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 :-

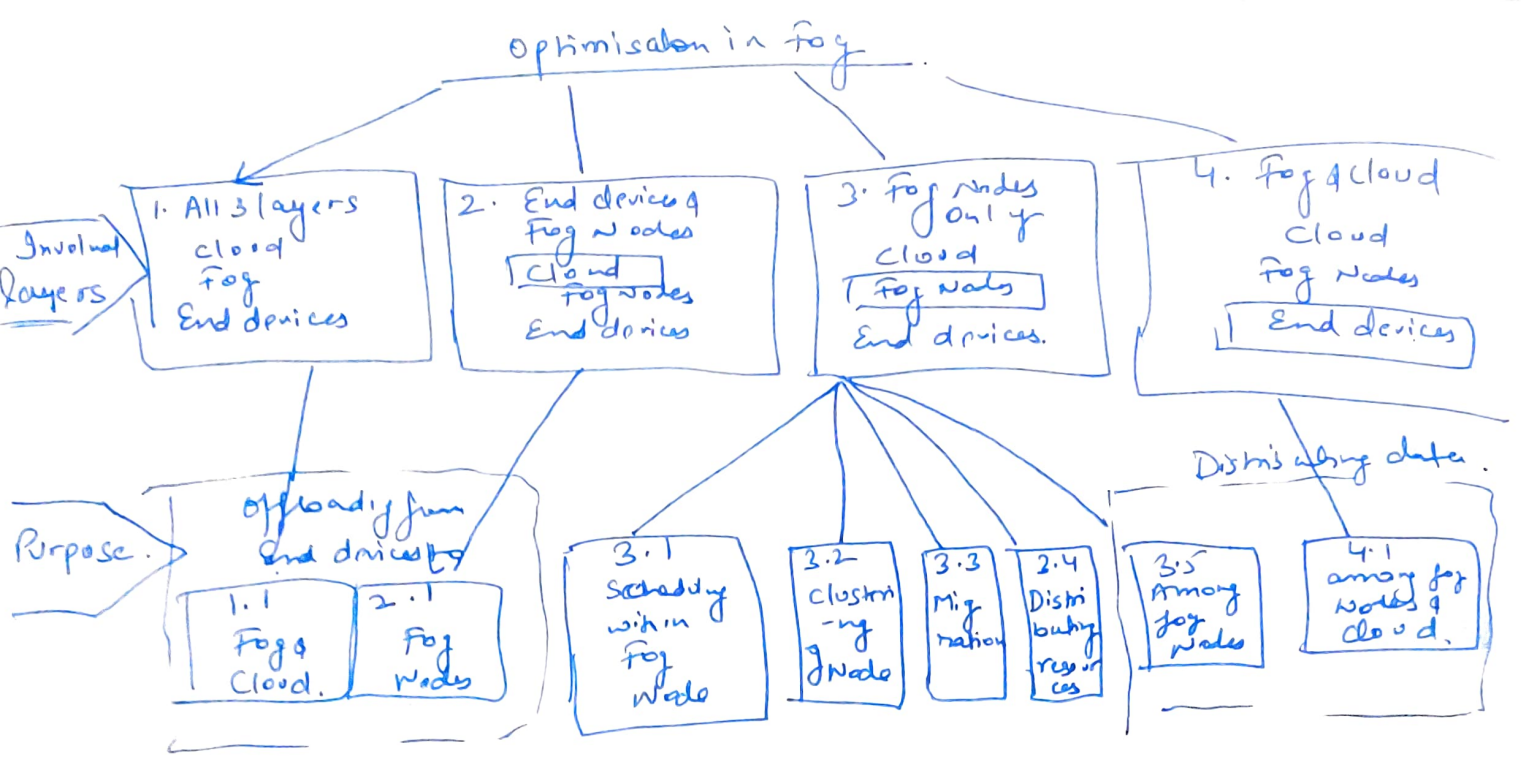
→ A Set of Variables that Encode decision to be made
→ The Set of possible values for each variable.
→ Set of Constraints
→ An objective function.

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

Taxonomy of optimisation problems in fog Computing.

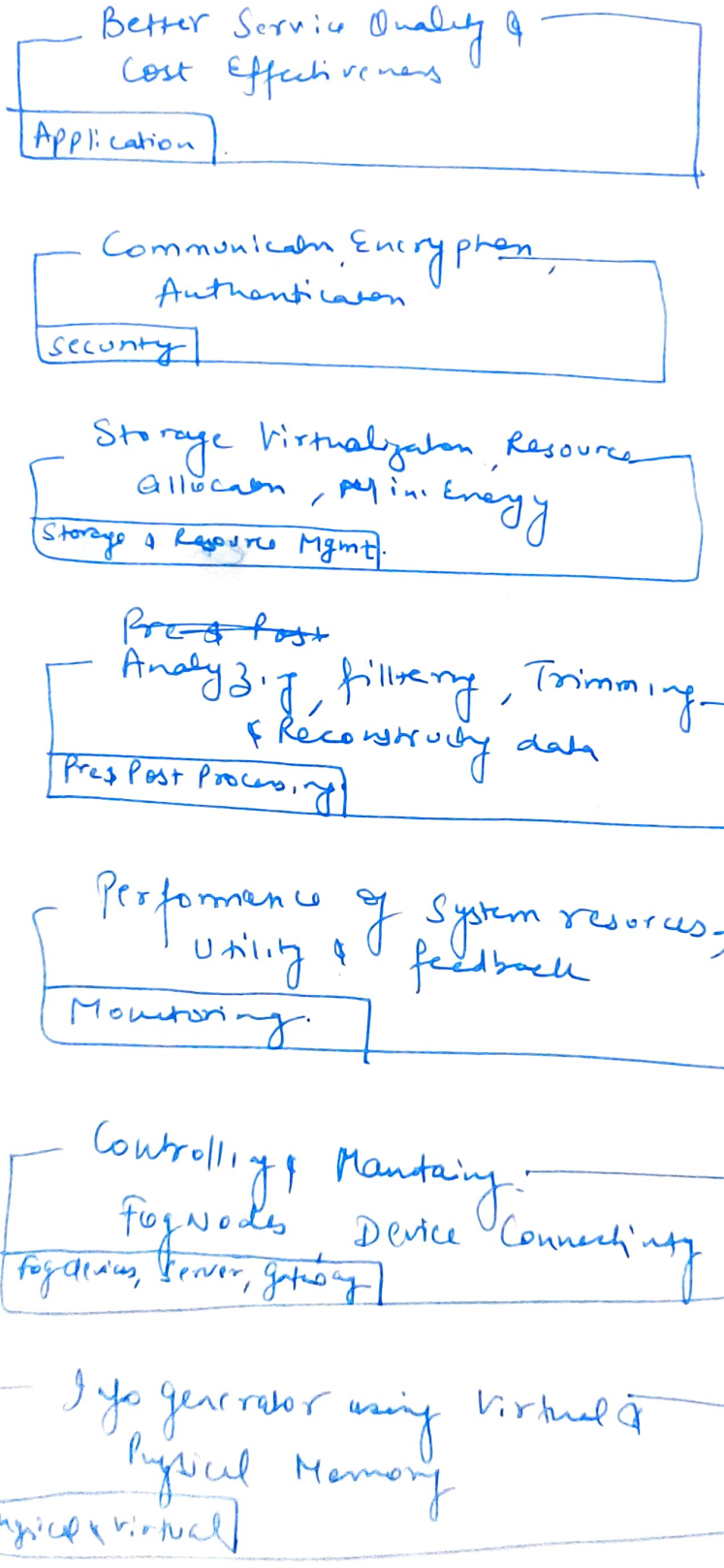
Four Categories are :-

(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



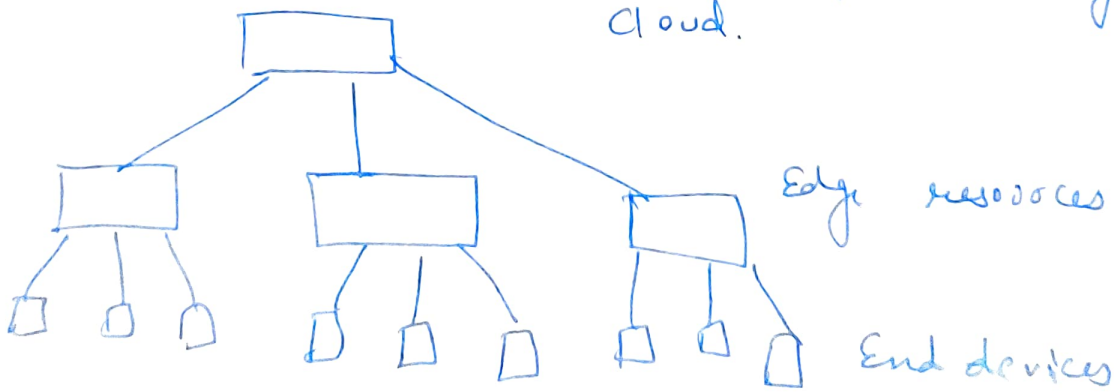
⇒ CASE FOR OPTIMISATION IN FOG COMPUTING

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.