Course Code : MCS-227

Course Title : Cloud Computing and IoT

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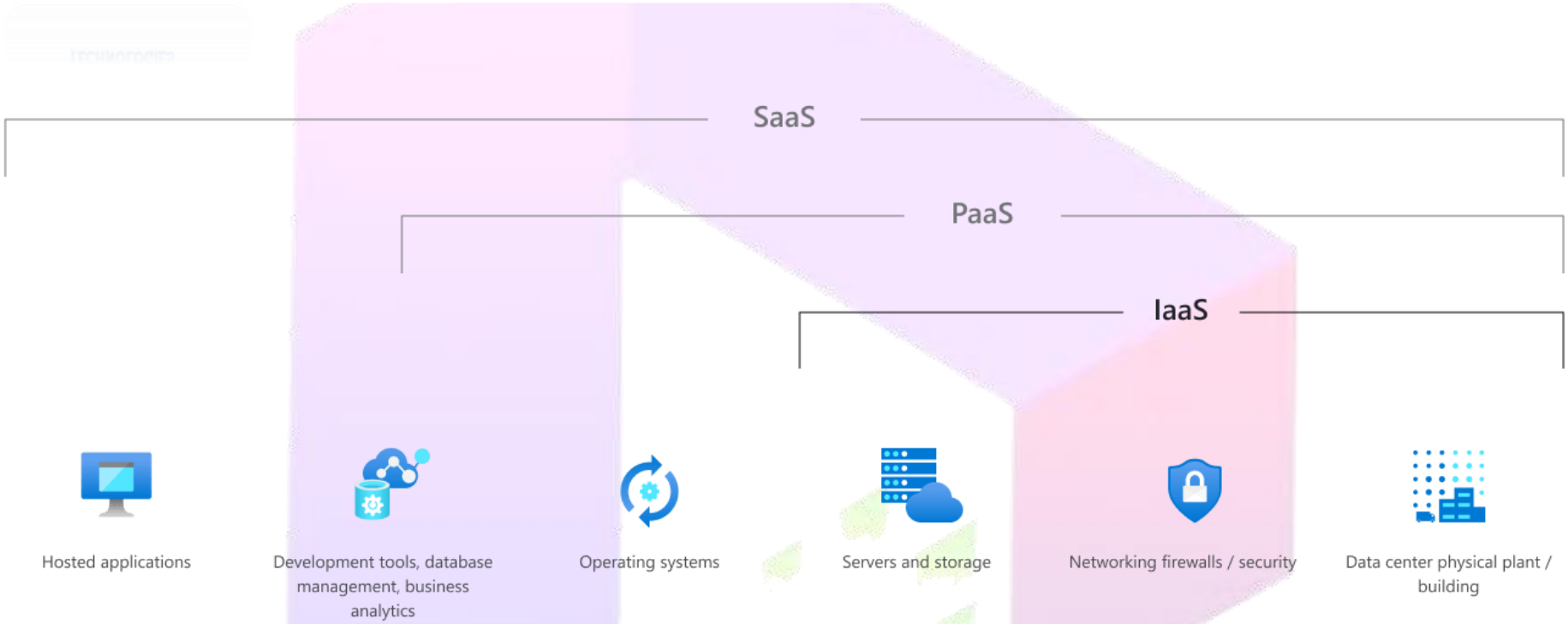
(for January session) 31st October, 2022(for July session)

Question 1: (10 Marks) Cloud Service models like Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (Saas) were discussed in the course. Explore the features, benefits and relevant use cases for other service models like Security as a Service (SECaaS), Database as a Service (DBaaS), Analytics as a Service (AaaS) and API as a Service (APIaaS).

Ans

Infrastructure as a service (IaaS) is a type of cloud computing service that offers essential compute, storage and networking resources on demand, on a pay-as-you-go basis. IaaS is one of the four types of cloud services, along with software as a service (SaaS), platform as a service (PaaS) and serverless.

Migrating your organisation's infrastructure to an IaaS solution helps you reduce maintenance of on-premises data centres, save money on hardware costs and gain real-time business insights. IaaS solutions give you the flexibility to scale your IT resources up and down with demand. They also help you quickly provision new applications and increase the reliability of your underlying infrastructure.



Lift-and-shift migration

This is the fastest and least expensive method of migrating an application or workload to the cloud. Without refactoring your underlying architecture, you can increase the scale and performance, enhance the security and reduce the costs of running an application or workload.

Test and development

Your team can quickly set up and dismantle test and development environments, bringing new applications to market faster. IaaS makes it quick and economical to scale dev/test environments up and down.

Storage, backup, and recovery

Your organisation avoids the capital outlay for storage and the complexity of storage management, which typically requires a skilled staff to manage data and meet legal and compliance requirements. IaaS is useful for handling unpredictable demand and steadily growing storage needs. It also can simplify planning and management of backup and recovery systems.

Web apps

IaaS provides all the infrastructure to support web apps, including storage, web and application servers and networking resources. Your organisation can quickly deploy web apps on IaaS and easily scale infrastructure up and down when demand for the apps is unpredictable.

High-performance computing

High-performance computing on supercomputers, computer grids or computer clusters helps solve complex problems involving millions of variables or calculations. Examples include protein folding and earthquake simulations, climate and weather predictions, financial modelling and product design evaluations.

Advantages of IaaS

Reduces capital expenditures and optimises costs

IaaS eliminates the cost of configuring and managing a physical datacentre, which makes it a cost-effective choice for migrating to the cloud. The pay-as-you-go subscription models used by IaaS providers help you reduce hardware costs and maintenance and enable your IT team to focus on core business.

Increases scale and performance of IT workloads

IaaS lets you scale globally and accommodate spikes in resource demand. That way, you can deliver IT resources to employees from anywhere in the world faster and enhance application performance.

Increases stability, reliability and supportability

With IaaS, there is no need to maintain and upgrade software and hardware or troubleshoot equipment problems. With the appropriate agreement in place, the service provider assures that your infrastructure is reliable and meets service-level agreements (SLAs).

Improves business continuity and disaster recovery

Achieving high availability, business continuity and disaster recovery is expensive because it requires a significant amount of technology and staff. But with the right SLA in place, IaaS helps to reduce this cost. It also helps you access applications and data as usual during a disaster or outage.

Enhances security

With the appropriate service agreement, a cloud service provider can offer better security for your applications and data than the security you would attain in house.
Helps you innovate and get new apps to users faster

With IaaS, once you have decided to launch a new product or initiative, the necessary computing infrastructure can be ready in minutes or hours, rather than in days or weeks. And because you don't need to set up the underlying infrastructure, IaaS lets you deliver your apps to users faster.

Security as a service

(SECaaS) is a business model in which a service provider integrates their security services into a corporate infrastructure on a subscription basis more cost-effectively than most individuals or corporations can provide on their own when the total cost of ownership is considered

Database as a service

Database as a service (DBaaS) is a cloud computing managed service offering that provides access to a database without requiring the setup of physical hardware, the installation of software or the need to configure the database.

Analytics As a service

Analytics-as-a-Service (AaaS) provides subscription-based data analytics software and procedures through the cloud. AaaS typically offers a fully customizable BI solution with end-to-end capabilities, organizing, analyzing, and presenting data in a way that lets even non-IT professionals gain insight and take action.

Question 2:

(a) What do you understand by Resource Virtualization and its underlying abstraction? (4 Marks)

Ans:-

Resource Virtualization

Virtualization uses software to create an abstraction layer over computer hardware that allows the hardware elements of a single computer—processors, memory, storage and more—to be divided into multiple virtual computers, commonly called virtual machines (VMs). Each VM runs its own operating system (OS) and behaves like an independent computer, even though it is running on just a portion of the actual underlying computer hardware.

underlying abstraction

It means to understand how a certain language is compiled/trans-piled into a machine byte code. How a certain program is actually executed in a certain language.

This will improve your program optimization techniques and concepts.

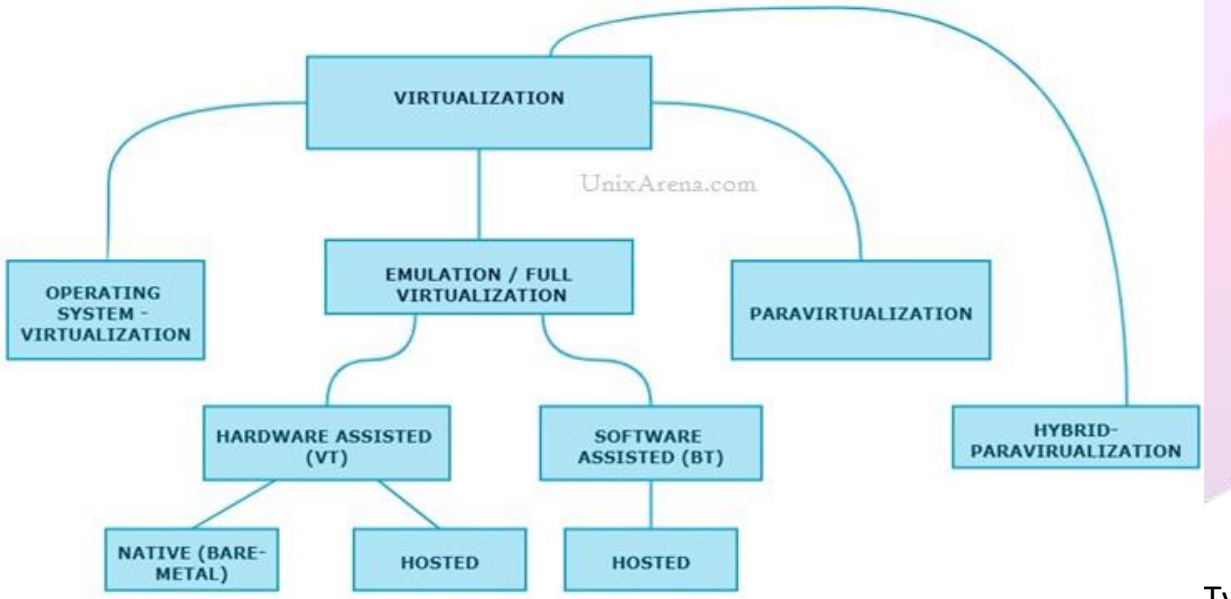
If you know how a sort function in C# will work on int and string types, you maybe able to create a better sort function for your certain scenario. But this is only possible when you test and try to find the underlying abstraction/implementation of the sort function.

This will help you if you're pursuing some research job or if you want to be data scientist because optimization is a key thing in those two fields. But for a consumer application developer, its not that important.

(b) Describe various Hypervisor based virtualization approaches like full virtualization, para virtualization and h/w-assisted virtualization. (6 Marks)

Virtualization is nothing but abstracting operating system, application, storage or network away from the true underlying hardware or software. It creates the illusion of physical hardware to achieve the goal of operating system isolation. In last decade, data centers were occupied by a large number of physical servers, network switches, storage devices. It consumed a lot of power and manpower to maintain the data centers. In that period, there were many companies were researching about the hardware emulation/simulation like QEMU, virtual PC etc.. It's very hard to list all the virtualization types here. So I have just listed down only the server virtualization types.

- Full Virtualization (Hardware Assisted/ Binary Translation)
- Paravirtualization
- Hybrid Virtualization
- OS level Virtualization



Types of virtualization

Full Virtualization:

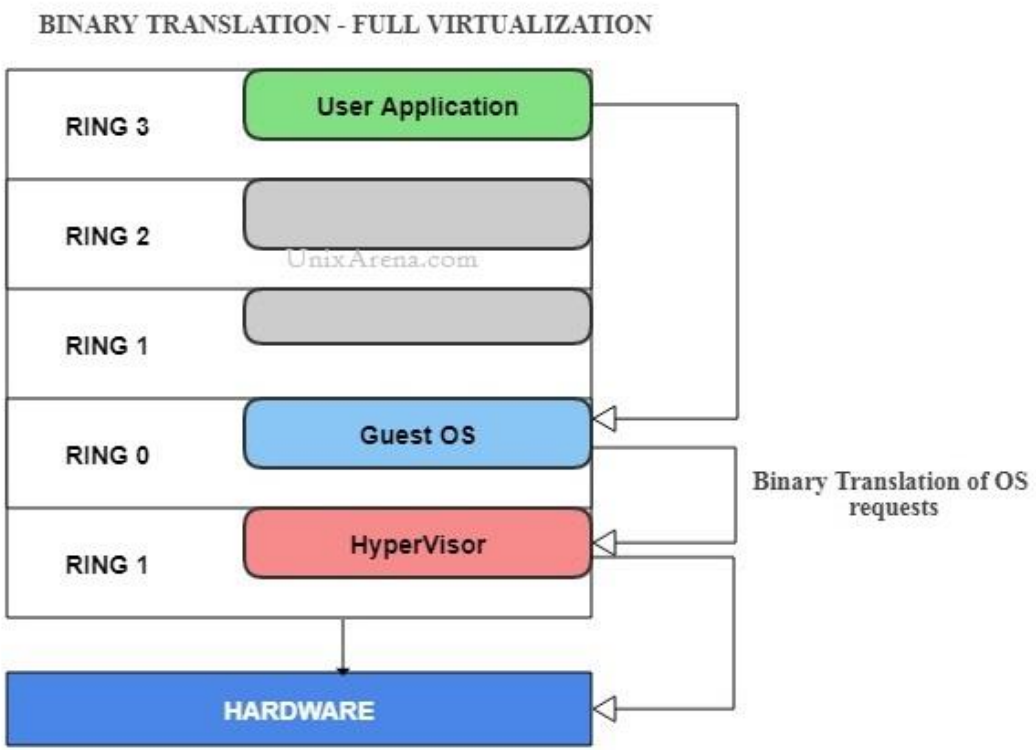
Virtual machine simulates hardware to allow an unmodified guest OS to be run in isolation. There is two type of Full virtualizations in the enterprise market. On both full virtualization types, guest operating system's source information will not be modified.

- Software assisted full virtualization
- Hardware-assisted full virtualization

Software Assisted – Full Virtualization (BT – Binary Translation)

It completely relies on binary translation to trap and virtualize the execution of sensitive, non-virtualizable instructions sets. It emulates the hardware using the software instruction sets. Due to binary translation, it often criticized for performance issue. Here is the list of software which will fall under software assisted (BT).

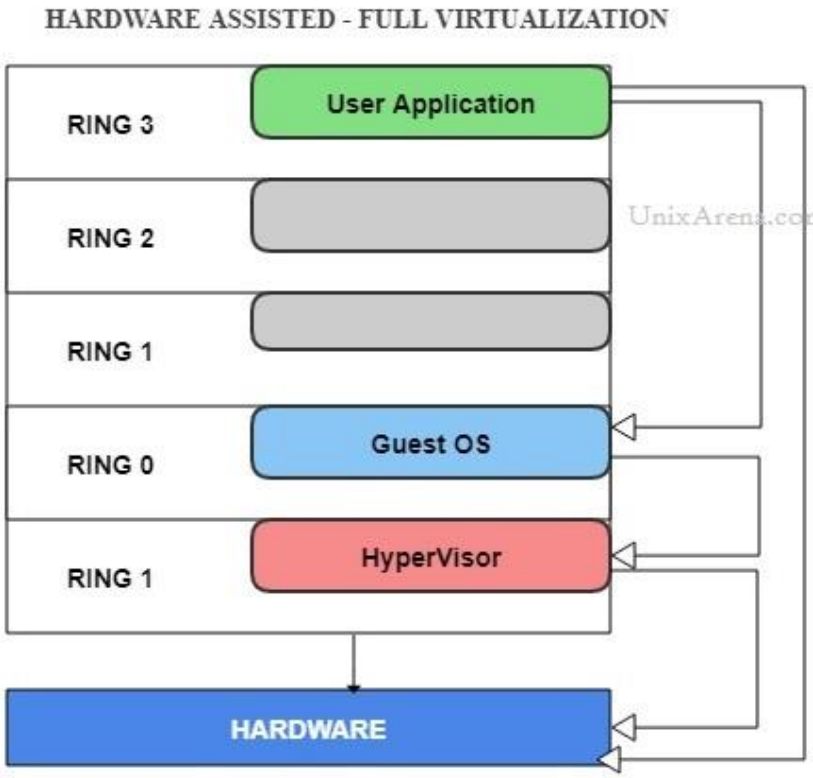
- VMware workstation (32Bit guests)
- Virtual PC
- VirtualBox (32-bit guests)
- VMware Server



Binary Translation – Full Virtualization

Hardware-Assisted – Full Virtualization (VT)

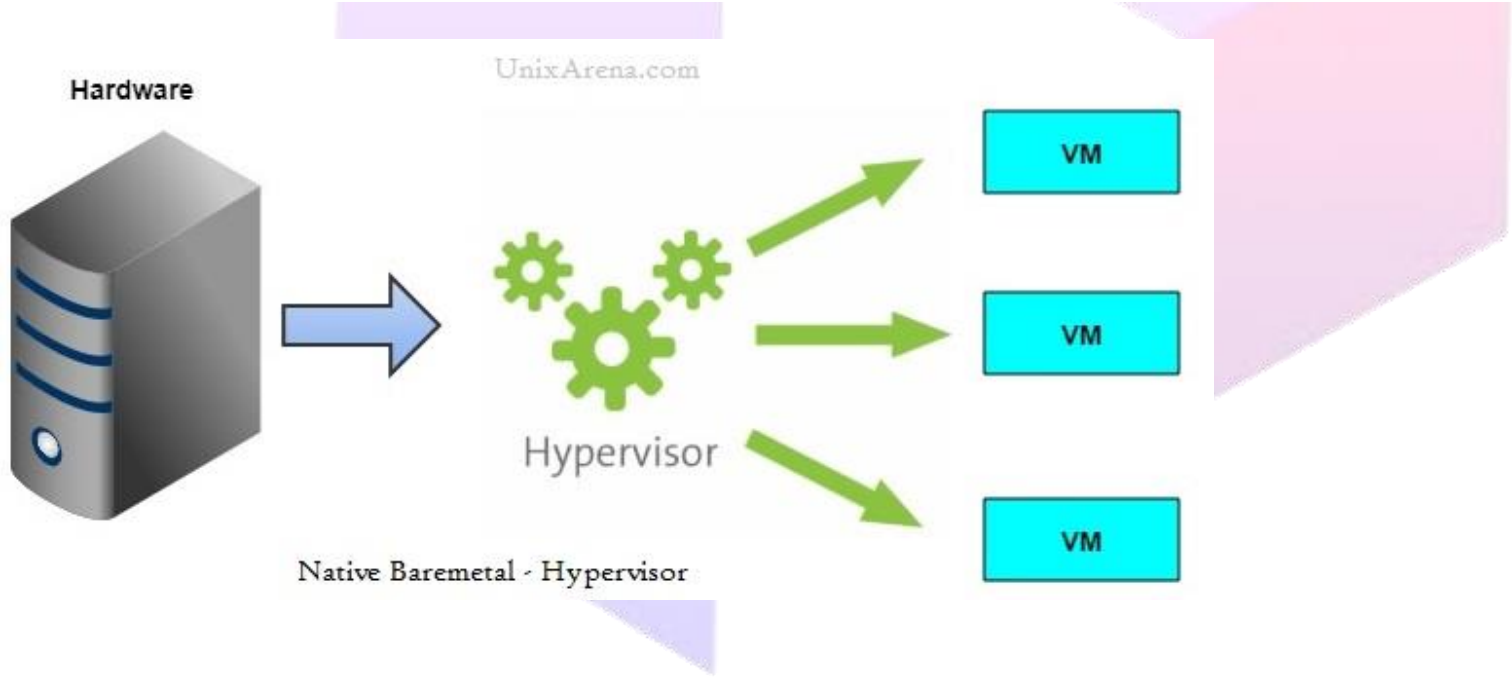
Hardware-assisted full virtualization eliminates the binary translation and it directly interrupts with hardware using the virtualization technology which has been integrated on X86 processors since 2005 (Intel VT-x and AMD-V). Guest OS's instructions might allow a virtual context execute privileged instructions directly on the processor, even though it is virtualized.



Hardware-assisted virtualization – Hypervisor

Here is the list of enterprise software which supports hardware-assisted – Full virtualization which falls under hypervisor type 1 (Bare metal)

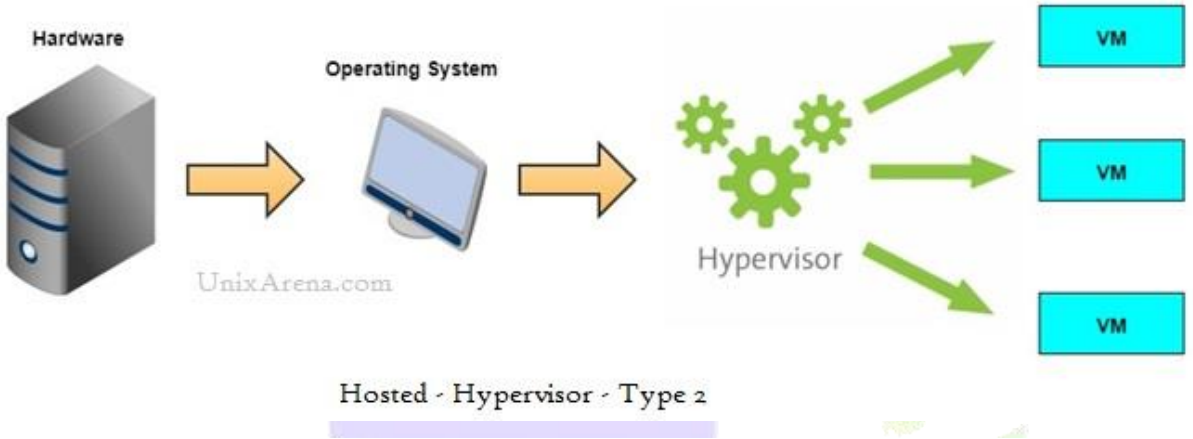
- VMware ESXi /ESX
- KVM
- Hyper-V
- Xen



hypervisor – Native – Bare-metal

The following virtualization type of virtualization falls under hypervisor type 2 (Hosted).

- VMware Workstation (64-bit guests only)
- Virtual Box (64-bit guests only)
- VMware Server (Retired)



Hosted – Hypervisor type 2

Paravirtualization:

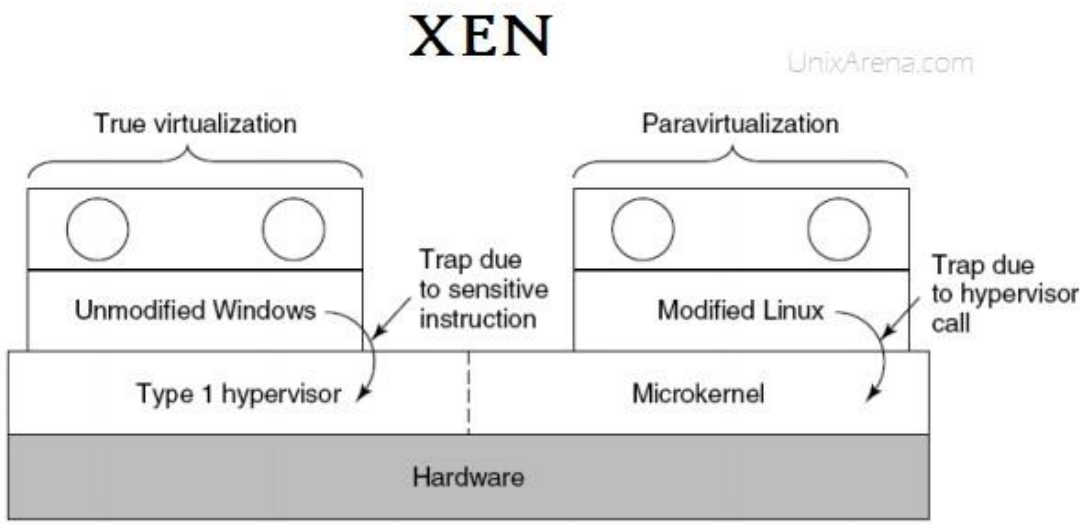
Paravirtualization works differently from the full virtualization. It doesn't need to simulate the hardware for the virtual machines. The hypervisor is installed on a physical server (host) and a guest OS is installed into the environment. Virtual guests aware that it has been virtualized, unlike the full virtualization (where the guest doesn't know that it has been

virtualized) to take advantage of the functions. In this virtualization method, guest source codes will be modified with sensitive information to communicate with the host. Guest Operating systems require extensions to make API calls to the hypervisor. In full virtualization, guests will issue a hardware calls but in paravirtualization, guests will directly communicate with the host (hypervisor) using the drivers. Here is the lisf of products which supports paravirtualization.

- Xen
- IBM LPAR
- Oracle VM for SPARC (LDOM)
- Oracle VM for X86 (OVM)

The below diagram might help you to understand how Xen supports both full virtualization and paravirtualization. Due to the architecture difference between windows and Linux based Xen hypervisor, Windows operating system can't be para-virtualized. But it does for Linux guest by modifying the kernel. But VMware ESXi doesn't modify the kernel for both Linux

and Windows guests.



Xen supports both Full virtualization and Para-virtualization

Hybrid Virtualization: (Hardware Virtualized with PV Drivers)

In Hardware assisted full virtualization, Guest operating systems are unmodified and it involves many VM traps and thus high CPU overheads which limit the scalability. Paravirtualization is a complex method where guest kernel needs to be modified to inject the API. By considering these issues, engineers have come with hybrid paravirtualization. It's a

combination of both Full & Paravirtualization. The virtual machine uses paravirtualization for specific hardware drivers (where there is a bottleneck with full virtualization, especially with I/O & memory intense workloads), and the host uses full virtualization for other features. The following products support hybrid virtualization.

- Oracle VM for x86
- Xen
- VMware ESXi

The following diagram will help you to understand how VMware supports both full virtualization and hybrid virtualization. RDMA uses the paravirual driver to bypass VMkernel in hardware-assisted full virtualization.

VMware ESXi – Example of Hybrid virtualization

OS level Virtualization:

Operating system-level virtualization is widely used.It also knowns “containerization”. Host Operating system kernel allows multiple user spaces aka instance.In OS-level virtualization, unlike other virtualization technologies, there will be very little or no overhead since its uses the host operating system kernel for execution. Oracle Solaris zone is one of the famous containers in the enterprise market. Here is the list of other containers.

- Linux LCX
- Docker

- AIX WPAR

Solaris Containers – OS-level virtualization Example

Each virtualization technologies have their own advantages and disadvantages. The choice of virtualization heavily depends on use and cost.

There are a lot of technologies are evolving and enterprise products support multiple virtualization types to improve the performance and reduce the resource overhead. I know its bit hard to understand and classify the virtualization technologies. But I have tried my level best to put it together.

(c) Compare Xenserver Vs VMware with respect to the features like Guest O/S support, Backup facility, Thin provisioning, asset management and configuration mapping, dynamic resource allocation and failover, graphics support, licensing, host server management and storage specifications.

Ans.

Open Source: Xen is an open-source virtualization server whereas VMware is that which provides virtualization software for x86-compatible computers.

Dynamic Resource Allocation: This feature is provided by the VMware whereas Xen does not.

Graphics Support: VMware's Graphics Support is much less comprehensive than XenServer's but much more limited.

Pricing and Licensing: XenServer is free and open-source, and also an extremely powerful hypervisor without buying additional features. Moreover, you can purchase a 1-year plan for maintenance license. In addition, Standard and Enterprise are two editions for maintenance. Whereas, VMware needs a proprietary license and is licensed per processor. VMware does offer a free version called **ESXi**, but it is not nearly as powerful or functional as XenServer's free offering.

Installation and Configuration: Designed in such a way that the process of installation is quickly done without the need to configure a complex management infrastructure or create a dedicated storage network. Whereas in VMware, provides up to 4GB free disk space to decompress the installation archive and approximately 2GB of these files are deleted after the installation is complete.

Host Server Management: XenServer is an enterprise-ready, cloud-proven virtualization platform with all the capabilities needed to create and manage a virtual infrastructure using the XenCenter management console. In VMware, vSphere's management kernel is completely custom grown by VMware. It does not use Linux, UNIX, or POSIX. The server management system for VMware uses the BusyBox environment to provide a shell environment for users to work in.

User-Friendly Management: XenServer is typically considered easier to use and manage, and because it is open-source, it is constantly improving features, such as IntelliCache designed to reduce the overall costs and improve performance of a XenDesktop installation. vSphere's GUI can be a challenge for some. It is designed for Linux, making it more difficult for Windows users to install and use.

Host Server Limits: The maximum limit per host for XenServer is 1000. vSphere's host server limits are slightly more complicated and updated often.

PARAMETER	XEN	VMWARE
Open Source	Yes	No
Dynamic Resource Allocation	No	Yes
Target audience	Personal use and small/medium users	Small/Medium users
Graphics Support	More comprehensive than VMware	Limited
Pricing and Licensing	Free	High cost and need licensing.
Support for MS-DOS, Sun Java Desktop System, and Solaris	Not supported	Supported
Installation and Configuration	Easy	Quite complex
Host Server Management	Enterprise-ready	Custom grown
User-Friendly Management	Easy than VMware	Complex
Host Server Limits/caveats	Max. 1000	Slightly more complicated

Question 3: (10 Marks) Define scaling concept in cloud computing. Explain the following scaling strategies: (a) Proactive Scaling (b) Reactive Scaling (c) Combinational Scaling

Ans:-

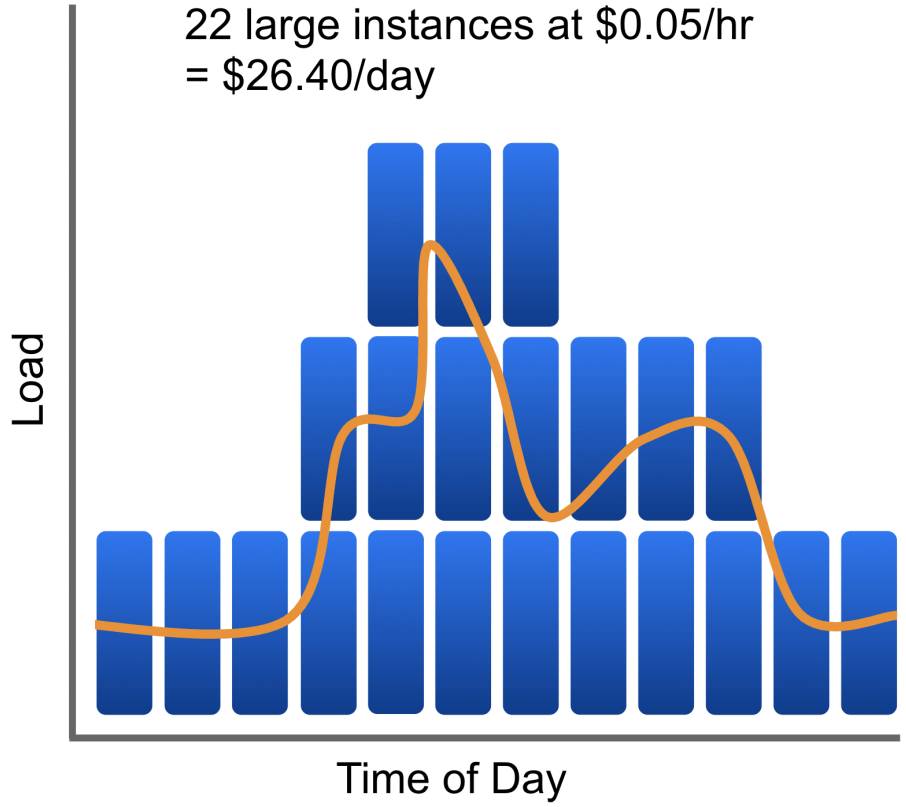
What is Cloud Scaling?

In cloud computing, scaling is the process of adding or removing compute, storage, and network services to meet the demands a workload makes for resources in order to maintain availability and performance as utilization increases. Scaling generally refers to adding or reducing the number of active servers (instances) being leveraged against your workload's resource demands. Scaling up and scaling out refer to two dimensions across which resources—and therefore, capacity—can be added.

Proactive Scaling

Proactive autoscaling does not wait for a trigger and rather scales on a cycle (each weekend or after business hours) or in anticipation of an upcoming event (e.g., Cyber Monday sales events or a new product release). Proactive scaling is appropriate when you either have data on typical and predictable load patterns that warrant up or downscaling. This can be especially appropriate when there is a startup time lag when creating an instance. If a service demand spikes quickly, it may be more efficient and performant to have the needed number of instances in place before the expected demand event.

Proactive or Predictive Scaling



Reactive Scaling

When we talk about auto-scaling, the typical approach is to set a trigger based on a use limit on memory or CPU or some other performance metric of importance. This is also known as reactive auto-scaling. When a limit is exceeded, say 85% CPU use for more than one minute, automation kicks in, and additional application replicas or infrastructure is created. This process is generally configured to continue automatically up to an upper resource limit based on an auto-scaling policy definition. Lower limit thresholds can also be similarly used to downscale resources. Automating this response to demand is especially useful in environments where there is no clear pattern to changes in demand. With auto-scaling automation in place, the system can appropriately address changes in load, ensuring performance SLOs are maintained, costs from idle infrastructure are avoided, and on-call engineers can get some well-deserved sleep. One caution with reactive scaling is that, depending on how quickly infrastructure or application replicas come online, lags between the trigger and resource availability can cause performance issues if load increases very quickly, as illustrated below.

Combinational Scaling:-

Till now we have seen need based and forecast based scaling techniques for scaling. However, for better performance and low cool down period we can also combine both of the reactive and proactive scaling strategies where we have some prior knowledge of traffic. This helps us in scheduling timely scaling strategies for expected load. On the other hand, we also have provision of load based scaling apart from the predicted load on the application. This way both the problems of sudden and expected traffic surges are addressed.

Question 4: (20 Marks) Compare and contrast Cloud Computing, Fog Computing and Edge Computing. Briefly discuss two applications for each of Fog Computing and Edge Computing.

Ans : **Cloud computing**

To break it down in the simplest terms, cloud computing means that data is processed and accessed over the Internet, rather than on a hard drive or local server. For businesses, cloud computing lowers costs through measured services and the ability to scale as needed to meet demand. It also allows employees to access documents wherever they are, as long as they have access to the network via the Internet. It also enables consumer applications such as mobile banking and streaming entertainment. Some disadvantages of cloud computing include the latency and limitations of real-time processing.

Edge computing

Edge Computing is a distributed computing model that collects data at the edge of the network, such as in a workshop, and processes that data in real time. The benefits of edge computing include reduced bandwidth usage, savings in money and bottlenecks, increased security through source encryption, and improved data performance by dividing the workloads of data. work between the edge and the cloud. Edge computing solves the disadvantages of the cloud by reducing latency.

Fog computing

Computing fog can seem very similar to advanced computing as both involve bringing processing closer to where the data is collected. But in fog computing, data is passed from the collection point to a gateway for processing, then sent back to

the edge for action. Fog Computing uses edge devices and gateways with a LAN for processing. Combining the ability to run applications at the edge with the capacity of the cloud, fog computing acts as a bridge, connecting the cloud and the edge.

Application of Fog computing

Healthcare Industry

The healthcare industry often depends on new technologies to improve its services and solutions. Similar to other technological advancements, the healthcare industry has also utilized Fog Computing for its benefit.

One of the most significant applications of fog computing in healthcare is eHealth. eHealth is an online and print platform that elegantly guides the healthcare stakeholders through the trajectory of healthcare that witnesses fascinating changes regularly due to increased technological intervention and other structural changes.

Fog Computing in Agriculture and Farming

The agriculture industry is one that has benefitted and transformed with the help of Fog Computing. A very prominent example here will be the SWAMP project, which stands for Smart Water Management Platform.

Water is an essential component in the agriculture industry, and it uses 70 % of freshwater, making it the most significant consumer. Often, there is a wastage of the resource due to leakages in distribution and irrigation systems and the field application methods.

Edge computing application

1. Autonomous vehicles

Autonomous platooning of truck convoys will likely be one of the first use cases for autonomous vehicles. Here, a group of truck travel close behind one another in a convoy, saving fuel costs and decreasing congestion. With edge computing, it will be possible to remove the need for drivers in all trucks except the front one, because the trucks will be able to communicate with each other with ultra-low latency.

2. Remote monitoring of assets in the oil and gas industry

Oil and gas failures can be disastrous. Their assets therefore need to be carefully monitored.
However, oil and gas plants are often in remote locations. Edge computing enables real-time analytics with processing much closer to the asset, meaning there is less reliance on good quality connectivity to a centralised cloud.

Question 5: (20 Marks)

Briefly discuss any two (for each of the sector) Use Cases of IoT in the following sectors:

(a) Agriculture

IoT use cases in agriculture
There are many types of IoT sensors for agriculture as well as IoT applications in agriculture in general.

1. **Monitoring of climate conditions**

Probably the most popular smart agriculture gadgets are weather stations, combining various smart farming sensors. Located across the field, they collect various data from the environment and send it to the cloud.

2. Greenhouse automation

The use of IoT sensors enables them to get accurate real-time information on greenhouse conditions such as lighting, temperature, soil condition, and humidity.

In addition to sourcing environmental data, weather stations can automatically adjust the conditions to match the given parameters. Specifically, greenhouse automation systems use a similar principle.

3. Crop management

Just like weather stations, they should be placed in the field to collect data specific to crop farming; from temperature and precipitation to leaf water potential and overall crop health. You can monitor your crop growth and any anomalies to effectively prevent any diseases or infestations that can harm your yield.

4. Cattle monitoring and management

Just like crop monitoring, there are IoT agriculture sensors that can be attached to the animals on a farm monitoring their health and log performance. Livestock tracking and monitoring help collect data on stock health, well-being, and physical location.

For example, such sensors can identify sick animals so that farmers can separate them from the herd and avoid contamination.

5. Precision farming

Also known as precision agriculture, precision farming is all about efficiency and making accurate data-driven decisions. It's also one of the most widespread and effective applications of IoT in agriculture.

By using IoT sensors, farmers can collect a vast array of metrics on every facet of the field microclimate and ecosystem: lighting, temperature, soil condition, humidity, CO2 levels, and pest infections. This data enables farmers to estimate optimal amounts of water, fertilizers, and pesticides that their crops need, reduce expenses, and raise better and healthier crops.

6. Agricultural drones

Perhaps one of the most promising agritech advancements is the use of agricultural drones in smart farming. Also known as UAVs (unmanned aerial vehicles), drones are better equipped than airplanes and satellites to collect agricultural data.

7. Predictive analytics for smart farming

Precision agriculture and predictive data analytics go hand in hand. While IoT and smart sensor technology are a goldmine for highly relevant real-time data, the use of data analytics helps farmers make sense of it and come up with important predictions: crop harvesting time, the risks of diseases and infestations, yield volume, etc.

Data analytics tools help make farming, which is inherently highly dependent on weather conditions, more manageable, and predictable.

8. End-to-end farm management systems

A more complex approach to IoT products in agriculture can be represented by the so-called farm productivity management systems. They usually include a number of agriculture IoT devices and sensors, installed on the premises as well as a powerful dashboard with analytical capabilities and in-built accounting/reporting features.

Things to consider before developing your smart farming solution

There are certain challenges you need to be aware of if you are considering investing in smart farming.

1. The hardware: To build an IoT solution for agriculture, you need to choose the sensors for your device (or create a custom one).

2. The brain: Data analytics should be at the core of every smart agriculture solution. The collected data itself will be of little help if you cannot make sense of it.

3. The maintenance: Maintenance of your hardware is a challenge that is of primary importance for IoT products in agriculture, as the sensors are typically used in the field and can be easily damaged.

4. The mobility: Smart farming applications should be tailored for use in the field. A business owner or farm manager should be able to access the information on-site or remotely via a smartphone or desktop computer.

5. The infrastructure: To ensure that your smart farming application performs well (and to make sure it can handle the data load), you need a solid internal infrastructure.

6. Connectivity: The need to transmit data between many agricultural facilities still poses a challenge for the adoption of smart farming.

7. Data collection frequency: Because of the high variety of data types in the agricultural industry, ensuring the optimal data collection frequency can be problematic. The data from field-based, aerial and environmental sensors, apps, machinery, and equipment, as well as processed analytical data, can be a subject of restriction and regulations.

OR

(b) Transportation

1. Fleet Management

Business leaders look for real-time fleet information so that they can reap business benefits to making intelligent decisions real-time. The Fleet Management technology is slowly and gradually getting adopted with the improvements in operational efficiency, maintenance cost, fuel consumption, regulatory compliance, and speed up accident response. GPS tracking, geo-fencing, customized dashboards, and real-time business decisions are some of the key features fleet management offers.

2. Public Transit Management

Public transit systems offer many benefits to passengers. But, tracking the real-time location of the vehicle and knowing when it will arrive at a particular stop was always a challenge. As real-time tracking of the vehicle is possible with the help of IoT in transportation, the data that is tracked is sent to an engineer or to a central system and, then, to an Internet-enabled mobile device. The Internet of Things has eradicated all the challenges that were faced in a public transit system

and has enabled re-routing features to help people make alternate arrangements as real-time tracking of the vehicle is easily done.

3. Smart Inventory Management

IoT in transportation has smart inventory management that acts as a catalyst telling the real-time information across the warehouse, distribution, and production center, which reduces the cost of inventory and improves the predictive maintenance. Smart inventory management systems have lowered the inventory cost and reduced the management errors of the inventory. The quality and depth of data from IoT sensors and systems have strengthened the legalized inventory management system.

4. Optimal Asset Utilization

IoT in transportation enables the asset tracking feature, which keeps track of the physical assets and their information, like location, status, etc. With Biz4Intellia, an end-to-end IoT solution provider, one can track the real-time location of their truck and can know how much load there is on the trailer of the respective truck. Not only this, but the latitude and longitude of an asset can also be known by IoT in transportation.

5. Geo-fencing

IoT in the transportation industry has come up with an advanced form of GPS, i.e. geo-fencing. It captures the location of an asset or device with the coordinates of a particular area. Geo-fencing helps in starting the automated tasks. IoT in the transportation industry is the most benefitted from geo-fencing. It allows you to receive alerts when a driver deviates from the prescribed path, as it can bring delay in delivery time and cause accidental loss.