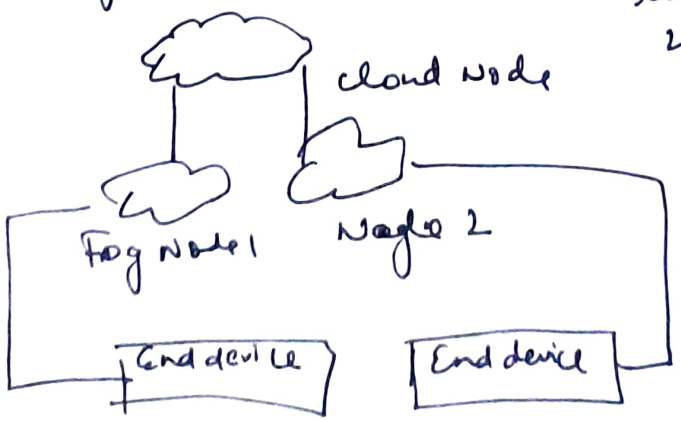
UNIT-1

⇒ FOG COMPUTING

Use of Emerging technologies like IOT, On line applications and popularity of Social Networking are leading to Increase of No of users on Internet. Hence data generated on daily basis is also increasing at an Enormous rate leading to Increase workload on cloud. Also demand for Increased Bandwidth & need for real time applications also Increasing. FOG COMPUTING is a technology Introduced to collaborate with cloud computing for providing solutions. It

Fog Computing is a technology in which resources like compute, data, Storage and applications are located in b/w the End user layer (where data is generated) & the cloud. Devices like gateway can be configured as fog devices

Fog Computing is term Coined by Cisco (2014) that refers to Extending Cloud Computing to an edge of the Enterprise N/W. It facilitates the Operation of computing Storage & N/W Services b/w End users & devices and computing data Centres. After this gained little popularity, IBM 2015 Coined a Similar term Edge Computing



1) The device composing the fog infrastructure known as fog nodes
2) In fog computing, all the storage capabilities, data along with applications are placed b/w cloud & the Physical Host.
3.) All these functionalities are placed more towards the host. This makes processing faster as it is done almost at the place where data is created
4.) It Improves the efficiency of system.

COMPONENTS OF FOG COMPUTING

1.) Physical & Virtual Nodes (end devices) :-
It serve as the points of contact to real world like Mobile phones, sensors.

2.) Fog Nodes :-
It is independent device that pick up the generated Information. Fog Nodes fall under 3 categories:
devices, Servers & gateways.

3.) Monitoring Services :-
It Includes API that keep track of system's performance & resource Availability

4.) Data processors :-
These are programs that run on fog Nodes. They filter, form & even reconstruct faulty data that flows from End devices.

5) Resource Manager :-
It allocates & deallocates resources to various Nodes & Schedules data transfer b/w Nodes & Cloud
It also take care of data backup.

6.) Security tools :-
Since fog components directly Interact with raw data sources, Security must be built

7) Applications :-
It provides actual services to End users.

→ ADVANTAGES OF FOG COMPUTING

1.) Low Latency :-
It provides the benefit of faster response due to geographical location i.e they are located Nearby

2.) Reduced Bandwidth requirements :-
Fog Servers allow low bandwidth consumption b/c data get processed at nearby fog servers. Hence avoiding huge amount of data to be forwarded to distant cloud servers for processing

3.) Reduced Cost :-
Most of the processing is done locally at the fog layer leading to Conservation of N/w resources.

4.) Security & privacy :-
It also allows applications to be Secure & private. b/c data can be processed locally instead of forwarding to remote Centralised cloud.

5) Mobility :-
Fog devices are Mobile. They can easily added or removed ~~from~~ N from N/w

→ APPLICATIONS

1.) Smart Cities :-
Cities that make use of technology to Improve quality of life & Services provided to people. Can be called Smart Cities. With help of this, it is possible to do tasks like creating Smart homes & buildings, maintaing Securities.

2.) Smart Car & Traffic Control System :-
By making use of IoT devices vehicles can Communicate with Internal as well as External Environments with help of Sensors. like Traffic light

3.) Smart Grids :-

Electric grid is a N/W which delivers Energy generated from various Sources to Consumers. The process of efficient distribution of Energy is possible by making use of fog computing. IOT Sensors Can Monitor Energy generated from various Sources like wind Energy farms, thermal plants. This data is then passed to Nearby fog Server to Identify the optimal Source of Energy to be used. & Identify equipment Malfunctions.

4) Smart healthCare Systems :-

Health reports of patients Can be recorded using different types of Sensors & forwarded to fog devices Fog devices after performing analysis Can take Necessary actions like diagnose Cardiac disease.

5) Surveillance :-

Security & Surveillance are deployed in many areas. It is difficult to send Massive amount of data collected by these Cameras to Cloud Servers. due to Bandwidth Constraints. Hence. data collected from these Can be forwarded to Nearby fog Servers. Fog Servers in turn Can perform Video processing to find out problems like theft, finding & Missing people.

CHALLENGES IN FOG

1.) Complexity :-

Fog devices Can be diverse in architecture and hence located at different locations adding more Complexity to N/W.

2) Power Consumption :-
It requires high power Consumption for proper functioning. Adding more fog devices increases energy Consumption.

3.) Data Management :-
Data is distributed across Multiple fog devices. Hence it is ~~challenging~~ Challenging

4.) Authentication :-
Establishing trust & authentication may raise issues.

5) Security :-
Since there are many fog devices. each with diffent IP adders. Hackers can hack.

⇒ LIMITATIONS OF CLOUD COMPUTING

EL

1.) Internet Connectivity :-
Every data is stored on cloud. & we access the data by using Internet Connection. ~~&~~ for this you have good Internet Connection.

2.) Vendor lock-in :-
Organisations may face problems when transferring their services from one vendor to another. As diffent vendors provides diffent platforms, this can cause difficulty moving from one cloud to another.

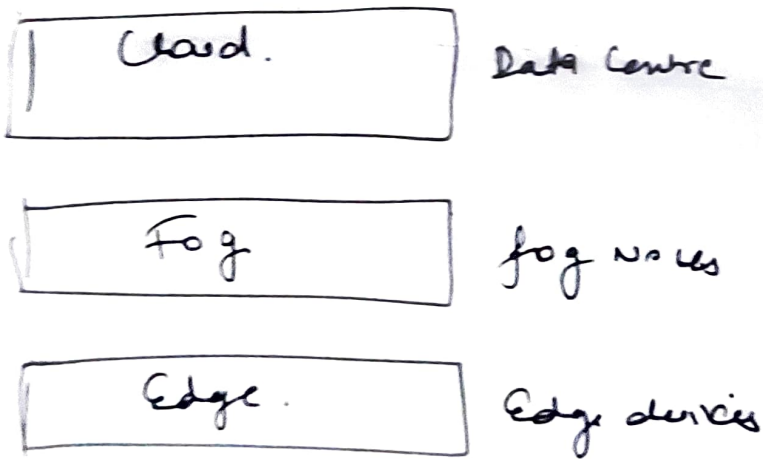
3.) Limited Control :-
Cloud Infrastructure is completely owned, managed & Monitored by Service provider, So Cloud users have lesser control over functions & Execution of Services within Cloud Infrastructure

④ Security :-
You should be aware that you will be sending all your organisation's sensitive info to third party the cloud computing service providers, while sending data, there may be chances that your organisation's info hacked by Hackers

⑤ Technical issues :-
It is always prone to an outage & other technical issues.

⑥ Lack of support :-
Cloud computing companies fails to provide proper support to customers. They depend on FAB's or online help which can be tedious job for non technical persons.

IOT data layers.



⇒ DIFF. B/W FOG & CLOUD COMPUTING

Speciality	Cloud Computing	Fog Computing
1) Delay	Higher latency	Low latency
2) Capacity	Not provide any reduction in data while sending / Recieving data	Reduces the amount of data sent to cloud computing
3.) Responsiveness	Response time is low	High.
4.) Security	lesser Security	High Security
5) Speed	Access Speed is high	even more high Speed
6.) Data Integration.	Multiple data Source can be Integrated	Multiple data Sources & devices Can be Integrated
7.) Mobility	Limited	Mobility is Supported
8.) No of Sever Nodes	Few No' of Server Nodes.	Larger No' of Nodes
9.) Geographical distribution	Centralized.	decentralized & distributed.
10) Location of Service.	Services provided within Internet	Services provided at Edge of local N/W
11.) Working Environment	Specific data Centre building with air Conditioning System	Outdoor (Streets, Cafe, homes)
12.) Communication Mode	IP N/W	Wireless Communication (WLAN, Wifi, 3G, 4G)

⇒ CHARACTERISTICS OF FOG COMPUTING

1.) Heterogeneity :- It is highly virtualized platform that yield compute, storage & N/W Services. They are building blocks of both cloud & fog.

2.) Edge location :- It support End points with such Services at edge of N/W like gaming

3.) Geographical distribution :-
Fog play active role in delivering high quality streaming to moving vehicles, along with highway & tracks.

4.) Large Scale Sensor N/W :- To Monitor the Environment & Smart grid and other Ex:- of Inherently distributed Systems.

5) Large No of Nodes.

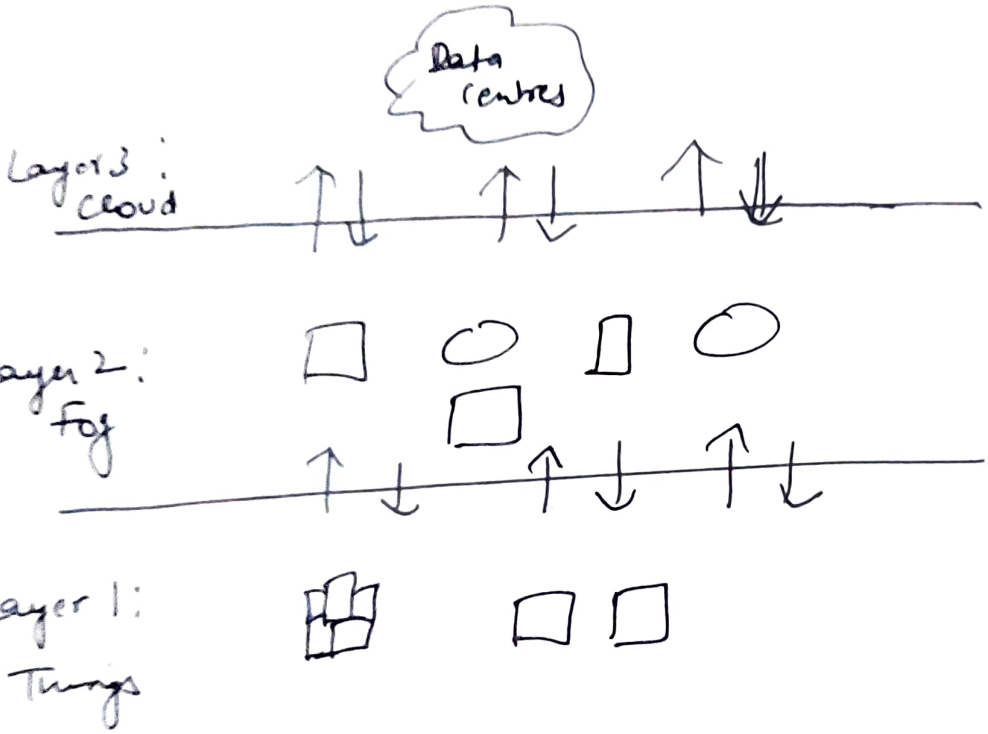
6.) Support for Mobility :-

7) Real time Interactions :-

8) Control of privacy.

⇒ ARCHITECTURE OF FOG COMPUTING

Fog architecture involved using Services of End devices (Switches, routers etc) for Computational Storage and Processing purposes. It consist of physical as well as logical elements of N/W, S/W & H/W to form Complete large no of Interconnecting devices.



(I) It consist of 3 layers:-

1.) Terminal layer

It is basic layer & Includes devices like Mobile Phones, Sensors, Smart Vehicles etc. Devices which Can Sense & Capture data are present in this layer

The layer mostly deals with data Sensing & Capturing. Devices from different Platforms & different architectures are mainly found in this layers.

Device have property of working in heterogenous Environment

2.) Fog layer

It Includes devices like router, gateway, access points Fog Servers called ~~as~~ fog Nodes.

Fog Nodes located at Edge of N/W. ~~Not~~ Nodes are Situated in b/w End devices & cloud data Centres.

Fog Nodes Can be static or moving

fog Nodes Ensures Services to end devices. Nodes Can Compute, transfer & Store data temporarily

3.) Cloud layer

It Consist of devices that Can provide large Storage & Servers with high performance.

This layer perfoms Computation analysis & Stores data permanently.

It has high Storage & powerful Computing Capabilities. The data Centre provide all basic Characteristics of Cloud computing to users.

The Cloud layer lies at the Extreme End of architecture. It act as as backup as well as provides permanent Storage for data.

Layered architecture

1.) Physical & Virtualization layer:-

This layer Comprises Nodes (Physical & Virtual) The Nodes perform the primary task of Capturing data & located at diffent locations. Nodes usually Involve Sensing technology to Capture their Surroundings.

2) Monitoring layer:

In this we perform Node, Monitoring related to various tasks. Nodes can be Monitored for the amount of time they work, the temp. & other physical properties, max. battery life of device

→ Performance is also Monitored.

→ Fog Nodes are checked for their energy Consumption.

3.) Preprocessing layer

→ It performs various data operation related to Analysis

→ Data is cleaned & checked for unwanted data present. Data Impurity is removed & only useful data is Collected.

4) Temporary Storage

→ It is associated with Non permanent distribution & replication of data.

→ Storage Virtualisation used in this layer.

→ Data is removed from Temporary layer once data is moved to cloud from this layer.

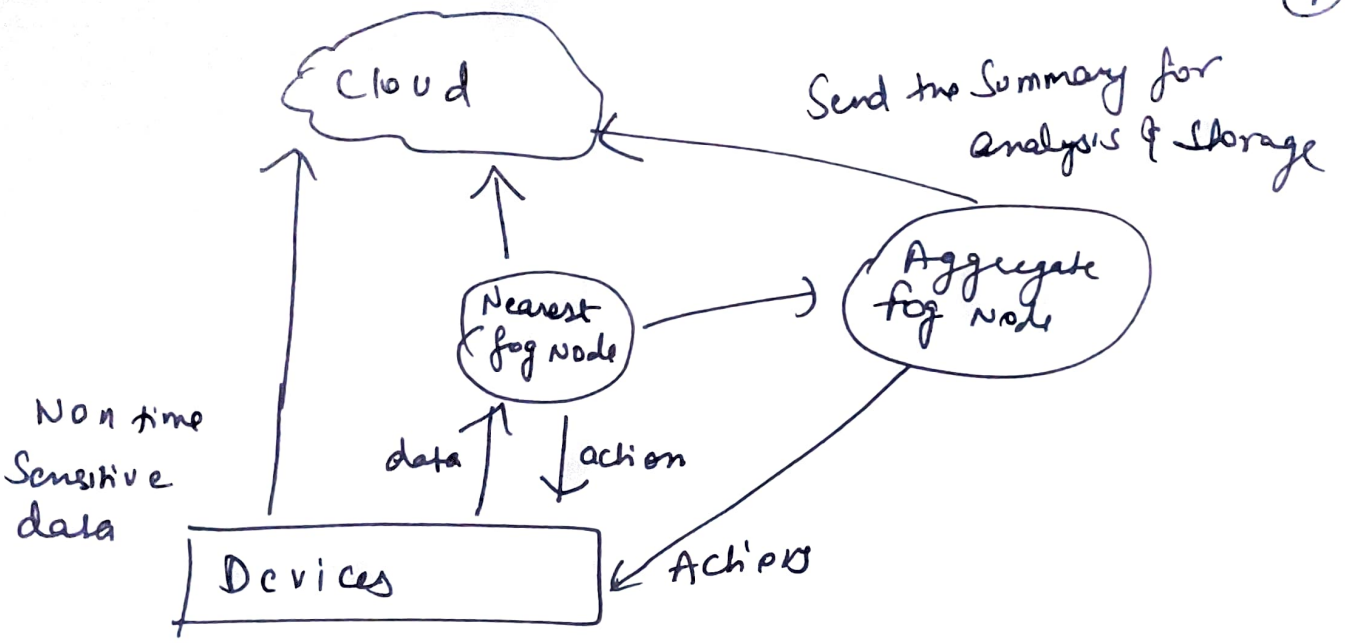
5) Security layer

Its function is to upload partly-processed & fine grained Secured data to cloud layer for permanent Storage.

The data is then passed through Smart gateways before uploading on cloud.

Transport layer	Uploading pre-processed & Secured ~~stored~~ data to cloud
Security layer	Encryption / decryption
Temp. Storage layer	Data distribution replication & de-duplication Storage space & devices
Pre processing layer	Data Analysis, filtering & ~~from~~ trimming
Monitoring layer	Activies Monitoring, POWER Monitoring, RESOURCE Monitoring
Physical & Virtualization layer	Virtual Sensor & Virtual Sensor N/W Things & physical Sensors ~~and~~ Wireless Sensor N/W

⇒ WORKING OF FOG COMPUTING



1.) Data is collected from various devices & Sensors Connected to Internet

2.) Then data is Sent to fog Node which can be Anything from Smartphone

3.) Fog Node process data & Sent it back to devices or Sensors

4.) The fog Node sends data to Central cloud Server

5) The data is then processed by Cloud Server & Stored in database.

UNIT-2

⇒ CHALLENGES IN FOG COMPUTING

1.) **Authentication & Trust Issues :-**

Authentication is one of the most Concerning Issues. Since most of Services are offered at large scale. Fog Service provider can be different parties like cloud Service providers, ISP & End users. This flexibility Complicates the whole Structure & Trust. A rouge fog Node is a fog device which pretends to be legal & coaxes end user to Connect to it. Once a user Connects to it, it can Manipulate Signals coming to & from user to cloud & easily launch attacks.

2.) **Privacy** –

It is Concerned when there are many N/w involved. Since fog Compuy is based on wireless technology, ~~a~~ large Concern regarding N/w ~~pol~~ privacy. More Sensitive Info is passes from End users to fog Nodes.

3) **Security** – It arises there are many devices Connected to fog Nodes & at different gateways. Each device has diffent IP adress & any hacker Can fake your IP address.

4.) **Fog Servers** –

The right placement of fog Servers Should be there So that it delievers its Max. Service. The Company Should analyse the demand & work done by fog Node.

(5) Energy Consumption

It is very high in fog computing as No of fog Nodes Present in fog Environment is high & require Energy to work

(6) Control & Management Issues

Nature of Nodes is Mobility, So changes are frequent which leads to change in Storage, Bandwidth.

(7) Task Scheduling

The Scheduling of task is Not Easy in fog. Bcoz task can move between various physical devices like fog Nodes.

⇒ PRIVACY & SECURITY ISSUE IN FOG COMPUTING

- Fog Computing Security Issues arises as there are many devices connected to fog Nodes & at different gateways.
- Authentication plays a major role in Establishing the Initial set of relation b/w IOT devices & fog Nodes in N/w but this is Not Sufficient as devices are always Malfunction to attacks.

Privacy preservation is more challenging since fog Nodes may Collect Sensitive data. As a result, Concerning the Identity of End users Compared to the remote cloud Servers that lies in Core N/w.

- Since fog Nodes are Scattered, Centralized Control is difficult

Network Security.

Due to the predominance of wireless in fog, wireless Security is big Concern. Ex:- attacks are Jamming attacks, Sniffer attacks. In N/w, we have to trust the Configurations Manually generated by the N/w administrator. Fog Nodes ~~attacks~~ deploy at Edge of Internet, which bring heavy burden on Net.

Secure data storage

User data is outsourced & user's Control over data is handed over to fog Node which Introduces Same Security threats. It is hard to Ensure data Integrity

Privacy

The leakage of private Info like data, location are gaining attentions when End users are using Servics like Cloud computing, IoT.

Fog Nodes are Vicinity of End users & Collect more Sensitive Info than remote Cloud

- Data privacy :- Fog Node at Edge Collects Sensitive Info generated by Senors & End devices.
- Usage privacy :- usage pattern with which a fog Client utilises the fog Services Ex: In Smart grid. the reading of Smart meter will ~~di~~ disclose lot of Info of household like at what time TV is on etc which absolutely breaches user privacy.

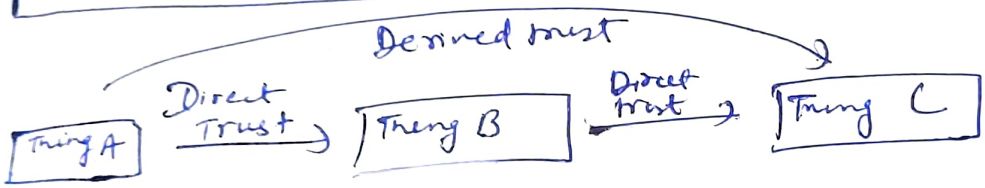
- Location privacy :- As fog clients offload its task to Nearest fog Node, the fog Node to whom task is given can infer that fog client is Nearby & farther from Nodes.

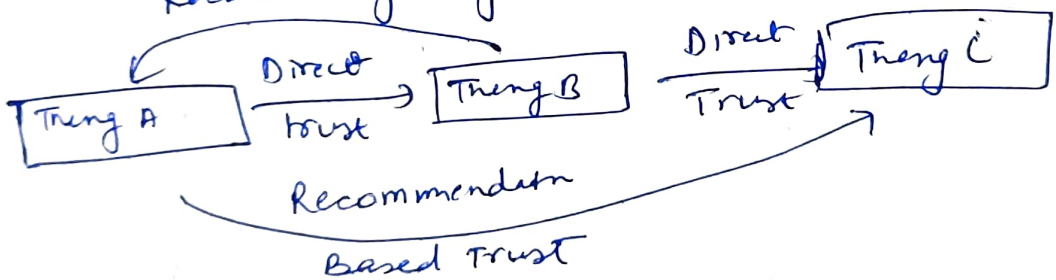
~~Access Control~~

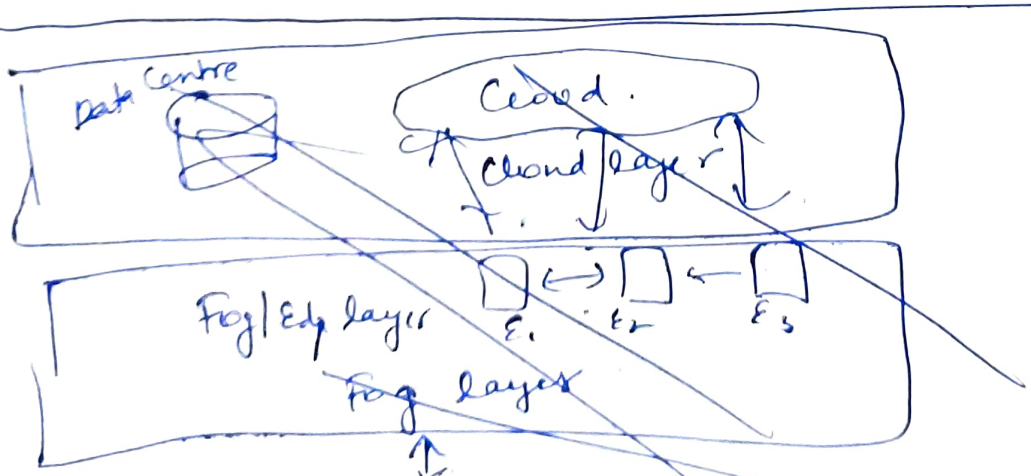
Intrusion detection

To Mitigate attacks like flooding, port, Scanning on VM or in Smart grid to Monitor power measurements & detect abnormal measurement that could have been Compromised by attackers.

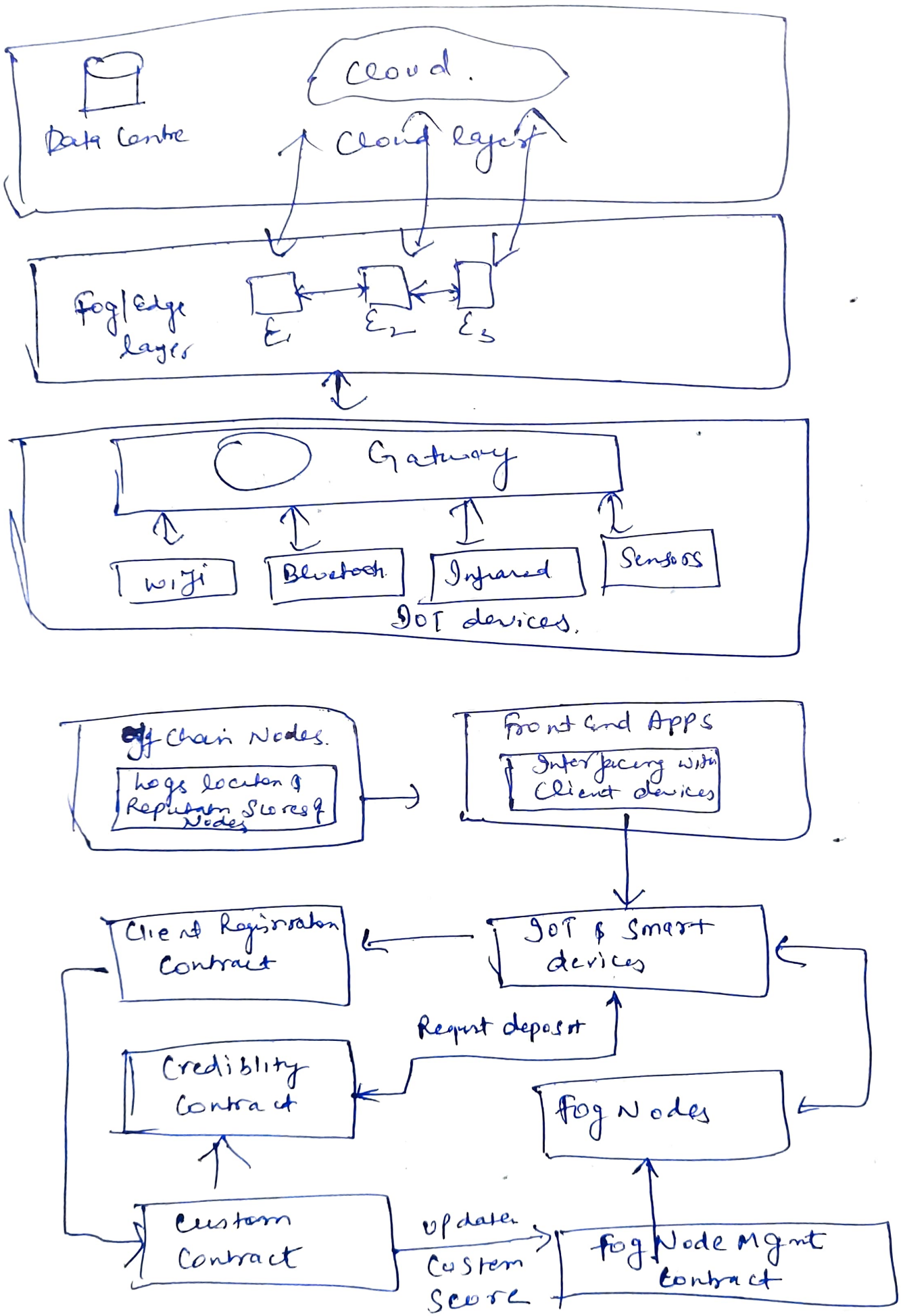
⇒ TRUST & REPUTATION MODEL of FOG COMPUTING







It helps in Evaluating trust worthiness of a user


Cloud.
Data Centre
Cloud layer
Fog/Edge layers
E_1
E_2
E_3
Gateway
WiFi
Bluetooth
Infrared
Sensors
IOT devices.
Chain Nodes.
Logs location & Reputation Scores of Nodes
Front end Apps
Interfacing with Client devices
Client Registration Contract
IOT & Smart devices
Request deposit
Credibility Contract
Fog Nodes
Custom Contract
update Custom Score
Fog Node Mgnt Contract

⇒ CURRENT RESEARCH IN FOG COMPUTING

(1) DITAS :- (Data Intensive applications Improvement by moving data & Computation in cloud Environment) is focussed on providing an abstraction layer for data storage by hiding complex architecture. It is composed of SDK & EE (Execution Environment)

(2) PROFESTO CLOUD - (Proactive cloud resources Management at Edge for Efficient real time Big data processing) Provides configurable fog computing architecture in order to support Big data streams at edge.

(3) mf2c :- It constitutes an open, Secure & decentralised Managment framework. It will try to set the bases of distributed System architecture. with privacy & Security

(4) RE DESIGN :- is a European project start in 2019 It aims to design distributed & Scalable wireless Fog N/W with ground & Mobile fog Nodes

(5) FOGHORN - It aims at developing the theoritical & algorithmic bases of fog aided wireless N/W.

(6) RECAP - Aims to develop the Next generation of fog Computing acc. to user Needs.

(7) ~~STORLET~~

(F) SOFIE - It is based on Existing open Standards like FIWARE, W3C

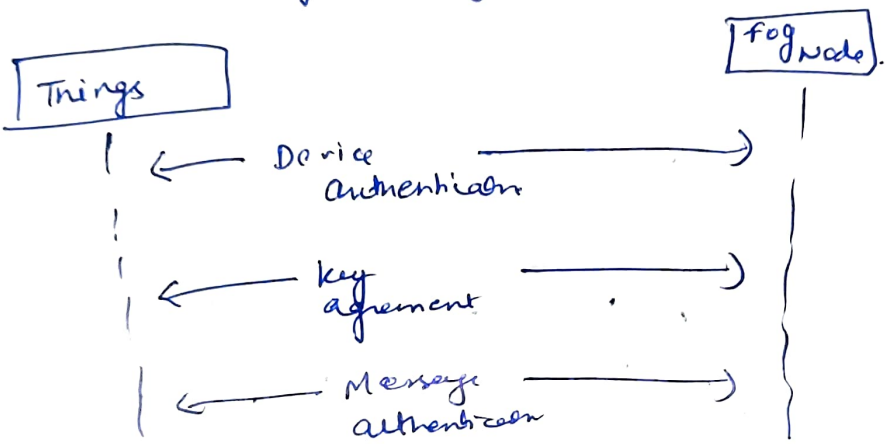
AUTHENTICATION IN FOG COMPUTING

The general authentication scheme is divided into 3 phases device authentication, Key agreement for Message authentication & Message authentication itself.

In first Phase both devices authenticate Each other.

Second phase is Exchange of keys for Message.

The result of key Exchange are then used in third phase of Message authentication



① Device Authentication phase.

Five alternative Sol. proposed for device authentication.

→ PKI - RSA :- a certificate is used for authentication

→ PKI-ECC - an Elliptic Curve Signature algo is used to create certificates.

→ Identity Based Encryption.

→ Authentication with Encryption. - Password.

② Key agreement phase

It is used to generate Symmetric key for Message authentication.

③ Message Authentication phase

It is Implement to avoid Reply attack.

⇒ DATA PREPROCESSING AND ANALYTICS

Fog Computing is highly Virtualized platform that Provides Compute Storage & Networking Services b/w End devices Google uses cloud Computing to Categorises photos.

Fog Analytics –

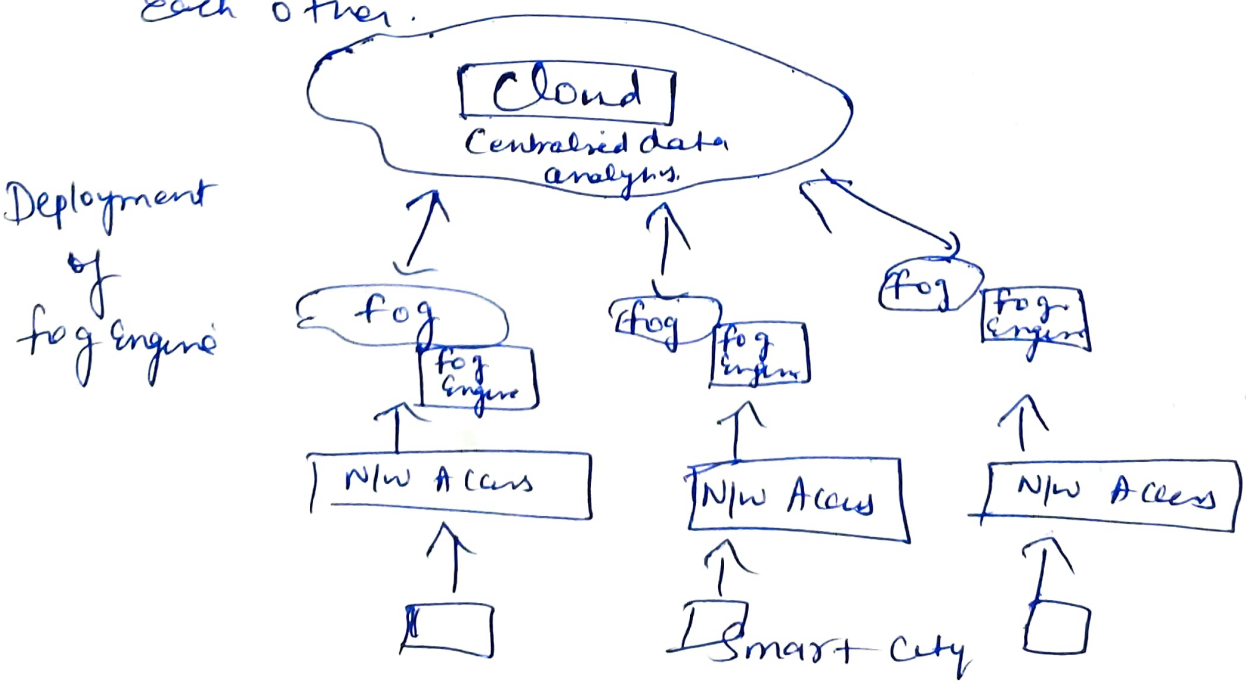
Collecting & transferring all data generated from IoT devices & Sensors into cloud for further processing Poses Serious Challenges on Internet.

Moving data to cloud for analytics work well for large volumes of historical data requiring low Bandwidth. Analytics give better approach.

Fog analytics require Standardization of device & data Interfaces, Integration with cloud to handle Incoming data.

Fog Engines –

End to End Solution called fog Engine that Provides data analytics as well as Capabilities for IoT devices to Communicate with Each other.



Data Analytics using fog Engine

Data Analytics performed near the data source using fog Engine before data volume grows significantly.

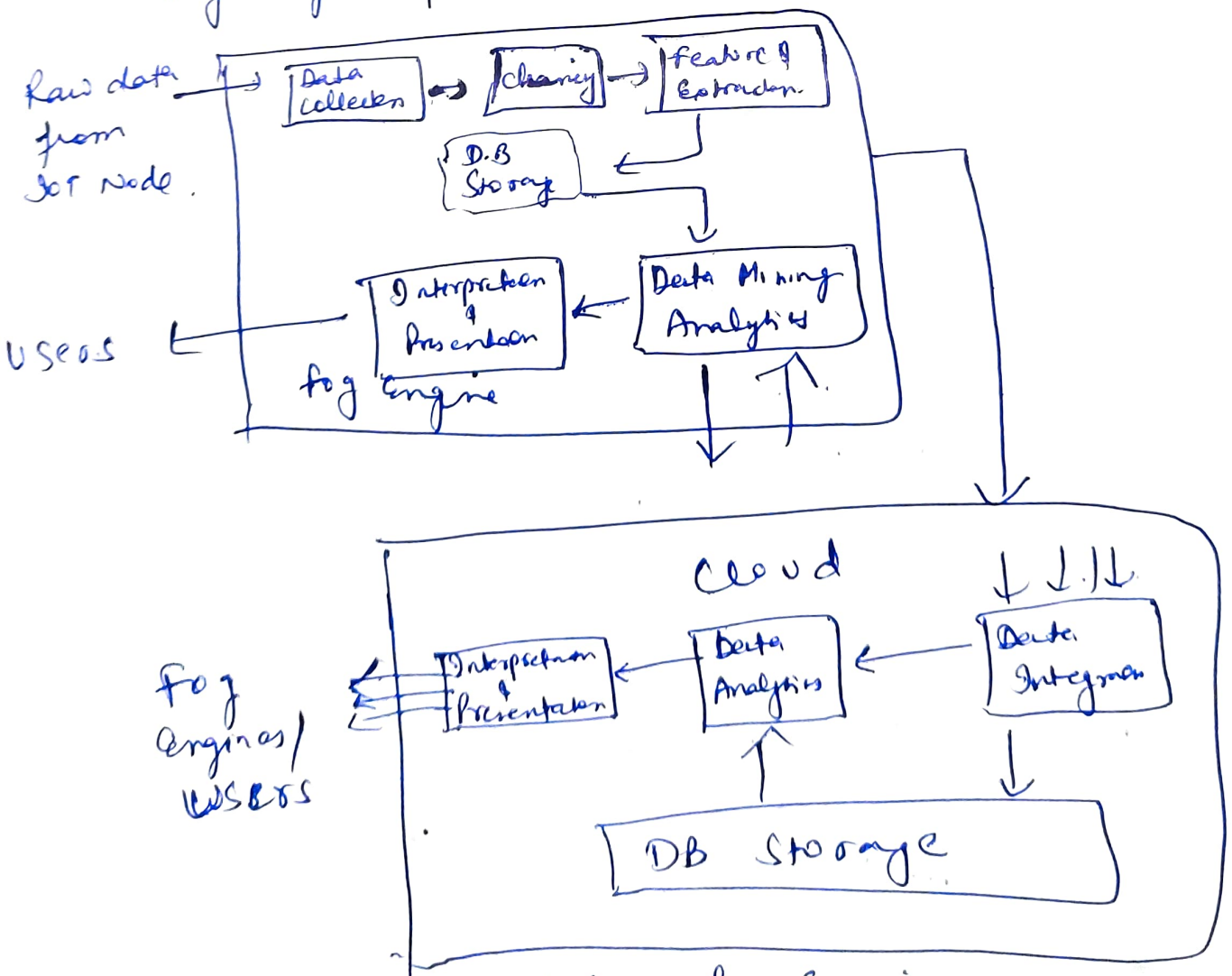
In stream data is analysed locally in fog Engines while data of fog Engines is collected & Transmitted to cloud.

The analytics Model Employed in fog Engine are updated based on polices

As data are processed, filtred & cleaned in the fog Engine prior to offloading to cloud the amount of transmitted data is lower

Analytics is real time.

Fog Engine provids limited Computy power



Data Analytic using fog Engine

⇒ | DATA STORAGE & PLACEMENT |

Data is Stored locally on Each End user device or device b/w them.
To Evaluate the performance behaviour of different data placement Strategies, ~~this~~ 3 algo are used:-

① Edge-ward Algo -

It is FCFS ~~stra~~ Strategy, result in placing data as close as possible to edge of N/W. on fog Nodes.
If a Specific Node Cannot Serve the requirements of application, Edge ward Selects additional fog devices. The algo Creates tuples of device representing path via application Modules.
Appln request are answered based on the order in which they arrive until are available Computing resources at each level.
→ It presents better performance.

② Cloud only algo -

It is based on traditional Implementation Executed in Cloud & uses a delay priority Strategy. It assumes all appln Modules run in data Centres. If Sensors Captures data, Such data is processed on Cloud, Cloud Send Info to actuators if needed.

③. Mapping algo -

It ~~rather~~ relies on Concurrent Strategy
Appln request are mapped preferably to fog devices. If CPU Capacity of Selected fog device does not fulfill to Serve an appln, then Mapping forms ~~an~~ a Processing Queue on fog Node

UNIT-3

⇒ INTRO TO EDGE COMPUTING

Edge Computing is the Model that Extends Cloud Computing Services to the edge of N/W. This Model aims to move decision making operations as close as possible to data Sources. Transferring all the data from the N/W edge to the cloud data centres for processing may Create latency problem & outstrip the N/W Bandwidth Capacity. To resolve this Issue, it is best to process data closer to the devices.

It may be referred as distributed IT architecture.

ORIGION OF EDGE COMPUTING

Edge Computing Can be ~~traced~~ traced back to 1990s when Akamai launched its Content delivering N/W (CDN) which Introduces Nodes at location geographically closer to the End user. These Nodes store Cached Static Content like Images. Edge Computing takes this Concept further by allowing Nodes to perform basic Computational task In 1997, Computer Scientist Brian Noble demonstrated how Mobile tech. could use edge Computing for Speech recognition. Two years later, this method also used to Extend battery life of phones.

1999 Saw the arrival of peer to peer Computing.

In 2006, Cloud Computing emerged with release of Amazon EC2 Service & Companies have adopted it in huge no's Since then. In 2009, the Case for VM based Cloudlet in Mobile Computing was published dealing end to End relationship b/w latency & Cloud Computing. In 2012 Cisco Introduced fog Computing

This brings us to Current edge Solutions.. Edge Computing became a key factor driving the adoption of technology IOT

Application of ~~Cloud~~ Edge Computing

① **Smart System** –

In this N/W Comm. technologies are interlinked with Sensors that are meant to send Signals to the System to take action.

Smart System have several areas –

→ Smart home
→ Smart city
→ Smart healthcare

② **Smart grid** –

It collect huge amount of Energy related data
To reap the benefit of Smart grid, many smart meters. Sensors must be used to collected shared data in Smart grid.

③ **Smart farm** –

To meet demands of food production, the agricultural sector has to Integrate IoT in various production. It can use edge Computing to operate vehicles & to perform remote monitoring.

④ **Video Analytics** –

The rapid spread of phones & N/w Cameras is giving rise to analytics technology.

Eg. – If child lost in City
In this case, edge Computing Model can be used to generate Search request for child from cloud & transmit it to ~~the~~ all things in target Area.

Advantages –

→ offers high Speed, Reduced latency better reliability
→ Better Security
→ less Expensive route to Scalability allowing Company to Expand their Computing Capacity

→ less time & resources Needed for data.

→ Cons :-

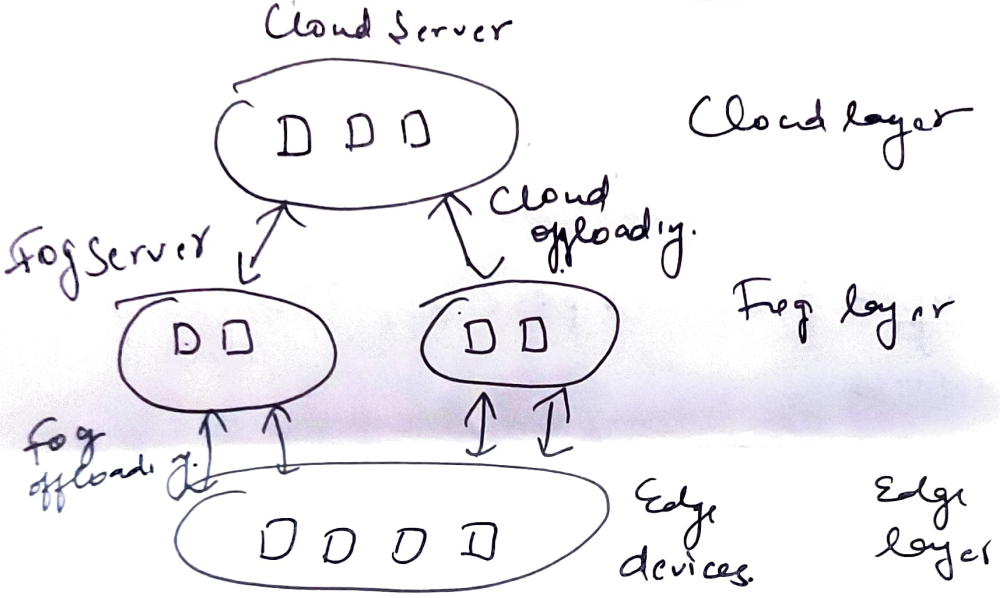
→ Require more Storage Capacity

→ Security challenges due to huge data

→ Only analyze data

→ Cost high

⇒ **ARCHITECURE OF EDGE COMPOTING**



Instead of sending all data directly to the cloud or fog layer from edge devices data is first processed at edge layer Processing data at edge layer gives near real time response. As data generated at edge layer is huge, it cannot be handled entirely at edge layer. Hence it is offloaded to the cloud or fog layer. In cloud - fog Edge Scenario data from edge layer is first offloaded fog server. In cloud - Edge Scenario data after Processing on Edge layer can be offloaded to cloud layer as resources at edge layer is insufficient to handle large data. Hence edge layer can decide what is relevant Hence reducing load.

Components of Edge Computing :—

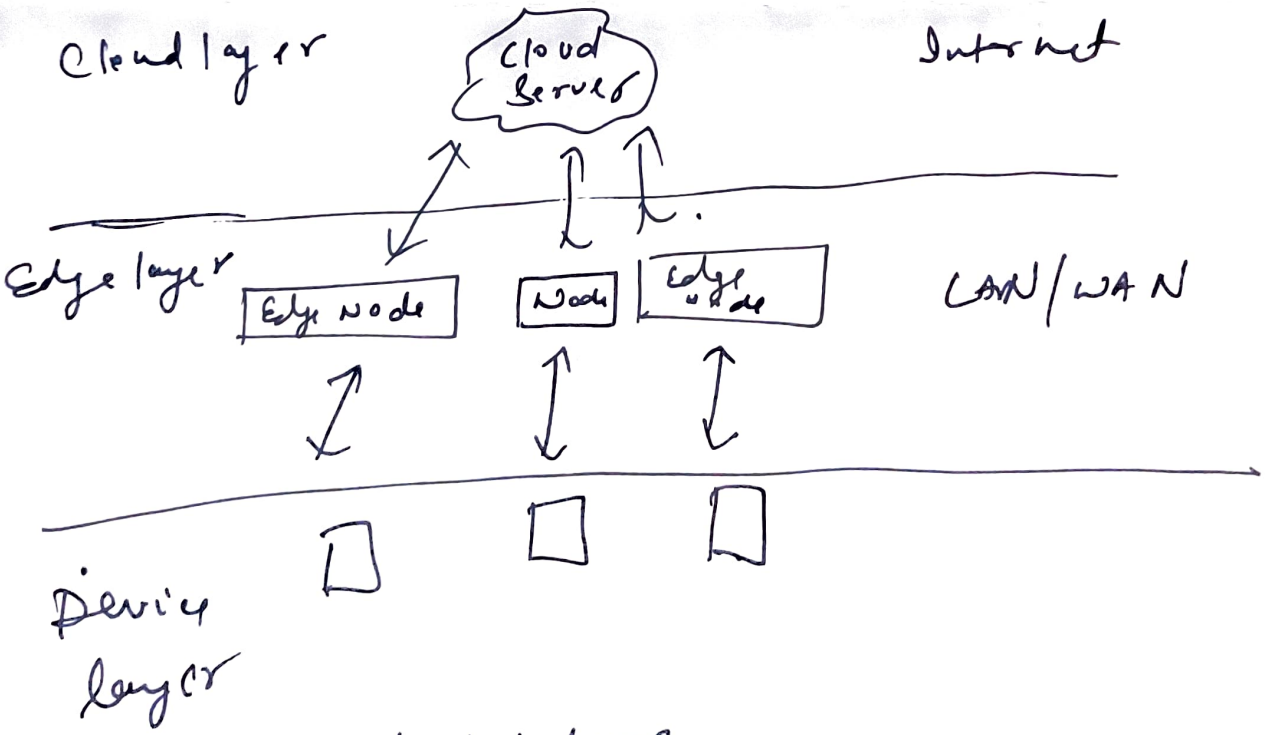
→ Cloud – Can be public or private. which can be repository for workloads like Application. These are host & run the applications that are used to manage Nodes.

→ Edge device –
It has Compute Capacity that is Integrated into that device Ex:- ATM.

→ Edge Node – referred to any device, Server or gateway

→ Edge Cluster/Server.
It is located in Remote operation facility like Hotel, bank Runs Enterprise application workloads

→ Edge gateway – host Enterprise appl*; workload & Shared Services



Architecture

⇒ **EDGE HELPING THE CLOUD**

Edge to cloud refers to the fact that Enterprise data is no longer confined to data centre, it is being generated at edge in ever growing amounts - Processed & Stored in Cloud.

In order to Extract business insight from data, it must flow seamlessly b/w edges, clouds & data centres & users in wide variety of work location & Environments.

Edge to Cloud is Necessary -

One approach is growing need for real time data driven decision making especially at edge. Ex:- Autonomous driving technology depends on AI, M/C learning System that can determine fraction of second.

An Edge to Cloud platform is designed to bring the Cloud Experience to all of an organisations apps & data It offers Consistent user Experience with Security It allows organization to pursue New business opportunities

How does Edge to Cloud platform work -

To deliver a Cloud Experience everywhere, a platform needs to Incorporate Several characteristics:

→ Self Service - organisations need the ability to Easily & quickly Spin up resources for New projects. A true Edge to Cloud platform provide a view into Cost, usage etc.

→ Rapidly Scalable - To deliver On cloud's promise of agility, a platform ~~needs~~ needs to Include built in buffer Capacity, So, when more Capacity is needed, it is already Installed & ready to go

→ Pay as you go — Billing should be based on actual capacity used. So business can get New projects up & running without heavy cost & delay

→ Managed for you — It should lift the operational burden of managing & updating the Infrastructure ; So IT can focus on building the business & revenue.

Benefits of Edge to cloud Technology -

→ Achieves greater agility - It gives organisations the flexibility to respond quickly to requests from business.

→ Modernize application - Workload that may not be suited to move to public cloud can run efficiently on today's as a service platform.

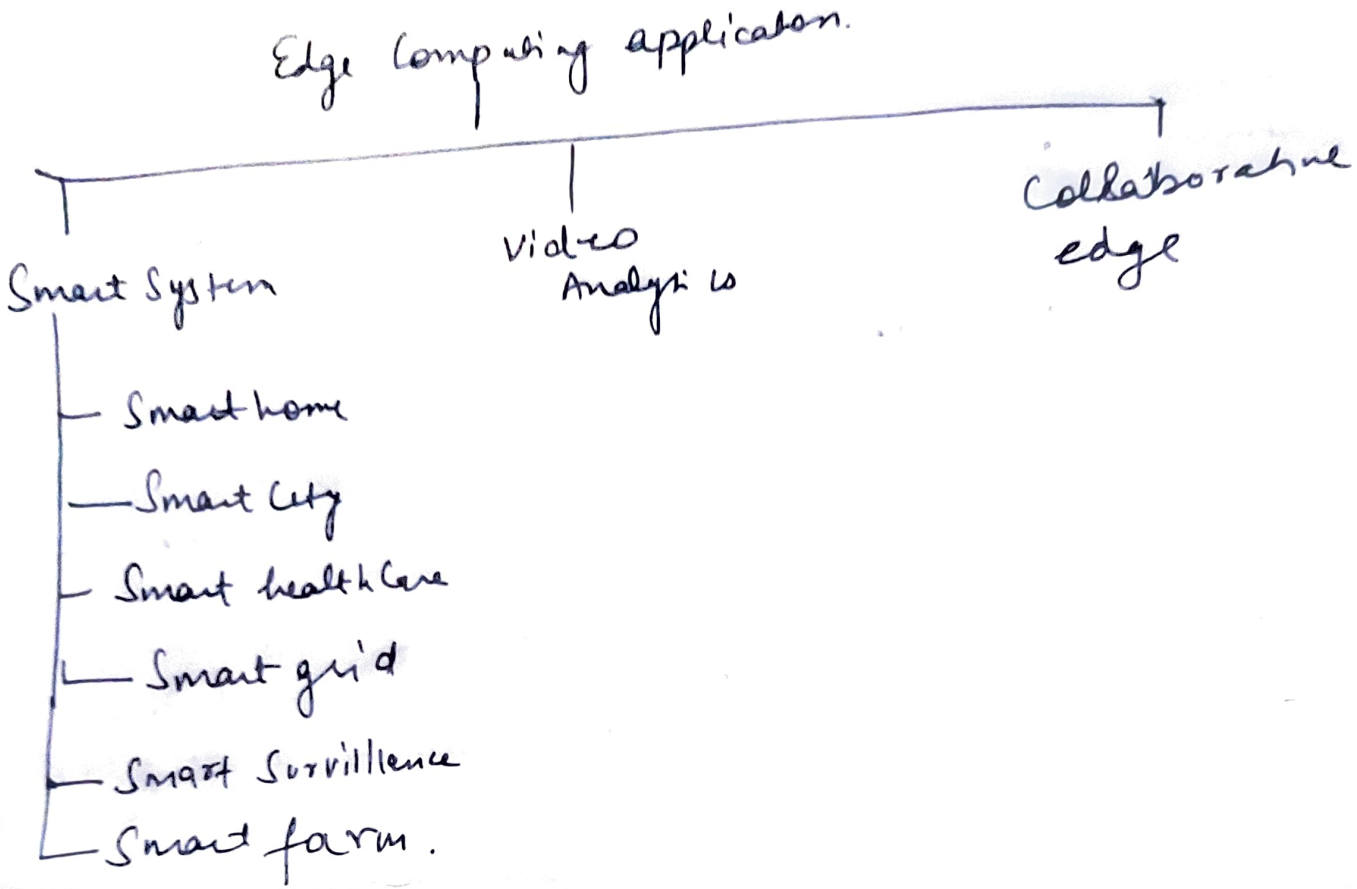
→ Develop hybrid cloud strategies with Confidence — Organisation can Easily create the optimal combinations of assets & quickly switch b/w them

→ Realize the transformational value of app & data — Some data are too large to make the move to cloud. An edge to cloud platform offers Max. availability & Min. latency.

⇒ EDGE VS FOG COMPUTING

Attributes	Cloud	Fog	Edge.
1) Target users	Internet user	Mobile user	Internet user.
2) Location of Servers	Edge Nodes.	Within Internet	Very Near to Edge Node.
3.) Geographical distribution	Centralised	Distributed	Distributed
4) Latency	Higher	less	less
5) Connectivity type.	Leased lines	wireless	wireless
6.) N/w Bandwidth	Large	less	less
7.) Security	less	more	~~low~~ less
8.) Goal	To provide Scalable & Easy access for IT Service	To reduce the redundancy & work efficiently when data is transferred for Processing, Storing	To reduce N/w Congestion & Improve appl^n Performance by Performing task closer to end user.
9.) Transmission of data.	System to cloud	System to System	Device to Device
10.) Architecture	Centralized	Distributed	Distributed
11) No of Nodes	few	many	Many
12) Latency	Low latency but greater than fog	Low latency in term of N/w	Low latency in term of N/w
13) Speed of process	Depends on VM Connectivity	High	faster
14.)			

APPLICATIONS OF EDGE COMPUTING



UNIT-4

⇒ OPTIMISATION OF FOG COMPUTING

Fog Computing Combines cloud Services with geographically distributed resources Near the N/w edge to offer Computational offloading Possibilities to End devices, featuring low latency. Optimisation of various resources latency, Bandwidth, energy Consumption plays a Vital role in Fog Computing. Diffrent algo techniques have been applied to Solve optimisation problems.

An optimization problem Consist of following :-

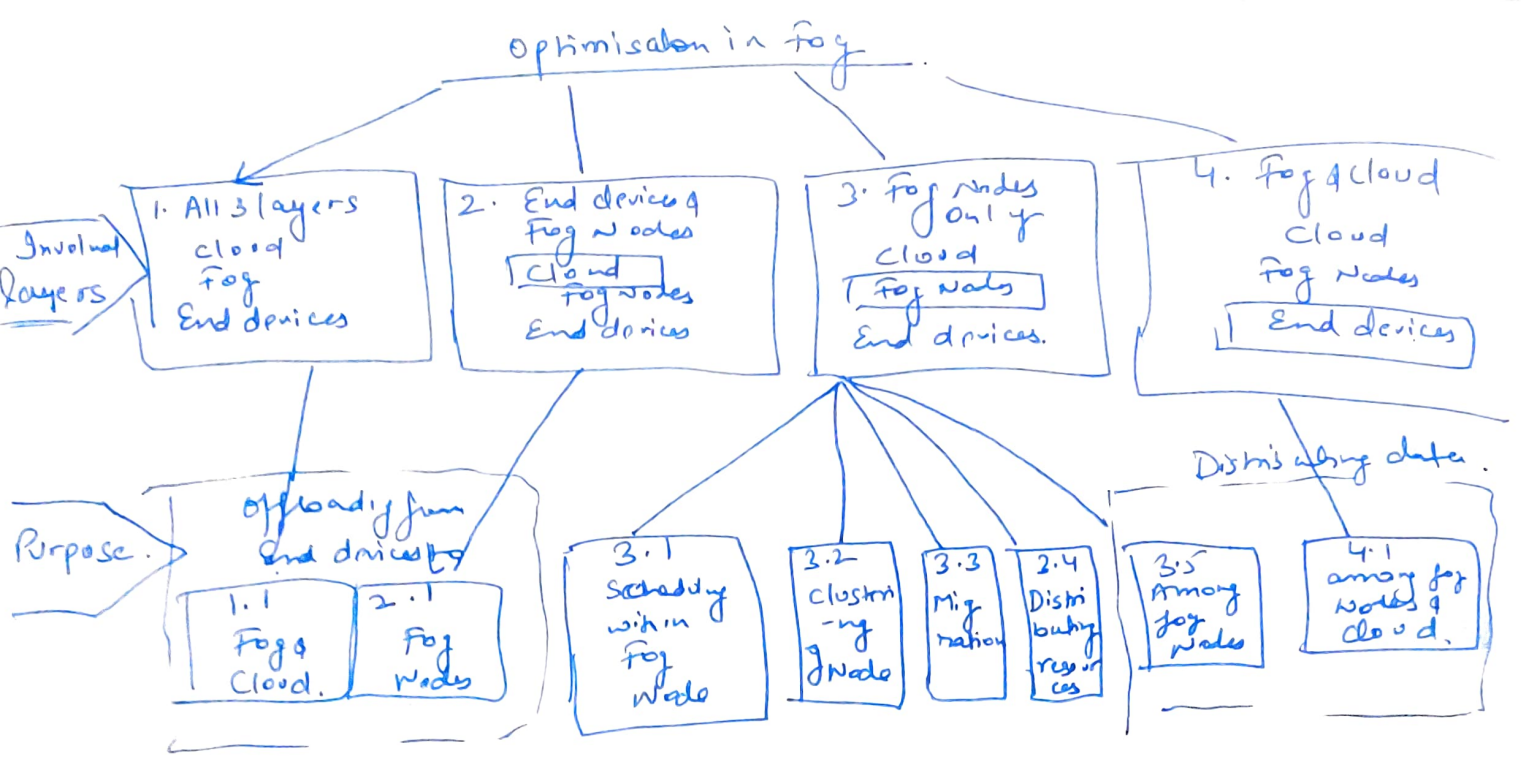
→ A Set of Variables that Encode decision to be made
→ The Set of possible values for each variable.
→ Set of Constraints
→ An objective function.

The aim of optimization to find a Sol. that minimizes / Maximises the objective function.

Taxonomy of optimisation problems in fog Computing.

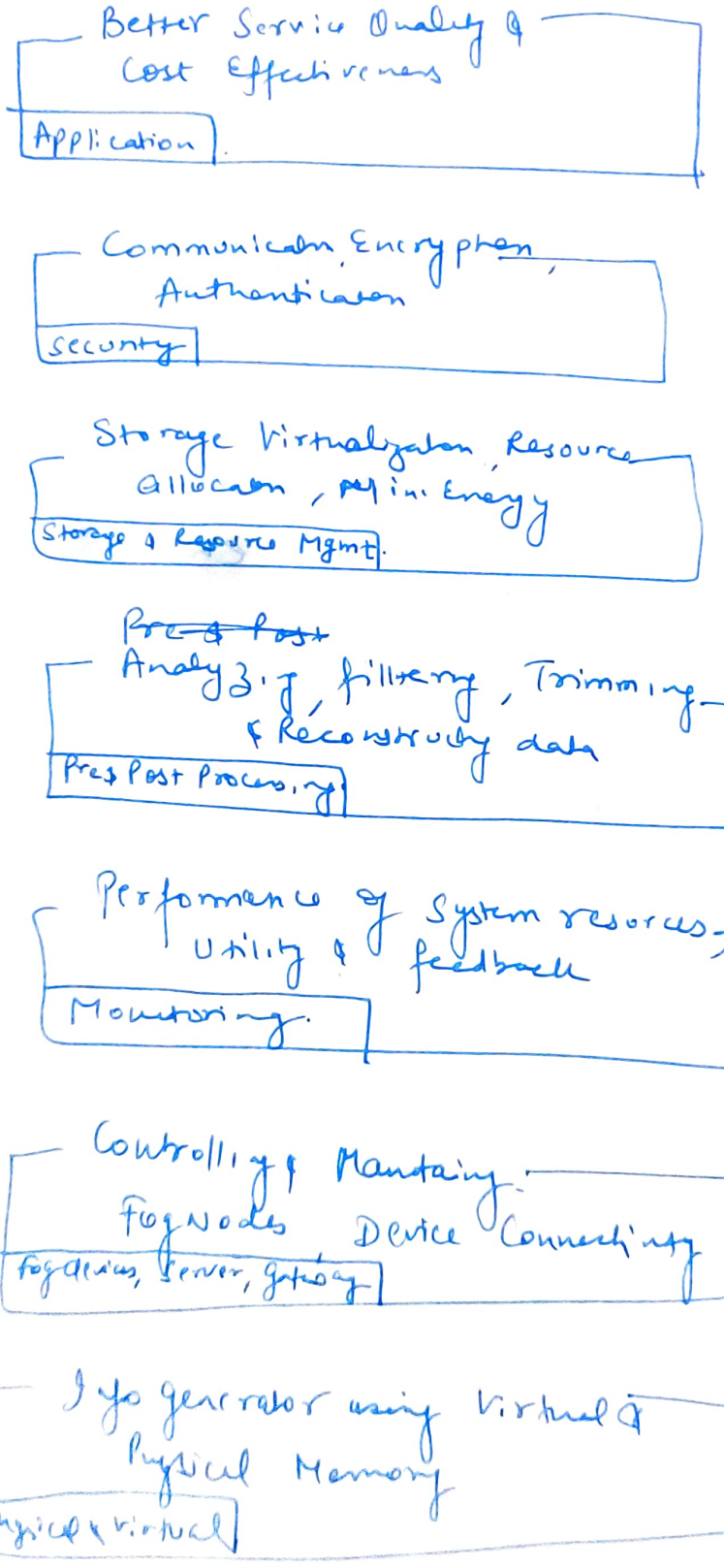
Four Categories are :-

(1) All 3 layer - It occurs when Computing tasks are offloaded from End devices & distributed over available fog Nodes
(2) End device & fog Nodes -
(3) fog Nodes only — Decision about Migrating data b/w Nodes
(4) fog Nodes & cloud - It occurs when data are distributed from Central cloud Services over fog Nodes to make data widely available.



Category	Subcategory	Decision resulting from optimisation
1. Optimisation of all 3 layers	1.1 offloading Compute task from End devices to fog Nodes & Cloud.	• whether to offload Compute task. • whether to further offload Compute task from fog Node to Cloud
2. optimisation involving End devices & fog Nodes	2.1 Offloading Compute task from End devices to fog Nodes	• whether to offload compute task from End device to fog Node • To which fog Node task should offloaded.
3. optimization involving fog node only	3.1 Scheduling within fog Node 3.2 Clustering " " " 3.3 Migration b/w fog Nodes 3.4 Distribute physical resources 3.5 Distribute data among fog Nodes	• How to assign task to resources within Node. • How to determine Size of cluster to handle requests • whether to migrate data b/w fog Node. • whether to place physical resources on N/W • which fog Node should host which application.
4. optimization involving fog Node & Cloud	4.1 Distribute data among fog Node & Cloud	• whether to place data on individual fog Node or in cloud

⇒ FRAMEWORK OF FOG COMPUTING



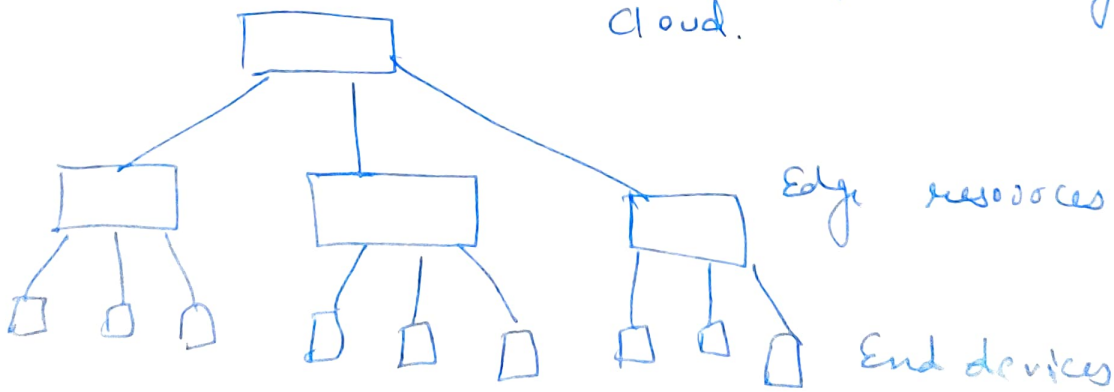
⇒ CASE FOR OPTIMISATION IN FOG COMPUTING

Optimisation plays a Imp. role in fog Computing. Ex:- Min. latency & Energy Consumption are important as maximizing Security & reliability. B/cz of high Complexity of fog deployments & their dynamic nature it is impossible to Ensure best Sol. by design. Rather than best Solution, we use appropriate optimisation techniques

Fog Computing Can be seen as extension of cloud Computing towards n/w edge with aim of lower latency from the point of view of End devices, fog Computing Increased Compute Capabilities, Enabling Execution of Compute - Intensive task quickly without major Impact on Energy Consumption of device.

⇒ FORMAL MODELLING FRAMEWORK FOR FOG

Before discussing Individual optimisation objectives, it is useful to define a generic framework for Modelling.



3 layer Model of fog Computing

Higher layer represent higher Computational Capacity but at same time also higher distance & higher latency. The Middle layer Consist of set of edge resources, Edge resources all connected to cloud. lower layer has End devices like Mobile phones.

Let C → Cloud
$\bar{E}$ → Edge resources
D_c → Set of end devices
R → Set of resources
a(r) → Compute Capacity of resource $r \in R$
s(r) → Compute Speed of " "
w(r) → Marginal Energy Consumption.
L → Set of all links b/w resources
t(l) → latency of link $l \in L$
b(r) → bandwidth
w(l) → Marginal Energy Consumption.

Set of links b/w resources is $L = \{ce : e \in E\} \cup \{ed : e \in \bar{E}, d \in D_c\}$

⇒ METRICS

There are several Metrics that need to be optimised in fog

1) Performance — There are several performance related Metrics like Execution time, latency, throughput Performance is related to the amount of time needed to accomplish task. Completion time may dependent on Computation time of Multiple resources.

2) Resource usage — Especially the lower layer of Model, the Economic use of scarce resource is vital. This applies to end device which have limited CPU & Memory Edge resources offer higher capacities, but also those capacities can be limited
Beyond CPU & M/M, b/w Bandwidth can be scarce resource both b/w end devices & edge resources.
Resource consumption needs to be considered at each node & link Separately.

3.) Energy Consumption – Energy can be scarce resource
Energy is consumed by all resources as well as N/W.
Even Idle resources consume Energy but their consumption
increases with usage. It linearly depends on CPU load
Energy consumption is Imp. on each layer of f/g.

4.) Financial Costs – The use of Cloud or Edge Infrastructure
may Incur Cost. It can be fixed or usage based.

5.) Quality attributes – All aspects are not sufficient
to guarantee a high quality of Experience for
users.. for this quality attributes needs to be
taken into account like reliability, security
Privacy which are harder to quantify.
Such quality attributes are not captured by the
optimisation problem, but rather achieved with
appropriate technical Solution.
Ex:- reliability may be achieved by creating
redundancy in architecture
Security by using cryptographic techniques.
Privacy by applying anonymization of personal data.

=> OPTIMISATION ~~OF~~ OPPORTUNITIES ALONG FOG ARCHITECTURE

Optimisation problem in fog Computing can be classified
acc to which ~~on~~ layers are Involved.
If only Cloud layer is Involved, then we have pure
cloud optimization problem.. If only End devices
Involved, then problem would not be in realm
of fog Computing but rather depends on kinds of
devices & their Interconnection.
Real fog Computing problem Involve at least
2 layers :- this Consideration leads to
following classification of optimization problems
in fog :-

→ Problem Involving Cloud & edge resources.
This is a meaningful setting, which allows for Ex:- to optimize overall energy Consumption of Cloud & edge resources subject to Capacity & latency Constraints

→ Problem Involving Edge resources & Edge devices.
It is a typical fog Computing problem. When a single edge resource is considered together with end devices it serves

→ In principle, all 3 layers can be optimized together The changes to the cloud, edge resources & end devices are typically made by different stakeholders on different time scales
In data related optimization, decision have to be Made about which piece of data are stored & Processed.
In code related optimization, program Code be deployed on Multiple resources & goal is to find optimal placement of program code.
In task related optimizer, the aim is to find optimal split of task among Multiple resources

⇒ OPTIMIZATION OPPORTUNITIES ALONG SERVICE LIFE CYCLE

Like cloud Computing, fog Computing also characterized by provision & Consumption of Services. By looking at different optimization opportunities at diff. Stages of Service life cycle, one Can differentiate the following options:-

→ Design time optimization — when a fog Service is designed, exact Info about End devices to be served is typically Not available

Hence optimizaton will be constrained mostly to Cloud & Edge layer, where more info available at design time. Concerning the End devices, optimizaton is constrained to questions dealing with type of devices.

→ Deployment time optimizaton - when the deployment of the service on specific resources is planned, the available info of resources can be used to make further decisions.

→ Run time optimizaton - Although some aspects of fog system may be optimized in advance i.e during design time many imp. aspects become clear only when system is running & used.

As can be seen, run time optimizaton plays an imp. role in optimizaton. This has some imp. result first the time available for executing an optimizaton algo during run time is seriously limited. thus the adopted optimizaton algo have to be fast.

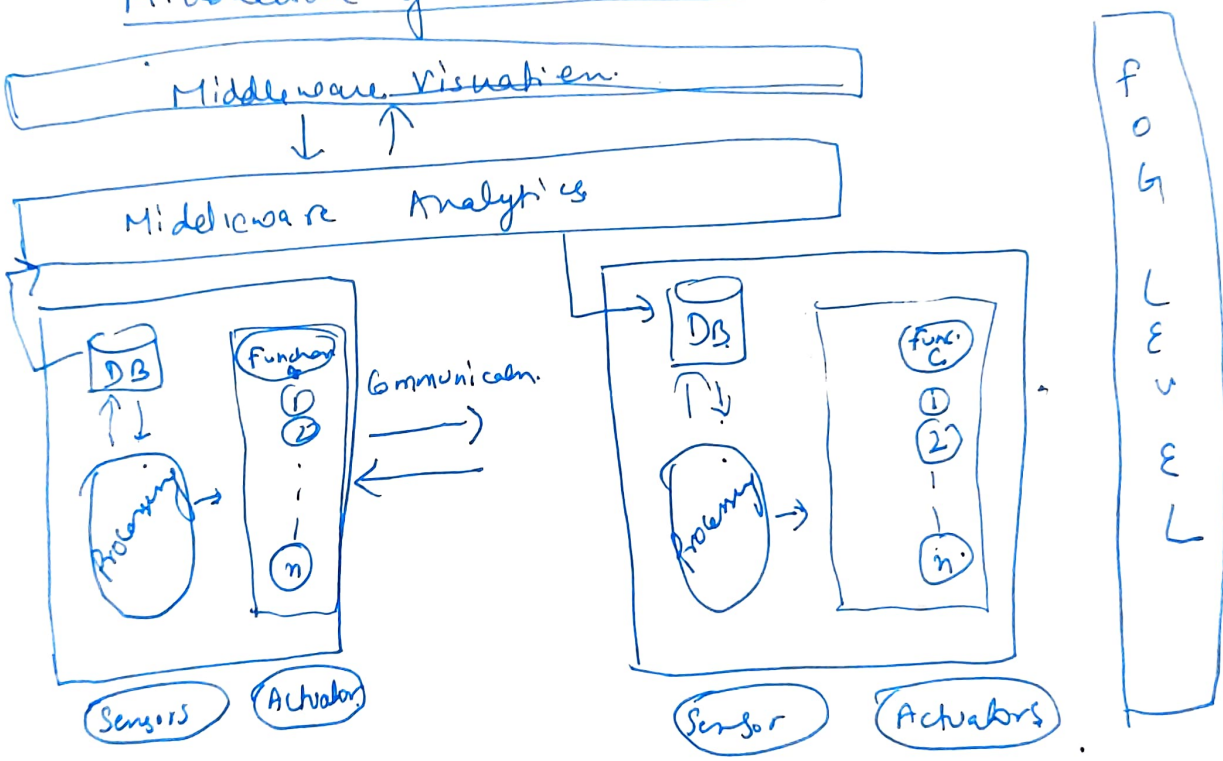
Second, run time optimizaton is not about laying out a system from scratch. but rather about adapting an existing step.

UNIT-5

⇒ MIDDLEWARE OF FOG & EDGE COMPUTING

The Existing IoT Systems gather data in Central place (cloud) for post processing & Situation awareness. Such a Collection & Computing method can not Sustain due to data growth; the Communication bandwidth is limited by Spectrum & Can't Catch up the data growth rate. The Middleware Enables a Mesh N/w Composed of many devices to share resources & Capabilities

Middleware general architecture.



Every Node has Small but powerful Computational Unit Nodes are able to Store raw & processed Info in the database. that is designed for Compressed data. Inside each processing unit, Nodes are able to manage I/I data generate real time Info.. Every Node is able to Communicate & cooperate with Neighbours using wireless. bluetooth

Middleware act as bridge b/w diverse technology, tools & DB So that you Can Integrate from Seamless into Single Systems

→ Middleware Enables the flow of real time info access within or among N/w

→ It helps streamline process & Improves efficiency

→ It is able to Maintain the Integrity of Info across Systems

→ It helps to create different types of N/w application.

→ It has the Capacity to Implement logic based on the request made by client.

→ It plays Imp. role in Concurrent processing, load balancing & Transaction Management

→ It helps to Secure access to back End resources

⇒ DESIGN GOALS

→ Middleware Identify the Issues design in wireless & Mobile Environments

→ Detailed design for an Image transcoding proxy & appl^n Session

→ Resource sharing, Shorter & Service response time. & Collaborative Service.

→ Lower data transmission load, faster & more accurate analysis.

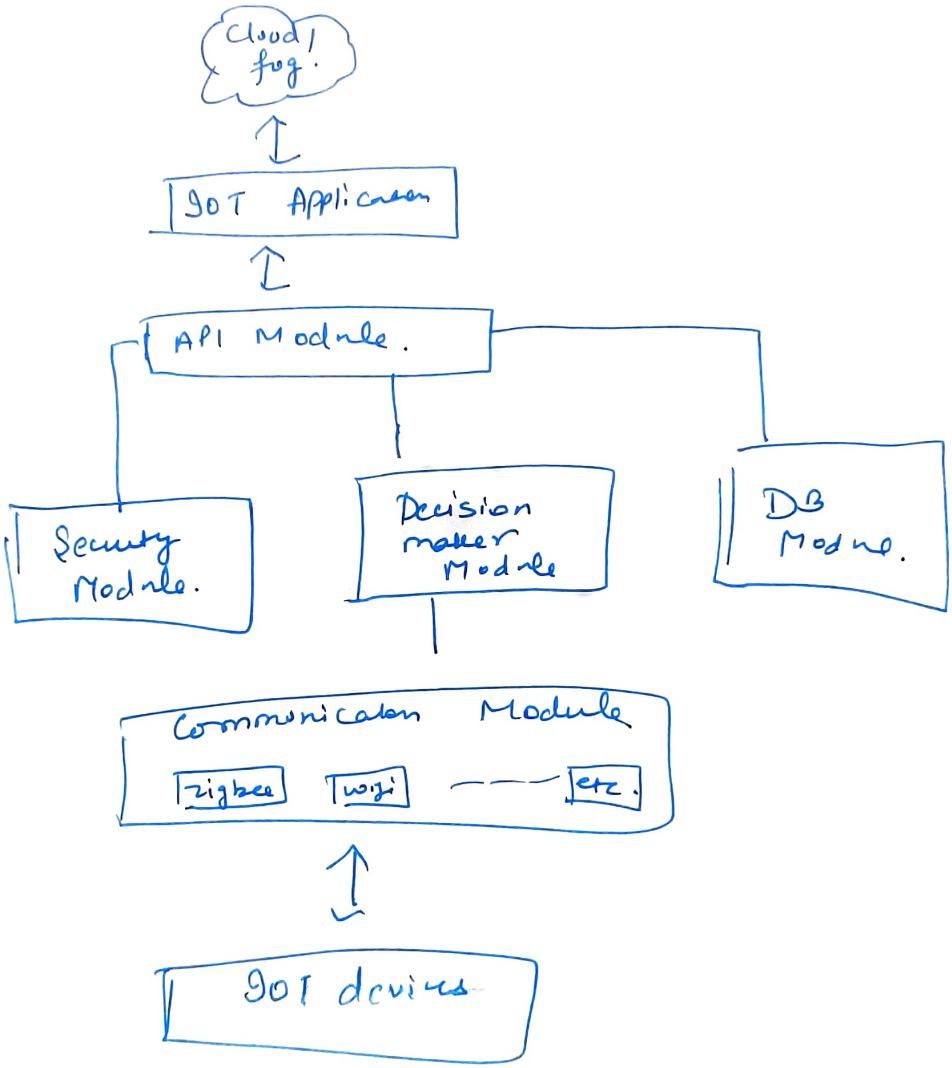
→ Latency - Low latency should be.

→ Efficiency - Efficient utilisation of resources & Energy

→ Generality - Due to heterogeneity of fog Node & client, we need provide same abstract to top layer & Appl^n Services for fog client

⇒ MIDDLEWARE SYSTEM ARCHITECTURE

Architecture consist of 4 distinct components IoT devices, Middleware, fog & cloud.
IoT devices collect data from surroundings & take basic security decisions. while Middleware take more advanced decision on whether data should be processed on fog or cloud.

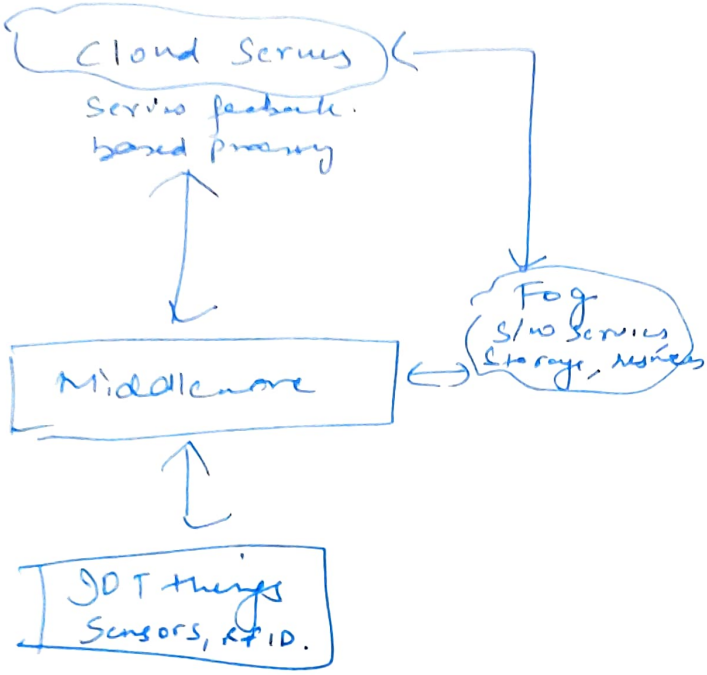


The Communication Module is in charge of communicating with various IoT devices.
Easy Integration, development & transparent data exchange with different IoT Entities. for this purpose protocols like Zigbee is used.

Decision maker Module has access to database of authorised things using their ID's

API Modules offers an Integrated & Improved access Interface for IoT applicatn.

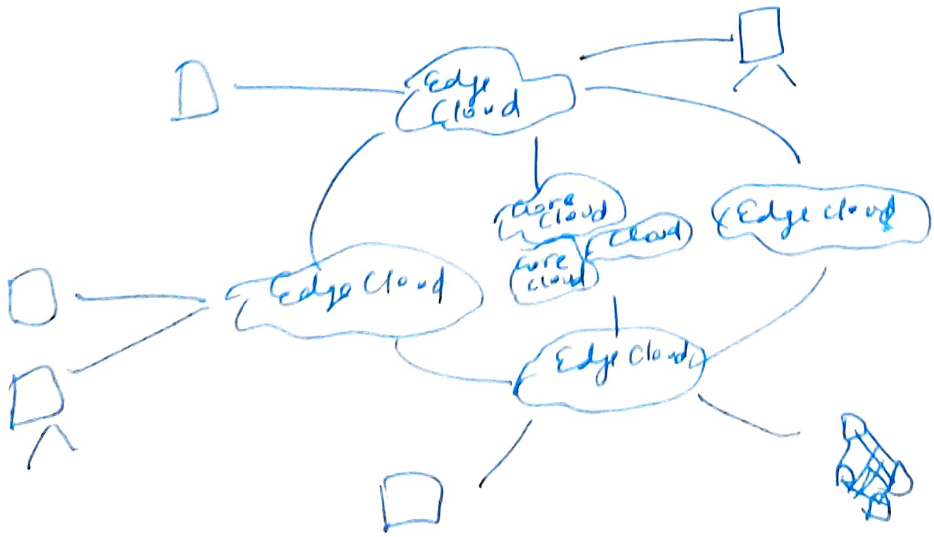
IoT applicatn - These are not resource Constrained Standard Security Sol. like SSL to Send request over Http.



=> CLUSTERS FOR LIGHT WEIGHT EDGE CLOUDS.

Cloud technology is moving towards more distribution across Multi Clouds & the Inclusion of various devices. Lightweight virtualisation Sol. are beneficial for this architectural setting with smaller but to manage solution.

Cloud edge Computing is pushing Computing applicatns, data & Service away from Centralised cloud data Centre architecture to edge of N/w.

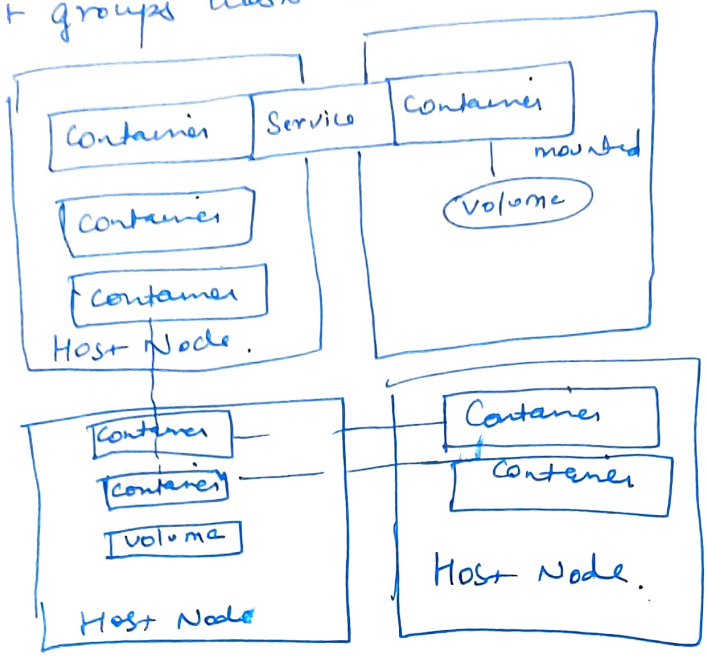


Resource architecture as cluster based Container architecture

In Centre & Edge clouds, but also IoT objects linked to Compute & Storage resources. & Applⁿ need to be Managed. i.e packaged, deployed.

Containers Clusters

It groups hosts into clusters.



Container based Cluster architecture.

Each cluster Consist of several host Nodes - where Nodes are virtual servers. Each host holds several containers with Common Services like Scheduling, load balancing & Applications. Each Container can hold Continuously provided Service payload Service. Links allow 2 or more Containers to Connect & Communicate.

Edge clouds move the focus from heavy weight data centre clouds to more light weight resources.

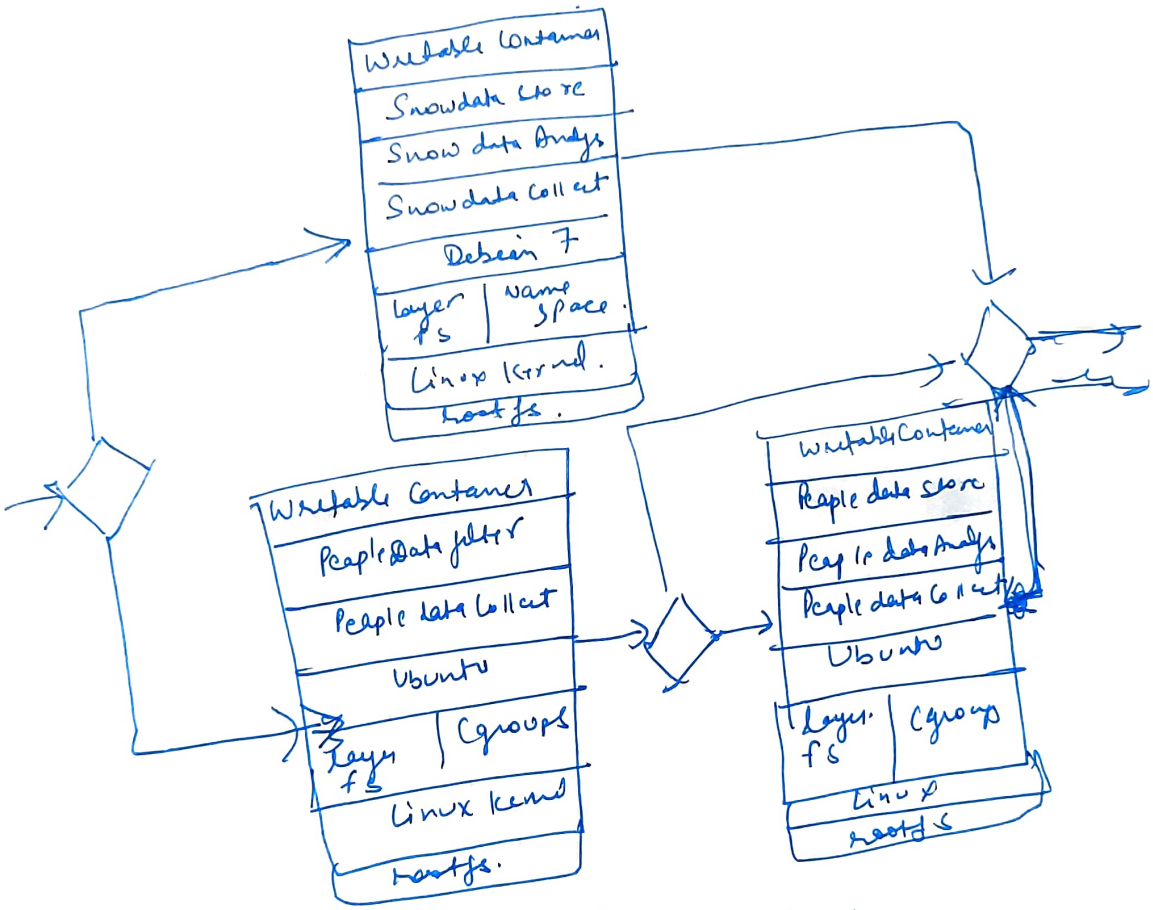
In the following we Explain how to build platform that are lightweight in terms of H/W & S/W.

① Lightweight Software - Containerization

Containerization that allow a light weight virtualization through the Construction of Containers. as application Packages from individual Images. This address performance & portability weakness of Current cloud Solutions.

Orchestration is about Constructing & Managing a possibly distributed assembly of container based S/w applⁿ. Container Orchestration is not only about Initial deployment Starting & Stopping of Containers but also about the Mgmt. A Multi-Pass based on Container clusters Can serve as Sol. for managing distributed S/w applⁿ

Orchestration plan for Ski resort Case study



(2) Light weight Hardware. — Raspberry Pi clusters.

Raspberry Pi's as the H/w device Infrastructure & Illustrate orchestration for Raspberry Pi clusters in Eg. cloud Env.

A Raspberry Pi (RPi) is relatively cheap & low power Consumption which make it possible to create an affordable & Energy efficient cluster that is suitable for Environment for which high-tech. Installation not Possible

=> NEED FOR FOG & EDGE COMPUTING MIDDLEWARE

Fog & Edge Computing are gaining acceptance due to high availability, low latency & low cost.
The Efficient design of middleware enables the realization of fog & Edge architectures. Middleware handles different tasks like N/w Mgmt, task Scheduling, Mobility Management, Security Management thereby reducing complexity of distributed mobile Appl^n design.
Middleware design is challenging because of appl^n requirements such as

→ Availability of Content on Sensing devices
→ Cost of data transfer
→ Limitation in No of edge device present
→ Strict latency constraints

=> DESIGN GOALS OF MIDDLEWARE

(1) Adhoc device discovery —
Data Sources in fog/Edge belong to wide category of devices ranging from IoT Sensors, mobile devices to fixed Servers. A channel of communication needs to be setup b/w requesting devices & adhoc discovered devices.

(2) Run time Execution Environment —
Middleware provides platform that Executes appl^n task remotely on Edge device.

(3) Minimal Task Disruption —
It affects the reliability of Execution of task.
It results in reinitialization of task. or unavailable results
Anticipatory ~~task~~ techniques can be used to Minimize the Interruption in task.

(4) Overhead of operational parameters

Establishg Comm. b/w adhoc edge devices, Selection of Candidate edge devices b/w Multiple edge devices. Incurs additional usage of Bandwidth & Energy Consumption on Edge devices. As these resources are expensive, minimizing the operational parameter is an Imp. aspect.

(5) Quality of Service - It is highly dependent on application. Many fog/edge appl" use Multidemensional data for achieving Specific goals.
Acquiring & processg such huge sensor data w.r.t. real time Constraint is requirement for these appl".
Real time response is an Imp. QOS measure.

→ STATE OF ART MIDDLEWARE INFRASTRUCTURE

Real time appl" that process the request for emergency rescue in disaster & Searchg for Missg persons.
Common requirement of these appl" need for Middleware to support easy design & development of such appl".
Popular IOT platform like Google Fit have a Cloud based IOT Middleware for Smartphones.
Service oriented middleware like GSN are proposed for processg data in distributed Environment.
In femtocloud System, the Mobile devices in edge can be configured to provide the Service to requesting devices.
Process on one or more devices where a data Stream generated on each device is processed on itself by Nakumera

	Devices	Security	Mobility Support	Context awareness	Data Analysis	optimized selection of devices
femto cloud.	Mobile	N	N	Y	Y	Y
Nakmore et al	Mobile & Sensor	N	N	N	Y	N
Aazam	Fog, MEC, cloud	Y	N	N	Y	Y
Bonomi	Fog, cloud.	N	Y	N	Y	Y
verbelan	Mobile Cloudlet	N	N	N	N	Y
cloudware	Cloudlet	N	N	Y	N	X
Piro	Cloud.	Y	Y	Y	Y	X

⇒ **SYSTEM MODEL**

FEA includes devices that classified into 5 types :-

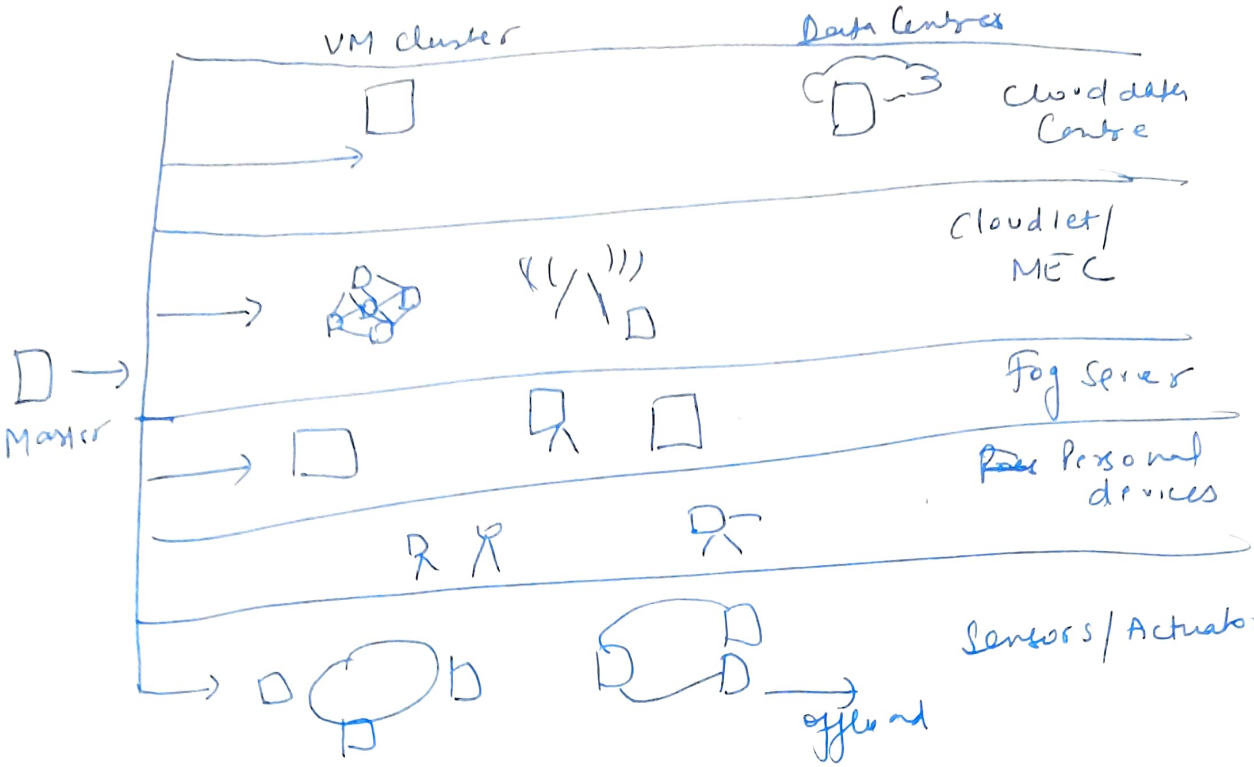
(1) Embeded Sensor / Actuators —
They are installed in physical structures or deployed on human body. Sensors are responsible for obtaining the Env. signals processed by body. while Actuators executes the action initiated by system.

(2) Personal devices —
It demonstrate mobility as they are owned by users. It act as an intermediate data hub or computing platform & provides comm. link to services.

(3) Fog Servers — It is more powerful than personal mobile devices. It provides cheaper option for offload virt. comm. costs. It used to process data.

(4) Cloudlets — It has high Bandwidth Internet Connectivity
They are Mobile Edge Computing Servers

(5) Cloud Server — It is associated with pay as you go Model. It can easily scale the no of VMs as to meet



Fog & Edge Computing devices.

⇒ PROPOSED ARCHITECTURE

Fog & Edge Computing appl^n include the following.

(i) Batch processing that needs large scale data acquisition

(ii) Quick response appl^n that needs response in real time

(iii) Stream appl^n that require processing of continuous data stream in real time.

Due to huge processing requirement, appl^n need a large distributed architecture that processes data in Multiple tiers. Lower tier performs filtering, preprocessing & Extraction. while Edge & fog servers used for processing & Analytics.

(1) API Code - Services designed as an API. It is then integrated into app.

(2) Security -

(3) Authentication -

(4) Privacy - fog Node provides Encryption Capabilities

(5) Device Discovery - It allow the new devices to participate & leave the N/w as they are available in N/w.

(6) Middleware

→ Context Monitoring & prediction -
It can adapt to dynamic changes in user Env.

→ Selection of participating devices -
It can process the data

→ Data Analytics - Some of the analytics task can be used to extract the essential info from raw data. Obtained on user devices.

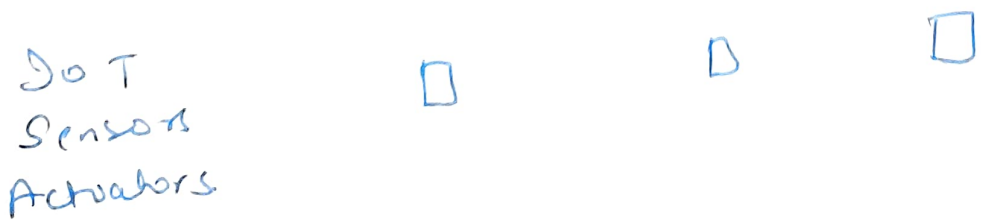
→ Scheduling & Resource Mgmt - Monitors the Incoming task & their assignment.

→ N/w Mgmt.

→ Execution Mgmt - It facilitates appl^n Specific code.

(7) Sensors / Actuators -

Applications	Health Care	Transport	Safety & rescue	
API	API Code	Security Authentication Privacy Encryption	Device Discovery	
Middleware Services	Context Monitoring & Prediction	Execution Mgmt Data Analytics	Scheduling & Resource Mgmt N/w Mgmt	Mobility Mgmt



CASE STUDY EXAMPLE

This is a Mobile appl" that performs real time tracking & Perpetrators through Video Surveillance using Surrogate Mobile phones available in the vicinity.

→ Device Discovery – one of the devices Initiates the Perpetrator tracking appl" by Sending a request on the publish Subscribe channel. Participating devices respond to request & comm. channel is established

→ Context Monitoring – Location is the main context that is required using GPS data on device.

→ Data Analytics – Instead of Sending all the Image data from Mobile devices for recognition Only Images that have faces is Sent.

→ Mobility Support – As perpetrator moves from one location to another Set of devices Select to run the appl" Change.. Moving devices are not ~~to~~ ~~be~~ to be used.

→ N/w Mgmt.

→ Execution Mgmt

→ Scheduling – GPS location of Perpetrator changes as the Preprator is on move.

→ Security Authentication of new device is performed on fog server. Data Encryption is performed.