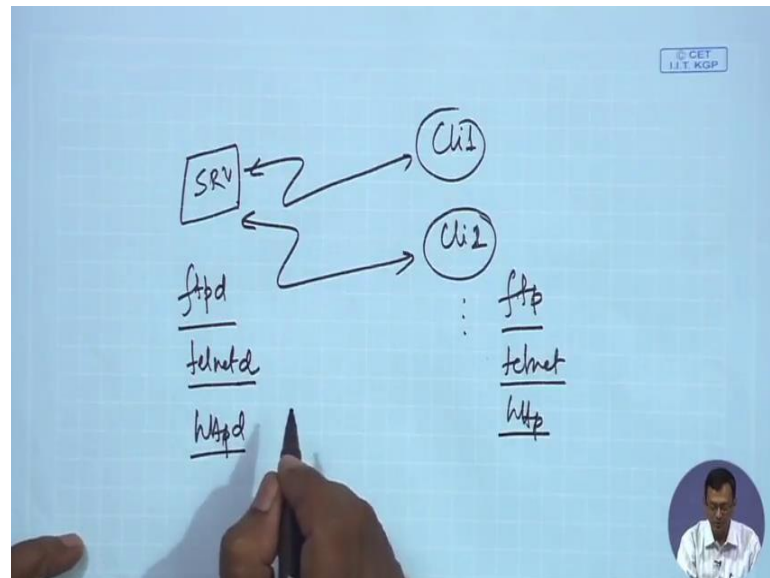


**Cloud Computing**  
**Prof. Soumya Kanti Ghosh**  
**Department of Computer Science and Engineering**  
**Indian Institute of Technology, Kharagpur**

**Lecture – 05**  
**Cloud Computing Architecture (Contd.)**

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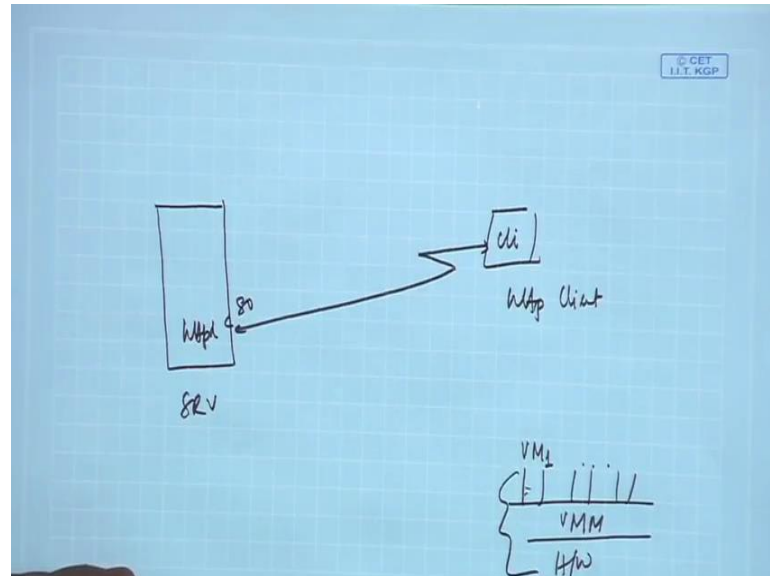


Hello, so we will continue our discussion with cloud computing architecture. So, in the last lecture, we are discussing about this client server - traditional client server paradigm, and what this cloud is offering from the service orientation point of view; we will continue that discussion with the things. So, what we have in case of a client server model and we have a server and we have several clients which are connecting to this server, right. So, we have several clients which are connecting to this particular server. So, this server and client logically or physically can be on the same machine, the same machine can be client server, different machine can the machine can be one client one server. A client can access server for some other things, etcetera.

So, what we do we have for every server things, we have a client like if I have a ftp client server. So, what we have ftpd daemon in a particular Linux flavor and there is a ftp client. So, ftp client look for a ftp server. So, in this case, what to try to realize a server basically the server process waits on a particular port. So, what we does like say if I have

ftp or telnet similarly telnet d, if the telnet daemon server then telnet or very popular thing httpd, then I have http server. So, these all these things are a way particular port.

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That means, a in the in the server machine say for say httpd. So, a particular in the server thing. So, in the port 80 that logical port 80, the http daemon is listening. So, from somewhere from a client or http client that is any of the browser, it basically same say request to the things if the server is speed connects to the things and the connects in the rest of this, right. So, server does a always listening to a particular port is any client is there. Whenever the client needs a service, it basically hook into that port and it goes on things.

And we have seen that 2 type of that can be a concurrent server will give service is concurrently or there can be a iterative server one after another, but all this things I require a one component of this whole process like for http, httpd and http etcetera to talk to each other. So, somewhat it is more strongly bound, but nevertheless it serves many of our purposes and it is serving and we will be serving and it diffract to our standard in any type of sort of application where data and application communicates with each other.

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**Client Server Architecture**

- Consists of one or more load balanced servers servicing requests sent by the clients
- Clients and servers exchange message in request-response fashion
- Client is often a thin client or a machine with low computational capabilities
- Server could be a load balanced cluster or a stand alone machine.

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Now, client server architecture consists of one or more load balancing server send by the things. Client and servers exchange messages by request-response. Client is often may be a thin or a machine with low computational capability, not necessarily, usually. Server can be load balanced cluster or a standalone machine, etcetera. Like if you think about out http server using the server is much stronger and fatter systems whereas your client on anything from your mobile device to laptops to or some any type of devices which can be there, but nevertheless it can be some higher end devices also. So, it basically tries to emulate a three type of architecture, one is a presentation layer at the top level, then logical layer and the data layer at the bottom level. So, this; try to realize a three tier architecture.

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**Client Server model vs. Cloud model**

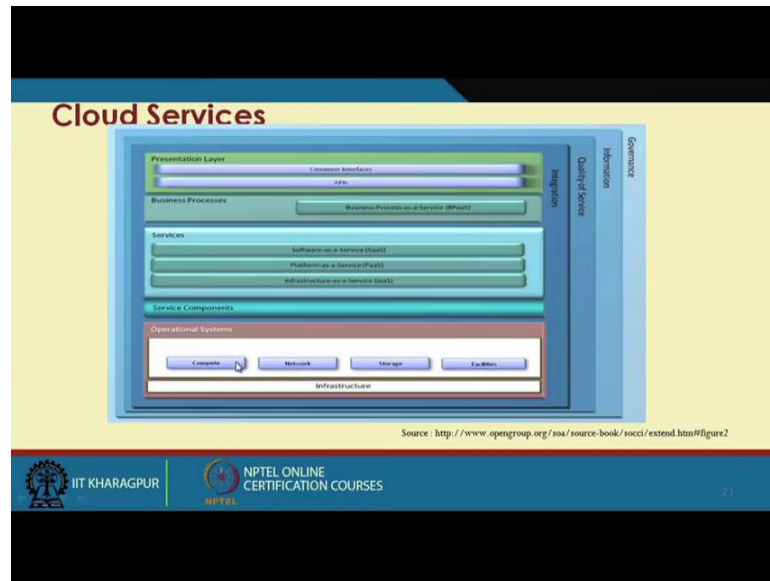
Client server model	Cloud computing model
<ul style="list-style-type: none"><li>• Simple service model where server services client requests</li><li>• May/may not be load balanced</li><li>• Scalable to some extent in a cluster environment.</li><li>• No concept of virtualization</li></ul>	<ul style="list-style-type: none"><li>• Variety of complex service models, such as, IaaS, PaaS, SaaS can be provided</li><li>• Load balanced</li><li>• Theoretically infinitely scalable</li><li>• Virtualization is the core concept</li></ul>

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And if we and this is a very popular things what we are which we are use to and if we try to look at that little bit comparison with the things what is the need of cloud computing or where it is different. So, in case of a client server, simple service models server service clients request, in case of a clouds variety of complex service models like IaaS, PaaS, SaaS can be provided. So, it is a so every service in case of a client server, I should have a sever program where the client connect, where in case of a cloud we have different type of XaaS type of service models. So, the way of looking at the service model it says different may or may not be load balanced in case of a client server. Whereas usually these clouds are load balanced that is one of the major aspects what we want to do.

Scalable to some extent in a cluster environment, so if the things are running over cluster this is scalable and in case of a cloud it is theoretically infinite scalable. So, anything can be there. The most important thing is there is no concept of virtualization right, in case of a client server. And the virtualization is our main concept or the core concept in cloud computing. So, these are some of the things and what we try to show or propose that this cloud computing is able to do much more justification or much more better utilization of the whole resources and able to cater a large number of stakeholders.

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The picture is not pretty clear but so just divide the things one is that at the bottom is the infrastructure of the operational, operational systems like you see that compute network storage facilities and middle is the different type of services. So, I have infrastructure thing. So, we want to have little bit broader view of this of this cloud computing cloud services. So, these are our core bare metal. So, layer is realization of the services right. I have IaaS, PaaS or SaaS type of services. These services you use to have some business processes to run. So, it is not the services not only the services, I want something business my business was need to be realize. So, I work use the services to run different business processes. So, this is business processes.

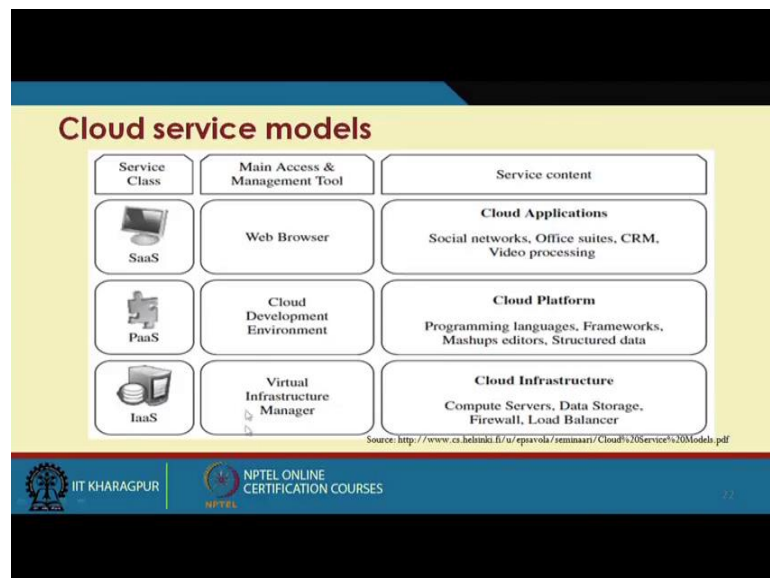
And I can have business process as a service to the thing. There is a presentation layer what we can have directly some interfaces with the users or I can have some API which allows me to connect to the connect to these different service model, like we are use to different type of APIs for different service provider is that I use that APIs to connect to the things. So, I do not I expose myself as a service provider this giving this API. So, or I can have customized user end some applications or what we say some particular interfaces to connect to the things.

Now whole thing should have a integration platform right, it is integration not that very strongly integration platform that is integration of the hardware it require some sort of a particular architectural point of view where I wants to have a service integration then I

should have a orchestration engine some sort of a execution three type of thing. So, service execution thing, so integration.

Then I whenever I do that then we require that some what is the quality of servicing doing all those things whether I can operate at the appropriate level of service what we want to confer. There is a dissemination of information or type of things right what sort of what services are provided how to hook in to the things that is information type of things. And finally, I should have a overall governance; this governance may be management of the infrastructure or the management of the whole system the governance we have also have legal issues and policies implemented, so that the legally valid as per the federal laws and regulations. So, this makes the governance.

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And we basically realize those things we having different services; I am not repeating this because we have seen this in several in other form in several sides. So, finally, we are using this different service model.

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**Simplified description of cloud service models**

- **SaaS** applications are designed for end users and are delivered over the web
- **PaaS** is the set of tools and services designed to make coding and deploying applications quickly and efficiently
- **IaaS** is the hardware and software that powers it all – servers, storage, network, operating systems

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So, we will just see a little bit again relook into this service model little bit in a little more detail SaaS, PaaS and IaaS.

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**Transportation Analogy**

- By itself, infrastructure isn't useful – it just sits there waiting for someone to make it productive in solving a particular problem. Imagine the Interstate transportation system in the U.S. Even with all these roads built, they wouldn't be useful without cars and trucks to transport people and goods. In this analogy, the roads are the infrastructure and the cars and trucks are the platform that sits on top of the infrastructure and transports the people and goods. These goods and people might be considered software and information in the technical realm

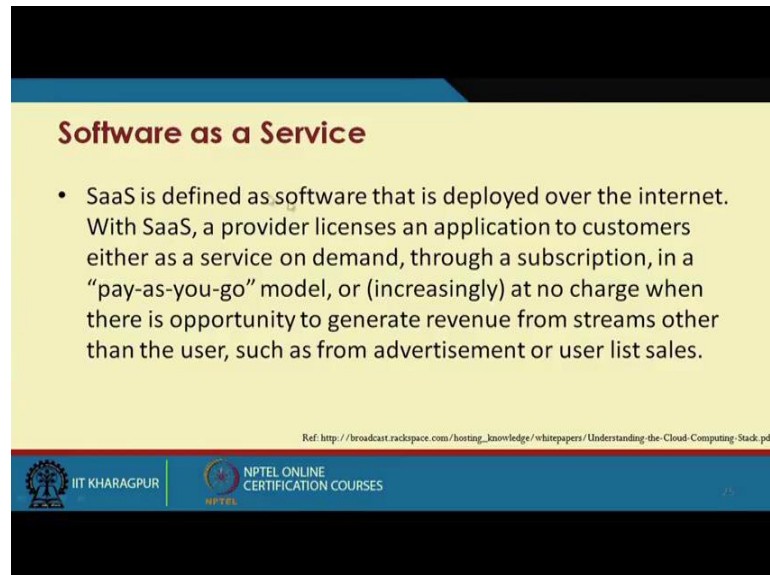
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Like one may be the sometimes; they have a we used to have a studies in analogy with our transportation like roads are the infrastructure, cars and trucks are the platforms which carries the thing, and goods and people might be considered at the software or information in a technical terms or technical paradigm. So, as if I have this infrastructure

over that I have different platform and this different applications are running over the things if we look at the point of our cloud computing paradigm.

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**Software as a Service**

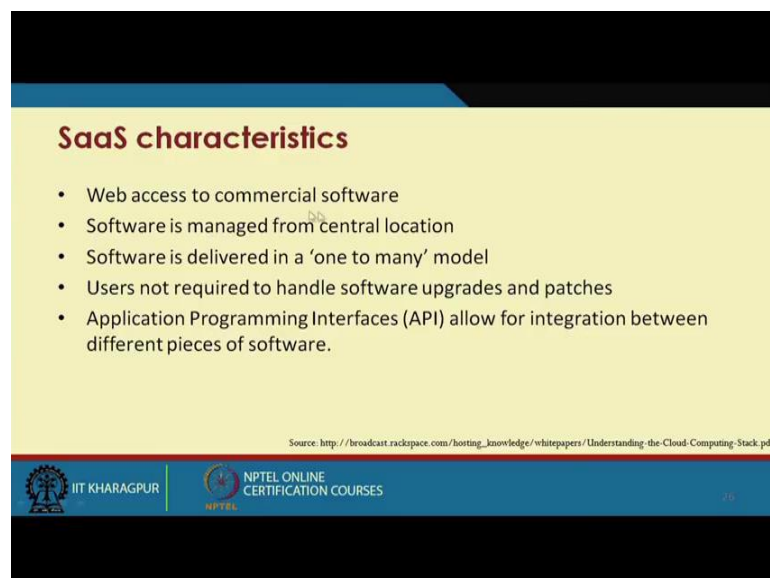
- SaaS is defined as software that is deployed over the internet. With SaaS, a provider licenses an application to customers either as a service on demand, through a subscription, in a “pay-as-you-go” model, or (increasingly) at no charge when there is opportunity to generate revenue from streams other than the user, such as from advertisement or user list sales.

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So, software as a service is this definition, I am not repeating this, it is a software that deployed over the internet, use as a pay as you go model, and you can basically search and leverage that service for things.

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**SaaS characteristics**

- Web access to commercial software
- Software is managed from central location
- Software is delivered in a ‘one to many’ model
- Users not required to handle software upgrades and patches
- Application Programming Interfaces (API) allow for integration between different pieces of software.

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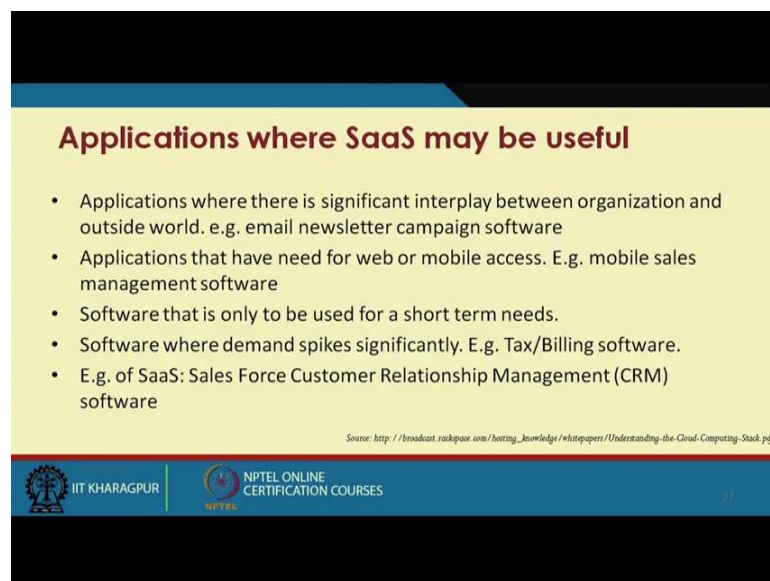
Characteristics; web access to commercial software that is one of the typical features; software is managed from some sort of a logically centralized location, so it may be



distributed and deployment distributed fashion, but the management is logically some sort of a centralize location, right I say that I give a some sort of software as a service for computational support for different simulation, so mathematical simulation, etcetera. So, this over all simulation platform may be running on heterogeneous different platforms may be on a distributed systems, but the overall management is logically centralize type of things.

Software is delivered in a one-to-many model. So, it is to one-to-many. Users not required to handle upgrades etcetera there is one of the features. Application programming interface allow for integration between different pieces of software or APIs allows us to amalgamate or integrate different software to realize a larger thing. Where it is extremely useful or may be useful is application where there is a significant interplay between organization and outside world, like email, letter campaign software like. So, there is a lot of interface between the things.

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**Applications where SaaS may be useful**

- Applications where there is significant interplay between organization and outside world. e.g. email newsletter campaign software
- Applications that have need for web or mobile access. E.g. mobile sales management software
- Software that is only to be used for a short term needs.
- Software where demand spikes significantly. E.g. Tax/Billing software.
- E.g. of SaaS: Sales Force Customer Relationship Management (CRM) software

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Application that have a need for web and mobile access; software that is only to be use for a short term needs I do not require something always, but I only want to use for a short term needs. Like, I want to execute I want to run a particular examination or particular written test for interview and I want to run that thing for a particular thing, there is for not that day to day I am running the things. So, neither I want to deploy those everything on the thing. So, I have a somewhat somewhere I can get the services and I

realize the services over the say desktop on a particular lab and execute that examination and then forget that thing for the time being.

So, software where demand spikes significantly like tax, billing, etcetera, right. So, the demands are have spikes right, like usually the tax submission or the tax fillings has a particular time window during the years and that time the demands increases otherwise slows down and that is important. Then there are these are some of the popular or will use thing that sales force, CRM and type of things.

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**Applications where SaaS may not be the best option**

- Applications where extremely fast processing of real time data is needed
- Applications where legislation or other regulation does not permit data being hosted externally
- Applications where an existing on-premise solution fulfills all of the organization's needs

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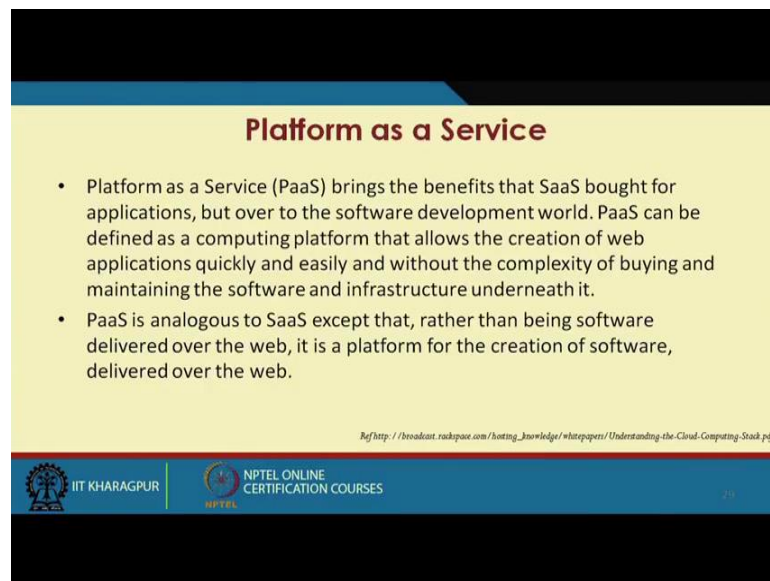
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Applications, where SaaS may not be the best option right, the other side of the story application where extremely fast processing or real time data is used. So, where because what we have see in that cloud computing may not be or cannot be considered as a high performance real type of operation, there can be delay as a times it may be slow down and type of things. So, it applications where extremely fast operations for real time data is needed is may not be the things may be say for example, disasters management etcetera. So, I cannot leverage something and which takes time and type of things. So, I too have something which is more concrete even I am provisioning it should be dedicated with a particular QoS maintenance.

Application; where legislation and other regulation does not permit data being hosted externally. Like, I can say that the my institutional work or in our institute say with that organization can say that all for a organization, the organization related communication

over the mail should be on the organization mail server or using the organizationally email id it cannot be on a public type of things. So, because that is the legal provision in the data where I do not know like to see. Application where an existing on-premise solution fulfills all the organizations needs it may be there that already you have a legacy applications which is fulfilling your organization need in may not be want to shift.

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**Platform as a Service**

- Platform as a Service (PaaS) brings the benefits that SaaS brought for applications, but over to the software development world. PaaS can be defined as a computing platform that allows the creation of web applications quickly and easily and without the complexity of buying and maintaining the software and infrastructure underneath it.
- PaaS is analogous to SaaS except that, rather than being software delivered over the web, it is a platform for the creation of software, delivered over the web.

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Similarly, for platform as a service it brings benefits of SaaS brought over the application, but over a software development platform. So, it provides the things. It is bring software delivered over the web. It is a platform for creation of the software deliver of the things. So, it gives a platform to develop your own system, etcetera.

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**Characteristics of PaaS**

- Services to develop, test, deploy, host and maintain applications in the same integrated development environment.
- Web based user interface creation tools help to create, modify, test and deploy different UI scenarios.
- Multi-tenant architecture where multiple concurrent users utilize the same development application.
- Built in scalability of deployed software including load balancing and failover.
- Integration with web services and databases via common standards.
- Support for development team collaboration – some PaaS solutions include project planning and communication tools.
- Tools to handle billing and subscription management

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So, there are several characteristics like services to develop, deploy, host, maintain in the same integrated development environment. Web based user interface to create tools to create, modify, test deploy different user interface and other things. Multi-tenant architecture; where multiple concurrent user utilize the same deployment application. Built in scalability is there integration with web services support for development team collaboration, that is important. Then I have a different a development team which is spread over several regions, may be several countries and want to have a common development platform and want to work on it that, it gives a good solution. And tools to handle billing subscription management etcetera are other aspects of the things, that how do I manage the whole.

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**Scenarios where PaaS is useful**

- PaaS is especially useful in any situation where multiple developers will be working on a development project or where other external parties need to interact with the development process
- PaaS is useful where developers wish to automate testing and deployment services.
- Popularity of agile software development, a group of software development methodologies based on iterative and incremental development, will also increase the uptake of PaaS as it eases the difficulties around rapid development and iteration of software.
- PaaS Examples: Microsoft Azure, Google App Engine

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So, where is extremely useful or very useful is that especially useful in the situation where multiple developers will be working on development project that we were discussing. Where other external parties needs interact with the development processes etcetera. So, I have a development teams which is the core in my in our organization office. I have development team at the customer premises which interact with the customer day-to-day basis and there may be other subsequent development team in head office and type of things. So, when we want to coordinate between these two, this platform may be plat form is the service may be a ideal base for do it this.

PaaS is useful where developers wish to automate testing and development. So, if you want to automate then this are the things where you put something, which is being checked. Popularity for agile software development a group of software development methodology based on iterative and incremental development, in these cases also what we find that PaaS will be extremely useful. So, some of the popular PaaS and type of things are one is Azure, and Google app engine or other several stuff where people are using for developing their applications then making it is web enabled and available over webs.

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**Scenarios where PaaS is not ideal**

- Where the application needs to be highly portable in terms of where it is hosted.
- Where proprietary languages or approaches would impact on the development process
- Where a proprietary language would hinder later moves to another provider – concerns are raised about vendor lock in
- Where application performance requires customization of the underlying hardware and software

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Scenarios where PaaS may not be ideal. So, it is not the good choice where application needs to be highly portable in terms of where it is hosted. So, if high portability is required then it may not be a good choice. Where proprietary languages or approaches would impact on the development process, so there may be proprietary languages or approaches, especially in mission-critical stuff, like in the case of a defense or in some cases of the financial sector. You may not want that organization may not want to do in this all-open system. I do not say that it is an open source only, but it is not on a public system rather than on proprietary things and there can be some proprietary approaches of looking at the problems. So, these types of things may not be useful.

Where a proprietary language would hinder later moves to another provider, concerns are raised about vendor locking. So, there is another issue of vendor lock-in that comes into the picture. So, it is a vendor lock-in, then also we have a problem here. Where application performance requires customization of underlying hardware and software. So, my objective is to have an application performing at its best, then I need to customize that the underlying hardware and software that means, I want to have a customized stack, right. I do not have a generic stack of the thing, but I have a customized stack then this type of things may not be PaaS may not be a good choice.

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**Infrastructure as a Service**

- Infrastructure as a Service (IaaS) is a way of delivering Cloud Computing infrastructure – servers, storage, network and operating systems – as an on-demand service.
- Rather than purchasing servers, software, datacenter space or network equipment, clients instead buy those resources as a fully outsourced service on demand.

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And finally, that IaaS, which provides a infrastructure in terms of servers, storage, network operating system on an on-demand bases right. So, in rather than purchasing or maintaining we can have a virtualization of those things like or I can have a virtual machines and virtual storage and type of thing. So, that is the IaaS, extremely popular and used.

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**Characteristics of IaaS**

- Resources are distributed as a service
- Allows for dynamic scaling
- Has a variable cost, utility pricing model
- Generally includes multiple users on a single piece of hardware

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Characteristics are well-known that resources are distributed as services, allows dynamic scaling. Has variable cost like this I can have I can pay as you use utility pricing model,

includes multiple users on a piece of hardware. So, I can have number of user working on a same hardware stack or realizing different virtual machine on the same hardware stack.

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**Scenarios where IaaS makes sense**

- Where demand is very volatile – any time there are significant spikes and troughs in terms of demand on the infrastructure
- For new organizations without the capital to invest in hardware
- Where the organization is growing rapidly and scaling hardware would be problematic
- Where there is pressure on the organization to limit capital expenditure and to move to operating expenditure
- For specific line of business, trial or temporary infrastructural needs

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Where it makes lot of sense, the demand is very volatile, right. I have some times a machine of a particular memory requirement sometime some other requirements. So, demands are very that means, there are spikes are there or new organizations without the capability of investment. In several organizations or several projects what we see that we immediately purchasing something on the hardware is may not be feasible or sometimes what we want to do some of the PoCs - proof of concept that time also these are not purchasing takes a lot of time so or I can have a kick start of the whole process. So, they are the IaaS is helpful where there is a pressure organization to limit capital expenditure may one of the things. For specific line of business trial or temporary infrastructural needs, so that means what we have say that proof of concept, etcetera.



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**Scenarios where IaaS may not be the best option**

- Where regulatory compliance makes the offshoring or outsourcing of data storage and processing difficult
- Where the highest levels of performance are required, and on-premise or dedicated hosted infrastructure has the capacity to meet the organization's needs

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Where some of the cases where it may not be the best option, where there may be regulatory compliance on all legal issues to make things you cannot make your data, your computing on the other premises or you cannot outsource the data storage or computing. There can be some of the legal issues or regulatory bindings on the things or where the highest level of performance are required on-premise or dedicated sources are required like I say some of the mission critical operations, where you require some of the highest level performance, where you want to customize the whole thing right that that in those cases this may not be a good solution having a generic infrastructural realize.

After all when you are having these VMs, so you are having multi things like you have underlying hardware over that some virtual machine monitor and then you are realizing different VM. So, what happened all these stuff is basically takes some amount of the resources and computational time. So, when it is a mission critical where you want highest level of performance, so you may not be looking for this.

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Provider	Software	Pricing model
Salesforce.com	CRM	Pay per use
Google Gmail	Email	Free
Process Maker Live	Business process management	Pay per use
XDrive	Storage	Subscription
SmugMug	Data sharing	Subscription
OpSource	Billing	Subscription
Appian Anywhere	Business process management	Pay per use
Box.net	Storage	Pay per use
MuxCloud	Data processing	Pay per use

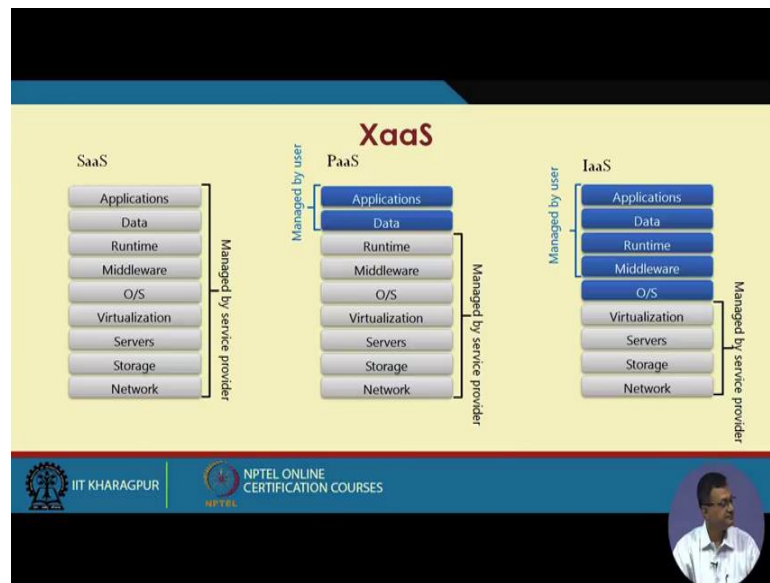
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So, these are some of the popular SaaS provider, we are not going much detail into the things. So, they have different pricing model like some are pay as you go, some of the provider are free, some are subscription base that amount of you subscribe for a year and then use it and type of things. These are feature of like PaaS provider. So, we are having different PaaS provider and the provide different type of thinks like some are on the using databases, big table on data bases. So, the different type of characteristics you can see that here different type of target to use, some dot NET platform, web development enterprise application, etcetera.

So, it has different type of flavors to offer to that. And there are IaaS provider major IaaS provider there are several other IaaS providers also. And they have different type of capacities like there you can have different type of hardware capacities, there are different types of operating systems and we have different type of billing mechanisms into the things. So, these are the different type of IaaS provider.

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And as we have discussed already and discussing. So, if you if you relook at that again typical stack of these components then what we see that in case of a SaaS up to the application level the manage by the service provider. So, it is at the application level, the responsibility of the cloud service provider look in, whereas in case of a XaaS the responsibility is up to this runtime things, so that data and applications are the users. Whereas in case of infrastructure up to virtualization and providing VMs is the responsibility of the provider, whereas over that sometimes it will provide the provider will provide the guest OS or you can allow you to load the guest OS actually basically you can choose your guest OS to be loaded on the virtual machine, so that. And rest of the things is basically a responsibility of the IaaS consumer or the user.

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**Role of Networking in Cloud Computing**

- In cloud computing, network resources can be provisioned dynamically.
- Some of the networking concepts that form the core of cloud computing are Virtual Local Area Networks, Virtual Private Networks and the different protocol layers.
- Examples of tools that help in setting up different network topologies and facilitate various network configurations are OpenSSH, OpenVPN etc.

Source: <http://www.slideshare.net/alexamies/networking-concepts-and-tools-for-the-cloud>

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So, if we look at another aspects of these cloud is the networking. This networking plays a very what we say important role critical role I should say in case in realization of the things because at the bare metal you are having different hardware resources right. So, they are connected over the network those who are those who have seen these different aspects different say rack server or the specially this blade server etcetera, you will find that that is the backbone network is very high redundant type of things, because these all these servers at a extremely high operating speed work with these networks. So, network is a important role in cloud computing.

There is another aspect of networking that whether I can virtualize this network. Like I say I have a typical network scenario for my organizational need. So, I want to setup a network for organizing a particular event and I have a thing like I can say that these are the these are my routers and these are my servers and so on and so forth. Now, one way of looking at is that I purchase the thing separate things and connect the things right other whether I can virtualizes this whole infrastructure itself, like I have a what I mean to say the as I get a virtual machine whether I can create a overall a virtual network. So, I realize this network for the time being where the events will be there, it may be some examination, it may be some other division making something etcetera and then I give away the network on the things.




So, in other words, I have some sort of a soft way of realizing this overall networking, so that is another aspect of this. So, in cloud computing network resources can be provisioned dynamically as we have seen. Some of the networking concept that can form the cloud core of the cloud computing are virtual local area network right or what we popularly say VLAN, VPN and different protocol layers. So, this allows me to have realize this example of tools that help in there are different tools and techniques like OpenSSH, OpenVPN and some of the popular thing.

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**Networking in different Cloud Models**

OSI Layer	Example Protocols	IaaS	PaaS	SaaS
7 Application	HTTP, FTP, NFS, SMTP, SSH	Consumer	Consumer	Provider
6 Presentation	SSL, TLS	Consumer	Provider	Provider
5 Session	TCP	Consumer	Provider	Provider
4 Transport	TCP	Consumer	Provider	Provider
3 Network	IP, IPSec	Consumer	Provider	Provider
2 Data Link	Ethernet, Fibre channel	Provider	Provider	Provider
1 Physical	Copper, optic fibre	Provider	Provider	Provider

Source: <http://www.slideshare.net/alexamits/networking-concepts-and-tools-for-the-cloud>

And if you have networking in different cloud models, so if you see that these are our typical OSI stack. And if we look at that in the IaaS, so in IaaS up to this data link layer is provided by the provider rest of the consumer responsibility. On the other hand, in case of a SaaS, the responsibility of the providers goes up to the whole stack right. So, where in case of a PaaS this what we have the provider has a responsibility up to the presentation or sometimes session layer etcetera that means, it gives a platform. So, if I want to realize these OSI as a service model then I have different type of realization when you look as a whole infrastructure, whole as a platform or as a software as a service. So, what we see that networking plays a important role into the things.


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**Network Function Virtualization**

- Network Functions Virtualization aims to transform the way that network operators architect networks by evolving standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in Datacentres, Network Nodes and in the end user premises.
- It involves the implementation of network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment.

Ref: [https://portal.etsi.org/nfv/nfv\\_white\\_paper.pdf](https://portal.etsi.org/nfv/nfv_white_paper.pdf)

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There is another concept what we say network function virtualization will just have a quick introduction. It aims to transform the way the network operator architects the networks by evolving standard it virtualization technology to consolidate many network equipment types into the industry standard switches etcetera could be located in datacenters. What it tries to say it says that it tries to emulate in it work over your over the infrastructure, as we are discussing. It involves implementation of the network functions in software that can run on a range of industry standard server hardware and that can be move instantiated in and various location of the network as required without need of installation of new equipment.

That means as if I will little bit discuss in our subsequent talk. So, as if I have a infrastructure and I realize several network over the things, like I these are the classical approaches and here I have infrastructure then I try to realize different network over this basic infrastructure or I can have different virtual networks over the same infrastructure. So, if it is possible then not only this having this different virtual machines, I can have different virtual networks for the things or I can realize a virtual network on that. So, will stop here for today's lecture and we will continue with our discussion in subsequent talks.

Thank you.