بسمه تعالی

Survey on Fog Computing: Architecture, Key Technologies, Applications and Open Issues

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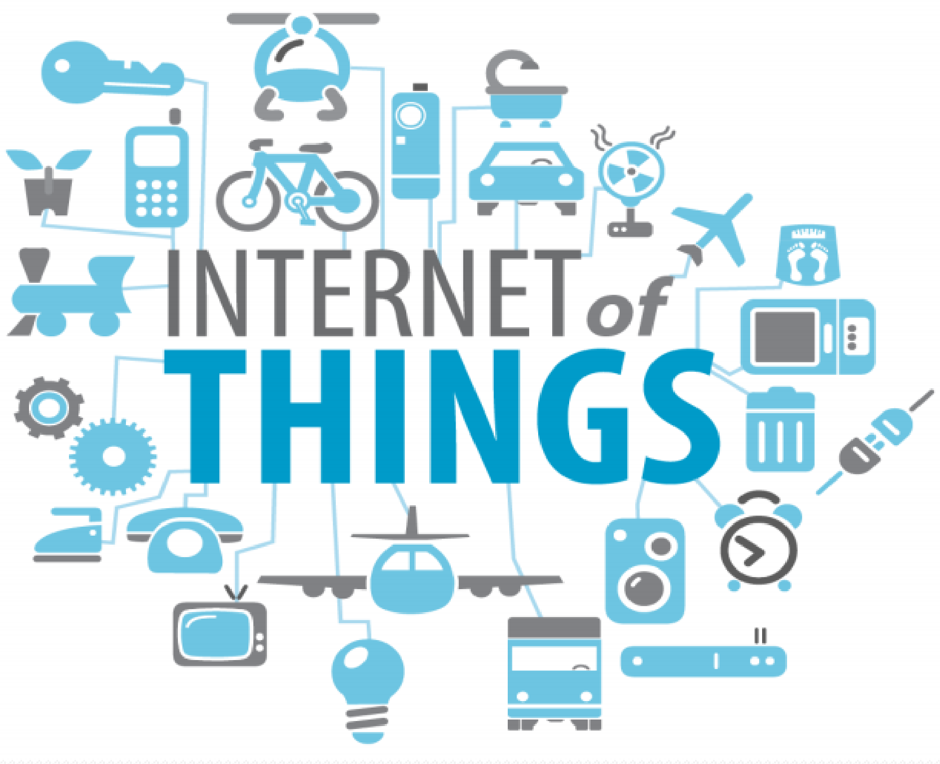
Internet of Things (IoT)

- The Internet of Things (IoT) is the network of physical objects devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data.
- By 2020, the number of “things” that are part of the IoT may reach up to 50 billion. That’s a lot of data being generated.



Existing Cloud Computing System

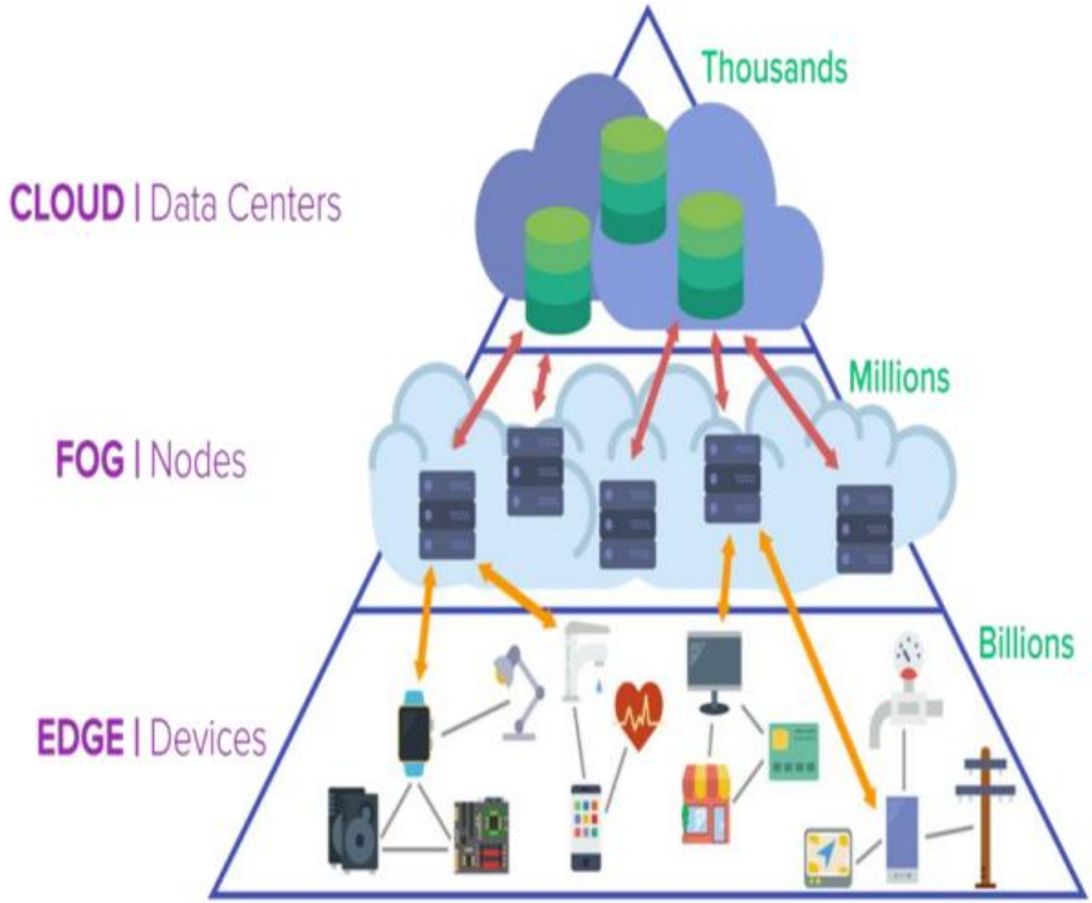
❑Cloud computing is a type of computing that relies on sharing computing resources rather than having local servers or personal devices to handle applications.

Cloud Computing Limitations

1) Not Always Connected:
   - Connectivity to the Cloud is a pre-requisite of cloud computing.
   - Some IoT systems need to work even if connection is temporarily unavailable.
2) Not Always Enough Bandwidth:
   - Cloud computing assumes that there is enough bandwidth to collect the data.
   - That can become an overly strong assumptions for Industrial IoT applications.
3) Cloud computing centralizes analytics:
   - Thus defining the lower bound reaction time of the system.
   - Some IoT applications won't be able to wait for the data to get to the cloud, be analyzed and for insights to get back.
4) Security Shortcomings:
   - Existing data protection mechanisms in Cloud Computing such as encryption failed in securing the data from the attackers.

Fog Computing

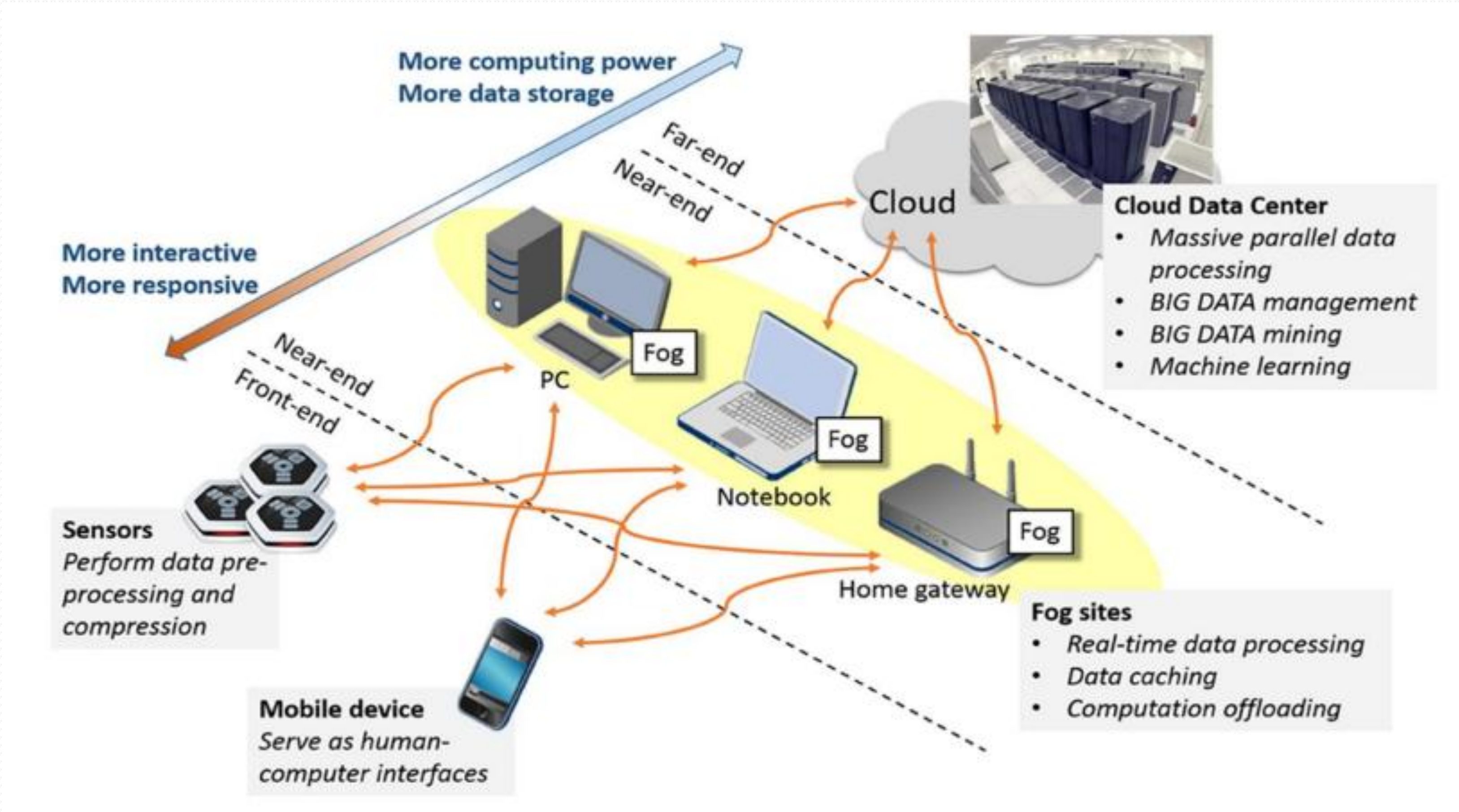
Whereas the cloud is "up there" in the sky somewhere, distant and remote and deliberately abstracted. The "fog" is close to the ground, right where things are getting done.



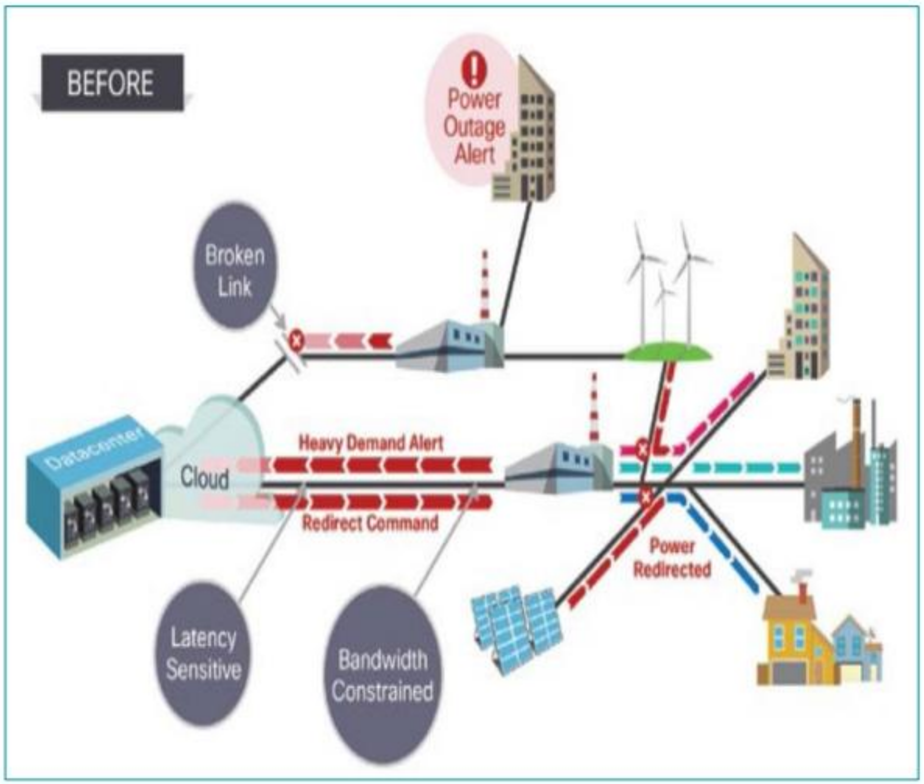
Fog Computing

- Fog computing (aka, Edge computing) is a paradigm that extends Cloud computing and services to the edge of the network.
- Fog computing places processes and resources at the edge of the cloud, often on network devices, while data remains stored in the cloud.
- This leads to faster processing times and fewer resources consumed.
- The term "Fog Computing" was introduced by the Cisco Systems in January 2014 as new model to ease wireless data transfer to distributed devices in the IoT network paradigm.

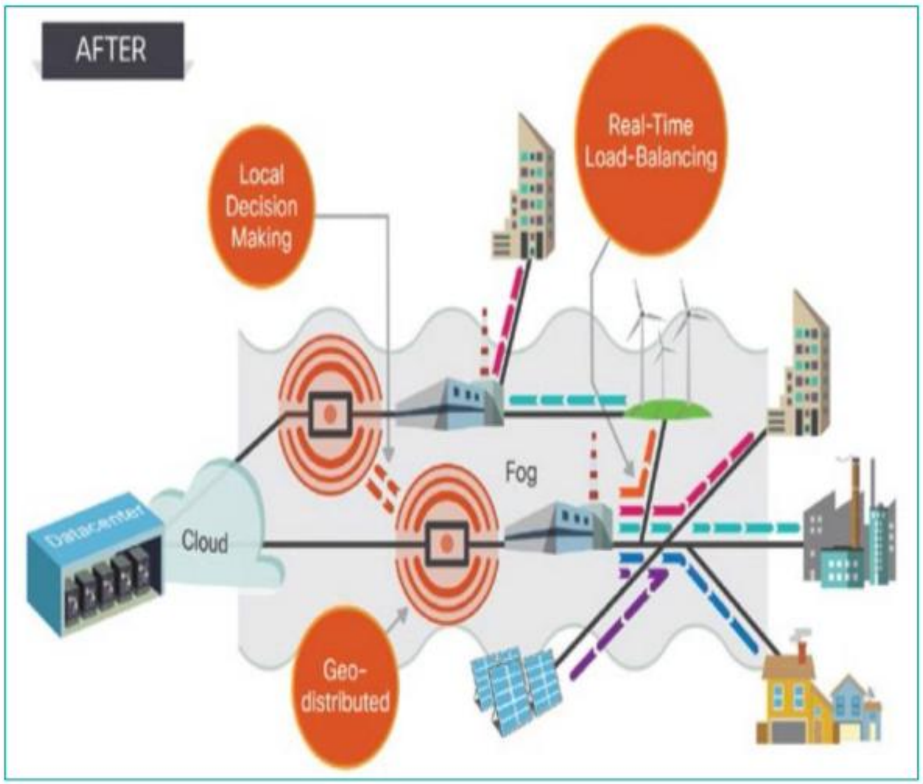
Fog Computing



Fog Computing: Before & After



Cloud architecture before the advent of fog technology



Cloud architecture with the advent of fog technology

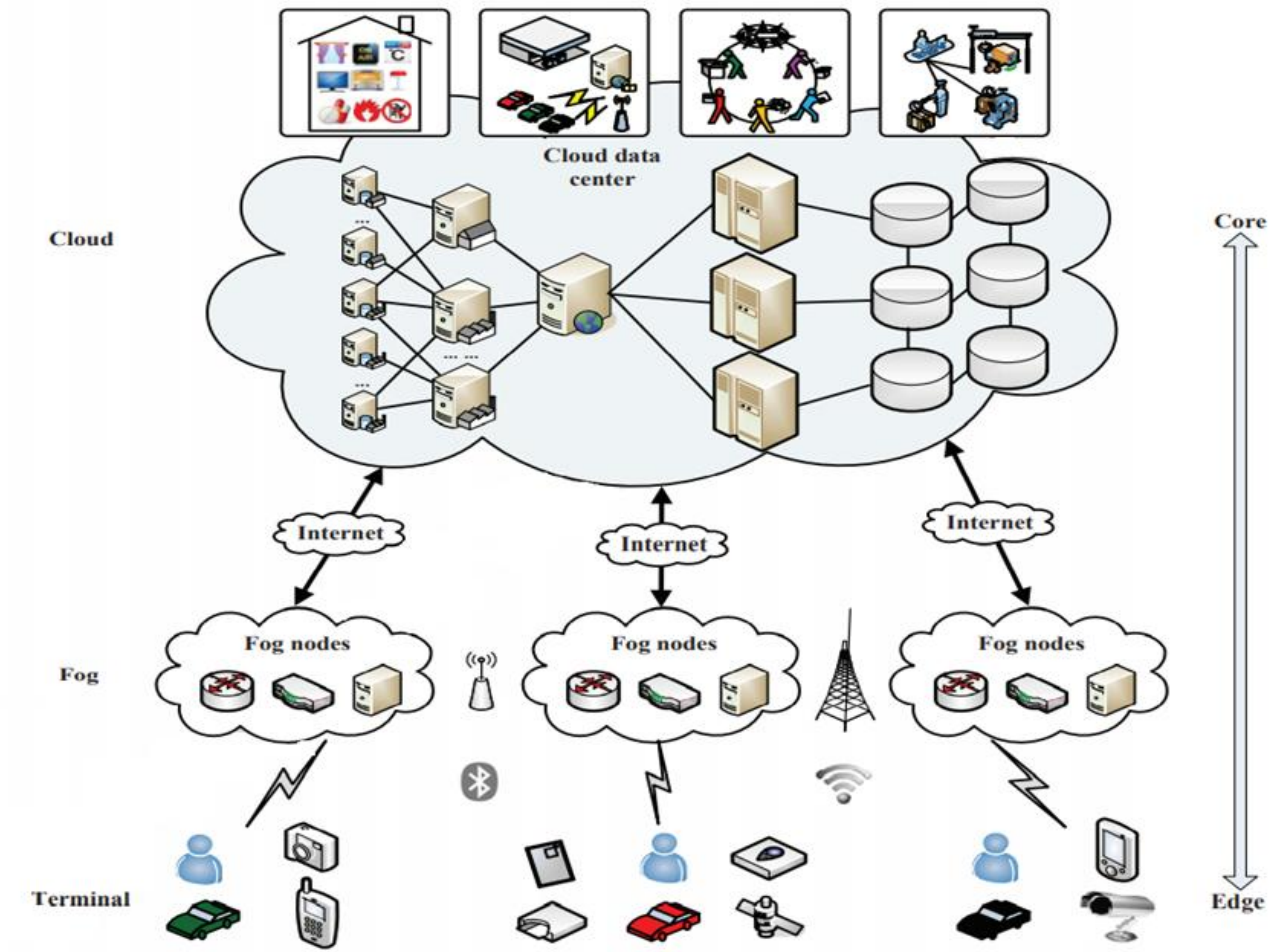
Fog Computing Characteristics

1) Low latency and real time interactions
2) Save bandwidth
3) Support for mobility
4) Geographical distribution and decentralized data analytic
5) Heterogeneity
6) Interoperability
7) Data security and privacy protection
8) Low energy consumption

Fog VS. Cloud

Requirement	Cloud Computing	Fog Computing
Latency	High	Low
Delay Jitter	High	Very Low
Location of Server Nodes	With in Internet	At the edge of local n/w
Distance between the client and server	Multiple Hops	One Hop
Security	Undefined	Can be Defined
Attack on data enrouter	High Probability	Very Less Probability
Location Awareness	No	Yes
Geographical Distribution	Centralized	Distributed
No. of server nodes	Few	Very Large
Support for Mobility	Limited	Supported
Real time interactions	Supported	Supported
Type of last mile connectivity	Leased line	Wireless

Fog Computing Architecture



Fog Computing Architecture

The architecture defines three main services for Fog and IoT environments that are described below:

❑Monitoring Components:

• Keep track of the resource utilization and availability of sensors, actuators, Fog devices and network elements. They keep track of the applications and services deployed on the infrastructure by monitoring their performance and status. Monitoring components supply this information to other services as required.

❑Resource Management:

• Is the core component of the architecture and consists of components that coherently manage resources in such a way that application level QoS constraints are met and resource wastage is minimized. To this end, Placement and Scheduler components play a major role by keeping track of the state of available resources to identify the best candidates for hosting an application module.

❑Power Monitoring:

• One of the toughest challenges that most IoT solutions face is utilization of resources of IoT nodes while considering constraints on energy consumption.

• In contrast to cloud data centers, Fog computing encompasses a large number of devices with heterogeneous power consumption, making energy management difficult to achieve.

What Happens in the Fog and the Cloud?

Fog nodes

- Receive feeds from IoT devices using any protocol, in real time.
- Run IoT-enabled applications for realtime control and analytics, with millisecond response time.
- Provide transient storage, often 1–2 hours.
- Send periodic data summaries to the cloud.

Cloud platform

- Receives and aggregates data summaries from many fog nodes.
- Performs analysis on the IoT data and data from other sources to gain business insight.
- Can send new application rules to the fog nodes based on these insights.

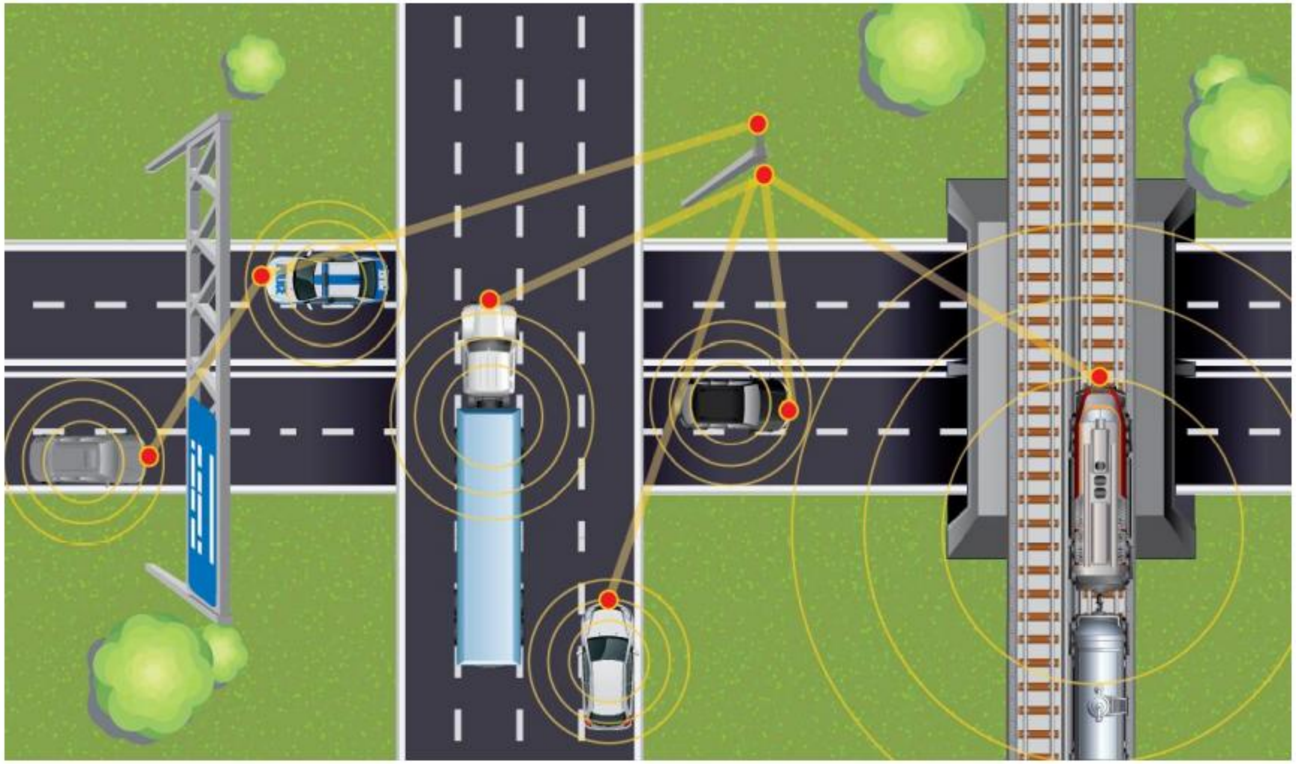
Fog Computing Applications : Healthcare Systems

Challenges For Healthcare

- ❑Healthcare systems in most countries face enormous challenges that will increase due to aging population and the rise of chronic diseases.
- ❑Growing nursing staff shortage.
- ❑Much time is wasted in hospitals by manually measuring biometric parameters and transferring the data between systems.

Fog Computing Applications : Connected Cars

- ❑ Fog computing is ideal for Connected Vehicles because real-time interactions will make communications between cars, access points and traffic lights as safe and efficient as possible.
- ❑ Fog computing will be the best option for all internet connected vehicles because fog computing gives real time interaction.



Connected Vehicles communicating each other

Fog Computing Applications : Smart Cities

❑ Fog computing would be able to obtain sensor data on all levels, and integrate all the mutually independent network entities within.

Summary

- Fog computing gives the cloud a companion to handle the two exabytes of data generated daily from the Internet of Things. Processing data closer to where it is produced and needed solves the challenges of exploding data volume, variety, and velocity.
- Fog computing accelerates awareness and response to events by eliminating a round trip to the cloud for analysis.
- It avoids the need for costly bandwidth additions by offloading gigabytes of network traffic from the core network. It also protects sensitive IoT data by analyzing it inside company walls. Ultimately, organizations that adopt fog computing gain deeper and faster insights, leading to increased business agility, higher service levels, and improved safety.

Resource management challenges in Fog Compiting

- ❑ The first problem is provisioning edge nodes for executing workloads offloaded from the cloud
- ❑ The second problem is deploying workloads on edge nodes.

(i) How to deploy a workload on the edge node?

On the cloud, Virtual Machines (VMs) are usually employed to execute a workload. However, VMs are less likely to be suitable on edge nodes given the availability of limited hardware resources.

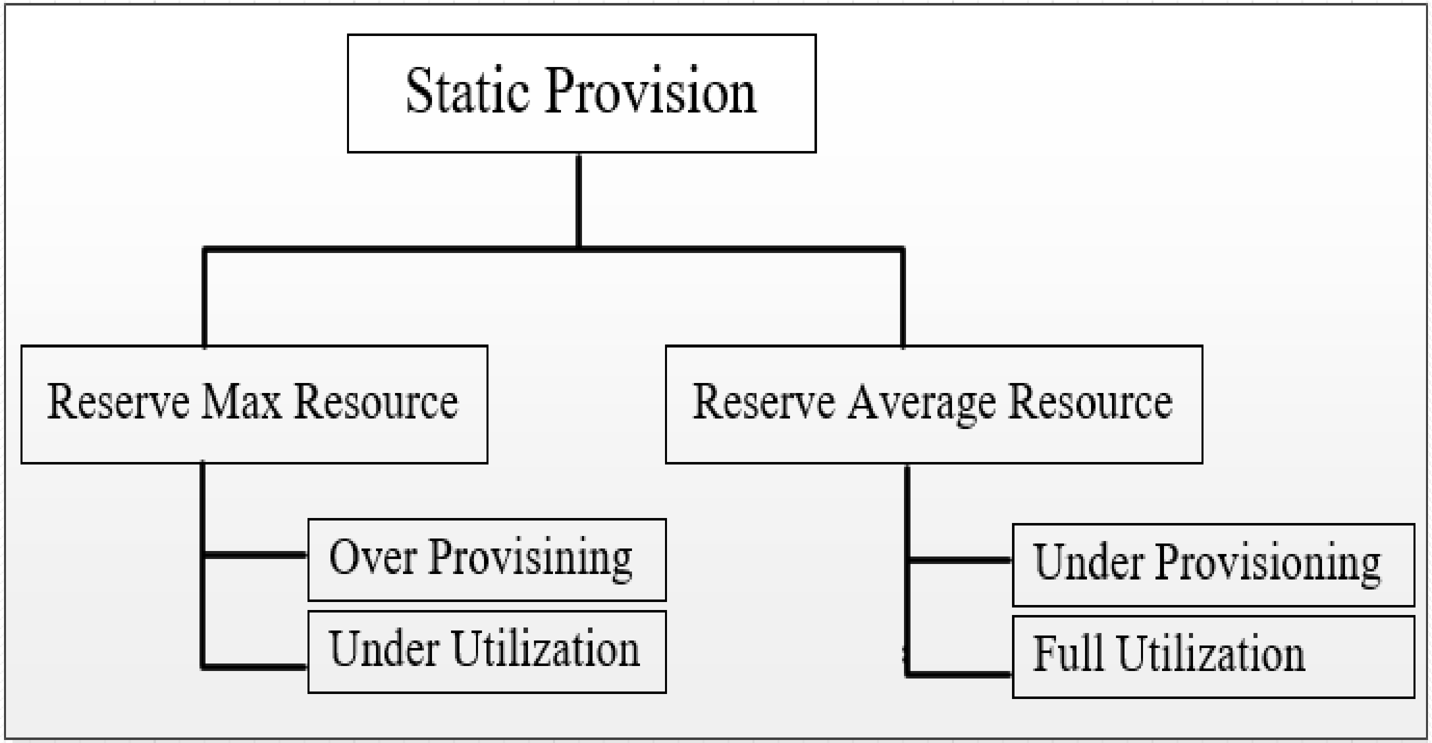
(ii) How much of the workload can be deployed on the edge node?

Large workloads are easily executed on the cloud given the access to a large amount of resources

- ❑ The third problem is managing resources on edge nodes. Due to its basic service, workloads offloaded to an edge node are of secondary priority, since the primary service cannot be compromised.

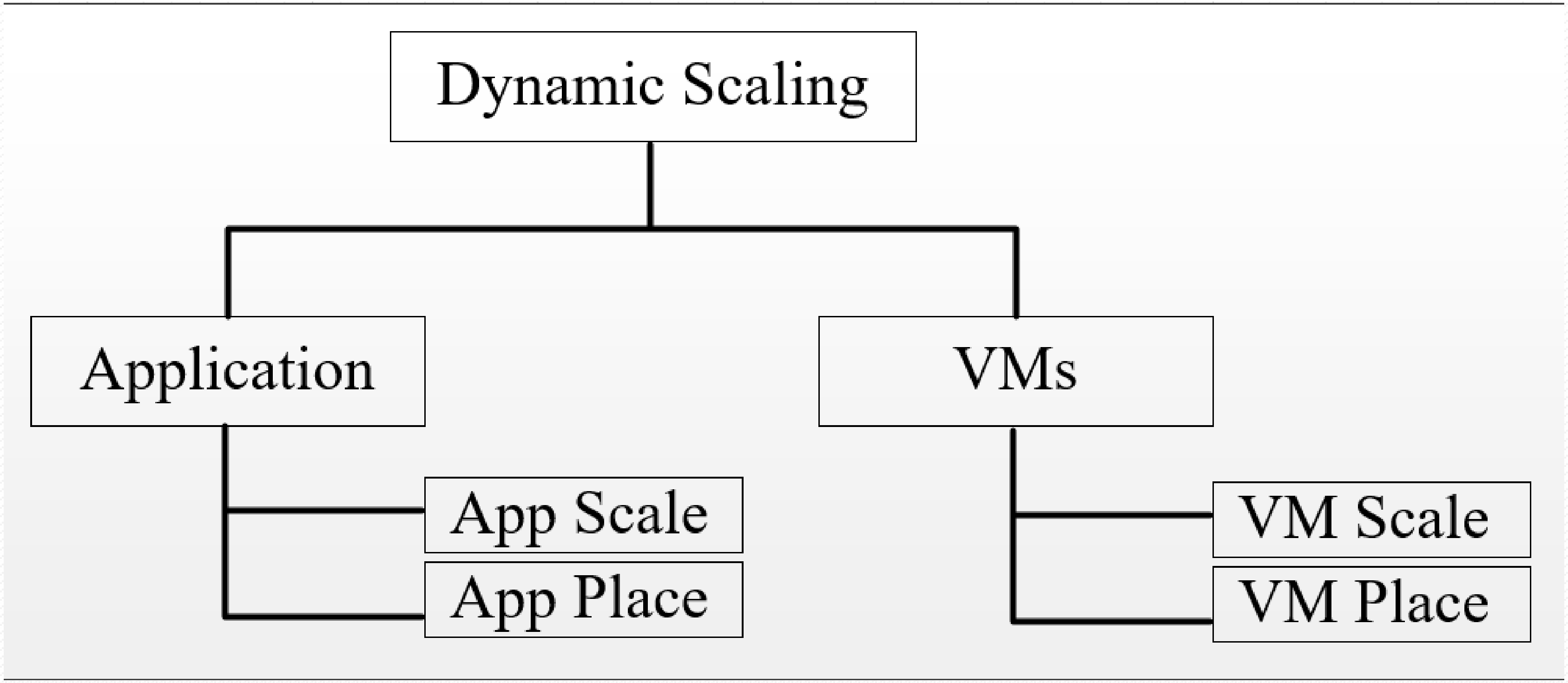
Provisioning types : Static Provisioning Vs Dynamic Provisioning

- **Challenges:**
  - **Over-Provisioning**
  - **Under-Provisioning**
  - **Oscillation**



Dynamic Provisioning

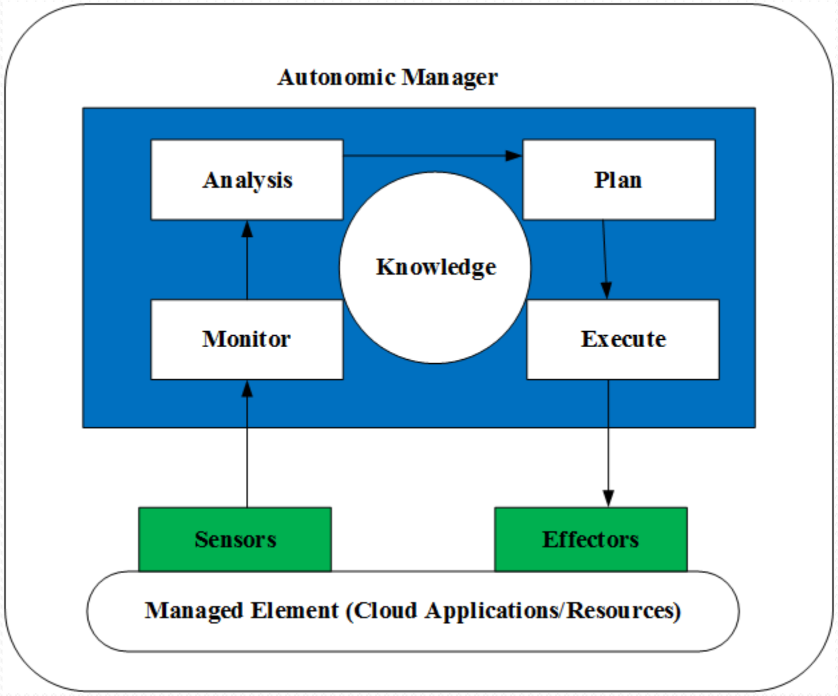
- In contrast, dynamic provisioning solves the under and over provisioning of resources by adjusting resource allocations to the changing workload that the system receives.
- dynamically adding and removing cloud resources to handle the fluctuating Internet user request demands of the applications



Auto-scaling

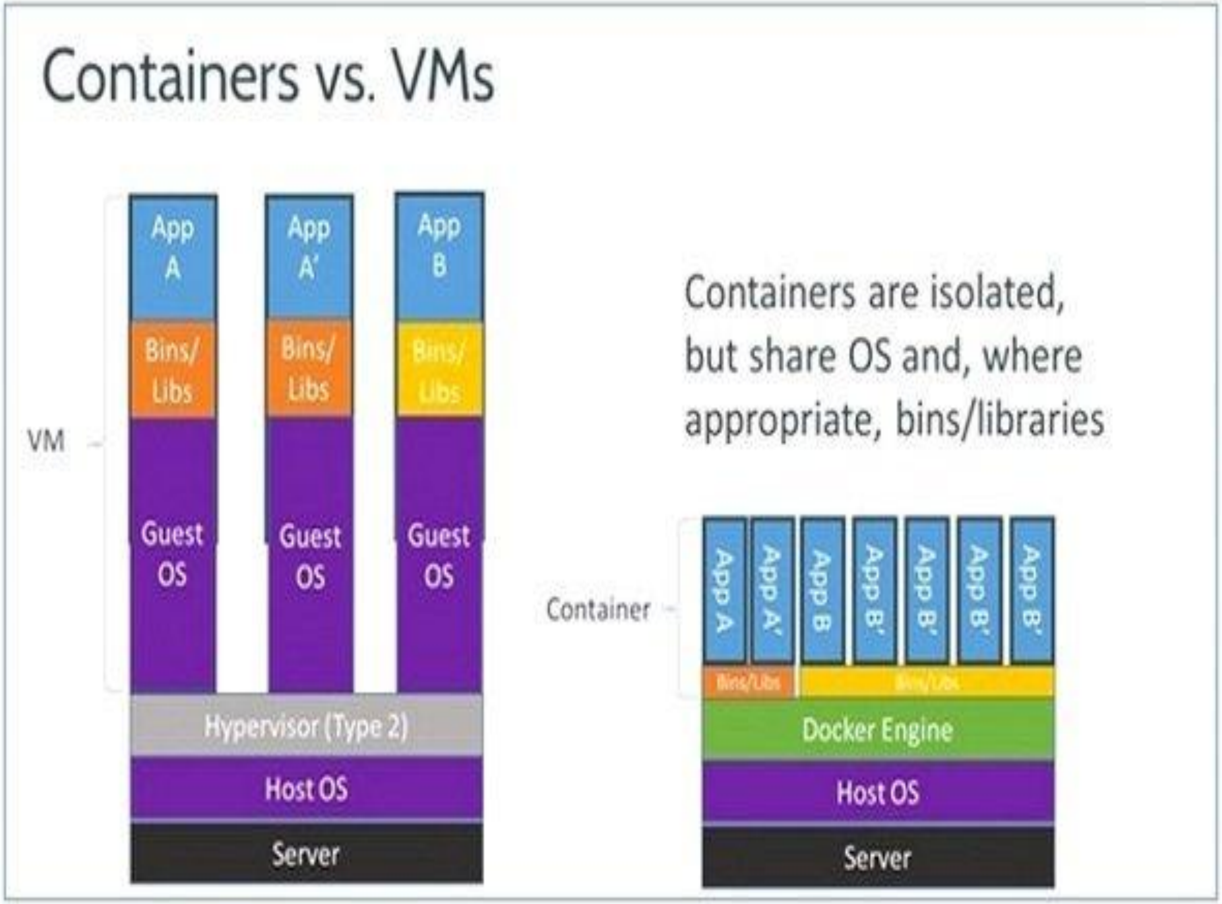
The importance of scaling resources allocated to an edge application server is in that:

- (i) the edge nodes have limited hardware resources (will need to be primarily used for basic services)
- (ii) the application server executing on the node requires more or less resources to the meet the QoS objective.



Hypervisor vs. Container

Which Virtualization
- VM Based
- Container Base
- VM&Container Base

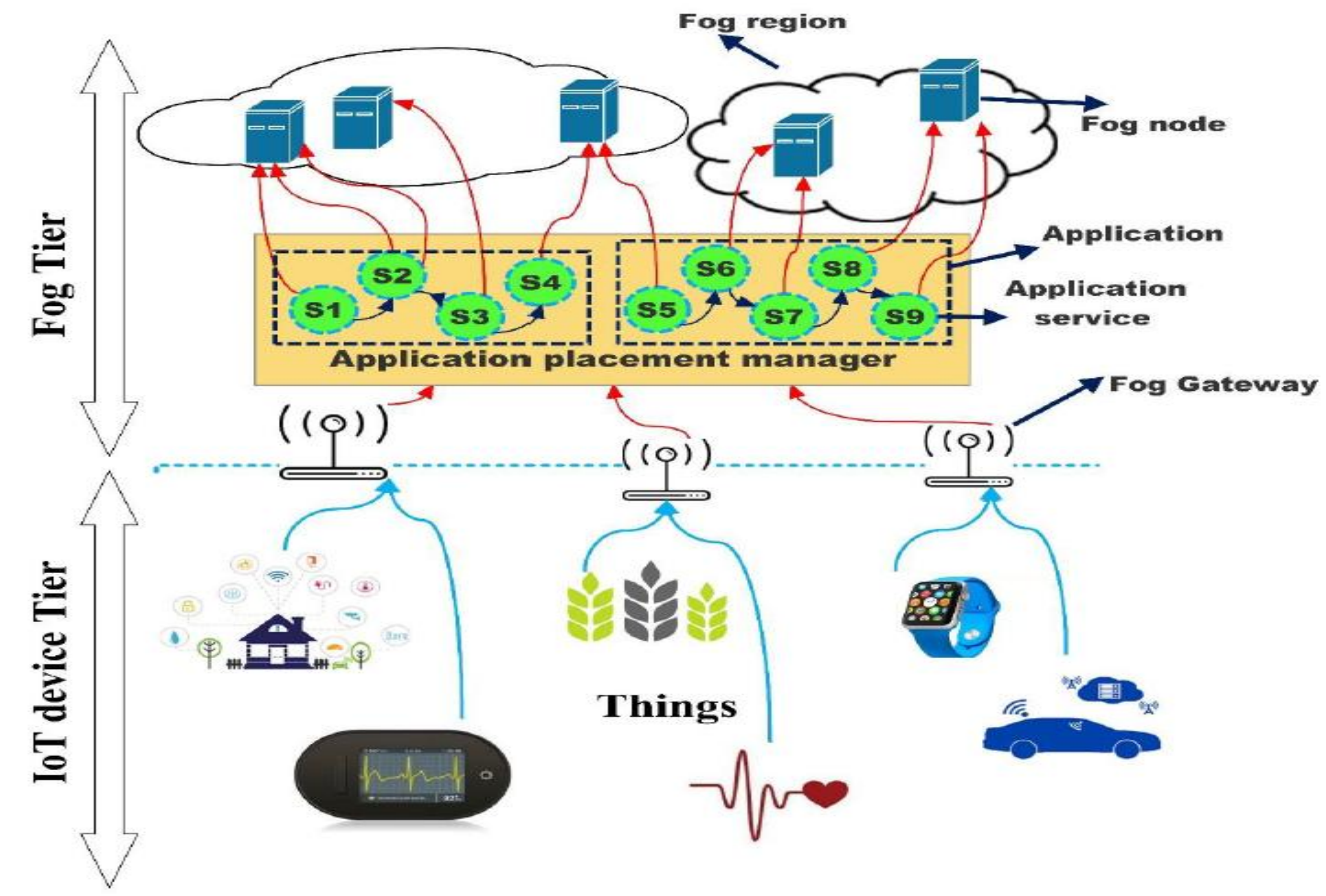


Resource Management Approaches in Fog Computing

- ❑Application Placement
- ❑Resource Scheduling
- ❑Task Offloading
- ❑Load Balancing
- ❑Resource Allocation
- ❑Resource Provisioning

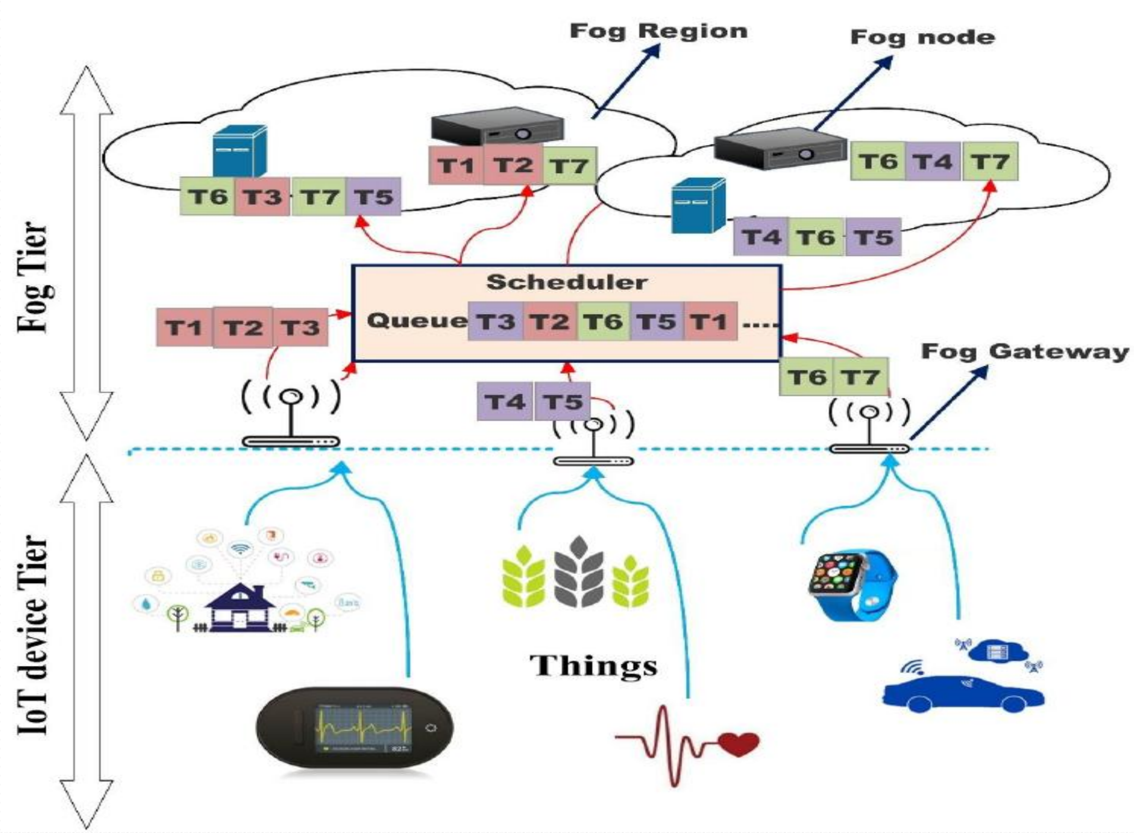
Application placement

The fog service placement problem in the fog landscape determines an optimal placement plan between IoT services and fog nodes with the objective of maximizing the fog resource utilization while meeting QoS requirements (e.g., service deadline) of IoT services



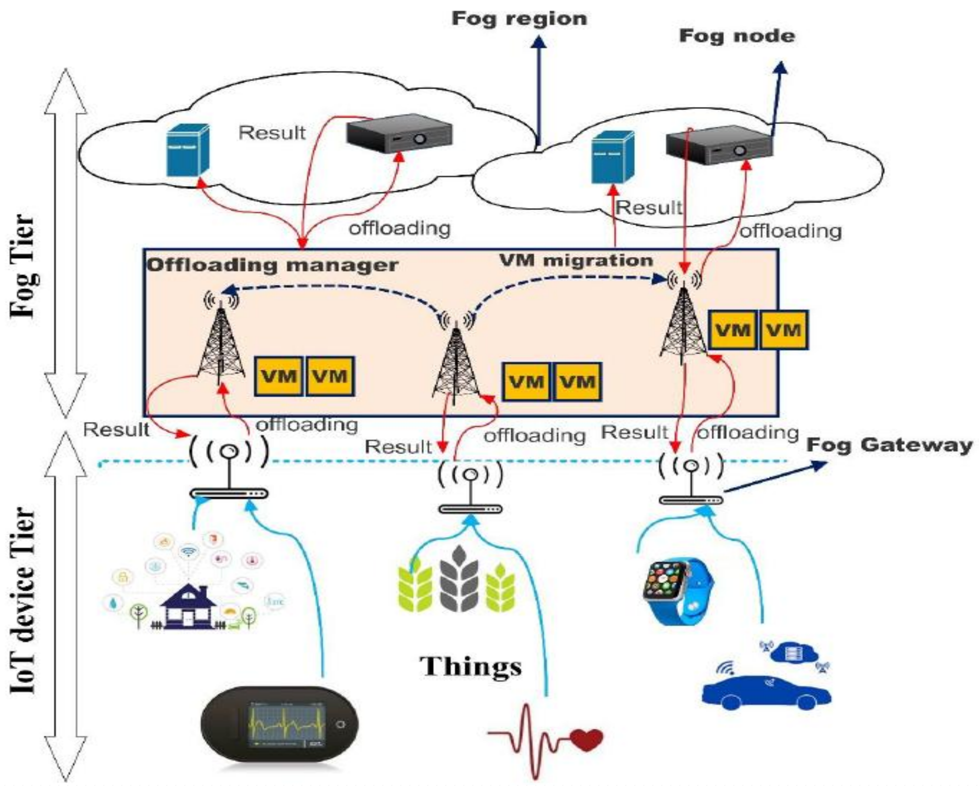
Resource Scheduling

The resource scheduling problem in fog computing determines an optimal assignment of different tasks submitted to be executed on the fog nodes placed at the edge of the network in order to meet SLA constraints signed with an IoT device user while minimizing the execution time for the task submitted



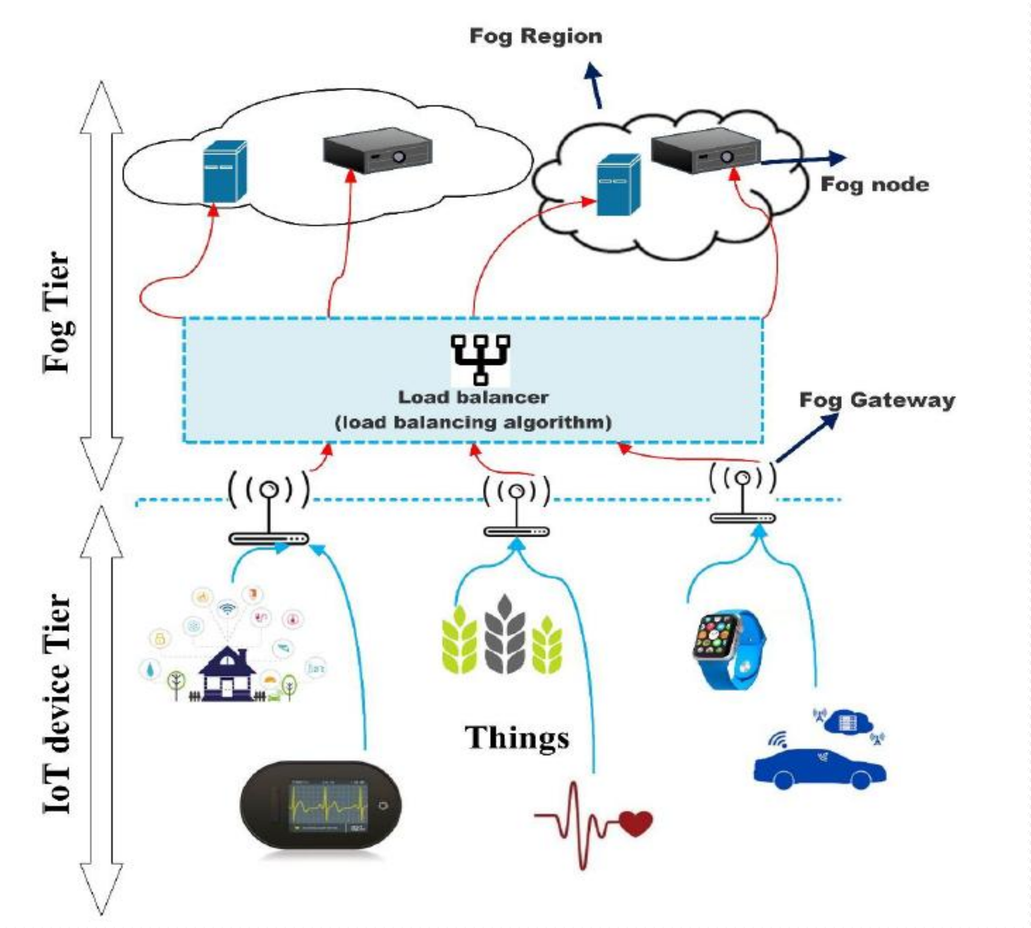
Task offloading

The task offloading technique can deal with the resource constraints on IoT devices, especially for the compute-intensive tasks in the mobile devices. Mobile devices are typically resource limited and, often it becomes need to outsource some of their tasks to the fog or cloud for improving their performance and saving battery. IoT applications need another component for tasks execution on behalf of the IoT devices and return the results to them which this process is called task offloading.



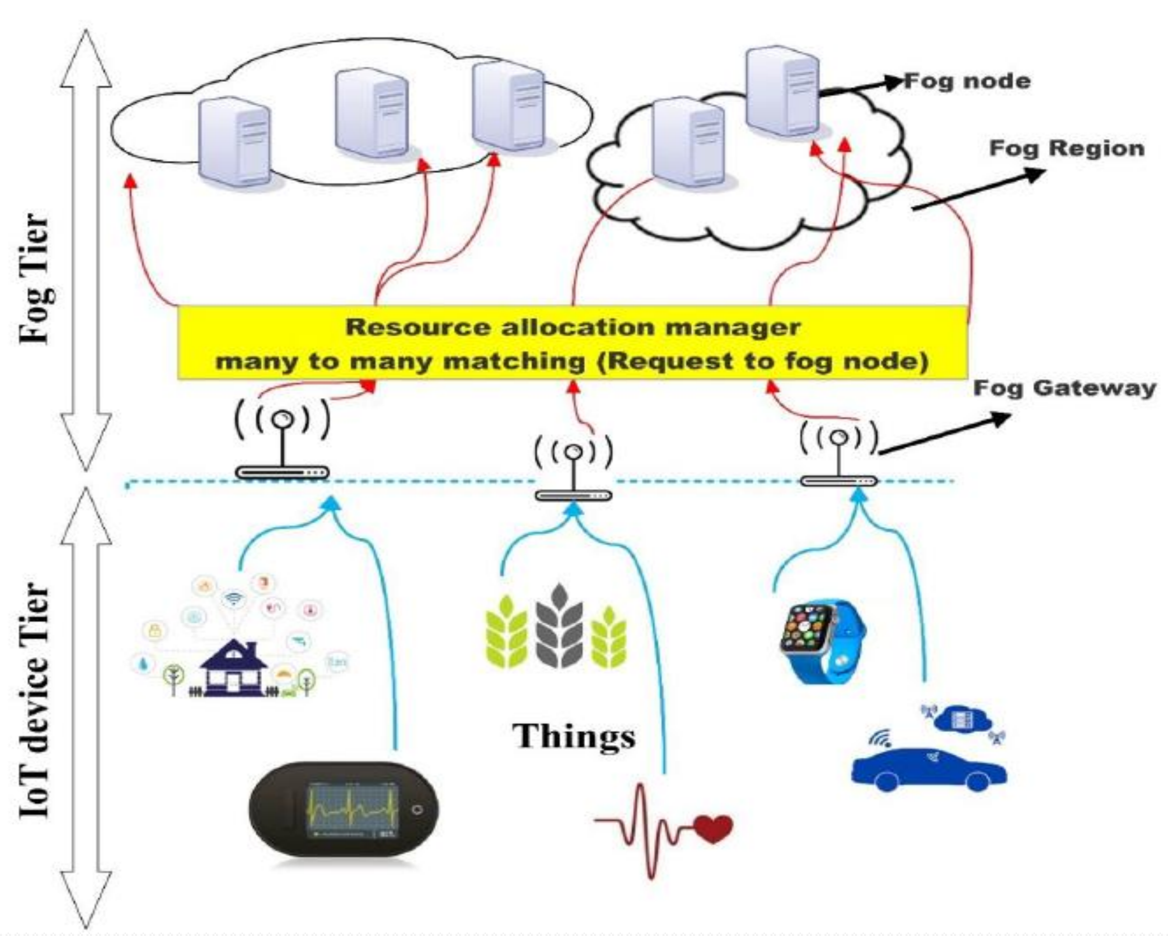
Load balancing

For balancing the load between fog nodes with different capabilities, the tasks are assigned to many fog nodes according to one strategy to avoid under-load or overload of the fog nodes, while could minimize response time



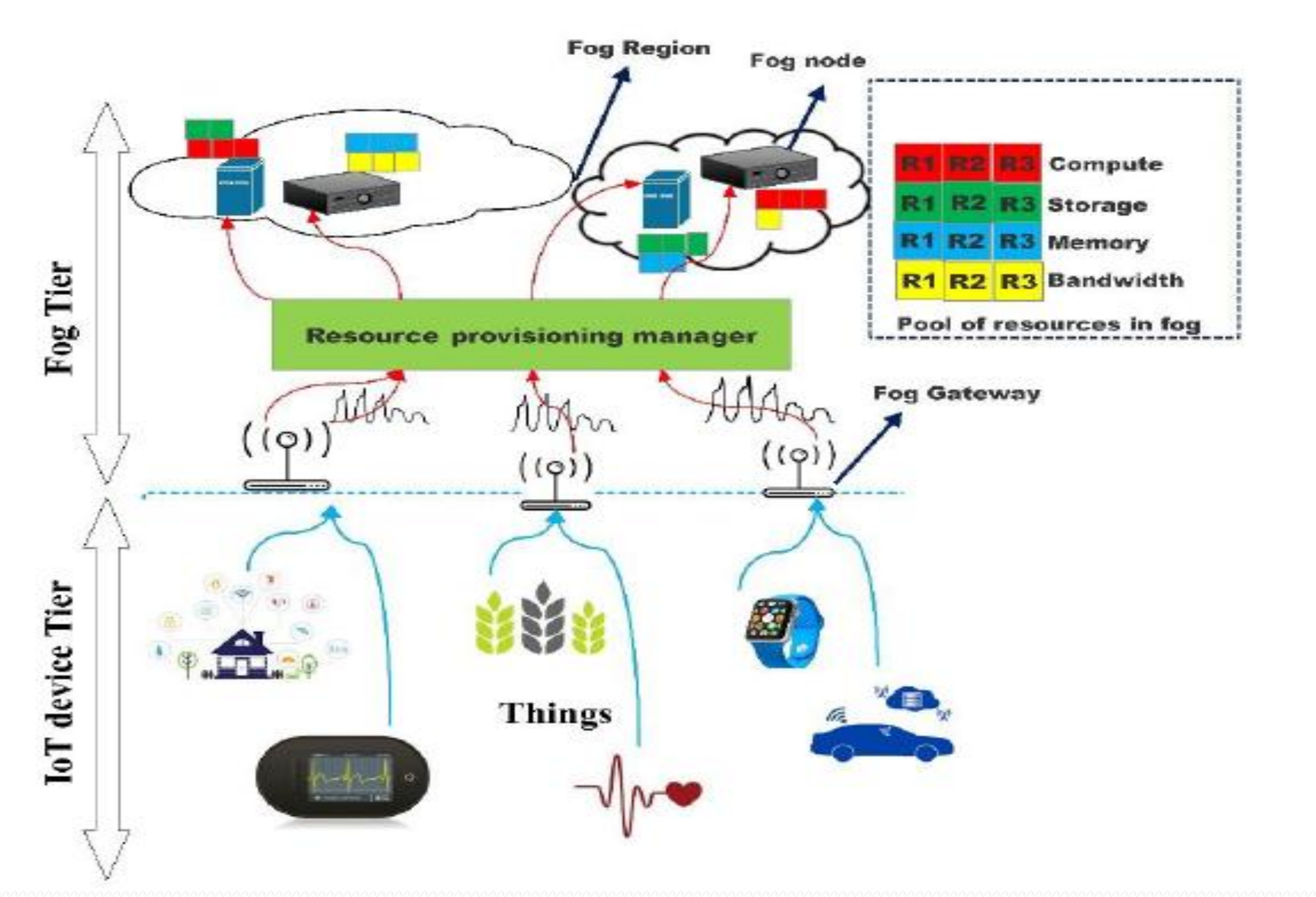
Resource Allocation

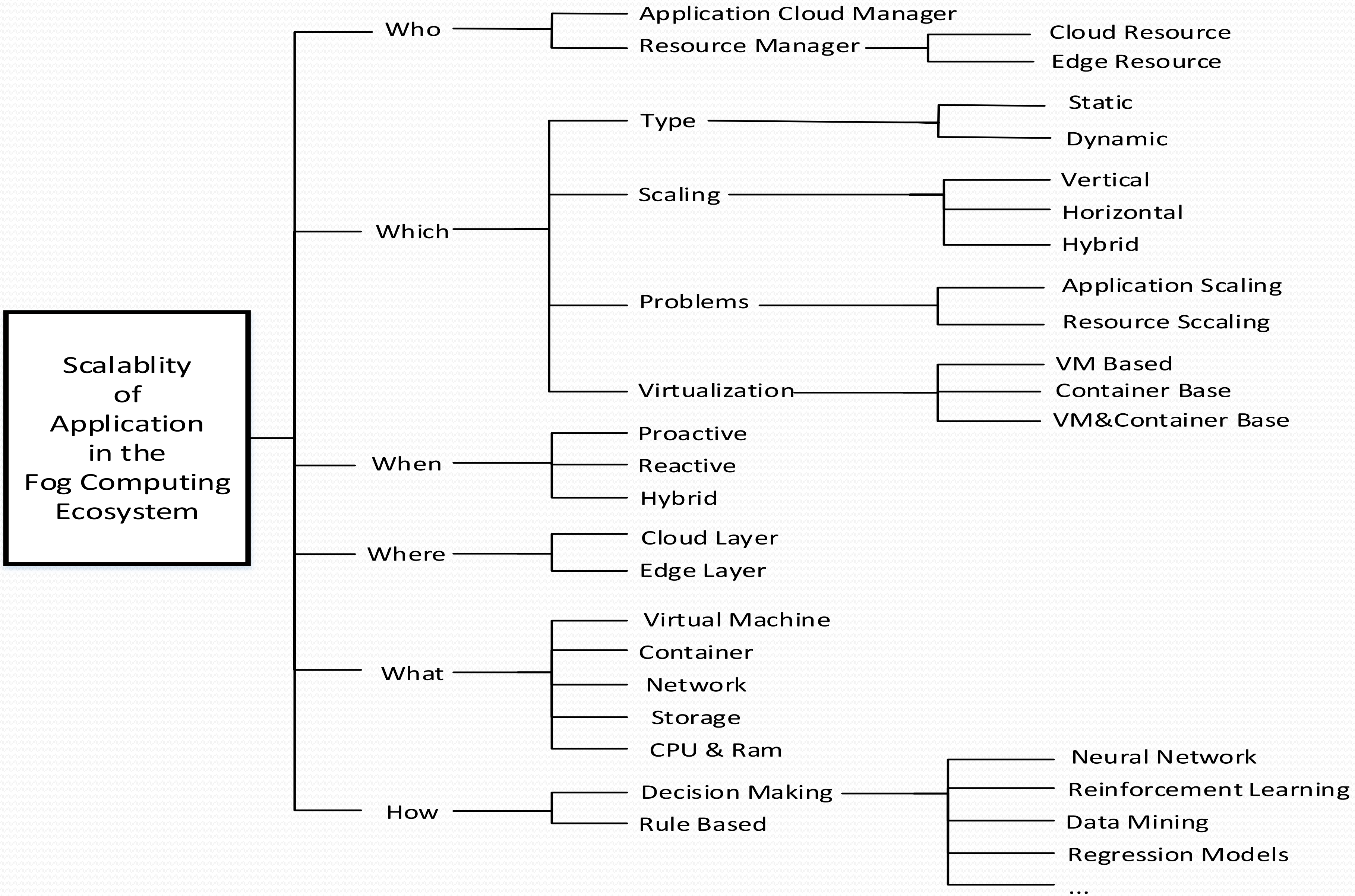
The resource allocation problem is efficiently allocate a set of geographically distributed heterogeneous fog nodes to competing IoT services with different QoS requirements, considering service priority and fairness.



Resource Provisioning

The dynamic resource provisioning is an efficient approach to deal with the IoT workload fluctuations and it is the ability to scale up and down fog nodes according to the incoming IoT devices workload.




Scalablity of Application in the Fog Computing Ecosystem
Who
Application Cloud Manager
Resource Manager
Cloud Resource
Edge Resource
Which
Type
Static
Dynamic
Scaling
Vertical
Horizontal
Hybrid
Problems
Application Scaling
Resource Sccaling
Virtualization
VM Based
Container Base
VM&Container Base
When
Proactive
Reactive
Hybrid
Where
Cloud Layer
Edge Layer
What
Virtual Machine
Container
Network
Storage
CPU & Ram
How
Decision Making
Rule Based
Neural Network
Reinforcement Learning
Data Mining
Regression Models
...


Clouds
Cloud Services
Cloud Consumers