CHAPTER 4-CLOUD COMPUTING ARCHITECTURE

4.1 INTRODUCTION

- Utility-oriented data centers are the first outcome of cloud computing, and they 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.
- 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.
- *Cloud computing is a utility-oriented and Internet-centric way of delivering IT services on demand. These services cover the entire computing stack: from the hardware infrastructure packaged as a set of virtual machines to software services such as development platforms and distributed applications.*

4.2 The cloud reference model

Cloud computing supports any IT service that can be consumed as a utility and delivered through a network, most likely the Internet. Such characterization includes quite different aspects: infrastructure, development platforms, application and services.

4.2.1 Architecture

It is possible to organize all the concrete realizations of cloud computing into a layered view covering the entire stack (figure next slide), from hardware appliances to software systems.

* This layer is implemented using a datacenter in which hundreds and thousands of nodes are stacked together.

* Cloud infrastructure can be heterogeneous in nature because a variety of resources.

* Database systems and other storage services can also be part of the infrastructure.

4.2 The cloud reference model

Cloud Computing Architecture

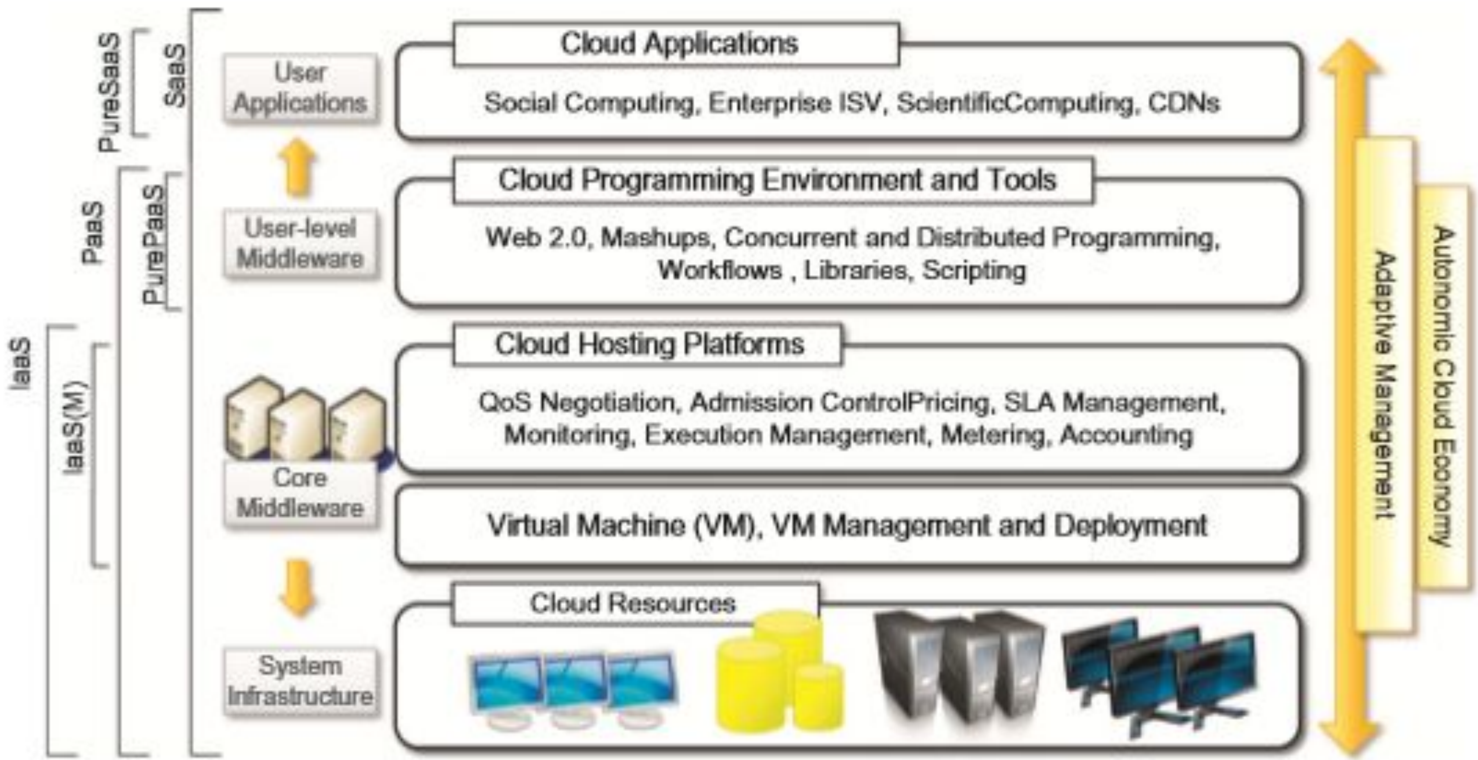

FIGURE 4.1

The cloud computing architecture.

4.2 The cloud reference model

* The physical infrastructure is managed by the core middleware, the objectives of which are to provide an appropriate runtime environment for applications and to best utilize resources.

* At the bottom of the stack, virtualization technologies are used to guarantee runtime environment customization, application isolation, sandboxing, and quality of service.

* Hardware virtualization is most commonly used at this level. Hypervisors manage the pool of resources and expose the distributed infrastructure as a collection of virtual machines.

* By using virtual machine technology it is possible to finely partition the hardware resources such as CPU and memory and to virtualize specific devices, thus meeting the requirements of users and applications.

4.2 The cloud reference model

* Programming-level virtualization helps in creating a portable runtime environment where applications can be run and controlled.

* This scenario generally implies that applications hosted in the cloud be developed with a specific technology or a programming language, such as Java, .NET, or Python.

* Infrastructure management is the key function of core middleware, which supports capabilities such as

1. negotiation of the quality of service,
2. admission control,
3. execution management and
4. monitoring, accounting, and
5. billing.

4.2 The cloud reference model

- The combination of cloud hosting platforms and resources is generally classified as a Infrastructure-as-a-Service (IaaS) solution.
- We can organize the different examples of IaaS into two categories:

  * Some of them provide both the management layer and the physical infrastructure;

  * Others provide only the management layer (IaaS (M)). In this second case, the management layer is often integrated with other IaaS solutions that provide physical infrastructure and adds value to them.

- IaaS solutions are suitable for designing the system infrastructure but provide limited services to build applications.
- PaaS- Users develop their applications specifically for the cloud by using the API exposed at the user-level middleware.
- This approach is also known as Platform-as-a-Service (PaaS) because the service offered to the user is a development platform rather than an infrastructure

4.2 The cloud reference model

* PaaS solutions generally include the infrastructure as well, which is bundled as part of the service provided to users.

* In the case of Pure PaaS, only the user-level middleware is offered, and it has to be complemented with a virtual or physical infrastructure.

- SaaS- Web-based applications that rely on the cloud to provide service to end users.

  * The horsepower of the cloud provided by IaaS and PaaS solutions allows independent software vendors to deliver their application services over the Internet.

* SaaS implementations should feature adaptively change and expose an autonomic behavior automatically, whereas PaaS and IaaS generally provide this functionality as a part of the API exposed to users.

4.2 The cloud reference model

- Everything as a Service (XaaS) is one of the most important elements of cloud computing:

  * Cloud services from different providers can be combined to provide a completely integrated solution covering all the computing stack of a system.

  * IaaS providers can offer the bare metal in terms of virtual machines where PaaS solutions are deployed.

- When there is no need for a PaaS layer, it is possible to directly customize the virtual infrastructure with the software stack needed to run applications.
- Cloud computing an interesting option for reducing startups' capital investment in IT, allowing them to quickly commercialize their ideas and grow their infrastructure according to their revenues.

4.2 The cloud reference model

- <u>Cloud Computing Services Classification:</u>

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

4.2.2 Infrastructure- and hardware-as-a-service

- Infrastructure- and Hardware-as-a-Service (IaaS/HaaS) solutions are the most popular and developed market segment of cloud computing.
- They deliver customizable infrastructure on demand. IaaS offering range from single servers to entire infrastructures, including network devices, load balancers, and database and Web servers.
- The main technology used to deliver and implement these solutions is hardware virtualization: one or more virtual machines opportunely configured and interconnected define the distributed system on top of which applications are installed and deployed
- IaaS/HaaS solutions bring all the benefits of hardware virtualization:

  workload partitioning,

  application isolation,

  sandboxing, and

  hardware tuning.

4.2.2 Infrastructure- and hardware-as-a-service

- From the perspective of the customer it reduces the administration and maintenance cost as well as the capital costs allocated to purchase hardware.
- At the same time, users can take advantage of the full customization offered by virtualization to deploy their infrastructure in the cloud.
- Virtual machines come with only the selected operating system installed and the system can be configured with all the required packages and applications.
- Other solutions provide prepackaged system images that already contain the software stack required for the most common uses: Web servers, database servers, or LAMP stacks.
- Additional services can be provided: SLA resource-based allocation, workload management, support for infrastructure design through advanced Web interfaces, and the ability to integrate third-party IaaS solutions.

4.2.2 Infrastructure- and hardware-as-a-service

- Figure provides an overall view of the components forming an Infrastructure-

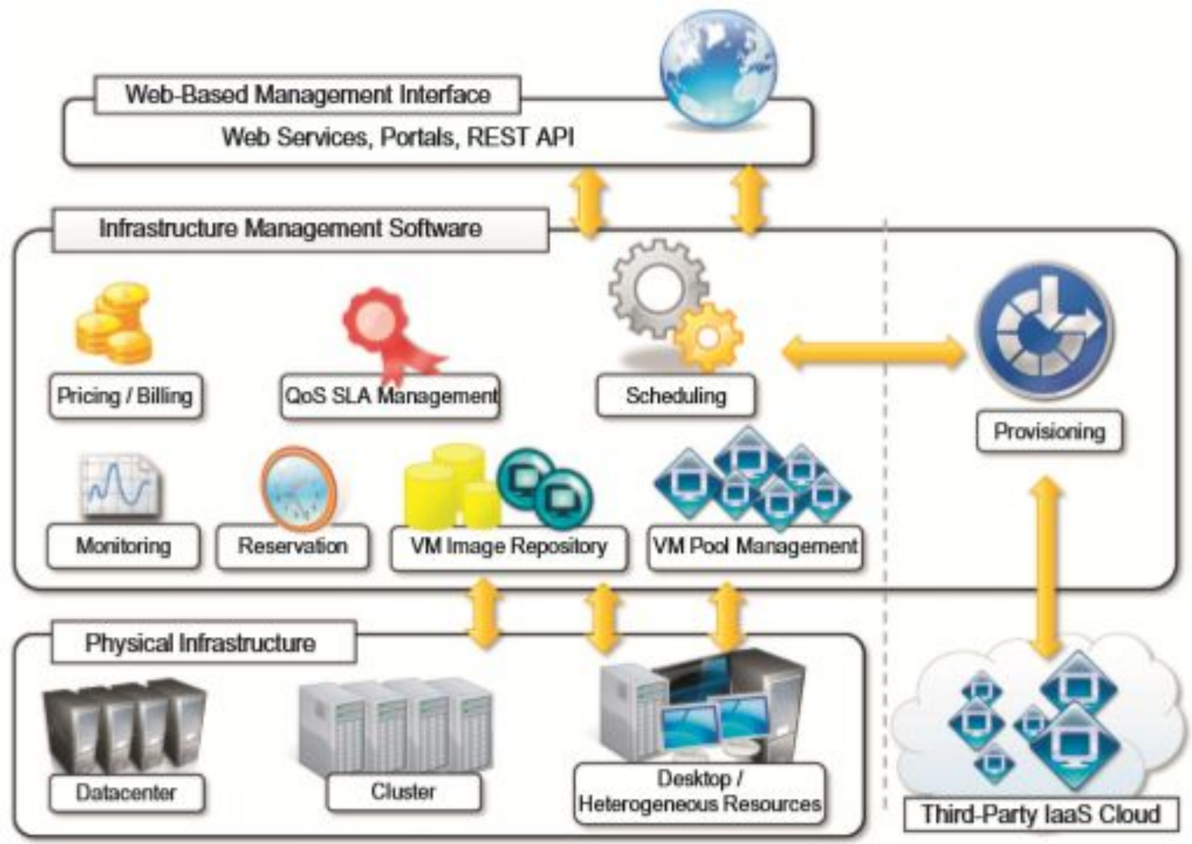

FIGURE 4.2

Infrastructure-as-a-Service reference implementation.

4.2.2 Infrastructure- and hardware-as-a-service

- It is possible to distinguish three principal layers:

  ->the physical infrastructure,

  ->the software management infrastructure, and

  ->the user interface.

1. User interface : It provides access to the services exposed by the software management infrastructure.

- Such an interface is generally based on Web 2.0 technologies: Web services, RESTful APIs, and mash-ups. These technologies allow either applications or final users to access the services.
- Web services and RESTful APIs allow programs to interact with the service without human intervention

4.2.2 Infrastructure- and hardware-as-a-service

2. Infrastructure management software layer.

The core features of an IaaS solution are implemented in the infrastructure management software layer.

- In particular, management of the virtual machines is the most important function performed by this layer. A central role is played by the scheduler, which is in charge of allocating the execution of virtual machine instances.
- The scheduler interacts with the other components that perform a variety of tasks:
- The pricing and billing component takes care of the cost of executing each virtual machine instance and maintains data that will be used to charge the user.
- 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 that have been executed or that will be executed in the future.

4.2.2 Infrastructure- and hardware-as-a-service

- A QoS/SLA management component will maintain a repository of all the SLAs made with the users; together with the monitoring component.
- The VM repository component provides a catalog of virtual machine images that users can use to create virtual instances.
- A VM pool manager component is responsible for keeping track of all the live instances.
- 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.

3. Physical infrastructure: The bottom layer is composed of the physical infrastructure, on top of which the management layer operates

A cloud infrastructure developed in house, in a small or medium-sized enterprise or within a university department, will most likely rely on a cluster

4.2.2 Infrastructure- and hardware-as-a-service

- It is also possible to consider a heterogeneous environment where different types of resources—PCs, workstations, and clusters—can be aggregated.
- In the case of complete IaaS solutions, all three levels are offered as service.
- This is generally the case with public clouds vendors such as Amazon, GoGrid, Joyent, Rightscale, Terremark, Rackspace, ElasticHosts, and Flexiscale, which own large datacenters and give access to their computing infrastructures using an IaaS approach.
- Other solutions instead cover only the user interface and the infrastructure software management layers.
- They need to provide credentials to access third-party IaaS providers or to own a private infrastructure in which the management software is installed. This is the case with Enomaly, Elastra, Eucalyptus, OpenNebula, and specific IaaS (M) solutions from VMware, IBM, and Microsoft.

4.2.3 Platform as a service

- Platform-as-a-Service (PaaS) solutions provide a development and deployment platform for running applications in the cloud.
- They constitute the middleware on top of which applications are built. A general overview of the features characterizing the PaaS approach is given in Figure 4.3.

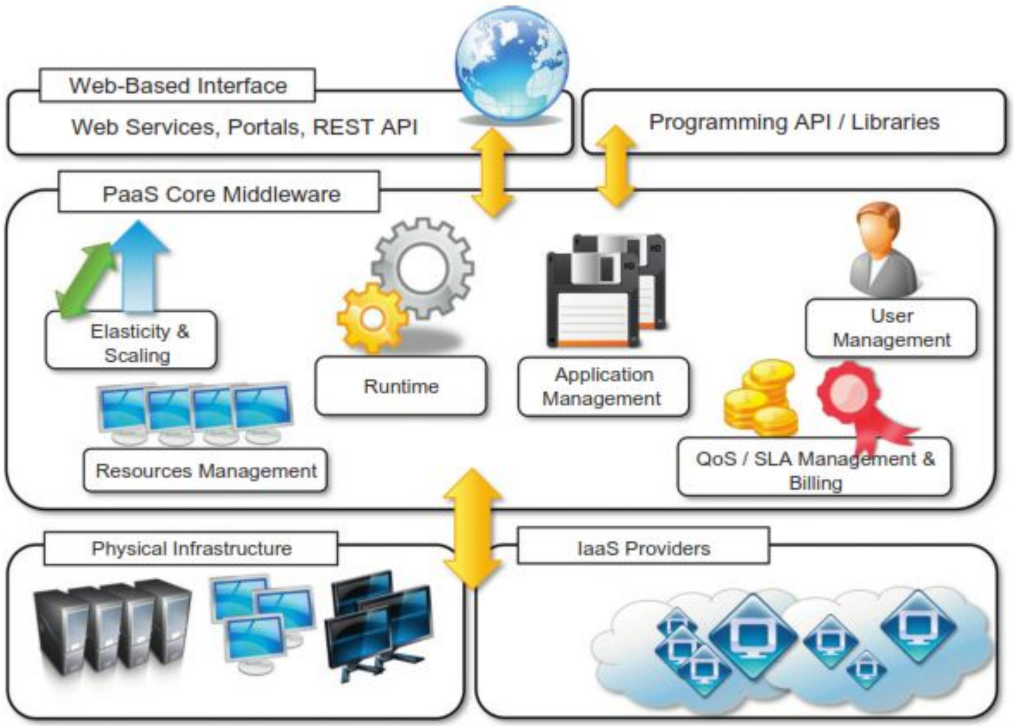

FIGURE 4.3

4.2.3 Platform as a service

- Application management is the core functionality of the middleware.
- PaaS implementations provide applications with a runtime environment and do not expose any service for managing the underlying infrastructure.
- They automate the process of deploying applications to the infrastructure, configuring application components, provisioning and configuring supporting technologies such as load balancers and databases, and managing system change based on policies set by the user.
- Developers design their systems in terms of applications and are not concerned with hardware (physical or virtual), operating systems, and other low-level services
- The core middleware is in charge of managing the resources and scaling applications on demand or automatically, according to the commitments made with users.\
- The specific development model decided for applications determines the interface exposed to the user.
- Other implementations of the PaaS model provide a complete object model for representing an application and provide a programming language-based approach.

4.2.3 Platform as a service

- Developers generally have the full power of programming languages such as Java, .NET, Python, or Ruby, with some restrictions to provide better scalability and security.
- PaaS solutions can offer middleware for developing applications together with the infrastructure or simply provide users with the software that is installed on the user premises.

- In the first case, the PaaS provider also owns large datacenters where applications are executed; in the second case, referred to in this book as Pure PaaS.

4.2.3 Platform as a service

- Table 4.2 provides a classification of the most popular PaaS implementations. It is possible to organize the various solutions into three wide categories: PaaS-I, PaaS-II, and PaaS-III.

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 1 Infrastructure Middleware 1 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 1 Infrastructure Middleware Middleware 1 Infrastructure Middleware 1 Infrastructure Middleware 1 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 1 Infrastructure Middleware Middleware Middleware Middleware Middleware	Microsoft Azure DataSynapse Cloud IQ Manjrasof Aneka Apprenda SaaSGrid GigaSpaces DataGrid

4.2.3 Platform as a service

- PaaS-I: The first category(PaaS-I) identifies PaaS implementations that completely follow the cloud computing style for application development and deployment.
- They offer an integrated development environment hosted within the Web browser where applications are designed, developed, composed, and deployed.
- Ex: Force.com and Longjump. Both deliver as platforms the combination of middleware and infrastructure.
- PaaS-II: we can list all those solutions that are focused on providing a scalable infrastructure for Web application, mostly websites.
- In this case, developers generally use the providers' APIs, which are built on top of industrial runtimes, to develop applications

- ex: Google AppEngine is the most popular product in this category
  - It provides a scalable runtime based on the Java and Python programming languages

.Joyent Smart Platform provides a similar approach to Google AppEngine. A different approach is taken by Heroku and Engine Yard, which provide scalability support for Ruby- and Ruby on Rails-based Websites

4.2.3 Platform as a service

- PaaS-III: The third category consists of all those solutions that provide a cloud programming platform for any kind of application, not only Web applications.
- Among these, the most popular is Microsoft Windows Azure, which provides a comprehensive framework for building service-oriented cloud applications on top of the .NET technology, hosted on Microsoft's datacenters.
- Other solutions in the same category, such as Manjrasoft Aneka, Apprenda SaaSGrid, Appistry Cloud IQ Platform, DataSynapse, and GigaSpaces DataGrid, provide only middleware with different services.

Essential characteristics that identify a PaaS solution:

- Runtime framework: This framework represents the "software stack" of the PaaS model.
- The runtime framework executes end-user code according to the policies set by the user and the provider.

4.2.3 Platform as a service

Essential characteristics that identify a PaaS solution(contd)

- Abstraction: PaaS solutions are distinguished by the higher level of abstraction that they provide.

  *In the case of IaaS solutions the focus is on delivering "raw" access to virtual or physical infrastructure, in the case of PaaS the focus is on the applications the cloud must support.

  *This means that PaaS solutions offer a way to deploy and manage applications on the cloud rather than a bunch of virtual machines on top of which the IT infrastructure is built and configured.

- Automation: PaaS environments automate the process of deploying applications to the infrastructure, scaling them by provisioning additional resources when needed.

  *This process is performed automatically and according to the SLA made between the customers and the provider.

  *This feature is normally not native in IaaS solutions, which only provide ways to provision more resources.

4.2.3 Platform as a service

Essential characteristics that identify a PaaS solution(contd)

- 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.
- Generally include specific components for developing applications, advanced services for application monitoring, management, and reporting.
- Another essential component for a PaaS-based approach is the ability to integrate third-party cloud services offered from other vendors by leveraging service-oriented architecture.

4.2.4 Software as a service

- Software-as-a-Service (SaaS) is a software delivery model that provides access to applications through the Internet as a Web-based service.
- It provides a means to free users from complex hardware and software management by offloading such tasks to third parties, which build applications accessible to multiple users through a Web browser.
- This requirement characterizes SaaS as a “one-to-many” software delivery model, whereby an application is shared across multiple users.
- This is the case of CRM3 and ERP4 applications that constitute common needs for almost all enterprises, from small to medium-sized and large business.

•The acronym SaaS was then coined in 2001 by the Software Information & Industry Association (SIIA) [32] with the following connotation:

In the software as a service model, 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” the applications from a central provider.

4.2.4 Software as a service

- The analysis carried out by SIIA was mainly oriented to cover application service providers (ASPs) and all their variations, which capture the concept of software applications consumed as a service in a broader sense. ASPs already had some of the core characteristics of SaaS:
- The product sold to customer is application access.
- The application is centrally managed.
- The service delivered is one-to-many.
- The service delivered is an integrated solution delivered on the contract, which means provided as promised.
- These opportunities eventually evolved into a more flexible model to deliver applications as a service: the SaaS model.
- ASPs provided access to packaged software solutions that addressed the needs of a variety of customers. Later became inconvenient when the cost of customizations and speciali-zations increased.

4.2.4 Software as a service

•The SaaS approach introduces a more flexible way of delivering application services that are fully customizable by the user by integrating new services, injecting their own components, and designing the application and information workflows.

•Possible with the support of Web 2.0 technologies, which allowed turning the Web browser into a full-featured interface, able even to support application composition and development.

•the SaaS approach lays on top of the cloud computing stack. It fits into the cloud computing vision expressed by the XaaS acronym, Everything-as-a-Service; and with SaaS, applications are delivered as a service. The benefits delivered at that stage were the following:

* 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

4.2.4 Software as a service

- In particular, SaaS 2.0 is focused on providing a more robust infrastructure and application plat-forms driven by SLAs.

- Software-as-a-Service applications can serve different needs. CRM, ERP, and social networking applications are definitely the most popular ones. SalesForce.com is probably the most successful and popular example of a CRM service.

- It provides a wide range of services for applications: customer relationship and human resource management, enterprise resource planning, and many other features.

- SalesForce.com builds on top of the Force.com platform, which provides a fully featured environment for building applications. It offers either a programming language or a visual environment to arrange components together for building applications.

- In particular, through AppExchange customers can publish, search, and integrate new services and features into their existing applications.

4.2.4 Software as a service

•Similar solutions are offered by NetSuite and RightNow.

*NetSuite is an integrated software business suite featuring financials, CRM, inventory, and ecommerce functionalities integrated all together.

*RightNow is customer experience-centered SaaS application that integrates together different features, from chat to Web communities, to support the common activity of an enterprise.

•Another important class of popular SaaS applications comprises social networking applications such as Facebook and professional networking sites such as LinkedIn.

•Office automation applications are also an important representative for SaaS applications: Google Documents and Zoho Office are examples of Web-based applications that aim to address all user needs for documents, spreadsheets, and presentation management

• They offer a Web-based interface for creating, managing, and modifying documents that can be easily shared among users and made accessible from anywhere.

4.3 Types of clouds

- Clouds constitute the primary outcome of cloud computing. They are a type of parallel and distributed system harnessing physical and virtual computers presented as a unified computing resource.

- It is then possible to differentiate four different types of cloud:

- 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.

4.3 Types of clouds

4.3.1 Public clouds

- Public clouds constitute the first expression of cloud computing. They are a realization of the canonical view of cloud computing in which the services offered are made available to anyone, from anywhere, and at any time through the Internet.
- They are a distributed system, most likely composed of one or more datacenters connected together.
- Public clouds were the first class of cloud that were implemented and offered.
- They offer solutions for minimizing IT infrastructure costs and serve as a viable option for handling peak loads on the local infrastructure.
- Interesting option for small enterprises, which are able to start their businesses without large up-front investments .
- 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

4.3 Types of clouds

4.3.1 Public clouds(contd)

•QoS management is a very important aspect of public clouds. A significant portion of the software infrastructure is devoted to monitoring the cloud resources, to bill them according to the contract made with the user, and to keep a complete history of cloud usage for each customer.

•A public cloud can offer any kind of service: infrastructure, platform, or applications. For example,

* *Amazon EC2* is a public cloud that provides infrastructure as a service;

* *Google AppEngine* is a public cloud that provides an application development platform as a service; and

* *SalesForce.com* is a public cloud that provides software as a service.

•Public clouds can be geographically dispersed datacenters.

•For example, Amazon Web Services has datacenters installed in the United States, Europe, Singapore, and Australia; they allow their customers to choose between three different regions: us-west-1, us-east-1, or eu-west-1

4.3 Types of clouds

4.3.2 Private clouds

- Public clouds are a viable option to cut IT costs and reduce capital expenses, but they are not applicable in all scenarios.
- Institutions such as government and military agencies will not consider public clouds as an option for processing or storing their sensitive data. The risk of a breach in the security infrastructure of the provider could expose such information to others;
- According to the specific location of data, some sensitive information can be made accessible to government agencies or even considered outside the law if processed with specific cryptographic techniques.
- For example, the USA PATRIOT Act5 provides its government and other agencies with virtually limitless powers to access information
- Private clouds are virtual distributed systems that rely on a private infrastructure
- Private clouds have the advantage of keeping the core business operations in-house by relying on the existing IT infrastructure and reducing the burden of maintaining it once the cloud has been set up.

4.3 Types of clouds

4.3.2 Private clouds(contd)

- In private clouds there is the possibility of testing applications and systems at a comparatively lower price rather than public clouds.
- Key advantages of using a private cloud computing infrastructure:

  * *Customer information protection.* Few provide satisfactory disclosure and few provide warranties about the specific level of security put in place on their systems.

  ->In-house security is easier to maintain and rely on.

  ** Infrastructure ensuring SLAs.* Quality of service implies specific operations such as appropriate clustering and failover

  data replication,

  system monitoring and maintenance,

  disaster recovery, and other uptime services can be commensurate to the application needs.

  ->Although public cloud vendors provide some of these features, not all of them are available as n

4.3 Types of clouds

4.3.2 Private clouds(contd)

* Compliance with standard procedures and operations- If organizations are subject to third-party compliance standards, specific procedures have to be put in place when deploying and executing applications.

-> This could be not possible in the case of the virtual public infrastructure.

- Private clouds can be implemented on more heterogeneous hardware: They generally rely on the existing IT infrastructure already deployed on the private premises.
- This could be a datacenter, a cluster, an enterprise desktop grid, or a combination of them.
- Figure(next slide) explanation: At the bottom layer of the software stack, virtual machine technologies such as Xen, KVM, and VMware serve as the foundations of the cloud.
- Virtual machine management technologies such as VMware vCloud, Eucalyptus [37], and OpenNebula can be used to control the virtual infrastructure and provide an IaaS solution.

4.3.2 Private clouds(contd)

- VMware vCloud is a proprietary solution, but Eucalyptus provides full compatibility with Amazon Web Services interfaces and supports VM technologies Xen, KVM, and VMware.
- Like Eucalyptus, OpenNebula is an open-source solution for virtual infrastructure management that supports KVM, Xen, and VMware, which has been designed to easily integrate third-party IaaS providers.

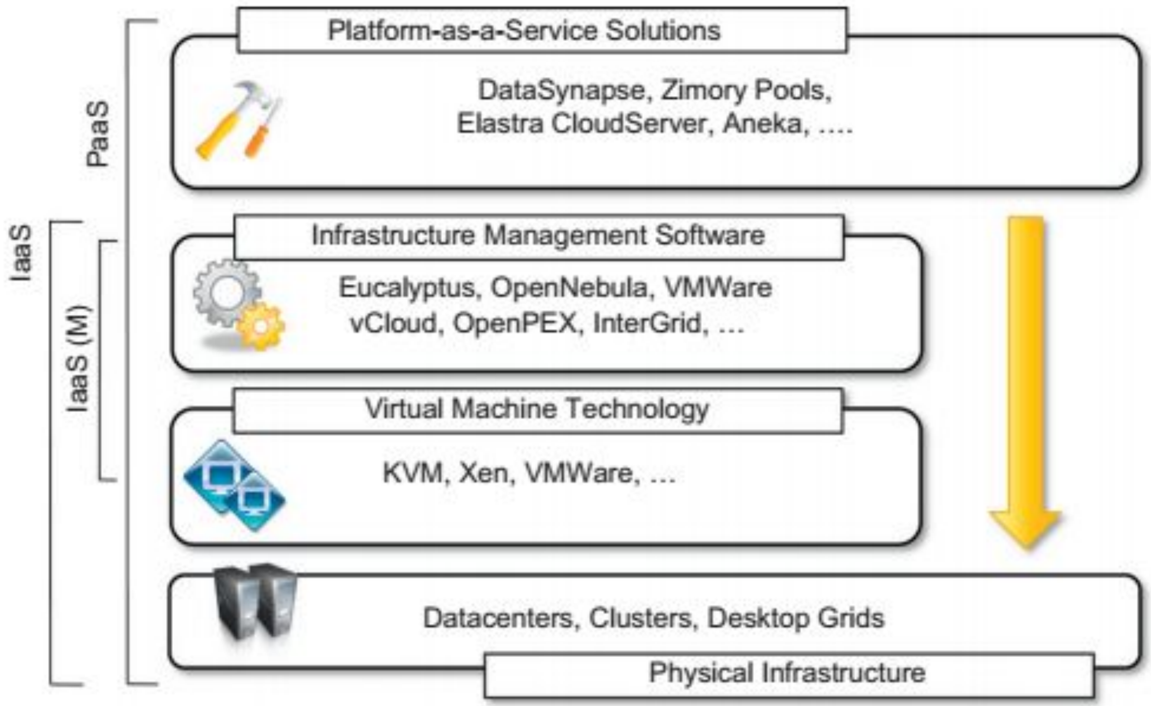

FIGURE 4.4

4.3.2 Private clouds(contd)

- OpenPEX is Web-based system that allows the reservation of virtual machine instances and is designed to support different back ends.
- InterGrid also allowing the reservation of virtual machine instances and managing multi-administrative domain clouds.
- DataSynapse is a global provider of application virtualization software. It provides a flexible environment for building private clouds on top of datacenters.
- Elastra Cloud Server is a platform for easily configuring and deploying distributed application infrastructures on clouds.
- Zimory provides a software infrastructure layer that automates the use of resource pools based on Xen, KVM, and VMware virtualization technologies.
- Aneka is a software development platform that can be used to deploy a cloud infrastructure on top of heterogeneous hardware: datacenters, clusters, and desktop grids.
- It supports the execution of distributed applications with different programming models:

  bag of tasks, MapReduce, and others.

4.3.3 Hybrid clouds

- Public clouds - suffer from security threats and administrative pitfalls.
- Private clouds - inability to scale on demand and to efficiently address peak loads.
- A hybrid solution -taking advantage of the best of the private and public worlds

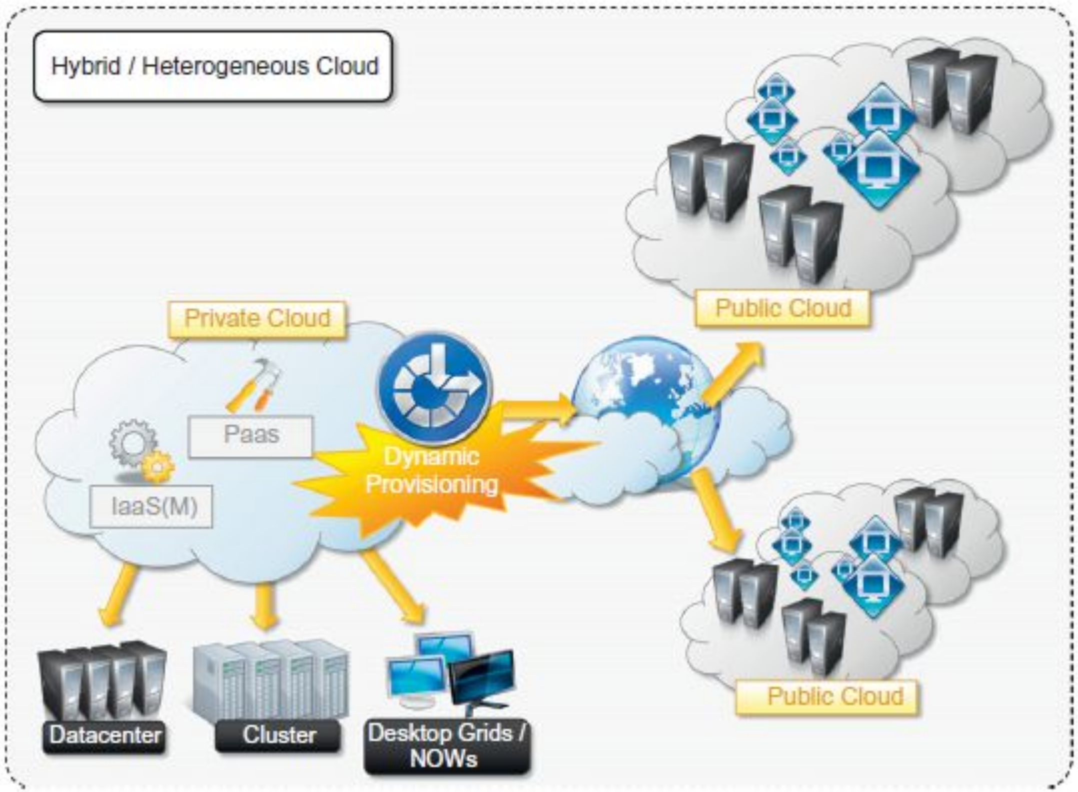

FIGURE 4.5

Hybrid/heterogeneous cloud overview.

4.3.3 Hybrid clouds(contd)

- Public clouds - suffer from security threats and administrative pitfalls.
- Private clouds - inability to scale on demand and to efficiently address peak loads.
- A hybrid solution -taking advantage of the best of the private and public worlds.
- Hybrid clouds allow enterprises to exploit existing IT infrastructures, maintain sensitive information within the premises, and naturally grow and shrink by provisioning external resources and releasing them when they're no longer needed.
- It is a heterogeneous distributed system resulting from a private cloud that integrates additional services or resources from one or more public clouds. So they are also called Heterogeneous Clouds

4.3.4 Community clouds

- Community clouds are distributed systems created by integrating the services of different clouds to address the specific needs of an industry, a community, or a business sector.
- The National Institute of Standards and Technologies (NIST) [43] characterizes community clouds as follows:

"The infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on premise or off premise."

- The users of a specific community cloud fall into a well-identified community, sharing the same concerns or needs; they can be government bodies, industries, or even simple users, but all of them focus on the same issues for their interaction with the cloud.
- This is a different scenario than public clouds, which serve a multitude of users with different needs.
- Also different from private clouds, where the services are generally delivered within the institution that owns the cloud.

4.3.4 Community clouds

- From an architectural point of view, a community cloud is most likely implemented over multiple administrative domains. Think of it as a public cloud environment, but with set levels of security, privacy, and even regulatory compliance of a private cloud.

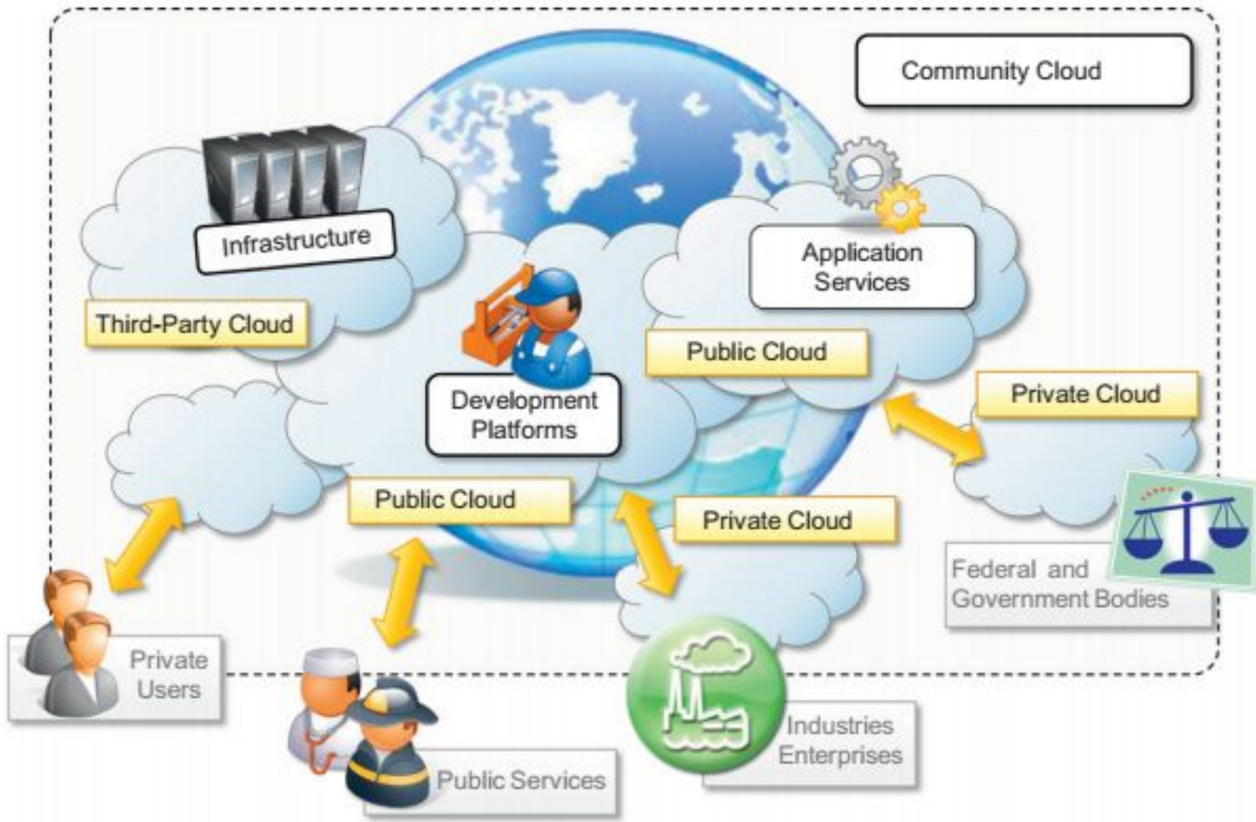

FIGURE 4.6

A community cloud.

4.3.4 Community clouds

- This means that different organizations such as government bodies,private enterprises, research organizations, and even public virtual infrastructure providers contribute with their resources to build the cloud infrastructure.

- Candidate sectors for community clouds are as follows:

1. Media industry. In the media industry, companies are looking for low-cost, agile, and simple solutions to improve the efficiency of content production.

Community clouds can provide a shared environment where services can facilitate business-to-business collaboration and offer the horsepower in terms of aggregate bandwidth, CPU, and storage required to efficiently support media production.

2. Healthcare industry. In the healthcare industry, community clouds can provide a global platform on which to share information and knowledge without revealing sensitive data maintained within the private infrastructure.

The naturally hybrid deployment model of community clouds can easily support the storing of patient-related data in a private cloud while using the shared infrastructure for noncritical services and automating processes within hospitals.

4.3.4 Community clouds

3.Energy and other core industries. In these sectors, community clouds can bundle the comprehensive set of solutions that together vertically address management, deployment, and orchestration of services and operations.

4.Public sector. Legal and political restrictions in the public sector can limit the adoption of public cloud offerings.

Moreover, governmental processes involve several institutions and agencies and are aimed at providing strategic solutions at local, national, and international administrative levels.

They involve business-to-administration, citizen-to-administration, and possibly business-to-business processes. Some examples include invoice approval, infrastructure planning, and public hearings.

5.Scientific research. Science clouds are an interesting example of community clouds. In this case, the common interest driving different organizations sharing a large distributed infrastructure is scientific computing.

4.3.4 Community clouds

The benefits of these community clouds are the following:

- Openness. By removing the dependency on cloud vendors, community clouds are open systems in which fair competition between different solutions can happen.

- Community. Being based on a collective that provides resources and services, the infrastructure turns out to be more scalable because the system can grow simply by expanding its user base.

- Graceful failures. Since there is no single provider or vendor in control of the infrastructure,there is no single point of failure.

- Convenience and control. Within a community cloud there is no conflict between convenience and control because the cloud is shared and owned by the community, which makes all the decisions through a collective democratic process.

- Environmental sustainability. The community cloud is supposed to have a smaller carbon footprint because it harnesses underutilized resources. Moreover, these clouds tend to be more organic by growing and shrinking in a symbiotic relationship to support the demand of the community, which in turn sustains it.

4.4 Economics of the cloud

The main drivers of cloud computing are economy of scale and simplicity of software delivery and its operation. In fact, the biggest benefit of this phenomenon is financial: *the pay-as-you-go model* offered by cloud providers.

In particular, cloud computing allows:

* 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

- A capital cost is the cost occurred in purchasing an asset that is useful in the production of goods or the rendering of services. Capital costs are one-time expenses that are generally paid up front and that will contribute over the long term to generate profit.

4.4 Economics of the cloud

- Enterprise will definitely have an IT department that is used to automate many of the activities that are performed within the enterprise: payroll, customer relationship management, enterprise resource planning, tracking and inventory of products, and others.
- In the case of IT capital costs, the depreciation costs are represented by the loss of value of the hardware over time and the aging of software products that need to be replaced because new features are required.
- Many enterprises own a small or medium-sized datacenter that introduces several operational costs in terms of maintenance, electricity, and cooling.Moreover, other costs are triggered by the purchase of potentially expensive software. With cloud computing these costs are significantly reduced or simply disappear according to its penetration.
- Cloud computing also introduces reductions in administrative and maintenance costs leverage
- In the case of a small startup, it is possible to completely leverage the cloud for many aspects, such as:
- IT infrastructure
- Software development

4.4 Economics of the cloud

- In terms of the pricing models introduced by cloud computing, we can distinguish three different strategies that are adopted by the providers:

• Tiered pricing. In this model, cloud services are offered in several tiers, each of which offers a fixed computing specification and SLA at a specific price per unit of time. This model is used by Amazon for pricing the EC2 service, which makes available different server configurations in terms of computing capacity (CPU type and speed, memory) that have different costs per hour.

• Per-unit pricing. This model is more suitable to cases where the principal source of revenue for the cloud provider is determined in terms of units of specific services, such as data transfer and memory allocation. In this scenario customers can configure their systems more efficiently according to the application needs. This model is used, for example, by GoGrid, which makes customers pay according to RAM/hour units for the servers deployed in the GoGrid cloud.

• Subscription-based pricing. This is the model used mostly by SaaS providers in which users pay a periodic subscription fee for use of the software or the specific component services that are integrated in their applications.

4.5 Open Challenges- Refer Assignment Note book

4.3.4 Community clouds

Cloud Storage Type	Host	Owner	Access	Users
Public cloud	service provider	service provider	Internet	public as individuals, organizations
Private cloud	Enterprise (Third Party)	Enterprise	Intranet, VPN	Business organizations
Hybrid cloud	Enterprise (Third Party)	Enterprise	Intranet, VPN	Business organizations
Community cloud	Community (Third party)	Community	Intranet, VPN	Community members