

2.1 Introduction and Benefits of Cloud Services

- Cloud services refers to a wide range of services delivered on demand to companies and customers over the Internet. Cloud services are fully managed by cloud computing vendors and service providers. They are made available to customers from the providers' servers, so there is no need for a company to host applications on its own on-premises servers.
- Services that a provider makes available to customers over the web are referred to as public cloud services. The SaaS, IaaS and PaaS are all providing public cloud-based services.
- Services that a provider does not make generally available to corporate users or subscribers are referred to as private cloud services. With a private cloud services model, apps and data are made available through the organization's own internal infrastructure.
- In a hybrid cloud environment, a private cloud solution is combined with public cloud services. This arrangement is often used when an organization needs to store sensitive data in the private cloud, but wants employees to access apps and resources in the public cloud for day-to-day communication and collaboration. Proprietary software is used to enable communication between the cloud services, often through a single IT management console.
- Examples of SaaS cloud service providers include Dropbox, G Suite, Microsoft Office 365.
- Examples of IaaS are Amazon Web Services (AWS), Microsoft Azure and Google Compute Engine.

Benefits :

1. Flexibility : Cloud computing lets users' access files using web-enabled devices such as smartphones and laptops.
2. Cloud brings a new level of portability for your data.
3. Remotely update and synchronize files.
4. Lowered costs : Many cloud services are provided on a monthly or annual subscription basis, eliminating the need to pay for on-premises software licenses.

2.2 Software as a Service

- Software as a Service (SaaS) is a way of delivering applications over the Internet. SaaS applications are sometimes called web-based software, on-demand software or hosted software.

- SaaS is closely related to the Application Service Provider (ASP) and on-demand computing software delivery models where the provider hosts the customer's software and delivers it to approved end users over the internet.
- Fig. 2.2.1 shows SaaS.

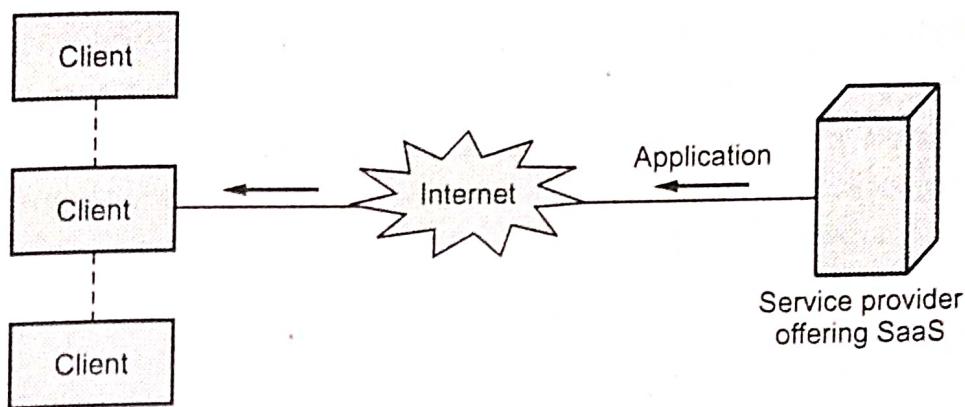


Fig. 2.2.1 SaaS

- Model in which an application is hosted as a service to customers who access it via the Internet.
- The provider does all the patching and upgrades as well as keeping the infrastructure running.
- The traditional model of software distribution, in which software is purchased for and installed on personal computers, is referred to as product.
- In this model, the user, client or consumer runs an application from a cloud infrastructure. Though an interface such as a web browser, the client or user may access this application from a variety of devices.
- The complete application is offered as on demand service. This saves the client from having to invest in any software licenses or servers up front and can save the provider money since they are maintaining and providing only a single application.
- In this model, the client does not manage cloud infrastructure, networks or servers, storage or operating systems. Even, Microsoft, Google and Zoho offer SaaS.
- The SaaS concept can be defined as providing robust "web-based, on-demand software, storage and various applications to organizations."
- The SaaS model has emerged as an alternative to traditional one-time licensing for providing and maintaining the software needed by knowledge workers within organizations.

2.2.1 Characteristics of SaaS

1. Software applications or services are stored remotely.
2. A user can then access these services or software applications via the Internet.
3. In most cases, a user does not have to install anything onto their host machine, all they require is a web browser to access these services and in some cases, a browser may require additional plug-in/add-on for certain services.
4. Network-based management and access to commercially available software from central locations rather than at each customer's site, enabling customers to access applications remotely via the Internet.
5. Application delivery from one to many model, as opposed to a traditional one to one model.

2.2.2 Multitenant Nature of SaaS

- In order to achieve cost efficiencies in delivering same applications to various sets of users it is a vital and obvious choice that an increasing number of applications are Multi-tenant instead of single tenant.
- Multi-tenant application should be able to satisfy the needs of multiple sub-organizations or sections within the organization (multiple tenants), using the single, shared stake of software and hardware.
- Fig. 2.2.2 shows multi-tenant organization.
- A traditional static application is not capable of addressing unique challenges of multi-tenancy.
- A Multi-tenant application should be dynamic in nature, or polymorphic, to fulfill the specific expectations of various tenants and their users.
- Application components need to be generated at runtime from meta-data-i.e. data about the application itself.

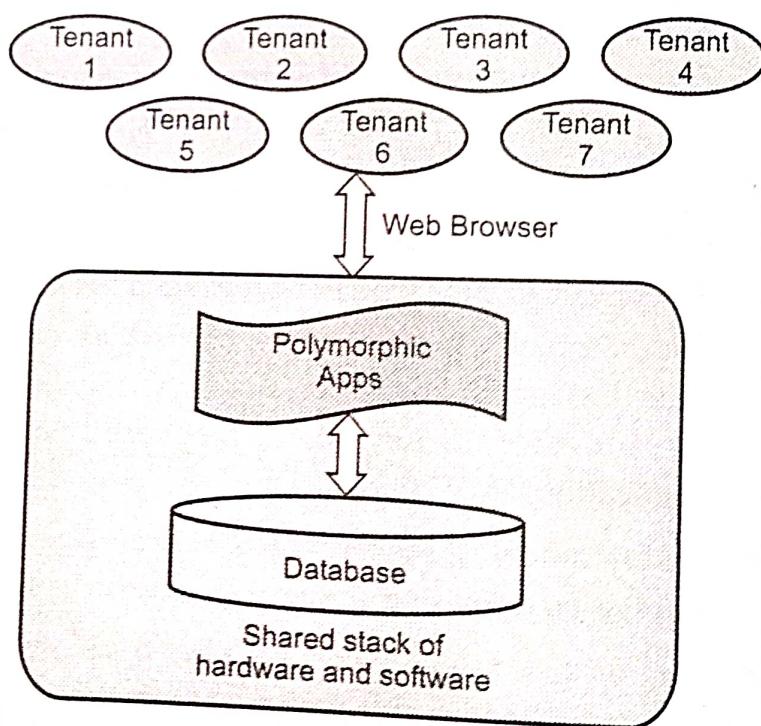


Fig. 2.2.2 Multi-tenant organization

- When tenants create custom application entities (i.e., custom tables), programmatically need to track of Meta-data concerning the entities, their Attribute, relationships and other entity definition characteristics.
- A few large database tables store the structured and unstructured data separately for all virtual tables and a set of related, specialized pivot tables in order to maintain data that makes the combined data set fully functional.
- A multi-tenant cloud is a cloud computing architecture that allows customers to share computing resources in a public or private cloud. Each tenant's data is isolated and remains invisible to other tenants.
- It allows multiple users to work in a software environment at the same time, each with their own separate user interface, resources and services.
- The multitenant application design was created to enable multiple users (tenants) to access the same application logic simultaneously.
- Tenants can individually customize features of the application, such as :
 - User Interface** : Tenants can define a specialized look for their application interface.
 - Business Process** : Tenants can customize the rules, logic and workflows of the business processes that are implemented in the application.
 - Data Model** : Tenants can extend the data schema of the application to include, exclude, or rename fields in the application data structures.
 - Access Control** : Tenants can independently control the access rights for users and groups.
- Benefits of a Multitenancy technology :
 - Costs savings** : It yields tremendous economy of scale for the provider so he can offer the service at a lower cost to customers.
 - Improved quality, user satisfaction and customer retention** : A multitenant application is one large community hosted by the provider which can gather operational information from the collective user population and make frequent, incremental improvements to the service that benefit the entire user community at once.

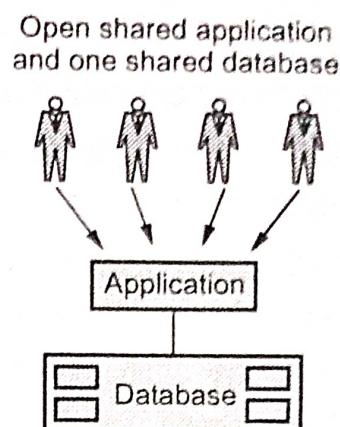


Fig. 2.2.3 Multi-tenant technology

- 3. **Improved security** : Most current enterprise security models are perimeter-based, making them vulnerable to inside attacks.
- Common characteristics of multitenant applications are as follows :
 1. **Usage Isolation** - The usage behavior of one tenant does not affect the application availability and performance of other tenants.
 2. **Data Security** - Tenants cannot access data that belongs to other tenants.
 3. **Recovery** - Backup and restore procedures are separately executed for the data of each tenant.
 4. **Application Upgrade** - Tenants are not negatively affected by the synchronous upgrading of shared software artifacts.
 5. **Scalability** - The application can scale to accommodate increases in usage by existing tenants and/or increases in the number of tenants.
 6. **Metered Usage** - Tenants are charged only for the application processing and features that are actually consumed.
 7. **Data Tier Isolation** - Tenants can have individual databases, tables and schemas isolated from other tenants.

2.2.3 Benefits of SaaS

1. User only pay for what they use.
2. Easier administration and invoicing.
3. Automatic updates and patch management.
4. Compatibility : All users have access to the same version of software.
5. Easier collaboration.
6. It support automated update and patch management services.

2.2.4 Applications

- SaaS products are also diverse, ranging from video streaming services to IT business analytics tools.
- There are SaaS applications for fundamental business applications such as email, sales management, customer relationship management, financial management, Human Resource Management (HRM), billing and collaboration.
- The most widely used online services such as Google, Facebook and Twitter are all examples of Software as a Service, as anyone can access these applications as long as they have an internet connection.

2.3 Platform as a Service

- Platform as a service is another application delivery model and also known as **cloud-ware**. Supplies all the resources required to build applications and services completely from the Internet, without having to download or install software.
- Services include : Application design, development, testing, deployment and hosting, team collaboration, web service integration, database integration, security, scalability, storage, state management and versioning.
- PaaS is closely related to SaaS but delivers a platform from which to work rather than an application to work with.
- This model involves software encapsulated and offered as a service, from which higher levels of service may then be built. The user, customer or client in this model is the one building applications which then run on the provider's infrastructure.
- This in turn provides customers and clients with the capability to deploy applications onto the cloud infrastructure using programming tools and languages, which the provider supports.
- The customer still does not manage the framework, network, servers or operating system, but has control over deployed applications and sometimes over the hosting environment itself.
- Some examples of Platform as a Service include Google's App Engine or Force.com
- PaaS consists of following components :
 1. Browser based development studio.
 2. Pay contrary to billing.
 3. Management and supervising tools.
 4. Seamless deployment to host run time environment.

2.3.1 Characteristics

1. It support multi-tenant architecture.
2. It support for development of group collaboration.
3. PaaS systems can be deployed as public cloud services or as private cloud services.
4. Provision of runtime environments. Typically each runtime environment supports either one or a small set of programming languages and frameworks.
5. Support for custom applications. Support for the development, development, deployment and operation of custom application.

6. Preconfigured capabilities. Many PaaS systems are characterized by capabilities that are preconfigured by the provider, with a minimum of configuration available to developers and customer operations staff.
7. Support for porting existing applications. While many PaaS systems are primarily designed to support "born on the cloud" applications.
8. Security is an important characteristic in PaaS. It needs to provide authentication and authorization to differentiate the access rights of different users.

2.3.2 Benefits of PaaS

1. Scalability including rapid allocation and deallocation of resources with a pay-as-you use model.
2. Reduced capital expenditure.
3. Reduced lead time with on-demand availability of resources.
4. Self-service with reduced administration costs.
5. Reduced skill requirements.
6. Support of team collaboration.
7. Ability to add new users quickly.

2.3.3 Application of PaaS

- Used in development and management of API. PaaS makes it much simpler for teams to develop, run, manage and secure application programming interfaces for sharing data and functionality between applications.
- PaaS can support a range of programming languages, tools and application environments used for IoT application development and real-time processing of data generated by IoT devices.
- PaaS can simplify migration of existing applications to the cloud particularly via re-platforming.
- PaaS can provide fully-configured environments for automating the software application lifecycle including integration, delivery, security, testing and deployment.

2.4 Infrastructure as a Service (IaaS)

- IaaS gives the storage room likeness to the in-house datacenter stood out from various organizations sorts.
- Center datacenter framework segments are capacity, servers (registering units), the system itself and administration apparatuses for foundation upkeep and checking.

- Each of these parts has made a different market specialty. While some little organizations have practical experience in just a single of these IaaS cloud specialties, vast cloud suppliers like Amazon or Right Scale have offerings over all IaaS territories.
- Fig. 2.4.1 shows IaaS.

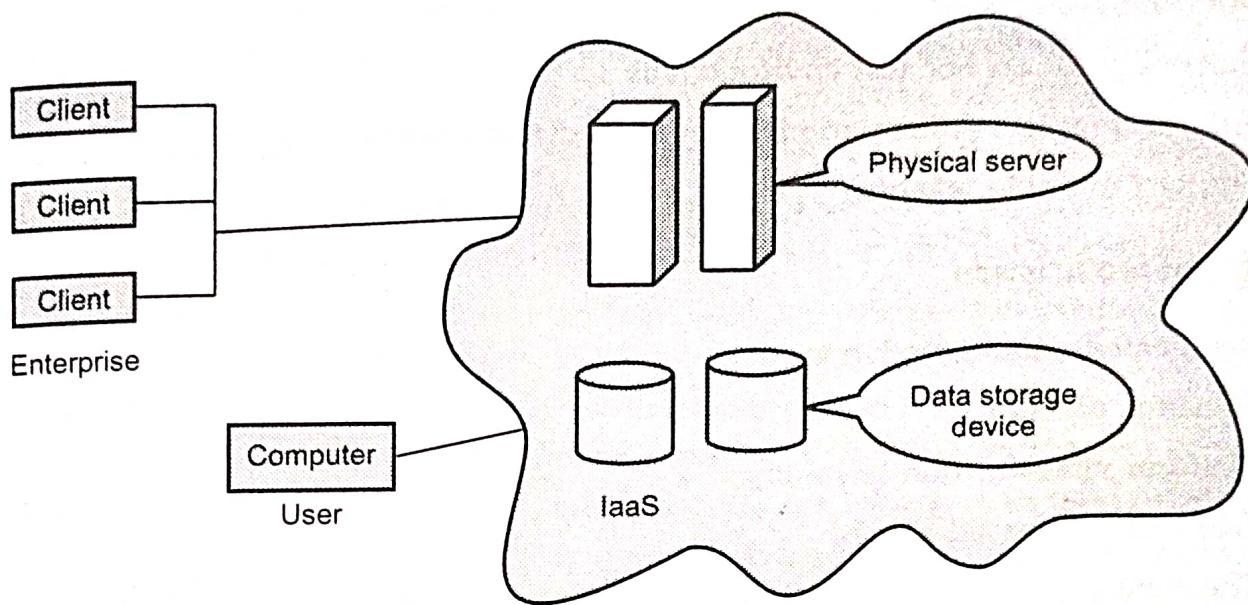


Fig. 2.4.1 IaaS

- It offers the hardware so that your organization can put whatever they want onto it. Rather than purchase servers, software, racks and having to pay for the datacenter space for them, the service provider rents those resources :
 1. Server space
 2. Network equipment
 3. Memory
 4. CPU cycles
 5. Storage space
- Again, the customer is not managing cloud infrastructure, but in this case, the customer does control operating systems, deployed applications, storage and sometimes-certain networking components.
- Examples : Amazon EC2, Rackspace Mosso, GoGrid
- IaaS server types :
 1. **Physical server** : Actual hardware is allocated for the customer's dedicated use.
 2. **Dedicated virtual server** : The customer is allocated a virtual server, which runs on a physical server that may or may not have other virtual servers.
 3. **Shared virtual server** : The customer can access a virtual server on a device that may be shared with other customers.

Advantages of IaaS :

1. Elimination of an expensive and staff-intensive data center.
2. Ease of hardware scalability.
3. Reduced hardware cost.
4. On-demand, pay as you go scalability.
5. Reduction of IT staff.
6. Suitability for ad hoc test environments.
7. Allows complete system administration and management.
8. Support multiple tenants.

2.4.1 Characteristics

- Automated administrative tasks.
- Dynamic scaling.
- Platform virtualization technology.
- GUI and API-based access.
- The company retains full control over its infrastructure.

2.4.2 Benefits and Disadvantages

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Disadvantages

1. Requires internal training.
2. Even though the infrastructure can be fully managed by the company, IaaS services are still vulnerable to security.
3. Legacy systems that operate in the cloud.

2.5 Network as a Service (NaaS)

- NaaS is a cloud model that enables users to easily operate the network and achieve the outcomes they expect from it without owning, building or maintaining their own infrastructure.
- Virtualization technology provides a platform for NaaS, which is related to other cloud services. Services are offered by cloud service providers in addition to NaaS include software-as-a-service, a computing platform for developing or hosting applications, known as platform-as-a-service; or an entire networking or computing infrastructure, known as Infrastructure-as-a-service.
- Cloud services such as NaaS and Paas are provided by building a large, scalable infrastructure that can be virtualized so that it can be sold to individual customers.
- Network-as-a-service goes hand in hand with network virtualisation technologies such as SDN (Software-Defined Networking) and NFV (Network Functions Virtualisation). It also incorporates machine learning technologies for real-time monitoring and automated alert management and threat detection.
- There are three primary services under the NaaS umbrella :
 - a) Virtual Private Networks (VPN) : NaaS extends a VPN and the resources contained in the network across other networks, like the public Internet. A VPN is only a point-to-point connection; from a remote worker's laptop to the company network.
 - b) Bandwidth on Demand (BoD) : A technique by which network capacity is assigned based on requirements between different nodes or users.
 - c) Mobile network virtualization : This is a model where a telecommunications manufacturer or independent network operator many of whom are NaaS providers builds and operates a network and sells its communication access capabilities to third parties.

2.6 Identity as a Service (IDaaS)

- Identity as a Service (IDaaS) is cloud-based authentication operated by a third-party provider.
- Identity as a service (IDaaS) are SaaS-based identity and access management (IAM) offerings that allow organizations to use single sign-on (SSO using SAML or OIDC), authentication and access controls to provide secure access to their growing number of software and SaaS applications.
- Five key capabilities are required to make enterprise IDaaS solutions possible :

1. **Single Sign-on (SSO)** : With single sign-on employees, partners and customers obtain easy, fast and secure access to all SaaS, mobile and enterprise applications with a single authentication using corporate credentials.
 2. **Multi-factor Authentication (MFA)** : MFA typically includes adaptive authentication methods-options to step up as risk increases based on situational changes, user behavior or application sensitivity.
 3. **Access Security** : Access security is policy-based access management for applications and APIs to enhance security beyond SSO.
 4. **Directory** : While most enterprises prefer to integrate IDaaS with their existing user stores, they may use a cloud directory, especially to support customers and/or partners.
 5. **Provisioning** : Through SCIM support and integration with on-premises provisioning, user data is synced with web and enterprise applications.
- IDaaS supplies cloud-based authentication or identity management to enterprises who subscribe. The goal is to ensure users are who they claim to be and to give them the right kinds of access to software applications, files, or other resources at the right times. If the infrastructure to make this happen is built on site, then the company has to figure out what to do every time a problem comes up.

Advantages of IDaaS :

1. Deliver access services efficiently and cost-effectively.
2. Protect against internal and external security threats.
3. With IDaaS, costs drop to the subscription fee and the administration work.
4. Your team has to keep up servers; purchase, upgrade and install software; back up data regularly; pay hosting fees.

2.7 Database as a Service (DbaaS)

- DBaaS is a cloud computing service that lets users access and use a cloud database system without purchasing and setting up their own hardware, installing their own database software or managing the database themselves. It is also known as managed database service.
- DBaaS is a cost-efficient solution for organizations looking to set up and scale databases, especially when operating large-scale, complex and distributed app components. Fig. 2.7.1 shows architecture of DBaaS.

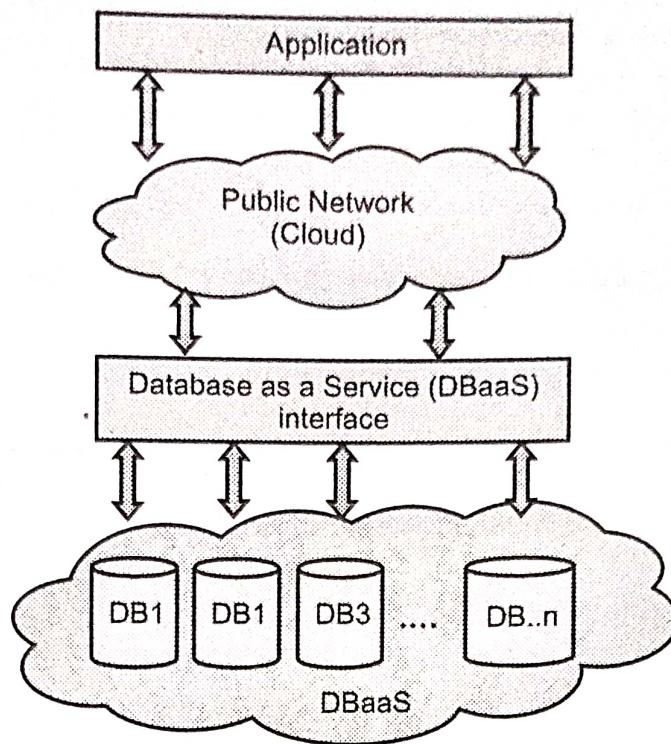


Fig. 2.7.1 Architecture of DbaaS

- Depending on the service, the DBaaS service can be a managed front-end SaaS service or a component of the comprehensive infrastructure as a service or platform as a service stack.
- MongoDB Atlas is a non-relational database hosted on your cloud platform of choice. The database can be deployed on Amazon Web Services (AWS), Microsoft Azure or Google Cloud Platform (GCP) to match your corporate cloud specifications and strategy.
- Advantages of using DBaaS / Cloud database
 - a) Highly scalable : Very large data storage capacity.
 - b) Cost-effectiveness : The cost of hardware and networking is eliminated.
 - c) The cloud can provide a low-cost alternative to investing in infrastructure to manage it all on their own sites.
 - d) Database licensing and renewal cost is borne by the service provider and the business need not invest in that.
 - e) Data security and business continuity are also taken care of by the service provider.

- Disadvantages of using DBaaS
 - a) No direct access control to the database.
 - b) No control on the physical safety of the servers.
 - c) Not suitable for smaller companies or mid-size databases.

2.8 Comparison of IaaS, PaaS and SaaS Cloud Services

IaaS	PaaS	SaaS
IaaS gives users automated and scalable environments. Amazon Web Services, for example, offers IaaS through the Elastic Compute Cloud or EC2. In IaaS, infrastructure as a service. Virtual platform on which required operating environment and application deployed. IaaS is a cloud service that provides basic computing infrastructure : Servers, storage, and networking resources. In other words, IaaS is a virtual data center. Major IaaS providers include Amazon Web Services, Microsoft Azure and Google Compute Engine. IaaS services are available on a pay-for-what-you-use model. Used by IT administrator.	PaaS provides a framework for quickly developing and deploying applications. Google Cloud Platform provides another PaaS option in App Engine. In Paas, platform as a service. Operating environment was included. PaaS refers to cloud platforms that provide runtime environments for developing, testing and managing applications. Examples of PaaS services are Heroku and Google App Engine. PaaS solutions are available with a pay-as-you-go pricing model. Used by software developers.	SaaS makes applications available through the internet. SaaS applications such as Gmail, Dropbox, Salesforce or Netflix. In SaaS, software as a service. Operating environment largely irrelevant, fully functional application provided. SaaS allows people to use cloud-based web applications. email services such as Gmail and Hotmail are examples of cloud-based SaaS services. SaaS services are usually available with a pay-as-you-go pricing model. Used by end user.

