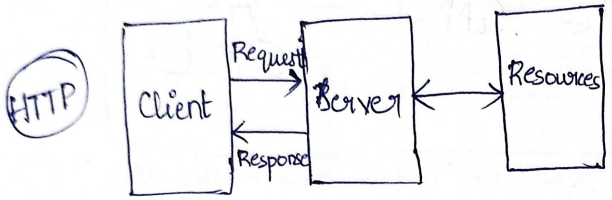
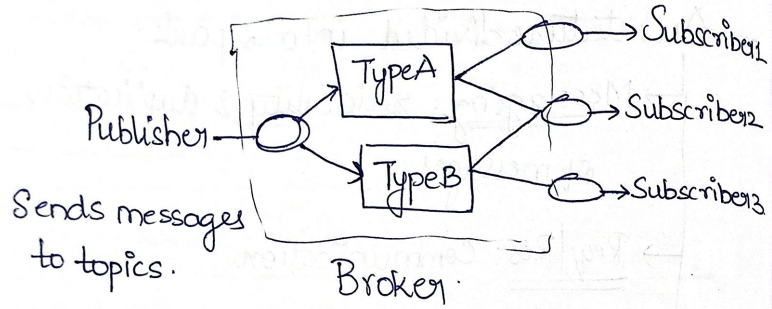
*IoT Communication Models:

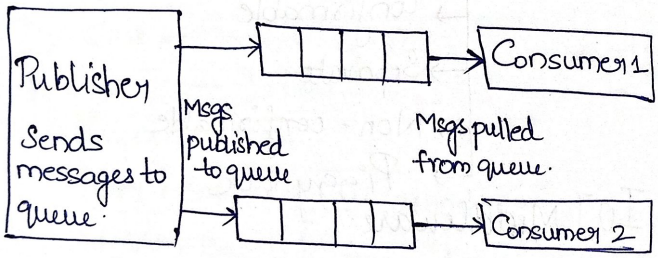
→ Request - Response Model: (Stateless communication)



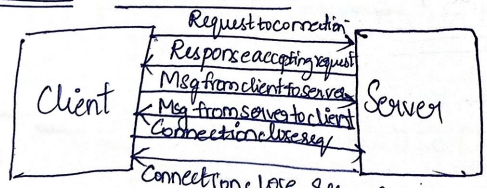
→ Publish - Subscribe Model:



→ Push - Pull Model:



→ Exclusive - Pair Model: (bidirectional)



*IoT Communication APIs:

→ Rest - based communication APIs.

→ Web - socket based communication APIs.

*→ Rest architectural constraint:

- → Client - Server
- → Stateless
- → Cache - able
- → Layered system.
- → Uniform interface
- → Code on demand.

*→ Web Socket - based Communication APIs:

- → these follow the exclusive - pair communication model.
- → The request (websocket handshake) is sent over HTTP & the server interprets it is an upgrade request.
- → most suitable for IoT Communication.

*→ IoT Enabling Technologies:

- → Wireless Sensor Network.
- → Cloud Computing
- → Big data analytics.

- Communication Protocols
- Embedded Systems.

→ Wireless Sensor Networks:

Ex: Indoor Air Quality Monitoring System; Weather Monitoring System; Soil Moisture Monitoring System, Surveillance Systems, Health Monitoring Systems.

*→ Protocols: IEEE 802.15.4, Zigbee.

Data rate: 250KBps; Range: upto 100 meters.

→ Cloud Computing:

* Deliver applications & services over internet.
* provides computing, networking & storage resources on demand.

*→ Types of Cloud computing Services:

- Infrastructure as a Service (IaaS): Web hosting
- Platform as a Service (PaaS): App cloud
- Software as a Service (Saas): Google docs

• IaaS: can use storage to install & manage OS.

• PaaS: clients can install, build & modify apps.

• SaaS: clients can access & use software at remote location.

*→ Benefits:

→ Automated backups & upgrades
→ Multi-tenant solution provided by vendor
→ Modern web based integration
→ Web and mobile access from anywhere.

→ 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.

- Data cleansing → Correcting, Removing, Replacing.
- Data munging → Converting data from one format to other.
- Data processing
- Data visualization

*→ Variety: structured, semi-structured, text, audio, video.

*→ Volume: amount of data.

*→ Velocity: refers to speed at which data is processed.

→ Communication Protocols:

* allows devices to exchange data over networks.
* define data exchange formats:
  - → data encoding
  - → addressing schemes.
  - → routing of packets from sources to destination.
* other functions:
  - → sequence control
  - → Flow control
  - → retransmission of lost packets.

→ Embedded Systems:

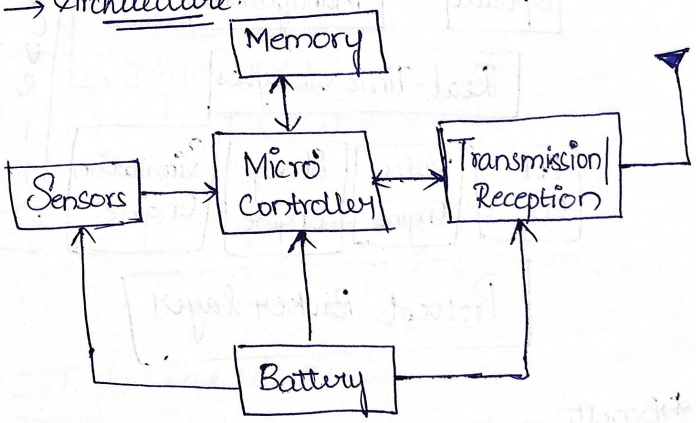
* designed to perform a specific task.
* independent system or a part of a large system.
* Applications:
  - → Industrial Robots.
  - → GPS receivers.
  - → Digital Cameras.
  - → DVD players
  - → Wireless Routers
  - → MP3 players
  - → Set-top boxes
  - → Gaming consoles.

* Key components:
  - → Microprocessor/micro-controller.
  - → Memory (RAM, ROM)
  - → Storage
  - → Networking units
  - → I/O units.

* SENSOR:

Ex: Ultrasonic Sensor, Gas sensor, Color sensor, PIR Sensor, accelerometer, potentiometer.

→ Architecture:



→ Active Sensors: requires an external source of power to operate.

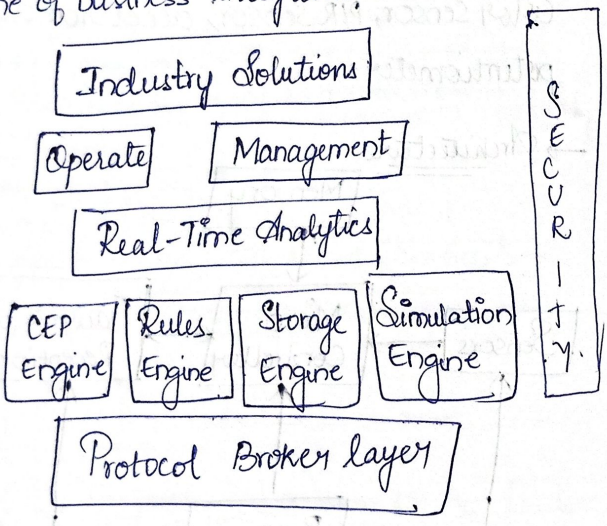
Ex: Smoke Sensor.

→ Passive Sensors: does not requires an external source of power to operate.

Ex: Thermometer.

* IoT : Platform as a Service:

Goals:
- → Event data collection
- → Data security & privacy.
- → Real time analytics.
- → Line of business integration.



* → Benefits:
- → provides common infrastructure to obtain value from industrial technologies
- → Enable uniform communication, security, analytics, etc.
- → provide simpler and more agile models for building industrial IoT solutions.

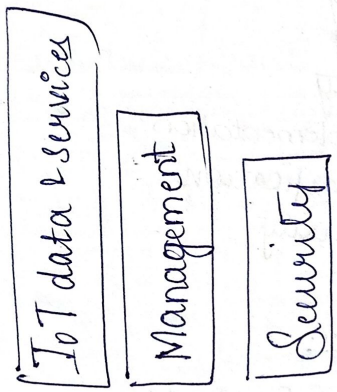
* → Everything as a Service means anything can now be a service with the help of cloud computing and remote sensing.
- → Advantages:
  - → Cost Saving
  - → Scalability
  - → Accessibility
  - → Faster Implementation.
  - → Quick Modification
  - → Better Security
  - → Flexibility.
- → Disadvantages:
  - → Internet Breakage
  - → Slowdown
  - → Difficult in Troubleshoot
  - → Change brings problem.

* IoT data characteristics:
- → Massive volumes of data streams.
- → Variety of data sources.
- → data structures (or) schemas

* IoT data processing requirements:

- → Capture
- → Interoperate
- → Analyze
- → Act.

* Functional Layers:

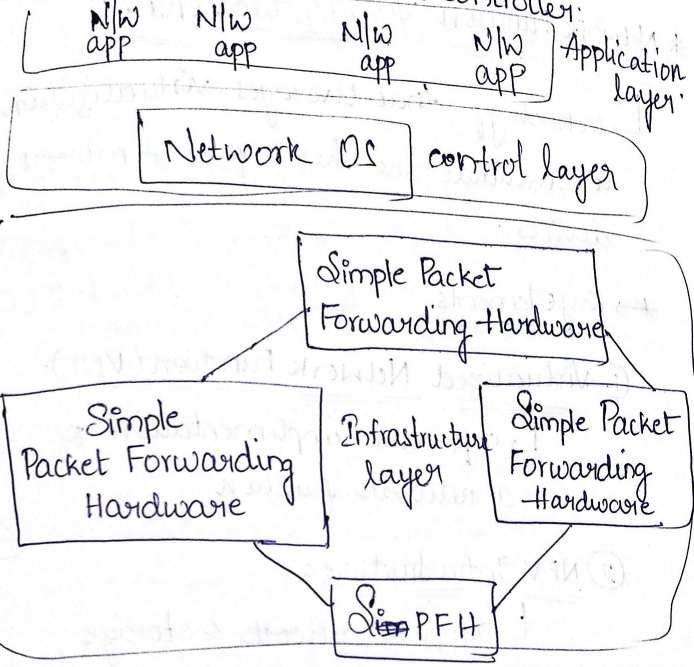


Business layer
Application layer
Data & Information layer
Service Support layer
Communication layer
Resource Layer
Asset layer.

* IoT	M2M
→ uses IP protocols.	→ uses Non-IP based protocols.
→ Things in IoT refer to physical objects.	→ machines are used.
→ Software based.	→ Hardware-based.
→ Data is collected into cloud.	→ Data is collected in point sol^{n}s.

* Software Defined Networking:

→ Separates control plane and data plane and centralizes network controller.



* Key Elements of SDN:

① Centralized Network Controller
- ↳ configure network

② Programmable open APIs:
- ↳ used as interface b/w SDN applica and control layers. (Northbound interface)

③ Standard Communication Interface:
- ↳ used as interface b/w

control and infrastructure layers (southbound)
↳ OpenFlow is an accepted SDN protocol.

* Network Function Visualization (NFV):
↳ technology that leverages virtualization to consolidate the heterogeneous network devices.

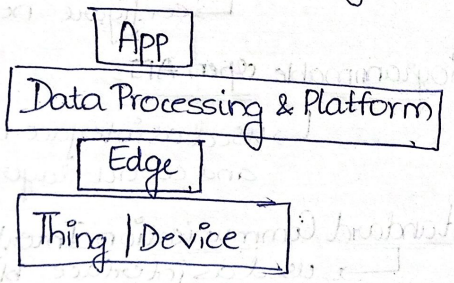
*→ Key Elements:

① Virtualized Network Function (VNF):
↳ software implementation of a network function

② NFV Infrastructure:
↳ compute, network & storage resources.

③ NFV Management & Orchestration:
↳ focusses on management tasks.

* IoT Stack:



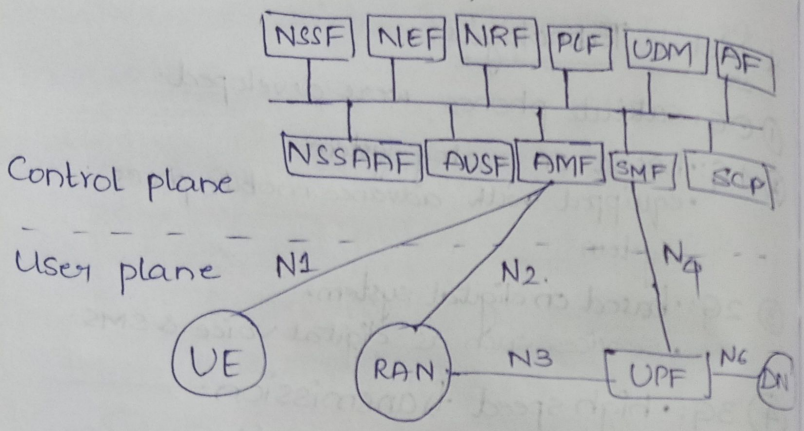
→ Thing / Device: Sensors, hardware / firmware
→ Device Edge: Device Hub & Device Management.
→ Data Processing: API design / build, Runtime management,
→ App: websites

* Mobile Technologies:

① 0G: satellite phones were developed.
② 1G: • based on analog system.
• equipped with advance mobile phone system.
③ 2G: • based on digital system.
• services such as digital voice & SMS.
④ 3G: • high speed transmission.
• advanced multi-media access.
• video conferencing support.
→ telemedicine, wireless advertising
⑤ 4G: • provides very smooth global roaming
• larger bandwidth for data sharing
→ traffic control; disaster management.
⑥ 5G: • UWB networks - higher BW at low energy levels.
• Bandwidth: 4000 Mbits/sec.
• Smart antennas.
• CDMA.

- wireless network including wireless LAN/WAN/PAN
- data bandwidth: 1 Gbps / higher
- low cost

5G architecture



* Key features:

- SDN:
  - Better user experience
  - Easily Programmable
  - Reduced complexity
- NFV: provide specific network related services.

* SDN operation:

- Control plane: logic for controlling forwarding behaviour
- Data plane: forward traffic acc. to control plane logic.

* LPWAN Network Topologies:

- Direct Device Connectivity:
  - base station that provides connectivity to many devices.
  - base station is responsible for translation of protocol from IoT protocols to device application protocols.
- Indirect device connectivity:
  - a local gateway is used which runs on main power
  - gateway has the capability to convert SRD (software defined radio technologies) to LPWAN technology.
  - Eg: Sigfox

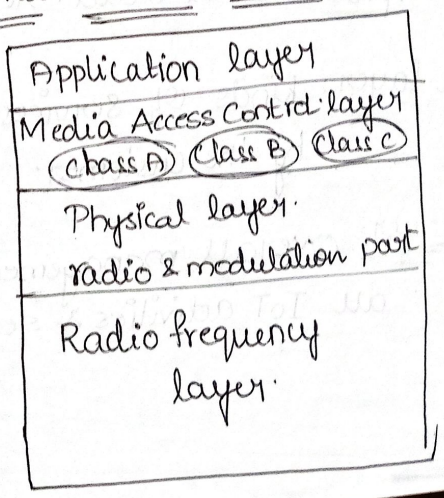
* Sigfox:

- Short range local connectivity
- Star topology for long range radio connectivity
- Used for applications that send small bursts of data.

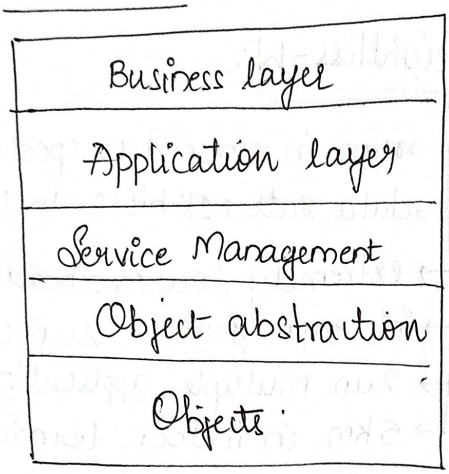
→ Ex: Alarm Systems, location monitoring systems & simple metering systems.
→ does not support bi-directional networks.
→ transmission range: 868/915 MHz frequency bands.

* Weightless:
→ open LPWAN standard.
→ 3 types: P, N, W
→ Weightless-P:
→ bi-directional communication.
→ provides.
→ committed performance rate
→ network reliability
→ security parameters
→ Low cost
→ Weightless-N:
→ one way communication
→ long battery life
→ low network cost.
→ star network architecture
→ provides
→ range of several kms.
→ low power consumption.
→ Supports encryption & authentication
→ Weightless-W:
→ runs in unused TV spectrum.
→ data rate: 1K bit/s to 10M bit/s
→ extremely low overhead.
→ interrupt feature supported.
→ run multiple applications.
→ 5 km in indoor terminals.

* LoRa (Long Range Radio)
→ targetted for M2M & IoT networks.
→ based on spread spectrum modulation.
→ LoRa end node consists 2 parts:
→ Radio module with antenna.
→ microprocessor.
→ LoRa Protocol Stack:



* Layered Architecture Of IOT:



Objects: Sensors.

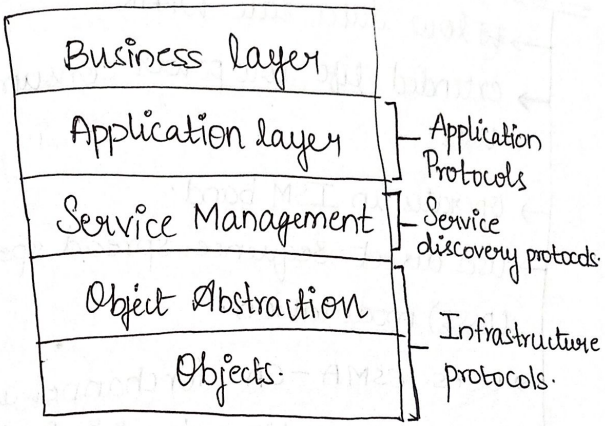
Object Abstraction: transfer data collected (RFID, 3G, WiFi, Infrared. to service management layer.

Service Management: Middleware for IoT systems & processes the data received.

Application layer: kinds of services requested by the customer.

Business layer: overall management of all IoT activities & services.

* Protocol Architecture Of IoT:



→ Infrastructure protocols:

↳ Routing protocols: low power lossy networks include WPANs, low power-line networks and wireless sensor networks.

↳ capability to optimize & save energy.
↳ capability to support traffic patterns.

*→ Application Protocols: DDS, CoAP, AMQP, MQTT, XMPP.

*→ Service discovery: mDNS, DNS-SD.

Routing protocol: RPL

*→ Network layer: 6LoWPAN | IPv4, IPv6.

*→ Link layer: IEEE 802.15.4

*→ Physical / device layer: LTE-A, IEEE 802.15.4, Z-wave.

* IEEE 802.15.4:
  - low data rate WPAN.
  - extended life low power consumption uses.
  - Operates in ISM band.
  - uses direct sequence spread spectrum (DSSS) modulation.
  - Uses CSMA-CA for channel access.
  - Power consumptions is minimized due to infrequently occurring very short packet transmissions.
  - topologies used are star, mesh; cluster-tree.
  - supports 2 types of nodes:
    - Full function devices.
    - Reduced function devices.

* IPv6 over 6LOWPWAN:
  - allows low power devices to connect to the internet.
  - IPv6 packets compressed and reformatted to fit the IEEE802.15.4 packet format.
  - uses include IOT, smart grid, M2M applications.

* Radio Frequency Identifier: (RFID)
  - Data is encoded in RFID tags; which can be read by a reader.
  - RFID tag consists of an integrated circuit and an antenna.
  - • Passive tags must be powered by reader.
    • Active tags have their own power supply.
  - derived from automatic identification and data capture (AIDC).
  - RFID uses radio waves to perform AIDC functions.

* Zigbee:
  - deployed enhancement of IEEE 802.15.4.
  - wireless sensor networks using mesh topology ⇒ (Use).
  - Features:
    - Low Power, low cost
    - Components:

① Zigbee End device:
- contains just enough functionalities
- enhances battery life.
- Memory requirements & cost of ZED are low.

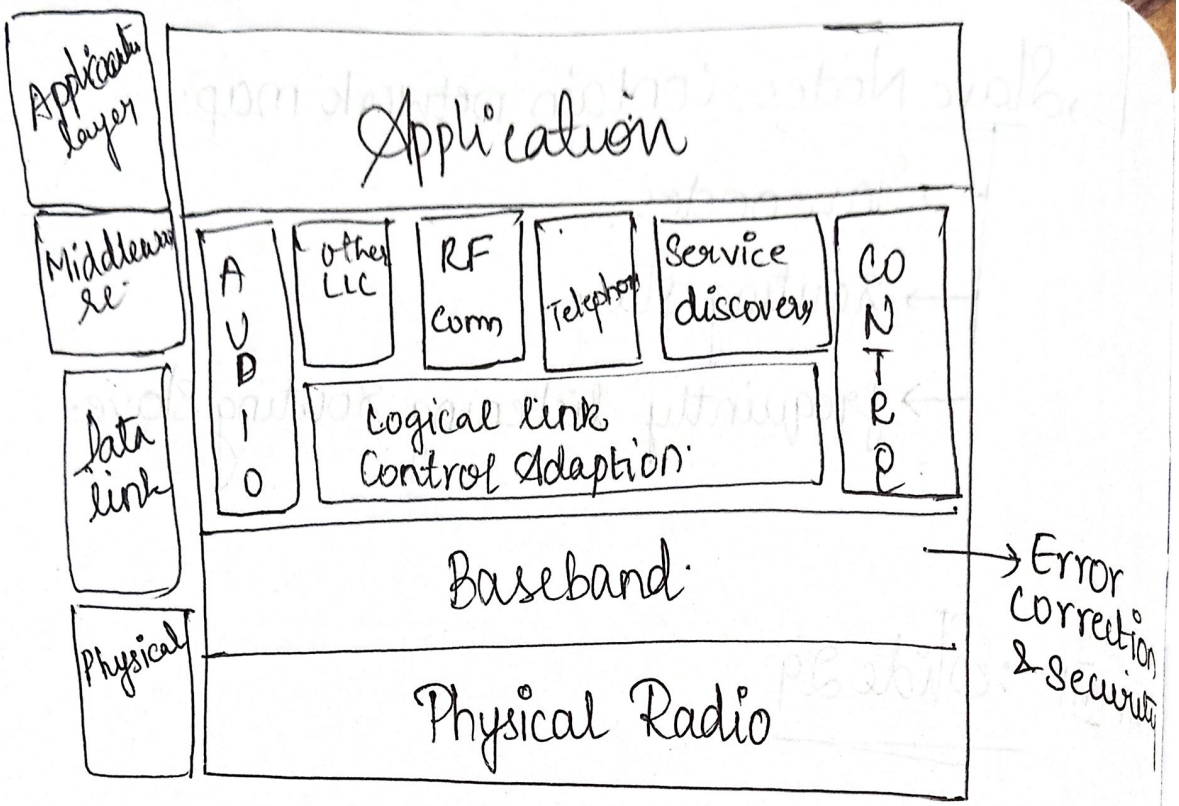
② Zigbee Router:
- running applications, relaying information.

③ Zigbee Coordinator:
- Responsible for selecting channel, PANID, Security policy.
- Responsible to start a zigbee network.

* Z-wave:
- low power wireless communication protocols.
- operates typically around 900 MHz.
- low powered mesh networking topology
- Components are controllers, slave nodes.
  - Controllers: build routing table
    - Types:
      - Primary Controller
      - Secondary Controller.
  - Slave Nodes: Contain network map.
    - Slave nodes
    - routing slave
    - frequently listening routing slave.

UNIT-III : Slide 29

* Bluetooth:
- wireless technology for short range communications.
- maintains high levels of security.
- operates in industrial, scientific & medical (ISM) band at 2.4 to 2.485 GHz.
- supports 1 Mbps data rate for version 1.2 & 3 Mbps for version 2.0 combined with error data rate.
- Modes of Operation:
  - Active
  - Sniff: sleeps and only listens.
  - Hold: Power-saving mode.
  - Park: Slave will become inactive.



* Bluetooth low energy:

→ uses short range radio with min. power and operates for a long time.

→ latency of BLE is 15 times is lesser than that of conventional bluetooth.