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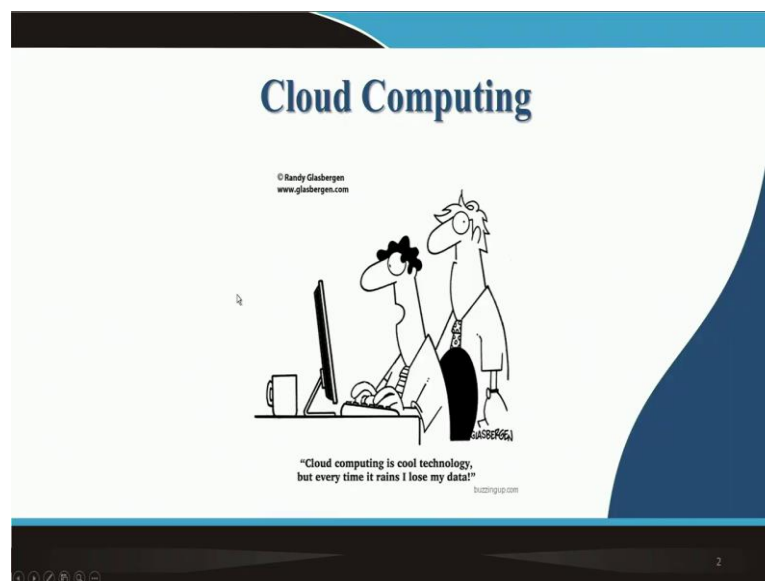
Module – 09
Emerging Technologies
Lecture – 40
Cloud Computing Part – I

Hello, welcome to this particular module on Emerging Technologies! So, you know that; you know so far we have been discussing the existing and the traditional technologies that are there in the world of information systems. So, in this particular module, we will be talking more about emerging technologies that exist in the world of information systems around us.

So, we will be talking about topics related to cloud computing, internet of things, big data, then we will also talk about block chain technology, and briefly about a lot of other technologies that exist around us; today emerging technologies of course, such as you know briefly, we will touch upon virtual reality, augmented reality and so on.

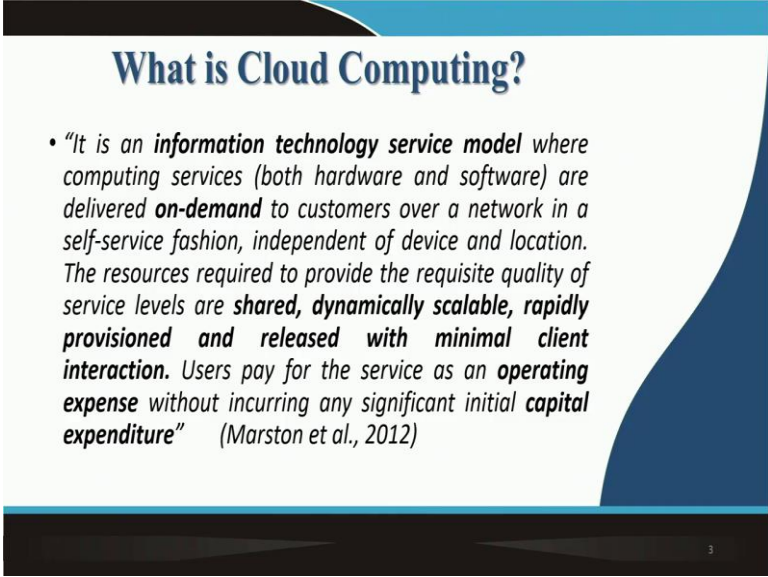
So, today's lecture is about 'cloud computing'. These you know, this lecture and the next one we will be focusing entirely on cloud computing which is a very important technology that is emerging and is in use today.

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So, I do not have much to say about this slide. The graphic itself explains. So, we will move ahead.

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What is Cloud Computing?

- *“It is an **information technology service model** where computing services (both hardware and software) are delivered **on-demand** to customers over a network in a self-service fashion, independent of device and location. The resources required to provide the requisite quality of service levels are **shared, dynamically scalable, rapidly provisioned and released with minimal client interaction**. Users pay for the service as an **operating expense** without incurring any significant initial **capital expenditure**” (Marston et al., 2012)*

3

What is cloud computing? So, you know it is a very important information technology service model. In this particular definition, which I have taken from Marston et al., in 2012, I have actually highlighted certain phrases, so I will be emphasizing on them and explaining them in detail.

It is an information technology service model where computing services which includes both hardware and software are delivered on-demand to customers over a network in a self-service fashion, independent of device and location.

So, why did we mention that you know both software and hardware are delivered on-demand to customers because in cloud computing, customers need not maintain any infrastructure on; of their own or they need not maintain hardware on their own, software on their own; right. They can procure all of these things as and when required over the cloud or from the service provider. So that is why we use the term on-demand; and it is of course, independent of service and location.

Therefore, cloud computing can be accessed you know your software of the cloud or maybe a hardware of the cloud or storage space of the cloud can be accessed from any

device and from any location. So, there are no restrictions with respect to device and location.

The resources required to provide the requisite quality of service levels are shared, dynamically scalable, rapidly provisioned and released with minimal client interaction. What this means is the services are shared. So, if you are talking about a public cloud in which you know you are sharing services. So, if you are a client and you are accessing the services of cloud services of a service provider, you would of course share the services with a lot of other clients. So, services are generally shared.

Leave you know leaving aside private cloud in which services are not shared, we will talk about it later, but that is of course an exception, but predominantly organizations when we talk about when organizations talk about cloud computing, they imply public cloud which is in which you share services along with several other clients.

Dynamically scalable means that you know as and when required you can avail services of the cloud. So, if at a period in time you require more services, you can obtain that and subsequently if you require less say you require less storage space or you require less processing capability you can of course, obtain less that depends on your relationship with the service provider.

Rapidly provisioned means that as in you know as soon as you require, the cloud service provider can provide you the services and finally, released with minimal client interaction. So, if you have to maintain an on premise say computing infrastructure, you would it would take a lot of time, and at the same time you would have to have a lot of in-house expertise.

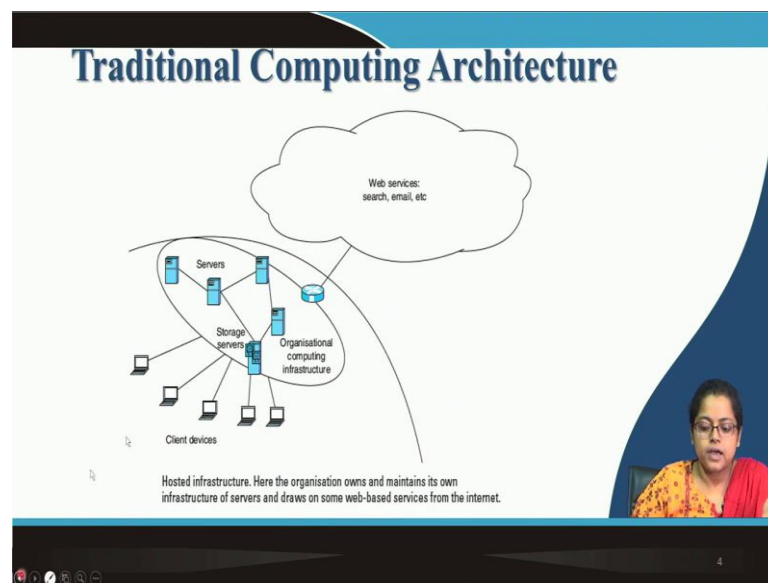
But in case of you know procuring services of the cloud, you it is rapidly provisioned and it is released with minimal client interaction. You do not require a dedicated in-house IT team. One or two people in-house who communicate with the service provider are enough.

Users pay for the service as an operating expense without incurring any significant initial capital expenditure, which means that if a user is availing services of the cloud, users pay as an operating expense as a day-to-day expense, they do not have to purchase or make any initial capital expenditure. They do not have to purchase any hardware, they do not

have to purchase any software in-house, they do not have to purchase any processing capability, so nothing has to be purchased.

So, therefore, there is you know literally no significant initial capital expenditure. All that is there is an operating expenditure. So, you pay as you go here. So, the amount that you use you pay only for that. So, this is the formal definition of cloud computing.

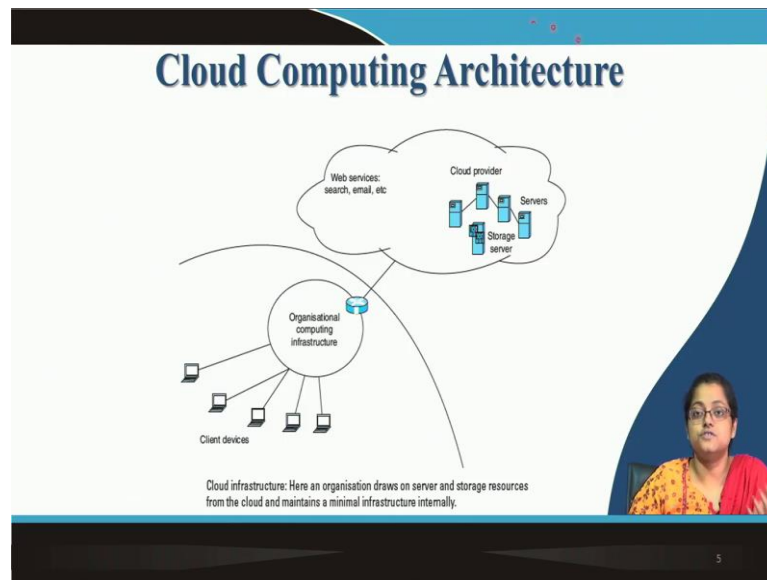
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Moving on if we have to compare traditional computing infrastructure with cloud computing infrastructure, the basic difference is you know in traditional computing infrastructure organization owns and maintains its own infrastructure of, you see here organization maintains its own infrastructure of servers and storage.

You know storage devices organisational computing infrastructure, and through a router it accesses only some web-based services from the internet, such as search, email etcetera. But other than that servers storage space, processing power, organisational computing infrastructure everything is maintained in-house.

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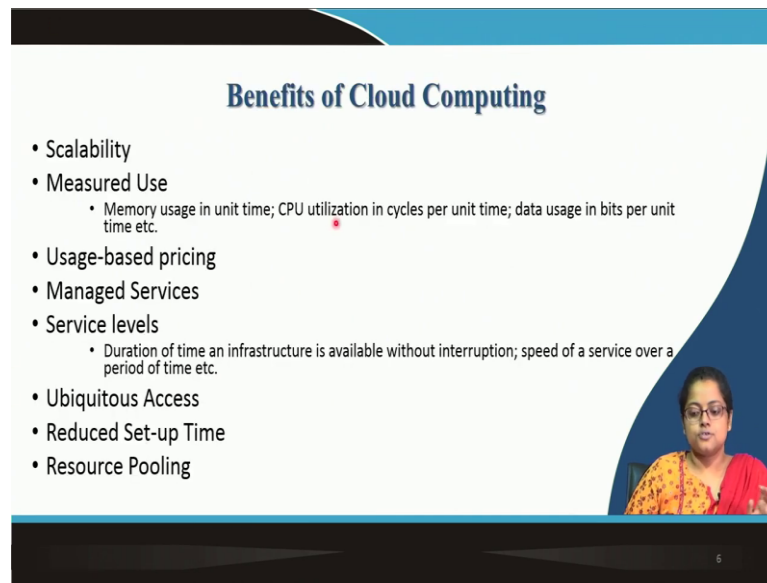


Contrary to this, if you move on to cloud computing architecture, you would see a drastic difference. So, in cloud computing architecture, there is a minimal organisational computing infrastructure in-house. But this particular infrastructure interacts and avails the services of a cloud provider.

So, storage servers, you know other servers, computing power, etcetera, everything is obtained from the cloud provided by a service provider. They do not have to maintain any of these things in-house. So, infrastructure need not be maintained in-house, everything can be procured from the cloud.

Along with this like you know in the traditional computing architecture, they do avail the services of your certain web services of the internet. But the basic computing infrastructure, the entire infrastructure that in case of in case of traditional computing resided in-house, now resides at the servers or the at the service providers end. You have to access it through the cloud on a pay as you go basis.

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Benefits of Cloud Computing

- Scalability
- Measured Use
 - Memory usage in unit time; CPU utilization in cycles per unit time; data usage in bits per unit time etc.
- Usage-based pricing
- Managed Services
- Service levels
 - Duration of time an infrastructure is available without interruption; speed of a service over a period of time etc.
- Ubiquitous Access
- Reduced Set-up Time
- Resource Pooling

6

So, what are the benefits of cloud computing? You must have observed a lot of benefits already, but I would like to reiterate some of them. So, the first one is scalability which means that and if you have a traditional computing infrastructure in-house, you have to maintain the, you know you have to maintain the entire infrastructure whether you use it or not.

But one of the major benefits of cloud computing is when you require extra services such as you know in say there is a festival or it is Christmas or it is Diwali, and you require more processing because there will be a lot of more transactions in your organization. So, you require a lot of processing and storage power. So, you can immediately obtain it off the cloud by having an agreement with the service provider.

At the same time if you know if you are using a cloud service for your educational institution where in you know during vacations, there are very few number of students on campus, and a lot of students a lot of users are not using the their licenses during the breaks or vacations.

You can actually have a deal with the service provider and you can reduce your requirements. So, you will pay much less at that time. So, therefore, it is scalable. When you require more, you get more. If you require less, you actually get less. So, therefore, it is the payment here is also on a pay as you go basis.

The second benefit of cloud computing is measured use. So, when you are having a traditional computing infrastructure in-house, you would usually not be able to measure how much you are using.

But when you are using the services of a cloud service provider, the service provider has certain matrix to measure your use usage such as memory usage in unit time; CPU utilization would be calculated in cycles per unit time, data usage in bits per unit time and so on. So, this would also help you keep a tab or keep a check on the amount of usage of each of these infrastructure.

Thirdly usage-based pricing. I think we have already discussed this. So, cloud computing infrastructure generally helps you obtain a pay as you go pricing. So, the amount that you use you pay only for that, nothing more, nothing less. Managed services this means that since the services are provided by a cloud service provider, the services are also maintained and managed by them.

So, maintenance, up-gradation, you know patches to your software, everything is done by the cloud service provider. You as a client have minimal role there. You do not have to get involved, you can rather focus on your core competency or you know maybe you can focus on what your organization is best at doing rather than focusing on maintaining your computational infrastructure in-house.

Service levels, this is another very important benefit of cloud computing. So, if you have a deal with the cloud service provider, you will be able to you would be assured of a minimum level of service based on your service level agreement. So, for example, you know duration of time and infrastructure is available without interruption or speed of a service over a period of time.

So, if you have certain agreed standards, then your service provider cannot deviate from these. And in case a service provider deviates, you can actually have a word with your service provider, and ensure that service provider gives you the level of service that was promised.

Ubiquitous access, of course, it is clear by now that clouds infrastructure can be accessed through any device and from any location. So, there is no restriction absolutely

whatsoever with respect to location or device. Therefore, access is ubiquitous if you are availing the services of the cloud.

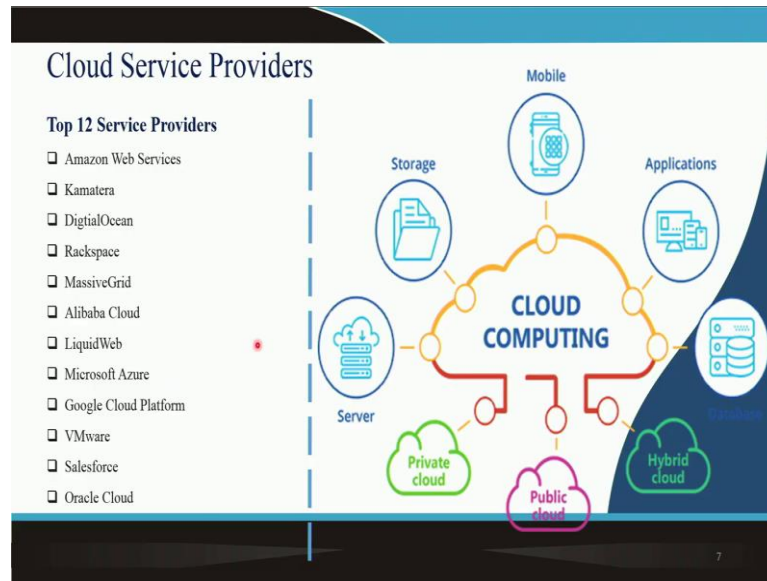
Reduce setup time, we had also discussed this in the previous slide that in case of you know cloud services if you are availing the services through a public cloud, you do not have to maintain any infrastructure in-house. The setup time to set up that particular infrastructure is minimal; because the cloud service provider already has it the service provider only has to provision it to you which may take say a few weeks or a few months compared to the a few weeks or a few days; sorry.

Compared to that, in case of a traditional computing setup, it would take months to years to set up a system. So, for example, if you have to set up an in-house on premise ERP for a medium sized organization it may take a minimum of 2 to 3 years. Whereas, on the contrary if you have to avail it of the cloud a cloud-based ERP, it would take say only a few days or a few weeks and finally, resource pooling.

So, the service provider is able to pool resources physical as well as virtual resources and that that can be IT resources and that can be available to you. So, resource pooling and you know provisioning of that pooled resource as and when required by a particular client is another benefit of cloud computing.

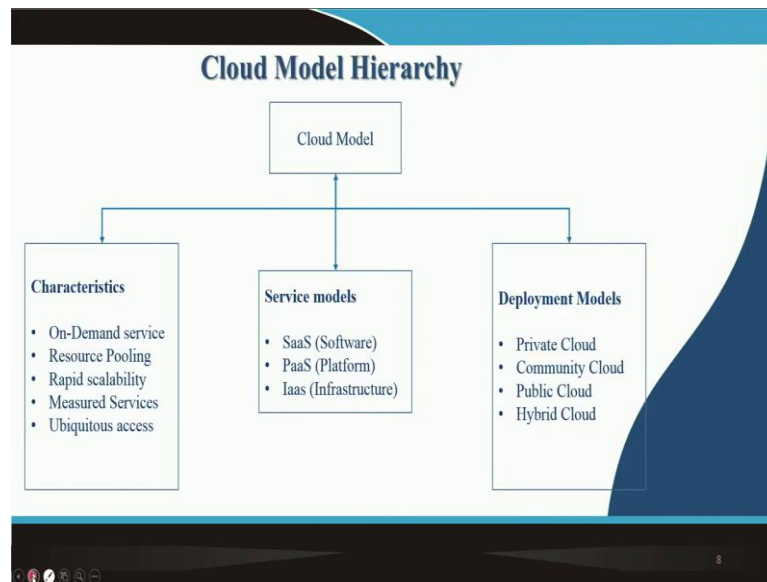
So, when a client requires the pool resource can be allocated to a particular client, and when the client releases those resources they can be again allocated to another client. So, these are overall some of the benefits of cloud computing over traditional computing infrastructure; ok.

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So, here we will focus on some of the cloud service providers. Here so for example, Amazon Web Services is very popular, along with that we have Alibaba Cloud, Microsoft Azure, Google Cloud Platform, VMware, Salesforce, Oracle Cloud, so these are some of the very popular cloud service providers across the world; ok.

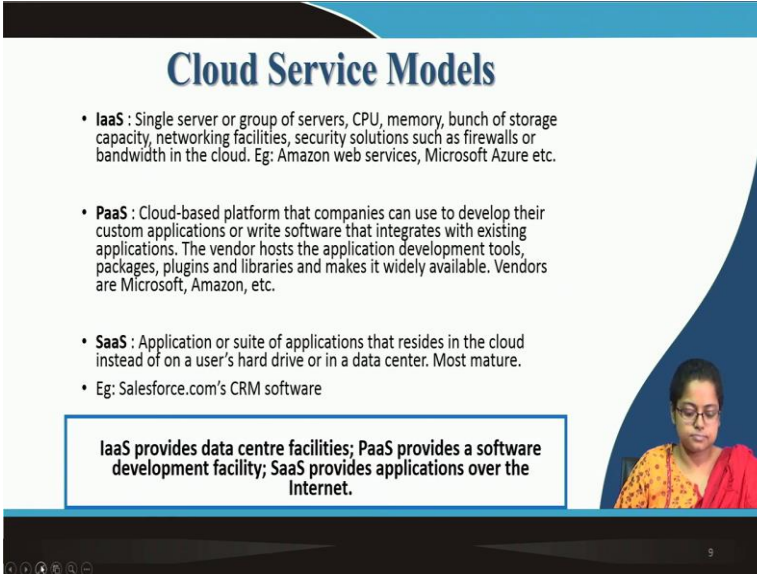
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So, moving on, cloud model hierarchy. So, here we have divided the hierarchy into you know we have divided into three parts the cloud model. The first part is the characteristics which are the benefits of cloud computing over traditional computing

architecture. We have already discussed this in detail. The second part that we will focus on is related to cloud service models. And the third part that we will spend some time on is related to cloud deployment models.

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Cloud Service Models

- **IaaS** : Single server or group of servers, CPU, memory, bunch of storage capacity, networking facilities, security solutions such as firewalls or bandwidth in the cloud. Eg: Amazon web services, Microsoft Azure etc.
- **PaaS** : Cloud-based platform that companies can use to develop their custom applications or write software that integrates with existing applications. The vendor hosts the application development tools, packages, plugins and libraries and makes it widely available. Vendors are Microsoft, Amazon, etc.
- **SaaS** : Application or suite of applications that resides in the cloud instead of on a user's hard drive or in a data center. Most mature.
- Eg: Salesforce.com's CRM software

IaaS provides data centre facilities; PaaS provides a software development facility; SaaS provides applications over the Internet.

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So, first we will talk about the various cloud service models that are available. So, here you see the first cloud service model that we would want to talk about is infrastructure as a service.

So, by the term infrastructure, you would understand that it could be a single server, or a group of servers, or CPUs, memory, bunch of storage capacity, networking facility, security solutions such as firewall or bandwidth or any other computing infrastructure in terms of hardware, hardware infrastructure could be availed of the cloud.

So, infrastructure as a service is a very basic cloud service model in which any sort of computing infrastructure can be availed of the cloud by a client. And popular service providers who provide you with infrastructure as a service are Amazon Web Servers and Microsoft Azure.

Now, the second cloud service model that we would want to focus on is platform as a service. So, a platform as a service is an advancement over infrastructure as a service, because here you know you it is a cloud-based platform that companies can use to develop custom applications or write software that integrates with existing applications.

The vendor hosts the application development tools packages plugins or libraries and make them widely available. So, what the client has to do is the client merely you know the infrastructure as well as these plugins or application development tools. The platform and the tools are available to the client, the client merely has to use these and start developing applications.

So, this is an advancement over infrastructure as a service, because it is infrastructure along with the application development tools. So, again popular vendors here are Microsoft and Amazon. So, they provide very superior quality of platform as a service applications.

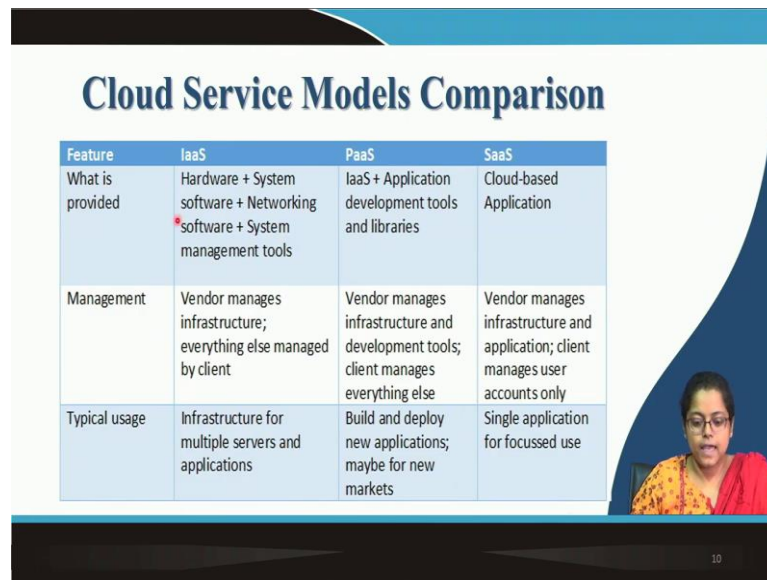
Finally, we will talk about software as a service which is the most evolved and the most mature of all the three cloud service models. So, this is an application or a suite of applications that reside in the cloud instead of on a user's hard drive or in a data center. So, if you would want to access certain applications, you do not have to install them on your own system or you know you do not have to install them on your own in your own data center.

You do not have to have them on your premise at all. You can rent them off the cloud. So, application or suite of applications that can be rented of the cloud. Now, why this is called the most mature because this is an advancement over the other two. Software as a service includes not only infrastructure as a service and platform as a service, but along with that you can actually rent an entire application and use it; ok.

Some there are a lot of popular examples of software as a service. For example, Salesforce.com CRM software, so this is a software as a, this is available in the form of software as a service. There are a lot of companies which also avail software as a service-based ERP systems; ok.

So, infrastructure as a service provides data center facilities basic data center facilities of the cloud. Platform as a service provides a software development facility of the cloud wherein you get the basic software you know application development tools and you have to develop the application yourself in-house. And software as a service provides applications over the internet. So, it provides the applications over the internet. So, this is the difference between the three cloud service models.

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Cloud Service Models Comparison

Feature	IaaS	PaaS	SaaS
What is provided	Hardware + System software + Networking software + System management tools	IaaS + Application development tools and libraries	Cloud-based Application
Management	Vendor manages infrastructure; everything else managed by client	Vendor manages infrastructure and development tools; client manages everything else	Vendor manages infrastructure and application; client manages user accounts only
Typical usage	Infrastructure for multiple servers and applications	Build and deploy new applications; maybe for new markets	Single application for focussed use

Now, moving ahead if you see this particular table, you would see that this is a comparison of the three cloud service models once again. So, here you will see that we have hardware. So, in, if we talk about infrastructure as a service, we have hardware, along with that we have system software, and we have networking software and system management tools.

Whereas if you move on to platform as a service in terms of what is provided, you have infrastructure as a service along with it you also have application development tools and libraries which we have just discussed. And finally, when we when you move on to software as a service, you have one and two plus cloud-based applications.

So, you can rent a lot of cloud-based applications rather than developing them in-house. In terms of management infrastructure as a service is vendor, vendor manages the infrastructure everything else is managed by the client.

In terms of platform as a service, vendor manages infrastructure and development tools, client manages everything else. And in terms of software as a service vendor manages infrastructure and application, client manages only the user account that is why software as a service is the most mature of all the cloud service models.

And in terms of typical usage, infrastructure for multiple servers and application is what is available in terms of infrastructure as a service in terms of PaaS with respect to typical

usage you would be able to build and deploy new applications and maybe may be for new markets and in terms of software as a service you would have single application for focused use. So, this is the difference between the three cloud service models.

If you know want to let us draw an analogy to understand the different cloud service models better. So, for example, if you want to rent a house right, you want to rent a house with you know with no basic infrastructure. It is only the four you know the house or the apartment that you are renting no infrastructure is provided. So, that is what is called you know it is not at all furnished, it is no basic infrastructure is provided, so that is called a an infrastructure as a service.

Similar to infrastructure as a service, because you are renting only the apartment without any other facility or any other furnishing available. Platform as a service is where you obtain you rent the entire apartment, you know along with you know along with some basic furnishing. So, you have some basic infrastructure such as you know you have a proper plumbing system, you have proper electric fittings, but the rest you have to manage right, so that is a platform as a service.

And finally, if you have to talk about software as a service, it is kind of a semi furnished accommodation that you are renting only maybe you can customize it according to your own choice. So, you can add a cupboard, you can add a piece of chair or a table, the rest everything is provided to you. So, I hope this particular analogy clarifies the difference between the three cloud service models even better.

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So far we have spoken primarily about the challenges related to cloud computing. So, now let us you know spend some time on the sorry we have spoken about the benefits a lot of benefits related to cloud computing. So, let us spend some time on the challenges of cloud computing. The first challenge that we see here is with respect to security and privacy.

So, cloud computing has you know there is a lot of issue with respect to security and privacy especially if you are availing the services of a public cloud. Because in this case your workload is shared with multiple other clients right, your data your processing everything is shared with multiple clients. So, there is an issue there could be an issue with respect to security.

Secondly, you know some of those also let me mention, some of those clients could also be hackers. So, they can they can be in they can actually hack your services, the services that the provider is providing you and may steal some of your data, so can gain an entry into your system as well.

With respect to privacy also it is a challenge, because you know a lot of your organization data is residing on the cloud which is providing services to multiple other clients. So, if any of them is your competitor or is a hacker, they can actually try to you know the you know you know get access to that data, so which means that you know the

privacy of your customers data is at stake because if it is available to unauthorized entities, then your customer may not be happy; right.

So, at the same time your processes your internal organizational processes might be visible to others if they are accessing the same services over the cloud. So, security and privacy might be a challenge, but having said that the popular crowd public cloud service providers also maintain certain minimal level of service level agreements by which they are they are supposed to give you an optimal level of security and privacy.

Therefore, it is advisable to go ahead with the more popular cloud service providers or if you are partnering with the newer one please ensure that you know your cloud service provider has appropriate service level agreements in place which the provider is bound to adhere to.

Of course, with private cloud this problem does not arise too much because security and privacy is taken care of. We will discuss all of these three you know the differences between public private clouds or the cloud deployment models subsequently.

Then we will speak about another important challenge which is related to availability and reliability. So, again if your cloud service provider does not maintain or deviates from the service level agreements availability and reliability of the service can be an issue, because you your service provider is actually providing the services to so many other clients.

So, it may it may happen that his system is the service is down for a certain period of time, reliability goes for a toss. So, that should not happen especially you know when in during critical times when you require your the service to be up 24-7. Service quality again service quality can be a challenge if your provider is not careful enough integration. The fourth challenge and a very important challenge is with respect to integration, because you have your own systems your own information system in place.

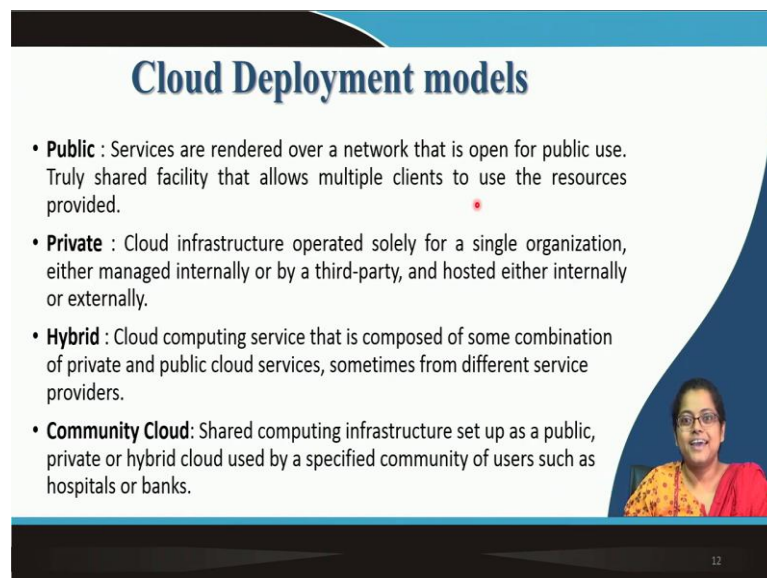
Now, when you want to you know partner with the service provider, there might be an issue because the service provider might not be you know his processes, his information system his technology might be entirely different. So, integration might become a challenge in case you are actually in case your service providers systems are entirely different from yours, so that can be a challenge, but that has to be taken care of.

And finally, regulations. So, with respect to cloud services certain countries or certain geographies have a lot of you know restrictions or regulations. So, for example, there are certain geographies such as the European Union, they have come up with their you know General Data Protection Regulation – GDPR.

So, as a part of which a lot of you know cloud service providers are bound to store data of that particular geography that that is European Union within the premises of European Union because generally what cloud service providers do is that they store data and processing of clients in data centers across the world depending on you know a lot of factors such as cost, depending on factors such as regulation, but there are a lot of countries which are very stringent about the fact that data of their country should reside within the country's premises and cannot reside outside.

So, for cloud service providers, this is a challenge which they have to deal with; ok. So, in this particular session, we have spoken about the challenges, with respect to challenges as well as benefits with respect to cloud computing. We have understood what it means and we have also tried to understand some of the applications related to cloud computing.

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Cloud Deployment models

- **Public** : Services are rendered over a network that is open for public use. Truly shared facility that allows multiple clients to use the resources provided.
- **Private** : Cloud infrastructure operated solely for a single organization, either managed internally or by a third-party, and hosted either internally or externally.
- **Hybrid** : Cloud computing service that is composed of some combination of private and public cloud services, sometimes from different service providers.
- **Community Cloud**: Shared computing infrastructure set up as a public, private or hybrid cloud used by a specified community of users such as hospitals or banks.

12

So, in the subsequent session, we will be talking about cloud deployment models and we will be discussing in detail the pros and cons of the various cloud deployment models; ok.

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The slide is titled "References" and features a background with various icons including gears, a tree with nodes, a hard hat, and a circuit board. A video inset in the bottom right corner shows a woman with glasses and a red shawl. The slide includes the following references:

- K. Laudon and J. Laudon (2016). Management Information Systems Publisher: Pearson. Edition 14e.
- R. De. (2018). MIS Managing Information Systems in Business, Government and Society. Publisher: Wiley. Second Edition.

At the bottom of the slide, there are logos for NPTEL and IIT Kharagpur, along with the page number 13.

So, as of now, thank you! These are some of my references. See you in the next lecture!

Thank you!