2.
When the guest operating system is scheduled to run again without para-virtualization, the VMM must continue injecting timer interrupts or inject back-to-back timer interrupts. This method of virtualization is neither dependable nor scalable. When using para-virtualization, a common change is to update the idle code to ask the VMM to inform itself after a certain amount of time has passed. The guest's time is then recalculated and restored.

References:
https://www.kernel.org/doc/ols/2007/ols2007v2-pages-87-96.pdf

3.
Local APIC is essential in x86 or x86-64 to support SMP, especially because operating systems must send IPI (InterProcessor Interrupt). The flat mode code for sending IPI on x86-64 native computers must access the APIC registers several times. For virtualization, each access to the APIC registers must be intercepted, resulting in overhead (often a transition to the VMM). Para-virtualization can replace numerous implicit queries with a single explicit hypercall, resulting in implementations that are faster, simpler, and more efficient.

References:
https://www.kernel.org/doc/ols/2007/ols2007v2-pages-87-96.pdf

4.
User stack is used only while the process is running in user mode. User mode is a normal mode where the process has limited access i.e. applications are not allowed to access the privileged resources such as memory, CPU directly.

System stack is used only in the kernel or system mode. When a user process needs to execute some privileged instruction (a system call or to access a file) it traps to kernel mode and the kernel executes it on behalf of the user process. This is done on the kernel stack of the process. One of the reasons for having a separate kernel stack is that the kernel needs a location to store data that is not accessible to user-mode programs. This prevents user-mode code executing in a different thread/process from impacting the kernel's execution inadvertently or intentionally.

Linux(Unix) uses both the stacks named user mode and kernel for each process when it runs. In fact, Each thread has its own user stack and a kernel stack.

5.
When the processor accesses any segment, it performs a limit check to ensure that the offset does not exceed the segment's limit. The LSL (load segment limit) instruction can be used in software to execute this limit check. The LSL instruction, like the LAR (Load Access Rights) instruction, specifies a segment selector and a destination register for the segment descriptor whose limit is to be verified. The following operations are then carried out by the instruction:
a. Check that the segment selector is not null.
b. Checks that the segment selector points to a segment descriptor that is within the descriptor table limit (GDT (Global Descriptor Table) or LDT (Local Descriptor Table)).

c. Checks that the segment descriptor is a code, data, LDT, or TSS (task state segment) segment descriptor type. d. If the segment is not a valid code segment, check if the segment descriptor is visible at the CPL (that is, if the CPL and the RPL of the segment selector less than or equal to the DPL).
e. If the privilege level check gets successfully passed, load the unscrambled limit (the limit scaled according to the setting of the G flag in the segment descriptor) into the destination register and set the ZF flag in the EFLAGS register. The LSL instruction does not modify the destination register and clears the ZF flag if the segment selector is not visible at the current privilege level or is an incorrect type for the LSL instruction.

References:
https://www.intel.com/content/dam/support/us/en/documents/processors/pentium4/sb/25366821.pdf

6.
a.
Advantages of MMU:
i. I/O MMU converts I/O virtual memory addresses to physical memory addresses, making direct device access safe and efficient. It also allows the VM driver to configure device DMA using its virtualized idea of memory address, while the hypervisor decides where VM memory is actually located.
ii.The IOMMU maps contiguous virtual addresses to the underlying fragmented physical addresses, so the huge region of memory can be allocated without needing to be contiguous in physical memory.
iii. Existing systems can be enhanced with additional capabilities by interposing and converting virtual I/O requests, transparently augmenting unmodified software. A disk write, for example, can be turned into duplicated writes to several drives, allowing the system to withstand disk device failures.
iv.Decoupling provides for even more flexible mappings between logical and physical objects, making mobility easier. Virtualization makes VMs portable between heterogeneous systems by permitting mappings of logical I/O devices to physical devices with different but operationally compatible interfaces.

Disadvantages of MMU:
i. There is a performance degradation while mapping the virtual address to physical address.
ii. Physical memory usage due to the addition of I/O page (translation) tables.

References:
Carl Waldspurger and Rosenblum, M. (2012) *I/O Virtualization.* Communications of the ACM, vol. 55, No 1. January 2012. Pages 66-72;

b.
Virtualization services that meet some or all of the expected qualities of a carrier grade solution are referred to as carrier grade. Maintaining carrier grad features in edge and core network elements such as IP Multimedia Systems (IMS) nodes becomes easier and less expensive with carrier grade virtualization. OEMs in the networking and telecommunications industries can also benefit from real-time virtualization software by repurposing existing investments in carrier grade systems.

Products available for Carrier grade hypervisor are:
i. Bare-Metal Xen Hypervisor.
ii. Oracle Solaris.

References:
http://www.linuxpundit.com/documents/CGV_WP_Final_FN.pdf

7.
AWS uses the nitro hypervisor to run EC2 instances. It is a lightweight hypervisor that manages memory and CPU allocation and delivers performance that is indistinguishable from bare metal. The Nitro Hypervisor is based on Linux Kernel-based Virtual Machine (KVM) technology.
Characteristic of Nitro Hypervisor:
i. Faster I/O and Better performance: This feature is taken care of by Nitro Card. These cards accelerate the I/O operations which ultimately leads to better performance in the system.
ii. Enhanced Security: This feature is taken care of by Nitro Security Chip. It uses a locked-down security model that prohibits all administrative access, including those of Amazon employees, eliminating the possibility of human error and tampering. That means it does not allow anyone to do any changes in the bare metal.

References:
https://aws.amazon.com/ec2/nitro/

8.
a. The EC2 unit is used to calculate a virtual machine's CPU power. These EC2 Compute Units are used to describe the amount of CPU allotted to a specific instance. Several tests are carried out to determine how much ECU is equivalent to physical processor memory.One EC2 Compute Unit provides the equivalent CPU capacity of a 1.0-1.2 GHz 2007 Opteron or 2007 Xeon processor.

b. Various types of instances:

i. General purpose: General-purpose instances have a good combination of computation, memory, and networking capabilities and can handle a wide range of applications. These instances are appropriate for applications like web servers and code repositories that require these resources in equal amounts.

ii. Compute optimized: Compute Optimized instances are suited for compute-intensive applications that benefit from high processor performance. Batch processing workloads, media transcoding, high performance web servers, high performance computing (HPC), scientific modeling, dedicated gaming servers and ad server engines, machine learning inference, and other compute intensive applications are well suited for instances belonging to this family.

iii. Memory optimized: These instances are designed to deliver fast performance for workloads that process large data sets in memory.

iv. Accelerated Computing instances: The latest generation of GPU-based instances, Amazon EC2 P4 instances deliver the best performance for machine learning training and high-performance computing in the cloud.

v. Storage Instances: AWS Graviton2 processors power Amazon EC2 Im4gn instances, which offer the highest pricing performance for storage-intensive workloads in Amazon EC2. In comparison to I3 instances, they offer up to 40% better pricing performance and a 44 percent lower cost per TB of storage.

c. Various Operating Systems such as Amazon Linux, CoreOS, Debian, CentOS, Fedora, Windows Server, Ubuntu Server etc. are been used to run the EC2 instances.

d. A template providing a software configuration such as operating system, an application server and applications is known as an Amazon Machine Image (AMI) . With the help of AMI, user can launch an instance, which is nothing but a copy of the AMI running as a virtual server in the cloud. User can run multiple instances of an AMI. User can launch multiple instances from a single AMI when there is a need to run multiple instances.

e. Components of an AMI:

i. One or more Amazon Elastic Block Store (Amazon EBS) snapshots, or, for instance-store-backed AMIs, a template for the root volume of the instance.

ii. Launch permission which make sure that designated AWS accounts can run only their instances.

iii.A block device mapping that specifies the volumes to attach to the instance when it's launched.

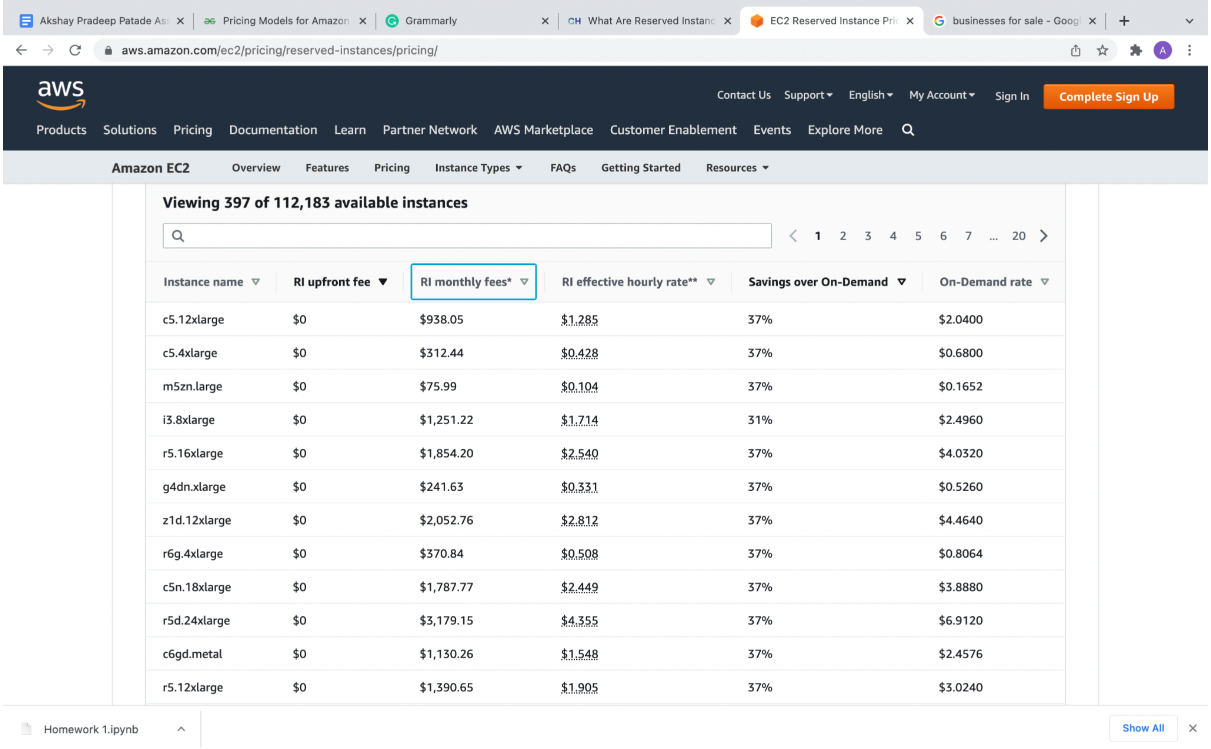
References:
https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/AMIs.html
https://aws.amazon.com/ec2/
https://stackoverflow.com/questions/19248087/what-does-ecu-units-cpu-core-and-memory-mean-when-i-launch-a-instance
https://aws.amazon.com/ec2/instance-types/

9.
There are models which are used for pricing EC2 instances: On-Demand Instances, Reserved Instances, Spot Instances, and Dedicated instances.

i. On-Demand Instances: It allows the user to pay for the compute capacity by the hour or by seconds with no long-term commitments. This purchasing model allows the user to be free from the cost and complexities of planning, purchasing, and maintaining the hardware. For example, consider an ec2 instance that provides 64 virtual CPUs, 256 Gibibyte memory, and

25Gibibyte of network for $2.464 per hour. If the user uses 3 hours of that instance and then releases the instance, then he would be charged $7.392.

ii. Reserved Instances: It is a discounted billing concept that was introduced in which businesses can obtain significant discounts compared to the standard On-Demand cloud computing instance prices in return for committing to a specified level of usage. The Businesses have to commit to the amount of computing capacity that would be needed over some time and qualify for a discount on the standard On-Demand price. With this pricing model, businesses can save more than 70% as compared to the On-Demand pricing model. Commitments can be of one year or three years based on the cloud service providers. Reserved Instances do not renew automatically. Once the reserved instances get expired, he/she will be charged based on the On-demand rates of the instances. Reserved Instances pricing model should be used if you are running the virtual machines at 100% utilization.



Viewing 397 of 112,183 available instances

Instance name	RI upfront fee	RI monthly fees*	RI effective hourly rate**	Savings over On-Demand	On-Demand rate
c5.12xlarge	$0	$938.05	$1.285	37%	$2.0400
c5.4xlarge	$0	$312.44	$0.428	37%	$0.6800
m5zn.large	$0	$75.99	$0.104	37%	$0.1652
i3.8xlarge	$0	$1,251.22	$1.714	31%	$2.4960
r5.16xlarge	$0	$1,854.20	$2.540	37%	$4.0320
g4dn.xlarge	$0	$241.63	$0.331	37%	$0.5260
z1d.12xlarge	$0	$2,052.76	$2.812	37%	$4.4640
r6g.4xlarge	$0	$370.84	$0.508	37%	$0.8064
c5n.18xlarge	$0	$1,787.77	$2.449	37%	$3.8880
r5d.24xlarge	$0	$3,179.15	$4.355	37%	$6.9120
c6gd.metal	$0	$1,130.26	$1.548	37%	$2.4576
r5.12xlarge	$0	$1,390.65	$1.905	37%	$3.0240

For example, consider the above image, and let's take an example of the c15.12xlarge instance which has a $1.285 reserved instance rate and a $2.04 on-demand rate per hour. If the business wishes to go for the long-term commitment and they are confident that the virtual machines are going to spin at 100% they should use the reserved instance, pricing model. This will allow them to save 37% of their operating cost.

iii. Spot Instances: Amazon EC2 Spot Instances is unused EC2 capacity in the AWS cloud. Spot Instances are available at up to a 90% discount compared to On-Demand prices. The price of the Amazon EC2 Spot Instances changes from time to time based on the demand and the supply. It supports both per hour and per second billing schemes. Applications that have flexible start and end times can choose Amazon EC2 spot Instances.

For example, consider one instance named a1.medium whose on-demand price is $0.90. Now the user will check its spot price in the amazon market. Let us say, the user saw a spot price of $0.3. The user will bid a price greater than the spot price, let us say $0.6, and then the user will submit the request. Once the request is submitted, cloud providers will accept the request and the user will be able to access the instance. If the Spot price increases above your bid price, capacity is no longer available, or the spot request has constraints that can't be met, then the Spot Instance will be terminated.

iv. Dedicated instances: Instances that run in the virtual private cloud and that are dedicated to only one user or organization with no long-term commitments. Dedicated Instance pricing has two components: (1) an hourly per instance usage fee and (2) a dedicated per region fee. User or organization is booked with an additional fee every hour where at least one dedicated instance of any type is running in a region.

Resources:
https://aws.amazon.com/ec2/pricing/reserved-instances/pricing/
https://aws.amazon.com/ec2/pricing/dedicated-instances/

10.
i.
To use the AWS free of cost, the user must take care in mind that the monthly billing cycle should not exceed $1.

ii.
a. Open the Amazon EC2 Console.
b. In the Launch Instance section, choose Launch Instance.
c. In the navigation panel, select Amazon Machine Images (AMIs) where a free word would be mentioned.
d. Select an instance type where free is mentioned.
e. Choose Next: Configure Instance Details.
f. On the Configure Instance Details page, make sure that Instance Tenancy is set to Shared, and that Request Spot instance isn't selected.
h. Click on Next: Add Storage. Select storage as per your requirement i.e. either S3 or EBS.
i. Select next and add tags
j. After that Configure Security Group.
k. Configure a security group that allows only trusted traffic in and out.
l. After that click on Review and Launch.
m. Review your configuration. If everything is fine you can select launch.

iii.
We can create a machine instance equivalent to our Computer and then transfer its image to the cloud provider. We will make use of AWS Management Console.
a. Configure an EC2 instance and its attached EBS volumes in the exact way you want them created in the custom AMI.
b. Logout of your instance.

c. Log in to the AWS Management Console, display the EC2 page for your region, then click Instances.
d. Choose the instance from which you want to create a custom AMI.
e. Click Actions and click Create Image. Write a name for your instance.
f. Click create an image.