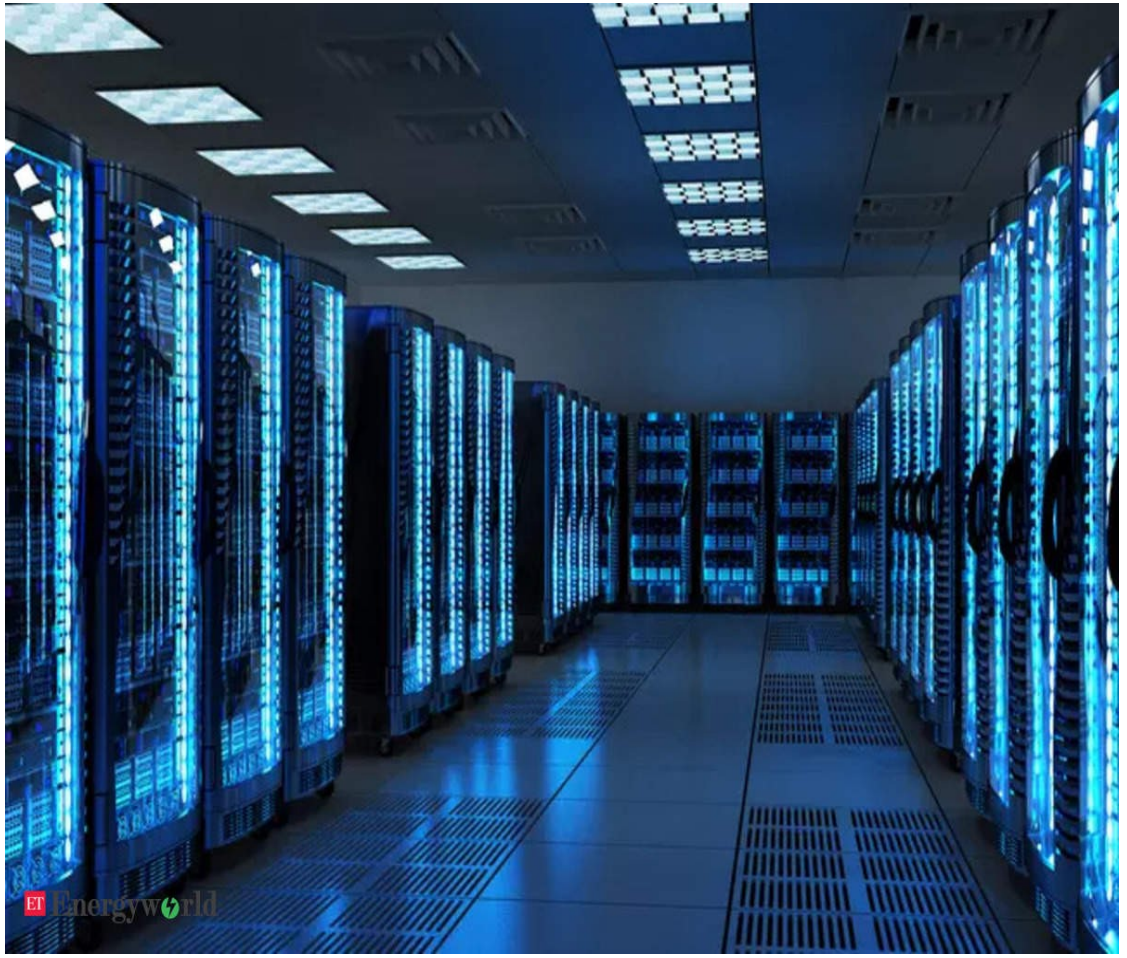
Cloud Computing Architecture

DATA CENTERS

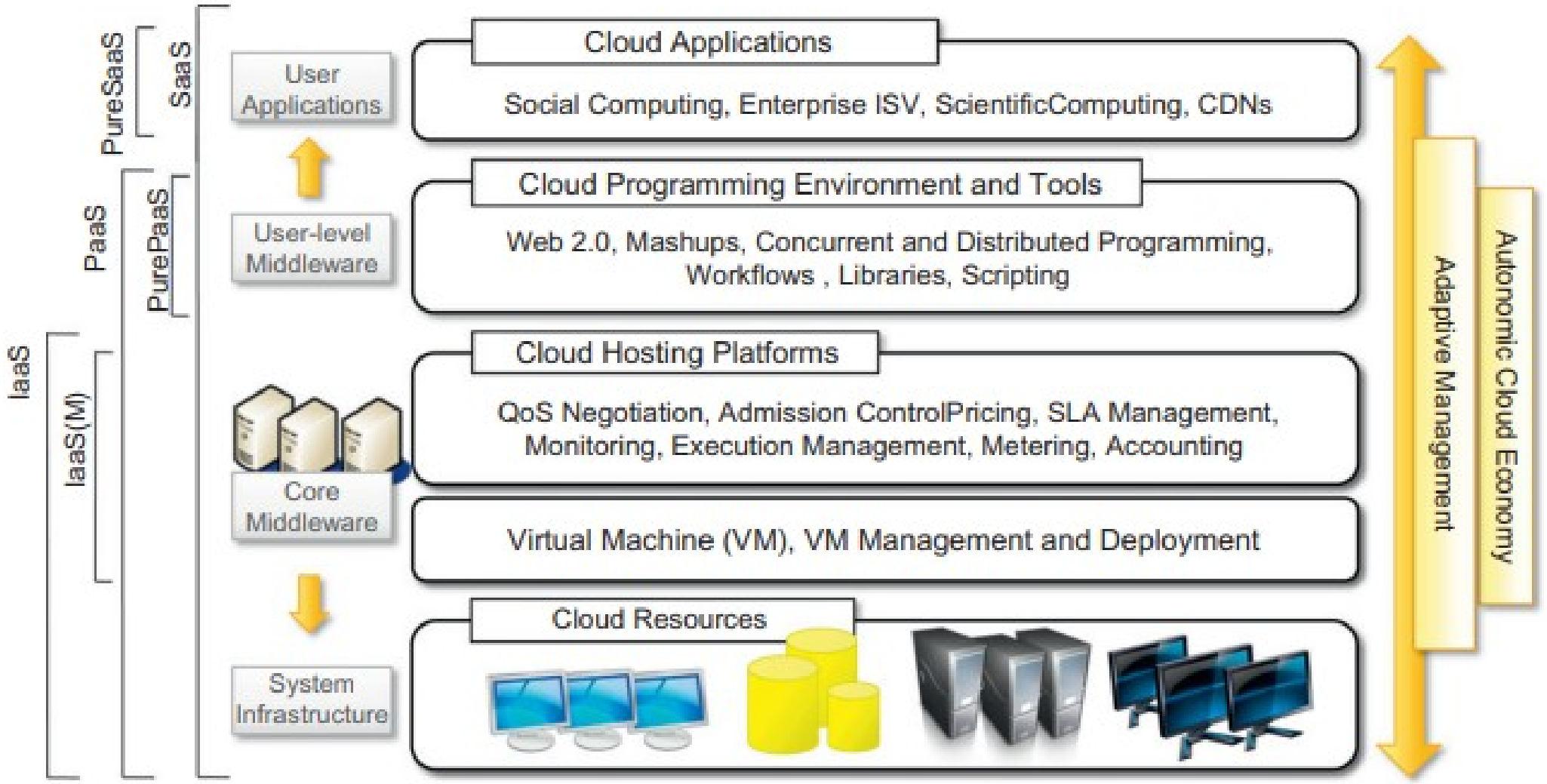
- Utility-oriented data centers are the first outcome of cloud computing.
- Serve as the infrastructure through which the services are implemented and delivered
- Any cloud service, whether virtual hardware, development platform, or application software, relies on a distributed infrastructure owned by the provider or rented from a third party

CLUSTER OF DATA CENTERS

- It can be implemented using a **datacenter, a collection of clusters, or a heterogeneous distributed system composed of desktop PCs, workstations, and servers**.
- Commonly, clouds are built by relying on one or more datacenters.
- In most cases hardware resources are virtualized to provide isolation of workloads and to best exploit the infrastructure.



The cloud computing architecture



The cloud computing architecture

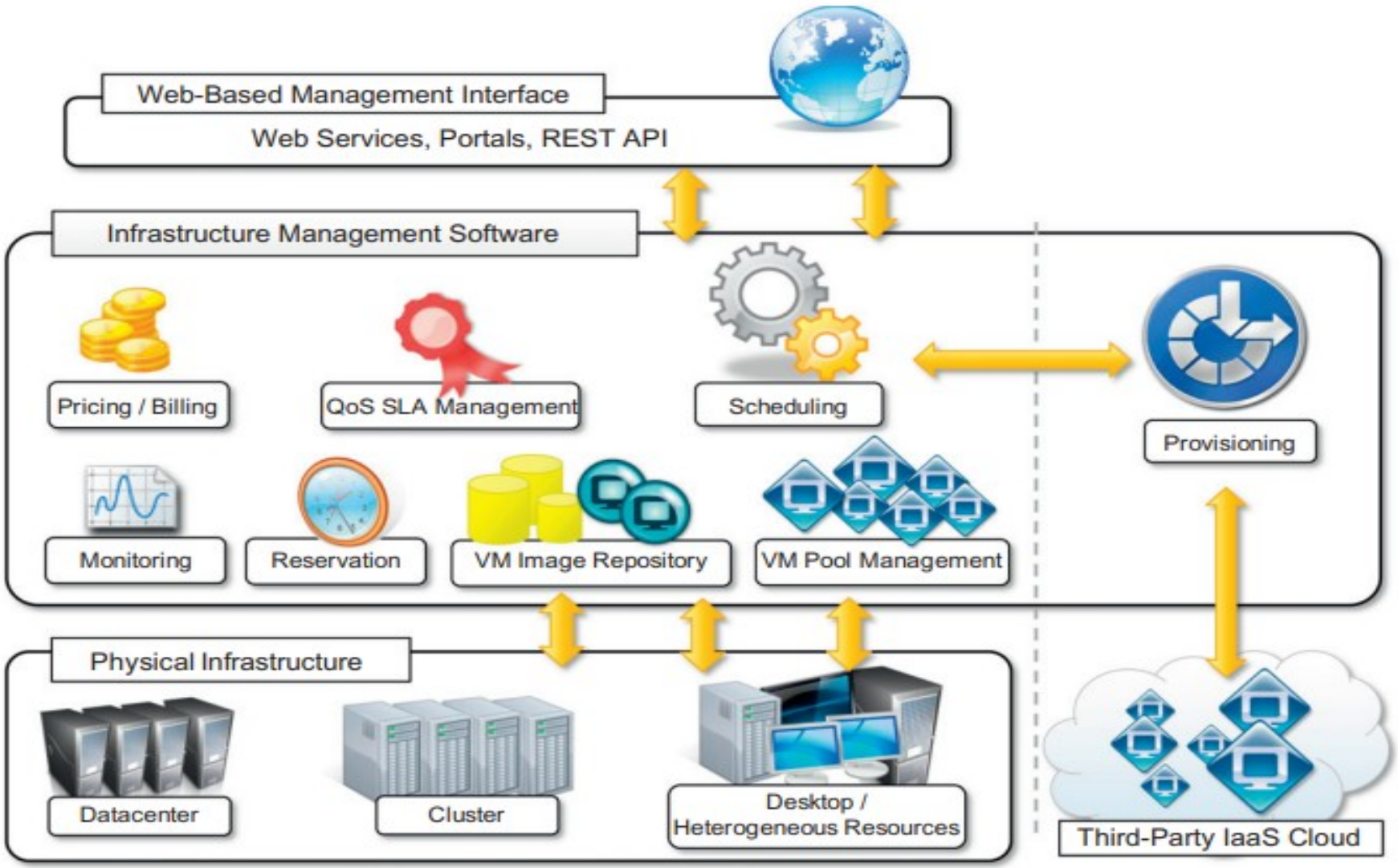
1. **Layered View of Cloud Computing**: Cloud computing can be organized into a layered structure from hardware to software systems, encompassing the entire stack (Figure 4.1). This includes hardware appliances, databases, and software systems.
2. **Cloud Resources and Datacenters**: Cloud resources, often managed in datacenters, provide the necessary computing power. These datacenters may consist of various nodes, making cloud infrastructure heterogeneous.
3. **Core Middleware**: The physical infrastructure is managed by core middleware, which ensures an appropriate runtime environment and optimal resource utilization.
4. **Virtualization Technologies**: At the base layer, virtualization technologies provide customization, isolation, and quality of service. Hypervisors manage these virtualized resources.

5. **Infrastructure-as-a-Service (IaaS)**: IaaS solutions manage both the infrastructure and a management layer. These can be further divided into those providing both layers and those offering only the management layer (IaaS (M)).
6. **Platform-as-a-Service (PaaS)**: PaaS offers development platforms for applications and includes both infrastructure and user-level middleware.
7. **Software-as-a-Service (SaaS)**: SaaS represents services delivered at the application level, often as web-based applications, leveraging cloud resources for scalability and availability.
8. **Adaptive and Autonomic Behavior**: Cloud services should adaptively scale and autonomously manage availability and performance, as highlighted in the reference model.
9. **Everything as a Service (XaaS)**: XaaS represents the integration of various cloud services across the computing stack, facilitating scalable and flexible solutions for businesses, particularly startups.

Table 4.1 Cloud Computing Services Classification

Category	Characteristics	Product Type	Vendors and Products
SaaS	Customers are provided with applications that are accessible anytime and from anywhere.	Web applications and services (Web 2.0)	SalesForce.com (CRM) Clarizen.com (project management) Google Apps
PaaS	Customers are provided with a platform for developing applications hosted in the cloud.	Programming APIs and frameworks Deployment systems	Google AppEngine Microsoft Azure Manjrasoft Aneka Data Synapse
IaaS/HaaS	Customers are provided with virtualized hardware and storage on top of which they can build their infrastructure.	Virtual machine management infrastructure Storage management Network management	Amazon EC2 and S3 GoGrid Nirvanix

Infrastructure- and hardware-



https://www.youtube.com/watch?v=5RRTnKOlSwY

- The pricing and billing component takes care of the cost of executing each virtual machine instance
- The monitoring component tracks the execution of each virtual machine instance and maintains data required for reporting and analyzing the performance of the system.
- The reservation component stores the information of all the virtual machine instances
- If support for QoS-based execution is provided, a QoS/SLA management component will maintain a repository of all the SLAs made with the users;
- Together with the monitoring component, this component is used to ensure that a given virtual machine instance is executed with the desired quality of service.

- The VM repository component provides a catalog of virtual machine images that users can use to create virtual instances.
- Some implementations also allow users to upload their specific virtual machine images.
- A VM pool manager component is responsible for keeping track of all the live instances.
- Finally, if the system supports the integration of additional resources belonging to a third-party IaaS provider
- A provisioning component interacts with the scheduler to provide a virtual machine instance that is external to the local physical infrastructure directly managed by the pool

The Platform-as-a-Service reference model

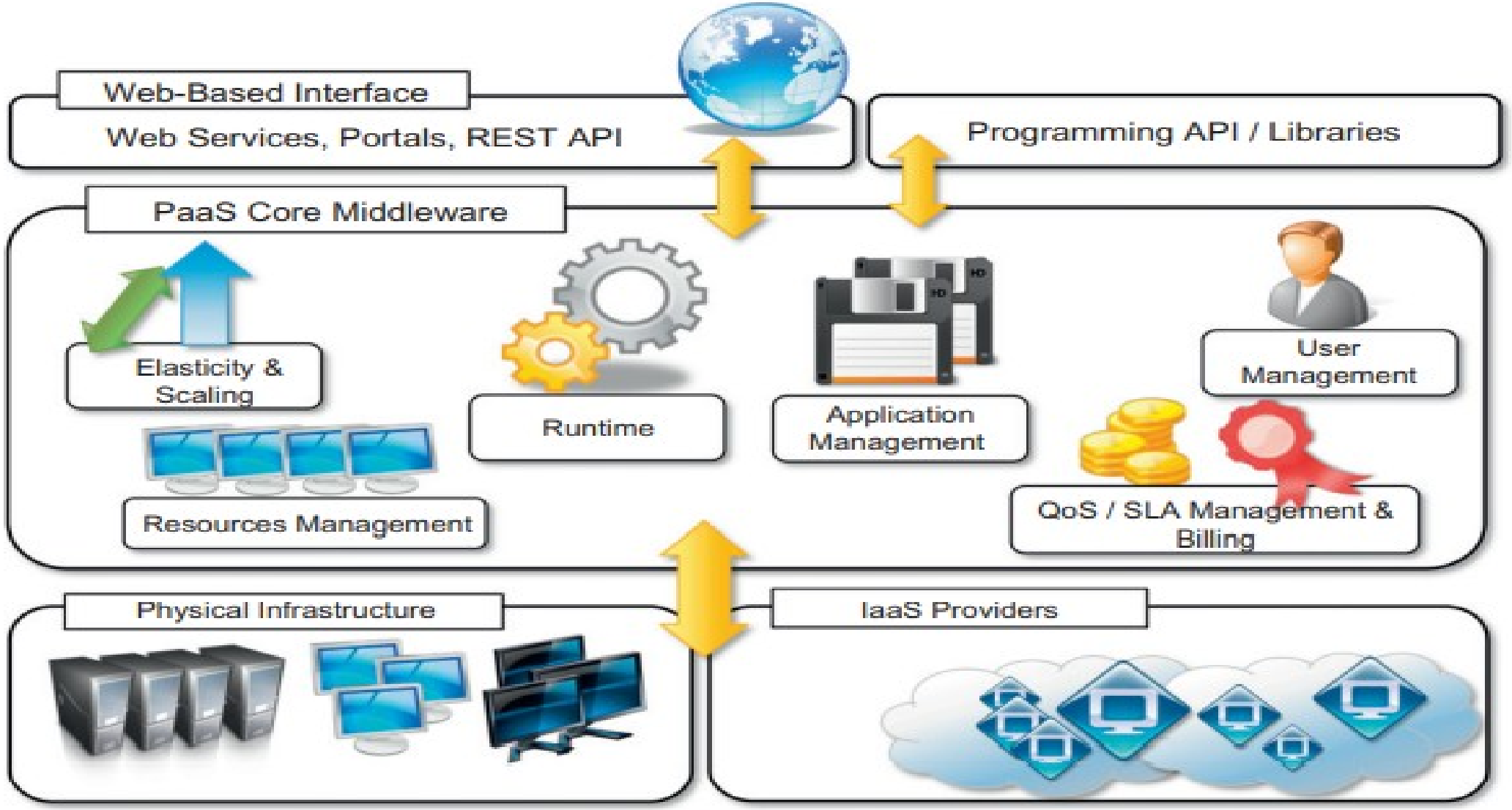


Table 4.2 Platform-as-a-Service Offering Classification

Category	Description	Product Type	Vendors and Products
PaaS-I	Runtime environment with Web-hosted application development platform. Rapid application prototyping.	Middleware + Infrastructure Middleware + Infrastructure	Force.com Longjump
PaaS-II	Runtime environment for scaling Web applications. The runtime could be enhanced by additional components that provide scaling capabilities.	Middleware + Infrastructure Middleware Middleware + Infrastructure Middleware + Infrastructure Middleware + Infrastructure Middleware	Google AppEngine AppScale Heroku Engine Yard Joyent Smart Platform GigaSpaces XAP
PaaS-III	Middleware and programming model for developing distributed applications in the cloud.	Middleware + Infrastructure Middleware Middleware Middleware Middleware Middleware	Microsoft Azure DataSynapse Cloud IQ Manjrasof Aneka Apprenda SaaSGrid GigaSpaces DataGrid

Essential characteristics of PaaS solution

- **Runtime framework**. The runtime framework executes end-user code according to the policies set by the user and the provider.
- **Abstraction**. PaaS solutions are distinguished by the higher level of abstraction that they provide.
- **Automation**. PaaS environments automate the process of deploying applications to the infrastructure, scaling them by provisioning additional resources when needed.
- **Cloud services**. PaaS offerings provide developers and architects with services and APIs, helping them to simplify the creation and delivery of elastic and highly available cloud applications.

Software as a service

- The application, or service, is deployed from a centralized datacenter across a network—Internet, Intranet, LAN, or VPN—providing access and use on a recurring fee basis.
- Users “rent,” “subscribe to,” “are assigned,” or “are granted access to”

- <u>Characteristics of SaaS:</u>

1. The product sold to customer is application access.
2. The application is centrally managed.
3. The service delivered is one-to-many.
4. The service delivered is an integrated solution delivered on the contract, which means provided as promised.

The benefits

- Software cost reduction and total cost of ownership (TCO) were paramount
- Service-level improvements
- Rapid implementation
- Standalone and configurable applications
- Rudimentary application and data integration
- Subscription and pay-as-you-go (PAYG) pricing

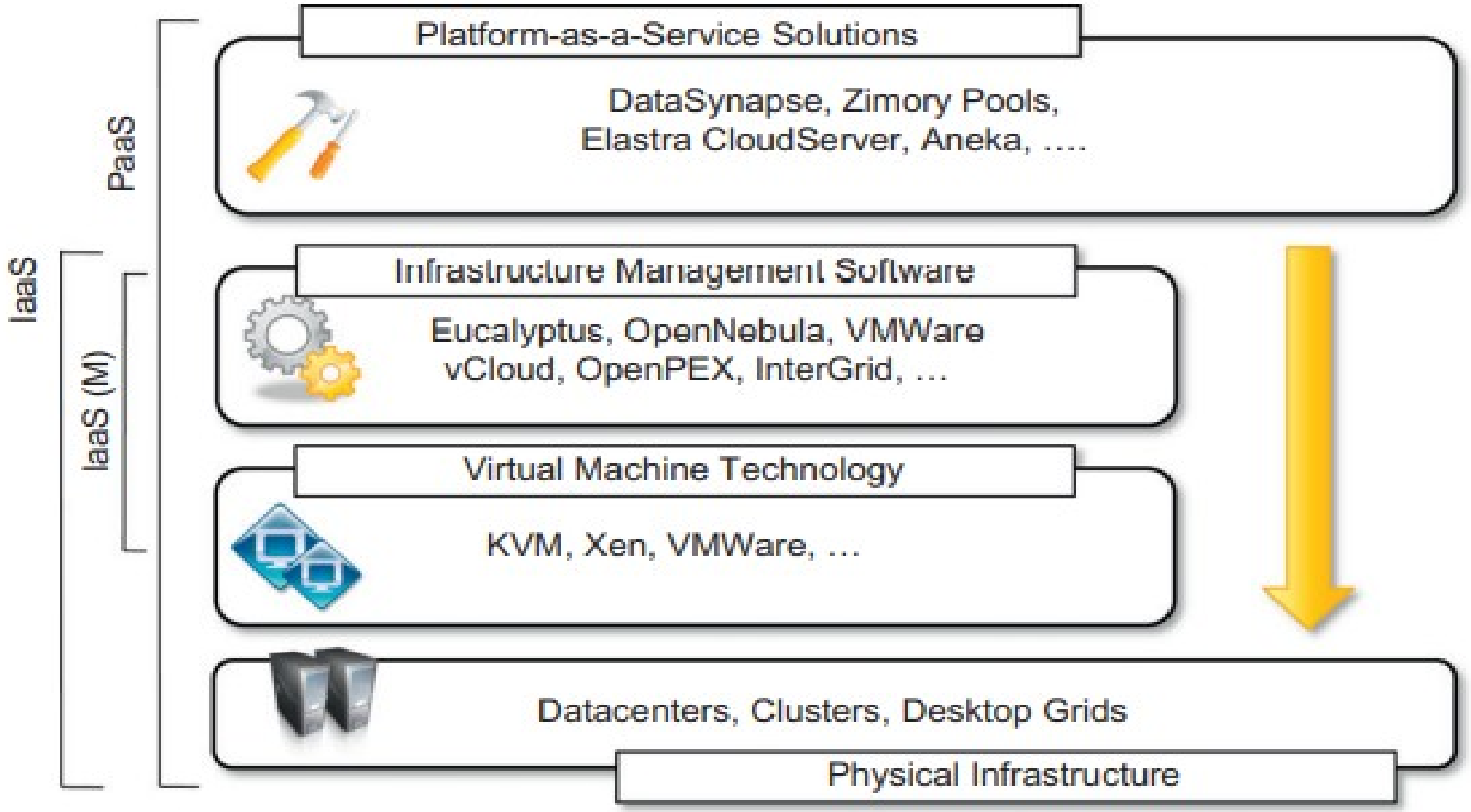
Types of clouds

- **Public clouds**. The cloud is open to the wider public.
- **Private clouds**. The cloud is implemented within the private premises of an institution and generally made accessible to the members of the institution or a subset of them.
- **Hybrid or heterogeneous clouds**. The cloud is a combination of the two previous solutions and most likely identifies a private cloud that has been augmented with resources or services hosted in a public cloud.
- **Community clouds**. The cloud is characterized by a multi-administrative domain involving different deployment models (public, private, and hybrid), and it is specifically designed to address the needs of a specific industry.

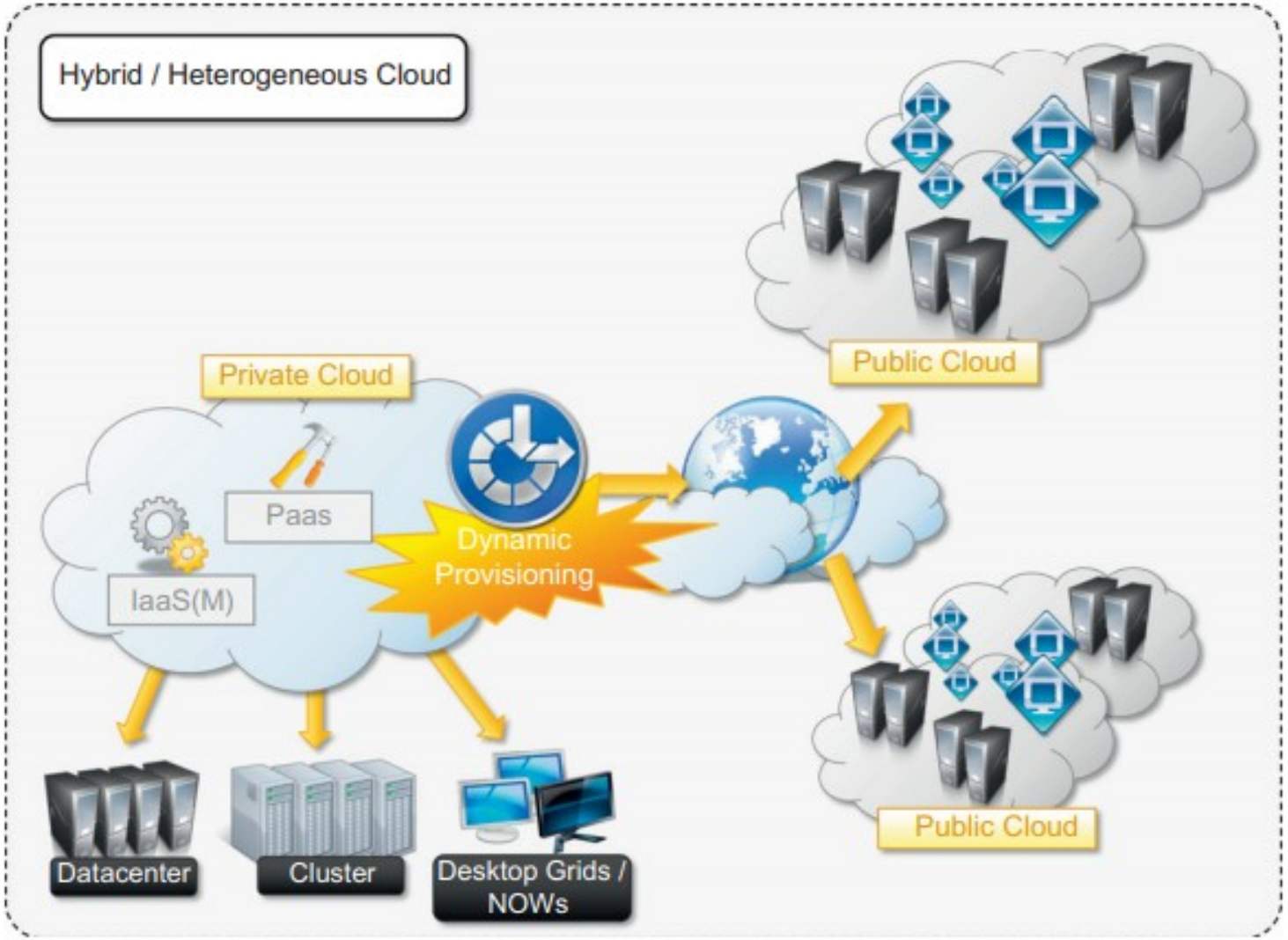
Public clouds

- A fundamental characteristic of public clouds is multitenancy.
- A public cloud is meant to serve a multitude of users, not a single customer.
- Any customer requires a virtual computing environment that is separated, and most likely isolated, from other users.
- This is a fundamental requirement to provide effective monitoring of user activities and guarantee the desired performance and the other QoS attributes negotiated with users.
- QoS management is a very important aspect of public clouds.

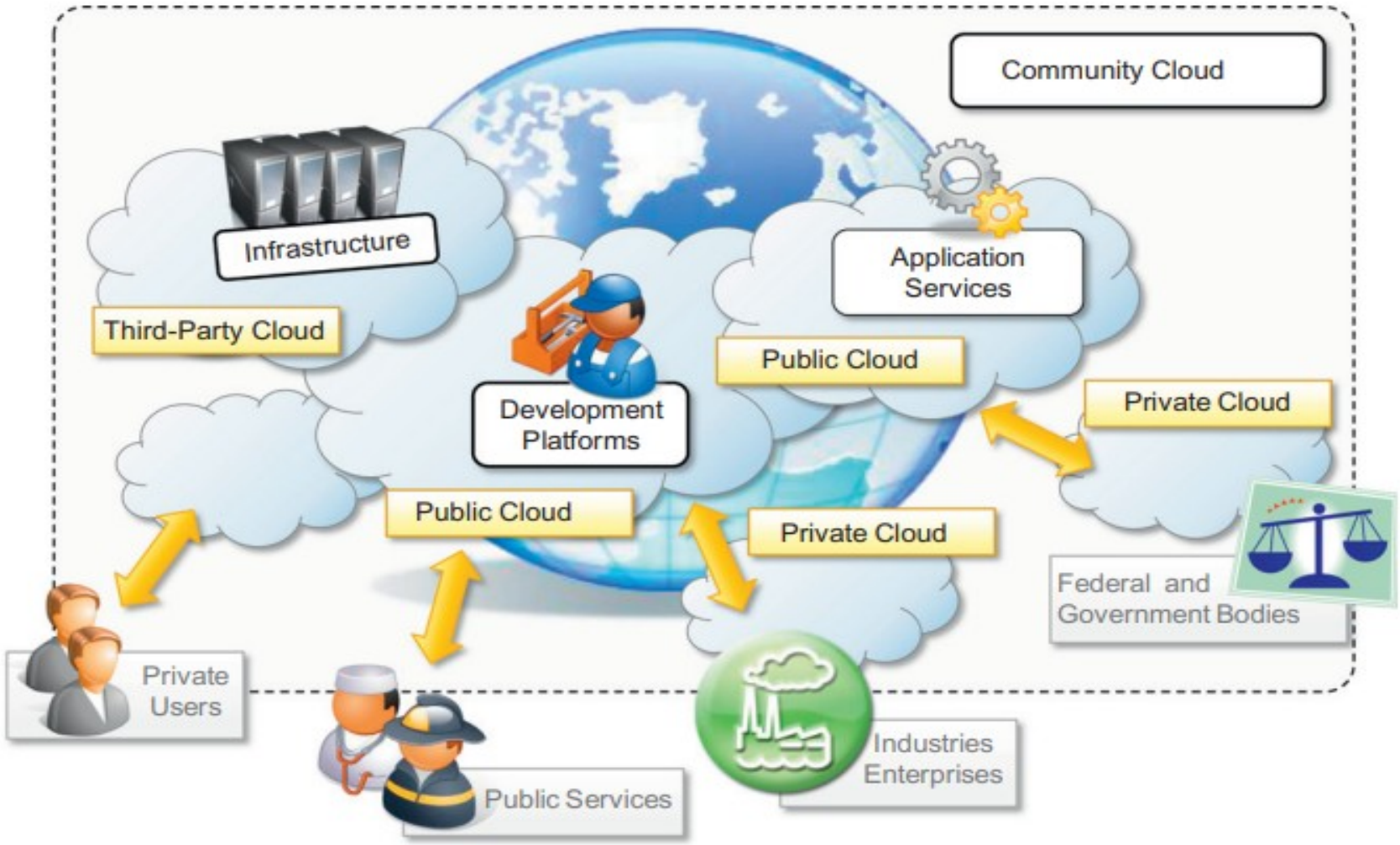
Private clouds



Hybrid clouds



Community clouds



Candidate sectors for community clouds are:

- Media industry
- Healthcare industry
- Energy and other core industries
- Public sector
- Scientific research

The benefits of these community clouds are

- Openness
- Community
- Convenience and control
- Environmental sustainability

Economics of the cloud

- The main drivers of cloud computing are
  - Economy of scale and
  - simplicity of software delivery and its operation.

The biggest benefit of this phenomenon is financial: the **pay-as-you-go** model offered by cloud providers

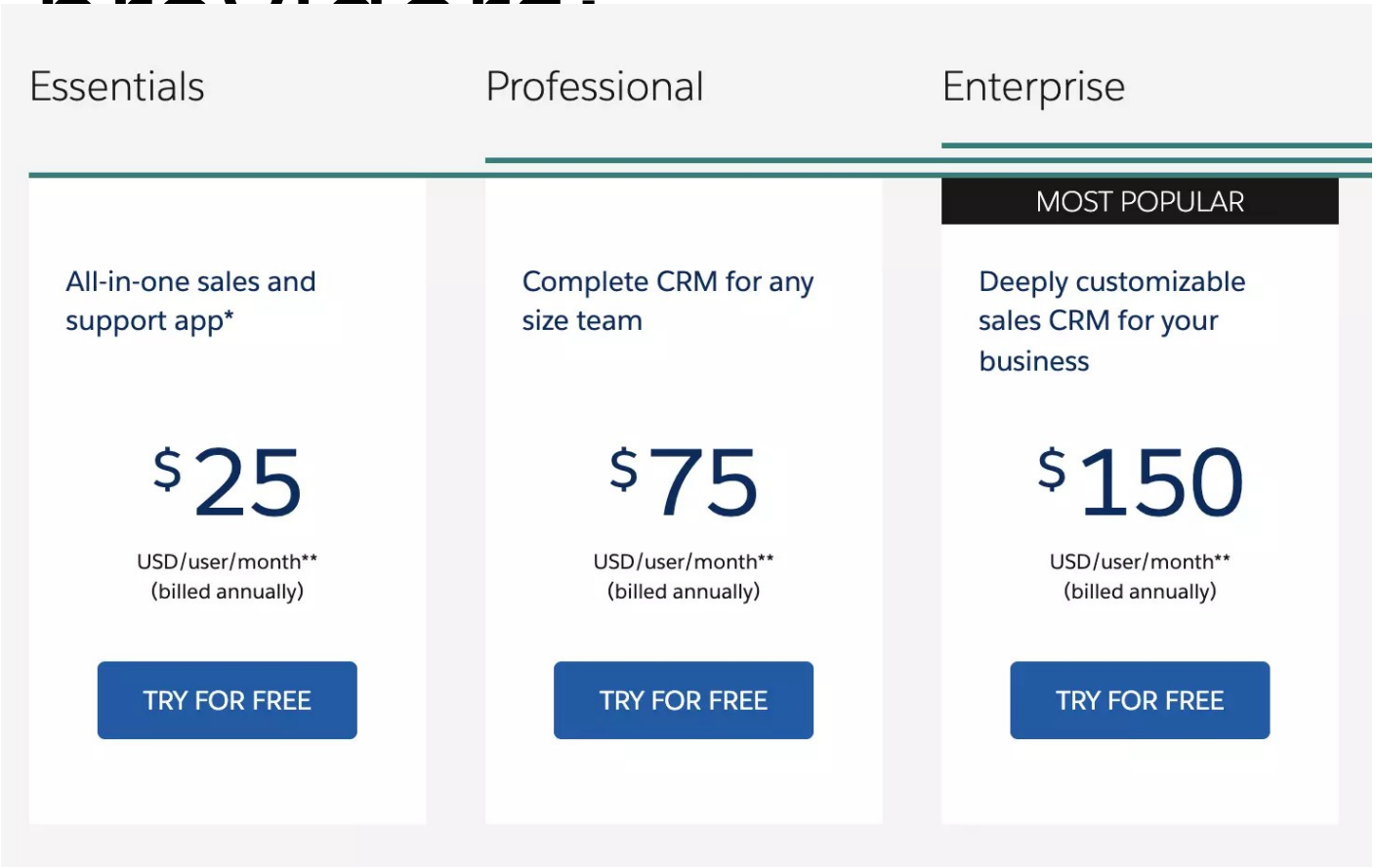
- Reducing the capital costs associated to the IT infrastructure
- Eliminating the depreciation or lifetime costs associated with IT capital assets
- Replacing software licensing with subscriptions
- Cutting the maintenance and administrative costs of IT resources

Cost Savings

- The amount of cost savings that cloud computing can introduce within an enterprise is related to the specific scenario in which cloud services are used and how they contribute to generate a profit for the enterprise.
- In the case of a small startup, it is possible to completely leverage the cloud for many aspects, such as:
  - ✓ IT infrastructure
  - ✓ Software development
  - ✓ CRM and ERP

Three different strategies that are adopted by the providers:

1. Tiered pricing
2. Per-unit pricing
3. Subscription-based pricing



5. OPEN CHALLENGES

1. Cloud definition
2. Cloud interoperability and standards
3. Scalability and fault tolerance
4. Security, trust, and privacy
5. Organizational aspects

1. Cloud definition

- NIST characterizes cloud computing as
  - on-demand self-service
  - broad network access
  - resource-pooling
  - rapid elasticity
  - measured service
- Classifies services as **SaaS, PaaS, and IaaS;**
- Categorizes deployment models as **public, private, community, and hybrid clouds.**
- The view is in line with our discussion and shared by many IT practitioners and academics.

What is Interoperability

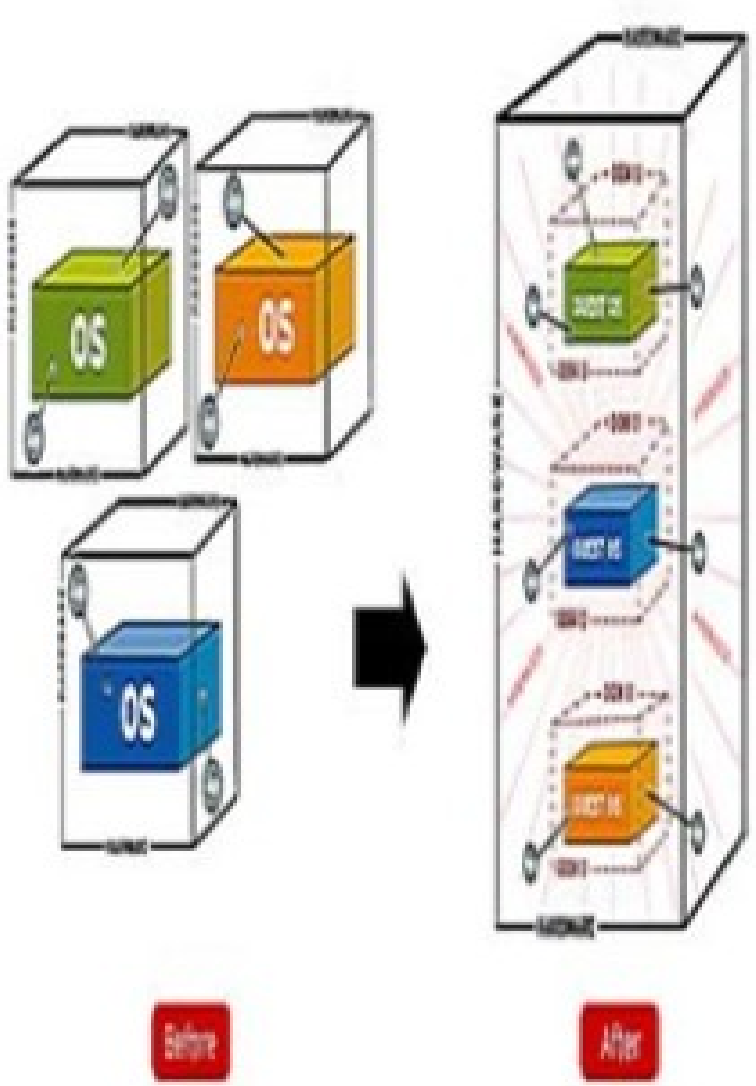
- Interoperability is an enabler for portability (at some level interoperability is portability)
  - Portability refers to the ability to port the layer above
  - Paas portability is needed when moving apps
- Interoperability refers to provisioning within the layer itself – Saas-to-Saas interoperability occurs between apps
- Why is interoperability different in a cloud ecosystem compared to normal software development?
- Motivations for interoperability:
  - 1. To increase customer choice, competition and innovation
  - 2. To allow more players in the market

Interoperability between Clouds?

- Ability to use the Cloud services provided by multiple vendors
- Ability to move data and code from one Cloud to another or back to the enterprise(portability)

Interoperability Challenges

- Distinct hypervisor and VM technologies
- Store and configure operating systems and applications differently
- Use various security standards and management interfaces



2. Cloud interoperability and standards

- The **Open Virtualization Format (OVF)** is an attempt to provide a common format for storing the information and metadata describing a virtual machine image.

- Even though the OVF provides a full specification for packaging and distributing virtual machine images in completely platform-independent fashion.

- The challenge is providing standards for supporting the migration of running instances

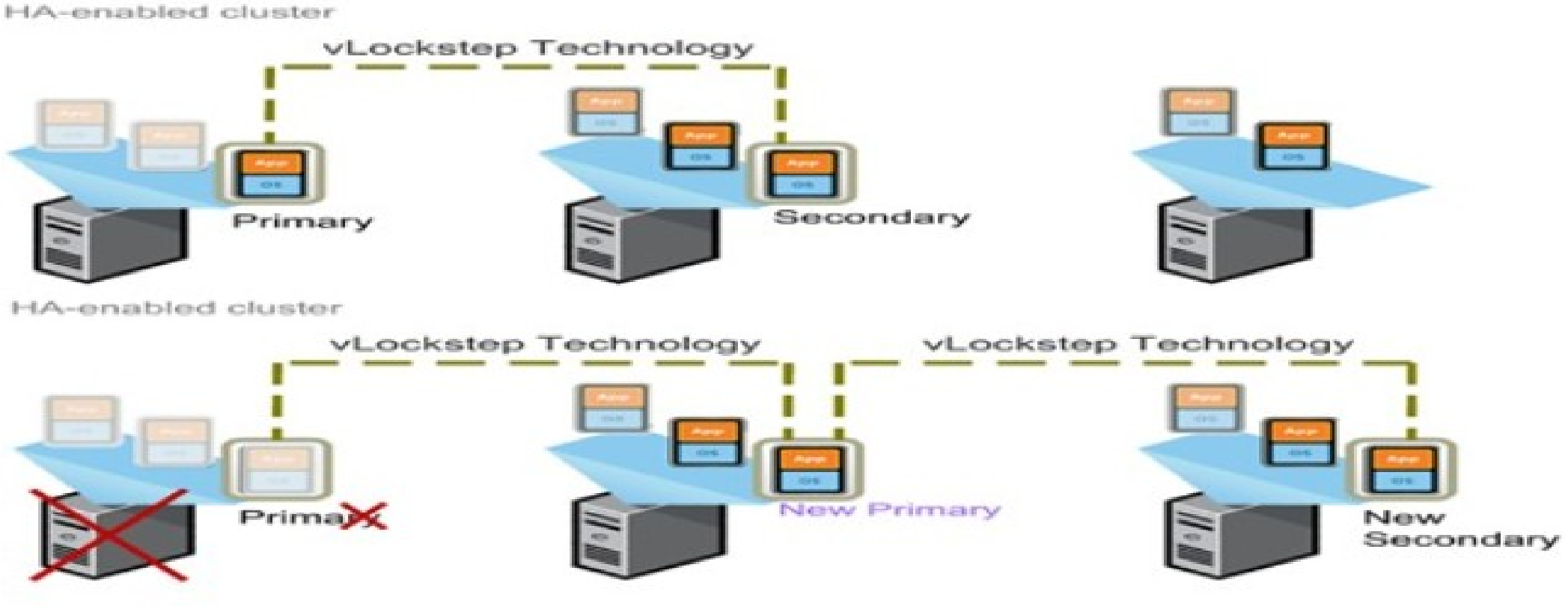
Organizations and standards

- **Cloud Computing Interoperability Forum** (CCIF),
- **Open Cloud Consortium**
- **Distributed Mgmt Force Task** (DMTF)
- **Cloud Standards Incubator**

- **Open Cloud Manifesto -** point of view of various stakeholders on the benefits of open standards in the field.
- The standardization efforts are mostly concerned with the lower level of the cloud computing architecture, which is the most popular and developed.

Scalability and Fault Tolerance

- **Fault tolerance** is the property that enables a system to continue operating properly in the event of the failure of (or one or more faults within) some of its components.



3.Scalability and fault tolerance

- The ability to scale on demand constitutes one of the most attractive features of cloud computing.
- Clouds allow scaling beyond the limits of the existing in-house IT resources, whether they are infrastructure (compute and storage) or applications services.
- To implement such capability, the cloud middleware has to be designed with the principle of scalability along different dimensions in mind—for example, performance, size, and load.
- The cloud middleware manages a huge number of resource and users, which rely on the cloud to obtain the horsepower that they cannot obtain within the premises without bearing considerable administrative and maintenance costs.

Scalability and fault tolerance

- These costs are a reality for whomever develops, manages, and maintains the cloud middleware and offers the service to customers.
- In this scenario, the ability to tolerate failure becomes fundamental, sometimes even more important than providing an extremely efficient and optimized system.
- Hence, the challenge in this case is designing **highly scalable and fault-tolerant systems that are easy to manage and at the same time provide competitive performance.**

4. Security, trust and privacy

- Security, trust and privacy issues are **major obstacles** for massive adoption of cloud computing.
- The **traditional cryptographic technologies** are used to prevent data tampering and access to sensitive information.
- The massive use of virtualization technologies **exposes the existing system** to new threats, which previously were not considered applicable.
- For example, it might be possible that **applications hosted in the cloud can process sensitive** information;

Security, trust and privacy - Solution

- Sensitive information can be stored within a cloud storage facility using the most **advanced technology in cryptography** to protect data
- Then be considered safe from any attempt to access it without the required permissions.
- Although these data are processed in memory, they must necessarily be **decrypted by the legitimate application**
- Since the application is hosted in a **managed virtual environment** it becomes accessible to the virtual machine manager that by program is designed to access the memory pages of such an application

5.Organizational aspects

- More precisely, storage, compute power, network infrastructure, and applications are delivered **as metered services** over the Internet.

- This introduces a **billing model** that is new within typical enterprise IT departments, which requires a certain level of cultural and organizational process maturity.

- In particular, a wide acceptance of cloud computing will require a significant **change to business processes and organizational boundaries**

Some interesting questions arise in IT department

- What is the new role of the IT department in an enterprise that completely or significantly relies on the cloud?

- How will the compliance department perform its activity when there is a considerable lack of control over application workflows?

- What are the implications (political, legal, etc.) for organizations that lose control over some aspects of their services?

- What will be the perception of the end users of such services?

Advantages

- One of the major advantages of moving IT infrastructure and services to the cloud is to reduce or completely remove the **costs related to maintenance and support.**
- As a result, users of such infrastructure and services lose a reference to deal with for IT **troubleshooting**.
- At the same time, the existing IT staff is required to have a different kind of competency and, in general, fewer skills, thus reducing their value.
- These are the challenges from an organizational point of view that must be faced and that will significantly change the relationships within the enterprise itself among the various groups of people working together.