CS 524 Introduction to Cloud Computing

Dharmit Viradia

Homework 2

Prof. Igor Faynberg

1) Complete reading Chapter 3 of the textbook and the lecture materials. Please note the errata: The references to [19] on p. 56 of the book should be replaced with references to [20]! Please also read [20] (available free) at https://www.kernel.org/doc/ols/2007/ols2007v2-pages-87- 96.pdf.

Sol: Completed Reading the Articles.

2) Explain the advantage that paravirtualization provides for handling timers in virtual machines.

Sol: All modern operating systems, even idle virtual machine rely on clock interrupts to maintain their internal timers, a feature that is particularly essential for real-time media processing. With paravirtualization, the virtual machine code is changed to request a notification at the specified time. The hypervisor without the paravirtualization would need to schedule timer interrupts back-to-back for idle machines when the guest operating system is scheduled back to run, which would not be considered as a reliable or scalable way of virtualization.

3) Explain how paravirtualization helps in minimizing access to APIC.

Sol: An operating system deals with multiple CPUs in the same way it deals with one; with modular design, it is just scheduler and the interrupt handlers that need to be fully aware of the differences. Note that, x86 based multiprocessor architectures use the Advanced Programmable Interrupt Controller (APIC) for interrupt redirection in support of Symmetric Multiprocessing (SMP). Accessing APIC in virtual mode is expensive because of the transitions into and out of the hypervisor. With paravirtualization, which has the full view of the code, the multiple APIC access request can be replaced with a single hyper call.

4) Find out if Linux (like Unix) has both the user-mode and system-mode stacks for each process it runs.

Sol: Yes, in Linux like Unix, has both the user-mode and system-mode (or supervisory mode or kernel-mode) stacks for each process it runs. The CPU may have more than one set of identical registers. As a minimum, one register set is reserved for the user mode in which application program executes and the other for the system mode in which only the operating system software executes. The switch from user mode to system mode is not done automatically by the CPU. The first thing that happens is CPU gets interrupted by interrupts (like timers, keyboards, etc.) and when these interrupts occur, the current running execution is stopped by the CPU and switch to system mode to execute interrupt handler which activates the system stack pointer. This handler saves the state of the CPU by performing its operations, then restore the state and returns to user mode.

5) Find out what “unscrambled” means in the description of the Intel LSL instruction (you can, for example, use the Intel manual referenced in the lecture).

Sol: “Unscrambled” in Intel Load Segment Limit (LSL) instruction means the limit scaled according to the setting of the G flag in the segment descriptor. The unscrambled limit is loaded when the privilege level and type checks pass into destination register and set a ZF flag in the EFLAGS register. If the segment selector is not visible at the current privilege level or is an invalid type for

the LSL instruction, the instruction does not modify the destination register and cleans the ZF flag. When the processor accesses any segment, it performs a limit check to make sure that the offset is within the limit of the segment. The software can perform the limit checking using the LSL (Load Segment Limit) instruction. The LSL instruction specifies the segment selector for the segment descriptor whose limit is to be checked and a destination register. Depending on the G flag. The limits are interpreted in a different way. When the G flag is clear, the effective limit is the value of the 20-bit limit in the segment descriptor. Here, the limit ranges from 0 to 1MB when the G flag is set 4KB page granularity, the processor scales the value in the limit field by a factor of 212 (4KBytes). In this case, the effective limit ranges from 4KB to 4GB.

(References: http://www.intel.com/Assets/ja_JP/PDF/manual/253668.pdf
http://www.nacad.ufrj.br/online/intel/vtune/users_guide/mergedProjects/analyzer_ec/mergedProjects/reference_olh/mergedProjects/instructions/instruct32_hh/vc163.html)

6) Read the following two papers:
• Carl Waldspurger and Rosenblum, M. (2012) I/O Virtualization. Communications of the ACM, vol. 55, No 1. January 2012. Pages 66-72; and
• Muli Ben-Yehuda; Xenidis, J.; Ostrowski, M.; Rister, K.; Bruemmer, A.; Van Doorn, L. (2007). The Price of Safety: Evaluating IOMMU Performance. Proceedings of the Linux Symposium on June 27th–30th, 2007. Ottawa, Ontario. Pages 225-230.
1) Explain the advantages and disadvantages of using I/O MMU by citing the appropriate text from the paper;
2) Research the Web to find what is meant by "carrier-grade hypervisors". What products are available?

Sol: 1) Advantages of I/O MMU
- I/O MMU translates the I/O virtual memory address to corresponding physical memory, making direct access by devices safe and efficient and allows the driver in the VM to program device DMA using its virtualized notion of memory address, while allowing the hypervisor to decide where VM memory is actually located.
- The large region of memory can be allocated without the need to be contiguous in physical memory – the IOMMU maps contiguous virtual addresses to the underlying fragmented physical addresses.
- Devices that do not support memory addresses long enough to address the entire physical memory can still address the entire memory through the IOMMU, avoiding overheads associated with copying buffers to and from the peripheral's addressable memory space.
- Decoupling enables time and space multiplexing of I/O devices, allowing multiple logical devices to be implemented by a smaller number of physical devices.
- The ability to multiplex logical I/O devices onto physical ones allows both administrators and automated systems to drive I/O devices at higher utilization and achieve better hardware efficiency. Much about virtualization rapid adoption over the past decade can be attributed to the significant cost savings resulting from such basic partitioning and server consolidation.
- Decoupling provides for flexible mappings between logical and physical devices, facilitating seamless portability. By supporting mappings of logical I/O devices to physical devices with different yet semantically compatible interfaces, virtualization makes VMs portable, even across heterogeneous systems.

- Decoupling also enables popular VM features such as the ability to suspend and resume a VM and the ability to move a running VM between physical machines, known as live migration.
- This virtualization layer may also change mappings to physical devices, even when the VM itself does not move. For example, by changing mappings while copying, storage contents, a VM's virtual disk can be migrated transparently between network storage units, even while remaining in active use by the VM.
- The same capability can be used to improve availability or balance load across different I/O channels.
- I/O virtualization provides a foothold for many innovative and beneficial enhancements of the logical I/O devices.
- One useful capability enabled by I/O virtualization is device aggregation, where multiple physical devices can be combined into a single more capable logical device that is exported to the VM. Examples include combining multiple disk storage devices exported as a single larger disk.
- New features can be added to existing systems by interposing and transforming virtual I/O requests, transparently enhancing unmodified software with new capabilities. For example, a disk write can be transformed into replicated writes to multiple disks, so that the system can tolerate disk-device failures. Disadvantages of I/O MMU.
- Some degradation of performance of translation and management overhead (e.g., page table walks).
- Consumption of physical memory for the added I/O page (translation) tables. This can be mitigated if the tables can be shared with the processor.

(References: I/O Virtualization by Carl Waldspurger, Mendel Roseblum, https://en.wikipedia.org/wiki/Input%E2%80%93output_memory_management_unit, http://www.linuxpundit.com/documents/CGV_WP_Final_FN.pdf)

2) Carrier Grade can be defined as virtualization services that fulfil some or all expected properties existing in carrier grade solution. Carrier Grade Virtualization reduces the cost and complexity of maintaining carrier grad properties in edge and core network elements such as IP Multimedia Systems (IMS) nodes. Also networking and telecommunication OEMs can reuse existing investments in their carrier grade system while gaining the benefits of using real-time virtualization software.
Some of its features are:
- Availability
- High performance scaling
- Small error recovery domains
- Real-time behavior
- Upgrade capabilities
- Configurable security
- Efficient and Uniform management services

Products available are:
- Virtual Logix Carrier Grade Hypervisors
- Bare-metal Xen Hypervisor
- NEC's Carrier Grade Cloud Platform
- Oracle Solaris

(Reference: http://www.linuxpundit.com/documents/CGV_WP_Final_FN.pdf)

7) Find out what hypervisors Amazon is using in EC2 and describe their major characteristics.

Sol: Amazon EC2 uses bare-metal hypervisors in Xen. Major characteristics are

a. Live VM Migration: It supports virtual machine live migration from one host to another allows workload balancing and the avoidance of downtime.

b. Live Storage Migration: Move live running virtual machines and their associated virtual disk image within and across resource pools leveraging local and shared storage.

c. Host Failure Protection: Deliver high availability by automatically restarting virtual machines if a failure occurs at the VM, hypervisor or server level. Link aggregation bonds network interfaces for network redundancy and increased throughput.

d. Host Power Protection: Take advantage of embedded hardware features to lower datacenter electricity consumption by dynamically consolidating VMs on fewer systems and then powering off underutilized servers as demand for services fluctuates.

e. Memory Overcommit: Reduce costs and improve application performance and protection by sharing unused server memory between VMs on the host server.

f. Site Recovery: Provides site-to-site disaster recovery planning and services for virtual environments. Site recovery is easy to set up, fast to recover, and has the ability to frequently test to ensure disaster recovery plans remain valid.

(References: https://en.wikipedia.org/wiki/Amazon_Elastic_Compute_Cloud, https://en.wikipedia.org/wiki/Xen, http://xenserver.org/overview-xenserver-open-source-virtualization/open-source-virtualization-features.html)

8) Examine the Amazon EC2 VM offer capabilities and particularly the Amazon Machine Image (AMI) (https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/AMIs.html) and answer the following questions:

a. How (i.e., in what units) does EC2 measure the CPU power of a virtual machine and how is the unit in question translated into the power of the physical processors)?

b. What kinds of machine instances are there as characterized by the power of their respective CPUs, platform (i.e., 32-bit or 64-bit), memory, storage, etc.? Please list all the instances in the nomenclature along with their respective characteristics;

c. Which operating systems are available on the above systems?

d. What is an AMI and what is its relationship to an instance?

e. What are the components of an AMI?

Sol: a. EC2 measures the CPU power of a virtual machine in ECU (EC2 Computing Units). ECU equates to a certain amount of computing cycles in a way that is purportedly independent of the actual hardware. So, several benchmarks and tests are used to determine how the Computing Units translate into power of the physical processor. According to the documentations, a single ECU is defined as the compute power of a 1.0 to 1.2 GHz of a 2007 server CPU capacity.

(References:https://aws.amazon.com/ec2/faqs/#What_is_an_EC2_Compute_Unit_and_why_did_you_introduce_it, https://www.datadoghq.com/blog/are-all-aws-ecu-created-equal/)

b. Amazon EC2 gives the option of choosing between different instance types and provides the flexibility to choose the combination of instance to meet the computing need most appropriately and these sets of instance combinations can be changed later depending upon change in business need. Each instance provides a predictable amount of dedicated compute capacity and is charged per instance hour consumed. The various types of instances are:
General Purpose: This instance family includes T2, M3, and M4 which is often the first choice because of variety of CPU size range. Also, the balance of resources makes them ideal for running small and mid-size databases, more memory-hungry data processing tasks, caching fleets, and backend servers.
Compute-Optimized: This instance family includes the C3 and C4 instance types and is geared towards applications that benefit from high compute power.
Memory Optimized: This instances family includes X1, R3 and R4 instance types and is designed for memory intensive applications. Instances have the lowest cost per GB of RAM of all other instance types.
Accelerated Computing/GPU: This instances family includes P2, G2 and F1 instance types and allows to take advantage of the parallel performance of NVIDIA Tesla GPU using CUDA or OpenCL programming models for GPGPU.
Storage Optimized: This instance family includes the I2 and D2 instance types and provides you with direct attached storage options optimized for applications with specific disk I/O and storage capacity requirements. Currently there are two types of storage-optimized instances.

(References: https://aws.amazon.com/blogs/aws/choosing-the-right-ec2-instance-type-for-your-application/ , https://aws.amazon.com/ec2/instance-types/, https://aws.amazon.com/ec2/previous-generation/)

c. Amazon EC2 currently supports a variety of operating systems including: Amazon Linux, CentOS, CoreOS, Debian, Fedora, FreeBSD, Gentoo, Genymotion, Oracle Linux, RancherOS, Red Hat Enterprise Linux (RHEL), SUSE, SUSE Linux Enterprise Server, TurnKey Core, Windows Server, and Ubuntu Server 14.04 LTS (HVM)
(References: http://docs.aws.amazon.com/opsworks/latest/userguide/workinginstances-os-linux.html, https://aws.amazon.com/marketplace/b/2649367011?ref_=header_nav_category_2649367011)

d. An Amazon Machine Image (AMI) is a special type of virtual appliance that is used to create a virtual machine within the Amazon Elastic Compute Cloud ("EC2"). It serves as the basic unit of deployment for services delivered using EC2. And it is a type of instance provided on AWS.

e. The components of AMI are:
Storage for the Root Device
Determining the Root Device Type of Your AMI
Stopped State
Default Data Storage and Persistence
Boot Times
AMI Creation

9) Find out about the pricing of the EC2 platforms and provide a few examples.

Sol: The Amazon EC2 platform is available for free to try. There are no hidden or minimum charges and the user have to pay according to the need and the usage of the services. And to calculate the estimated monthly bill, a monthly calculator available.
There are four ways to pay for Amazon EC2 instances: On-Demand, Reserved Instances, Spot Instances and Dedicated Hosts.
1. On-Demand Instance is useful for unpredicted or short-term workload for this user has to pay for compute capacity by the hour with no long-term commitments or upfront payments.

2. Reserved Instances are useful for predictable workload to reserve the capacity and available with significant discounts up to 75% off as compared to On-Demand Instance. All the standard reserved instances are available always (i.e. 24x7) and allow launching the reserved instances at the time of need.

3. Spot Instances are helpful for urgent computing needs for large amounts of additional capacity and allow to bid on spare computing capacity for up to 90% off the On-Demand Instances price.

4. Dedicated Hosts are helpful to meet compliance requirements to reduce costs by allowing using existing server-bound software licenses (subject to user's license terms). Dedicated Hosts either can be purchased On-Demand on an hourly basis or can be purchased as a reservation for up to 70% off the On-Demand price.

Few examples are as follows:

T2.nano			STANDARD 1 YEAR TERM		
Payment Option	Upfront	Monthly	Effective Hourly	Saving over on-Demand	On-Demand Hourly
No Upfront	$0	$3.29	$0.005	24%	$0.0059 (per hour)
Partial Upfront	$18	$1.46	$0.004	32%	
All Upfront	$34	$0	$0.004	34%	
M4.large			STANDARD 1 YEAR TERM		
Payment Option	Upfront	Monthly	Effective Hourly	Saving over on-Demand	On-Demand Hourly
No Upfront	$0	$53.81	$0.074	31%	$0.108 (per hour)
Partial Upfront	$276	$23.00	$0.063	42%	
All Upfront	$541	$0	$0.062	43%	
C4.large			STANDARD 1 YEAR TERM		
Payment Option	Upfront	Monthly	Effective Hourly	Saving over on-Demand	On-Demand Hourly
No Upfront	$0	$51.25	$0.070	30%	$0.1 (per hour)
Partial Upfront	$263	$21.90	$0.060	40%	
All Upfront	$515	$0	$0.059	41%	

(References: https://aws.amazon.com/ec2/pricing/)

10) From the above exercise, you will learn that it is possible to create a free machine instance. Please, do the following:
a. Find out and document the essence of the respective Service Level Agreement (SLA); in particular write down what one needs to do in order to maintain this service free;
b. Describe the process (i.e., what exactly one needs to do) to create a free machine instance that could be used as a server. (Do not, however, create anything yet!)
c. Can you create a machine instance equivalent to your own PC and then transfer your own PC image there? If so, how would you achieve that?

Sol: a. Service Level Agreement (SLA) is a contract between a cloud provider (either internal or external) and the service user that outlines responsibilities, quality, and scope on both sides. The most common component of SLA is that the services should be provided to the customer as agreed upon in the contract.
In order to maintain free services of Amazon EC2, one needs to sign up under the Free Tier, to get hands for 12 month period. Then the one need to create an account and use the services provided under certain usage limits. The need to follow the steps:
i. Sign up for an AWS account,
ii. Have to provide credit card information and billing address. Until the free usage exceeds the limits, you would not be charged for the services.
iii. Get started with AWS Cloud services by choosing any of the products listed under the Free Tier service.

(References: http://searchcloudcomputing.techtarget.com/essentialguide/Breaking-down-whats-in-your-cloud-SLA, https://www.paloaltonetworks.com/documentation/glossary/what-is-a-service-level-agreement-sla, https://en.wikipedia.org/wiki/Service-level_agreement, https://aws.amazon.com/ec2/sla/)

b. The process what exactly one need to do to create a free machine instance, that could be used as a server are followed:
i. First, have to create an instance of Amazon EC2 which can be used as a server for hosting an application on the cloud.
ii. Then have to create a server for the database which would be a database instance.
iii. After performing above steps, a web app can be deployed on the server.
iv. After that, load balancing and scaling needs to be done so that the traffic is distributed across the number of servers or application servers.
v. In the last, user can associate or use a name with your web application.

(References: http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/AMIs.html)

c. Yes, we can create a machine instance equivalent to my own PC and then transfer our own PC image there. All of this can be done by creating an EC2 instance on the Amazon Cloud and host it as a server. After that, we need to connect our own PC to that server and then transfer the image.

(References: https://aws.amazon.com/premiumsupport/knowledge-center/)