Cloud Computing
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Lecture – 07
Virtualization

Hi; so, welcome to our next lecture on cloud computing. We will quickly go through the virtualization concept; we have already discussed some of these aspects in our previous lectures. But I thought that we will have some few more slides on it, one of the core concepts. So, virtualization is one of the core concepts or one of the core prime mover or having these cloud computing. For which the cloud computing is existing today and if you see this virtualization is not a new concept, it is already there. We; many of our are used to virtualizes. We virtualize a Linux system over a window system over a Linux system. So, I have some sort of a virtual realization of the things.

And if you look at that other end, we are used to different other resources like networking, etcetera. So, I have a; we can have a virtual LAN or VLAN, which is pretty popular which we have VPN virtual private networks and so forth. So, virtualization is there and this cloud computing architecture technology, tries to exploit this feature for giving different services of cloud. So, as we have seen this IaaS or infrastructure as a service. So, from the subscriber point of view, what the subscriber gets. So, access to virtual computers, right, network accessible virtual storage, network infrastructure components like firewall configuration services, etcetera.

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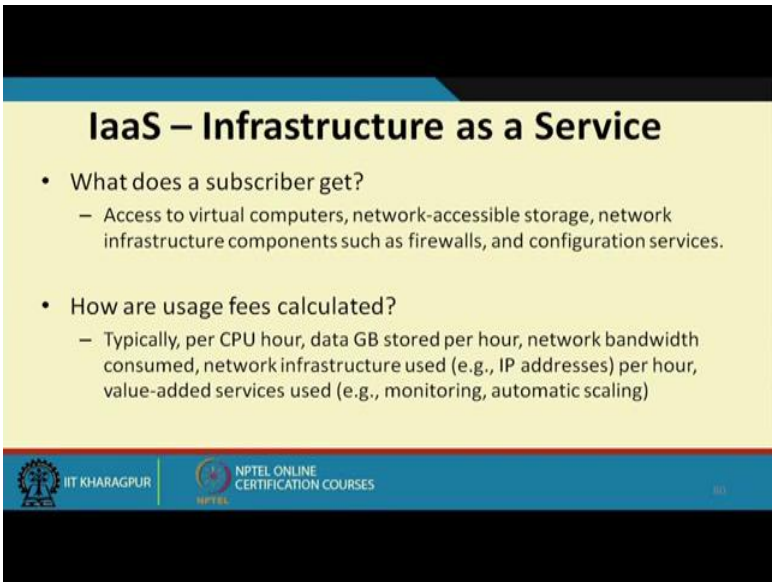

So, as if I being a subscriber, I get access to a virtual machine right or set of machines. And then, I may want that particular machine with particular storage and other configurations. So, I do not know where it is, how it is configured. But for me if through this particular that interface; It is a type of machines which I am looking for. Even it is possible that, I have a combination of these virtual machines, along with a particular backbone network and realize a network infrastructure for my purpose right. So, this is that what subscriber gets form me and how uses and what I pay for it. Is basically typically, per CPU hour, GB data stored, may be on a hourly basis. Network bandwidth consumed on a particular rate, network infrastructure used. That how much IP address which are the routers etcetera and value added there can be value added services. Like I monitoring automatic scaling and type of things are the things which are value added services.

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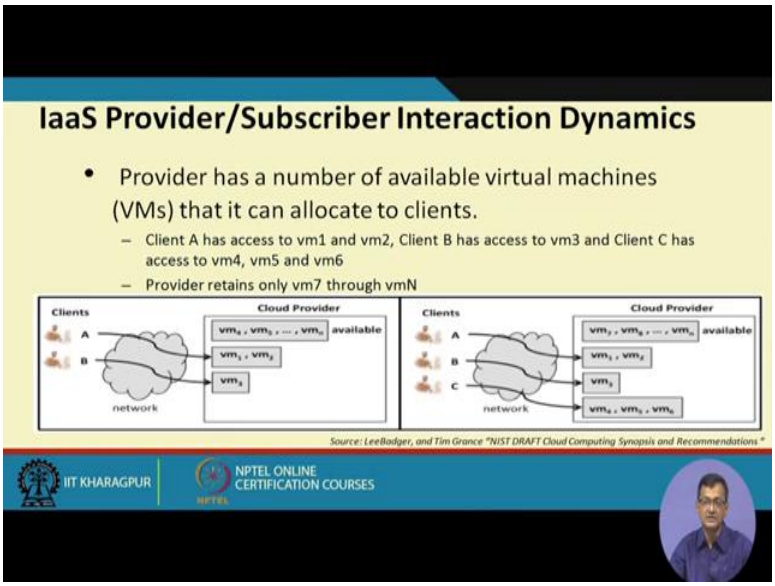

So, providers theoretically have a large pool of virtual machines; that means, if I am a cloud service provider, I say that these are my flavors of virtual machines which are I am having at my thing, right. And then I say that if you want a set of virtual machine, then I go on provisioning it right. And usually these are into different categories. Though theoretically, I can configure any of the virtual machine, but in practical sense it is under with specific configuration and etcetera. Like I say that I have VM with very low things, like in case of our 'Megamala', IIT Kharagpur. We have a virtual three type of virtual machines, one is IIT KGP VMs, which has a 4 GB RAM, with 20 GB hard disk space and these are the other processing etcetera. We have a IIT KGP large, which has a 8GB RAM so and so far. Which have a we have a IIT KGP extra large, which has a 60 GB RAM; say these are the three flavor.

Now, based on that based on my backbone resource availability, I have a mix and match of the things not only that, the type of VMs. I will have is also dependent on type of request, I get on this VMs, right. If I have a heavy request on only the smaller type of VM then, I want to provision that smaller type of VM much more than the higher things, So and so far. So, these are the considerations which come into play right. So, like in this case A has a access to VM1 to VM2, right. Whereas, B has a access to VM3, where the client C has a access to VM4 to VM6. Where the providers retain VM7 through VMn for it is other users. So, that can be that can be a modeled and go on doing that and these are typically done like that.

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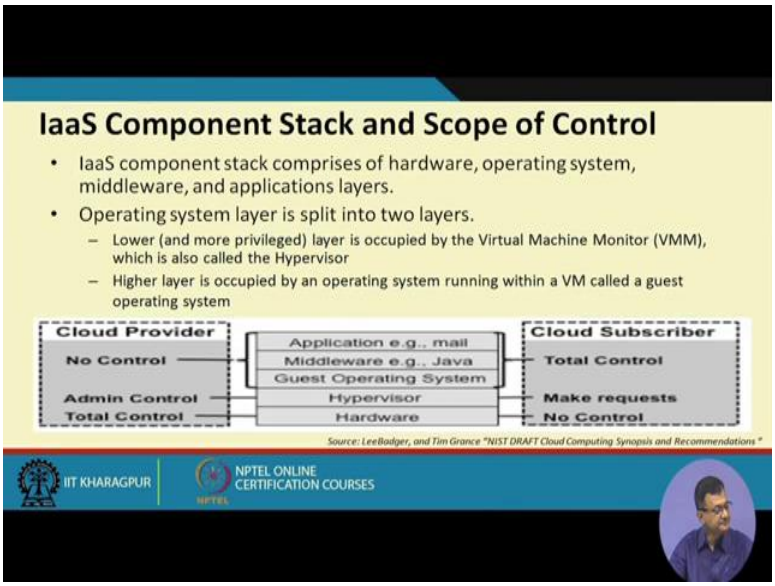

So, if you look at the IaaS component stack and scope of control. IaaS components stack comprises of hardware operating system, middleware and applications layer. So, these are the typical thing. So, operating system is built into 2 layers, lower the most privilege layer. So, if we look at the more code to the operating system is occupied by the virtual machine monitor or VMM which is also called the hypervisor, right. Higher layer is occupied by the operating system running within a VM called a Guest operating system.

So, the as we have seen that we have a like in this case, In the middle, if you see that I have the bare metal hardware, where the cloud providers have a total control; cloud subscriber has practically low control. Over that, we have a hypervisor right or VMM or virtual machine monitor. Where the administrative control of the cloud provider are cloud subscriber can basically request a request for VM etcetera to this hypervisor. And then we have, other layers like Guest OS, middleware like java etcetera. Application like mail and CRM and other type of things, where the subscriber has the total control in case of a Iaas. Where the provider does not have any control or does not provider does not control it for the thing right. So, this is the way it goes on. So, if we look at it the type of control at the upper layers are moved to the subscriber and type of control at the lower layers are moved to the provider side.

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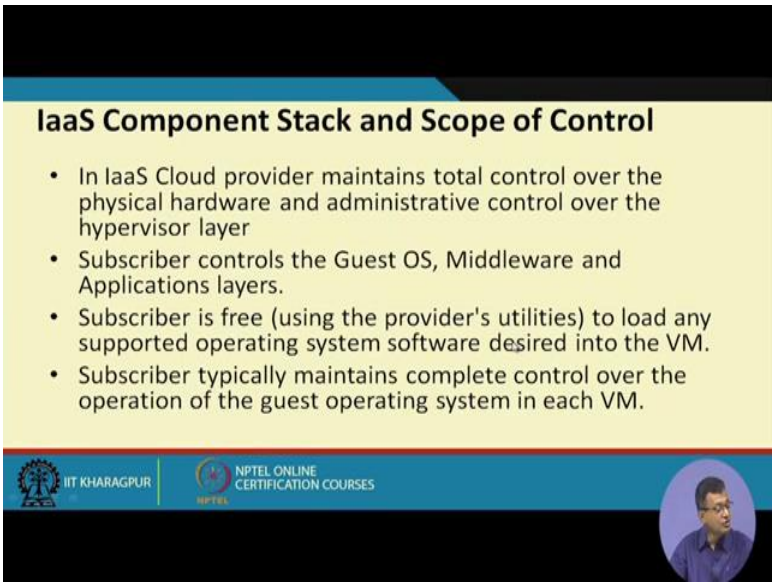

So, in IaaS cloud provider maintains total control over the physical hardware and administrative control over the hypervisor layer. Subscriber control the Guest OS, middleware and the application layers. Which are which over the subscriber. Subscriber is free using provider's utility to load any support operating system things. So, if the provider provides the support, the subscriber can load any Guest OS. Subscriber typically maintains complete control over the operation of the Guest operating system in each VM. So, though the subscriber once it loads it has the total control over the Guest OS, like if the cloud provider is providing me some Linux OS and hypervisor and allows me to load Linux or windows, etcetera. So, if I load some flavor of Linux, then I have a total control over that particular thing.

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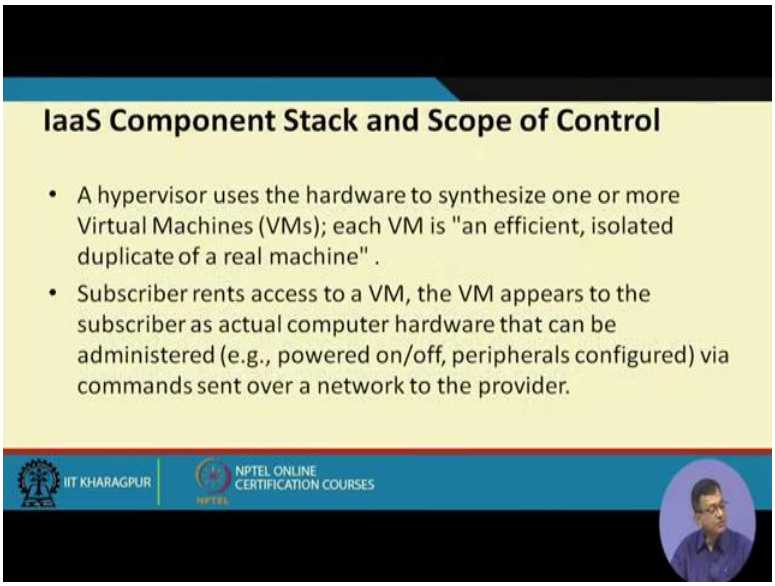

IaaS components stack and other thing, the hypervisor uses hardware to synthesis one or more virtual machines or VMs. Is an efficient isolated duplicate real machine, subscriber rents access to VM, the VM appears to be subscriber as actual computer hardware that can be administered, that is powered on off, peripherals configures via commands send over the network, etcetera. So, that it because what I am having as a subscriber is primarily interface with the provider and I can go on communicating with that.

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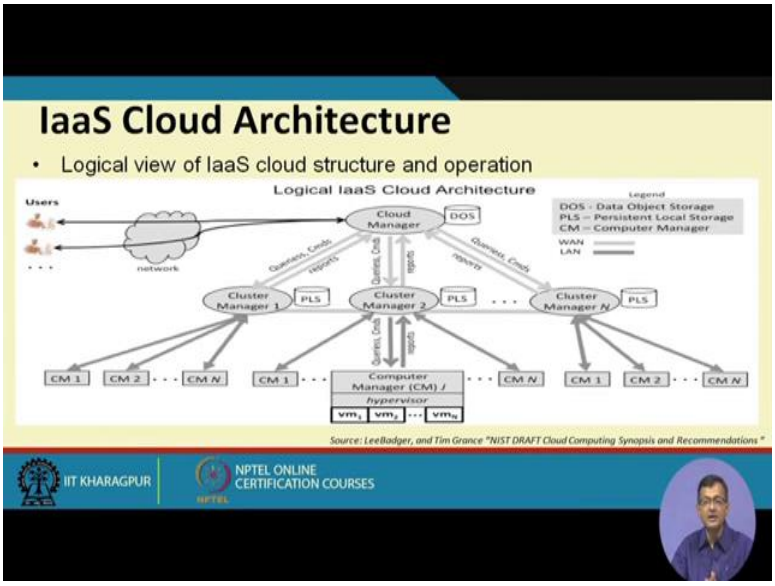

So, typically if you look at a typical architecture. So, there are several components over at the top is the cloud manager. There are different cluster managers, which are at the second level of the things and below that is the computer manager or CM, right. And the CM is basically at the; has this hypervisors and different type of virtual machine immolated over the things, right. So, we have at the cloud manager and the data object storage, which is the muster data base of keeping track of the things. Then at the lower level we have a persistent local storage like so; that means, the storage which does not go have a when the cloud provider is not there. When the VMs are not used or shut down and type of things.

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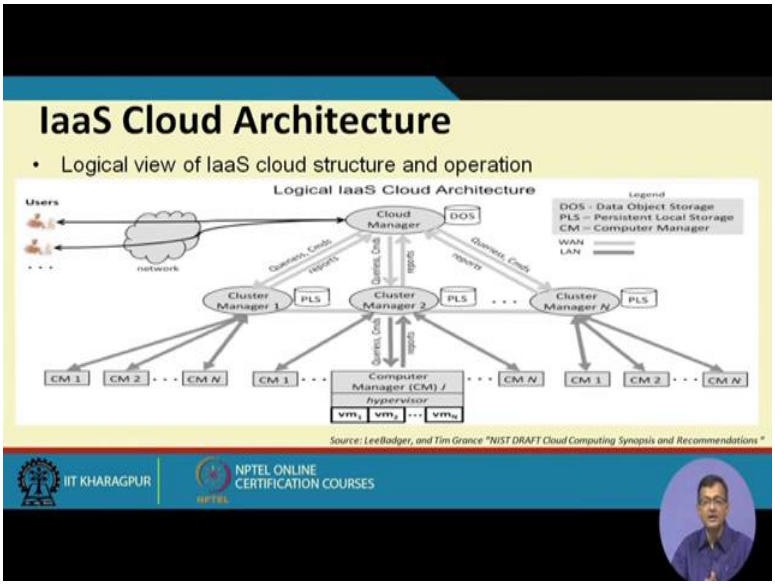

So, if we look at that 3 level hierarchies of the components, have 1 is the top level is responsible for the central control, like the cloud manager. The middle level is responsible for management of possibly large computer cluster and may be geographically distance from one another. So, if you look at this cluster manager, it is managing this large clusters, which maybe geographically spread and the third is the bottom is responsible for running the host computing system on which virtual machines are created. So, these are running this host computing system, where the VMs are created, right. So, this is typically 3 layer of control subscriber quarries and comment generally flow into the system. At the top are forwarded down through the layers which either answer quarries or execute commands.

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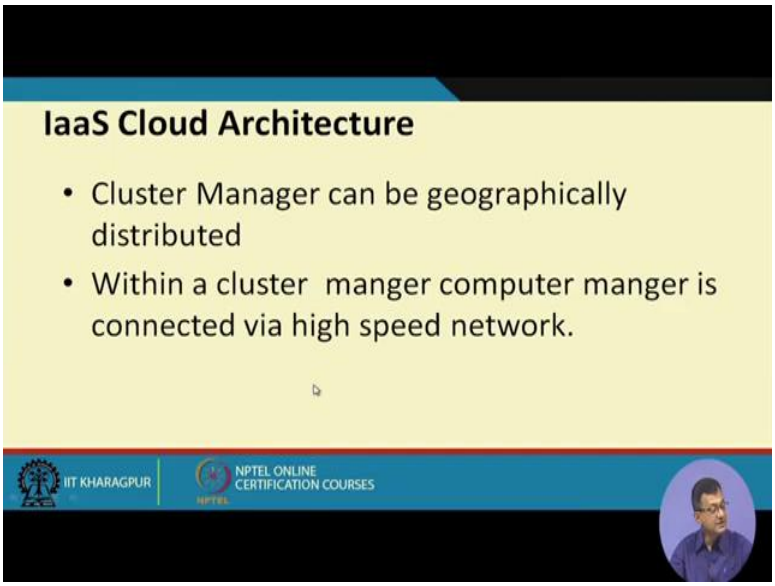

So, IaaS cloud architecture cloud manager can be geographically distributed. Within a cluster manager, computers manager is connected by a high speed network. So, this is this if you look at the cluster manager, these are all connected through a high speed network.

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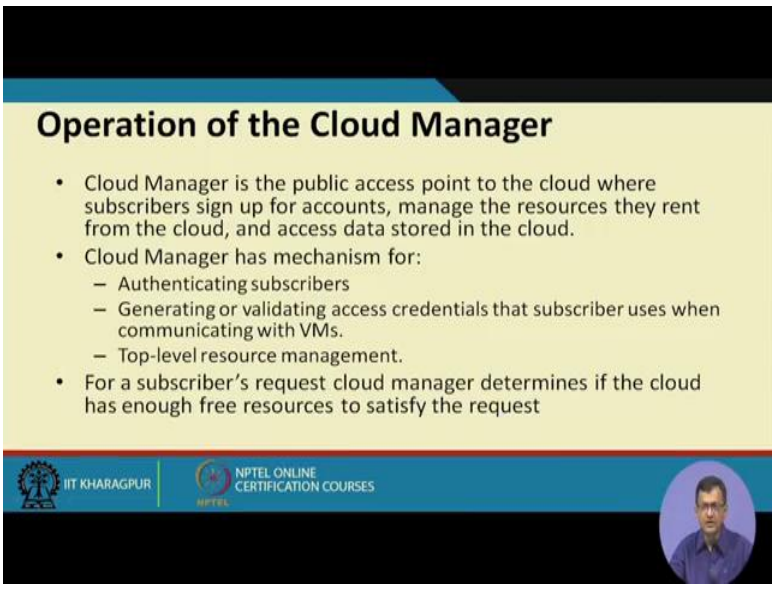

So, now if you look at the quickly that operation of the different things; so, what we have cloud manager at the top, then the cluster manager then the computer manager which manages the individual things right. So, if you look at the cloud manager duty, is the

public access point of the cloud that is the first thing. So, whenever somebody access the cloud in the public, where the subscriber sign in for accounts manage and resources they rent from the cloud etcetera.

Cloud manager has the mechanism for authenticating subscriber. Whether the authentication mechanisms, generating or validating access credential with the subscriber uses when the communication with the VMs like when it is basically the frontend of whole system, top level resource management. So, for subscriber request cloud manager determines, if the cloud has enough free resource or to satisfy the thing. So, subscriber resource on the things. So, cloud manager maintains metadata information. So, if I request for a particular VM or a set of VMs which are not available on the cloud, then it becomes the cloud manager has to take a call. So, it is manages at the subscriber level.

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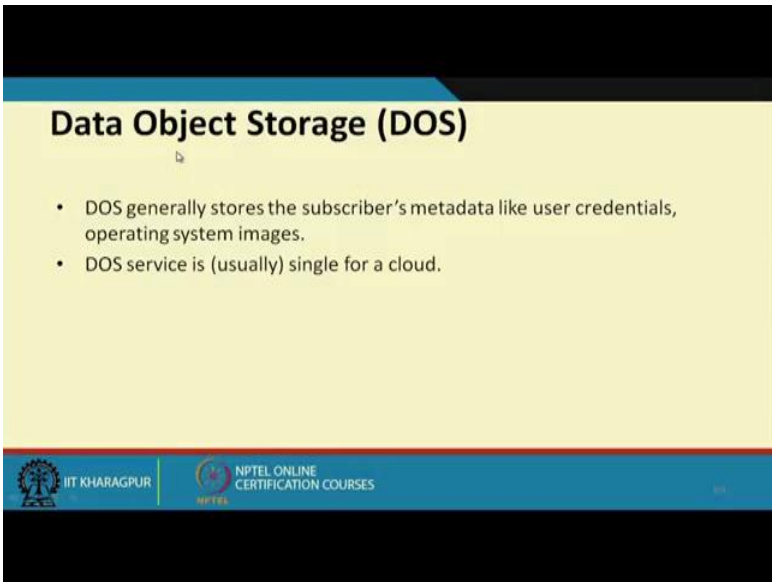

There is a thing called data object storage or DOS. DOS generally store the subscriber's metadata as we are talking about the user credential operating system etcetera. DOS service usually single for a cloud.

So, what we say that the particular DOS service is for a particular cloud. So, it maintains a; what we say registry or a cataloging or a metadata service for that whole cloud. So, it is the binding block of the whole thing, that what are the services available whether the free resources available etcetera are all updated in those.

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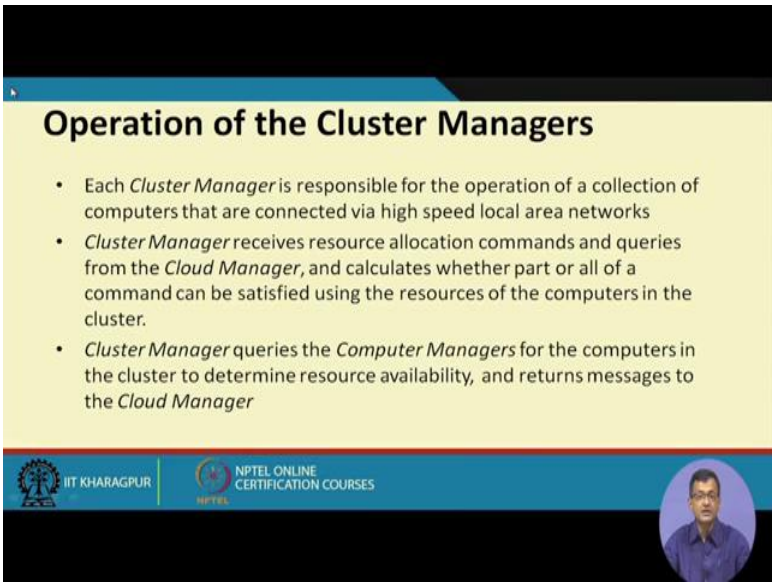

So, if we look at the cluster manager that this middle level. So, it is responsible for operation of collection of computers that are connected via high speed local area network, right. So, that is the; it manages the lower level computers, cluster manager receive resources allocation commands and queries from the cloud manager at the top and calculate whether the part or all of a command can be satisfied using the resource of computers in the cluster. That means, when the cluster manager gets a request, it checks that whether the; it is available resource within the cluster. Whether it is able to satisfy the things and accordingly it says appropriate signal to the things. Like so, that it can accept or cannot accept and type of things.

Cluster manager queries the computer manager for the computers in the cluster to determine resource availability, returns messages to the cloud manager. That mean, it becomes a middleware or a agent between the cluster manager and the cloud manager. If you look at the operation, there it get the direction for the cloud manager and then instructs the computer managers to perform resource allocation, reconfiguration, de allocation of resources and etcetera. Is cluster managers connected to a persistent local storage; that means, it is the. So, called coat uncoated non volatile storage. When the particular virtual machine is shutdown, deprivation or some issues come up. So, that it has a local storage into the things.

So, this PLS provide persistent disk like storage to the virtual machine. So, it is as if persistent disk like the same things are there. So, the data when you next time log in it will be available with you.

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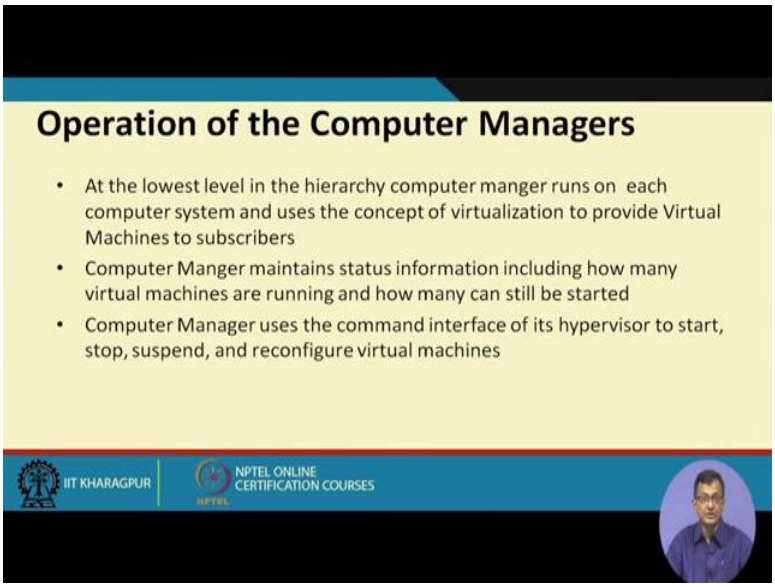

So, look at the; if we look at the operation of the cloud manager. At the lowest level in the hierarchy cloud manager runs on each computer system uses the concept of virtualization to provide virtual machine to the subscriber. So, cloud manager is basically providing the VMs. So, it is the to the subscriber this providing VMs it is responsible for that, computer manager maintains status information including how many virtual machines are running, etcetera. So, it maintains the status information, as of now how many virtual machines are running. Also cloud manager uses command interface to hypervisor to start, suspend and reconfigure virtual machines.

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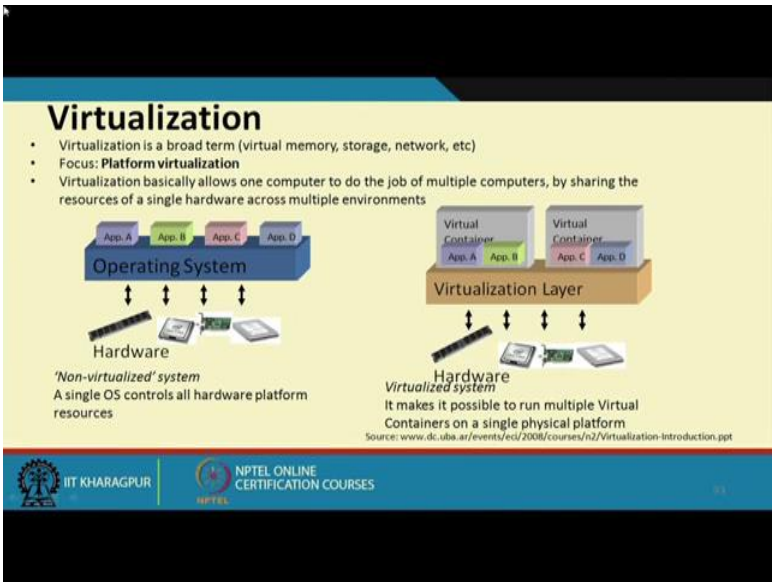

So, it also same if there is a need to the computer manager. So, all this what we see is, virtualization place important role, right. So, how this virtualization is made and what are the aspects etc: thing we will try to see quickly in the subsequent slides. So, virtualization is a broad term, it can be a virtual memory, it can be virtual network, it can be virtual storage, etcetera. So, anything which can be virtualized is a virtualization aspect. Our primary focus is the platform for virtualization, right. Virtualization basically allows, one computer to do the job of multiple computers, right, by sharing resources of a single hardware across multiple environment.

So, that is important so; that means, I have a bare metal then, I create different machines or virtual machines which can cater to the things. But at the back end, my same bare metal is running. Now this becomes a very tricky. So, because suppose you are running if you are having the your bare metal on particular environment and then you are running one machine on windows, one machine Guest OS on Linux, one machine or some other things etcetera. Then there is a problem of issue of how this say instruction set of this Guest OS will be running on the hardware at the end. So, that there are issues of like that, there are issues of application sizing there are issues when the VM says that, I require more resources or I want to release other things, how it manage So and So forth.

So, of we look at the hardware. So, if it is a no virtualizes system a single OS controls the all hardware platform resources. If it is a virtualization system it takes the possibly, it

makes it possible to run multiple virtual containers on a single physical platforms. So, I can have multiple virtual containers, which can run on or which can be plugged into a single physical infrastructure.

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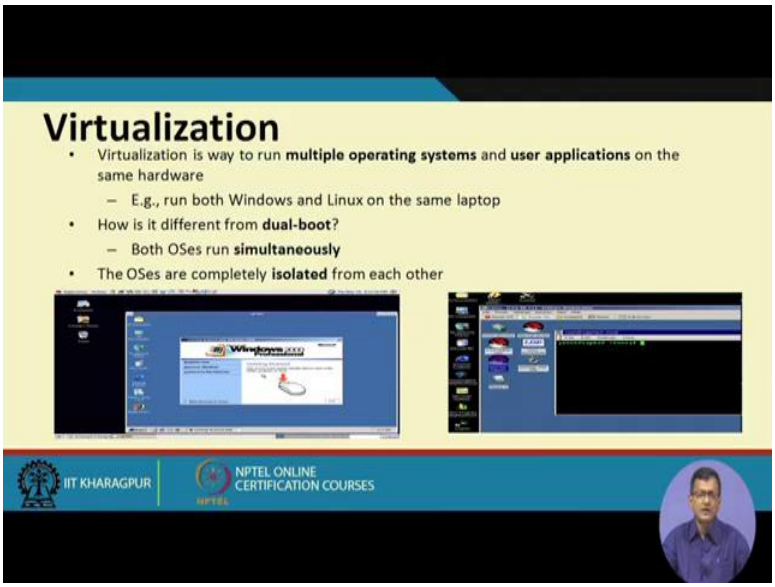

So, we are somewhat experienced with this virtualization. So, virtualization is a way to run multiple operating system and user application on the same hardware. So, that is virtualizes. So, I can I have 2 different operating system on the same; that means, I say I virtualized one this OS out of this, right.

So, run both windows Linux on the left off. So, how is it different for dual boot also? We are doing that once windows etcetera. Here in case of virtualization this different OS or all the OSs are running together right or simultaneously. The OSs are completely isolated from each other, right. They are completely isolated from each other in case of a true virtualization.

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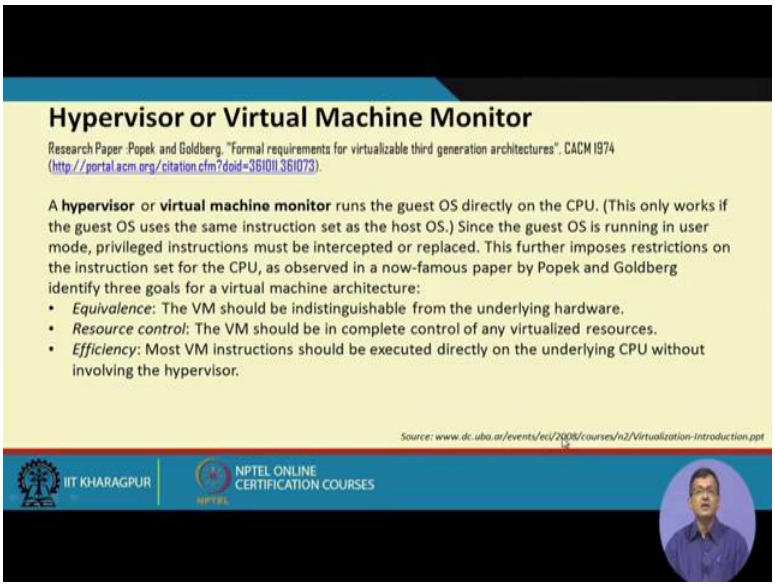

Now, another important aspect of things which come into play is the virtual machine monitor or hypervisor. So, a hypervisor or a virtual machine monitor runs the Guest OS directly on the CPU right. so that means, I have a Guest OS and at the as my which has been immolated or installed by the subscriber or running on the or it is application on the of the client. And then the hypervisor is responsible to execute this or run this Guest OS directly on the hardware, at the back and the things.

So, this works if the Guest OS uses the same instruction set of the host OS right. If it is a different instruction set, then there is a instruction translation should come into play right. So, there are several issues, as depicted by Popek and Goldberg, that 3 goals of virtual machine architecture: are there, 1 is that equivalence the VM, should be indistinguishable from the underlying hardware. So, as if the virtual machine is running on the hardware itself. So, what we say it is equivalence or resource control, the VM should be incomplete control of the virtualizes resource.

So, if you give me 4 GB machine, 30 GB or 60 GB hard disk so and so forth that I should have to complete control over the thing right as subscriber. And efficiency, most VM instruction should be executed directly on the underlying CPU without involving the hypervisor. So, that is another thing. So, efficiency will increase if the most of the virtual machine instruction, should able to execute directly on the underlying CPU without intervention of this other involvement the hypervisor. So, these are the aspects which

need to be looked into, when we have virtual machine monitor or hypervisor in place which allows me to emulate VMs.

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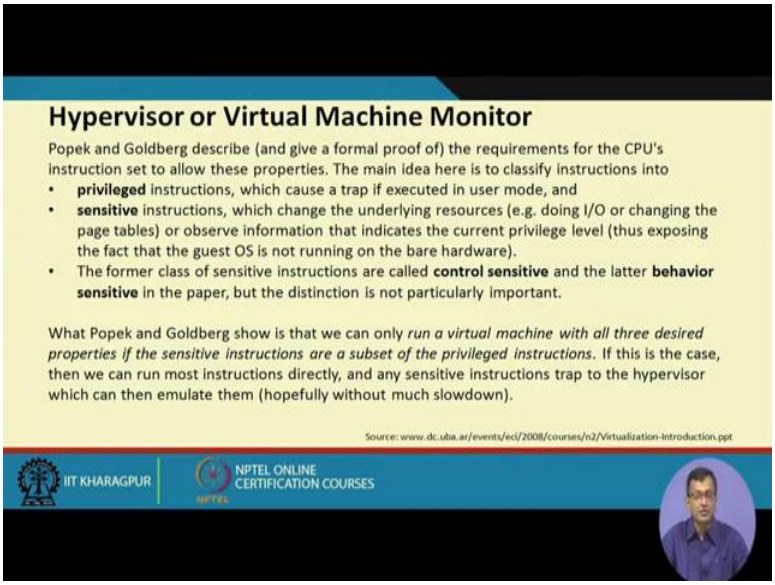

So, again in the same work these Popek and Goldberg describe and also give a provided a formal proof of the requirement of the CPUs instruction set to allow these properties to happen. Like to allow truly virtualization happen at the IaaS level, the main idea is classifying this instruction into 3 different thing. One is privileged instruction, which cause a trap in the executed in the user mode. There is a sensitive instruction, which change the underlining resources, that is doing IO or changing the fact that the Guest OS is running on the bare metal etc; a sorry means first of all changing the IO or the page tables or observe the information indication on the current privilege level.

So, if you remember your basic architecture things. So, I have different level of operations like level 0 level 1 so and so forth. So, more the lower the level, as I go more on the more closer to the bare metal. So, it all depends that your virtualization at which point it operates. More the higher level then more latency will come into play, more translation will come into play. So, we need to look into the things that what level operations I need to do; especially when we do IaaS type of operations.

And the former class of sensitivity instructions also called controls sensitive or latter call are behavior sensitive operations right. So, what this Popek and Goldberg show, that if we can run a virtual machine with all the 3 desired property if the sensitive instruction

are a subset of a privilege instruction. In their work they have shown that, these sorts of things are true and we can realize a true virtual machine.

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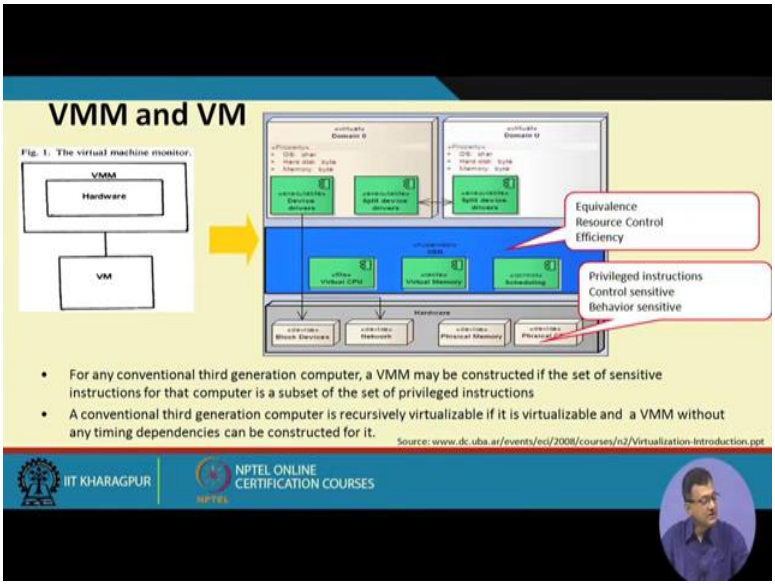

So, the same thing or thus whatever we are discussing. So, we have this VMs and this hardware over this virtual machine monitors is running and it is allows us to emulate this different VMs right. So, it can be yours. So, some where other whatever the Guest OS running on the VM. The instruction set need to be converted which can be understood by this hardware, right. So, that is our bottom line. So, whether it is whether the whole VMM will have a total abstraction or also have some sort of overlapping with the things, that that depends on whatever the implementation.

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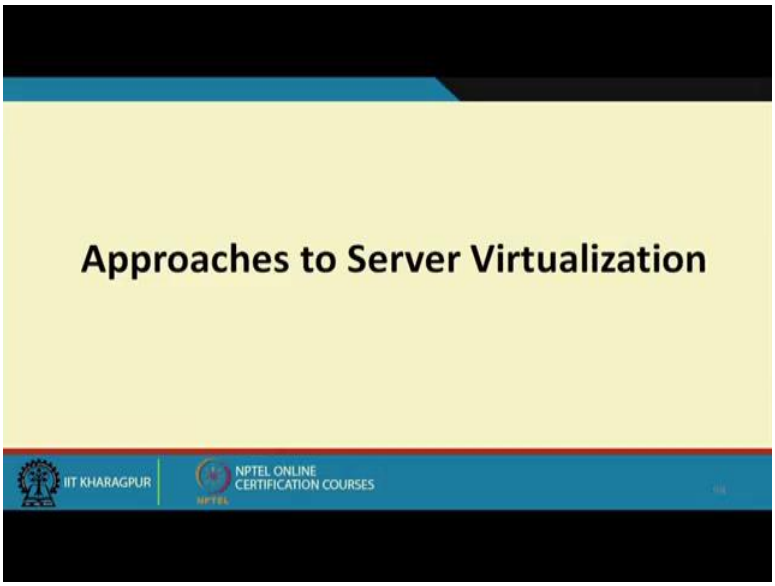

So, if we look at the approaches typical approaches to virtualization.

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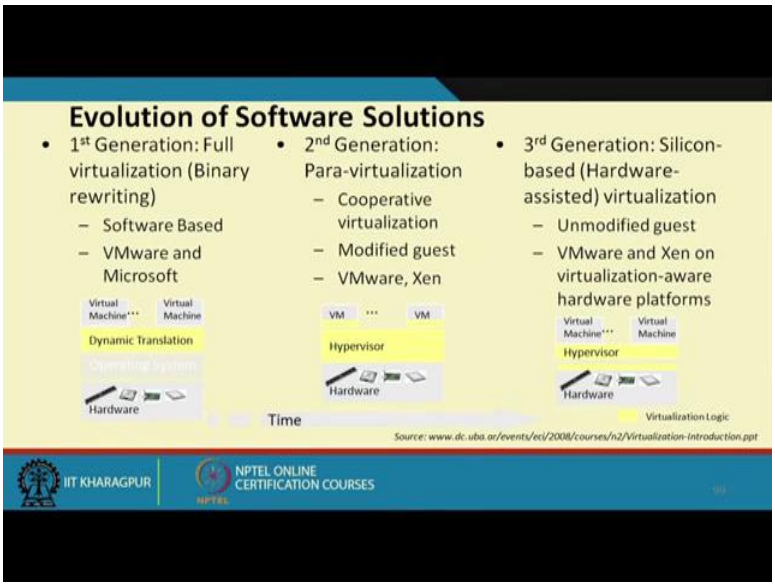

So, if you see the evolution of this virtualization, one is what we say first generation or full virtualization so, binary rewriting. So, it is software base, VMware and Microsoft supports this. So, whatever the virtual machines are generating a dynamic translator, rewrites to the underlining hardware So and So forth. In case of a second generation: virtualization or Para virtualization cooperative virtualization. So, it is a cooperative virtualization the Guest OS or the modified guest and VMware and xen does it. So, it

basically if you look at here. So, it penetrates little bit into the VM; that means, that is modified on the things. In case of a third generation or what we say silicon based, their is hardware assisted virtualization, unmodified Guest, VMware and xen on the virtualization aware hardware platform. So, now your hardware platform is a virtualization aware. So, it is hardware assisted virtualization. So, in these cases these hardware platforms are not aware of this virtualization. Whatever is done by this your hypervisor?

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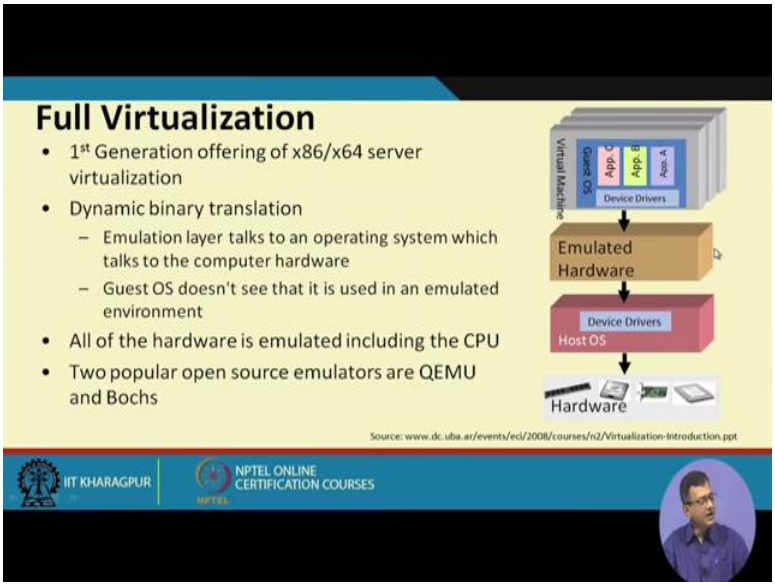

So, there are different things in case of full virtualization, first generation offering. So, dynamic binary translation of the source code, as we have seen all the hardware is emulated including the CPU. To popular open source emulator, many of you might have seen QEMU and Bochs. These are the two popular emulator which change that open source.

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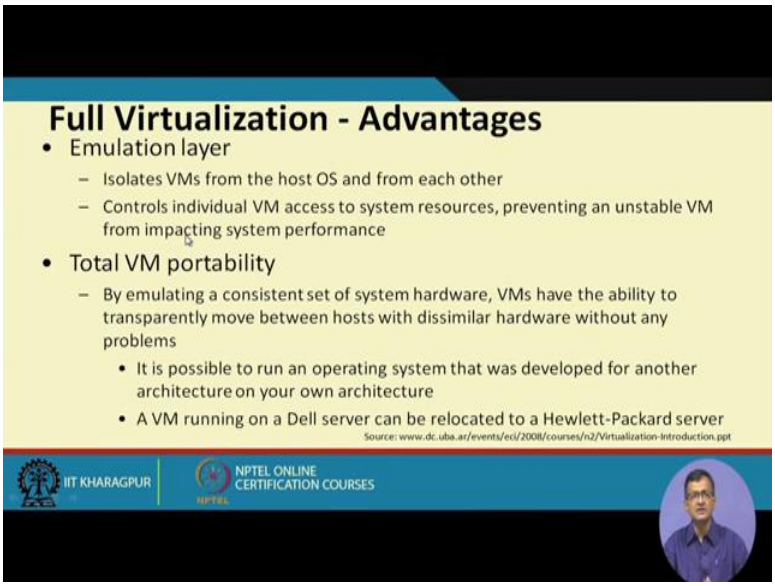

Full virtualization, there are advantages of emulation layer, like you do not bothered about that two things are separated. Total VM portability, like I can put take the VM from one to another. So, put total portability, because only the VMM, I need to understand this. There are drawbacks this hardware emulations comes with a performance price.

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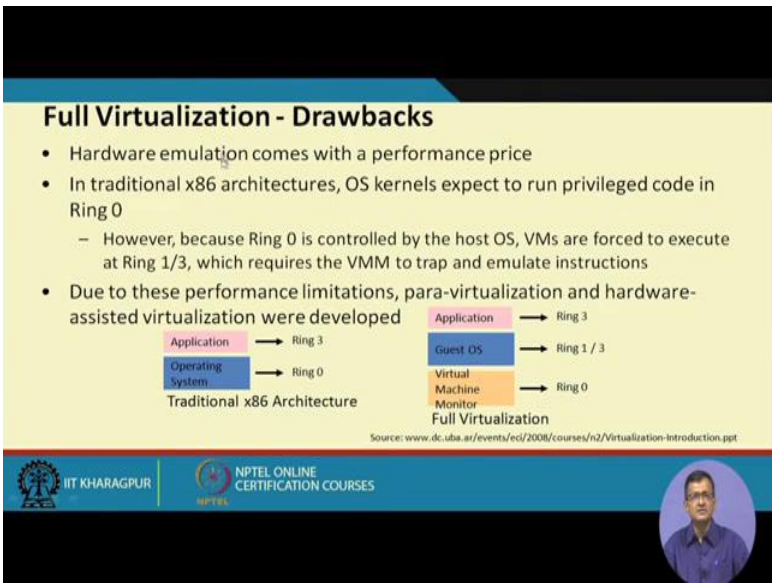

Whenever you want to emulate a hardware performance price in traditional x86 architecture, OS kernels expect to run on the privilege ring 0. And now you want to run

them at a higher level and that need to be, there should be more latency and other things come into play.

So, we need to pay for that, or what we need to there is a performance price for that thing.

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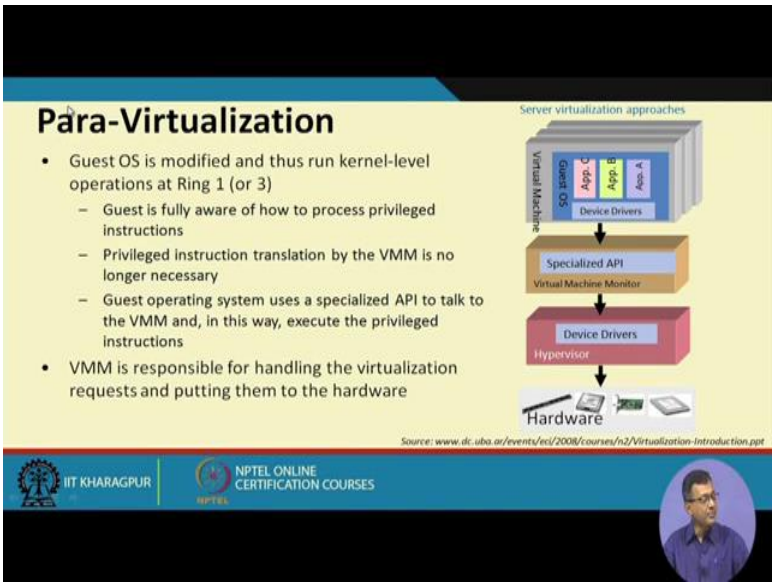

In case of Para virtualization, Guest OS is modified and thus run kernel level operating system at ring 1 or ring 3. That is much higher level Guest is fully aware of how to process privileged instruction. Privilege instruction translated to VMM is no longer necessary. Guest operating systems uses specialized API to talk to the VMM right. So, it is Para; that means, your VMM is penetrating to use some sort of a some into your VMs. So, that now it is not full translation, but I have a Para virtualization the performance increases and this thing is becoming pretty popular.

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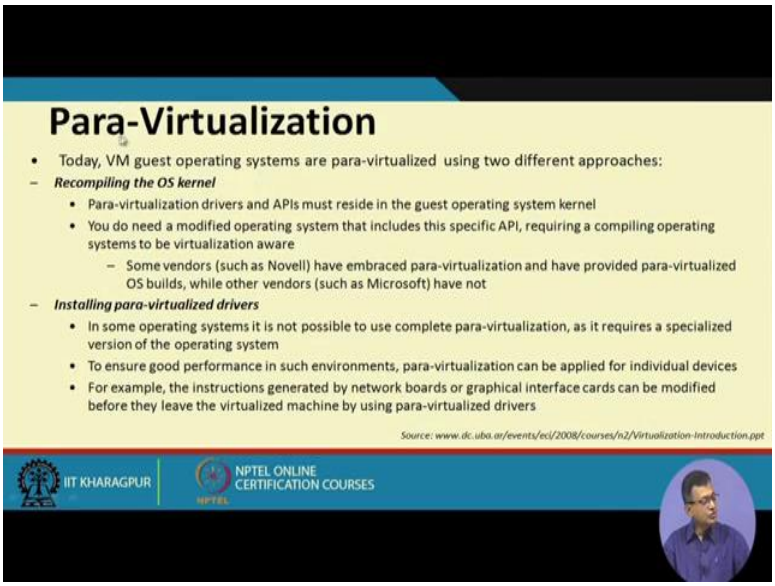

So, in case of Para virtualization recompiling of the OS kernel is required because, there is penetrating into the things installing of Para virtualized drivers are required. So, that it takes care at your Guest OS level.

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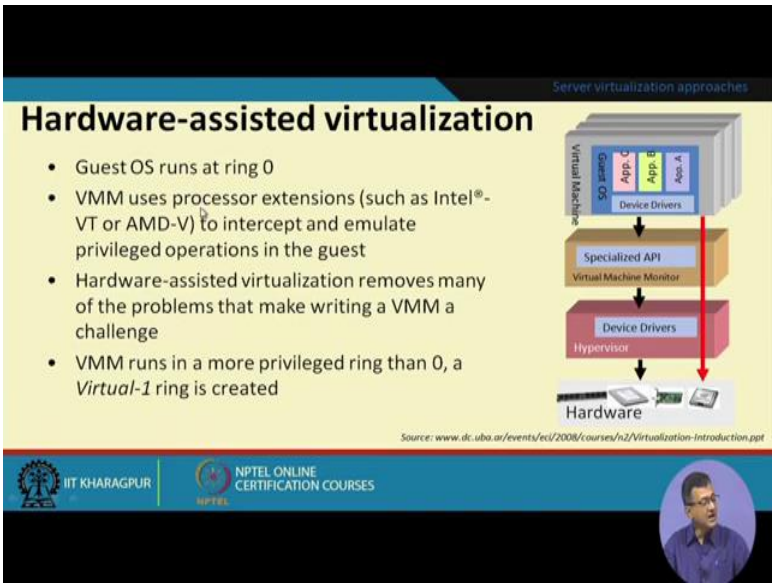

The third one is a hardware OS running on a ring 0. VMM uses processor extensions like in case of Intel VT or AMD V and type of things to interpret the privileged things. Hardware assisted virtualization removes many problems that take place in writing a VMM into a, rather it is a big challenge. So, that it is hardware assistant so; that means,

you go directly over thing is totally fully complied. In doing so, you lose that portability of the VMs right it becomes a more tricky issue because you need to migrate to something which understand that hardware. Pros it allows run unmodified OS, right you the OSs need to not be modified; cons is the speed and flexibility is issues that when that your flexibility you lose and the speed it depends when the migration, etcetera comes into play.

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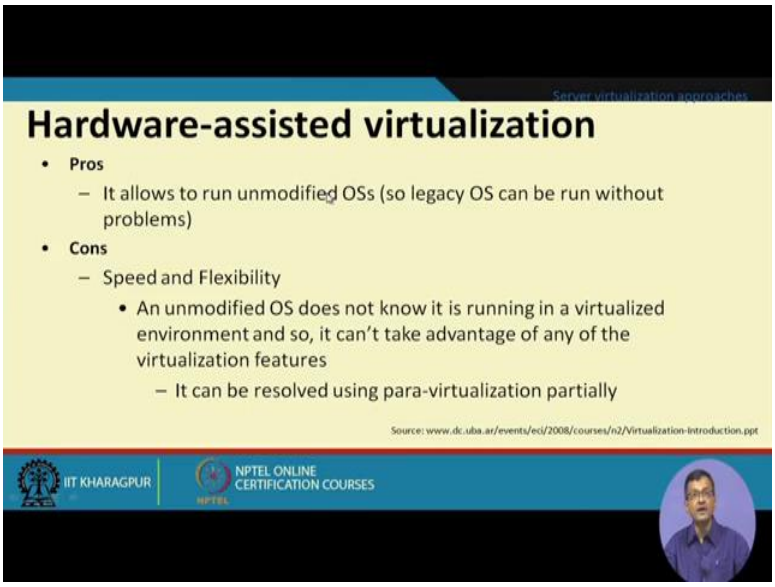

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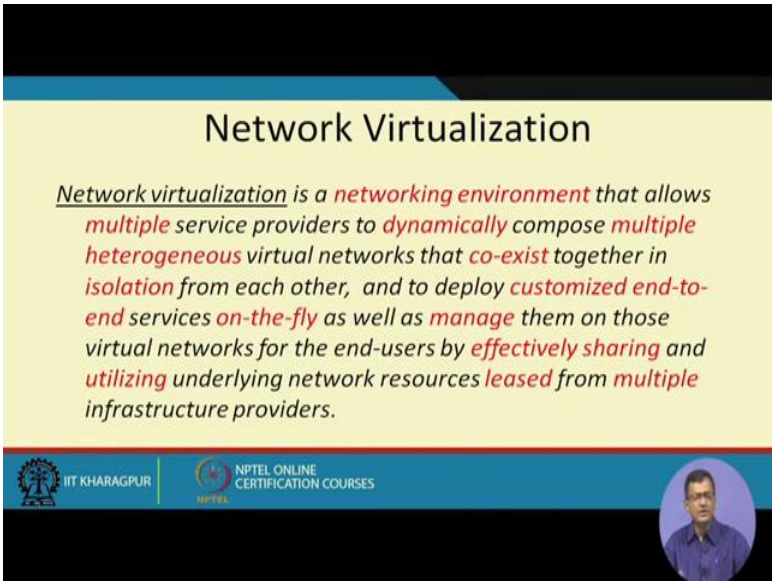

So, with that we will just touch upon, some of the more aspects of the things what we say network level virtualization.

So, that now what we are looking as the hardware, now we are looking at the network level; that means, I need to emulate a network over a virtual network over a given network, right.

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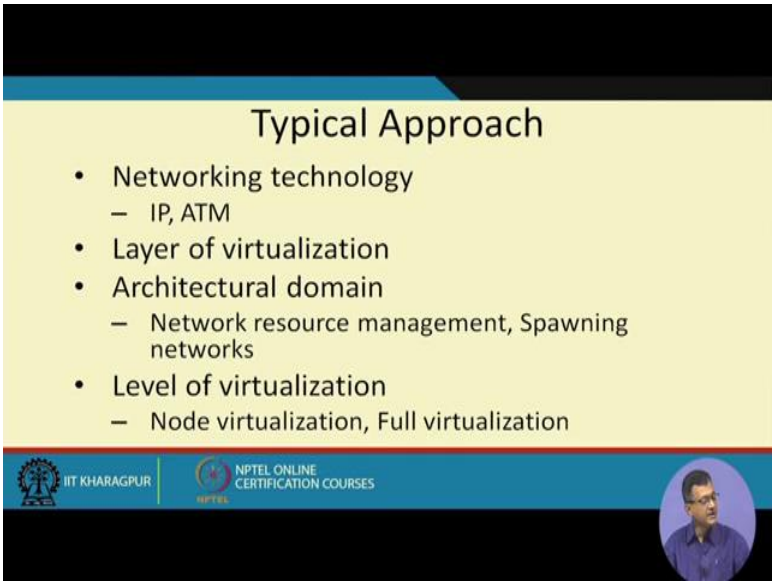

So, typical approaches what we have seen is that in case of a network technology that is whether IP base or ATM base layer. Which layer of virtualization is there are architectural domain, like network resource managements, spawning network and type of things, level of virtualization which is node level or full virtualization of the things like.

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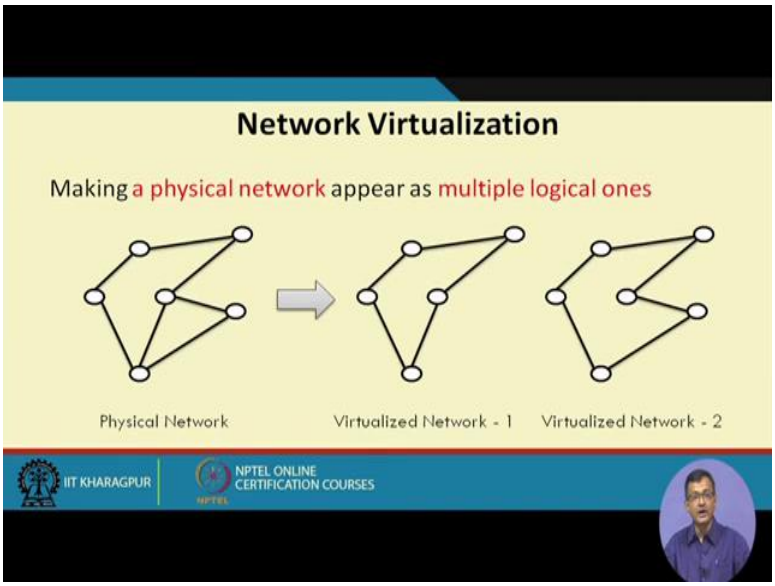

If you look at suppose I have a network like this. Then I can emulate a virtual network like this or I can emulate virtualizes network like this, right. So, this is my base network. So, it I can have 2 type of virtual network on the thing over and above of this thing.

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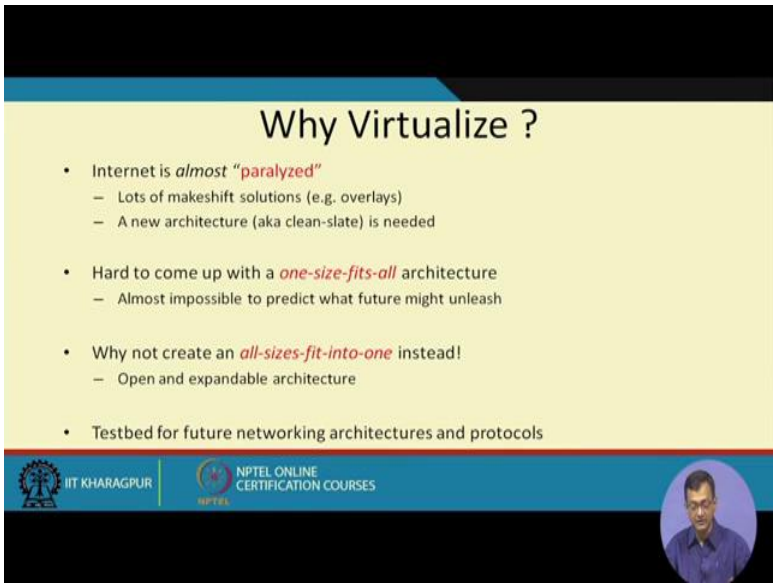

So, I emulate a virtual network, why to virtualizes now what people say that not only internet in your own networking paradigm is becoming paralyze. Like you do not have much in go space. Hard to come with a 1 size fit all type of architecture in number of cases. Like you have a network configuration and fits everybody. So, why not to create

something that all sizes fit to one instead type of scenario. So, that is the things what we want to do. So, test bed for future and there is that is and any futuristic working on the network, protocols and etcetera. Require a test bed for that putting a whole networking things may be a challenge. So, I can have a sort of virtualizes network.

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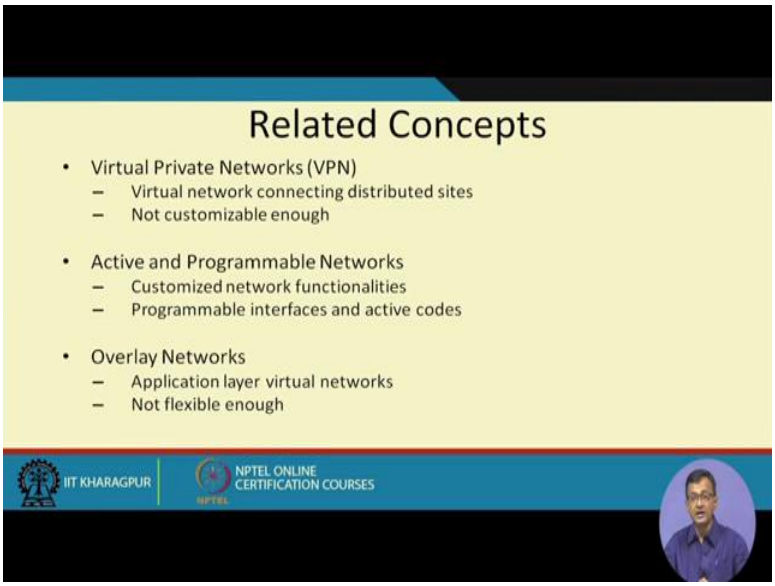

And this is not suddenly came into play, we have lot of things which are already in play that is a virtual private network active and programmable networks, overlay networks these are already in place for several years and this is being emulated over that.

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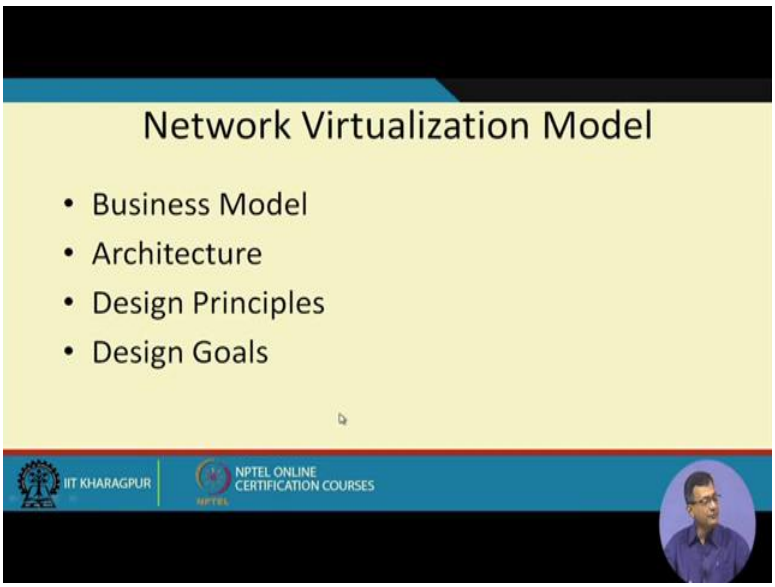

And if you look at there are different type of aspect like business model architecture, design principle, design goal and those are the things.

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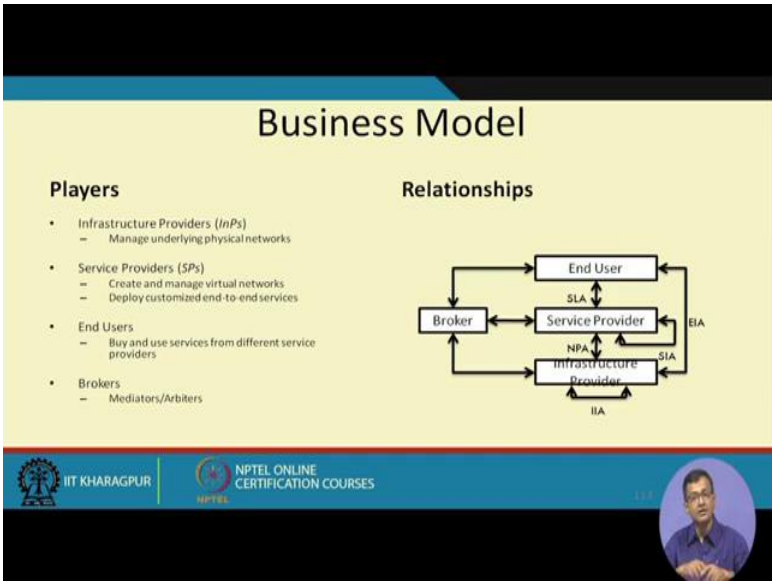

And there are different aspects of those, like infrastructure providers, service provider's, end user, brokers. These are the different players and they have a very complex relationship between each other that how things will be there. And this business model is not only true for network virtualization, it is true for other sort of virtualization as well and if we look at that architecture.

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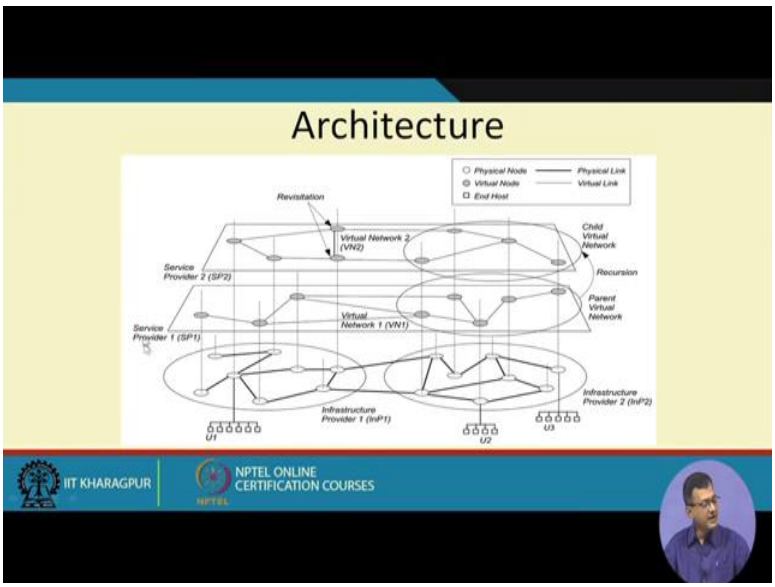

So, if I have that infrastructure provider, then I have a service provider 1 which is have some sort of a virtual network. Emulated from this, like making active some of the networks etcetera and I can have other type of service provider 2, SP2 emulating, other type of networks as well. So, I can emulate different variety of network on a basic underlying network. So, I can realize different networks into the things. So, these are also becoming very popular. So, having say not only having servers like, I want to conduct a particular testing over across the geographical space.

So, not only I want these servers into the place. I also have a particular network infrastructure into play, right. Then those then if you want to have those, type of things then I not only require the virtualization at the IaaS level or the server level virtualization. I also require a network level virtualization into play and making this overall I can have a virtualized IP infrastructure into place right. So, we will continue our discussion in our subsequent lectures we will stop here today.

Thank you.