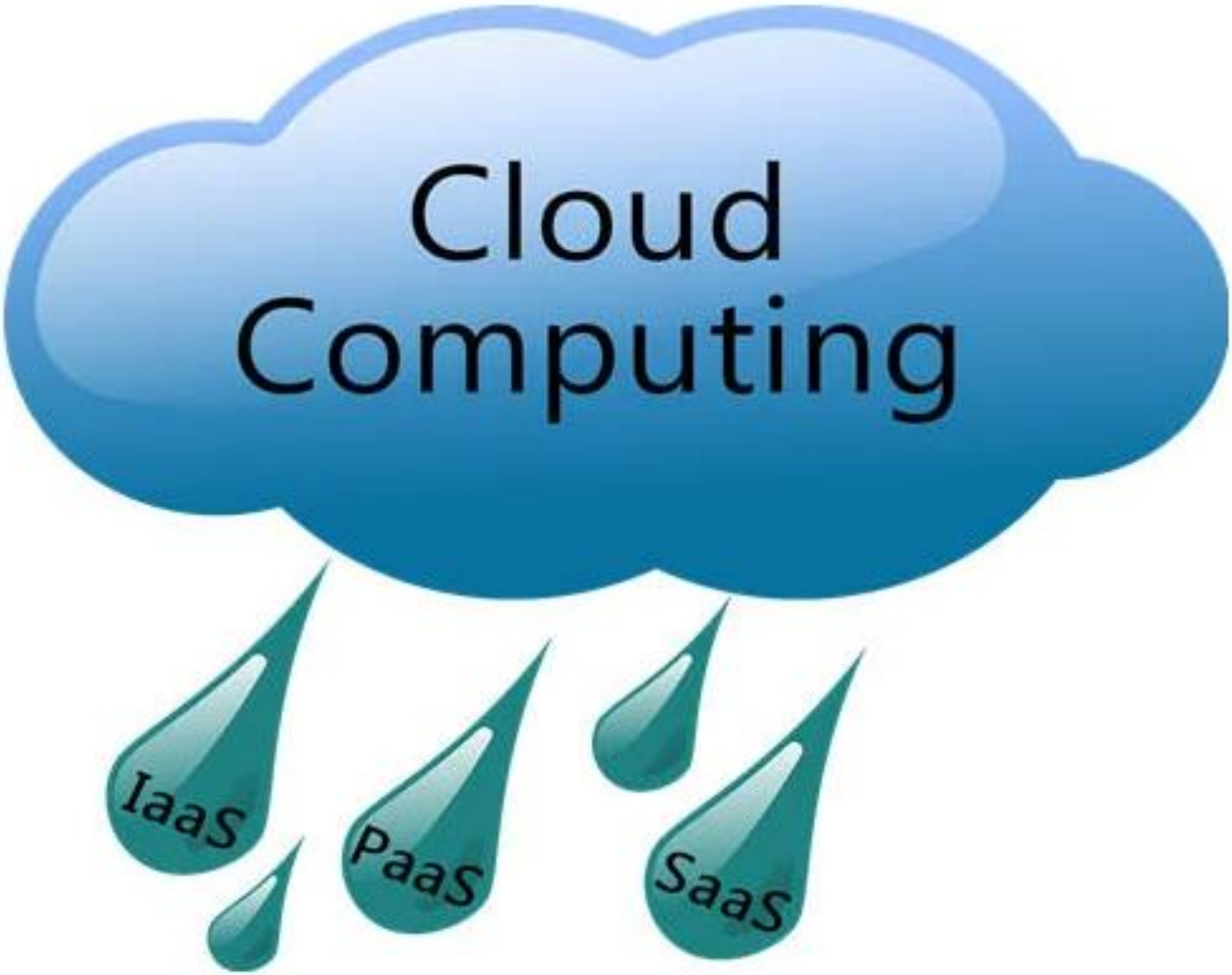
Cloud Computing

What is Cloud Computing?

- **Cloud Computing** is defined as storing and accessing of data and computing services over the internet.
- It doesn’t store any data on your personal computer.
- It is the on-demand availability of computer services like servers, data storage, networking, databases, etc.

What is Cloud Computing?

- The main purpose of cloud computing is to give access to data centers to many users.
- Users can also access data from a remote server.
- **Examples of Cloud Computing Services:** AWS, Azure, Google cloud.

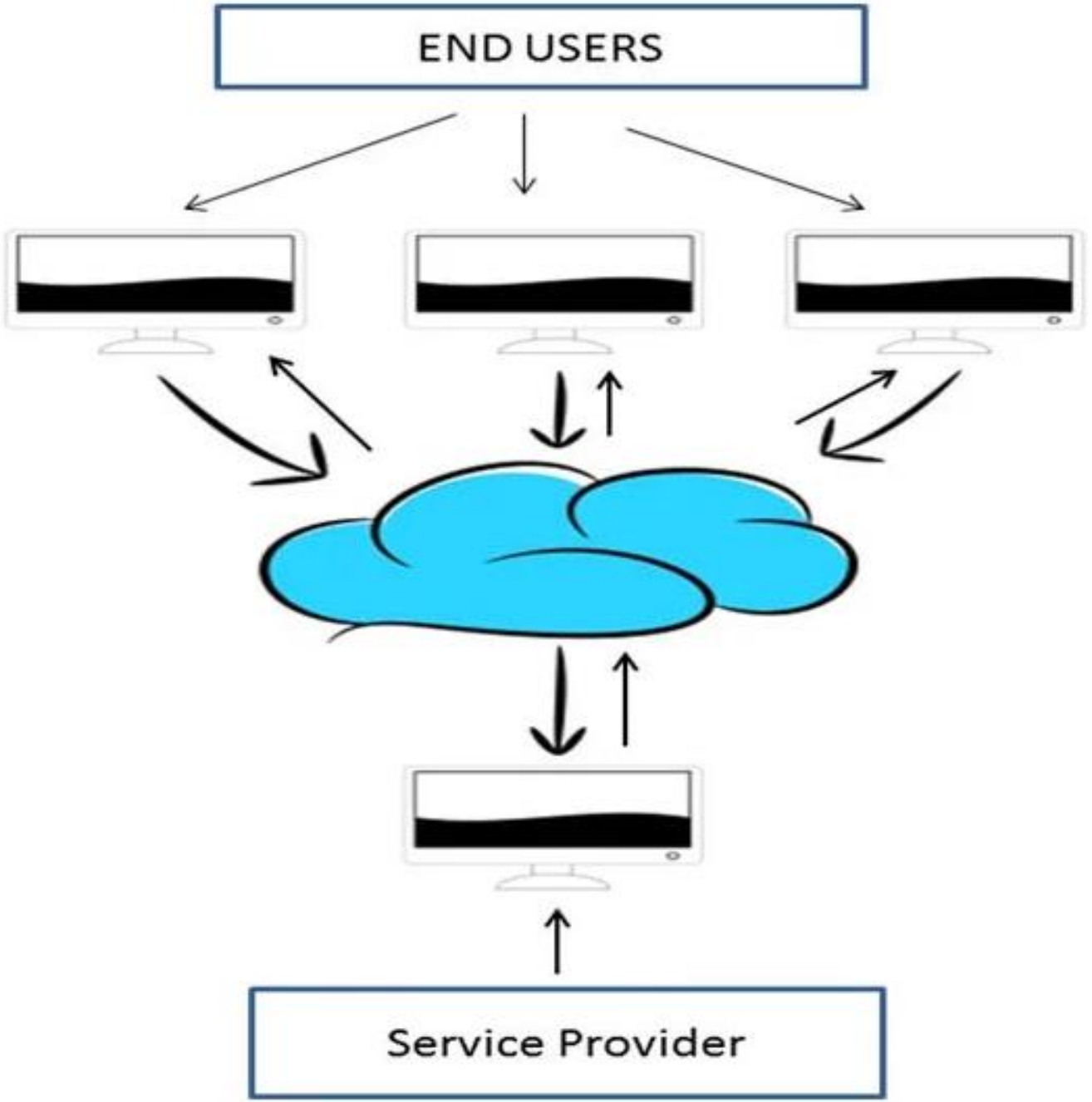

Cloud
Computing
IaaS
PaaS
SaaS

Example

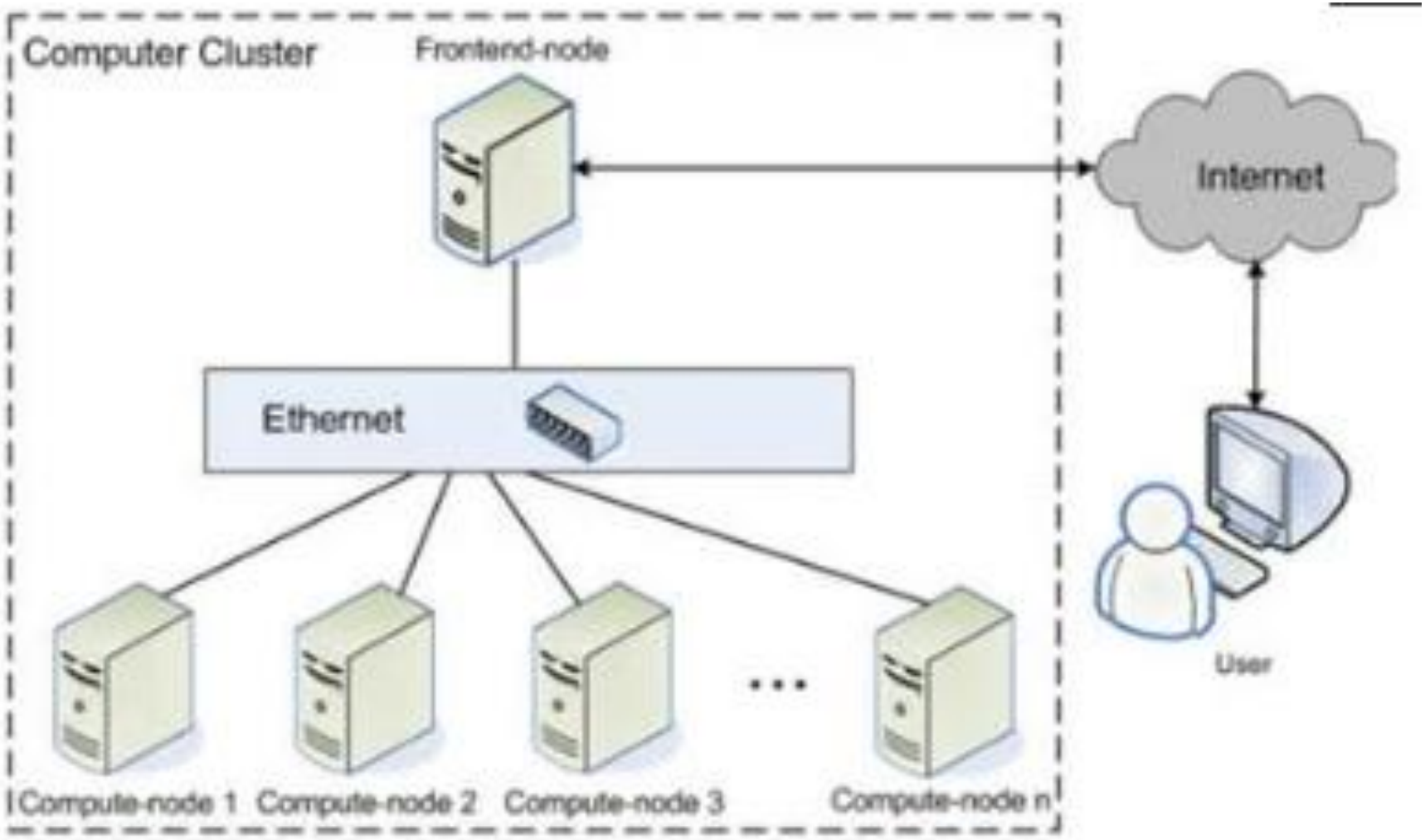
- Whenever you travel through a bus or train, you take a ticket for your destination and hold back to your seat till you reach your destination.
- Likewise other passengers also takes ticket and travel in the same bus with you and it hardly bothers you where they go.
- When your stop comes you get off the bus thanking the driver.
- Cloud computing is just like that bus, carrying data and information for different users and allows to use its service with minimal cost.

Why the Name Cloud?

- The term “Cloud” came from a network design that was used by network engineers to represent the location of various network devices and there inter-connection.
- The shape of this network design was like a cloud.


END USERS
Service Provider

Grid computing



Cloud computing at a glance

- In 1969, Leonard Kleinrock, one of the chief scientists of the original Advanced Research Project Agency Network(ARPANET),which seeded the Internet, said:
- *As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of 'computer utilities' which, like present electric and telephone utilities, will service individual homes and offices across the country.*

Cloud computing at a glance

- Cloud computing allows renting infrastructure, runtime environments, and services on a pay-per-use basis.
- End users leveraging cloud computing services can access their documents and data anytime, anywhere, and from any device connected to the Internet.
- One of the most diffuse views of cloud computing can be summarized as follows:

Cloud computing at a glance

- *“I don’t care where my servers are, who manages them, where my documents are stored, or where my applications are hosted. I just want them always available and access them from any device connected through Internet. And I am willing to pay for this service for as a long as I need it.”*

Cloud computing at a glance

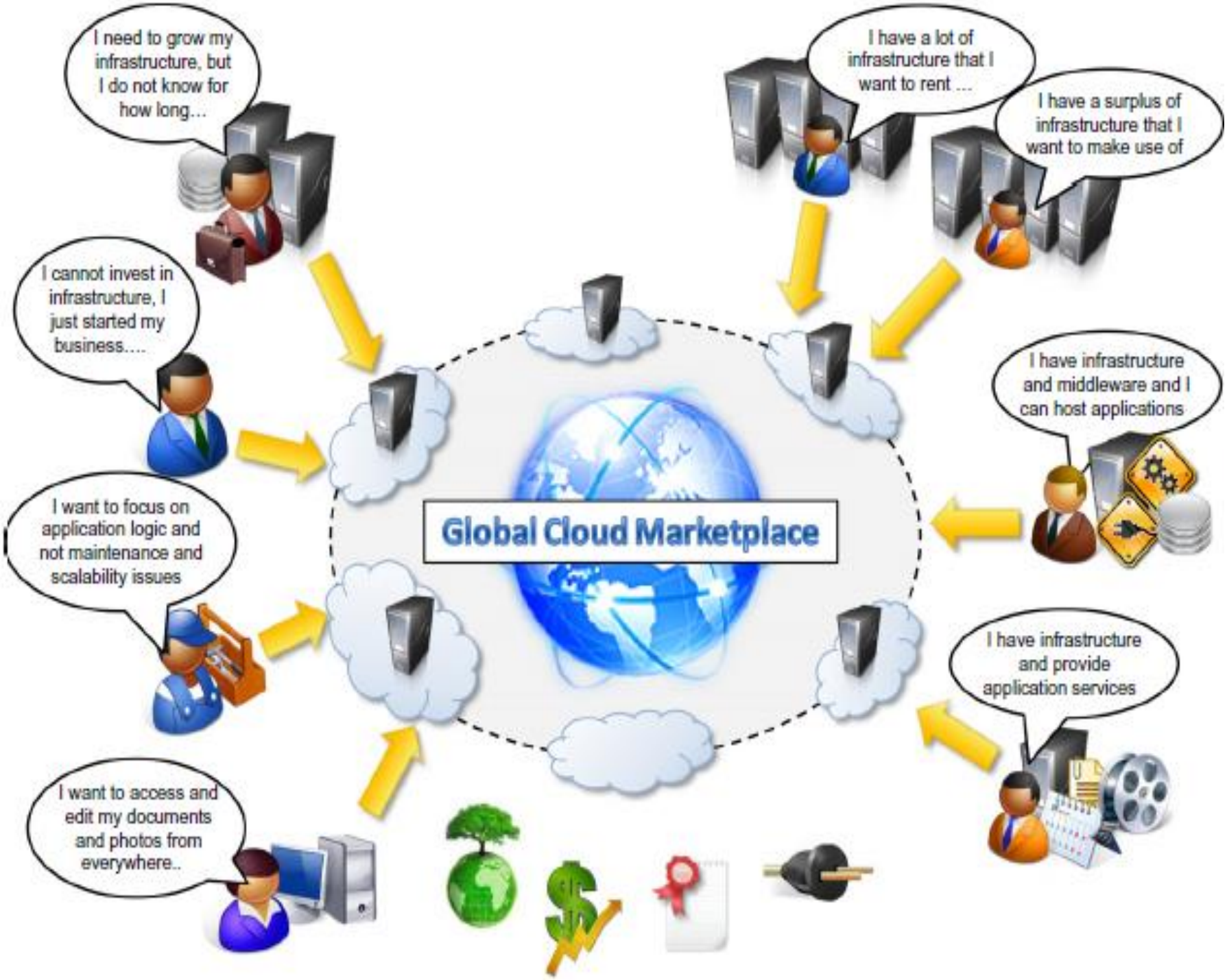
- **Web 2.0** technologies play a central role in making cloud computing an attractive opportunity for building computing systems.
- **Service orientation** allows cloud computing to deliver its capabilities with familiar abstractions.
- **Virtualization** confers on cloud computing the necessary degree of customization, control, and flexibility for building production and enterprise systems.

THE VISION OF CLOUD COMPUTING

- **Cloud Computing** means storing and accessing the data and programs on remote servers that are hosted on internet instead of computer's hard drive or local server.
- Cloud computing is also referred as **Internet based computing**.

THE VISION OF CLOUD COMPUTING

- Cloud computing provides the facility to provision virtual hardware, runtime environment and services to a person having money.
- These are used for as long as needed, with no up-front commitments required.
- The entire stack of a computing system is transformed into a collection of utilities, which can be provisioned and composed together to deploy systems in hours rather than days and with virtually no maintenance costs.


I need to grow my infrastructure, but I do not know for how long…
I have a lot of infrastructure that I want to rent …
I have a surplus of infrastructure that I want to make use of
I cannot invest in infrastructure, I just started my business….
I have infrastructure and middleware and I can host applications
Global Cloud Marketplace
I want to focus on application logic and not maintenance and scalability issues
I have infrastructure and provide application services
I want to access and edit my documents and photos from everywhere..

THE VISION OF CLOUD COMPUTING

- Previously, the lack of effective standardization efforts made it difficult to move hosted services from one vendor to another.
- **The long-term vision of cloud computing is that IT services are traded as utilities in an open market, without technological and legal barriers.**
- In this cloud marketplace, cloud service providers and consumers, trading cloud services as utilities, play a central role.

THE VISION OF CLOUD COMPUTING

- Many of the technological elements contributing to this vision already exist.
- The capability for Web- based access to documents and their processing using sophisticated applications is one of the appealing factors for end users.

THE VISION OF CLOUD COMPUTING

- Vision of cloud computing is that in the near future it will be possible to find the solution that matches the customer needs by simply entering our request in a global digital market that trades cloud computing services.
- The existence of such a market will enable the automation of the discovery process and its integration into existing software systems.

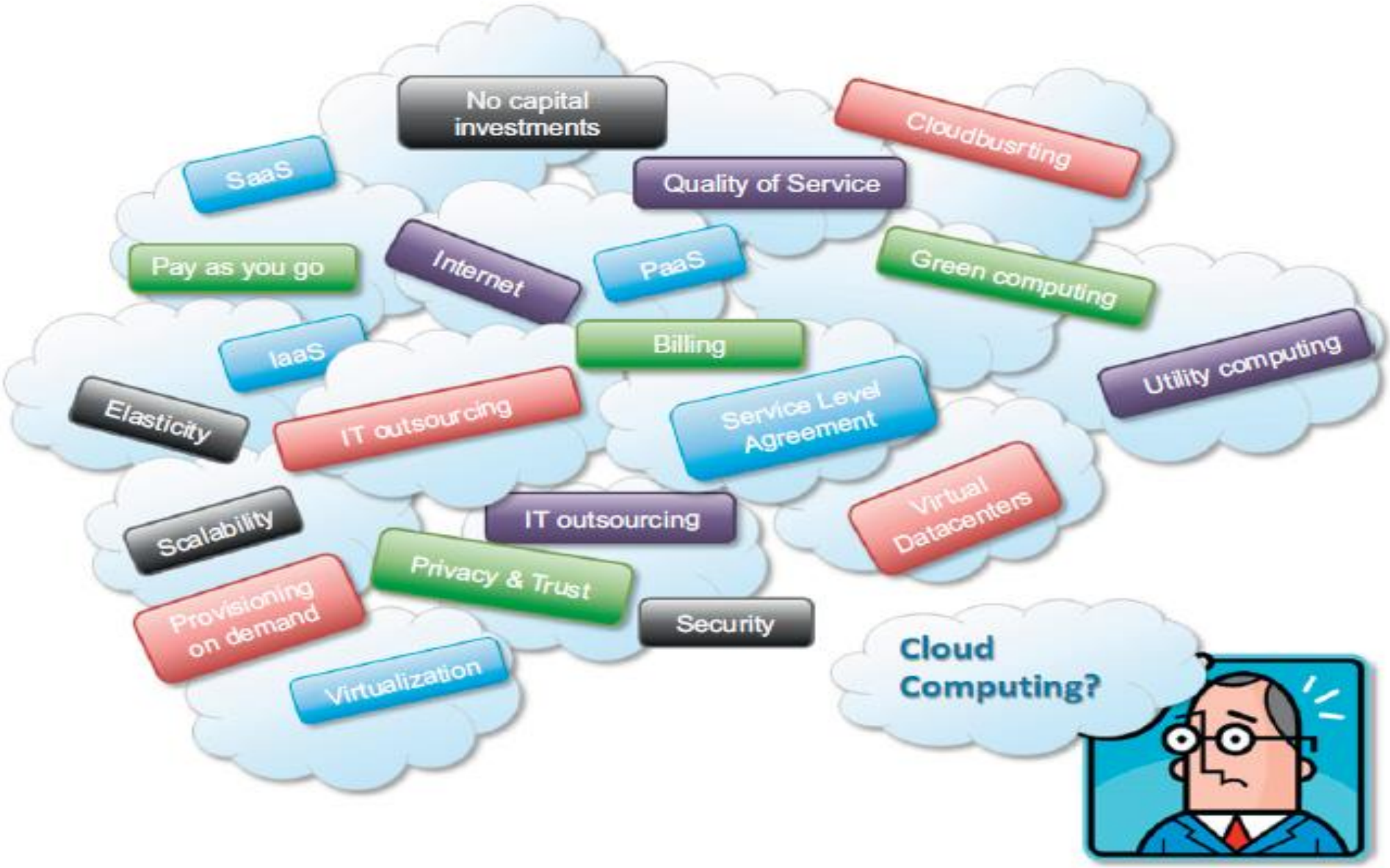
THE VISION OF CLOUD COMPUTING

- The existence of a global platform for trading cloud services will also help service providers become more visible and therefore potentially increase their revenue.
- A cloud provider might become a consumer of a competitor service in order to fulfill its own promises to customers.

DEFINING A CLOUD

- Different notions of cloud computing is as shown in figure.

DEFINING A CLOUD



DEFINING A CLOUD

- The Internet plays a fundamental role in cloud computing, since it represents either the medium or the platform through which many cloud computing services are delivered and made accessible.
- This aspect is also reflected in the definition given by Armbrust:

DEFINING A CLOUD

- *"Cloud computing refers to both the applications delivered as services over the Internet and the hardware and system software in the datacenters that provide those services."*

DEFINING A CLOUD

- This definition describes cloud computing as a phenomenon touching on the entire stack: from the underlying hardware to the high-level software services and applications.
- It introduces the concept of *everything as a service*, mostly referred as *XaaS*, where the different components of a system—IT infrastructure, development platforms, databases, and so on—can be delivered, measured, and consequently priced as a service.

DEFINING A CLOUD

- The approach fostered by cloud computing is global.
- This notion of multiple parties using a shared cloud computing environment is highlighted in a definition proposed by the U.S. National Institute of Standards and Technology (NIST):

DEFINING A CLOUD

- *"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."*

DEFINING A CLOUD

- According to Reese, we can define three criteria to discriminate whether a service is delivered in the cloud computing style:
  - The service is accessible via a Web browser (nonproprietary) or a Web services application programming interface (API).
  - Zero capital expenditure is necessary to get started.
  - You pay only for what you use as you use it.

DEFINING A CLOUD

- The utility-oriented nature of cloud computing is clearly expressed by Buyya:
- *"A cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers."*

A Closer Look

- Cloud computing is helping enterprises, governments, public and private institutions, and research organizations shape more effective and demand-driven computing systems.
- Practical examples of such systems exist across all market segments:
- ***Large enterprises can offload some of their activities to cloud-based systems.***
  - Recently, the New York Times has converted its digital library of past editions into a Web-friendly format. This required a considerable amount of computing power for a short period of time. By renting Amazon EC2 and S3 Cloud resources, the Times performed this task in 36 hours and relinquished these resources, with no additional costs.

A Closer Look

- ***Small enterprises and start-ups can afford to translate their ideas into business results more quickly, without excessive up-front costs.***
  - Animoto is a company that creates videos out of images, music, and video fragments submitted by users. The process involves a considerable amount of storage and backend processing required for producing the video, which is finally made available to the user. Animoto does not own a single server and bases its computing infrastructure entirely on Amazon Web Services.

A Closer Look

- ***System developers can concentrate on the business logic rather than dealing with the complexity of infrastructure management and scalability.***
  - Little Fluffy Toys is a company in London that has developed a widget providing users with information about nearby bicycle rental services. The company has managed to back the widget's computing needs on Google AppEngine and be on the market in only one week.

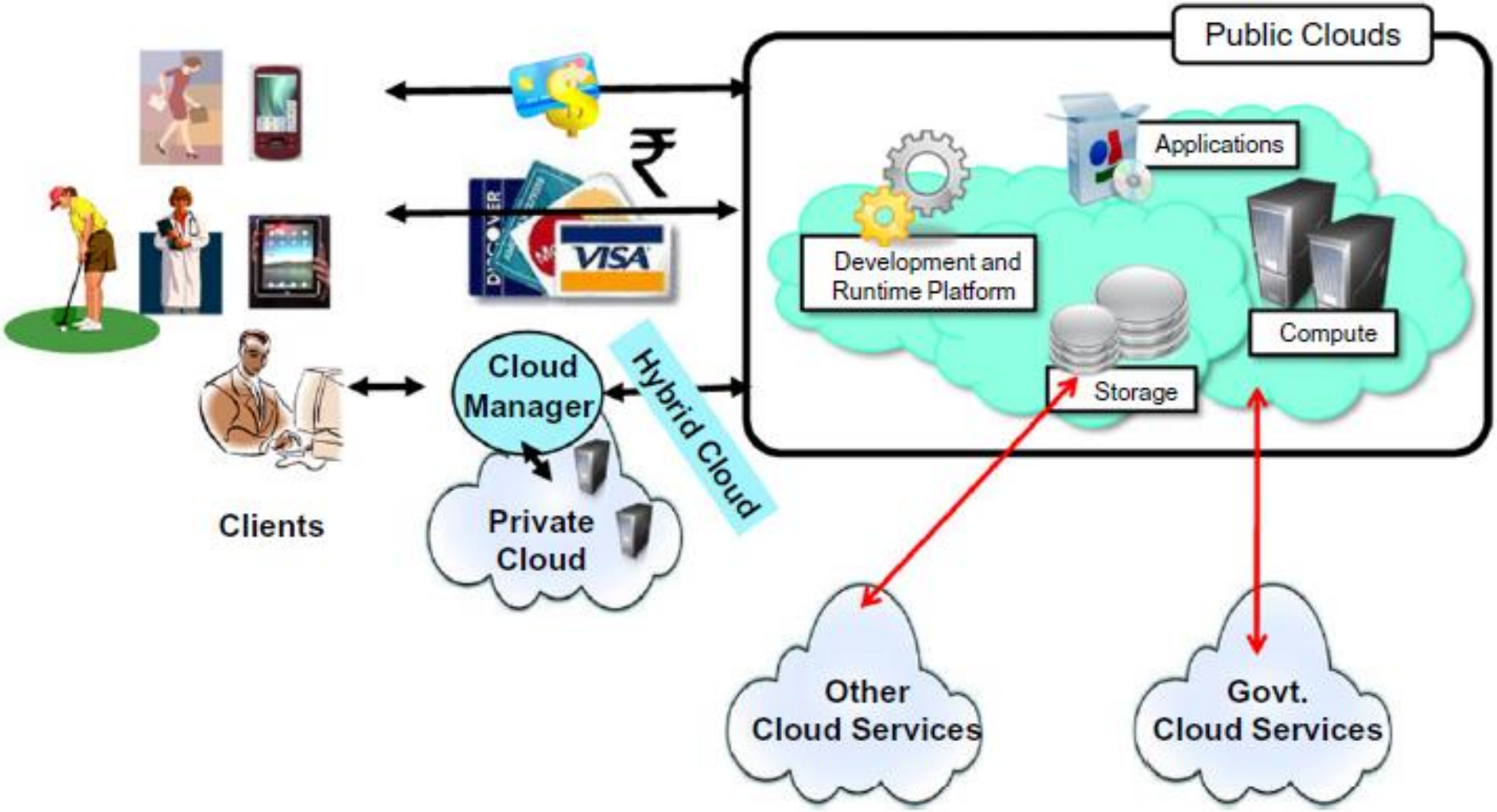
A Closer Look

- ***End users can have their documents accessible from everywhere and any device.***
  - Apple iCloud is a service that allows users to have their documents stored in the Cloud and access them from any device users connect to it.

A Closer Look

- Cloud computing does not only contribute with the opportunity of easily accessing IT services on demand, it also introduces a new way of thinking about IT services and resources: as utilities.
- A bird's-eye view of a cloud computing environment is shown in below figure:

A Closer Look



A Closer Look

- The three major models for deploying and accessing cloud computing environments are -
  - Public/Internet Clouds
  - Private/Enterprise Clouds
  - Hybrid/Inter Clouds

Cloud Deployment Models

Public/Internet Clouds

***Third-party, multitenant cloud infrastructure and services**

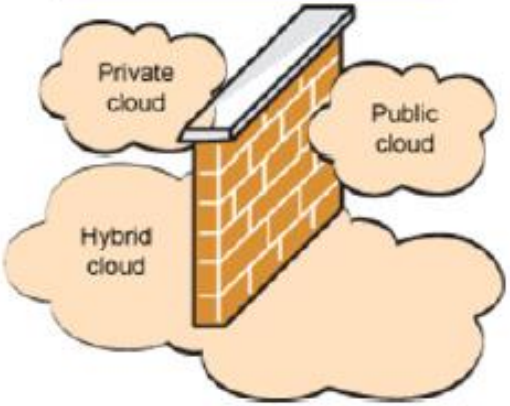
***Available on a subscription basis to all**

Private/Enterprise Clouds

***A public cloud model within a company's own datacenter/infrastructure for internal and/or partners' use**

Hybrid/Inter Clouds

*** Mixed use of private and public clouds; leasing public cloud services when private cloud capacity is insufficient**



Public Clouds

- ***Public clouds*** are the most common deployment models in which necessary IT infrastructure (e.g., virtualized datacenters) is established by a third-party service provider that makes it available to any consumer on a subscription basis.
- Such clouds are appealing to users because they allow users to quickly leverage compute, storage, and application services.
- In this environment, users' data and applications are deployed on cloud datacenters on the vendor's premises.

Private Clouds

- Large organizations that own massive computing infrastructures can still benefit from cloud computing by replicating the cloud IT service delivery model in-house.
- This idea has given birth to the concept of ***Private Clouds*** as opposed to public clouds.
- In 2010, for example, the U.S. federal government, one of the world's largest consumers of IT spending started a cloud computing initiative aimed at providing government agencies with a more efficient use of their computing facilities.

Private Clouds

- The use of cloud-based in-house solutions is also driven by the need to keep confidential information within an organization's premises.
- Institutions such as governments and banks that have high security, privacy, and regulatory concerns prefer to build and use their own private or enterprise clouds.

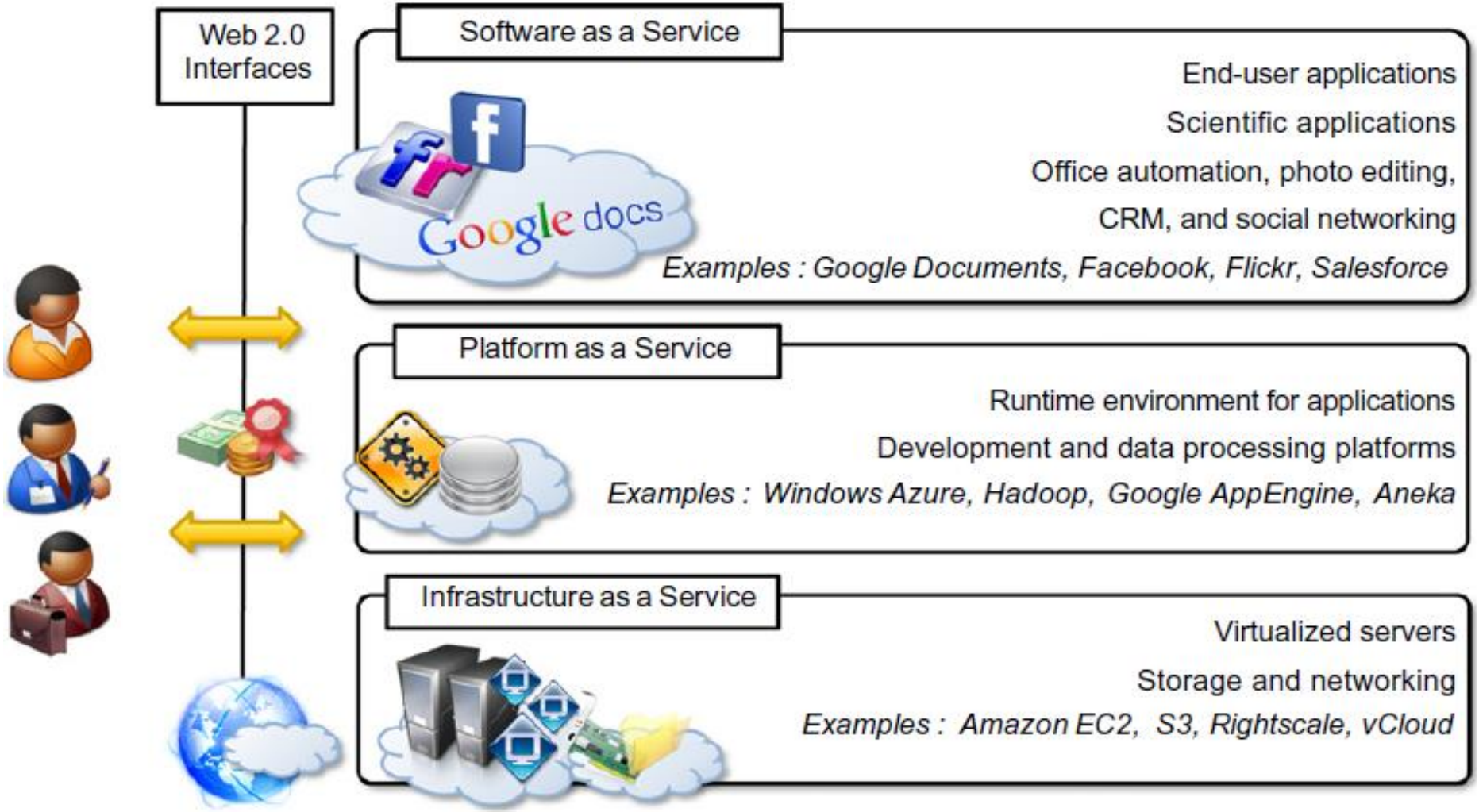
Hybrid Clouds

- Whenever private cloud resources are unable to meet users' quality-of-service requirements, hybrid computing systems, partially composed of public cloud resources and privately owned infra-structures, are created to serve the organization's needs.
- These are often referred as ***hybrid clouds***, which are becoming a common way for many stakeholders to start exploring the possibilities offered by cloud computing.

Cloud Computing Reference Model

- A fundamental characteristic of cloud computing is the capability to deliver, on demand, a variety of IT services that are quite diverse from each other.
- This variety creates different perceptions of what cloud computing is among users.
- Despite this lack of uniformity, it is possible to classify cloud computing services offerings into three major categories:
  - **Infrastructure-as-a-Service (IaaS)**
  - **Platform-as-a-Service (PaaS)**
  - **Software-as-a-Service (SaaS)**
- These categories are related to each other as described in below figure.

The Cloud Computing Reference Model



- The model organizes the wide range of cloud computing services into a layered view that walks the computing stack from bottom to top.

Infrastructure-as-a-Service

- At the base of the stack, **Infrastructure-as-a-Service(IaaS)** solutions deliver infrastructure on demand in the form of **virtual hardware, storage, and networking**.
- **Virtual hardware** is utilized to provide compute on demand in the form of virtual machine instances. These are created at users' request on the provider's infrastructure, and users are given tools and interfaces to configure the software stack installed in the virtual machine.
- The **pricing model** is usually defined in terms of **dollars per hour**.
- **Virtual storage** is delivered in the form of raw disk space or object store.
- **Virtual networking** identifies the collection of services that manage the networking among virtual instances and their connectivity to the Internet or private networks.

Platform-as-a-Service

- **Platform-as-a-Service solutions(PaaS)** are the next step in the stack.
- They deliver scalable and elastic runtime environments on demand and host the execution of applications.
- These services are backed by a core middleware platform that is responsible for creating the abstract environment where applications are deployed and executed.
- It is the responsibility of the service provider to provide scalability and to manage fault tolerance, while users are requested to focus on the logic of the application developed by leveraging the provider's APIs and libraries.
- This approach increases the level of abstraction at which cloud computing is leveraged but also constrains the user in a more controlled environment.

Software-as-a-Service

- At the top of the stack, **Software-as-a-Service(SaaS)** solutions provide applications and services on demand.
- **Most of the common functionalities of desktop applications—such as office automation, document management, photo editing, and customer relationship management (CRM) software**—are replicated on the provider's infrastructure and made more scalable and accessible through a browser on demand.
- These applications are shared across multiple users whose interaction is isolated from the other users.
- The SaaS layer is also the area of social networking Websites, which leverage cloud-based infrastructures to sustain the load generated by their popularity.

Cloud Computing Reference Model

- Each layer provides a different service to users.
- **IaaS** solutions are sought by users who want to leverage cloud computing from building dynamically scalable computing systems requiring a specific software stack.
- **IaaS** services are used to develop scalable Websites or for back-ground processing.

Cloud Computing Reference Model

- **PaaS** solutions provide scalable programming platforms for developing applications and are more appropriate when new systems have to be developed.
- **SaaS** solutions target mostly end users who want to benefit from the elastic scalability of the cloud without doing any software development, installation, configuration, and maintenance.

Characteristics and Benefits

- Cloud computing has some interesting characteristics that bring benefits to both cloud service consumers (CSCs) and cloud service providers (CSPs). These characteristics are:
  - No up-front commitments
  - On-demand access
  - Nice pricing
  - Simplified application acceleration and scalability
  - Efficient resource allocation
  - Energy efficiency
  - Seamless creation and use of third-party services

Characteristics and Benefits

- **The most evident benefit from the use of cloud computing systems and technologies is the increased economical return due to the reduced maintenance costs and operational costs related to IT software and infrastructure.**
- This is mainly because IT assets, namely software and infrastructure, are turned into utility costs, which are paid for as long as they are used, not paid for upfront.

Characteristics and Benefits

- Cloud computing transforms IT infrastructure and software into utilities, thus significantly contributing to increasing a company's net gain.
- Cloud computing also provides an opportunity for small organizations and start-ups: these do not need large investments to start their business, but they can comfortably grow with it.
- Maintenance costs are significantly reduced: by renting the infrastructure and the application services, organizations are no longer responsible for their maintenance.
- This task is the responsibility of the cloud service provider can bear the maintenance costs.

Characteristics and Benefits

- Increased agility in defining and structuring software systems is another significant benefit of cloud computing.
- Since organizations rent IT services, they can more dynamically and flexibly compose their software systems, without being constrained by capital costs for IT assets.
- There is a reduced need for capacity planning, since cloud computing allows organizations to react to unplanned surges in demand quite rapidly.

Characteristics and Benefits

- For example, organizations can add more servers to process workload spikes and dismiss them when they are no longer needed.
- **Ease of scalability is another advantage.**
- By leveraging the potentially huge capacity of cloud computing, organizations can extend their IT capability more easily.
- Scalability can be leveraged across the entire computing stack.

Characteristics and Benefits

- **Infrastructure** providers offer simple methods to provision customized hardware and integrate it into existing systems.
- **Platform-as-a-Service** providers offer runtime environment and programming models that are designed to scale applications.
- **Software-as-a-Service** offerings can be elastically sized on demand without requiring users to provision hardware or to program application for scalability.

Characteristics and Benefits

- **End users can benefit from cloud computing by having their data and the capability of operating on it always available, from anywhere, at any time, and through multiple devices.**
- Information and services stored in the cloud are exposed to users by Web-based interfaces that make them accessible from portable devices as well as desktops at home.
- Since the processing capabilities (i.e, office automation features, photo editing, information management, and so on) also reside in the cloud, end users can perform the same tasks that previously were carried out through considerable software investments.

Characteristics and Benefits

- The cost for such opportunities is generally very limited, since the cloud service provider shares its costs across all the tenants that he is servicing.
- Multitenancy allows for better utilization of the shared infrastructure that is kept operational and fully active.
- The concentration of IT infrastructure and services into large datacenters also provides opportunity for considerable optimization in terms of resource allocation and energy efficiency, which eventually can lead to a less impacting approach on the environment.

Characteristics and Benefits

- **Finally, service orientation and on-demand access create new opportunities for composing systems and applications with a flexibility not possible before cloud computing.**
- New service offerings can be created by aggregating together existing services and concentrating on added value.
- Since it is possible to provision on demand any component of the computing stack, it is easier to turn ideas into products with limited costs and by concentrating technical efforts on what matters: the added value.

Challenges Ahead

- As any new technology develops and becomes popular, new issues have to be faced.
- Cloud computing is not an exception.
- New, interesting problems and challenges are regularly being posed to the cloud community, including IT practitioners, managers, governments, and regulators.

Challenges Ahead

- Besides the practical aspects, which are related to configuration, networking, and sizing of cloud computing systems, a new set of Challenges concerning the dynamic provisioning of cloud computing services and resources arises.
- For example, in the Infrastructure-as-a-Service domain, how many resources need to be provisioned, and for how long should they be used, in order to maximize the benefit?
- Technical challenges also arise for cloud service providers for the management of large computing infrastructures and the use of virtualization technologies on top of them.

Challenges Ahead

- Security in terms of confidentiality, secrecy, and protection of data in a cloud environment is another important challenge.
- Organizations do not own the infrastructure they use to process data and store information.
- This condition poses challenges for confidential data, which organizations cannot afford to reveal.

Challenges Ahead

- Therefore, assurance on the confidentiality of data and compliance to security standards, which give a minimum guarantee on the treatment of information on cloud computing systems, are sought.
- The problem is not as evident as it seems: even though cryptography can help secure the transit of data from the private premises to the cloud infrastructure, in order to be processed the information needs to be decrypted in memory.

Challenges Ahead

- Legal issues may also arise.
- These are specifically tied to the ubiquitous nature of cloud computing, which spreads computing infrastructure across diverse geographical locations.
- Different legislation about privacy in different countries may potentially create disputes as to the rights that third parties (including government agencies) have to your data.

Challenges Ahead

- U.S. legislation is known to give extreme powers to government agencies to acquire confidential data when there is the suspicion of operations leading to a threat to national security.
- European countries are more restrictive and protect the right of privacy. An interesting scenario comes up when a U.S. organization uses cloud services that store their data in Europe.
- In this case, should this organization be suspected by the government, it would become difficult or even impossible for the U.S. government to take control of the data stored in a cloud datacenter located in Europe.