CLOUD COMPUTING

UNIT-3

CLOUD PLATFORM ARCHITECTURE

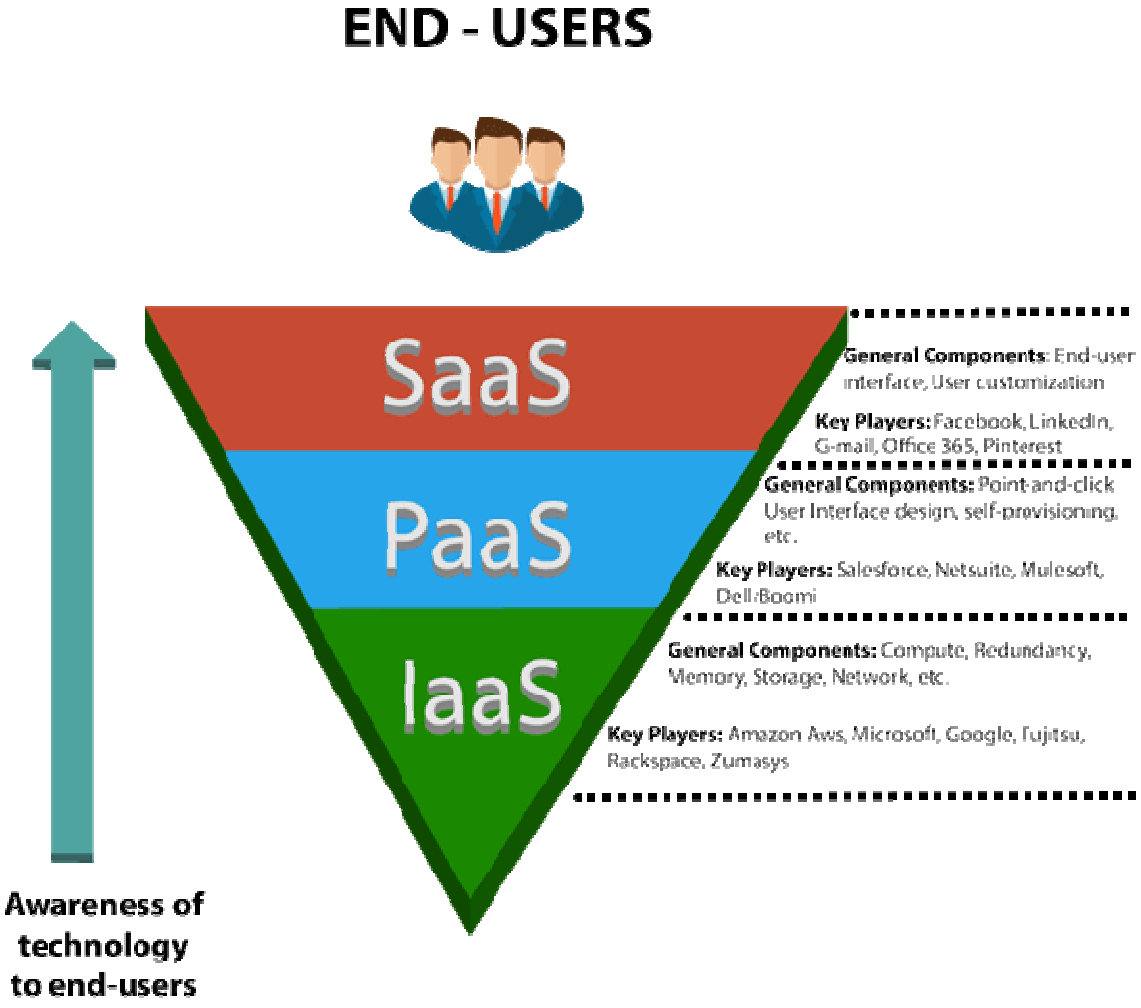
CLOUD COMPUTING & SERVICE MODELS:

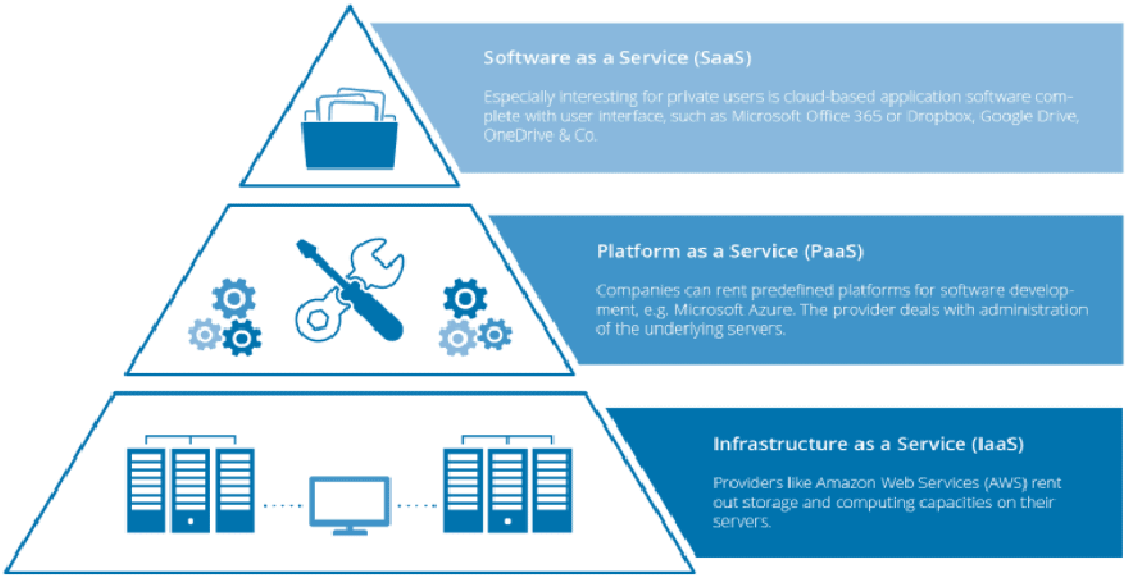
Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services). This cloud model is composed of five essential characteristics, three service models, and four deployment models.

There are three main types of service models of cloud computing. Each type of cloud computing provides different levels of control, flexibility, and management so that you'll select the proper set of services for your needs.

The **three Cloud Service Models** are as follows:

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





Infrastructure As A Service (IaaS)

- It is the **most flexible** type of cloud service which lets you rent the hardware and contains the basic building blocks for cloud and IT.
- **It gives complete control over the hardware** that runs your application (servers, VMs, storage, networks & operating systems).
- It's an **instant computing** infrastructure, provisioned and managed over the internet.
- IaaS gives you the very best level of flexibility and management control over your IT resources.
- It is most almost like the prevailing IT resources with which many IT departments and developers are familiar.
- **Examples** of IaaS: Virtual Machines or AWS EC2, Storage or Networking.

Benefits of IaaS

IaaS is an efficient and cost-effective way to deploy, operate, and scale your IT infrastructure. It's easy to set up and configure, so you can start using it quickly. And because it's available as a service from an external provider, you don't have to worry about building and maintaining your own infrastructure. IaaS offers the following benefits:

Cost savings: IaaS is more cost-effective than building your own data center. You pay only for what you need — storage space, CPU power, bandwidth, and other resources. This makes it easier to scale up or down as needed.

On-demand access: You can instantly provision new resources whenever they're needed without having to invest in new hardware and software or hire additional IT staff members. The cloud provider takes care of all the maintenance and upgrades required to keep your servers online 24/7 with 99 percent uptime guarantees (or better).

Flexibility: With cloud computing, you can easily add more resources when demand increases without having to upgrade equipment or hire more IT professionals.

IaaS Use-Cases

Here are some common IaaS use cases:

- IaaS is useful for backing up, storing, and recovering data and also helps in managing fluctuating storage needs.
- It is cheaper and faster to set up test and development environments with IaaS.
- Companies working with Big Data often use IaaS as it allows them to significantly increase their computing power.
- IaaS can be an optimal basis for some complex web projects particularly for sites with profoundly fluctuating traffic, as a website hosted in the cloud can profit from the verbosity rendered by a massive network of physical servers and demand scalability to manage unpredictable demands
- Due to its stability, IaaS can be a better alternative for complex tasks which include millions of variables or calculations and in general, might require the use of supercomputers or clusters.
- Users can easily access high-end apps with IaaS. They can run graphic-intensive applications without any latency issues as the cloud servers offer superior performance and in addition to this, they will have increased productivity because the app will run with great speed.
- The application deployment over the cloud can be done in less time with IaaS. You can scale up or down the apps based on unpredictable

demands. Moreover, all your infrastructure and storage requirements are borne by the providers so that you can easily deploy the applications.

IaaS delivery

IaaS delivers cloud computing infrastructure through virtualization technology, including servers, networks, operating systems, and storage. These cloud servers are provided to the organization using a dashboard or an API that gives IaaS clients complete control over the entire infrastructure.

It provides the same technology and capabilities as a traditional data center, but you don't need to maintain or manage all of it. Clients of the IaaS service can access their servers and storage directly, but all of this is outsourced to a "virtual data center" on the cloud.

Platform As A Service (PaaS)

- PaaS is a cloud service model that gives a ready-to-use development environment where developers can specialize in writing and executing high-quality code to make customized applications.
- It helps to create an application quickly without managing the underlying infrastructure. For example, when deploying a web application using PaaS, you don't have to install an operating system, web server, or even system updates. However, you can scale and add new features to your services.
- This cloud service model makes the method of developing and deploying applications simpler and it is more expensive than IaaS but less expensive than SaaS.
- This helps you be more efficient as you don't get to worry about resource procurement, capacity planning, software maintenance, patching, or any of the opposite undifferentiated work involved in running your application.
- **Examples** of PaaS: Elastic Beanstalk or Lambda from AWS, WebApps, Functions or Azure SQL DB from Azure, Cloud SQL DB from Google Cloud, or Oracle Database Cloud Service from Oracle Cloud.

Benefits of PaaS

PaaS is an easy way to build an application, and it offers a lot of benefits. Here are just a few:

Faster development time – You don't have to build infrastructure before you can start coding.
Reduced costs – Your IT department won't need to spend time on manual deployments or server management.
Enhanced security – PaaS providers lock down your applications so that they're more secure than traditional web apps.
High availability – A PaaS provider can make sure your application is always available, even during hardware failures or maintenance windows.

PaaS Use-Cases

There are multiple use cases for PaaS, in a wide range of business contexts. Some of them are:

- PaaS is useful for companies developing, running, and managing app programming interfaces and microservices. The same goes for the development of new APIs and complete API management.
- PaaS is suitable for setting up and managing an organization's database. It offers a scalable, secure, and on-demand platform to create, administer, and maintain databases.
- PaaS tools allow for advanced analysis of business data, to identify patterns, make predictions, and ultimately make more qualified and

data-driven decisions. These tools can help companies predict behaviors and events for better planning.

- PaaS supports various programming languages, application environments, and tools, which allows connectivity and integrations required in IoT deployments.
- PaaS can be a delivery mechanism for communication and collaboration which means that features like voice, chat, and videos can be added to applications built on the PaaS cloud service model.

Pass delivery

The delivery model of PaaS is quite similar to SaaS. The only difference between the two is that PaaS provides a platform for software creation while PaaS is delivered via the web. This cloud computing model allows developers to concentrate on building the software without worrying about software updates, operating systems, storage, or infrastructure. Businesses can also design and develop applications built into the PaaS with special software components.

Software As A Service (SaaS)

- SaaS provides you with a complete product that is run and managed by the service provider.
- The software is hosted online and made available to customers on a subscription basis or for purchase in this cloud service model.
- With a SaaS offering, you don't need to worry about how the service is maintained or how the underlying infrastructure is managed. It would help if you believed how you'd use that specific software.
- **Examples** of SaaS: Microsoft Office 365, Oracle ERP/HCM Cloud, SalesForce, Gmail, or Dropbox

Benefits of SaaS

The benefits of SaaS are numerous and varied. Many businesses have already made the switch to SaaS, but some are still skeptical about making the change. Here are some of the top reasons why you should consider switching to SaaS:

Lower Total Cost of Ownership: One of the biggest benefits of SaaS is that it lowers your total cost of ownership (TCO) by eliminating hardware expenses and maintenance costs. There is no longer a need to buy servers or hire IT professionals to maintain or monitor them, which results in fewer upfront costs and reduced maintenance fees over time.

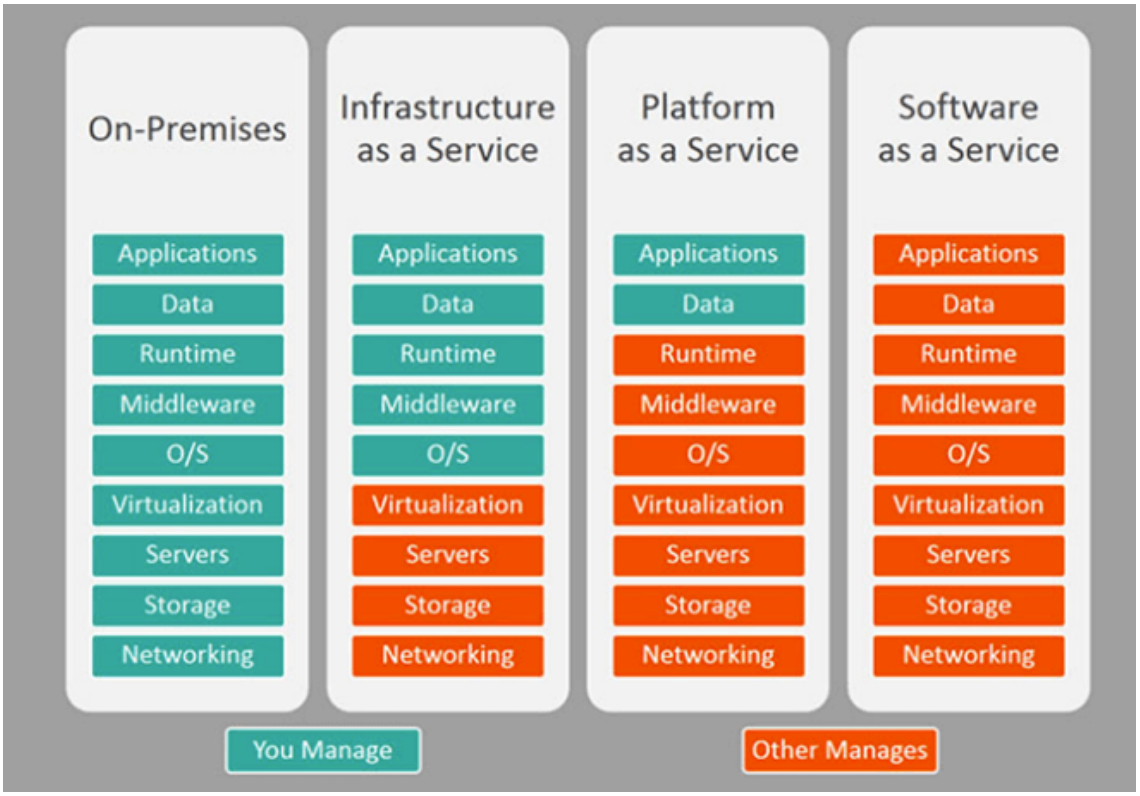
Better Security: Another benefit of SaaS is improved security. Since most services are hosted on secure servers in data centers with 24/7 monitoring, there's less chance for hackers to gain access or steal your data. This makes SaaS a more secure option for storing sensitive information than other options like on-premise software or local servers. In fact, according to Gartner's 2017 Magic Quadrant report, "Software as a service (SaaS) offerings provide better security than self-hosted software does."

SaaS Use-Cases

- Pop-up live events are well-suited to SaaS models, specifically live sports and esports tournaments, where the event's temporary nature only requires services for a few hours a day in a week.
- SaaS brings new benefits for content owners looking to take their content directly to the consumer (D2C), with deployments covering everything from the Customer Management Systems (CMS), subscriber management systems, and user experience.
- SaaS helps in delivering applications that can be widely distributed and accessed. For example, Google's Gmail which is a fully managed email-based application and is most easily accessed over the internet without requiring you to install any software on your local device to be able to use it.

SaaS delivery

The SaaS delivery model helps you to eliminate the need for IT staff to download and install applications on each computer. All potential technical issues, like data, middleware, servers, and storage, are managed by SaaS providers. It allows businesses to maintain and support their systems more efficiently.



SaaS vs PaaS vs IaaS: Differences

Parameter	SaaS	PaaS	IaaS
Used by	The end users use it.	Developers use PAAS.	Network architects use it.
Access	SAAS gives access to the end user.	PAAS gives access to the runtime environment for deployment and development tools	It provides access to the resources like virtual machines and virtual storage.
Model	It is a service model in cloud computing that hosts software.	It is a cloud computing service model that delivers tools that are used for the development of applications.	IaaS is a service model that provides virtualized computing resources over the internet.
Technical understanding	No need for technical knowledge.	Some knowledge is required for basic setup.	It requires technical writing.

Control is given to developers	Nothing	Data of Application	OS, Runtime, Middleware, etc
Abstraction	Complete abstraction	Abstraction of the underlying hardware and software resources.	Only for underlying hardware resources
Operational Cost	Minimal	Lower	Highest
Portability	No portability	Lower	Best
Risk of Vendor Interlock	Highest	Medium	Lowest
Examples of Cloud services	Google Workspace, Salesforce, Dropbox, CISCO, MS Office Web, etc.	Windows Azure, Force.com, Google App Engine, OpenShift, Heroku, etc.	AWS, Google Compute Engine, Rackspace, Digital Ocean, VCloud Express, Sun, etc.

PUBLIC CLOUD PLATFORMS: GAE, AWS, AND AZURE

Public cloud is defined as the availability of computing services by third-party providers. In a public cloud, IT resources, such as compute, storage, development platforms, applications, are available as a service over the internet. The services on public cloud are available to anyone who wants to use or purchase them.

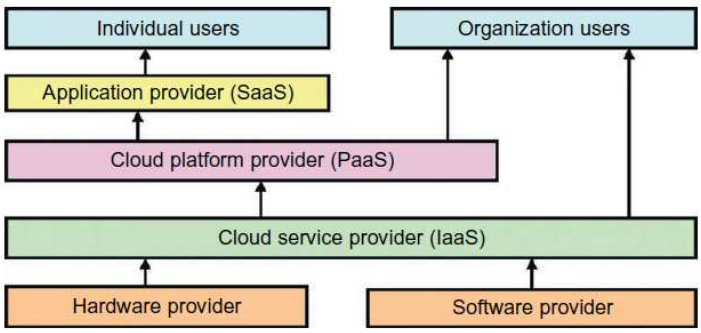


FIGURE 4.19

Roles of individual and organizational users and their interaction with cloud providers under various cloud service models.

Cloud services are demanded by computing and IT administrators, software vendors, and end users.

Figure 4.19 introduces five levels of cloud players. At the top level, individual users and organizational users demand very different services. The application providers at the SaaS level serve mainly individual users. Most business organizations are serviced by IaaS and PaaS providers. The infrastructure services (IaaS) provide compute, storage, and communication resources to both applications and organizational users. The cloud environment is defined by the PaaS or platform providers.

Table 4.5 Five Major Cloud Platforms and Their Service Offerings [36]

Model	IBM	Amazon	Google	Microsoft	Salesforce
PaaS	BlueCloud, WCA, RC2		App Engine (GAE)	Windows Azure	Force.com
IaaS	Ensembles	AWS		Windows Azure	
SaaS	Lotus Live		Gmail, Docs	.NET service, Dynamic CRM	Online CRM, Gifttag
Virtualization		OS and Xen	Application Container	OS level/ Hypel-V	
Service Offerings	SOA, B2, TSAM, RAD, Web 2.0	EC2, S3, SQS, SimpleDB	GFS, Chubby, BigTable, MapReduce	Live, SQL Hotmail	Apex, visual force, record security
Security Features	WebSphere2 and PowerVM tuned for protection	PKI, VPN, EBS to recover from failure	Chubby locks for security enforcement	Replicated data, rule-based access control	Admin./record security, uses metadata API
User Interfaces		EC2 command-line tools	Web-based admin. console	Windows Azure portal	
Web API	Yes	Yes	Yes	Yes	Yes
Programming Support	AMI		Python	.NET Framework	

Note: *WCA: WebSphere CloudBurst Appliance; RC2: Research Compute Cloud; RAD: Rational Application Developer; SOA: Service-Oriented Architecture; TSAM: Tivoli Service Automation Manager; EC2: Elastic Compute Cloud; S3: Simple Storage Service; SQS: Simple Queue Service; GAE: Google App Engine; AWS: Amazon Web Services; SQL: Structured Query Language; EBS: Elastic Block Store; CRM: Consumer Relationship Management.*

Table 4.5 summarizes the profiles of five major cloud providers by 2010 standards. As Table 4.5 shows, all IaaS, PaaS, and SaaS models allow users to access services over the Internet, relying entirely on the infrastructures of the cloud service providers. These models are offered based on various SLAs between the providers and the users. SLAs are more common in network services as they account for the QoS characteristics of network services. For cloud computing services, it is difficult to find a reasonable precedent for negotiating an SLA. In a broader sense, the SLAs for cloud computing address service availability, data integrity, privacy, and security protection.

Blank spaces in the table refer to unknown or underdeveloped features.

Google App Engine (GAE):

Google has the world's largest search engine facilities. The company has extensive experience in massive data processing that has led to new insights

into data-center design and novel programming models that scale to incredible sizes. The Google platform is based on its search engine expertise, but as discussed earlier with MapReduce, this infrastructure is applicable to many other areas. Google has hundreds of data centers and has installed more than 460,000 servers worldwide.

For example, 200 Google data centers are used at one time for a number of cloud applications.

Data items are stored in text, images, and video and are replicated to tolerate faults or failures.

Google's App Engine (GAE) which offers a PaaS platform supporting various cloud and web applications.

Google Cloud Infrastructure

Google has pioneered cloud development by leveraging the large number of data centers it operates.

For example, Google pioneered cloud services in Gmail, Google Docs, and Google Earth, among other applications. These applications can support a large number of users simultaneously with HA.

Notable technology achievements include the Google File System (GFS), MapReduce, BigTable, and Chubby. In 2008, Google announced the GAE web application platform which is becoming a common platform for many small cloud service providers. This platform specializes in supporting scalable (elastic) web applications. GAE enables users to run their applications on a large number of data centers associated with Google's search engine operations.

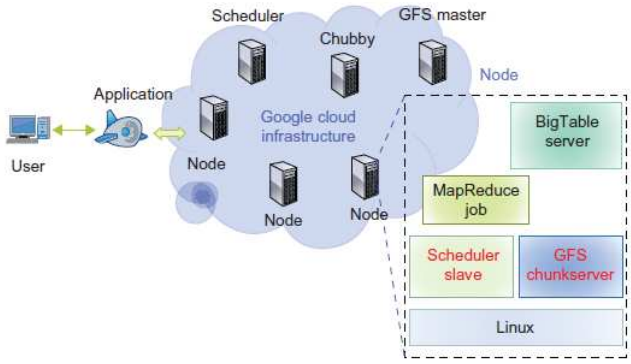


FIGURE 4.20

Google cloud platform and major building blocks, the blocks shown are large clusters of low-cost servers.

Figure 4.20 shows the major building blocks of the Google cloud platform which has been used to deliver the cloud services highlighted earlier. GFS is used for storing large amounts of data.

MapReduce is for use in application program development. Chubby is used for distributed application lock services. BigTable offers a storage service for accessing structured data.

Users can interact with Google applications via the web interface provided by each application. Third-party application providers can use GAE to build cloud

applications for providing services. The applications all run in data centers under tight management by Google engineers. Inside each data center, there are thousands of servers forming different clusters.
Google is one of the larger cloud application providers, although its fundamental service program is private and outside people cannot use the Google infrastructure to build their own service.
The building blocks of Google's cloud computing application include the Google File System for storing large amounts of data, the MapReduce programming framework for application developers,
Chubby for distributed application lock services, and BigTable as a storage service for accessing structural or semistructural data. With these building blocks, Google has built many cloud applications.
Figure 4.20 shows the overall architecture of the Google cloud infrastructure. A typical cluster configuration can run the Google File System, MapReduce jobs, and BigTable servers for structure data. Extra services such as Chubby for distributed locks can also run in the clusters.
GAE runs the user program on Google's infrastructure. As it is a platform running third-party programs, application developers now do not need to worry about the maintenance of servers. GAE can be thought of as the combination of several software components. The frontend is an application framework which is similar to other web application frameworks such as ASP, J2EE, and JSP. At the time of this writing, GAE supports Python and Java programming environments. The applications can run similar to web application containers. The frontend can be used as the dynamic web serving infrastructure which can provide the full support of common technologies.

Functional Modules of GAE

The GAE platform comprises the following five major components. The GAE is not an infrastructure platform, but rather an application development platform for users.

a. The datastore offers object-oriented, distributed, structured data storage services based on BigTable techniques. The datastore secures data management operations.

b. The application runtime environment offers a platform for scalable web programming and execution. It supports two development languages: Python and Java.

c. The software development kit (SDK) is used for local application development. The SDK allows users to execute test runs of local applications and upload application code.

d. The administration console is used for easy management of user application development cycles, instead of for physical resource management.

e. The GAE web service infrastructure provides special interfaces to guarantee flexible use and management of storage and network resources by GAE.

Google offers essentially free GAE services to all Gmail account owners. You can register for a GAE account or use your Gmail account name to sign up for the service. The service is free within a quota. If you exceed the quota, the page instructs you on how to pay for the service. Then you download the SDK and read the Python or Java guide to get started. Note that GAE only accepts Python, Ruby, and Java programming languages. The platform does not provide any IaaS services, unlike Amazon, which offers Iaas and PaaS. This model allows the user to deploy user-built applications on top of the cloud infrastructure that are built using the programming languages and software tools supported by the provider (e.g., Java, Python). Azure does this similarly for .NET. The user does not manage the underlying cloud infrastructure. The cloud provider facilitates support of application development, testing, and operation support on a well-defined service platform.

GAE Applications

Well-known GAE applications include the Google Search Engine, Google Docs, Google Earth, and Gmail. These applications can support large numbers of users simultaneously. Users can interact with Google applications via the web interface provided by each application. Third-party application providers can use GAE to build cloud applications for providing services. The applications are all run in the Google data centers. Inside each data center, there might be thousands of server nodes to form different clusters. (See the previous section.) Each cluster can run multipurpose servers.

GAE supports many web applications. One is a storage service to store application-specific data in the Google infrastructure. The data can be persistently stored in the backend storage server while still providing the facility for queries, sorting, and even transactions similar to traditional database systems. GAE also provides Google-specific services, such as the Gmail account service (which is the login service, that is, applications can use the Gmail account directly). This can eliminate the tedious work of building customized user management components in web applications. Thus, web applications built on top of GAE can use the APIs authenticating users and sending e-mail using Google accounts.

Amazon Web Services (AWS):

VMs can be used to share computing resources both flexibly and safely. Amazon has been a leader in providing public cloud services (http://aws.amazon.com/). Amazon applies the IaaS model in providing its services. Figure 4.21 shows the AWS architecture. EC2 provides the virtualized platforms to the host VMs where the cloud application can run. S3 (Simple Storage Service) provides the object-oriented storage service for users. EBS (Elastic Block Service) provides the block storage interface which can be used to support traditional applications. SQS stands for Simple Queue Service, and its job is to ensure a

reliable message service between two processes. The message can be kept reliably even when the receiver processes are not running. Users can access their objects through SOAP with either browsers or other client programs which support the SOAP standard.

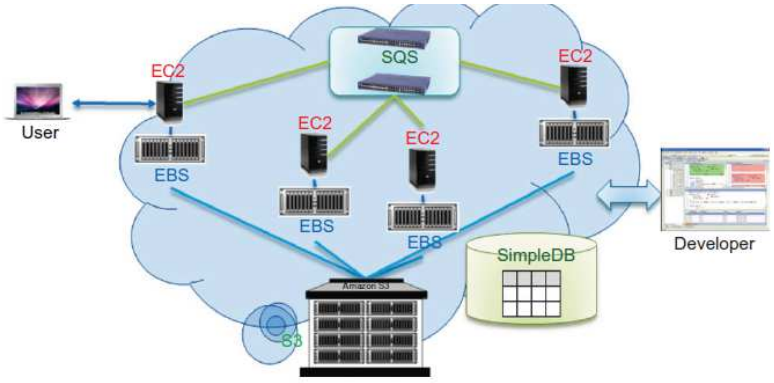


FIGURE 4.21

Amazon cloud computing infrastructure (Key services are identified here; many more are listed in Table 4.6).

Amazon offers queuing and notification services (SQS and SNS), which are implemented in the AWS cloud.

Note brokering systems run very efficiently in clouds and offer a striking model for controlling sensors and providing office support of smartphones and tablets. Different from Google, Amazon provides a more flexible cloud computing platform for developers to build cloud applications. Small and medium-size companies can put their business on the Amazon cloud platform. Using the AWS platform, they can service large numbers of Internet users and make profits through those paid services.

ELB automatically distributes incoming application traffic across multiple Amazon EC2 instances and allows user to avoid nonoperating nodes and to equalize load on functioning images. Both autoscaling and ELB are enabled by CloudWatch which monitors running instances. CloudWatch is a web service that provides monitoring for AWS cloud resources, starting with Amazon EC2.

It provides customers with visibility into resource utilization, operational performance, and overall demand patterns, including metrics such as CPU utilization, disk reads and writes, and network traffic.

Amazon (like Azure) offers a Relational Database Service (RDS) with a messaging interface to be covered in Section 4.1. The Elastic MapReduce capability is equivalent to Hadoop running on the basic EC2 offering. AWS Import/Export allows one to ship large volumes of data to and from

EC2 by shipping physical disks; it is well known that this is often the highest bandwidth connection between geographically distant systems. Amazon CloudFront implements a content distribution network. Amazon DevPay is a simple-to-use online billing and account management service that makes it easy for businesses to sell applications that are built into or run on top of AWS.

FPS provides developers of commercial systems on AWS with a convenient way to charge Amazon's customers that use such services built on AWS. Customers can pay using the same login credentials,
shipping address, and payment information they already have on file with Amazon. The FWS allows merchants to access Amazon's fulfillment capabilities through a simple web service interface.
Merchants can send order information to Amazon to fulfill customer orders on their behalf. In July 2010, Amazon offered MPI clusters and cluster compute instances. The AWS cluster compute instances use hardware-assisted virtualization instead of the para-virtualization used by other instance types and requires booting from the EBS. Users are freed to create a new AMI as needed.

Table 4.6 AWS Offerings in 2011

Service Area	Service Modules and Abbreviated Names
Compute	Elastic Compute Cloud (EC2), Elastic MapReduce, Auto Scaling
Messaging	Simple Queue Service (SQS), Simple Notification Service (SNS)
Storage	Simple Storage Service (S3), Elastic Block Storage (EBS), AWS Import/Export
Content Delivery	Amazon CloudFront
Monitoring	Amazon CloudWatch
Support	AWS Premium Support
Database	Amazon SimpleDB, Relational Database Service (RDS)
Networking	Virtual Private Cloud (VPC) (Example 4.1, Figure 4.6), Elastic Load Balancing
Web Traffic	Alexa Web Information Service, Alexa Web Sites
E-Commerce	Fulfillment Web Service (FWS)
Payments and Billing	Flexible Payments Service (FPS), Amazon DevPay
Workforce	Amazon Mechanical Turk

Microsoft Windows Azure:

In 2008, Microsoft launched a Windows Azure platform to meet the challenges in cloud computing.
This platform is built over Microsoft data centers. Figure 4.22 shows the overall architecture of Microsoft's cloud platform. The platform is divided into three major component platforms. Windows Azure offers a cloud platform built on Windows OS and based on Microsoft virtualization technology.

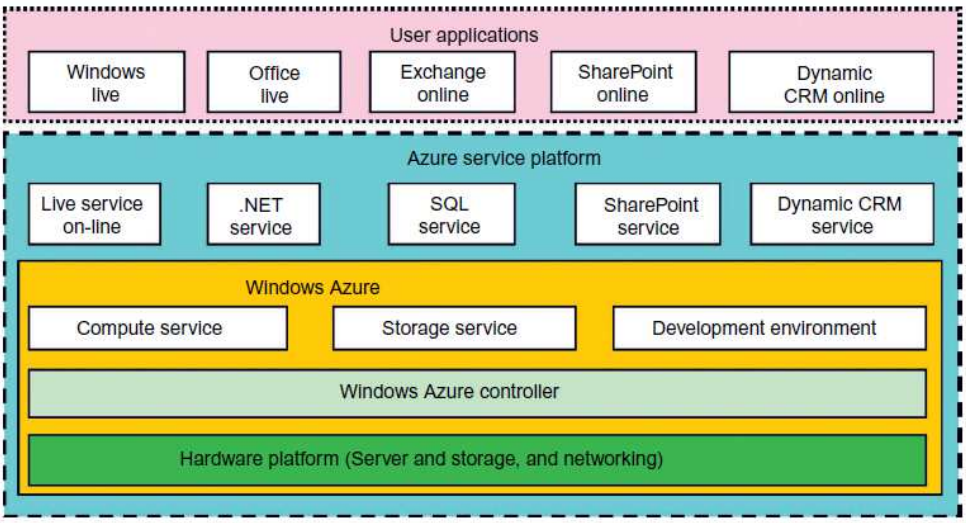


FIGURE 4.22

Microsoft Windows Azure platform for cloud computing.

Applications are installed on VMs deployed on the data-center servers. Azure manages all servers, storage, and network resources of the data center. On top of the infrastructure are the various services for building different cloud applications. Cloud-level services provided by the Azure platform are introduced below.

• Live service Users can visit Microsoft Live applications and apply the data involved across multiple machines concurrently.

• .NET service This package supports application development on local hosts and execution on cloud machines.

• SQL Azure This function makes it easier for users to visit and use the relational database associated with the SQL server in the cloud.

• SharePoint service This provides a scalable and manageable platform for users to develop their special business applications in upgraded web services.

• Dynamic CRM service This provides software developers a business platform in managing CRM applications in financing, marketing, and sales and promotions.

All these cloud services in Azure can interact with traditional Microsoft software applications, such as Windows Live, Office Live, Exchange online, SharePoint online, and dynamic CRM online. The Azure platform applies the standard web communication protocols SOAP and REST.

The Azure service applications allow users to integrate the cloud application with other platforms or third-party clouds. You can download the Azure development kit to run a local version of Azure. The powerful SDK allows Azure applications to be developed and debugged on the Windows hosts.