Introduction to Internet of Things
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Lecture - 37
Cloud Computing- Fundamentals

So this lecture is on Cloud Computing, and this is the first lecture on the series of cloud computing. So, the first one will be on fundamentals. So, here in this lecture I am going to speak about some of the basic motivation behind cloud computing, particularly from the use of cloud computing in internet of things. Then about some of the basic models of cloud that are popularly used and also how the cloud can be deployed in different environments and the models there of. So, this particular lecture is focused on these specific issues.

So, before we start I would like to mention a few different things. So, the first thing is that why do you need cloud. So, let us try to understand this thing why do we need cloud and the second thing that will try to understand is why do we need cloud specifically for internet of things and that will basically justify why we are devoting a few lectures on cloud computing in a course on IoT. So, the second one will come next, but let us first look at what is cloud. So, cloud computing is all about using computing as utility

So, we all are users of different utilities; utilities such as electricity, utilities such as water resources and so on and so forth. So, electricity water supply etcetera are utilities which we use first of all we have to subscribe to those utilities then some connections will be given at our home for those utilities. Then there will be some meter which is going to measure how much units of electricity or water we are using at our home and based on our units of usage we are going to be finally built at the end of the month for the use of these resources.

So, what did we see that if I have to use electricity at my home if I have to use water at my home it is not required for me to be bothered at all about deploying the necessary infrastructure for generation of electricity for the transmission of electricity similarly the pumping out of water from river or ground or the distribution of the water I do not I do not really have to be worried at all about this.

So, I subscribe to these utilities I will be given a connection at my home for these utilities then based on the units of usage of these resources electricity water etcetera at the end of the

month I will be billed for this I will be billed for this. So, what did we see that I do not really have to bother about how the electricity or water was generated or pumped out how it was distributed? So, I do not need to be worried about all I need to be worried about is whenever I required I will be using it and at the end of the month I should be paying for the units of usage.

So, this basically can serve as a motivation behind why cloud computing is required in the same way as water is a utility, electricity as a utility people thought about can we have computing as utility what does it mean computing as utility computing means what computing means hardware resources like servers workstations which again include processors which can do certain computations etcetera memory storage and so on. So, these computational resources hardware plus software resources plus development platforms; so, all these things offered as utility why do we need, because that will have some business value that will save some cost and it also has certain advantages and this is what we are going to learn in this particular lecture.

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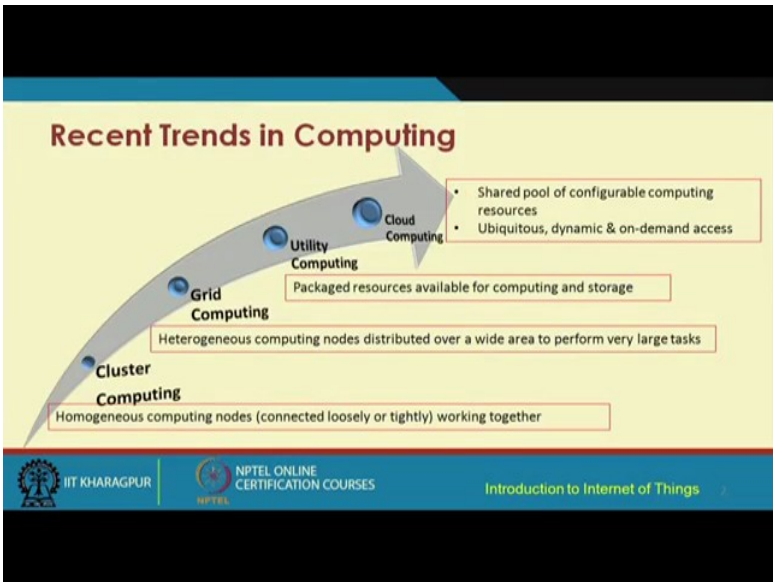

So, first let us have a quick glance through how computing evolved over the years. So, you must have already heard about cluster computing, grid computing at least these 2 you must have heard about. So, cluster computing is basically you know having some kind of computing nodes connected together in the form of a cluster. So, the cluster as a whole which can be loosely or tightly connected the cluster as a whole would be accomplishing some

computational job which will be; it will be executing some computational job. So, this is cluster computing grid computing is sort of like a wide area kind of heterogeneous computing platform which will be performing large volumes of tasks or tasks which are large in size then we have the utility computing where this resources the computational resources are packaged for delivering as utility for use by consumers as utility.

So, this is the whole premise of how utility computing evolved and then we have this cloud computing which was basically sort of like an integration of the concepts from all these com cluster computing distributed sorry grid computing and utility computing their advantages put together in order to have this new model of computing which is known as the cloud computing. So, in cloud computing we have shared pool of configurable computing resources shared pool of resources and whenever it is required wherever it is required dynamically these resources will be offered will be offered to the users as service on payment.

So, this is like a scalable kind of model that that has been conceptualized over all these cluster grid and utility computing models.

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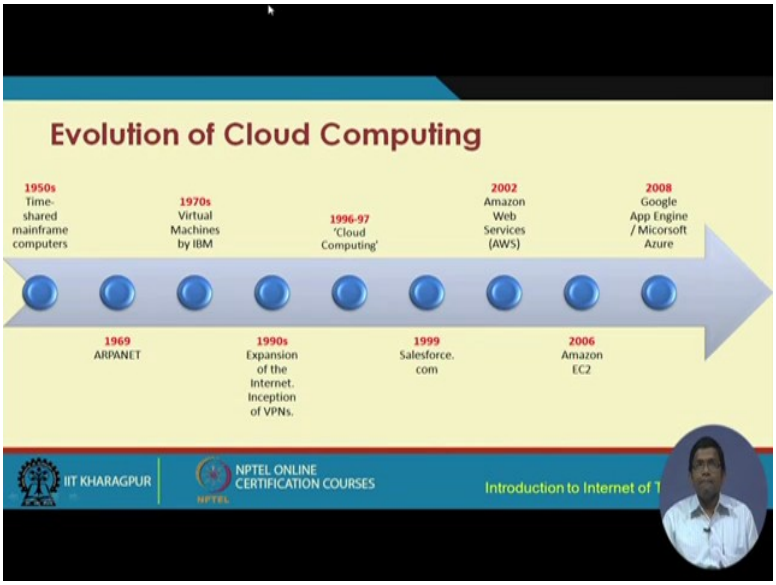

So, you know cloud is more or less a very recent kind of phenomenon it started in the mid 1990s and in the last few years it has become even more popular there are different commercially available cloud platforms that are there people are still using it companies are subscribing to these cloud services, but going back in the 1950s people were more concerned about time shared mainframe computers in the 1960s ARPANET and the like oriented

network based services became popular virtual machines became popular in 1970s; 1990s the internet was expanded virtual private networks were formed.

And in the late or mid 1990s onwards cloud computing came into being popularity has been more in the last couple of years of cloud computing different platforms offering software you as utility platform as utility infrastructure, as utility are offered by different companies such as sales force dot com, Amazon web services, Amazon EC2, Google app engine and so on. So, these are the different companies which are basically daily offering these different services as utility.

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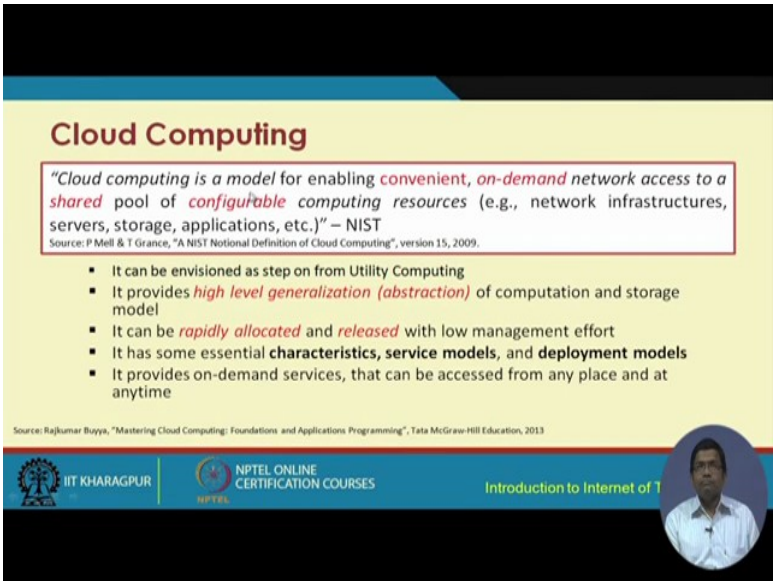

Now when we talk about cloud computing NIST has done quite a bit of work on in cloud computing it. In fact, has some literature and as per that literature of NIST cloud computing is defined in this particular way I will read it out for you it is there in front of the slide in front of you in the slide and for the benefit of everyone. Let me read it out for you cloud computing is a model for enabling convenient on demand network access to a shared pool of configurable computing resources example network infrastructure servers storage applications etcetera.

So, there are few key words that will drill down for the convenient network access. So, whenever it is required for me at any time of the day at any time of the month whenever it is required conveniently I should be able to get network access to the to these different resources that we just went through that we just gone have gone through on demand on

demand means that whenever it is required I should be able to on my demand I should be able to get access to these resources. And there is a shared pool of resources which are configurable shared pool. That means, that these servers storage etcetera, etcetera, which will be shared all across and the computing platform is configurable with respect to these network infrastructure you know servers, etcetera.

So, basically it might so, happen that you know as a user my job as a cloud user my you know computational job is getting executed to me it I will get a feeling that it is get getting executed at my dedicated machine that has been given to me by the cloud platform, but in actuality physically maybe there are multiple servers which are geographically separated from one another which are together being pooled to execute different parts of my job. So, this is basically you know to me it is like a single entity which I am using, but in the back end there is so much of seamlessness that is there that I would not be able to understand that how and where and when things are getting executed.

I in fact, do not need to be worried at all about it of course, I would tell you that it is not that I do not need to be completely worried cloud computing also has some privacy security concerns as well. So, will you know for this course we are not going to understand what are these issues, but there are indeed certain issues, but we will consider that you know there is no such issue and you know I do not really need to be worried about how when and where my computation job that I have is getting executed, but to me I will get a feeling that I am paying for it and it is getting executed at my end actually it is not happening that way it is because of virtualization that I am getting such a feeling.

So, I will talk about it in more detail later on. So, cloud computing is sort of like a step ahead of utility computing it provides abstraction or high level generalization of the computation and storage software platform etcetera from and this kind of abstraction is made available to the end users for use on a paper use basis the resources are in a cloud platform rapidly allocatable and they can be also released whenever it these resources are no longer required and that can these can be done with low management effort.

So, there are some essential characteristics something called the service models and the deployment models which we are going to go through of cloud computing. So, what are these essential characteristics broad network access is one.

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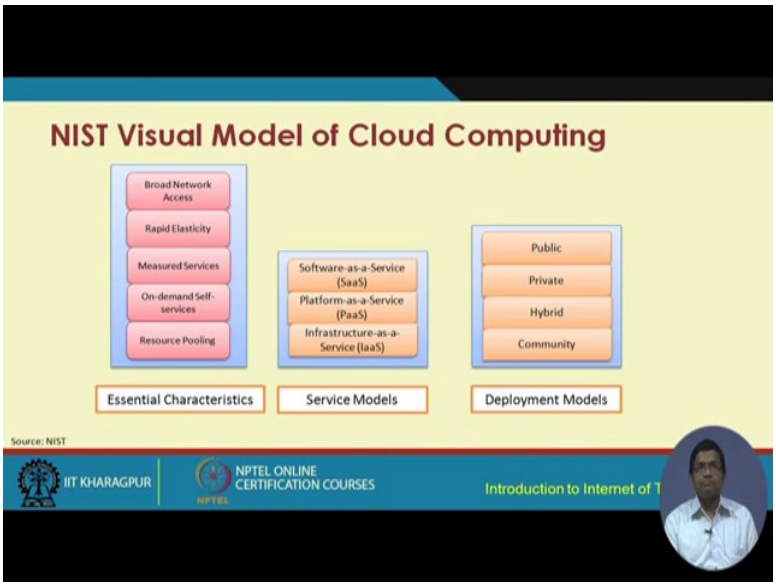

So, this network you know access is offered in such a way that from anywhere and from anywhere in the world geographically even if I am distributed at different locations my company has different. So, I would still be able to get access to these cloud resources. So, these computational resources rapidly elasticity means that as and when required you know if I require more I would be able to scale up. And I should be able to get these computational resources if I require less I should be able to scale down. So, this dynamic scaling has to be made possible through cloud.

Third is measured services paper use you know. So, I would be paying for the units of utility cloud utility. That means, the computational utility that I am using on demand self services. So, whenever required I should be able to subscribe to and be able to get access to these services resource pooling means that you know if a particular server is not able to physically. You know physically give the services as per requirement then the services can be a can be obtained from other servers, other physical computers by pooling resources from them. So, these are some of these essential characteristics of cloud computing and there are different service models the very popular software as a service platform as a service and infrastructure as a service in short these are popularly termed as SaaS; SaaS, PaaS and IaaS and in terms of deployment there are different models like the public cloud, private cloud, hybrid cloud and the community cloud.

So, we will talk about each of these service models and deployment models later on. So, what are the businesses advantages I told you that cloud has certain business advantages.

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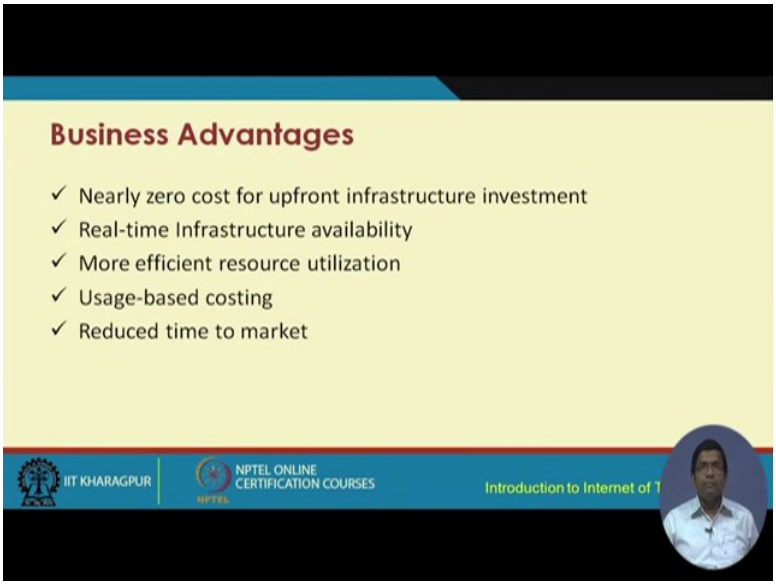

So, without any upfront infrastructure investment a company who has computational requirements they do not have to go and buy their own servers for instance and use them, but within almost 0 cost of infrastructure investment in terms of procurement deployment etcetera the you know they should be able to get access to this computing resources on demand on whenever it is required in a ubiquitous manner.

Real time infrastructure able ability means that the infrastructure is going to be made available for real time use at any time the resources are going to be made available and will be made available for real time access more efficient resource utilization. So, these resources will be utilized in a more efficient manner usage based con costing is another thing. So, usage based costing means based on how much I am using these resources I would be billed for those units only reduce time to market, because you are not basically investing time.

And of course, money for procurement for initiating the procurement for process tendering, then you know getting all the infrastructure buying them the delivery time etcetera, etcetera and then starting to use. So, you are cutting down on the time to market of the product that the company is building, because whenever you require you are getting access to your computational resources over the internet at any time.

So, basically we have not you through the use of cloud computing we have not spent too much of time on the procurement of these computational resources, which otherwise traditionally used to happen and that would kill significant amount of time in business.

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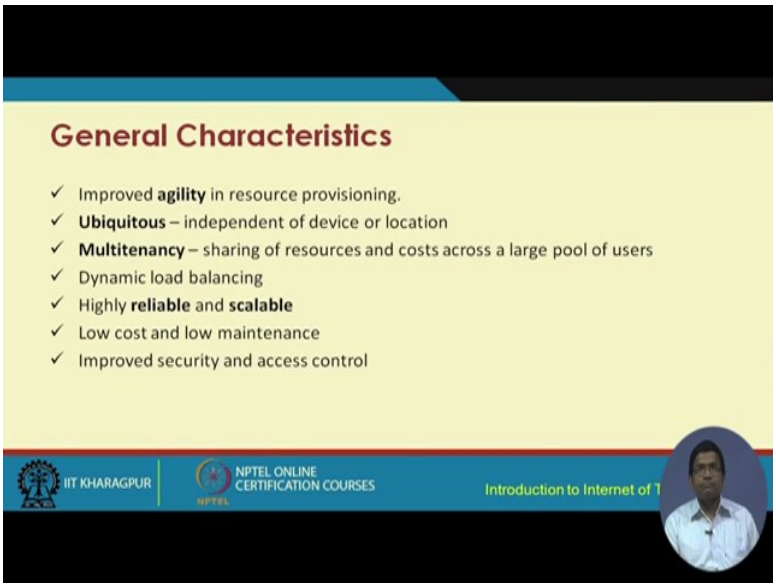

Some general characteristics improved agility in resource provisioning is one this I do not need to explain explain further ubiquity independence of device or location multi-tenancy which basically talks about sharing of resources and costs across a large pool of users. Dynamic load balancing means that the computation or even communication load it would be it is possible through the cloud model to be able to dynamically balance the load throughout the entire cloud platform cloud system. This cloud model is highly reliable, because physically if some network some computational resource has gone down or is broken or is not available for whatever reason there are other resources which can be easily pooled into and be made available to the users.

So, it is highly reliable and is scalable likewise. So, for the same reasons this is scalable as well and cloud also comes with low cost and low maintenance for the company the users of the company which is investing on in which was traditionally investing on infrastructure and improved security and access control as well. So, you know. So, these are some of the different characteristics of cloud computing.

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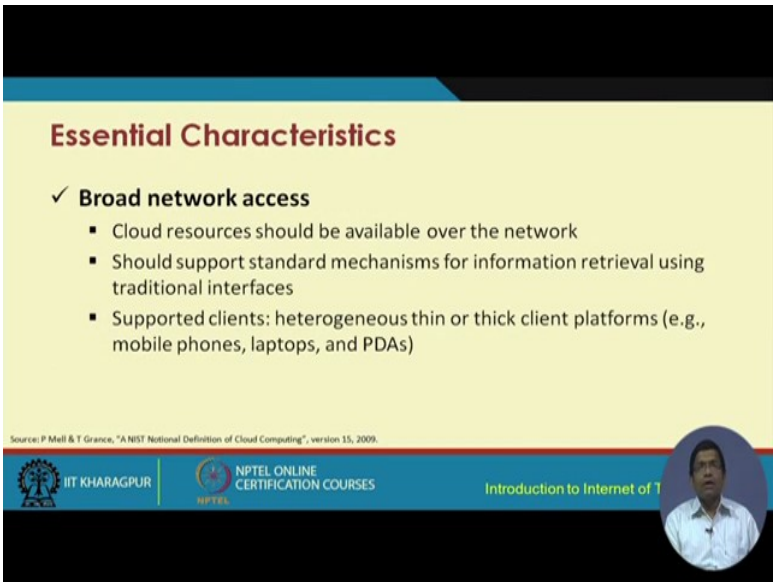

So, let us start with the essential characteristic the first one is the broad network access cloud resources should be available over the network and this is what is happening over the internet the cloud resources are man made available. And it should support the standard mechanisms for information retrieval using traditional interfaces. For example, different clients could be used different types of clients whether thick client the thin clients or mobile phones laptops etcetera these all are supported in a cloud platform.

So, basically what is going to happen you can very easily you can use thin platforms and it is like a bare basic terminal which will be you can simply have to you have to buy those low cost cheap bare basic terminals the thin clients etcetera. And the computation, the resources are going to be made available to you through the cloud platform you simply need to have some network access the broad network access in the form of internet or the like and should be able to connect to the cloud in order to get access to those resources.

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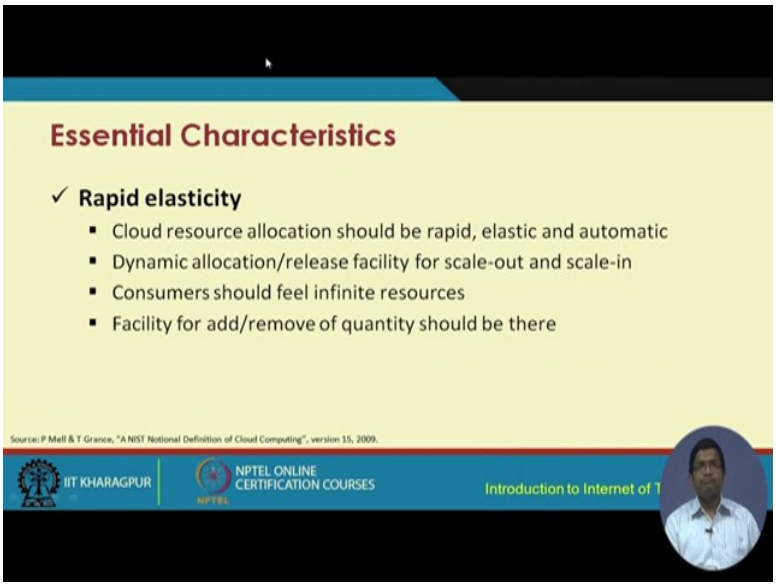

Rapid elasticity; so, cloud resource allocations should be rapid elastic and automatic dynamic allocation and release of facility for scaling in and scaling out of resources should be made possible. So, whenever additional resources are required you know it should be able to you know the cloud should be able to scale out. That means, increase the scalability of these resources. And whenever it is no longer required scaling in should be made possible by the release of these resources to the consumers. Consumers feel that it is a highly elastic system seamlessly things are integrated in such a way that the consumers feel that they have access to infinite resources and the and there is facility for adding or removing of quantity should be there in cloud.

So, whatever you know if you need more quantity or if you need less quantity the addition or the release of resources to reduce the number should also be made available and this is the property of rapid elasticity. So, elastically we should be able to expand. Elastically we should be able to reduce and release resources through the cloud model.

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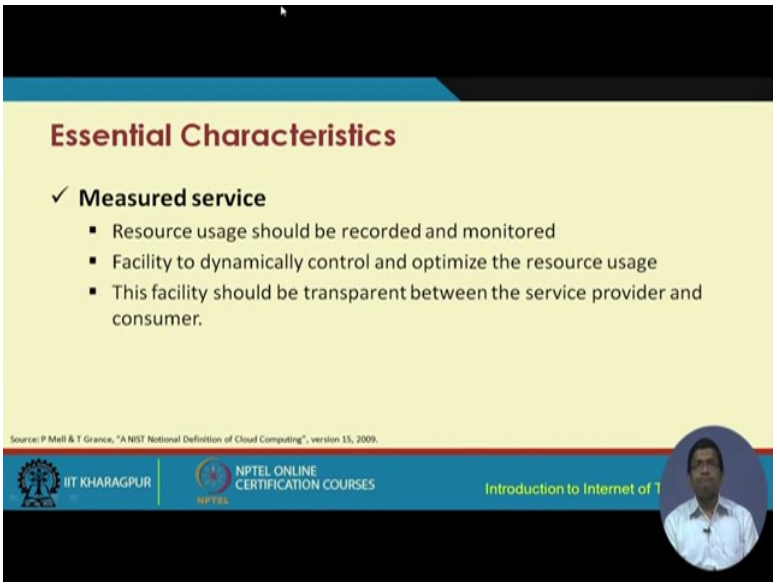

It is a measured service resources and their uses would be recorded and monitored. So, the use of these resources should be recorded and monitored and at the end of a particular time duration maybe a month. So, the cloud service provider is going to send out a bill to the end user in order for them to be able to pay for it. So, this can also be done at the same time you pay immediately, and then get access to your resources immediately as well. So, there should be facility to dynamically control and optimize the resource usage and this facility should be transparent between the service provider and the consumer.

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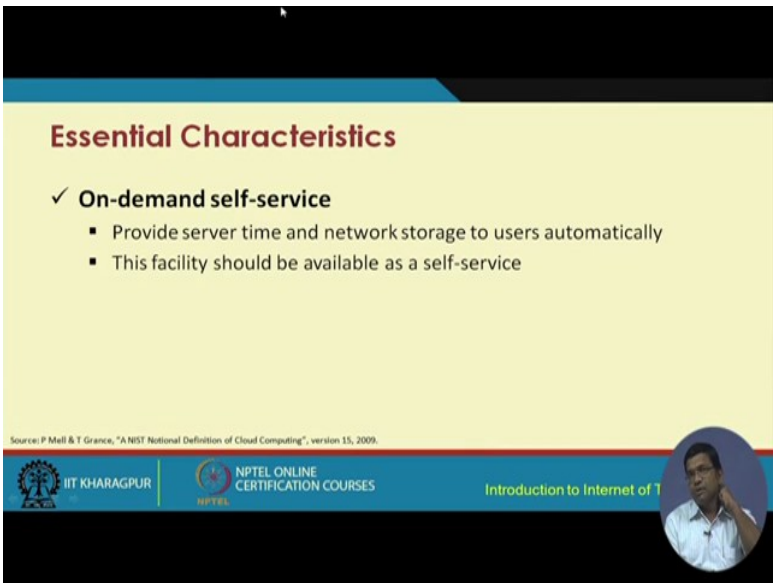

On demand self service, self service means whenever required the user should be able to get access to this resources through a self service manner. And cloud should be able to provide the server time and network storage to users automatically on demand whenever it is required.

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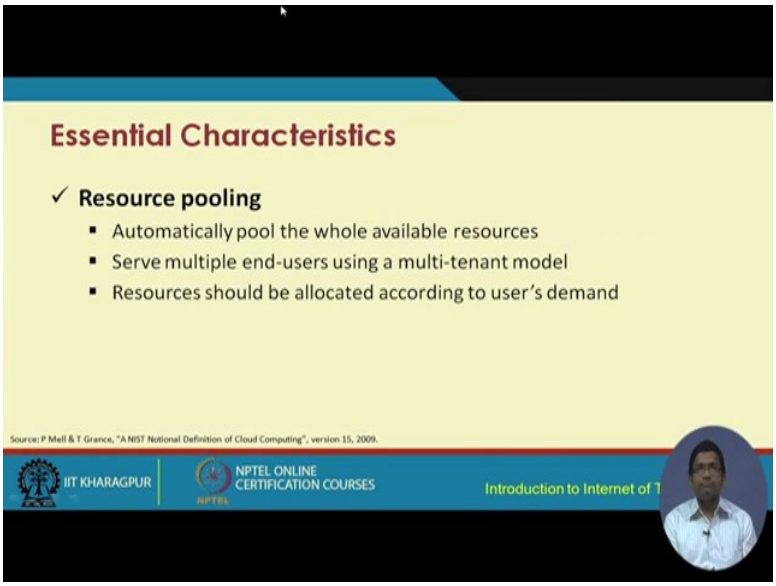

Resource pooling means that it is sort of like a multi-tenancy model, where there are multiple end users and automatically as per the requirement the whole available resources would be made available will should be made automatically available. And should be pooled from all these available sources the resources should be allocated according to the users demand.

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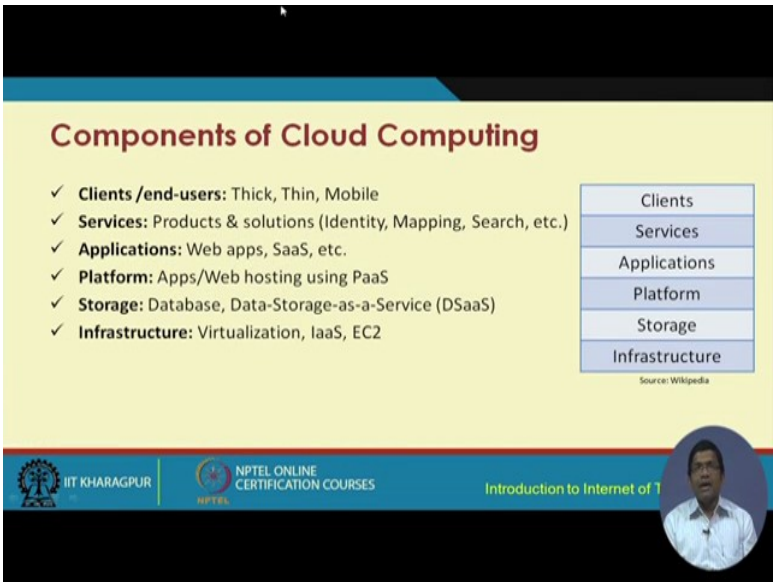

There are different components of cloud computing from the user end you have these clients and the end users which may who may use thin clients which are very popular in a cloud model. So, which are low cost as well they could be using the thick, the traditional thick clients as well. Or the mobile devices as clients services product solutions applications like web apps you know software service platforms such as web hosting platforms, application hosting platforms, should be made available through the cloud computing storage.

For instance, different databases then data storage as a service are components of cloud computing and infrastructure lastly which is very important should be virtualized and be made available in the form of infrastructure as a service model. And I am going to talk about that shortly.

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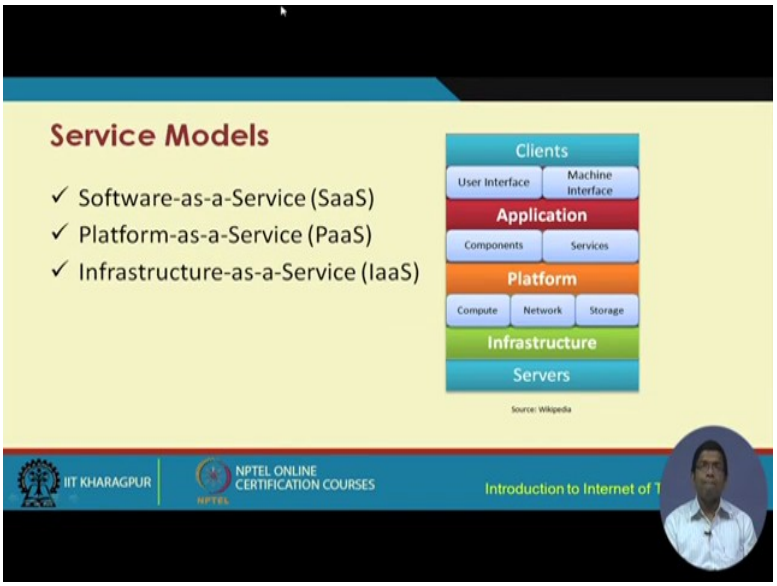

So, different service models include the software as a service, platform as a service and infrastructure as a service, these service models have been very popular. Since, the last few years I mean from the time cloud computing became very popular these service models are core service models of cloud computing, but mind you that at present people are also talking about different other types of service.

So, not just software platform and infrastructure as a service, but also something like x as a service where x could be anything, some people are talking about hardware as a service, some peoples people are talking about sensors as a service like that database as a service security as a service, people are talking about all different types of service models made available through cloud.

So, if you look at this particular figure we have all these cloud models. So, we have the servers underneath then infrastructure as a service platform as a service and application as a service, clients are getting access to each of these different computational resources through different interfaces.

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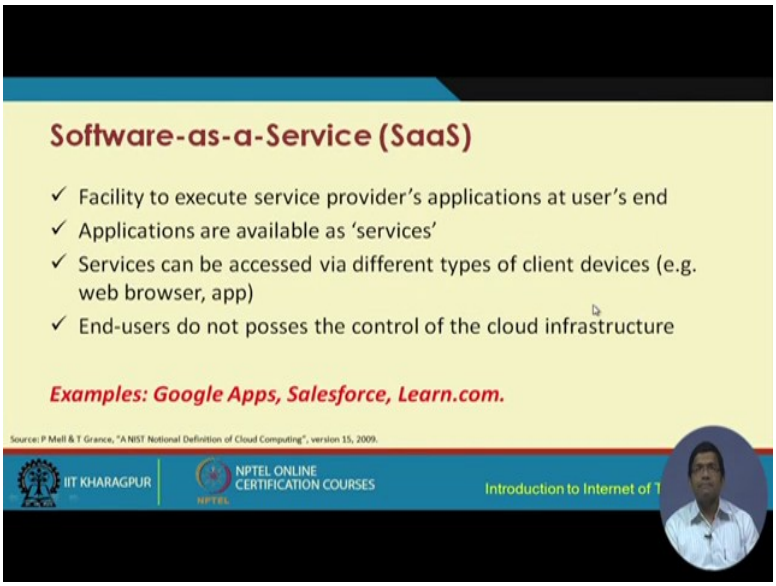

So, we have the first one which is software as a service the commonly used software as a service platforms available commercially is the Google apps the sales force learn dot com and so on. So, as this name suggests software as a service basically gives you facility to execute service provider's applications at the users end. So, applications are available as services; services can be accessed via different types of client devices example web browsers apps different types of apps and so on.

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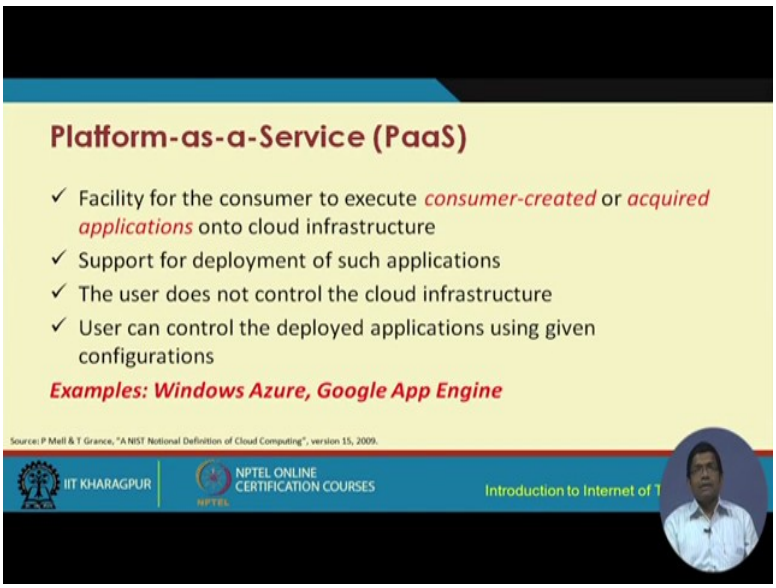

So, end users do not basically possess the control of the cloud infrastructure platform as service examples include the commercially available Windows Azure, Google app engine and so on. So, here basically the development platform is basically made available to the consumers as facilities to execute consumer created and acquired applications on to the cloud infrastructure.

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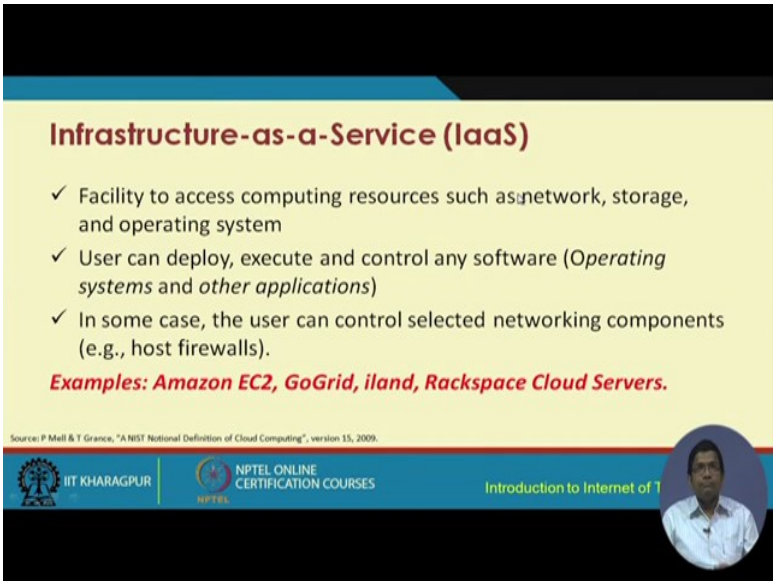

Infrastructure as a service basically talks about most of this computing infrastructure like network storage operating system to be made available as facilities through the internet accessing these facilities as computational resources dynamically, whenever it is required on a paper use basis operating systems other applications can also be made available through this facility. So, popular examples of infrastructure as a service include the Amazon EC2, GoGrid, iland, Rackspace Cloud Servers and so on.

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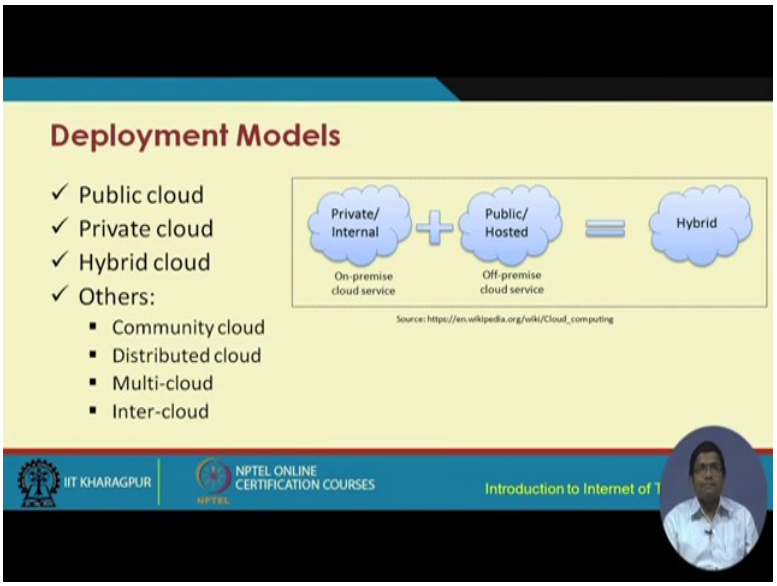

Now let us talk about having spoken about the different service models software as a service, platform as a service and infrastructure as a service let us now talk about how cloud is deployed typically what are the different deployment models that are available in cloud computing we have number one the public cloud, the second is the private cloud, the third is the hybrid cloud. And there could be other types of cloud like community cloud, distributed cloud, multi cloud inter cloud and so on. So, you know private cloud is internal to an organization and these cloud resources are made available to the users within the institution only. For example, in IIT; Kharagpur we have our own private cloud which is known as the Meghamala.

So, like that different organizations have their own private cloud, but there are some publicly hosted cloud facilities which are available off campus, off premises and these are made available by different companies like Amazon like TCS and different other companies who are sort of like service providers of these cloud. So, these are public clouds that are that are available. Hybrid clouds basically is sort of like an integration of some features of private cloud and some features of the public cloud.

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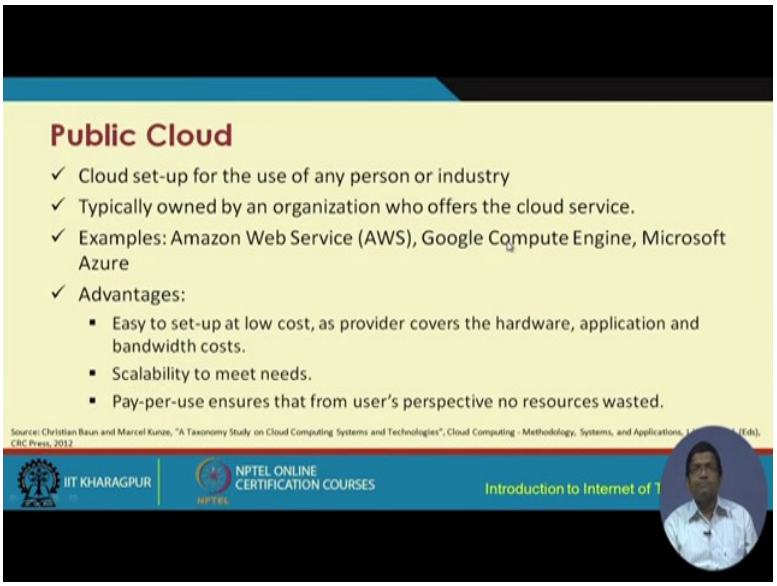

So, the public cloud is set up for the use of any person or industry typically it is owned by any organization who offers the cloud service examples include Amazon web services, Google compute engine and Microsoft azure the advantage is that this is easy to set up at low cost as the provider covers the hardware application and bandwidth cost or any other cost that is made that is in available to them.

So, this basically is a highly scalable model you just pay for the resources that are being used and there will be lack of wastage of resources.

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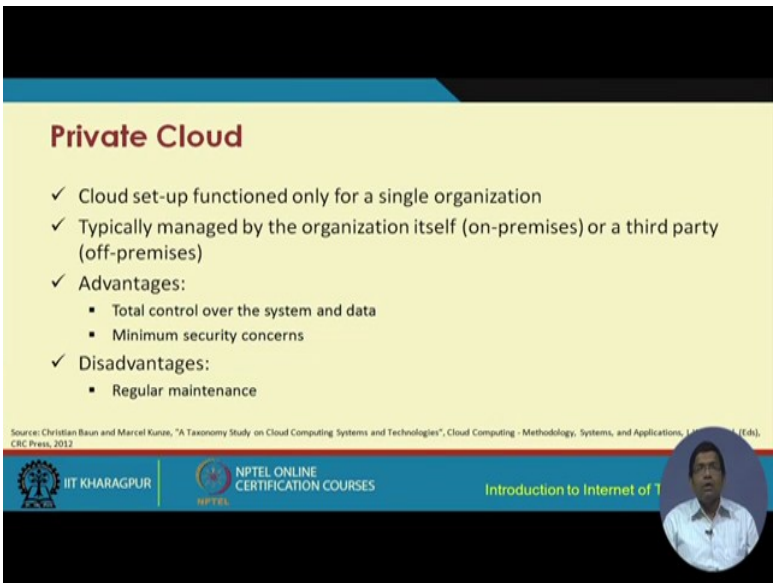

So, it is a highly scalable model that can be made available on a payment basis. Private cloud is typically restricted to a single organization the cloud functionalities are made available only within the organization typically these are managed by the organization itself or a third party. And the advantages are that there is total control over the system. And the data in such a private cloud being deployed; of course, there is some initial investment in setting up the cloud.

But once it is done then this model is quite advantageous it is low cost and these resources can be made available to the users of the organization on on their requirement basis. The disadvantage is that you have to be bothered too much about the regular maintenance, you need to have a group which will be regularly performing the maintenance tasks in a private cloud.

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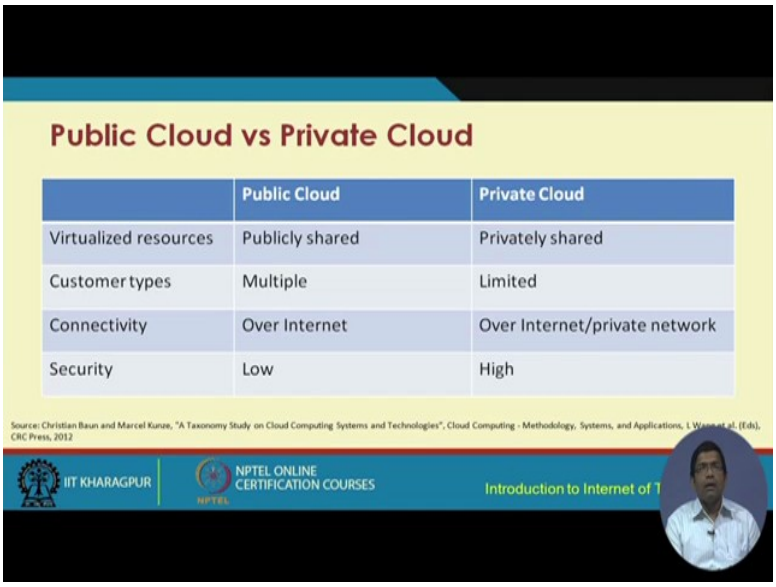

So, comparison wise public cloud and private cloud in terms of the virtualized resources in public cloud these resources are publicly shared, in a private cloud this resources are privately shared, customer type in a public cloud is basically multiple customers. And in a private cloud only a few customers who are typically limited or users of the organization like the employees of the organization.

Or the students of an organization are basically users of they serve as the customers of the private cloud in terms of connectivity public cloud is made available over the internet and private cloud. Over the internet as well as through the private network of the organization in

terms of security public cloud security is much lower compared to the security issues in a private cloud.

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And there is a hybrid cloud as I said before with basically combines the facilities of 2 or more types of unique cloud types. For example, private community or public cloud the resources in this case are pooled together by standardized tools some resources can be pooled from a private infrastructure some from the public infrastructure and together this cloud model basically offers different services to their inducers.

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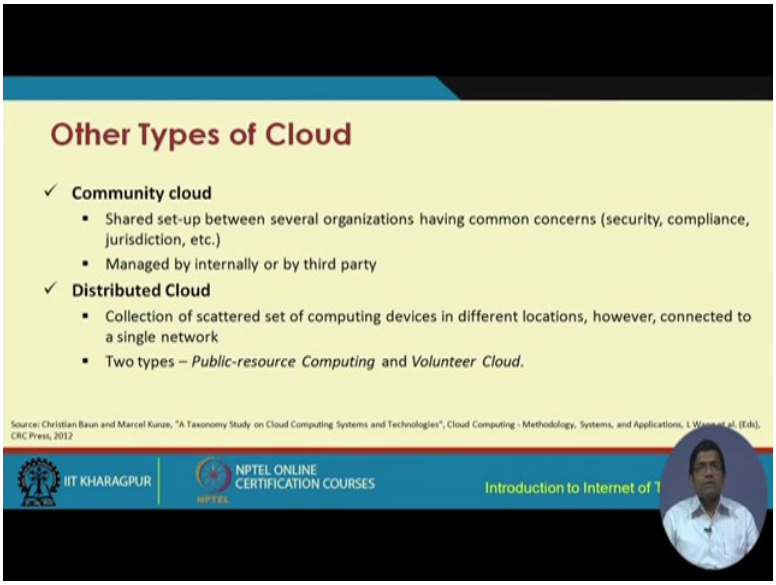

Then we have this community cloud typically this is restricted to certain communities like medical community, hospital community, security community, compliance. So, only the users of that community would be able to get access to the services of such a cloud. So, this is known as the community cloud and then we have the distributed cloud which comes in different flavors where there is collection of the scattered set of computing devices in different locations. However, connected to a single network and there are 2 types of distributed cloud- the public resource computing and the volunteer cloud. So, we are not going to go through it in the interest of time.

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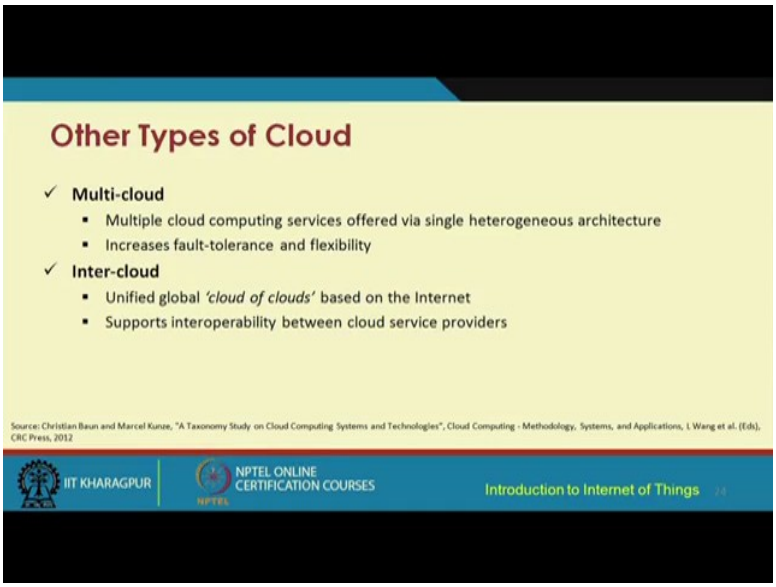

Multi cloud basically it is you know heterogeneous architecture single architecture combining multiple different cloud platforms together to increase the fault tolerance and flexibility of the system inter cloud is basically cloud of clouds. So, you have multiple different-different clouds which are put together unified through the internet and these basically would interoperate between each other between the different cloud service providers. And that giant cloud of cloud services is going to be made available to the users. So, these are the different models of cloud deployment.

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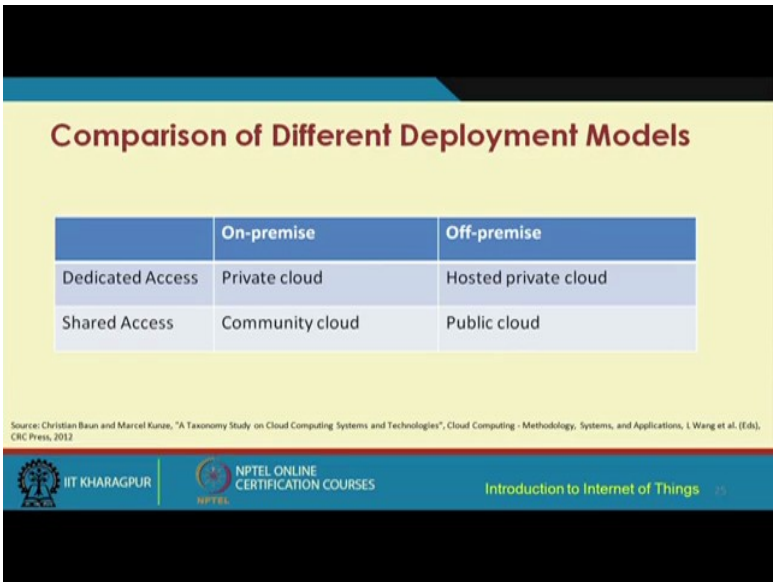

So this comparison of this private public and this community cloud are as follows. So, in this particular table as you can see that private cloud is on-premise and offers dedicated access the privately hosted cloud is off-premise and has dedicated access as well and the community cloud is on-premise and offer shared access and the public cloud is off-premised offered offers shared access.

So, with this we come to an end of the lecture on the fundamentals of cloud computing. So, we have a series of three more lectures on this particular topic of cloud computing we have already understood at the outset of this lecture about why cloud computing is being very popular in the internet of things community cloud is I will talk about it later on as well.

But cloud you can understand that it is one of the most important enabling technologies or if core building block for internet of things development, because you have to deal with heterogeneous resources offering different types of data collecting different type of data which has to be processed quite fast without much in you know infrastructure involvement. That means, this infrastructure should be taken care of quite automatically I do not have to really buy this infrastructure and waste time and money for it. I should be able to get access to these resources and I should be able to enjoy the computing facility on a paper use kind of modeled.

So, this is all about cloud computing. In the next lecture we will talk about some more details of cloud computing.

Thank you.