Cloud Computing Course

What is Cloud Computing?

Cloud computing is ubiquitous. It is the most talked about topic nowadays. Businesses talk about adopting cloud software and solutions to reduce operational cost. We use emails which are stored somewhere in a remote location. We upload our pictures to a website that stores them in cloud storage (e.g. iCloud). Our files are stored in Amazon Cloud drive. Our videos are uploaded to YouTube. In today's world, it is tough to imagine a scenario where cloud computing has not touched our lives. So what exactly is cloud computing?

Cloud computing is a term used to signify a way of accessing software, infrastructure, and computing power from a location other than our own. The resources usually reside in someone else's computer or distant data centres. Nowadays the reach of cloud computing is so vast that the resources are located in a different country and continent that often we have no clue of the exact location. Think of the emails in your Gmail inbox. The emails do not reside in our computers. Google serves these emails from the servers that reside in any of the data centres located in Americas, Asia, or Europe.

All the elements inside the cloud – applications, platform, and infrastructure – are oblivious to the end users. All the users need is the access devices such as laptops, phones, tablets, etc. and network connectivity to the cloud that is mostly provided by Cloud service providers.

Definitions for Cloud Computing

*Cloud computing is the delivery of computing as a service rather than a product, whereby shared resources, software, and information are provided to computers and other devices as a utility (like the electricity grid) over a network (typically the Internet) – **Wikipedia***

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

The National Institute of Standards and Technology (NIST)

*"Cloud Computing", by definition, refers to the on-demand delivery of IT resources and applications via the Internet with pay-as-you-go pricing. – **Amazon***

*...the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer. – **Google***

According to NIST, the cloud computing model is composed of five essential characteristics, three service models, and four deployment models.

Characteristics	Service Models	Deployment Models
On-demand self-service	Software as a Service (SaaS)	Public Cloud
Broad network access	Platform as a Service (Paas)	Private Cloud
Resource pooling	Infrastructure as a Service	Community Cloud
Rapid elasticity		Hybrid Cloud
Measured service		

Cloud Computing History

Cloud computing is the result of evolution of a number of key technology concepts such as virtualization, grid computing, multi-tenancy, scalability, and the exponential increase in computing power and storage.

Even though the origin of cloud computing is not exactly known, the analogy of cloud computing has been existed since 1950s when mainframe computers became available to perform high-volume computing processing. Mainframes were costly and bulky to use.

Therefore to make more efficient use of them, a practice evolved that allowed a number of thin clients (or static computer terminals) to share the computing power of mainframes. And this is how "resource pooling" and "time-sharing" – key terms associated with cloud computing – came into common parlance.

The 1990s saw telecommunication service providers using virtual private network (VPN) to manage their network bandwidth effectively. Depending on the demand load, they would switch the traffic to the available servers. This process happened at the infrastructure and data centre level without the users being aware of it. The telecommunication service providers began to use the cloud symbol to demarcate the boundary between the network service providers and the users. In other words, it is akin to saying to end users, "You do not need to know where and how you get the network bandwidth as long as it is available to you uninterrupted. Leave it to us." In essence, this is where the concept of Infrastructure-as-a- Service took roots.

The decade of 2000s saw the actual emergence and evolution of Cloud computing to its present form. Scientists and technologists explored ways to extend Cloud computing beyond applications and platforms. Technology companies made major breakthroughs in their Cloud products and services. This decade saw the introduction and popularization of "pay-as-yougo" pricing model. Gartner predicted that Cloud computing would change the relationship between consumers and providers of IT services. It also observed that "organizations are switching from company-owned hardware and software assets to per-use service-based models" so that the "projected shift to computing…will result in dramatic growth in IT products in some areas and significant reductions in other areas."

Major cloud technology innovations were made in this decade. In 2008, OpenNebula came out with open-source software for deploying private and hybrid clouds. In 2008, Rackspace – another major player in Cloud space – launched OpenStack, an open-source cloud software. In 2011, IBM launched SmartCloud framework to support Smarter Planet.

Companies such as Microsoft, Amazon, and Oracle also came out with your own Cloud products and services. Today most of the technology companies have some presence in the Cloud market space. Today Cloud computing has become so ubiquitous that people are no longer talking about the potential or implementation-challenges of Cloud. The talk of the town is how Cloud platforms can be used for the next generation innovations such as Big Data, Internet of Things, Mobility, Analytics, Digitization, and Advanced Research.

Characteristics of Cloud Computing

Cloud computing has a variety of characteristics, with the main ones being:

• Shared Infrastructure — Uses a virtualized software model, enabling the sharing of physical services, storage, and networking capabilities. The cloud infrastructure, regardless of deployment model, seeks to make the most of the available infrastructure across a number of users.

• Dynamic Provisioning — Allows for the provision of services based on current demand requirements. This is done automatically using software automation, enabling the expansion and contraction of service capability, as needed. This dynamic scaling needs to be done while maintaining high levels of reliability and security.

• Network Access — Needs to be accessed across the internet from a broad range of devices such as PCs, laptops, and mobile devices, using standards-based APIs (for example, ones based on HTTP). Deployments of services in the cloud include everything from using business applications to the latest application on the newest smart phones.

• Managed Metering — Uses metering for managing and optimizing the service and to provide reporting and billing information. In this way, consumers are billed for services according to how much they have actually used during the billing period.

Cloud Computing Service Models

Cloud Providers offer services that can be grouped into three categories.

1. Software as a Service (SaaS): In this model, a complete application is offered to the customer, as a service on demand. A single instance of the service runs on the cloud & multiple end users are serviced. On the customers" side, there is no need for upfront investment in servers or software licenses, while for the provider, the costs are lowered, since only a single application needs to be hosted & maintained. Today SaaS is offered by companies such as Google, Salesforce, Microsoft, Zoho, etc.

2. Platform as a Service (Paas): Here, a layer of software, or development environment is encapsulated & offered as a service, upon which other higher levels of service can be built. The customer has the freedom to build his own applications, which run on the provider"s infrastructure. To meet manageability and scalability requirements of the applications, PaaS providers offer a predefined combination of OS and application servers, such as LAMP platform (Linux, Apache, MySql and PHP), restricted J2EE, Ruby etc. Google"s App Engine, Force.com, etc are some of the popular PaaS examples.

3. Infrastructure as a Service (Iaas): IaaS provides basic storage and computing capabilities as standardized services over the network. Servers, storage systems, networking equipment, data centre space etc. are pooled and made available to handle workloads. The customer would typically deploy his own software on the infrastructure. Some common examples are Amazon, GoGrid, 3 Tera, etc.

Cloud Computing Deployment Models

1. Public Cloud

Public clouds are owned and operated by third parties; they deliver superior economies of scale to customers, as the infrastructure costs are spread among a mix of users, giving each individual client an attractive low-cost, "Pay-as-you-go" model. All customers share the same infrastructure pool with limited configuration, security protections, and availability variances. These are managed and supported by the cloud provider. One of the advantages of a Public cloud is that they may be larger than an enterprises cloud, thus providing the ability to scale seamlessly, on demand.

2. Private Cloud

Private clouds are built exclusively for a single enterprise. They aim to address concerns on data security and offer greater control, which is typically lacking in a public cloud. There are two variations to a private cloud:

On-premise Private Cloud: On-premise private clouds, also known as internal clouds are hosted within one''s own data center. This model provides a more standardized process and protection, but is limited in aspects of size and scalability. IT departments would also need to incur the capital and operational costs for the physical resources. This is best suited for applications which require complete control and configurability of the infrastructure and security.

Externally hosted Private Cloud: This type of private cloud is hosted externally with a cloud provider, where the provider facilitates an exclusive cloud environment with full guarantee of privacy. This is best suited for enterprises that don''t prefer a public cloud due to sharing of physical resources.

3. Hybrid Cloud

Hybrid Clouds combine both public and private cloud models. With a Hybrid Cloud, service providers can utilize 3rd party Cloud Providers in a full or partial manner thus increasing the flexibility of computing. The Hybrid cloud environment is capable of providing on-demand, externally provisioned scale. The ability to augment a private cloud with the resources of a public cloud can be used to manage any unexpected surges in workload.

4. Community Cloud

The cloud infrastructure is shared among a number of organizations with similar interests and requirements. This may help limit the capital expenditure costs for its establishment as the costs are shared among the organizations. The operation may be in-house or with a third party on the premises.

Deployment Model	Scope of Services	Managed by	Security Level
Public model	General public and large industry groups	Cloud service provider	low
Private model	Single organization	Single organization	high
Community model	Organization those share the same policy, mission and same security aspects	Several organization or Cloud service providers	high
Hybrid model	Organization and public	Organization and public	medium

Cloud Computing Companies

Many companies are delivering services from the cloud. Some notable examples include the following:

• Google — Has a private cloud that it uses for delivering Google Docs and many other services to its users, including email access, document applications, text translations, maps, web analytics, and much more.

• Microsoft — Has Microsoft® Office 365® online service that allows for content and business intelligence tools to be moved into the cloud and Microsoft currently makes its office applications available in a cloud.

• Salesforce.com — Runs its application set for its customers in a cloud, and its Force.com and Vmforce.com products provide developers with platforms to build customized cloud services.

• Amazon Web Services (AWS) — It provides a cloud computing platform for all business sizes. AWS helps business organization to choose their own computing platform as in need of the organization and pay for what they use. Services provided AWS are:- Amazon Elastic compute cloud, Amazon Simple Storage services,

Amazon Virtual Private Cloud, Amazon Cloud front, Amazon Relational Database and Amazon Simple Queue services.

Communications in the Cloud

For service developers, making services available in the cloud depends on the type of service and the device(s) being used to access it. The process may be as simple as a user clicking on the required web page, or could involve an application using an API accessing the services in the cloud. Telcos are starting to use clouds to release their own services and those developed by others, but using Telco infrastructure and data. The expectation is that the Telco's communications infrastructure provides a revenue generating opportunity.

Using the Communications Services

When in the cloud, communications services can extend their capabilities, or stand alone as service offerings, or provide new interactivity capabilities to current services.
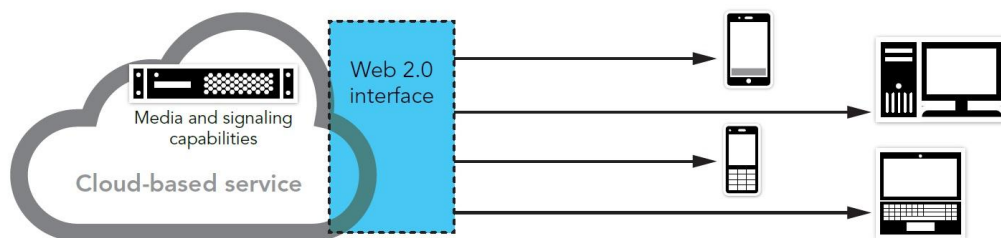
Cloud-based communications services enable businesses to embed communications capabilities into business applications, such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems. For "on the move" business people, these can be accessed through a smartphone, supporting increased productivity while away from the office.

These services are over and above the support of service deployments of VoIP systems, collaboration systems, and conferencing systems for both voice and video. They can be accessed from any location and linked into current services to extend their capabilities, as well as stand alone as service offerings.

In terms of social networking, using cloud-based communications provides click-to-call capabilities from social networking sites, access to Instant Messaging systems and video communications, broadening the interlinking of people within the social circle.

Accessing through Web APIs

Accessing communications capabilities in a cloud-based environment is achieved through APIs, primarily Web 2.0 RESTful APIs, allowing application development outside the cloud to take advantage of the communication infrastructure within it.


These APIs open up a range of communications possibilities for cloud-based services, only limited by the media and signaling capabilities within the cloud. Today's media services allow for communications and management of voice and video across a complex range of codecs and transport types. By using the Web APIs, these complexities can be simplified and the media can be delivered to the remote device more easily. APIs also enable communication of other services, providing new opportunities and helping to drive Average Revenue per User (ARPU) and attachment rates, especially for Telcos.

Media Server Control Interfaces

When building communications capabilities into the "core of the cloud," where they will be accessed by another service, the Web 2.0 APIs can be used, as well as a combination of SIP or VoiceXML and the standard media controlling APIs such as MSML, MSCML, and JSR309. The combinations provide different capability sets, but with MediaCTRL being developed in the Internet Engineering Task Force (IETF), it is expected that MediaCTRL will supersede MSML and MSCML and have an upsurge in availability and more developments after it is ratified. JSR309 is a notable choice for those seeking Java development, as it provides the Java interface to media control.

This is an example of accessing services in the cloud through Web 2.0 and media control interface APIs.
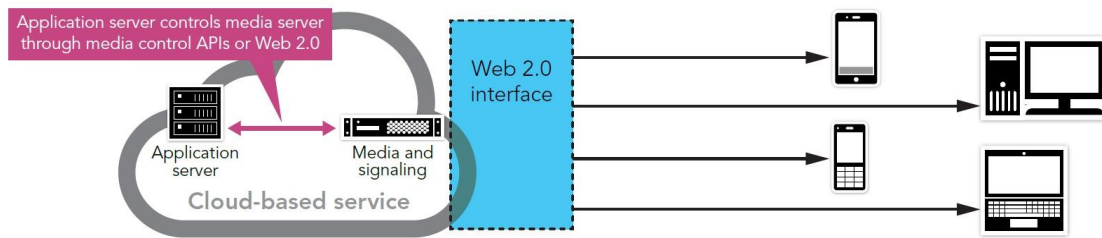
Whether businesses are deploying communications services for access from outside of or within the cloud, the environment is one that supports the speedy development and rollout of these capabilities.

Communications Scalability

To deliver on the scalability requirements for cloud-based deployments, the communications software should be capable of running in virtual environments. This allows for easily increasing and decreasing session densities based on the needs at the time, while keeping the physical resource requirement on servers to a minimum.

Applications of Cloud Computing

Cloud Computing is one of the most dominant field of computing resources online because sharing and management of resources is easy using cloud. These properties have made it an active component in the following fields as follows.

E-Learning

It is a new trend in the field of education that provides an attractive environment for students, faculty members, and researchers. Students, faculty members, researchers can connect to the cloud of their organization and access data and information from there.

Enterprise resource planning (ERP)

Use of Cloud in ERP comes into existence when the business of any organization grows. The work of managing applications, human resources, payroll etc becomes expensive and complex. To overcome it service providers can install ERP in the cloud itself.

E-Governance

Cloud computing can improve the functioning of a government by improving the way it provides the services to its citizens, institutions and cooperation with other governments. This can be done by expanding the availability

of environment, making environment more scalable and customized. It also cut off the burden of managing, installing and upgrading applications.

Application	Services provided
E-learning	E-mail, simulation tools, files broadcasting, class recording, virtual classrooms, virtual labs, surveys, education forums
ERP Cloud	Supply chain and vendor, project and HR Management, customer Relationship management, finance and accounting
E-governance	Complaint resolution system, employee management system, E-police, E-court, payment and tax system, agriculture and food, industry and energy

Benefits of Cloud Computing

The following are some of the possible benefits for those who offer cloud computing-based services and applications:

1. **Cost Savings -** Companies can reduce their capital expenditures and use operational expenditures for increasing their computing capabilities. This is a lower barrier to entry and also requires fewer in-house IT resources to provide system support.
2. **Scalability/Flexibility -** Companies can start with a small deployment and grow to a large deployment fairly rapidly, and then scale back if necessary. Also, the flexibility of cloud computing allows companies to use extra resources at peak times, enabling them to satisfy consumer demands.
3. **Reliability -** Services using multiple redundant sites can support business continuity and disaster recovery.
4. **Maintenance -** Cloud service providers do the system maintenance, and access is through APIs that do not require application installations onto PCs, thus further reducing maintenance requirements.
5. **Mobile Accessible -** Mobile workers have increased productivity due to systems accessible in an infrastructure available from anywhere.

Challenges of Cloud Computing

The following are some of the notable challenges associated with cloud computing, and although some of these may cause a slowdown when delivering more services in the cloud, most also can provide opportunities, if resolved with due care and attention in the planning stages.

1. **Security -** One of the biggest challenges of cloud computing is its perceived security risks. There is a general notion that anything hosted on cloud is not safe and secure; they are vulnerable to hackings and data compromise.
2. **Data Privacy and Integrity -** As users, we are mostly concerned with data privacy. How do we know that our sensitive personal information is not sold by the cloud service provider to a third-party?
3. **Lack of Standards -** Clouds have documented interfaces; however, no standards are associated with these, and thus it is unlikely that most clouds will be interoperable. The Open Grid Forum is developing an Open Cloud Computing Interface to resolve this issue and the Open Cloud Consortium is working on cloud computing standards and practices. The findings of these groups will need to mature, but it is not known whether they will address the needs of the people deploying the services and the specific interfaces these services need. However, keeping up to date on the latest standards as they evolve will allow them to be leveraged, if applicable.

4. **Management Capabilities -** Despite there being multiple cloud providers, the management of platform and infrastructure is still in its infancy. Features like „Auto-scaling" for example, are a crucial requirement for many enterprises. There is huge potential to improve on the scalability and load balancing features provided today.

5. **Disaster Recovery -** It is a concern of enterprises about the resiliency of cloud computing as data may reside in multiple servers and geographical locations. In such a situation, what is the disaster recovery plan if any of the servers go down? What if we lose data at a point in time due to server failure? Organizations therefore are extremely concerned on the disaster recovery plan.

6. **Regulatory and Compliance Restrictions -** In some of the European countries, Government regulations do not allow customer's personal information and other sensitive information to be physically located outside the state or country. In order to meet such requirements, cloud providers need to setup a data center or a storage site exclusively within the country to comply with regulations. Having such an infrastructure may not always be feasible and is a big challenge for cloud providers.

7. **Continuously Evolving -** User requirements are continuously evolving, as are the requirements for interfaces, networking, and storage. This means that a "cloud," especially a public one, does not remain static and is also continuously evolving.

How does Cloud Computing Work?

As mentioned earlier, Cloud computing model is created so that customers pay only for usage; not for investment in hardware, software licenses, upgrades, maintenance fees, and man-power cost to run the service in-house. A major reason for this shift is the increasing commoditization of IT. Internet has become cheaper and available everywhere, cost of IT platforms have reduced substantially, hardware could be commoditized, storage has become cheaper, virtualization technologies have become common and affordable, increasing adoption of open source software, abstraction for the users, and lastly increased standardization of IT. Additionally there has been a constant pressure to cut IT costs (largely because in most organizations, IT is still a cost centre rather than a profit centre).

From an architectural standpoint, Cloud computing includes dynamic delivery of capabilities (or services) in the form of applications (Software as a Service), Platform services (Platform as a Service), and Infrastructure services (Infrastructure as a Service).
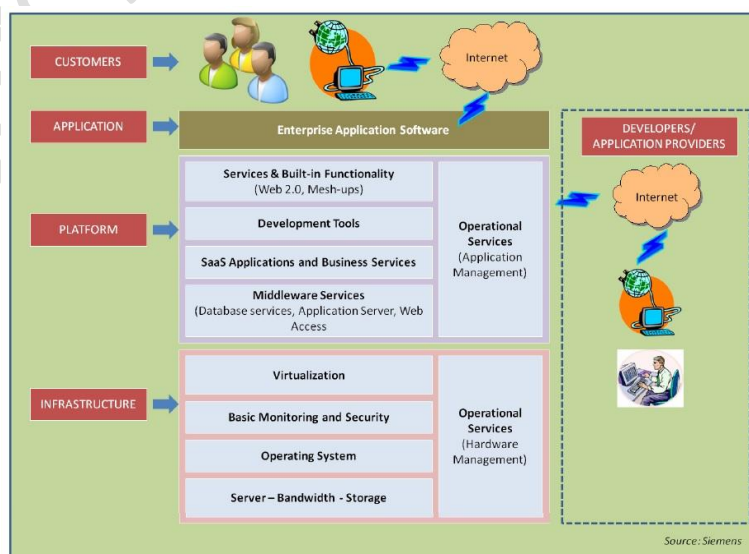
Cloud service provides expose these services mostly through a web interface. All the consumers need to do is have a stable internet connect, and subscribe to these services. Basically they are leasing the services and return them when they no longer need them.

Cloud Computing Pricing Model

The pricing of Cloud Computing is based on amount of resources allocated. This makes Cloud pricing constitute a significant portion of variable pricing. Think of Cloud pricing model similar to the utility services you consume. You pay electricity bill for the number of units you consumed, or the amount of your water consumption bill is proportionate to the amount of consumption. The bill varies as per your consumption. While the pricing of Cloud computing is similar in concept, there is a slight variance as compared to the utility service pricing. The shift from fixed-price model to variable-price model mainly happened due to the fact that not all users have the same need; hence charging them for units they don't consume is not considered fair. Cloud Computing pricing varies according to its various models. A SaaS model will be priced differently than an IaaS model. The table below shows the key components of Cloud pricing based on the Cloud service model.

IaaS	Amount of resource allocated	No. of physical or virtual machines, IP addresses, firewalls, load balancers, virtual machine images, virtual local area networks (VLANs)
PaaS	Usage of Computing platform	Operating systems, hardware, programming language execution environments, servers, and databases.
SaaS	Usage of software applications	No. of software licenses

Cloud computing pricing consists of two main approached – fixed and dynamic. In fixed pricing, the customer the same amount at all times. This includes the pay-per-use model, in which the customers pay for the amount they consume of a product or the amount of time they use a certain service. In dynamic pricing, the pricing varies according to the level of consumption, service features, Quality of Services (QoS), etc. A new pricing model that is being increasingly adopted is the market-dependent pricing; this pricing depends on the real-time market conditions such as bargaining, auctioning, demand behavior, and yield management.

Note the key drivers of Cloud Computing pricing are on-demand self-service, range of network access, speed of elasticity, resource pooling, and quality of service. The most important factors that influence pricing in cloud computing are:

• Initial Costs: This is the initial setup costs the service provider spends to buy resources.

• Contract Period: This is the period the customer will lease resources from the service provider. Longer the contract period, lower is the subscription price.

• Quality of Service: This is the quality of service the service provider guarantees to meet. This is the mostly debated component of Cloud pricing. Better the QoS guaranteed, higher is the pricing.

• Age of resources: This is the age of the resources employed by the service provider. The older the resources are, the lower the price charged will be.

• Cost of maintenance: This is the amount the service provider spends to maintain the cloud service. In general terms, the cloud pricing model consists of three main components: actual cloud pricing approach, Quality of Service (QoS), and Utilization/Contract Period.

As mentioned earlier, Cloud computing pricing models have undergone tremendous innovation and changes in recent years. Partly due to the fact that a Cloud service provider's incoming cash flow may decrease because of consumers' preference for pay-per-use mechanism, industry has come up with various Cloud pricing model. The table below provides a quick summary of these models.

Pricing Model	Approach
Pay-as-you-go model	Price is set by service provider and remains constant
Subscription	Price is based on the period of subscription
A novel-financial economic model	Usage-based
Pay-for-resources model	Cost-based
Pricing algorithm for cloud computing	Real-time pricing
Dynamic resource pricing on federated clouds	Auction-based pricing
Genetic model for pricing in cloud computing markets	Real-time pricing
Datacenter net profit optimization with individual job deadlines	Based on job scheduling
Value-based pricing	Price set according to the value perceived by the customer
Cost-based pricing	Price set by adding a profit element on top of cost
Competition-based pricing	Price set according to competitors' prices
Customer-based pricing	Price set according to what the customer is prepared to pay
Hybrid pricing	Price changed according to the job queue wait times

In short, the underlying theme of Cloud computing pricing is "pay-as-you-go" model. It is advised to prospective consumers of Cloud Computing services that they should negotiate adding Quality of Service (QoS) attributes to the pricing set by Cloud service providers.

This will ensure that the pricing is not biased towards the service provider; and they have a pressure to deliver on consistent performance and Quality of Service.

How to Choose a Cloud Computing Service

Cloud computing is right solution for you depends on various factors:

• **Total Cost of Ownership (TCO)**: Since cost savings is one of the most important decision factors for opting for Cloud solution, it needs to be assessed what impact it would have on the TCO. A thorough TCO analysis needs to be done. It has been observed that the actual value (value realized after adopting Cloud) vs. Perceived value (expected value perceived before adopting Cloud) is quite marginal for some organizations if other non-tangible factors are considered (e.g. data security, implementation ease, support availability, Quality of Service, etc.).

• **Data Security**: Data security is still one of the top fear factors for enterprises. There have been ample evidences of breach of data security in recent years. The high profile Sony hack is now famous in the industry. In 2014, JP Morgan Chase saw 80 million records breached for use of identity theft. In the same year, Apple iCloud was a victim of hacking of major celebrity accounts, leading to the release of private photos and videos to public domain. If your business involves dealing with mission critical accounts and sensitive confidential customer information, conduct proper risk assessment and evaluation of cloud service provider. Perform proper and regular risk assessments to identify where the cloud service provider stores and transmits valuable data. In such cases, opting for private cloud could be a better option than public cloud.

• **Compliance and Governance**: Cloud computing gets increasingly complex (for both Cloud service providers and consumers) when it comes to legal, regulatory and compliance issues. There are a host of regulations to deal with. There are government regulations such as Sarbanes-Oxley and European Union Data Protection Act, and industry regulations such as PCI DSS for payment cards, and HIPAA for healthcare. Additionally there are geo-specific regulations such as country and state laws to deal with. Therefore before embarking on a Cloud solution (for service consumers), evaluate how creating and implementing measures to comply with the regulations is going to add to the existing workload. Check with your service providers where Cloud data centres are located; and ascertain whether the regulations permit storing data outside the country. For example, the EU Data Protection Act mandates keeping personal information within the European Union. If an organization is storing health-related information regardless of which industry it belongs to, then it is subjected to HIPAA. Hence work closely with your cloud service provider to identify all legal and regulatory requirements, and the steps to meet these regulations. Even if you are dealing with a third-party provider, subject them to the same contractual clauses as you would do for your primary supplier. After all, non-compliance could be costly. The Payment Card Industry (PCI) can impose fines of up to $100,000 per month for violations to its compliance.

• **Ease of Integration**: Determine how easy it is to integrate the cloud solution to your existing IT landscape. Check for interoperability with your corporate applications, custom applications, in-house developed solutions, and non-standard interfaces.

• **Service Level Agreements (SLA)**: A carefully-crafted SLA is paramount to receiving the right Quality of Service (QoS). Not that by adopting cloud services, you are giving up control of your ability to manage availability, performance, maintainability, and timely support as you would have with your in-house infrastructure. Therefore negotiate the process, control mechanisms, and SLAs tightly with your service provider to guarantee consistent QoS.

Next Generation Cloud Computing

The next generation of cloud computing will be the confluence of three key cloud capabilities.

(a) ability to build and deploy quickly in Cloud environment (Platform as a Service)

(b) ability to work from anywhere and anytime using cloud solutions (Software as a Service)

(c) availability of host of next generation Cloud services (e.g. Data as a Service).
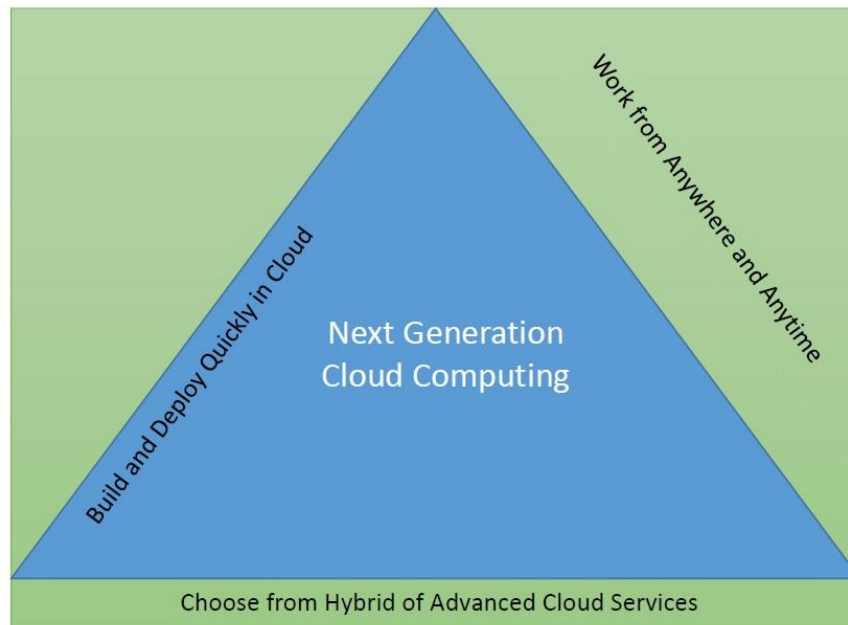
Next generation cloud computing will bring in enormous amount of benefits to end users. End users will increasingly use more personal cloud services such as putting personal data in the cloud. Organizations will realize that employees no longer maintain personal folders in their office workstations; employees just put everything in cloud (e.g. Google drive, Apple iCloud) by leveraging BYOD (Bring Your Own Device) policies that corporates extend. Therefore employers will be compelled to explore ways to incorporate personal cloud services in the enterprise environment.