Cloud Concepts - Principles of Cloud Computing

Introduction

When you turn on a light, you simply want the light to work. You know you need electricity for that to happen, but in that moment, the details of how the electricity gets to the light bulb aren't important. You might not think about electricity being created in a power plant, traveling through a large network of high-voltage transmission lines to your town, going through a substation, and eventually making its way into your home.

The process of turning on a light is hidden behind the simple act of flipping a switch. At this point, electricity becomes a utility, which has many benefits. First, you only pay for what you need. When you buy a light bulb, you don't pay your electricity provider up front for how long you could possibly use it. Instead, you pay for the amount of electricity that you actually use. Second, you don't worry about how or when power plants upgrade to the latest technology. Finally, you don't have to manage scaling the electricity. For example, as people move to your town, you can rest assured that your light will stay on.

As a technology professional, it would be nice to have these same benefits when developing and deploying applications. Storing data, streaming video, or even hosting a website all require managing hardware and software. This management is an unnecessary obstacle when delivering your application to your users. Luckily there is a solution to this problem: **cloud computing**.

What is cloud computing?

Cloud computing is renting resources, like storage space or CPU cycles, on another company's computers. You only pay for what you use. The company providing these services is referred to as a cloud provider. Some example providers are Microsoft, Amazon, and Google.

The cloud provider is responsible for the physical hardware required to execute your work, and for keeping it up-to-date. The computing services offered tend to vary by cloud provider. However, typically they include:

- **Compute power** - such as Linux servers or web applications used for computation and processing tasks
- **Storage** - such as files and databases
- **Networking** - such as secure connections between the cloud provider and your company
- **Analytics** - such as visualizing telemetry and performance data

Cloud computing services

The goal of cloud computing is to make running a business easier and more efficient, whether it's a small start-up or a large enterprise. Every business is unique and has different needs. To meet those needs, cloud computing providers offer a wide range of services.

You need to have a basic understanding of some of the services it provides. Let's briefly discuss the two most common services that all cloud providers offer – *compute power* and *storage*.

Compute power

When you send an email, book a reservation on the Internet, pay a bill online, or even take this Microsoft Learn module you're interacting with cloud-based servers that are processing each request and returning a response. As a consumer, we're all dependent

on the computing services provided by the various cloud providers that make up the Internet.

When you build solutions using cloud computing, you can choose how you want work to be done based on your resources and needs. For example, if you want to have more control and responsibility over maintenance, you could create a *virtual machine* (VM). A VM is an emulation of a computer - just like your desktop or laptop you're using now. Each VM includes an operating system and hardware that appears to the user like a physical computer running Windows or Linux. You can then install whatever software you need to do the tasks you want to run in the cloud.

The difference is that you don't have to buy any of the hardware or install the OS. The cloud provider runs your virtual machine on a physical server in one of their datacenters - often sharing that server with other VMs (isolated and secure). With the cloud, you can have a VM ready to go in minutes at less cost than a physical computer.

VMs aren't the only computing choice - there are two other popular options: *containers* and *serverless computing*.

What are containers?

Containers provide a consistent, isolated execution environment for applications. They're similar to VMs except they don't require a guest operating system. Instead, the application and all its dependencies is packaged into a "container" and then a standard runtime environment is used to execute the app. This allows the container to start up in

just a few seconds, because there's no OS to boot and initialize. You only need the app to launch.

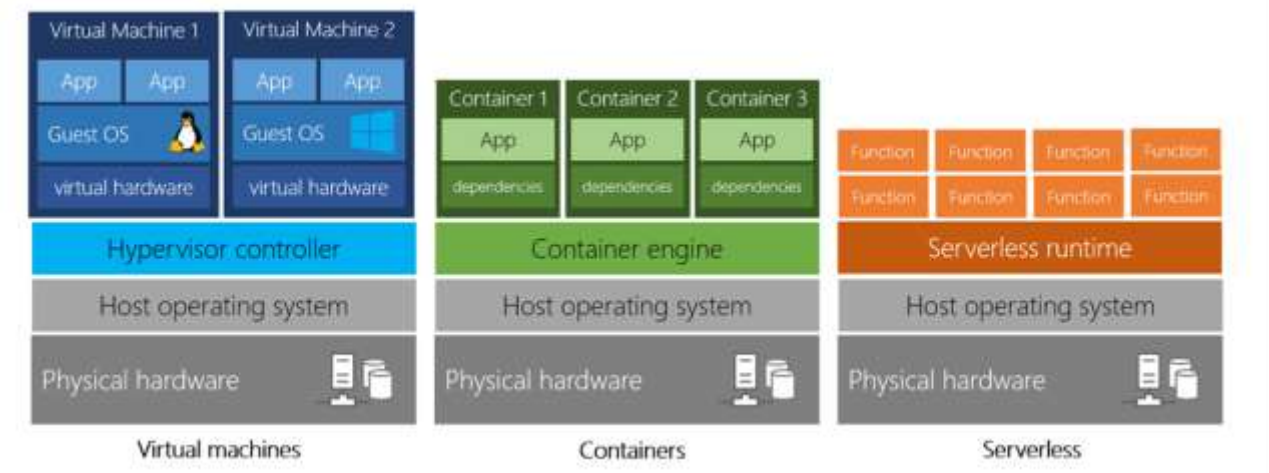
The open-source project, Docker, is one of the leading platforms for managing containers. Docker containers provide an efficient, lightweight approach to application deployment because they allow different components of the application to be deployed independently into different containers. Multiple containers can be run on a single machine, and containers can be moved between machines. The portability of the container makes it easy for applications to be deployed in multiple environments, either on-premises or in the cloud, often with no changes to the application.

What is Serverless computing?

Serverless computing lets you run application code without creating, configuring, or maintaining a server. The core idea is that your application is broken into separate *functions* that run when triggered by some action. This is ideal for automated tasks - for example, you can build a serverless process that automatically sends an email confirmation after a customer makes an online purchase.

The serverless model differs from VMs and containers in that you only pay for the processing time used by each function as it executes. VMs and containers are charged while they're running - even if the applications on them are idle. This architecture doesn't work for every app - but when the app logic can be separated to independent units, you can test them separately, update them separately, and launch them in microseconds, making this approach the fastest option for deployment.

Here's a diagram comparing the three compute approaches we've covered.



The three verticals, virtual machines, containers, and serverless, show different architectures. Virtual machines starts at physical hardware and has layers built on it: host operating system, hypervisor controller, and then two virtual machines on top with one running Linux and two apps and one running Windows and two apps. Containers starts with physical hardware with additional layers: host operating system, container engine, and then three containers, each with their own dependencies and hosted apps. Serverless starts with physical hardware with additional layers: host operating system, serverless runtime, and then eight functions.

Storage

Most devices and applications read and/or write data. Here are some examples:

- Buying a movie ticket online
- Looking up the price of an online item
- Taking a picture
- Sending an email
- Leaving a voicemail

In all of these cases, data is either *read* (looking up a price) or *written* (taking a picture). The type of data and how it's stored can be different in each of these cases.

Cloud providers typically offer services that can handle all of these types of data. For example, if you wanted to store text or a movie clip, you could use a file on disk. If you

had a set of relationships such as an address book, you could take a more structured approach like using a database.

The advantage to using cloud-based data storage is you can scale to meet your needs. If you find that you need more space to store your movie clips, you can pay a little more and add to your available space. In some cases, the storage can even expand and contract automatically - so you pay for exactly what you need at any given point in time.

Summary

Every business has different needs and requirements. Cloud computing is **flexible** and **cost-efficient**, which can be beneficial to every business, whether it's a small start-up or a large enterprise.

Benefits of Cloud Computing

Cloud computing isn't an all-or-nothing service approach. Companies can choose to use the cloud to store their data and execute logic as much, or as little, as necessary to fulfill their business requirements. Existing businesses might choose a gradual movement to save money on infrastructure and administration costs (referred to as "lift and shift"), while a new company might start in the cloud.

Let's learn some of the top benefits of cloud computing.

It's cost-effective

Cloud computing provides a **pay-as-you-go** or **consumption-based** pricing model.

This consumption-based model brings with it many benefits, including:

- No upfront infrastructure costs
- No need to purchase and manage costly infrastructure that you may not use to its fullest
- The ability to pay for additional resources only when they are needed
- The ability to stop paying for resources that are no longer needed

This also allows for better cost prediction. Prices for individual resources and services are provided so you can predict how much you will spend in a given billing period based on your expected usage. You can also perform analysis based on future growth using historical usage data tracked by your cloud provider.

It's scalable

You can increase or decrease the resources and services used based on the demand or workload at any given time. Cloud computing supports both *vertical* and *horizontal* scaling depending on your needs.

Vertical scaling, also known as "scaling up", is the process of adding resources to increase the power of an existing server. Some examples of vertical scaling are: adding more CPUs, or adding more memory.

Horizontal scaling, also known as "scaling out", is the process of adding more servers that function together as one unit. For example, you have more than one server processing incoming requests.

Scaling can be done manually or automatically based on specific triggers such as CPU utilization or the number of requests and resources that can be allocated or de-allocated in minutes.

It's elastic

As your workload changes due to a spike or drop in demand, a cloud computing system can compensate by automatically adding or removing resources.

For example, imagine your website is featured in a news article, leading to a spike in traffic overnight. Since the cloud is elastic, it automatically allocates more computing resources to handle the increased traffic. When the traffic begins to normalize, the cloud automatically de-allocates the additional resources to minimize cost.

Another example is if you are running an application used by employees, you can have the cloud automatically add resources for the peak operating hours during which most people access the application, and remove the resources at the usual end of the day.

It's current

When you use the cloud, you're able to focus on what matters: building and deploying applications. Cloud usage eliminates the burdens of maintaining software patches, hardware setup, upgrades, and other IT management tasks. All of this is automatically done for you to ensure you're using the latest and greatest tools to run your business.

Additionally, the computer hardware is maintained and upgraded by the cloud provider. For example, if a disk fails, the disk will be replaced by the cloud provider. If a new hardware update becomes available, you don't have to go through the process of replacing your hardware. The cloud provider will ensure that the hardware updates are made available to you automatically.

It's reliable

When you're running a business, you want to be confident your data is always going to be there. Cloud computing providers offer data backup, disaster recovery, and data replication services to make sure your data is always safe. In addition, redundancy is often built into cloud services architecture so if one component fails, a backup component takes its place. This is referred to as *fault tolerance* and it ensures that your customers aren't impacted when a disaster occurs.

It's global

Cloud providers have fully redundant datacenters located in various regions all over the globe. This gives you a local presence close to your customers to give them the best response time possible no matter where in the world they are.

You can replicate your services into multiple regions for redundancy and locality, or select a specific region to ensure you meet data-residency and compliance laws for your customers.

It's secure

Think about how you secure your datacenter. You have *physical security* – who can access the building, who can operate the server racks, and so on. You also have *digital security* – who can connect to your systems and data over the network.

Cloud providers offer a broad set of policies, technologies, controls, and expert technical skills that can provide better security than most organizations can otherwise achieve. The result is strengthened security, which helps to protect data, apps, and infrastructure from potential threats.

When it comes to physical security – threats to cloud infrastructure, cloud providers invest heavily in walls, cameras, gates, security personnel, and so on, to protect physical assets. They also have strict procedures in place to ensure employees have access only to those resources that they've been authorized to manage.

Let us talk about digital security. You want only authorized users to be able to log into virtual machines or storage systems running in the cloud. Cloud providers offer tools

that help you mitigate security threats, and you must use these tools to protect the resources you use.

Summary

Cloud computing makes running a business easier. It's cost-effective, scalable, elastic, current, reliable, and secure. This means you're able to spend more time on what matters and less time managing the underlying details.

Capital expenditure (CapEx) versus operational expenditure (OpEx)

In the past, companies needed to acquire physical premises and infrastructure to start their business. There was a substantial up-front cost in hardware and infrastructure to start or grow a business. Cloud computing provides services to customers without significant upfront costs or equipment setup time.

These two approaches to investment are referred to as:

- **Capital Expenditure (CapEx)**: CapEx is the spending of money on physical infrastructure up front, and then deducting that expense from your tax bill over time. CapEx is an upfront cost, which has a value that reduces over time.
- **Operational Expenditure (OpEx)**: OpEx is spending money on services or products now and being billed for them now. You can deduct this expense from your tax bill in the same year. There's no upfront cost. You pay for a service or product as you use it.

CapEx computing costs

A typical on-premises datacenter includes costs such as:

Server costs

This area includes all hardware components and the cost of supporting them. When purchasing servers, make sure to design fault tolerance and redundancy, such as server clustering, redundant power supplies, and uninterruptible power supplies. When a server needs to be replaced or added to a datacenter, you need to pay for the

computer. This can affect your immediate cash flow because you must pay for the server up front.

Storage costs

This area includes all storage hardware components and the cost of supporting it. Based on the application and level of fault tolerance, centralized storage can be expensive. For larger organizations, you can create tiers of storage where more expensive fault-tolerant storage is used for critical applications and lower expense storage is used for lower priority data.

Network costs

Networking costs include all on-premises hardware components, including cabling, switches, access points, and routers. This also includes wide area network (WAN) and Internet connections.

Backup and archive costs

This is the cost to back up, copy, or archive data. Options might include setting up a backup to or from the cloud. There's an upfront cost for the hardware and additional costs for backup maintenance and consumables like tapes.

Organization continuity and disaster recovery costs

Along with server fault tolerance and redundancy, you need to plan for how to recover from a disaster and continue operating. Your plan should consist of creating a disaster recovery site. It could also include backup generators. Most of these are upfront costs, especially if you build a disaster recovery site, but there's an additional ongoing cost for the infrastructure and its maintenance.

Datacenter infrastructure costs

These are costs for construction and building equipment, as well as future renovation and remodeling costs that may arise as demands grow. Additionally, this infrastructure incurs operational expenses for electricity, floor space, cooling, and building maintenance.

Technical personnel

While not a capital expenditure, the personnel required to work on your infrastructure are specific to on-premises datacenters. You will need the technical expertise and workforce to install, deploy, and manage the systems in the datacenter and at the disaster recovery site.

OpEx cloud computing costs

With cloud computing, many of the costs associated with an on-premises datacenter are shifted to the service provider. Instead of thinking about physical hardware and datacenter costs, cloud computing has a different set of costs. For accounting purposes, all these costs are operational expenses:

Leasing software and customized features

Using a pay-per-use model requires actively managing your subscriptions to ensure users do not misuse the services, and that provisioned accounts are being utilized and not wasted. As soon as the provider provisions resources, billing starts. It is your responsibility to de-provision the resources when they aren't in use so that you can minimize costs.

Scaling charges based on usage/demand instead of fixed hardware or capacity.

Cloud computing can bill in various ways, such as the number of users or CPU usage time. However, billing categories can also include allocated RAM, I/O operations per second (IOPS), and storage space. Plan for backup traffic and disaster recovery traffic to determine the bandwidth needed.

Billing at the user or organization level.

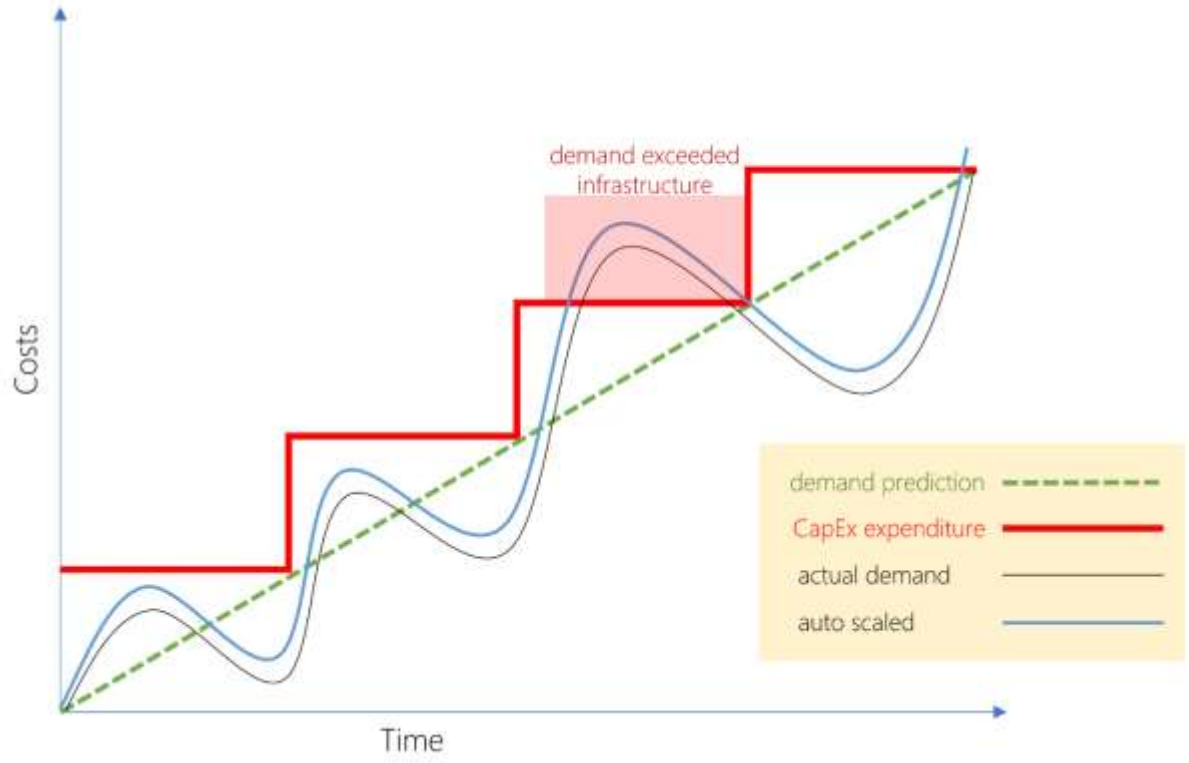
The subscription (pay-per-use) model is a computing billing method that is designed for both organizations and users. The organization or user is billed for the services used, typically on a recurring basis. You can scale, customize, and provision computing resources, including software, storage, and development platforms. For example, when using a dedicated cloud service, you could pay based on server hardware and usage.

Benefits of CapEx

With capital expenditures, you plan your expenses at the start of a project or budget period. Your costs are fixed, meaning you know exactly how much is being spent. This is appealing when you need to predict the expenses before a project starts due to a limited budget.

Benefits of OpEx

Demand and growth can be unpredictable and can outpace expectation, which is a challenge for the CapEx model as shown in the following graph.



Graph shows costs versus time, with time on the horizontal axis. Lines are plotted for demand prediction, actual demand costs, capital expenditure costs, and auto scaled costs. The demand prediction goes up linearly over time. Actual costs form an increasing sine wave style plotting. Capital expenditure costs go up in a stairstep shape as infrustructure is added to meet exceeded actual demand. Auto scaled costs nearly align to the sine wave style curve of the actual demand.

With the OpEx model, companies wanting to try a new product or service don't need to invest in equipment. Instead, they pay as much or as little for the infrastructure as required.

OpEx is particularly appealing if the demand fluctuates or is unknown. Cloud services are often said to be *agile*. Cloud agility is the ability to rapidly change an IT infrastructure to adapt to the evolving needs of the business. For example, if your service peaks one month, you can scale to demand and pay a larger bill for the month. If the following month the demand drops, you can reduce the used resources and be charged less. This agility lets you manage your costs dynamically, optimizing spending as requirements change.

Cloud Deployment models

There are three different cloud deployment models. A cloud deployment model defines where your data is stored and how your customers interact with it – how do they get to it, and where do the applications run? It also depends on how much of your own infrastructure you want or need to manage.

Explore the three deployment methods of cloud computing

Public versus Private versus Hybrid

Public cloud

This is the most common deployment model. In this case, you have no local hardware to manage or keep up-to-date – everything runs on your cloud provider's hardware. In some cases, you can save additional costs by sharing computing resources with other cloud users.

Businesses can use multiple public cloud providers of varying scale. Microsoft Azure is an example of a public cloud provider.

Advantages

- High scalability/agility – you don't have to buy a new server in order to scale
- Pay-as-you-go pricing – you pay only for what you use, no CapEx costs
- You're not responsible for maintenance or updates of the hardware
- Minimal technical knowledge to set up and use - you can leverage the skills and expertise of the cloud provider to ensure workloads are secure, safe, and highly available

A common use case scenario is deploying a web application or a blog site on hardware and resources that are owned by a cloud provider. Using a public cloud in this scenario allows cloud users to get their website or blog up quickly, and then focus on maintaining the site without having to worry about purchasing, managing or maintaining the hardware on which it runs.

Disadvantages

Not all scenarios fit the public cloud. Here are some disadvantages to think about:

- There may be specific security requirements that cannot be met by using public cloud
- There may be government policies, industry standards, or legal requirements which public clouds cannot meet
- You don't own the hardware or services and cannot manage them as you may want to
- Unique business requirements, such as having to maintain a legacy application might be hard to meet

Private cloud

In a private cloud, you create a cloud environment in your own datacenter and provide self-service access to compute resources to users in your organization. This offers a simulation of a

public cloud to your users, but you remain completely responsible for the purchase and maintenance of the hardware and software services you provide.

Advantages

This approach has several advantages:

- You can ensure the configuration can support any scenario or legacy application
- You have control (and responsibility) over security
- Private clouds can meet strict security, compliance, or legal requirements

Disadvantages

Some reasons teams move away from the private cloud are:

- You have some initial CapEx costs and must purchase the hardware for startup and maintenance
- Owning the equipment limits the agility - to scale you must buy, install, and setup new hardware
- Private clouds require IT skills and expertise that's hard to come by

A use case scenario for a private cloud would be when an organization has data that cannot be put in the public cloud, perhaps for legal reasons. An example scenario may be where government policy requires specific data to be kept in-country or privately.

A private cloud can provide cloud functionality to external customers as well, or to specific internal departments such as Accounting or Human Resources.

Hybrid cloud

A hybrid cloud combines public and private clouds, allowing you to run your applications in the most appropriate location. For example, you could host a website in the public cloud and link it to a highly secure database hosted in your private cloud (or on-premises datacenter).

This is helpful when you have some things that cannot be put in the cloud, maybe for legal reasons. For example, you may have some specific pieces of data that cannot be exposed publicly (such as medical data) which needs to be held in your private datacenter. Another example is one or more applications that run on old hardware that can't be updated. In this case, you can keep the old system running locally, and connect it to the public cloud for authorization or storage.

Advantages

Some advantages of a hybrid cloud are:

- You can keep any systems running and accessible that use out-of-date hardware or an out-of-date operating system
- You have flexibility with what you run locally versus in the cloud
- You can take advantage of economies of scale from public cloud providers for services and resources where it's cheaper, and then supplement with your own equipment when it's not
- You can use your own equipment to meet security, compliance, or legacy scenarios where you need to completely control the environment

Disadvantages

Some concerns you'll need to watch out for are:

- It can be more expensive than selecting one deployment model since it involves some CapEx cost up front
- It can be more complicated to set up and manage

Summary

Cloud computing is flexible and gives you the ability to choose how you want to deploy it. The cloud deployment model you choose depends on your budget, and on your security, scalability, and maintenance needs.

Types of Cloud Services

When talking about cloud computing, there are three major categories. It's important to understand them because they are used in conversation, documentation, and training.

Explore the three categories of cloud computing

IaaS versus PaaS versus SaaS

Infrastructure as a service (IaaS)

Infrastructure as a Service is the most flexible category of cloud services. It aims to give you the most control over the provided hardware that runs your application (IT infrastructure servers and virtual machines (VMs), storage, and operating systems). Instead of buying hardware, with IaaS, you rent it. It's an instant computing infrastructure, provisioned and managed over the internet.

Note

When using IaaS, ensuring that a service is up and running is a shared responsibility: the cloud provider is responsible for ensuring the cloud infrastructure is functioning correctly; the cloud customer is responsible for ensuring the service they are using is configured correctly, is up to date, and is available to their customers. This is referred to as the **shared responsibility model**.

IaaS is commonly used in the following scenarios:

- **Migrating workloads.** Typically, IaaS facilities are managed in a similar way as on-premises infrastructure and provide an easy migration path for moving existing applications to the cloud.
- **Test and development.** Teams can quickly set up and dismantle test and development environments, bringing new applications to market faster. IaaS makes scaling development and testing environments, fast and economical.
- **Storage, backup, and recovery.** Organizations avoid the capital outlay and complexity of storage management, which typically requires skilled staff to manage data and meet legal and compliance requirements. IaaS is useful for managing unpredictable demand and steadily growing storage needs. IaaS can also simplify the planning and management of backup and recovery systems.

Platform as a service (PaaS)

PaaS provides an environment for building, testing, and deploying software applications. The goal of PaaS is to help you 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.

PaaS is a complete development and deployment environment in the cloud, with resources that enable organizations to deliver everything from simple cloud-based apps to sophisticated cloud-enabled enterprise applications. Resources are purchased from a

cloud service provider on a pay-as-you-go basis and accessed over a secure Internet connection.

PaaS is commonly used in the following scenarios:

- **Development framework.** PaaS provides a framework that developers can build upon to develop or customize cloud-based applications. Just like Microsoft Excel macro, PaaS lets developers create applications using built-in software components. Cloud features such as scalability, high-availability, and multi-tenant capability are included, reducing the amount of coding that developers must do.
- **Analytics or business intelligence.** Tools provided as a service with PaaS allow organizations to analyze and mine their data. They can find insights and patterns, and predict outcomes to improve business decisions such as forecasting, product design, and investment returns.

Software as a service (SaaS)

SaaS is software that is centrally hosted and managed for the end customer. It is usually based on an architecture where one version of the application is used for all customers, and licensed through a monthly or annual subscription. Office 365, Skype, and Dynamics CRM Online are perfect examples of SaaS software.

Cost and Ownership

TABLE 1

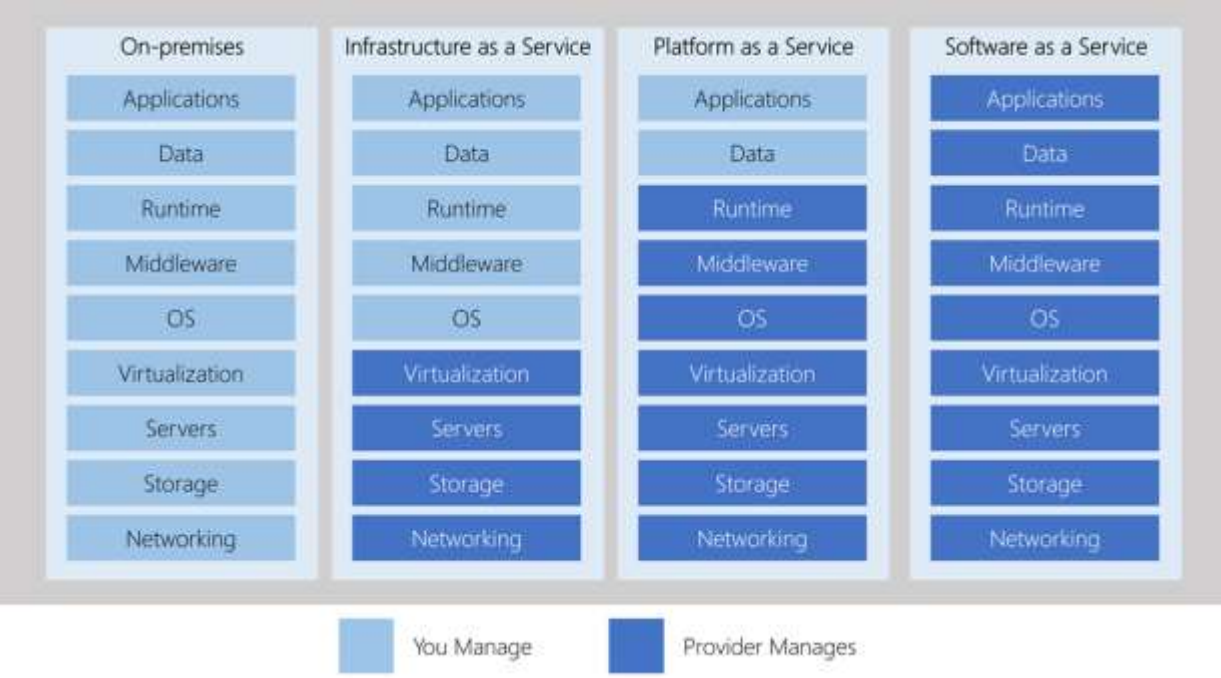
	IaaS	PaaS	SaaS
Upfront costs	There are no upfront costs. Users pay only for what they consume.	There are no upfront costs. Users pay only for what they consume.	Users have no upfront costs; they pay a subscription, typically on

TABLE 1

	IaaS	PaaS	SaaS
			a monthly or annual basis.
User ownership	The user is responsible for the purchase, installation, configuration, and management of their own software, operating systems, middleware, and applications.	The user is responsible for the development of their own applications. However, they are not responsible for managing the server or infrastructure. This allows the user to focus on the application or workload they want to run.	Users just use the application software; they are not responsible for any maintenance or management of that software.
Cloud provider ownership	The cloud provider is responsible for ensuring that the underlying cloud infrastructure (such as virtual machines, storage, and networking) is available for the user.	The cloud provider is responsible for operating system management, network, and service configuration. Cloud providers are typically responsible for everything apart from the application that a user wants to run. They provide a complete managed platform on which to run the application.	The cloud provider is responsible for the provision, management, and maintenance of the application software.

Management responsibilities

One thing to understand is that these categories are layers on top of each other. For example, PaaS adds a layer on top of IaaS by providing a level of abstraction. The abstraction has the benefit of hiding the details that you may not care about, so that you can get to coding quicker. However, one aspect of the abstraction is that you have less control over the underlying hardware. The following illustration shows a list of resources that you manage and that your service provider manages in each cloud service category.



First column, on-premises, shows all elements managed by you. Second, infrastructure as a service, moves virtualization, servers, storage, and networking to the cloud provider. Third, platform as a service, moves runtime, middleware, and OS to the cloud provider. And fourth, software as a service, moves all elements to the cloud provider, with applications and data being the last elements moving.

- IaaS requires the most user management of all the cloud services. The user is responsible for managing the operating systems, data, and applications.
- PaaS requires less user management. The cloud provider manages the operating systems, and the user is responsible for the applications and data they run and store.
- SaaS requires the least amount of management. The cloud provider is responsible for managing everything, and the end user just uses the software.

Combine cloud services to fit your needs

IaaS, PaaS, and SaaS each contain different levels of managed services. You may easily use a combination of these types of infrastructure. You could use Office 365 on your company's computers (SaaS), and in Azure, you could host your VMs (IaaS) and use Azure SQL Database (PaaS) to store your data. With the cloud's flexibility, you can use any combination that provides you with the maximum result.