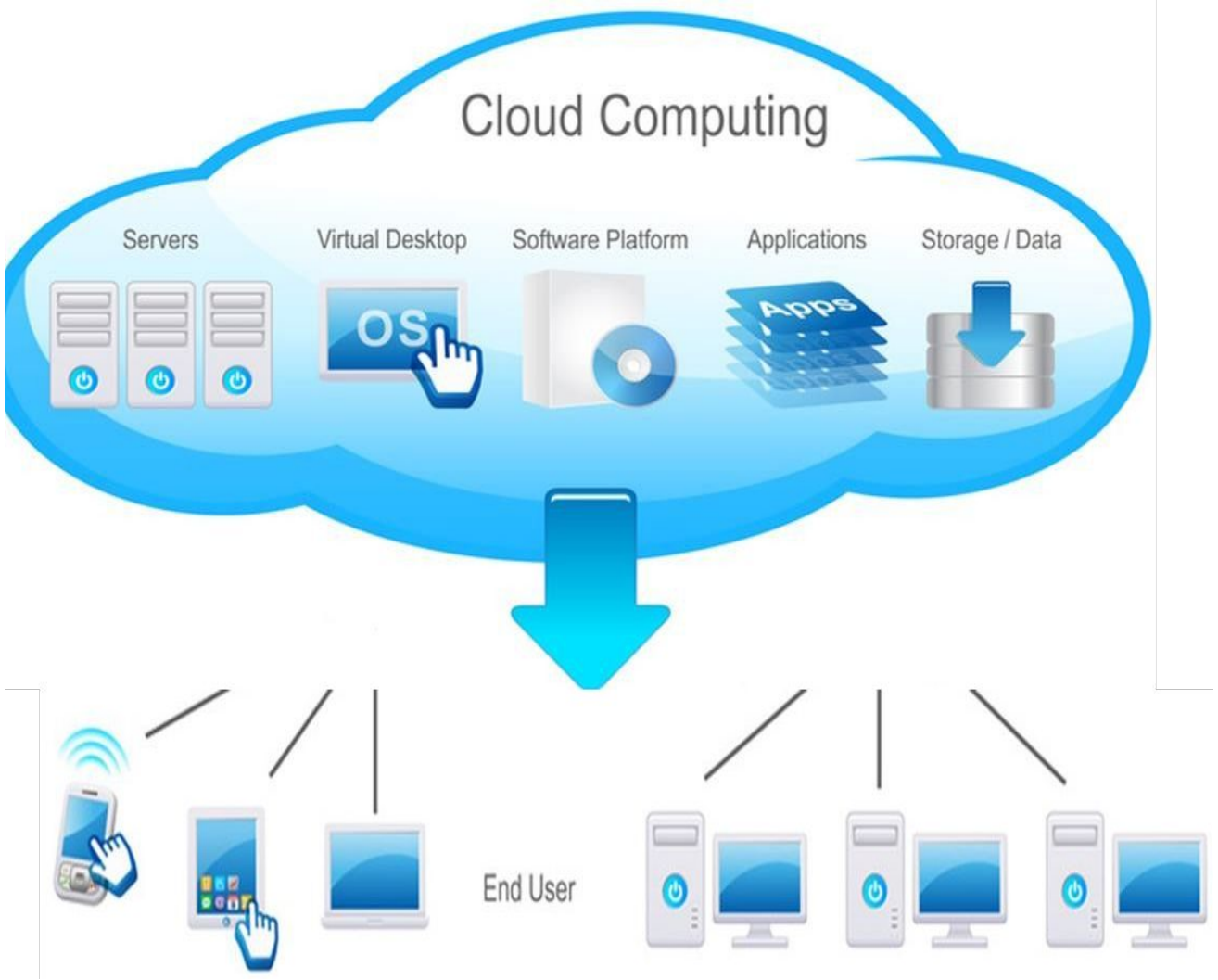
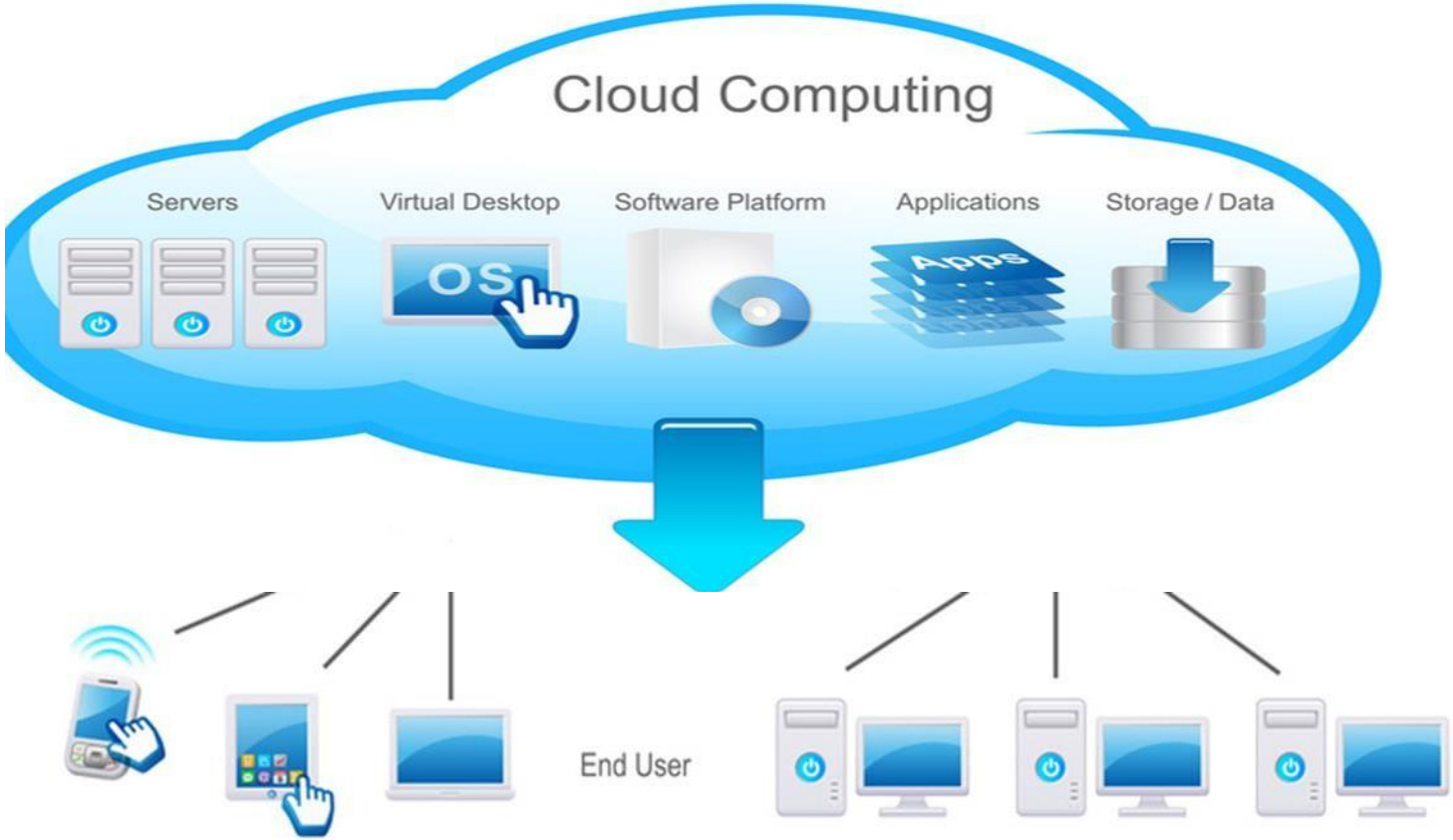
Cloud Computing



CLOUD COMPUTING

- Cloud computing is a **service provisioning technique** where **computing resources** like **hardware such as servers and storage devices**, **software's** and **complete platform for developing applications** are provided **as a service by the cloud providers to the customers.**



- Customers **can use these resources as and when needed**, **can increase or decrease resource capacities dynamically** according to their requirements and **pay only for how much the resource were used**.

- Customers **no need to invest money to purchase**, **manage** and **scale infrastructures**, **software upgradation** and **software licensing.**

Cloud Service Models

- The services that are provided by the cloud providers are broadly classified into three categories:

  - **Infrastructure-as-a-Service (IaaS)**
  - **Platform-as-a-Service (PaaS)**
  - **Software-as-a-Service (SaaS)**

Cloud Service Models

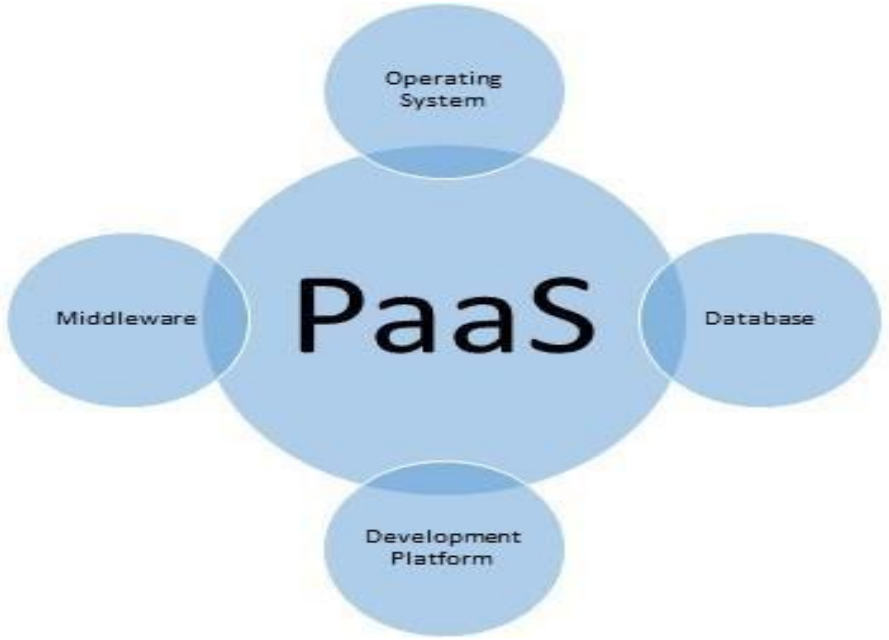
- **Infrastructure-as-a-Service (IaaS):** In Infrastructure-as-a-Service model, the service provider owns the hardware equipment's such as **Servers, Storage**, **Network** and is **provided as services** to the clients. The **client uses these equipment's and pays on per-use basis.**

- E.g. **Amazon Elastic Compute** (EC2) and **Simple Storage Service** (S3).

Cloud Service Models

- **Platform-as-a-Service (PaaS):** In Platform-as-a-Service model, **complete resources** needed to **Design**, **Develop**, **Testing**, **Deploy** and **Hosting** an application are provided as services **without spending money for purchasing and maintaining the servers, storage and software**.

- **PaaS is an extension of IaaS**. **In addition to the fundamental computing resource supplied by the hardware** in an IaaS offering, **PaaS models also include the software and configuration required to create an applications**.



- E.g. **Google App Engine**.

Cloud Service Models

- **Software-as-a-Service (SaaS):** In Software-as-a-Service model, the service provider provides **software's** as a service over the Internet, eliminating the need to **buy**, **install**, **maintain**, **upgradation and licensing** on their local machine.

- E.g. **Accounting, CRM, Google Docs** are all popular examples of SaaS.

Cloud Deployment Models

- Mainly there are four cloud deployment models (4 ways we can create/organize a cloud)
  - **Public Cloud**
  - **Private Cloud**
  - **Community Cloud**
  - **Hybrid Cloud**

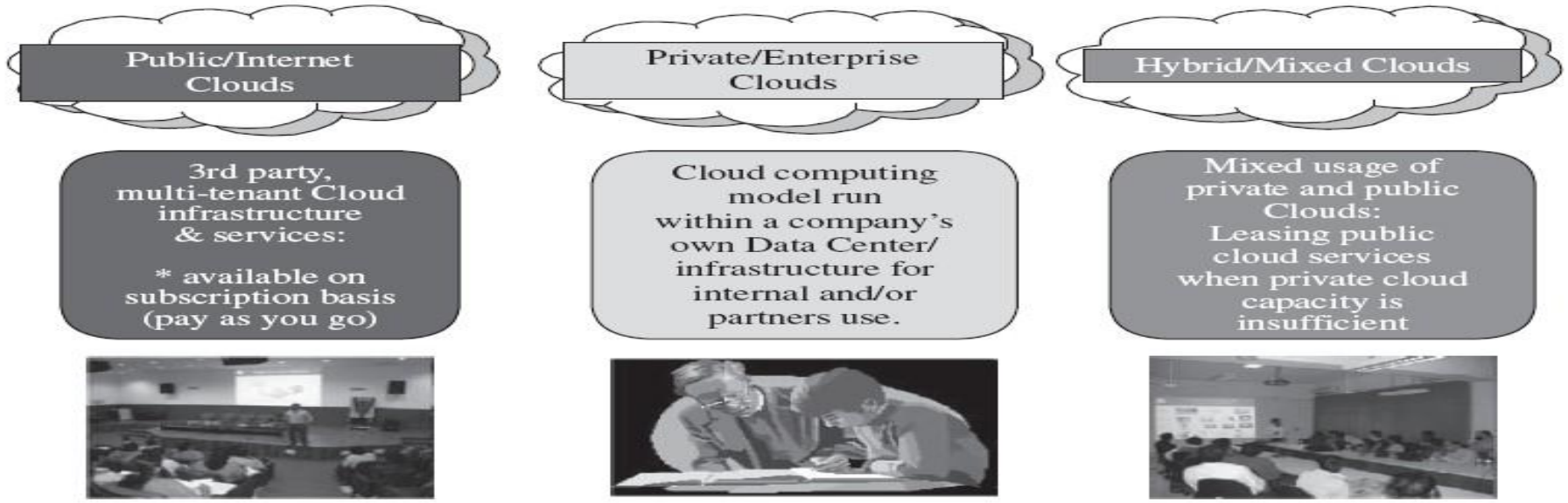


FIGURE 1.4. Types of clouds based on deployment models.

Cloud Deployment Models

- **Public Cloud**: A public cloud is a cloud in which **services and infrastructure are hosted off-site by a cloud provider** (owned by an organization selling cloud services) and easily **accessible to general public via internet**.

- **Private Cloud:** Private Cloud is a cloud where **services and infrastructure are operated for a single operation accessible via private network**, managed internally or by a third party. It is greater level of security.

Cloud Deployment Models

- **Community Cloud:** Community Cloud is a cloud where services and infrastructure are accessible by a group organizations

- **Hybrid Cloud:** Hybrid Cloud is a cloud which is a **mixture of private and public cloud**. In this type of cloud **all critical and sensitive applications and data are stored in private cloud** and **non critical and non sensitive applications and data are stored in public cloud**.

Features of Cloud Computing

- **It is elastic:** Cloud computing is flexible in nature, where users can **scale up** and **scale down** the resources as needed.
- **Pay per use:** Usage is metered and user **pays only for how much the resources were used**.
- **Operation:** The services are completely **handled by the provider**.
- **Reduce capital cost:** No need to **invest money** on purchasing and maintaining of hardware and software, software licensing, training required for IT staff.
- **Remote accessibility:** Users can access **applications and data stored on cloud** from anywhere any time worldwide through a device with internet connection.
- **Better use of IT staff:** Staff with in enterprise need not worry on purchasing and maintaining of servers, softwares, up gradation of servers and softwares, software licensing etc., instead they can concentrate more on work.

Cloud Services Examples:
IaaS-Amazon EC2, Google Compute Engine, Azure VMs

- **Amazon Elastic Compute Cloud** is an Infrastructure as a Service offering from Amazon.

- EC2 is a web service that **provides a computing capacity in the form of virtual machines**.
- Amazon EC2 allows **users to launch instances on demand using a simple web based interface**.
- Amazon provides **pre-configured Amazon Machine Images** (AMIs) which are templates of cloud instances.

	Small	Large	Extra Large	High CPU-Medium
Compute unit	1	4	8	5
Memory	1.7 GB	7.5 GB	15 GB	1.7 GB
Storage	160 GB	850 GB	1690 GB	350 GB
Platform	32 bit	64 bit	64 bit	32 bit

- Users can also **create their own AMIs with custom applications, libraries and data**.

Amazon EC2

- Amazon EC2 also provides **instances with high memory, high CPU resources, Cluster Compute instances, Cluster Graphical Processor unit (GPU)instances and high Input/Output instances**.

- Instances can be launched with a **variety of operating systems**.
- Users can **load their applications on running instances** and rapidly and easily **increase or decrease capacity to meet dynamic application performance requirements**.
- With EC2, **users can even provision hundreds or thousands of server instances simultaneously**, manage network access permissions and monitor usage resources through web interface. (Create 2 VMs at 3 different places and running applications, creating network among 3 and allowing data transfer among 3 VMs and monitoring resource usage)

Amazon EC2

- Amazon EC2 provides **instances of various computing capacities ranging from Small Instances** (Eg: 1 Virtual core with 1 EC2 compute unit, 1.7 GB memory and 160 GB instance storage) to **Extra Large Instances** (Eg: 4 Virtual cores with 2 EC@ compute unit each with 15GB memory and 1690 GB instance storage).

- The **pricing model for EC2 instances is based on Pay-Per Use model**. Users are billed based on the number on instance hours used for on demand instances.
- EC2 also provides **spot instances that allow users to bid on unused Amazon EC2 capacity and run those instances for as long as their bid exceeds the current spot price**.

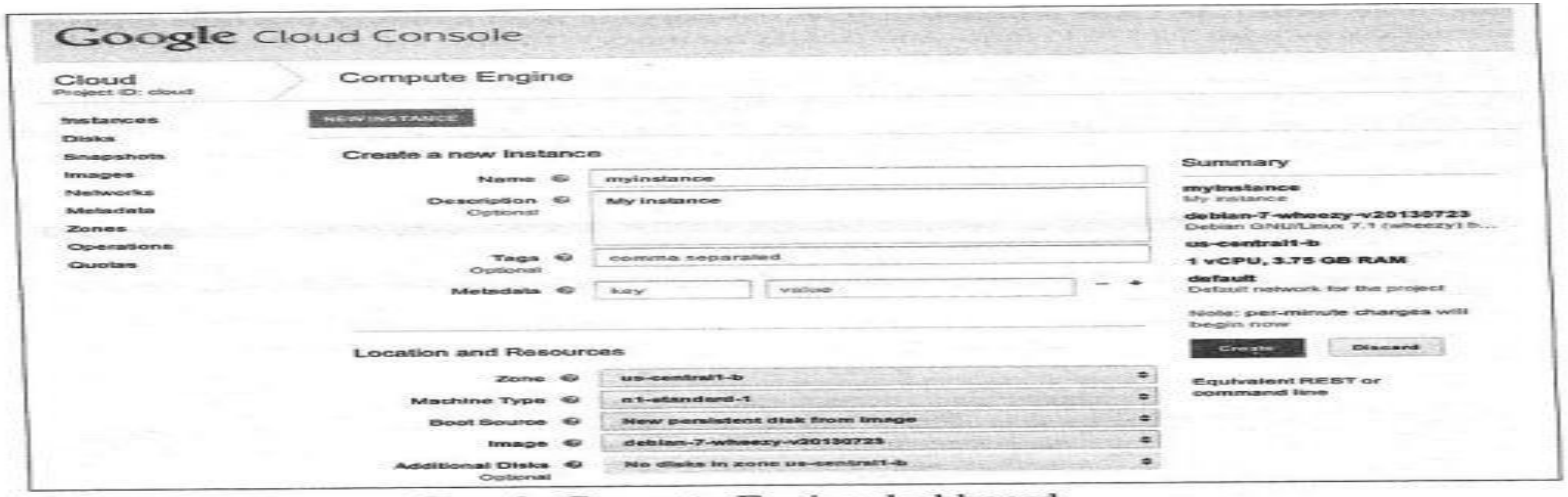
Amazon EC2

- The below figure shows screenshot of Amazon EC2 dashboard

Amazon EC2 dashboard

Google Compute Engine

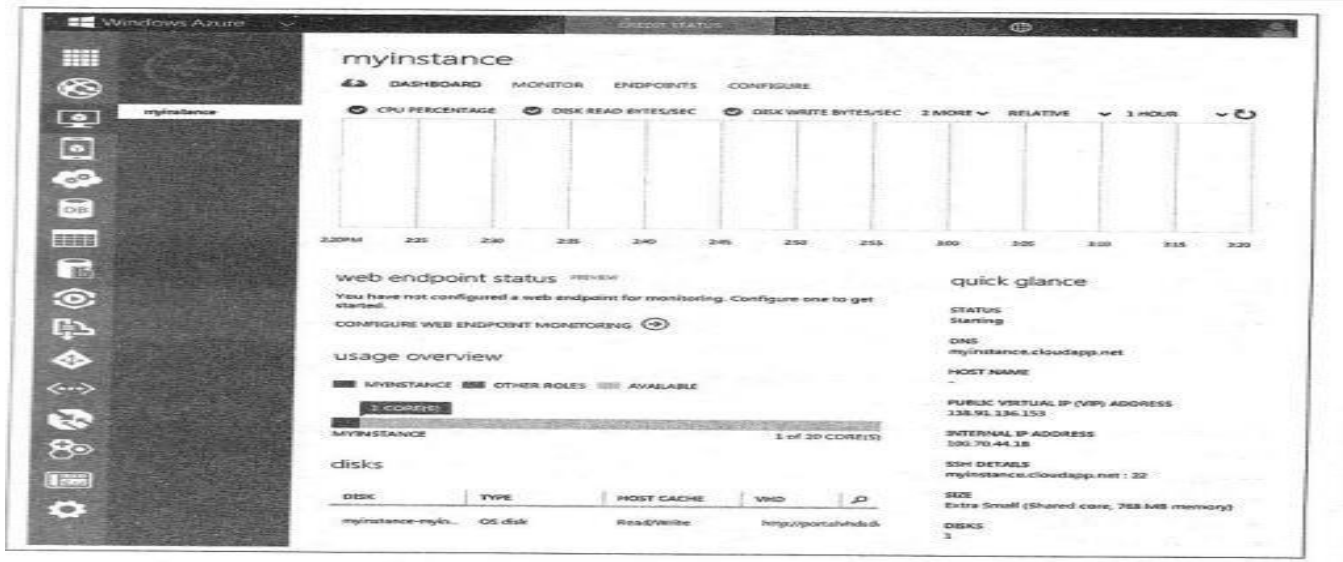
- **Google Compute Engine (GCE) is an IaaS offering from Google**.
- GCE provides **virtual machines of various computing capacities ranging from small instances** (Eg: Virtual cor with 1.38 GCE unit and 1.7 GB memory) **to high memory machine types** (8 virtual cores with 22 GCE unit and 5 GB memory.The below figure shows screenshot of Google Compute Engine dashboard



Google Compute Engine dashboard

Windows Azure

- **Windows Azure Virtual Machine is an IaaS offering from Microsoft**.
- Azure VMs provides **virtual machines of various computing capacities ranging from small instances** (1 virtual core with 1.75GB memory) to **memory intensive machine types** (8 virtual cores with 56GB memory).
- The below figure shows screenshot of Google Compute Engine dashboard.



Windows Azure Virtual Machines dashboard

Google App Engine

- **Google App Engine (GAE) is a Platform as a Service offering from Google**.
- GAE is a cloud based **web service for hosting web applications and storing data**.
- GAE allows users to **build scalable and reliable applications that run on the same systems that power Google's own applications**.
- GAE provides a **Software Development Kit (SDK) for developing webapplications software that can be deployed on GAE.**

- Developers can **develop and test their applications with GAE SDK on a local machine** and **then upload it to GAE** witha simple click of a button

- Applications hosted in GAE are **easy to build, maintain and scale**. Users **don't need to worry about launching additional computing instances when the applications load increases**.

- GAE provides **automatic scaling and load balancing capability**.

- GAE **supports applications written in several programming language**.

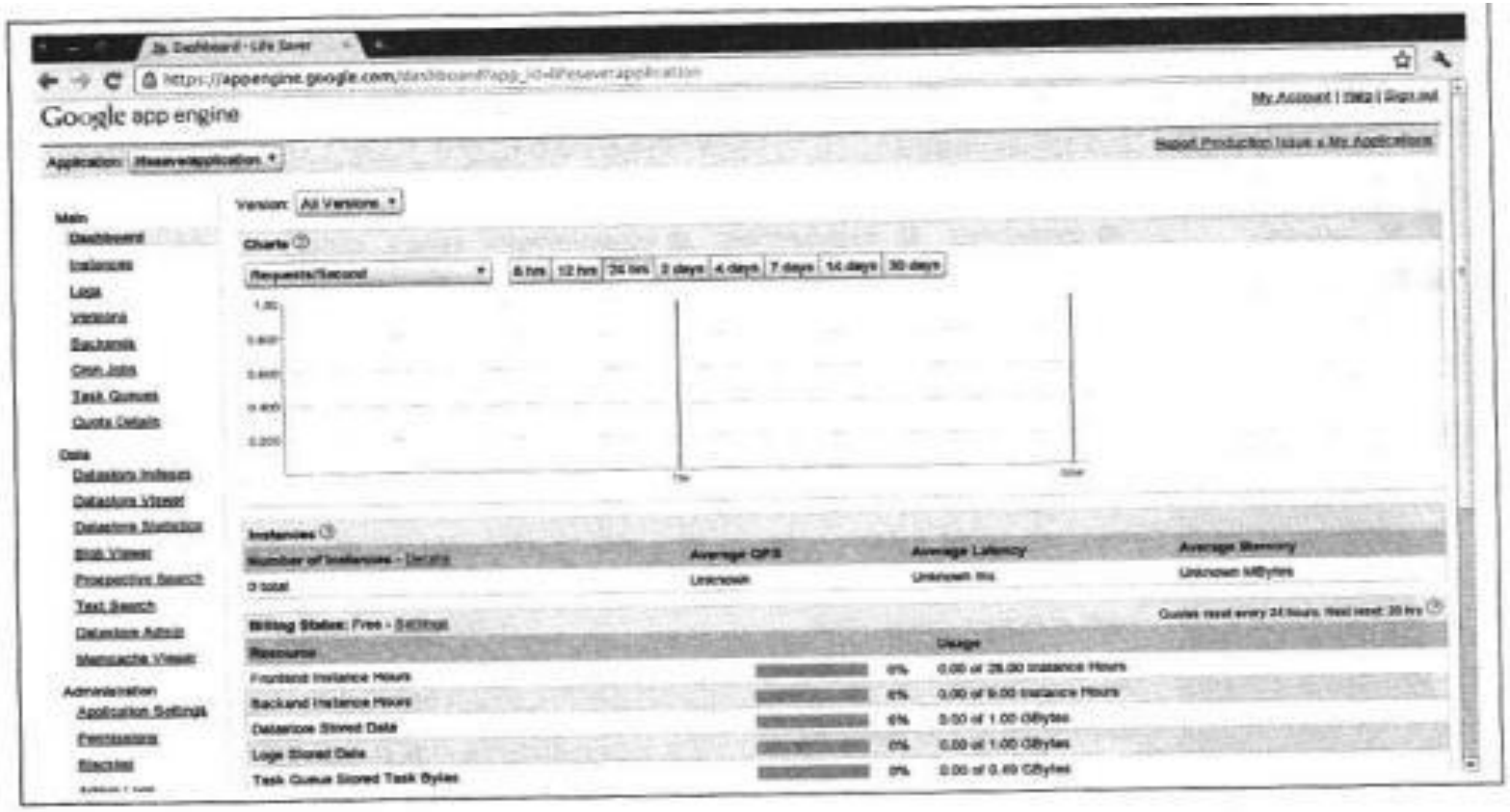
- With Java runtime environment developers can **build applications using Java programming language and standard Java technologies such as Java Servlets**. GAE also **provides runtime environment for Python programming languages**.

Cloud Services Examples: PaaS-Google App Engine

- **Applications hosted in GAE run in secure sandbox** with limited access to the underlying operating system and hardware.

- The **pricing model for GAE is based on the amount of computing resources used**.
- GAE provides **free computing resources for applications up to a certain limit**. **Beyond that limit, users are billed based on the amount of computing resources used such as amount of bandwidth consumed, number of resource instance hours, amount of data stored**.

- The below figure shows the screenshot of GAE dashboard.



Google App Engine dashboard

Cloud Services Examples: SaaS-Salesforce

Salesforce Sales Cloud

- Salesforce **Sales Cloud** is a cloud based **Customer Relationship Management (CRM) SaaS offering**.
- Users can **access CRM application from anywhere through internet enabled devices such as workstations, laptops, tablets and smartphones.**
- Sales Cloud allows **sales representatives to manage customer profiles**, **track opportunities**, **optimize campaigns from lead to close** and monitor the impact of campaigns. (A lead can be a company or an individual who has expressed interest in a company's product and/or service).

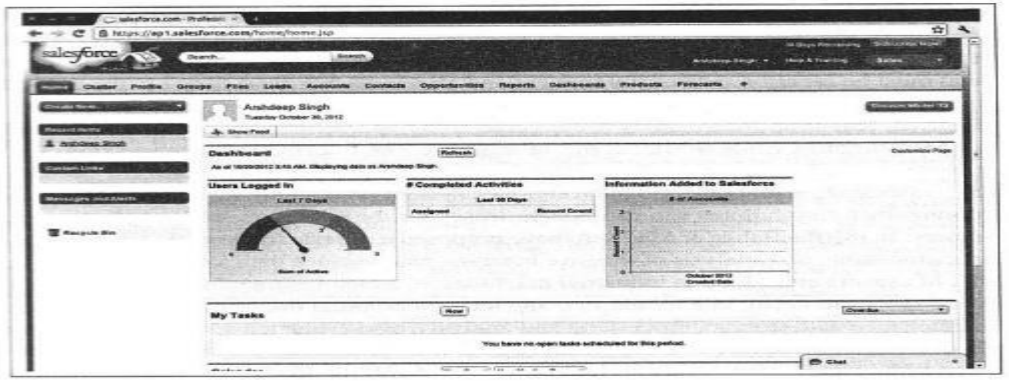
Cloud Services Examples: SaaS-Salesforce

Salesforce Service Cloud

- **Salesforce Service Cloud is a cloud based Customer Service Management SaaS**.
- Service cloud provides companies a call center like view and allows creating, tracking, routing and escalating cases.
- Service cloud includes a **social networking plug-in** that enables social customer service **where comments from social media channels can be used to answer customer questions**.

Salesforce Marketing Cloud

- **Salesforce Marketing Cloud is cloud based social marketing SaaS**.
- Marketing cloud allows companies to **identify sales leads from social media**, discover advocates, identify most trending information on any topic.
- Marketing cloud **allows companies to pro-actively engage with customers**, manage **social advertisement campaigns** and track the performance of social campaigns.
- The below figure shows a screenshot of Salesforce dashboard



Salesforce dashboard

Salesforce Marketing Cloud

- **Some of the tools included in the Salesforce Sales, Service and Marketing Clouds include**
  - **Accounts and Contacts**
  - **Leads**
  - **Opportunities**
  - **Campaigns**
  - **Chatter**
  - **Analytics an Forecasts**

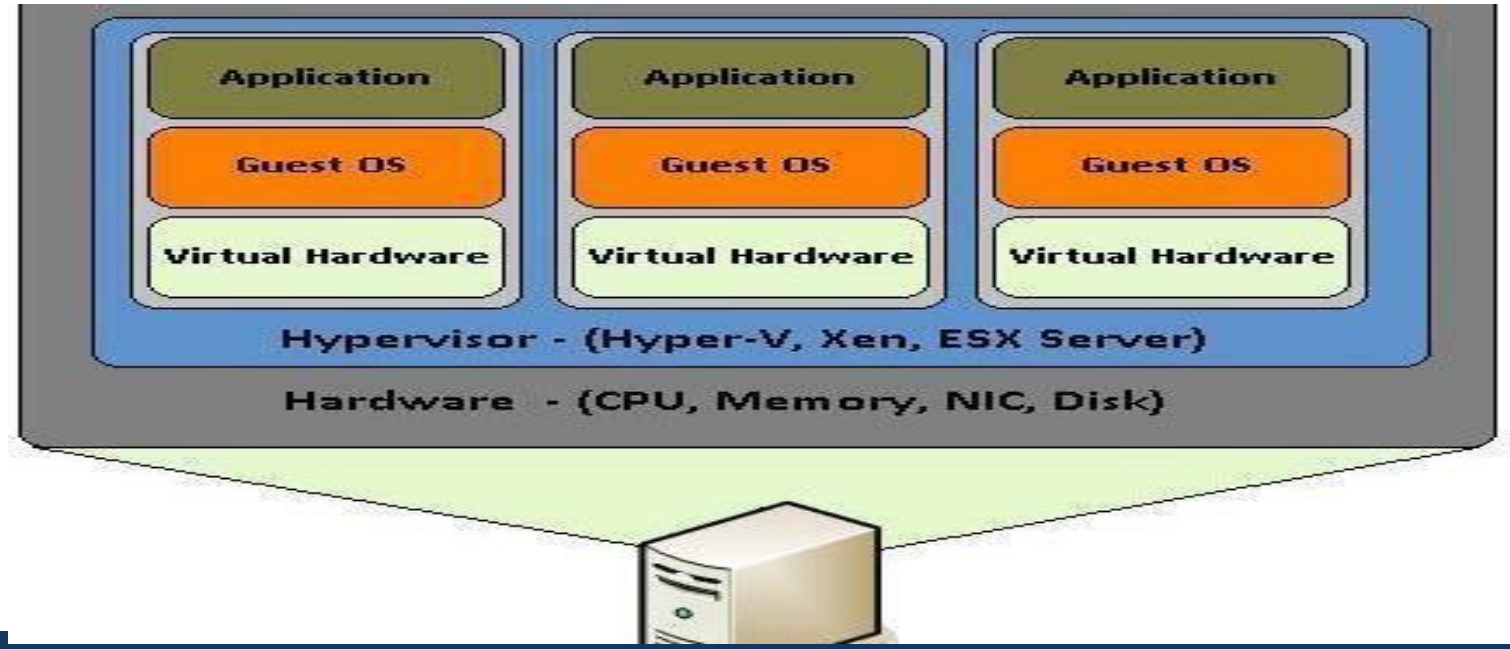
- Virtualization
- Load Balancing
- Scalability and Elasticity
- Deployment
- Replication
- Monitoring
- Software Defined Networking
- MapReduce
- Identity and Access Management
- Service Level Agreements
- Billing

Virtualization for Cloud

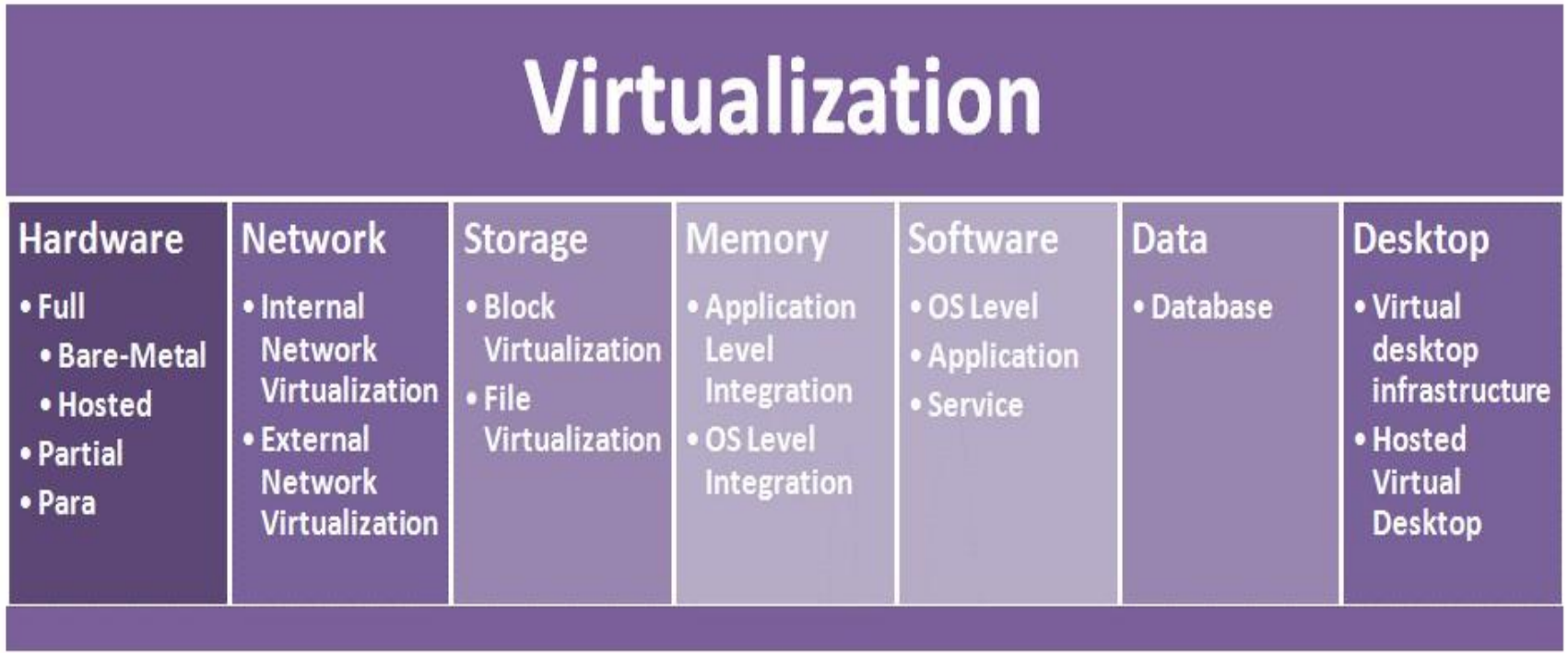
- **Virtualization is a technology** that makes it possible to **run multiple applications and various operating systems on the same server at the same time**.
- It increases **hardware utilization, saves energy and costs**.

What makes virtualization possible?

- The software that makes virtualization possible is known as a **Hypervisor**, also known as a **Virtualization Manager**.
- **Hypervisor** sits between the **hardware and the operating system**, and **assigns the amount of access that the applications** and **operating systems have with the processor** and **other hardware resources**. (Hypervisor assigns the CPU and other hardware resources needed to run OS & app)



- Hardware/Server Virtualization
- Network Virtualization
- Storage Virtualization
- Memory Virtualization
- Software Virtualization
- Data Virtualization
- Desktop virtualization



Pros and Cons of Virtualization

Pros:

- Sandbox
- Hardware independent
- OS independent
- Fast Recovery
- Live Backup
- Migrate data
- Reduced Hardware
- Run Multiple OS Simultaneously
- Cost savings
- Use of Multicore processors
- System Security
- Test and Development

Cons:

- Less Efficient
- Unstable Performance
- Tools lack ability
- Rapid Deployment
- Latency of Virtual Disk
- Backup and Data Sets
- Security Issues
- Hardware compatibility issues
- Managing and Securing is difficult

Virtualization

- Virtualization refers to **the partitioning the resources of a physical system** (such as computing, Storage, Network and Memory) **into multiple virtual resources**.

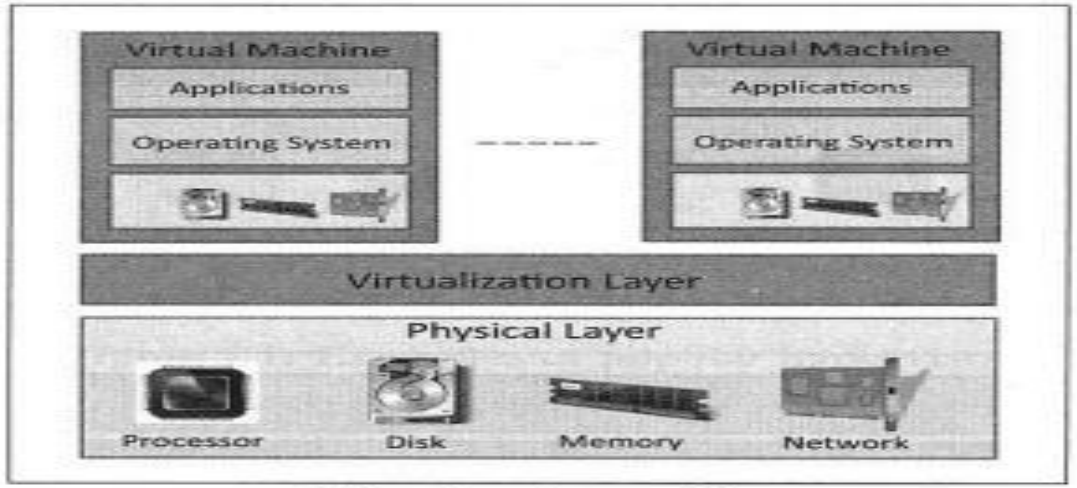
- In cloud computing, **resources are pooled to serve multiple users using Multi-Tenancy**.

- Multi-Tenant aspects of the cloud **allow multiple users to be served by the same physical hardware**.

- The figure shows the architecture of a virtualization technology in cloud computing.

- The physical resources such as **computing, storage, memory and network resources are virtualized**.

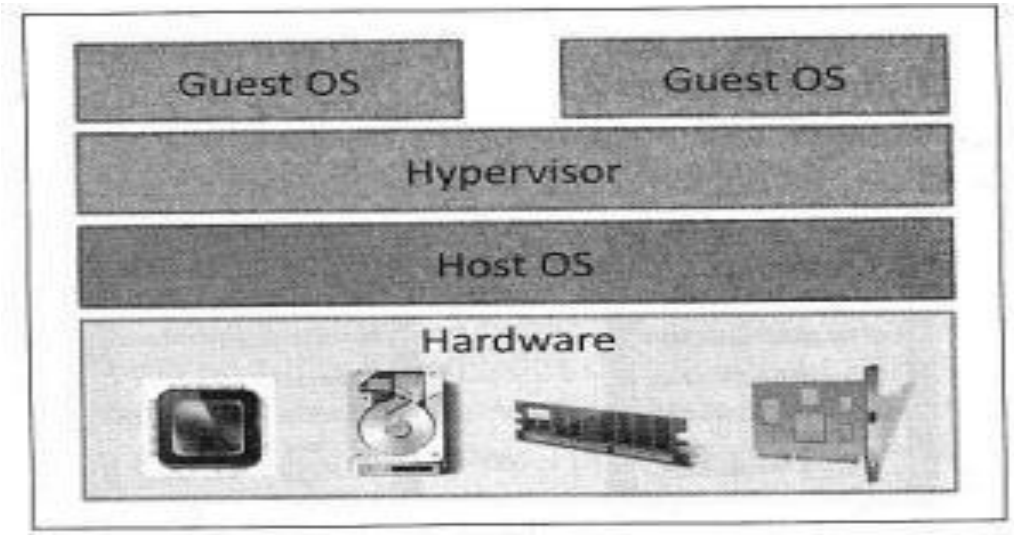
- The **virtualization layer partitions the physical resources into multiple virtual machines**.



Virtualization architecture

Virtualization: Guest Operating System

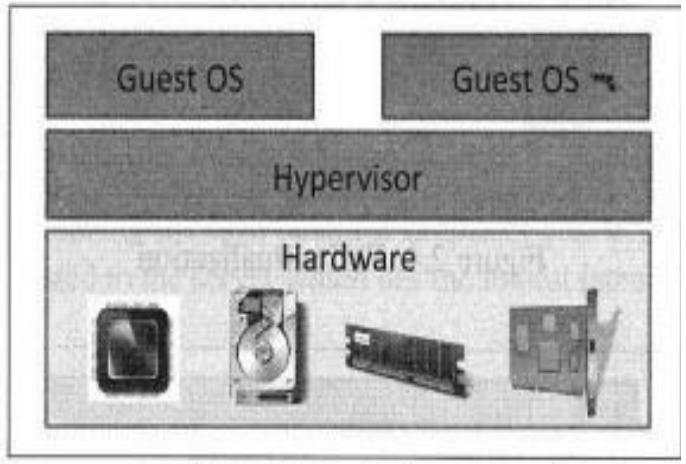
- A **guest OS is an operating system that is installed in a virtual machine** in addition to the host OS.
- In virtualization, the **guest OS can be different from the host OS**.



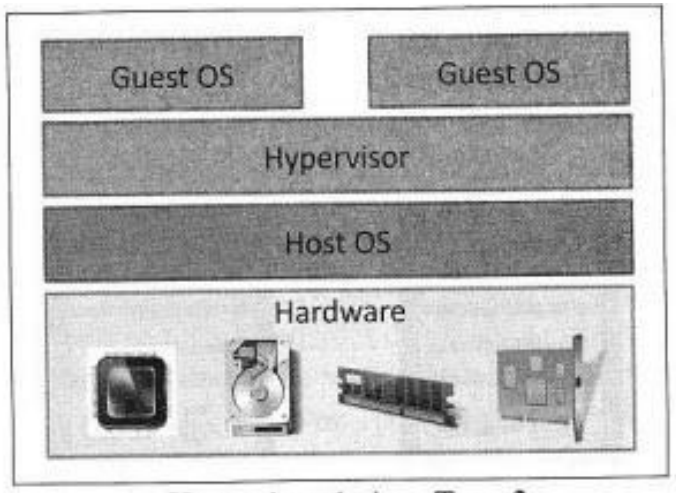
Virtualization: Hypervisor

- The **virtualization layer consists of a hypervisor or a Virtual Machine Monitor (VMM)**.
- There are two types of hypervisors
  - **Type-1 Hypervisors or Native Hypervisors**
  - **Type-2 Hypervisors or Hosted Hypervisors** **Type-1**

Hypervisors or Native Hypervisors



Hypervisor design: Type-1



Hypervisor design: Type-2

- **Type-1 Hypervisors or Native Hypervisors run directly on the host hardware** and **control the hardware** and **monitor the guest operating system**.

Type 2 Hypervisors or Hosted Hypervisors

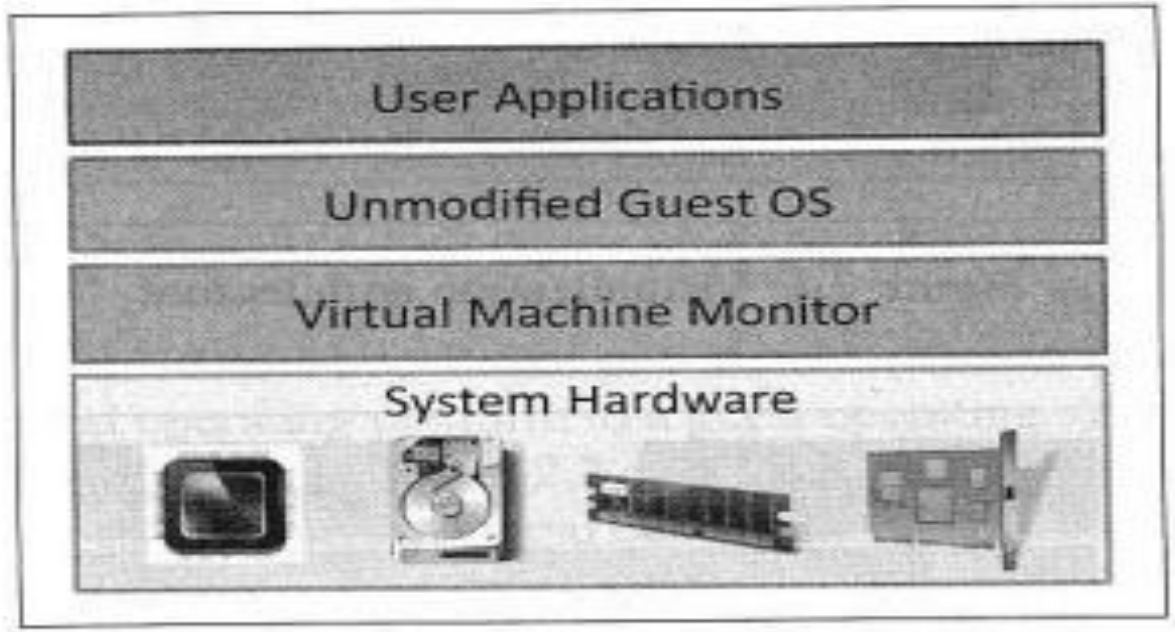
- **Type 2 Hypervisors or Hosted Hypervisors run on top of a conventional** (main or Host) **operating system** and **monitor the guest operation systems.**

Virtualization: Guest Operating System

- Various forms of virtualization approaches exist:
  - **Full Virtualization**
  - **Para-Virtualization**
  - **Hardware Virtualization**

Virtualization: Full Virtualization

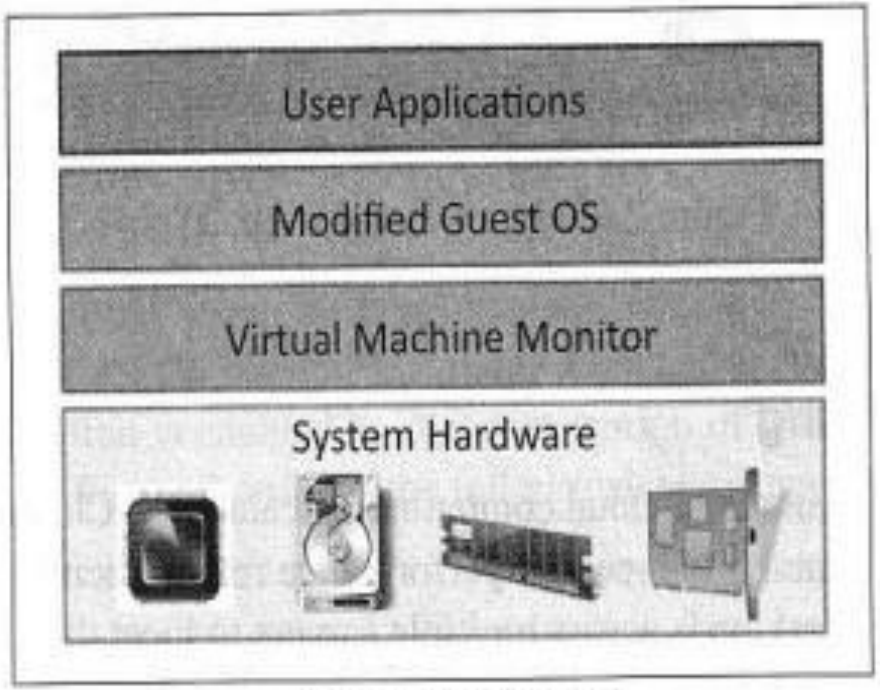
- In Full Virtualization, **- the guest OS requires no modification** and **is not aware that it is being virtualized**.
- **It is enabled by direct execution of user requests** and **binary translation of OS requests**.



Full virtualization

Virtualization: Para Virtualization

- In Para virtualization, **the guest OS is modified to enable communication with the hypervisor** to improve performance and efficiency. The **guest OS kernel is modified to replace non virtualizable instructions with hypercalls that communicate directly with the virtualization layer hypervisor.**



Para-virtualization

Virtualization: Hardware Assisted Virtualization

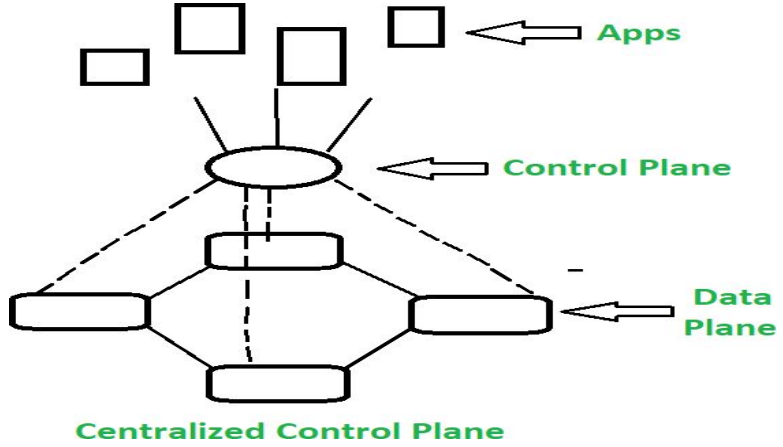
- Hardware Assisted virtualization **is enabled by hardware features such as Intel's Virtualization technology** (VT-x) and AMD's **AMD-V**. In hardware virtualization, privileged and sensitive calls are set to automatically trap to the hypervisor.

- Thus, **there is no needed for either binary translation or Para virtualization**. Hardware-assisted full virtualization **eliminates the binary translation** and it **directly interrupts with hardware** using the virtualization technology which has been integrated on X86 processors since 2005 (Intel VT-x and AMD-V).

- **Guest OS's instructions might allow a virtual context execute privileged instructions directly on the processor, even though it is virtualized**.

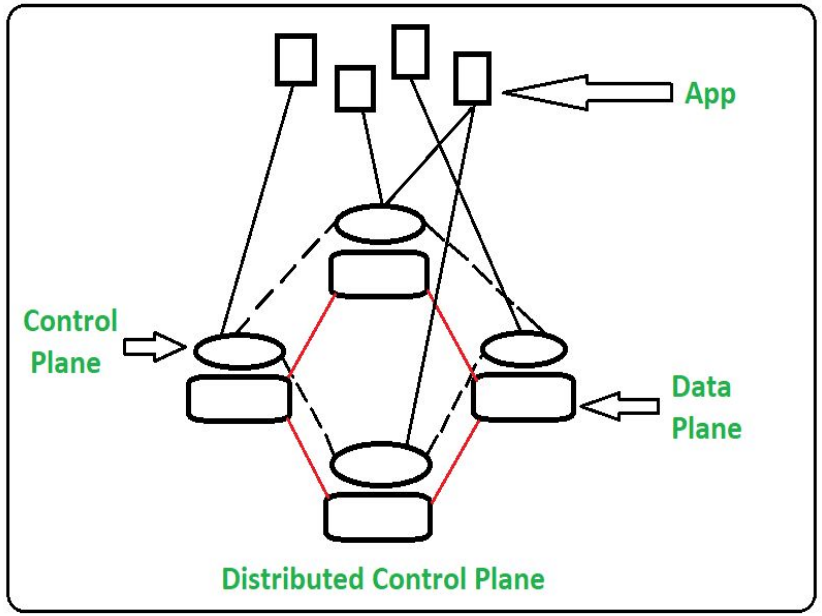
Software Defined Networking

- **SDN decouples the network and control forwarding functions.**
- SDN stands for Software Defined Network which is networking architecture approach. It enables the control and management of network using software applications.
- Through Software Defined Network (SDN) networking **behavior of entire network and its devices are programmed in centrally controlled manner through software applications** using open APIs.



Traditional Network

- **Traditional network refers to the old conventional way of networking which uses fixed and dedicated hardware devices such as routers and switches to control network traffic.**
- **Inability to scale and network security and performance are the major concern** now a days in the current growing business situation so that SDN is taking control to traditional network. **Traditional network is static** and based on hardware network appliances.



- **SDN decouples the network and control forwarding functions.** It separates the **control plane** (making traffic decision) from the **data plane** (packet forwarding).
- The figure shows the conventional network architecture built with specialized hardware (Switches, routers etc).

- **In the conventional network architecture, the control plane and data plane are coupled**. **Control plane** is the part of the network that carries the **signaling and routing message traffic** while the **data plane** is the part of the network **that carries the payload data traffic**.

- **Conventional network architecture has following limitations**

Complex Network Devices

Conventional networks are getting increasingly complex with more and more protocols being implemented to improve link speed and reliability. **The conventional networks are well suited for static traffic patterns**. **Due to the complexity of conventional network devices, making changes in the networks to meet the dynamic traffic patterns has increasingly difficult**.

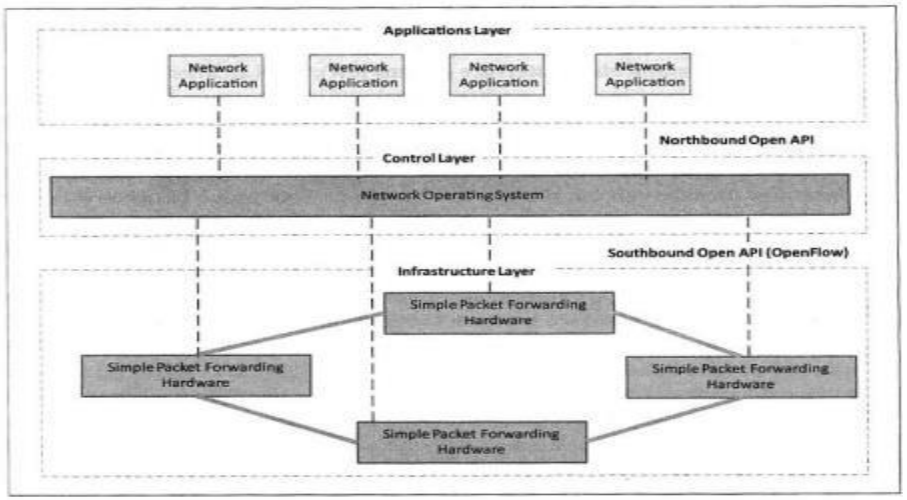
Management Overhead

Network mangers find it increasingly difficult to manage multiple network devices. **Up gradation of network requires configurations changes in multiple devices** (**switches, routers, firewalls** etc.)

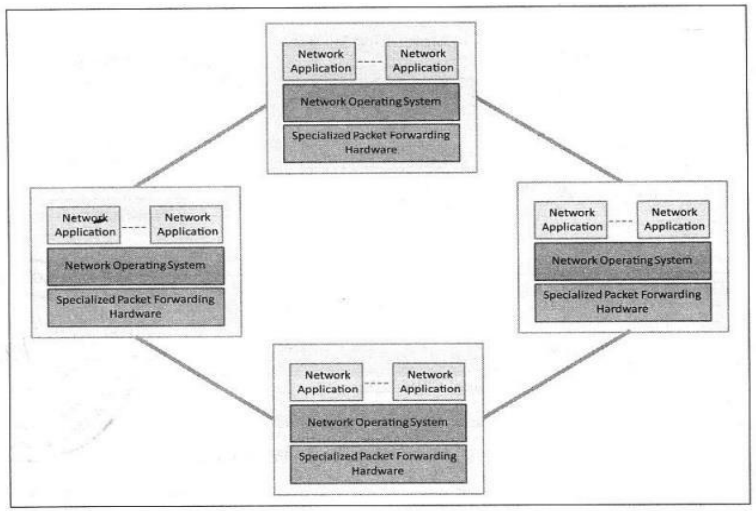
Limited scalability

Big data applications run distributed algorithms on a large number of virtual machines. Such computing environments require highly scalable with minimum manual configurations which is difficult with conventional networks. (running each module of the applications at different places with multiple copies of data at different locations, need to scaling of the network)

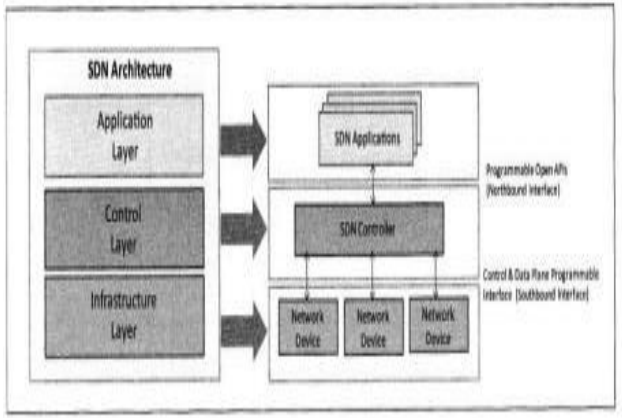
- **SDN attempts to create network architecture that are simpler, inexpensive, scalable, agile and easy to manage.**
- In SDN architecture, **the control plane and data planes are decoupled and network controller is centralized.**
- The **underlying infrastructure in SDN uses simple packet forwarding hardware as opposed to specialized hardware in conventional networks.**
- **Network devices become simple with SDN as they do not require implementation of large number of protocols.**
- **Network devices receive instructions from the SDN controller on how to forward the packets.**



SDN architecture



Conventional network architecture



SDN layers

Map Reduce

- **Map Reduce is a parallel data processing technique for processing and analyzing large scale data**. (data intensive problem). (The framework takes care of scheduling tasks, monitoring them and re-executing any failed tasks.)

- **The Map Reduce model includes two important phases: Map and Reduce functions.**

- **Map function takes a set of data and converts it into another set of data, where individual elements are broken down into tuples (key/value pairs).** Secondly, **reduce function, which takes the output from a map as an input and combines those data tuples into a smaller set of tuples**.

Cloud Computing for Healthcare

- The figure shows the application of cloud computing environments to the healthcare ecosystem.
- Hospitals and their affiliated providers can securely access patient data stored in the cloud and share the data with the other hospitals and physicians.
- Patients can access their own health information from all of their care providers and store it in a personal health record (PHR)
- The PHR can be a vehicle for e-prescribing, a technique known to
- reduce medication dispensing errors and to facilitate medication reconciliation.
- History and information stored in the cloud can be streamline the admissions, care and discharege process by eliminating redundant data collection and entry.

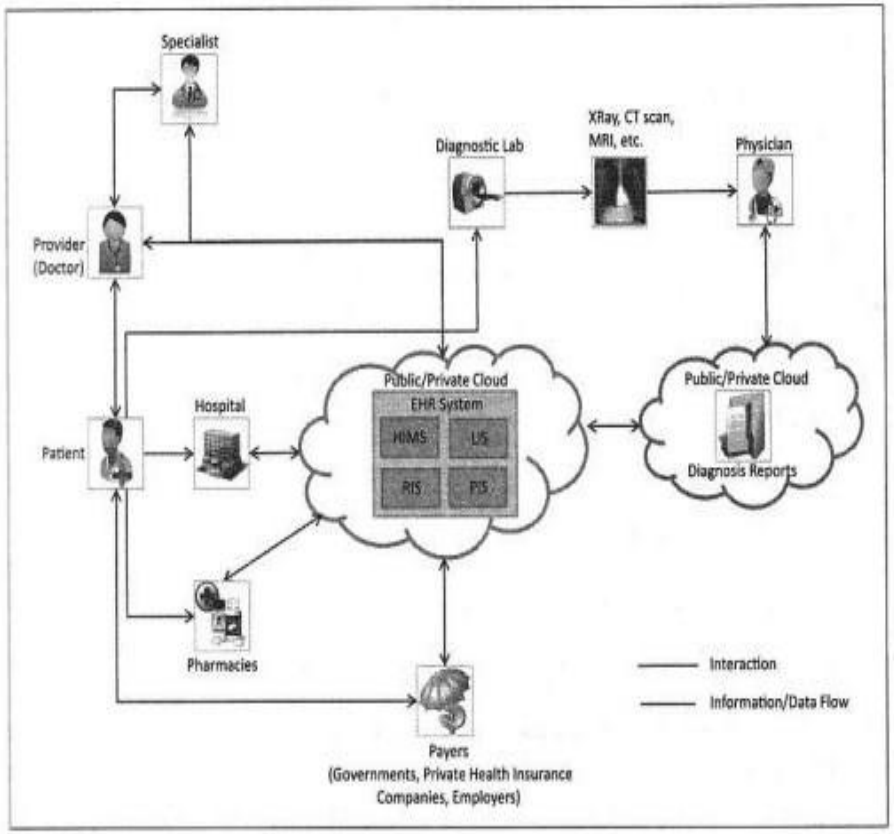


Figure : Cloud computing for healthcare

- Health payers can increase the effectiveness and lower the cost of their care management programs by providing value added services and giving access to health information to members.

Cloud Computing for Energy Systems

- Energy systems such as Smart Grids, Power Plants, Wind Turbine etc. have thousands of sensors that gather real time maintenance data continuously for condition monitoring and failure prediction purposes.
- The energy systems have a large number of critical components that must function correctly so that the systems can perform their operations correctly.
- For eg: a wind turbine has number of critical components like bearings, turning gears etc. that must be monitored carefully as wear and rear in such critical components or sudden change in operating conditions of the machines can result in failures. In systems such as power grids, real time information is collected using specialized electrical sensors called Phasor Measurement Units (PMU) at the sub-stations. The information received from PMUs must be monitored in real time for estimating the state of the system and for predicting failures.
- There is a generic framework "CloudView" for storage, processing and analysis of massive machine maintenance data collected from a large number of sensors embedded in industrial machines in a cloud computing environment.
- figure shows a generic use case of cloud for energy systems.

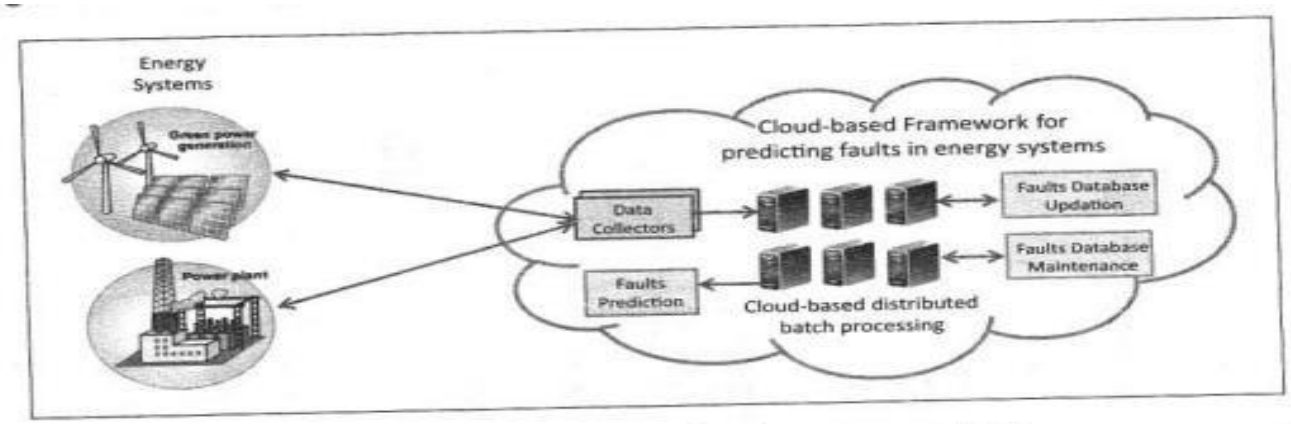
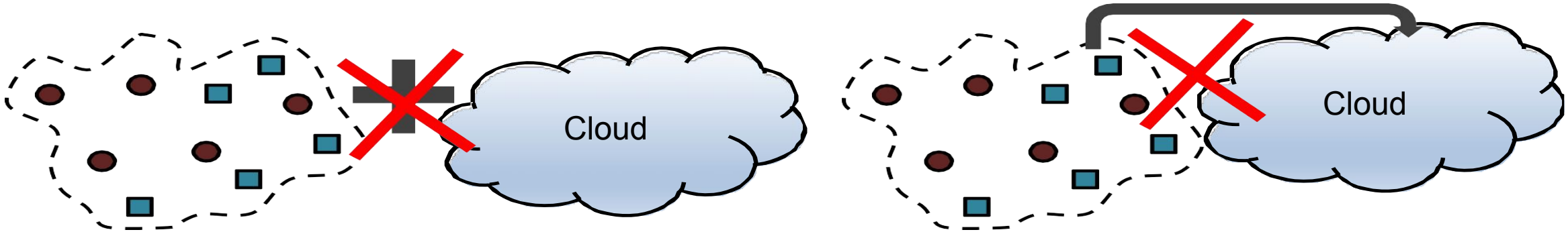


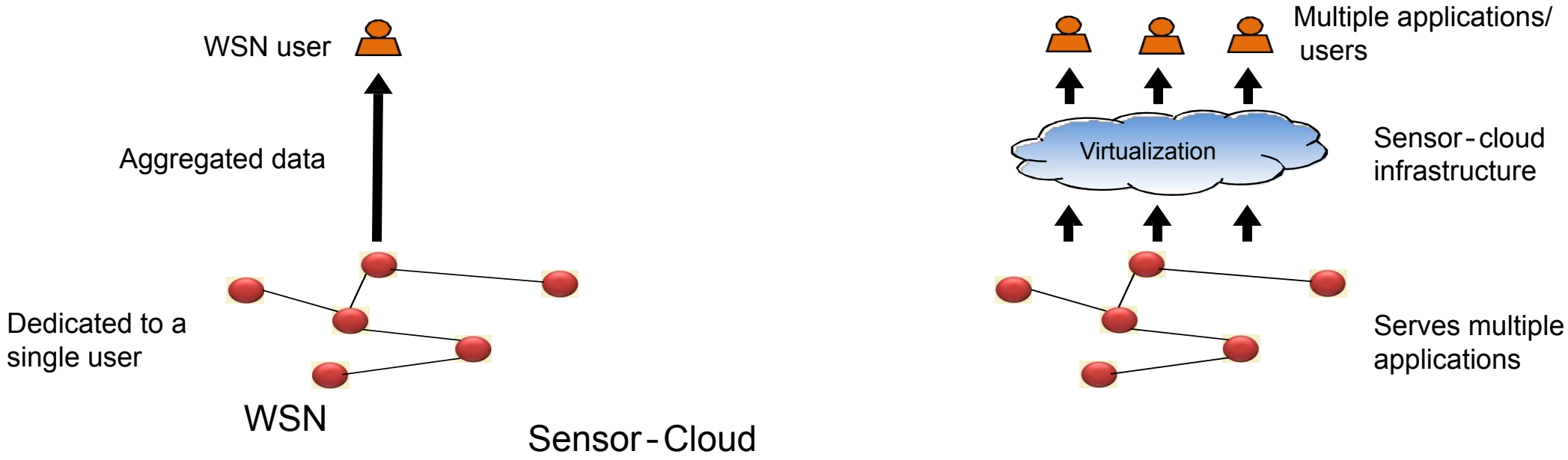
Figure : Cloud computing for energy systems

Introduction- WSN and Sensor-Cloud

- ✔ It is not mere integration of sensors and cloud computing
- ✔ It is not only “dumping the sensor data into cloud”
- ✔ Contain sensor nodes which sense some physical phenomena from the environment
- ✔ Transmit the sensed data (through wireless communication) to a centralized unit, commonly known as Sink node
- ✔ The communication between Sink node and other sensor nodes in the network may be single/multi-hop
- ✔ Sink node further process data



Difference with WSN



Source: S. Misra; S. Chatterjee; M. S. Obaidat, "On Theoretical Modeling of Sensor Cloud: A Paradigm Shift From Wireless Sensor Network," in *IEEE Systems Journal* , vol.PP, no.99, pp.1-10

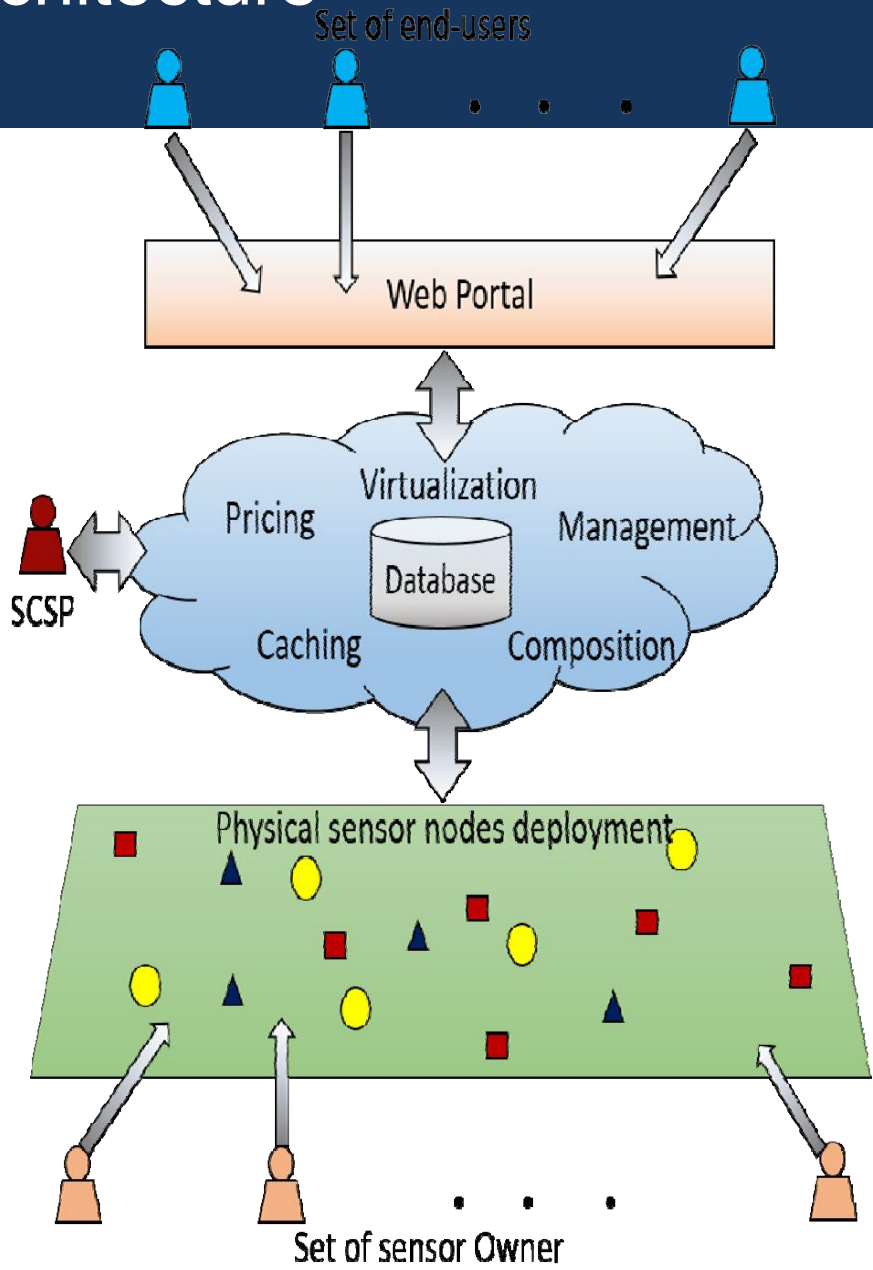
Difference with WSN

Actors and Roles		
Attributes	**WSN**	**Sensor Cloud**
Ownership	WSN-user	Sensor-owner
Deployment	WSN-user	Sensor-owner
Redeployment	WSN-user	SCSP
Maintenances	WSN-user	SCSP
Overhead	WSN-user	SCSP
Usage	WSN-user	End-user

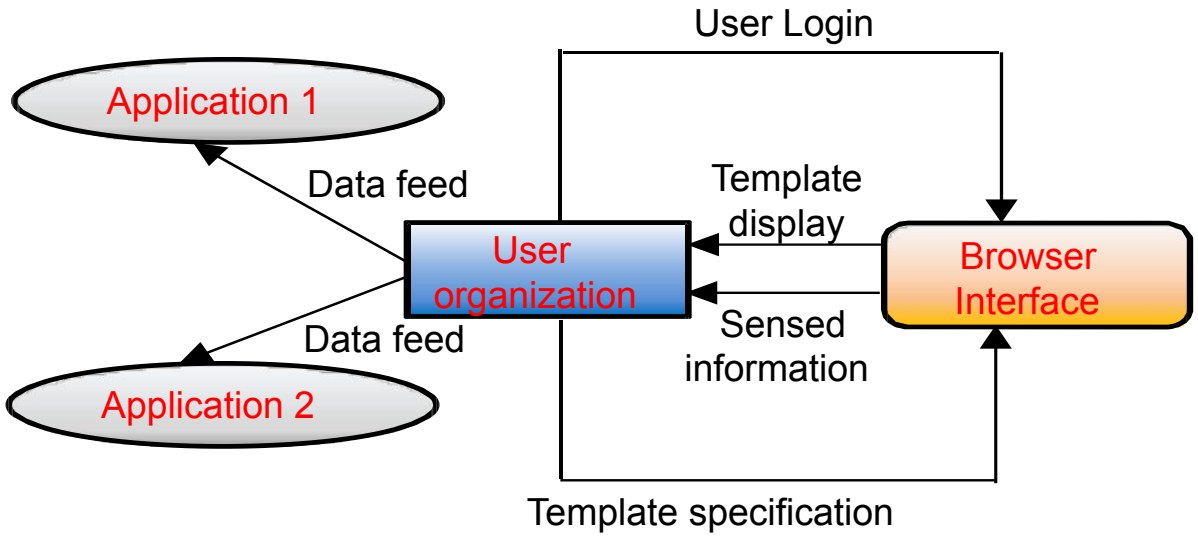
Source: S. Misra; S. Chatterjee; M. S. Obaidat, "On Theoretical Modeling of Sensor Cloud: A Paradigm Shift From Wireless Sensor Network," in *IEEE Systems Journal* , vol.PP, no.99, pp.1-10

Sensor-cloud: Architecture

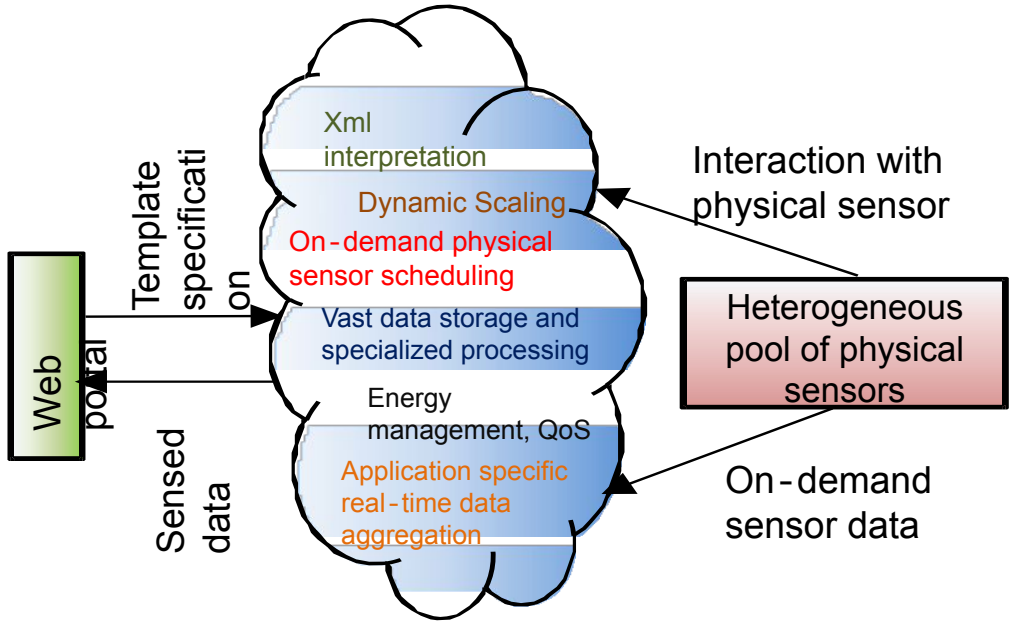
- End-users: Registered themselves, selects templates, and request for application(s). Enjoy Se-aaS through applications as per the requirements. Unknown about what and which physical sensor is/are allocated to serve the application
- Sensor-owner: Plays a role from business perspective. They purchase physical sensor devices, deployed over different geographical locations, and lend these devices to the sensor-cloud-Sensor-Cloud Service Provider (SCSP) .Deploy heterogeneous/ homogeneous physical sensor nodes over different geographical location
- SCSP: Plays managerial role A business actor. SCSP charges price from the end-users as per their usage of Se-aaS



Sensor-cloud: View



User organization view



Real View

Source: S. Misra; S. Chatterjee; M. S. Obaidat, "On Theoretical Modeling of Sensor Cloud: A Paradigm Shift From Wireless Sensor Network," in *IEEE Systems Journal* , vol.PP, no.99, pp.1-10

Case Study: Target Tracking

"We consider a WSN-based target tracking application, in which a WSN owner refuses to share the sensed information with an external body, even in exchange of money. Consequently, any organization that wishes to detect intrusion within a particular zone has to deploy its own WSN. This leads to a long-term investment due to costly network setup and maintenance overheads. However, in a sensor-cloud environment, the same organization can use the same tracking application and still get the service without actually owning the WSN"

Source: S. Misra; S. Chatterjee; M. S. Obaidat, "On Theoretical Modeling of Sensor Cloud: A Paradigm Shift From Wireless Sensor Network," in *IEEE Systems Journal* , vol.PP, no.99, pp.1-10

Issues

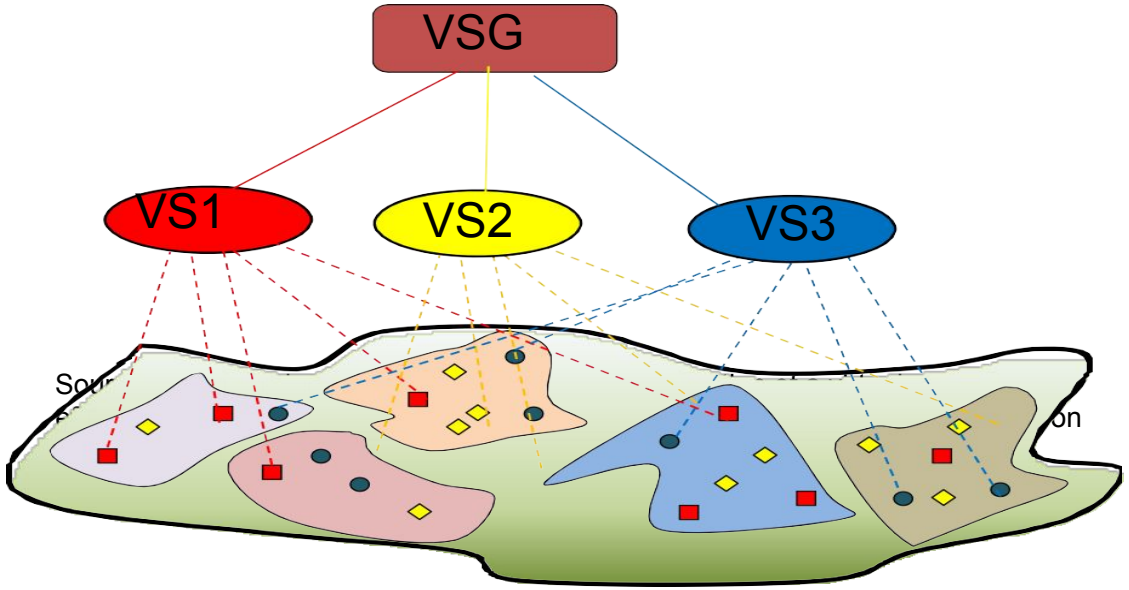
- ✔ Optimal Composition of virtual sensor nodes
- ✔ Data Caching
- ✔ Optimal Pricing

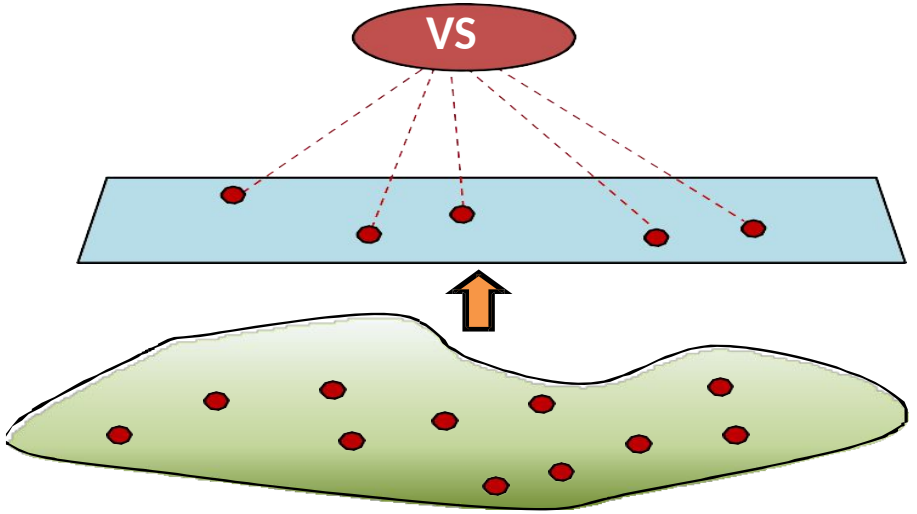
Solutions

- ✔ Efficient virtualization of the physical sensor nodes
- ✔ An optimal composition of VSs
- ✔ Consider same geographic regions
- ✔ Spanning across multiple regions

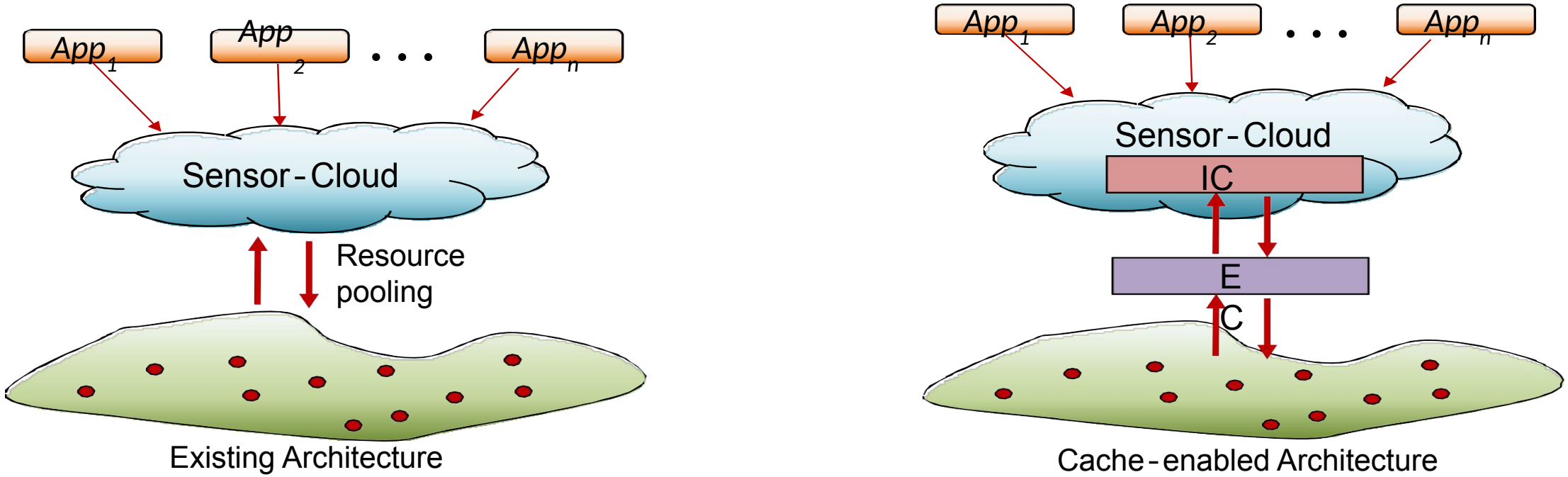
Formation of Virtual Sensor

- ✔ Optimal formation of Virtual Sensor (VS) and group(VSG)
- ✔ Homogeneous sensor nodes within same geographical boundary





Architecture of Caching

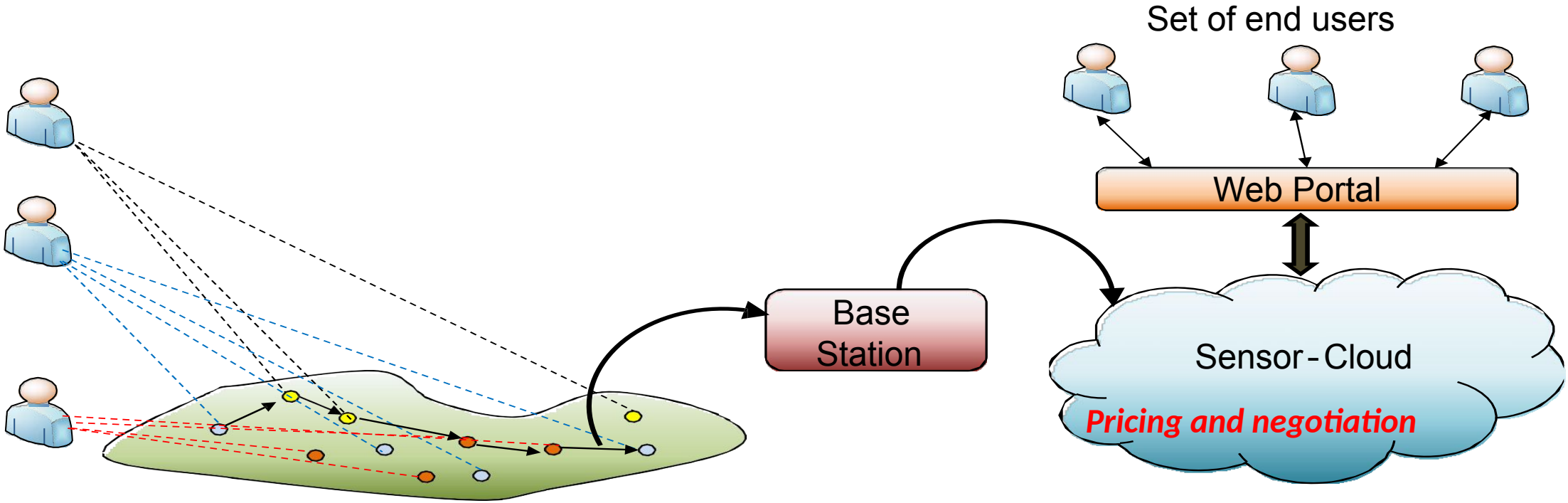


Source: S. Chatterjee, S. Misra, "Dynamic and Adaptive Data Caching Mechanism for Virtualization within Sensor - Cloud", IEEE ANTS 2014.

Practically, in some cases, the change in environmental condition are significantly slow.
Due to the slow change in environment, the sensed data of physical sensors unaltered .In such a situation, unnecessary sensing causes energy consumption.

Pricing in Sensor-Cloud

Set of sensor owner



Introduction to FOG computing

- ✔ Fog computing or fogging is a term coined by CISCO.
- ✔ The idea of fog computing is to extend the cloud nearer to the IoT devices.
- ✔ The primary aim: solve the problems faced by cloud computing during IoT data processing.
- ✔ An intermediate layer between cloud and devices.

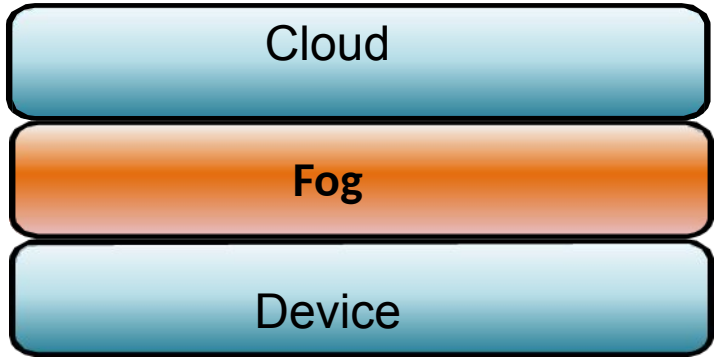


Fig. Fog as intermediate layer between cloud and device

The total number of connected vehicles worldwide will be 300 millions by 2030.There will be more than 50 billion IoT devices. The amount of data generated by IoT devices is simply huge.

Why Fog Computing

- The ability of the current cloud model is insufficient to handle the requirements of IoT.
- Issues are:
  - Volume
  - Latency
  - Bandwidth

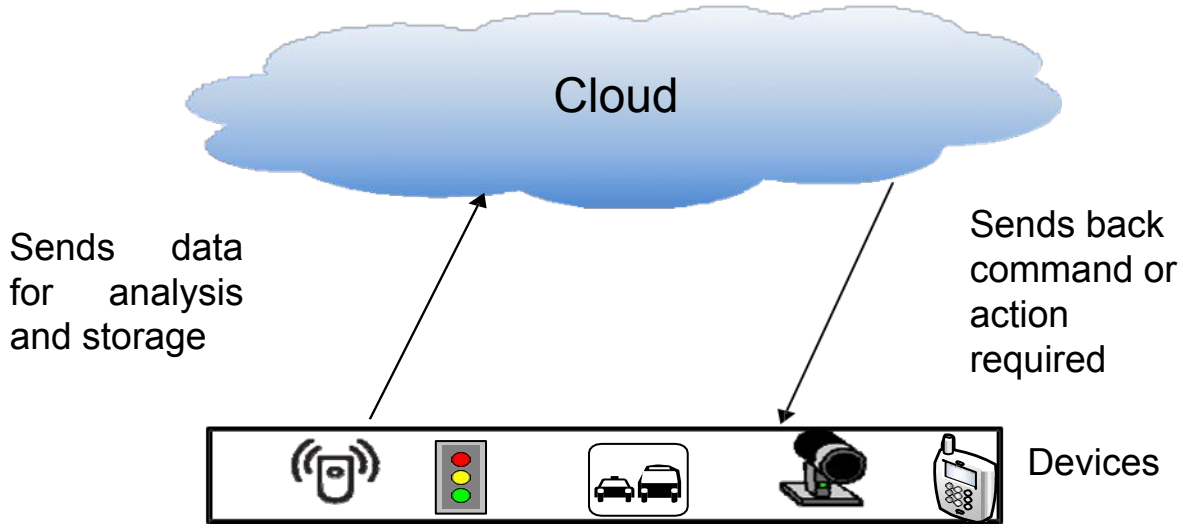
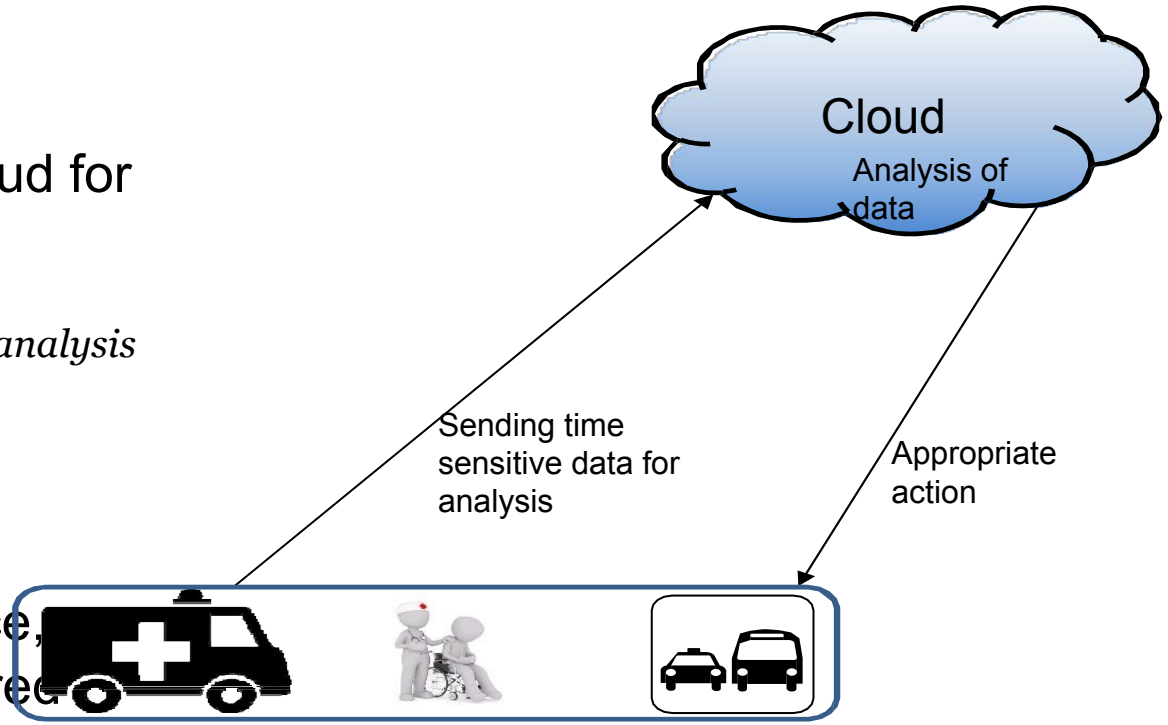


Fig.1: Present day cloud model

Why Fog Computing

- ✔ Sending time-sensitive data to cloud for analysis
- ✔ Latency = $T_{from\ device\ to\ cloud} + T_{data\ analysis} + T_{from\ cloud\ to\ device}$

  where T = Time
- ✔ Latency will be increased
- ✔ When the action reaches the device, accident may have already occured

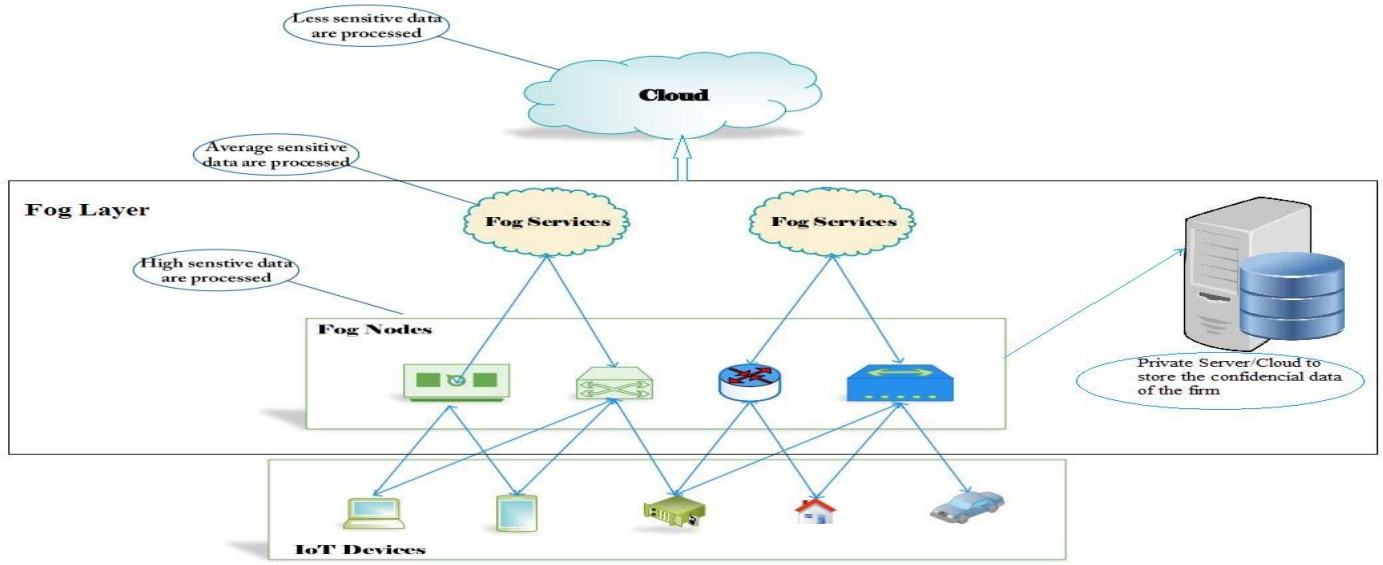


Requirements of IoT

- ✔ Reduce latency of data:
  - ✔ Appropriate actions at the right time prevents major accidents machine failure etc.
  - ✔ A minute delay while taking a decision makes a huge difference
  - ✔ Latency can be reduced by analyzing the data close to the data source
- ✔ Data security:
  - ✔ IoT data must be secured and protected from the intruders.
  - ✔ Data are required to be monitored 24x7
  - ✔ An appropriate action should be taken before the attack causes major harm to the network
- ✔ Operation reliability:
  - ✔ The data generated from IoT devices are used to solve real time problem
  - ✔ Integrity and availability of the data must be guaranteed
  - ✔ Unavailability and tampering of data can be hazardous

Architecture of Fog

- ✔ Cloud services are extended to IoT devices through fog
- ✔ Fog is a layer between cloud and IoT devices
- ✔ many fog nodes can be present
- ✔ Sensor data are processed in the fog before it is sent to the cloud
- ✔ Reduces latency, save bandwidth and save the storage of the cloud



Working of Fog

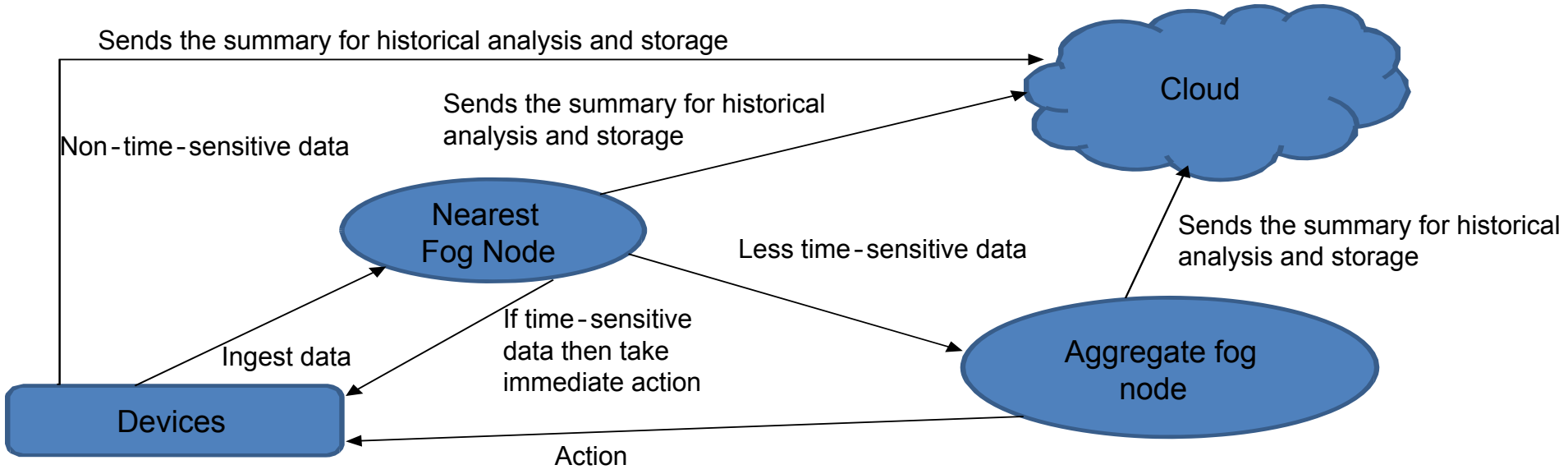


Fig : Working of fog

Working of Fog

- ✔ The nearest fog node ingest the data from the devices.
- ✔ Most time-sensitive data
  - ✔ Data which should be analyzed within fraction of a second
  - ✔ Analyze at the nearest node itself
  - ✔ Sends the decision or action to the devices
  - ✔ Sends and stores the summary to cloud for future analysis
- ✔ Less time-sensitive data
  - ✔ Data which can be analyzed after seconds or minutes
  - ✔ Are sent to the aggregate node for analysis
  - ✔ After analysis, the aggregate node send the decision or action to the device through the nearest node
  - ✔ The aggregate node sends the summary to cloud for storage and future analysis.
- ✔ Non-time-sensitive data
  - ✔ Data which can be wait for hours, days, weeks
  - ✔ Sent to cloud for storage and future analysis.
  - ✔ Those summaries from fog nodes can be considered as less time sensitive data.

Working of Fog

	Fog node closest to devices	Fog aggregate nodes	Cloud
Analysis duration	Fraction of second	Seconds to minutes	Hours to weeks
IoT data storage duration	Transient	Hour, days	Months to years
Geographical coverage	Very local	Wider	Global

Advantages of Fog

- ✔ Reduces unwanted accidents
  - ✔ Latency will be reduce during decision making
  - ✔ Quick decision making
- ✔ Better privacy
  - ✔ Every industry can analyze their data locally
  - ✔ Store confidential data in their local servers
  - ✔ Send only those data which can be shared to the cloud
- ✔ Deployable in remote places
  - ✔ Can be deployed in remote places
  - ✔ Can be subjected to harsh environmental conditions
  - ✔ Under sea, railway tracks, vehicles, factory floor etc
- ✔ Better data handling
  - ✔ Can operate with less bandwidth
  - ✔ Data can be analyzed locally
  - ✔ Reduce the risk of latency
- ✔ Low operation cost
  - ✔ Data are processed in the fog nodes before sending to cloud
  - ✔ Reduces the bandwidth consumption

Applications of Fog

- ✔ Real time health analysis
  - ✔ Patients with chronic illness can be monitored in real time
  - ✔ Stroke patients
  - ✔ Analyze the data real time
  - ✔ During emergency, alerts the respective doctors immediately
  - ✔ Historical data analysis can predict future dangers of the patient