

Lecture 8 – Virtualisation

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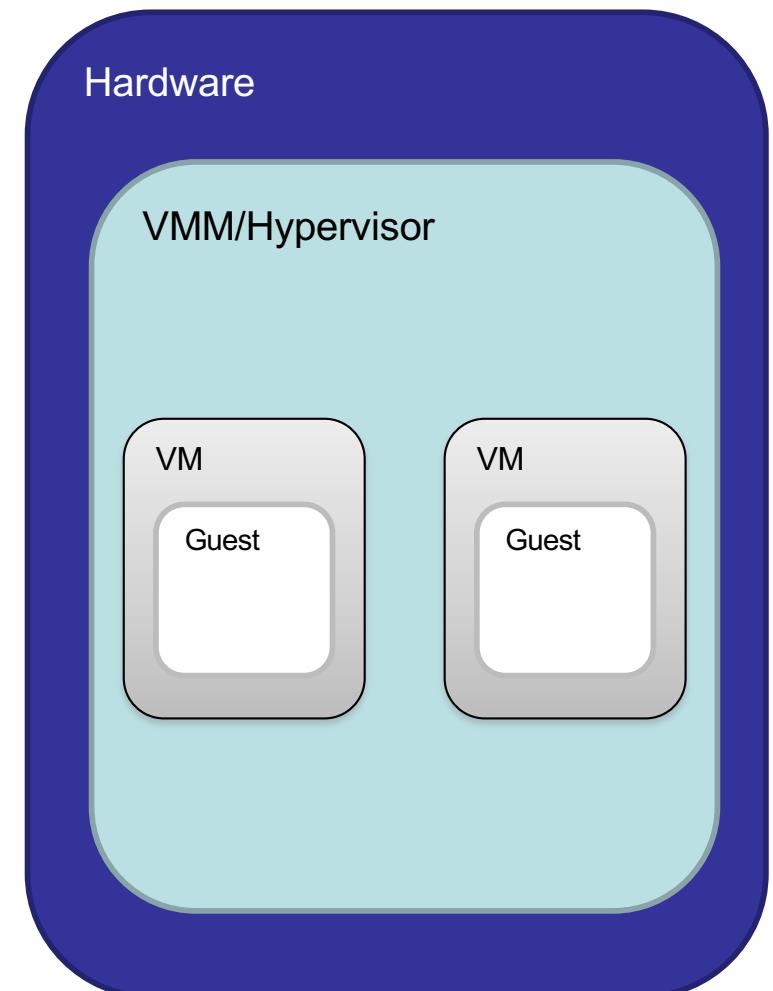
Overview

- Virtualisation
 - Motivation
 - What happens in a VM?
 - Historical perspective
 - Requirements for virtualisation
 - Virtualisation approaches
 - Memory management
 - Live migration
- AWS Demonstration

- Server Consolidation
 - Increased utilisation
 - Reduced energy consumption
- Personal virtual machines can be created on demand
 - No hardware purchase needed
 - Public cloud computing
- Security/Isolation
 - Share a single machine with multiple users
- Hardware independence
 - Relocate to different hardware

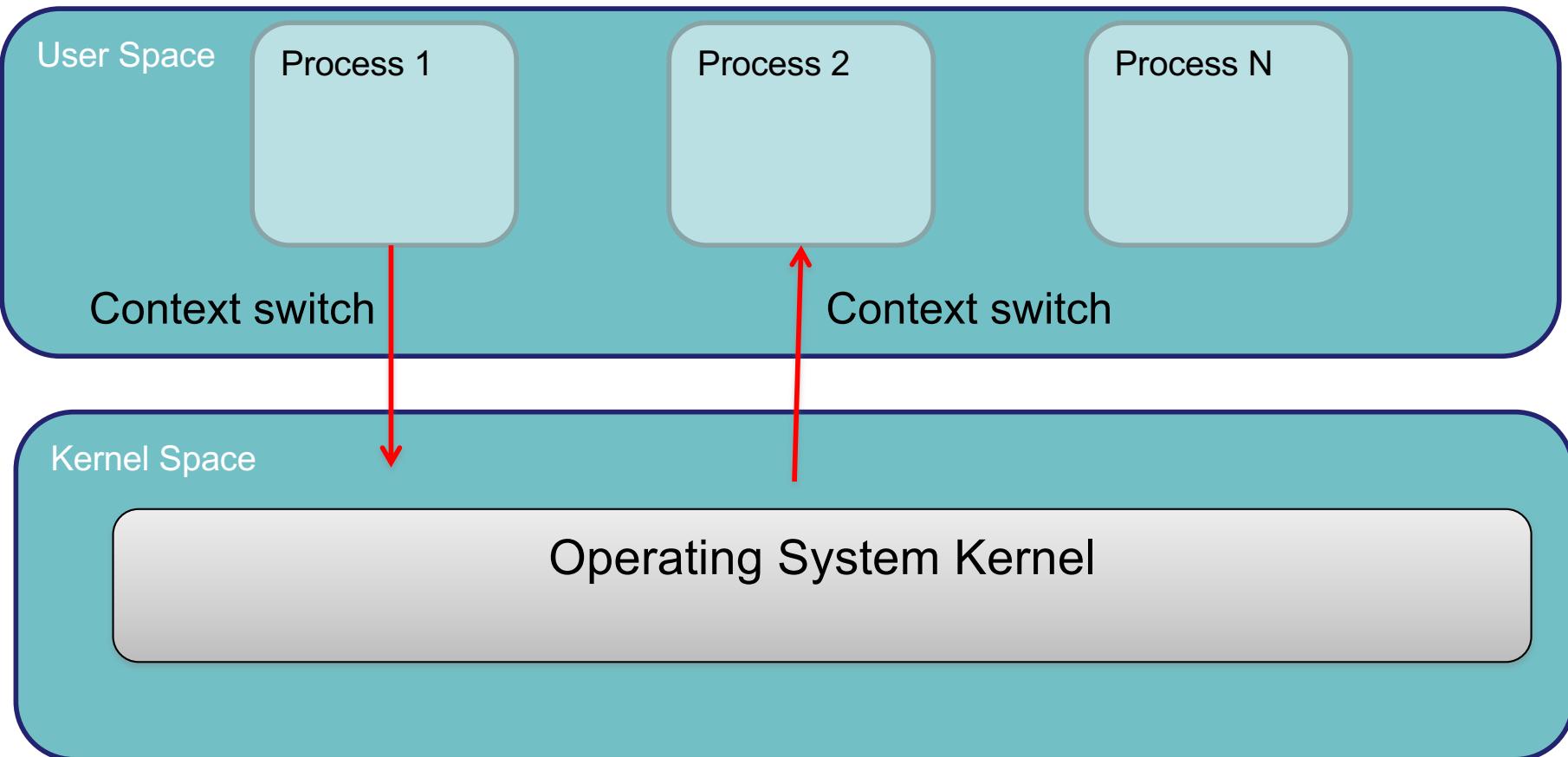
Terminology

- **Virtual Machine Monitor/Hypervisor:**
The virtualisation layer between the underlying hardware (e.g. the physical server) and the virtual machines and guest operating systems it supports.
 - The environment of the VM should appear to be the same as the physical machine
 - Minor decrease in performance only
 - Appears as though in control of system resources
- **Virtual Machine:** A representation of a real machine using hardware/software that can host a guest operating system
- **Guest Operating System:** An operating system that runs in a virtual machine environment that would otherwise run directly on a separate physical system



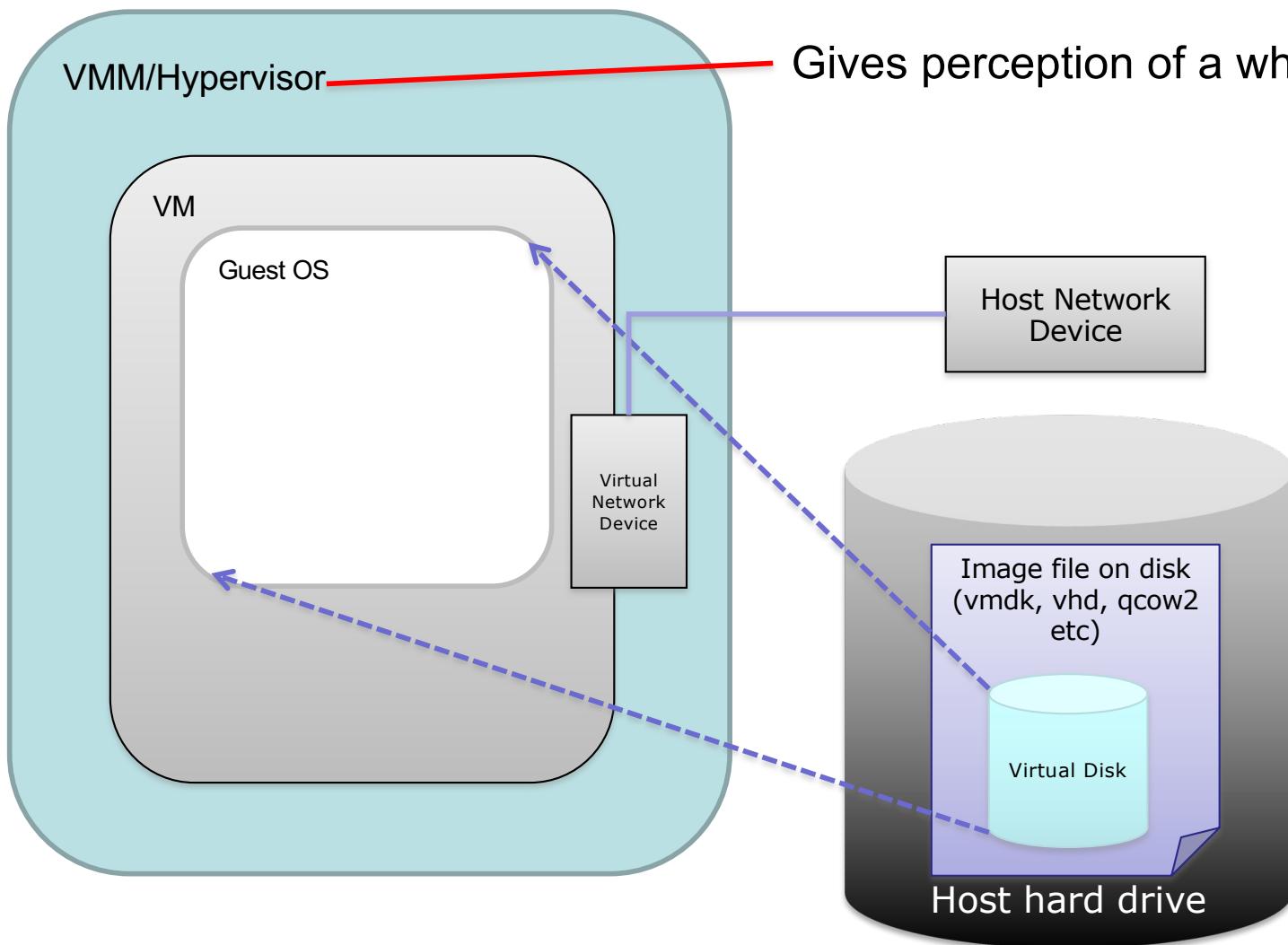


Recap on Kernel-User mode separation



- Processes run in **lower privileged (user) mode**
- OS Kernel runs in privileged Kernel mode
- OS typically virtualises memory, CPU, disk etc giving appearance of complete access to CPU/memory/disk to application processes
 - Each process has illusion of access to some/all of the memory or the CPU (but actually shared across multiple processes)
- **Context switches can catch (trap) “sensitive” calls**
 - e.g. add two numbers vs change bios settings;
 - Sensitive calls -> instruction sets are typically device specific, e.g. ARM vs x86 vs ...

What Happens in a VM?



VHD (Virtual Hard Disk represents a virtual hard disk drive (HDD). May contain what is found on a physical hard disk, such as disk partitions and a file system, which in turn can contain files and folders.

VMDK (Virtual Machine Disk) describes containers for virtual hard disk drives to be used in virtual machines like VMware.

qcow2 (Quick Emulator (QEMU) Copy On Write) file format for disk image files. It uses a disk storage optimization strategy that delays allocation of storage until it is actually needed.

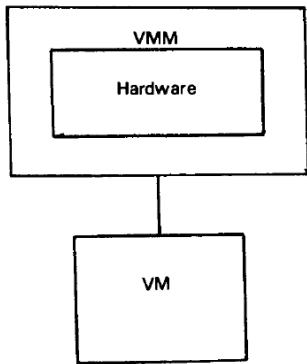
- Guest OS apps “think” they write to hard disk but translated to virtualised host hard drive by VMM
- Which one is determined by image that is launched

Historical Perspective

- Virtualisation concept goes back to 1960s
- IBM System/370
- System/370 featured hardware support for *interpretive* execution
- Formal requirements laid down by Popek and Goldberg (1974)
- Why then?
 - Mainframes needed ability to run multiple kinds of applications
 - Hardware was very expensive “back in the day”

Origins - Principles

Fig. 1. The virtual machine monitor.



“an efficient, isolated duplicate of the real machine”

- Properties of interest
 - **Fidelity**: Software on the VMM executes behaviour identical to that demonstrated when running on the machine directly, barring timing effects
 - **Performance**: An overwhelming majority of guest instructions executed by hardware without VMM intervention
 - **Safety**: The VMM manages all hardware resources

Formal Requirements for Virtualizable Third Generation Architectures

Gerald J. Popek
University of California, Los Angeles
and

Robert P. Goldberg
Honeywell Information Systems and
Harvard University

Virtual machine systems have been implemented on a limited number of third generation computer systems, e.g. CP-67 on the IBM 360/67. From previous empirical studies, it is known that certain third generation computer systems, e.g. the DEC PDP-10, cannot support a virtual machine system. In this paper, model of a third-generation-like computer system is developed. Formal techniques are used to derive precise sufficient conditions to test whether such an architecture can support virtual machines.

Communications of the ACM, vol 17, no 7, 1974, pp.412-421



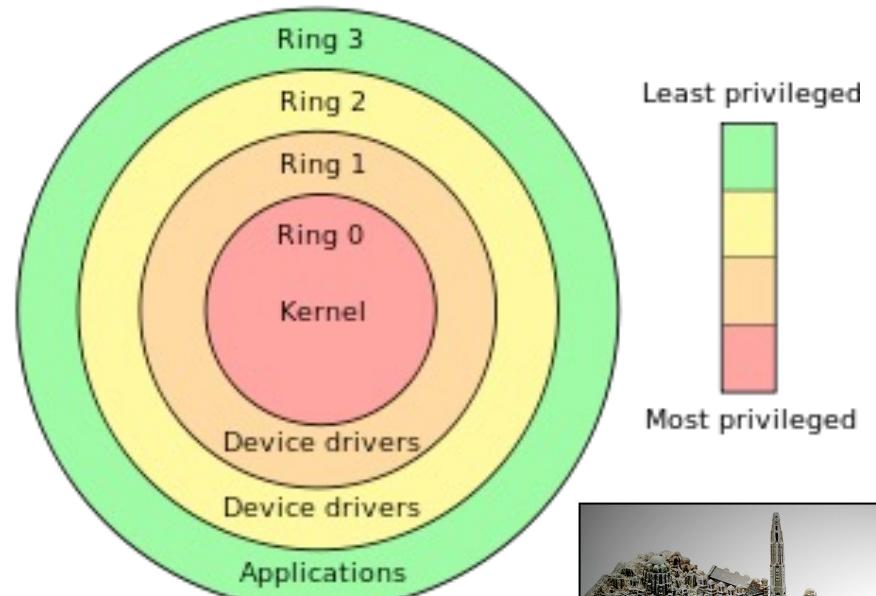
- **Privileged Instructions**: instructions that trap if the processor is in user mode and do not trap in kernel mode
- **Sensitive Instructions**: instructions whose behaviour depends on the mode or configuration of the hardware
 - Different behaviours depending on whether in user or kernel mode
 - e.g. POPF interrupt (for interrupt flag handling)
- **Innocuous Instructions**: instructions that are neither privileged nor sensitive
 - Read data, add numbers etc

- Theorem (Popek and Goldberg)

- For any conventional third generation computer, a virtual machine monitor may be constructed if the set of **sensitive instructions** for that computer is a subset of the set of **privileged instructions**
 - i.e. have to be trappable

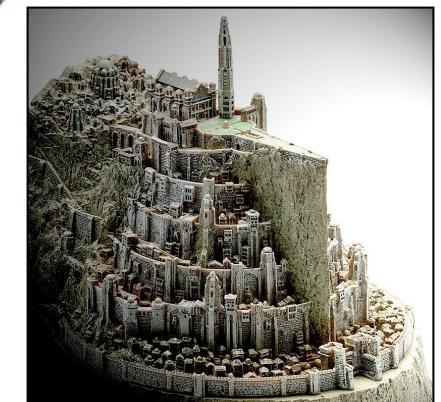
Example of Privilege Rings

- Ring 0: Typically hardware interactions
- Ring 1: Typically device drivers
- Specific gates between Rings (not ad hoc)
- Allows to ensure for example that spyware can't turn on web cam or recording device etc



- Significance

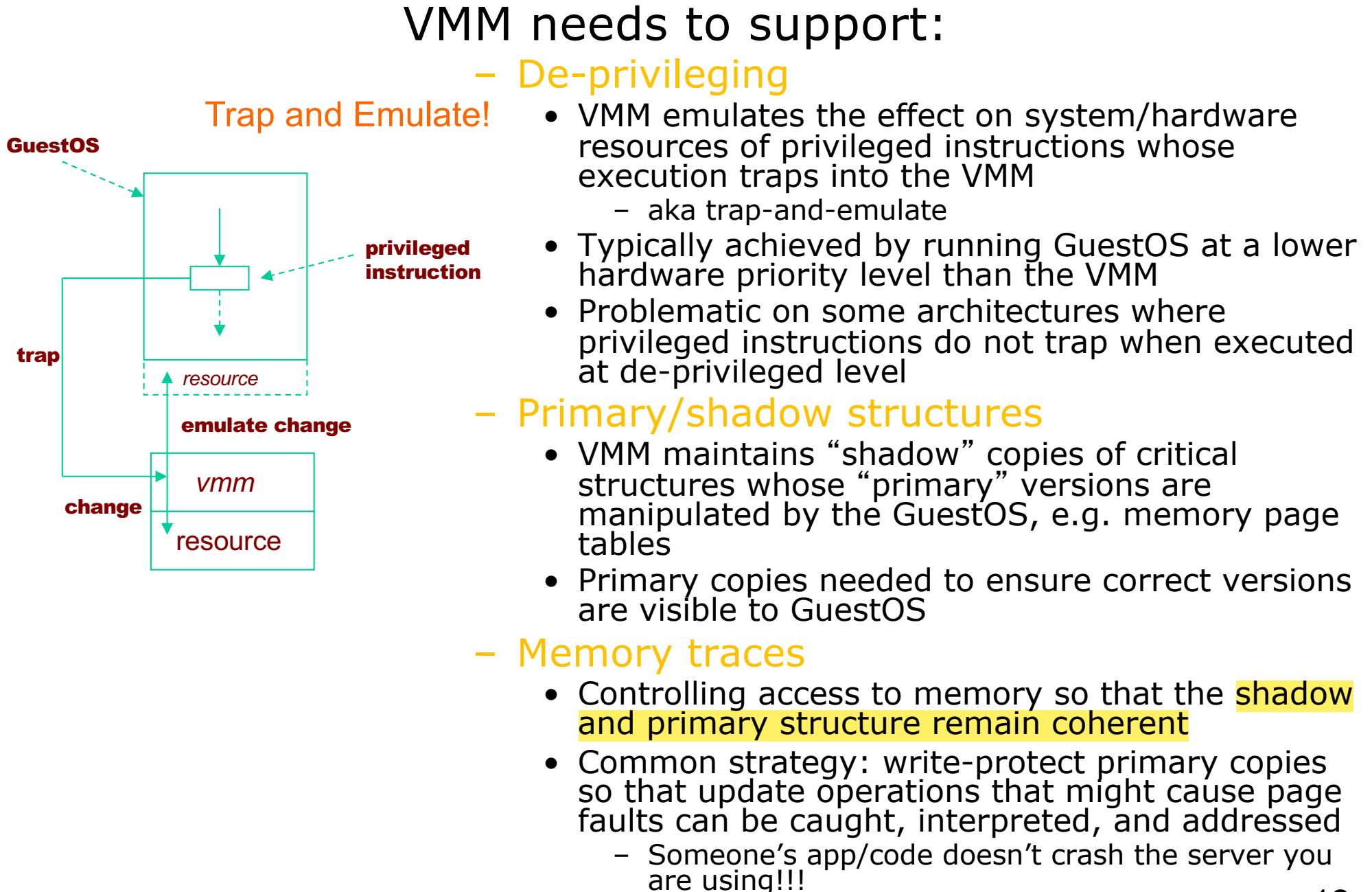
- The IA-32/x86 architecture was not originally virtualisable



- x86 architecture was historically not virtualisable, due to **sensitive instructions** that could not be trapped, e.g. instructions such as:
 - *SMSW* – storing machine status word
 - *SGDT, SLDT* – store global/local descriptor table register
 - *POPF* – interrupt flag (user/kernel mode)
 - Robin and Irvine, Analysis of an Intel Pentium's Ability to Support a Secure Virtual Machine Monitor, Usenix, 2000
- Intel and AMD introduced extensions to make x86 virtualisable
 - AMD SVM (Secure Virtual Machine)
 - Intel VT (Virtualisation Technology)
- These are very similar, but use slightly different machine instructions



Typical Virtualisation Strategy



Major VMM and Hypervisor Providers

VMM Provider	Host CPU	Guest CPU	Host OS	Guest OS	VM Architecture
VMWare Workstation	x86, x86-64	x86, x86-64	Windows, Linux	Windows, Linux, Solaris, FreeBSD, OS/2	Full Virtualization
VMWare ESX Server	x86, x86-64	x86, x86-64	No Host OS	Same as VMWare workstation	Baremetal hypervisor
Xen	x86, x86-64, IA-64	x86, x86-64, IA-64	NetBSD, Linux, Solaris	Windows, Linux, Solaris, FreeBSD, OS/2, NetBSD	Para-virtualisation
KVM			Linux	Linux, Windows, FreeBSD, Solaris	Hardware virtualisation



- **Full virtualisation** – allow an unmodified guest OS to run in isolation by simulating full hardware (e.g. VMWare)
 - Guest OS has no idea it is not on physical machine

vs

- **Para-virtualisation** – VMM/Hypervisor exposes special interface to guest OS for better performance. Requires a modified/hypervisor-aware Guest OS (e.g. Xen)
 - Can optimise systems to use this interface since not all instructions need to be trapped/dealt with



- **Advantages**

- Guest is unaware it is executing within a VM
- Guest OS need not be modified
- No hardware or OS assistance required
- Can run legacy OS

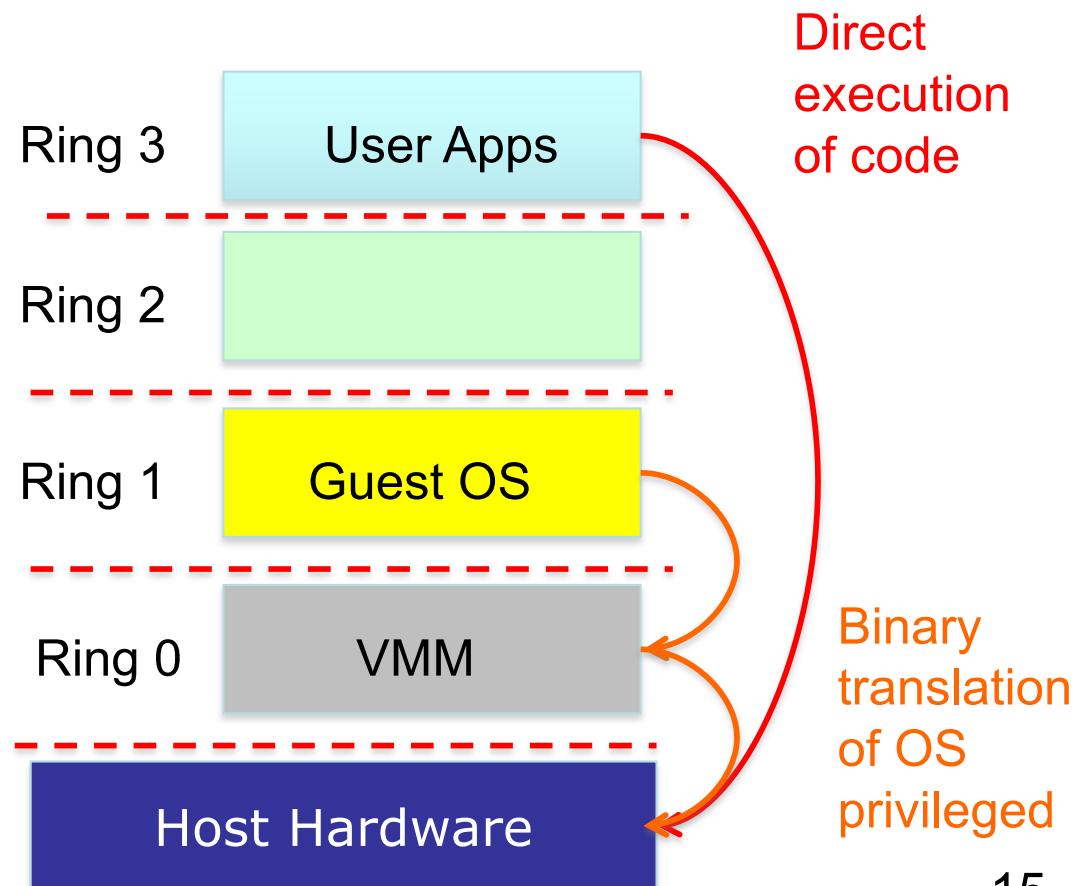
- **Disadvantages**

- can be less efficient

User/kernel split typically

- VMM run Ring 0
- Apps run in Ring 3

Virtualisation (Guest OS) uses extra rings; VMM traps privileged instructions and translates to hardware specific instructions





QUESTION

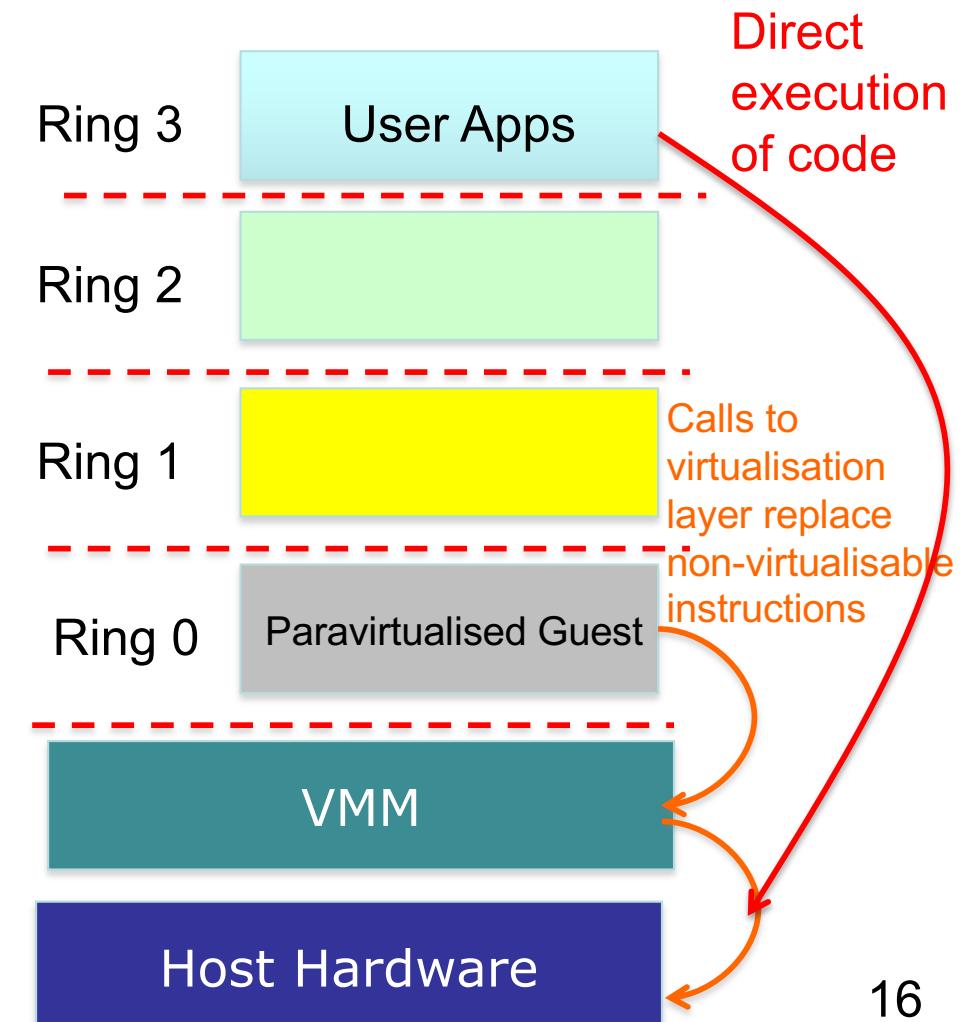
ANSWER

• Advantages

- Lower virtualisation overheads, so better performance, e.g. Xen

• Disadvantages

- Need to modify guest OS
 - Can't run arbitrary OS!
- Less portable
- Less compatibility



- **Hardware-assisted virtualisation** – Hardware provides architectural support for running a Hypervisor (e.g. KVM)
 - New processors typically have this
 - Requires that all sensitive instructions trappable

vs

- **Binary Translation** – Trap and execute occurs by scanning guest instruction stream and replacing sensitive instructions with emulated code (e.g. VMWare)
 - Don't need hardware support, but can be much harder to achieve
 - Rarely ever 1:1 mapping between instruction sets



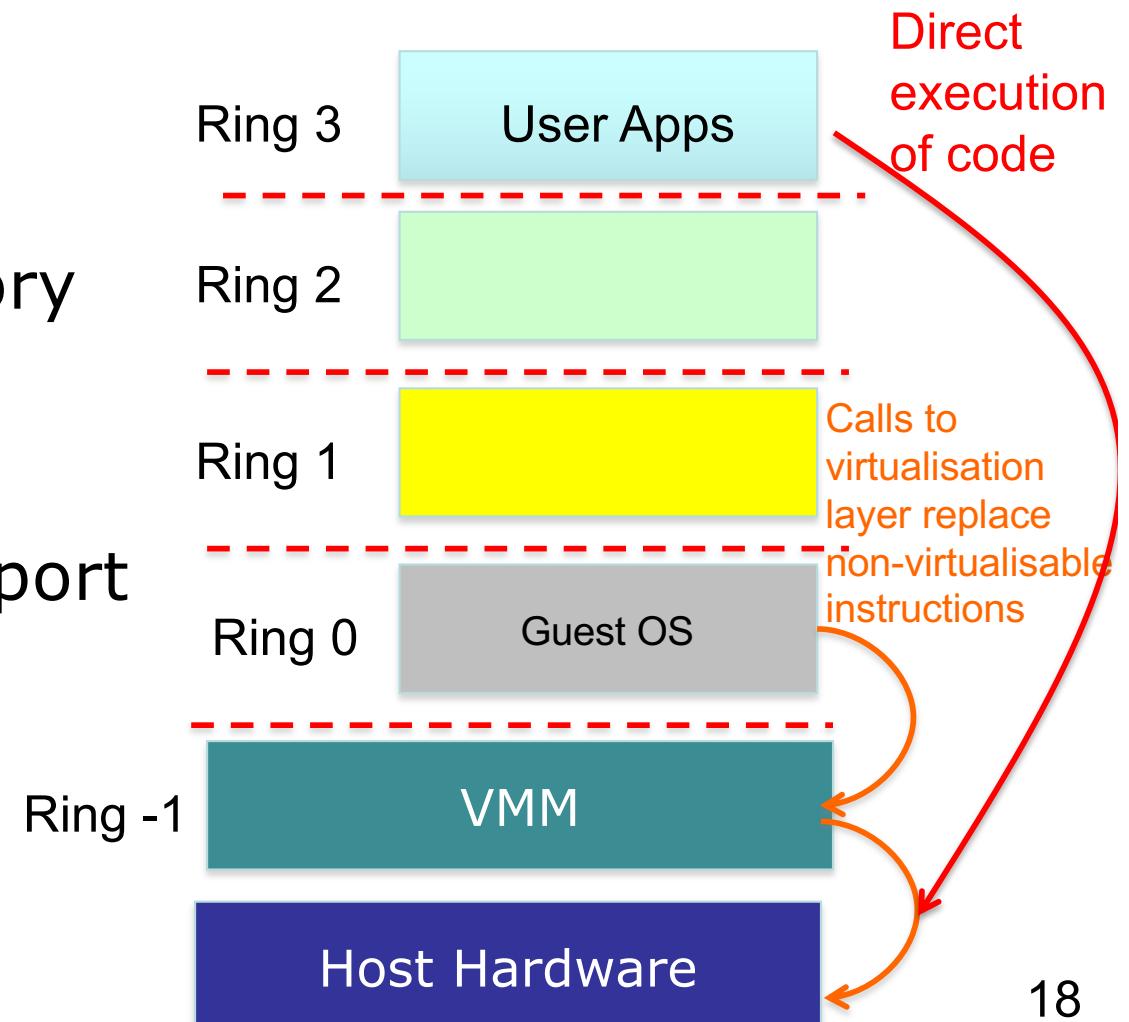
- Advantages

- Good performance
- Easier to implement
- Advanced implementation supports hardware assisted DMA, memory virtualisation, ...

- Disadvantages

- Needs hardware support

New Ring -1 supported
Page tables, virtual memory
mgt, direct memory access for
high-speed reads etc



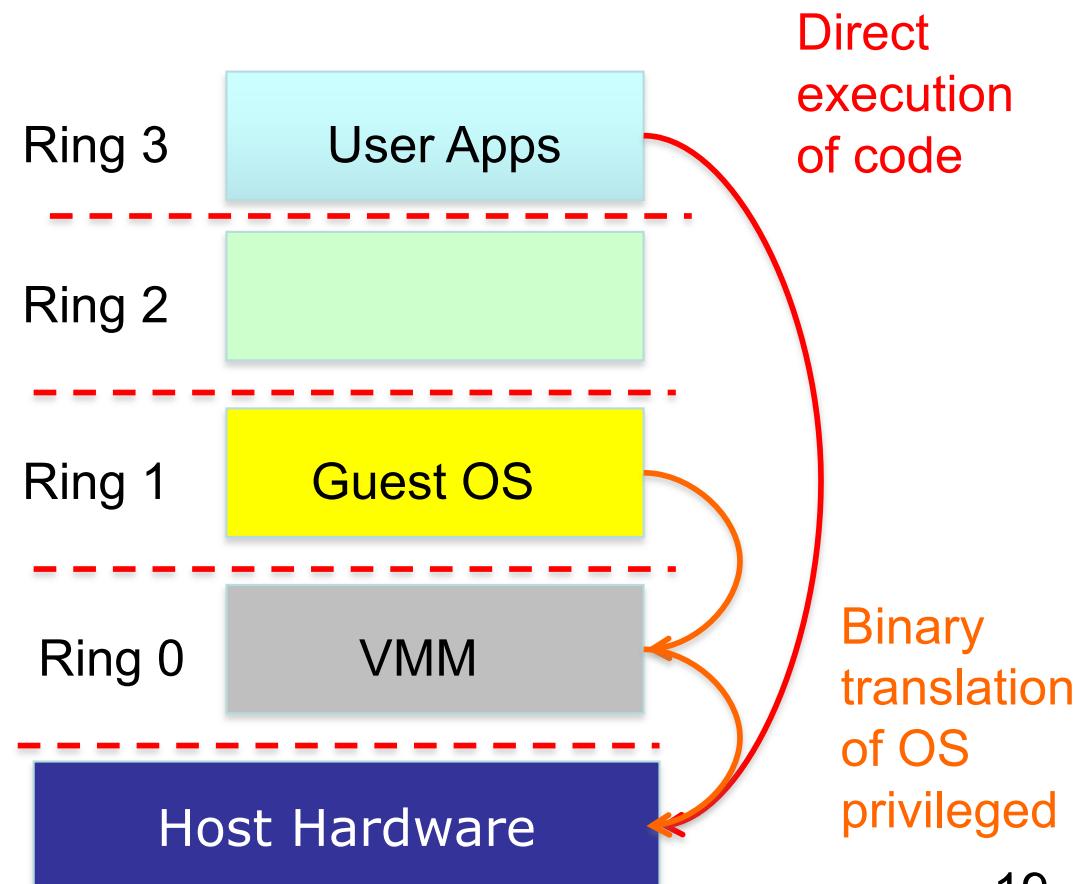


- **Advantages**

- Guest OS need not be modified
- No hardware or OS assistance required
- Can run legacy OS

- **Disadvantages**

- Overheads
- Complicated
- Need to replace instructions “on-the-fly”
- Library support to help this, e.g. vCUDA



Aspects of VMMs (contd...)

- **Bare Metal Hypervisor** – VMM runs directly on actual hardware (e.g. VMWare ESX Server)
 - Boots up and runs on actual physical machine
 - VMM has to support device drivers, all HW mgt

VS

- **Hosted Virtualisation** – VMM runs on top of another operating system (E.g. VMWare Workstation,...)



- *Lightweight VMs (containers)*
- Instead of whole-system virtualisation, the OS creates mini-containers
 - A subset of the OS is often good enough for many use cases
 - Can't use for running Windows on Linux etc, but often not needed!
 - Akin to an advanced version of “*chroot*”
 - operation that changes apparent root directory for current running process and subprocesses. Program run in such a modified environment cannot access files and commands outside that environmental directory tree.
- Examples:
 - LXC, Docker, OpenVZ, FreeBSD Jails etc



- **Advantages**

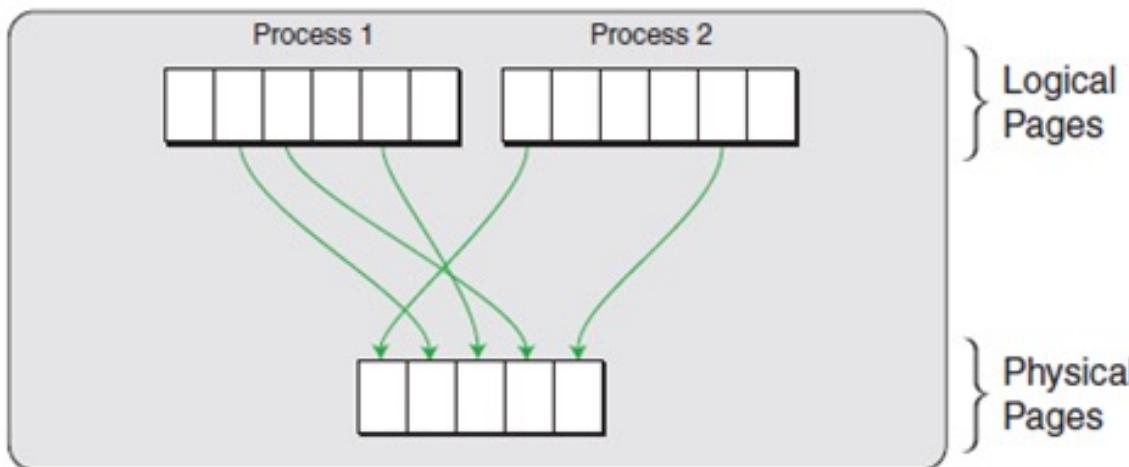
- Lightweight
- Many more VMs on same hardware
- Can be used to package applications and all OS dependencies into container

- **Disadvantages**

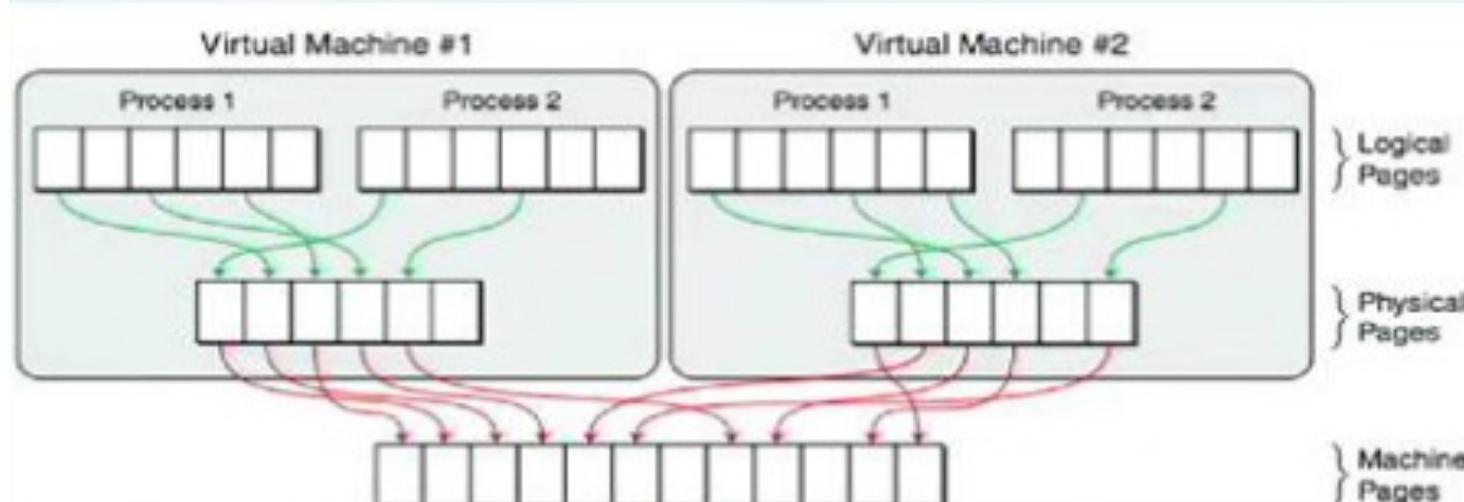
- Can only run apps designed for the same OS
- Cannot host a different guest OS
- Can only use native file systems
- Uses same resources as other containers

Memory Virtualisation

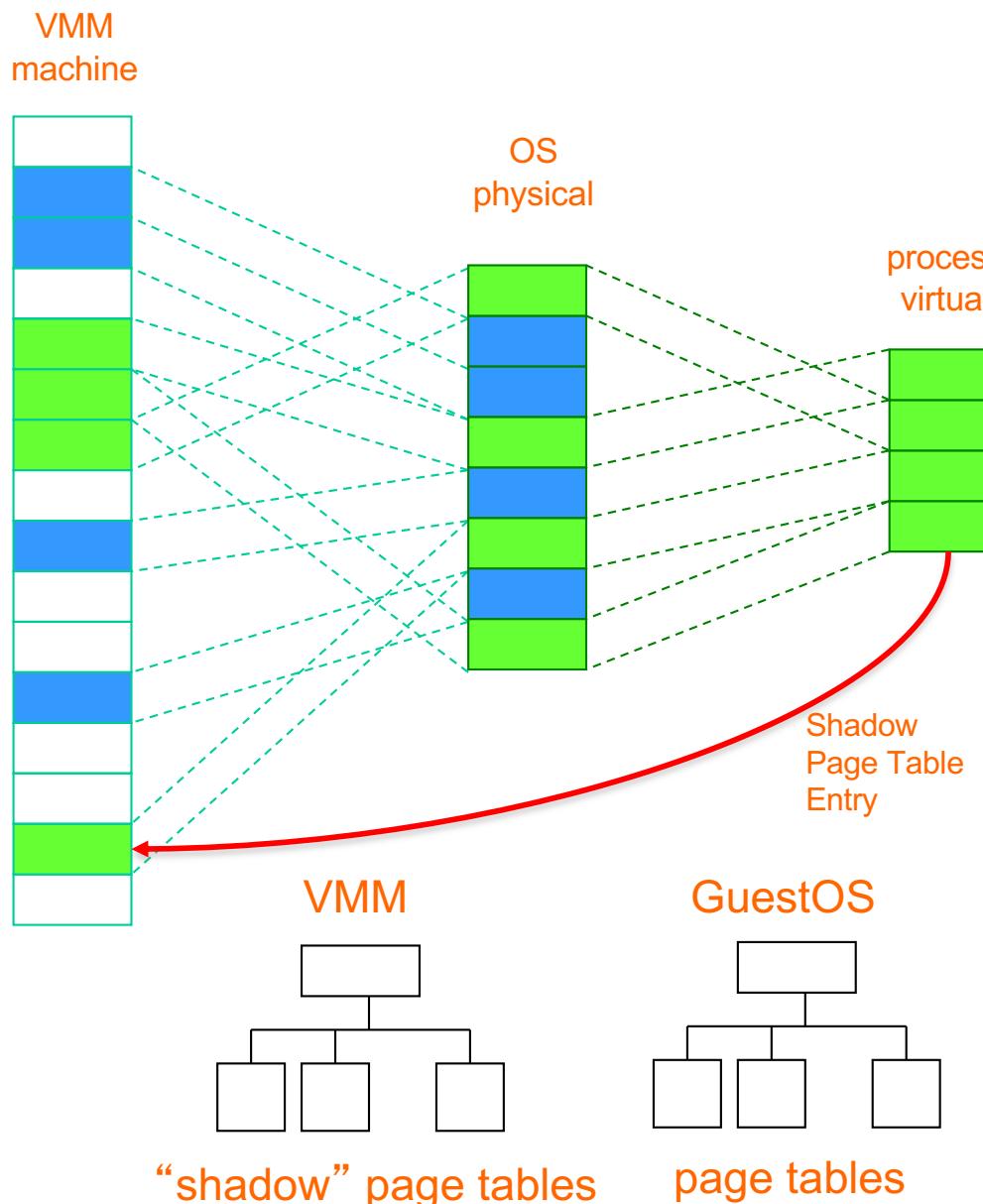
- Conventionally page tables store the logical page number -> physical page number mappings
 - Seems like more memory than actually have



- What happens in a VM?



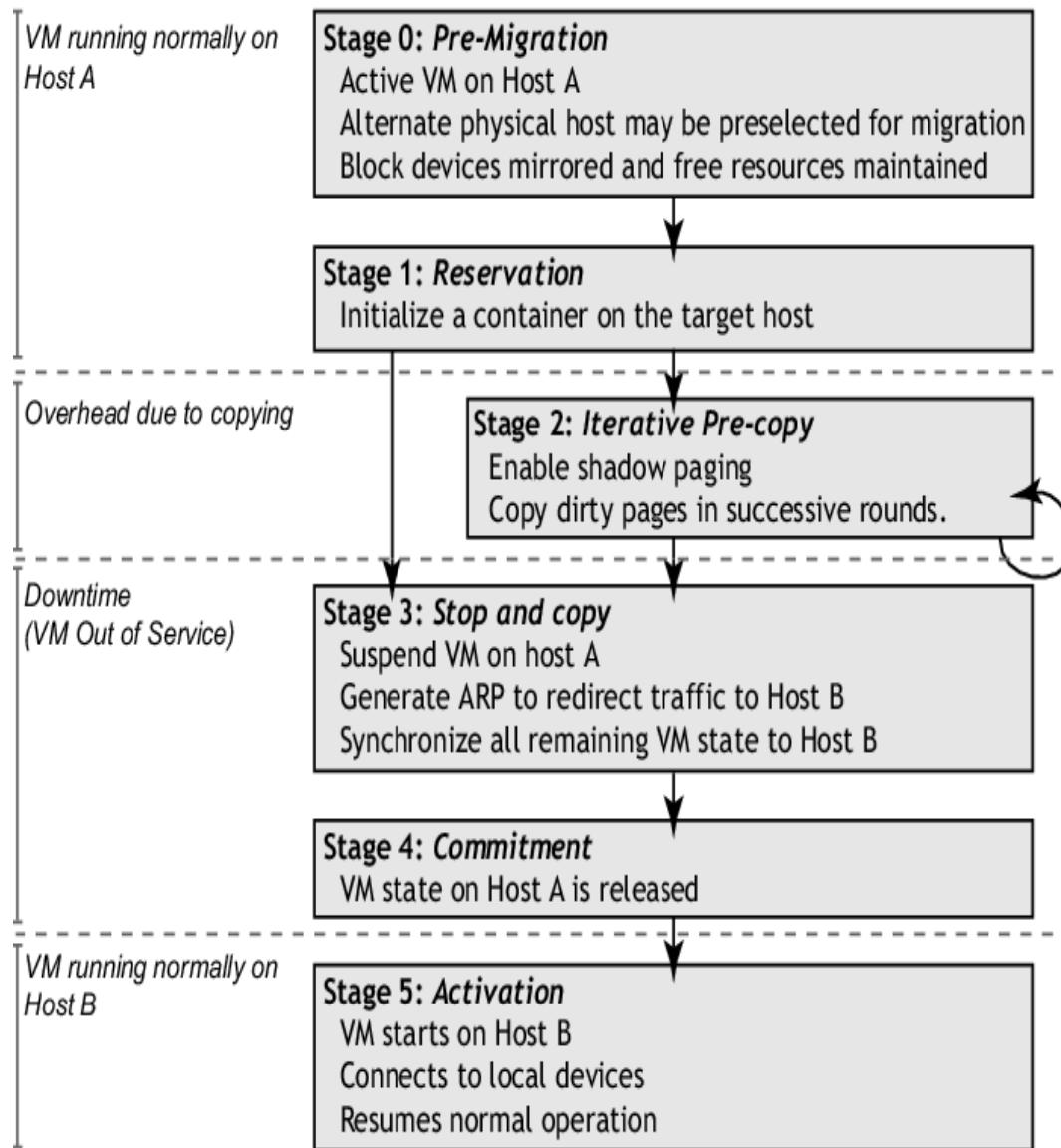
Shadow Page Tables



- VMM maintains shadow page tables in lock-step with the page tables
- Adds additional management overhead
- Hardware performs guest -> physical and physical -> machine translation



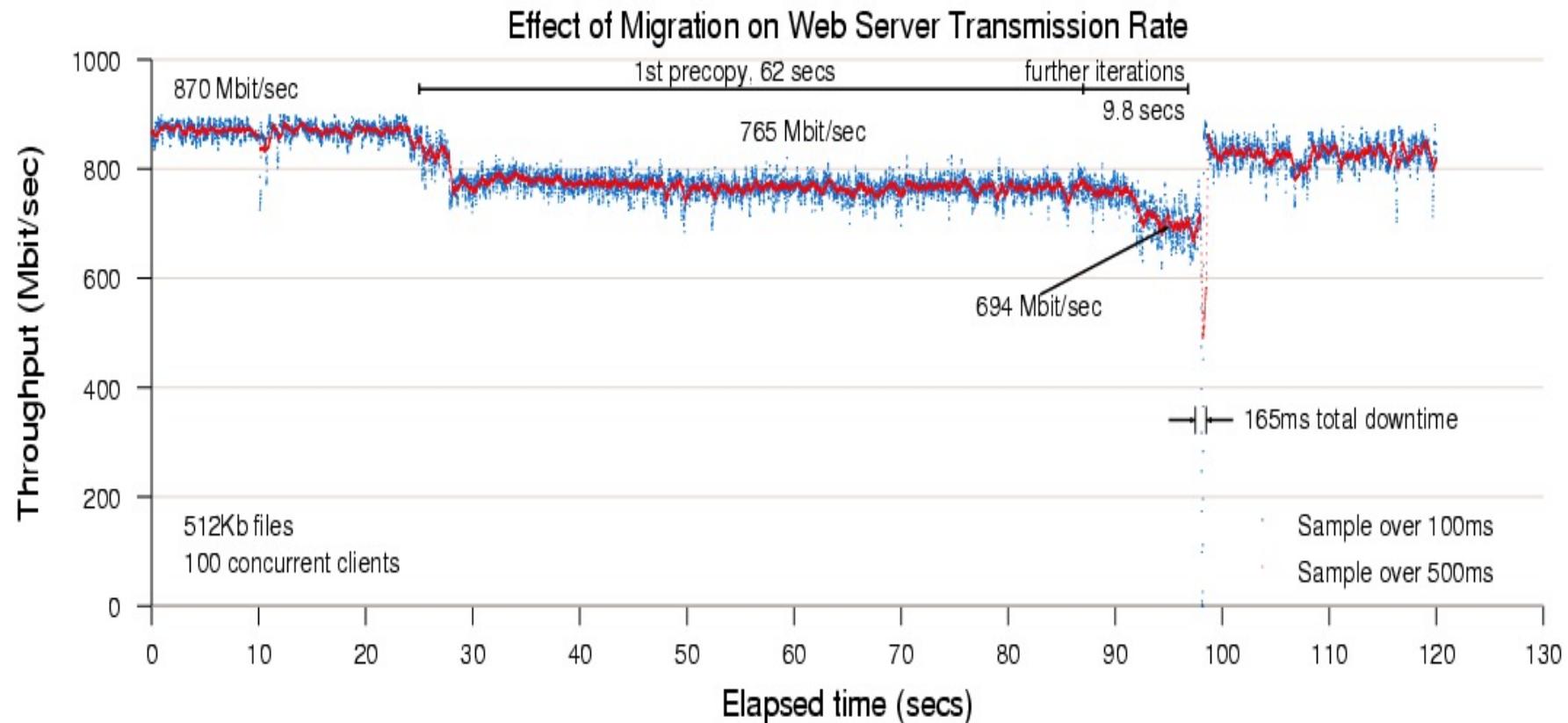
Live Migration from Virtualisation Perspective



Source: Clark et al, Live migration of virtual machines, NSDI 2005

Clark et al. Live migration of virtual machines, NSDI 2005.

Effects of Live Migration



Source: Clark et al, Live migration of virtual machines, NSDI 2005

References

- Hwang, Dongarra & Fox, 2011. Distributed and Cloud Computing, 1st Edition. Elsevier.
- Rosenblum M & Garfinkel T. 2005. Virtual machine monitors: Current technology and future trends, in IEEE Computer.
- Clark et al, 2005. Live migration of virtual machines. In Proceedings of the 2nd ACM/USENIX Symposium on Networked Systems Design and Implementation (NSDI). pp. 273-286
- K. Adams, O. Agesen, 2006. A Comparison of Software and Hardware Techniques for x86 Virtualization, ASPLOS 2006

BREAK

MRC (OpenStack)

vs

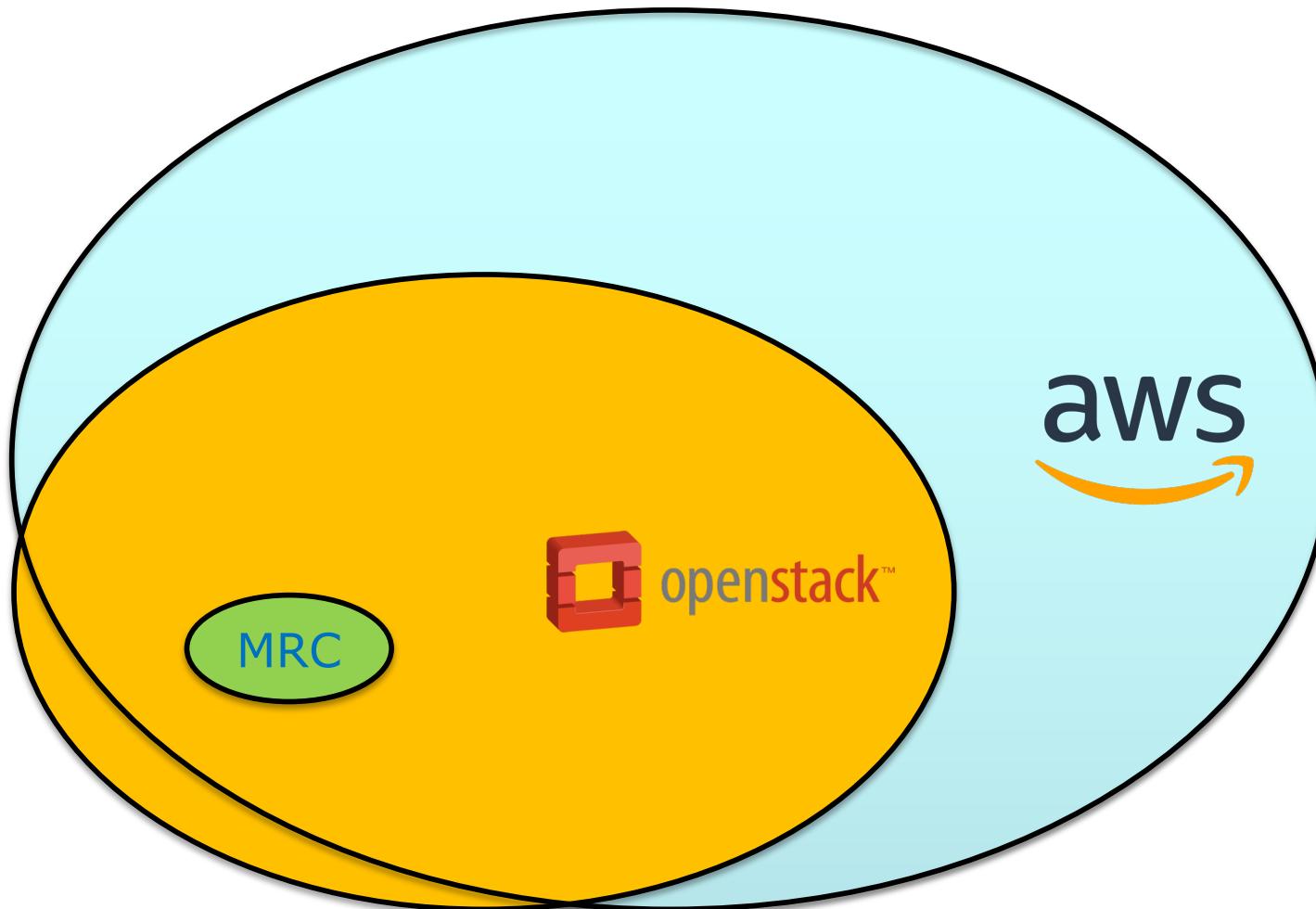
Amazon AWS





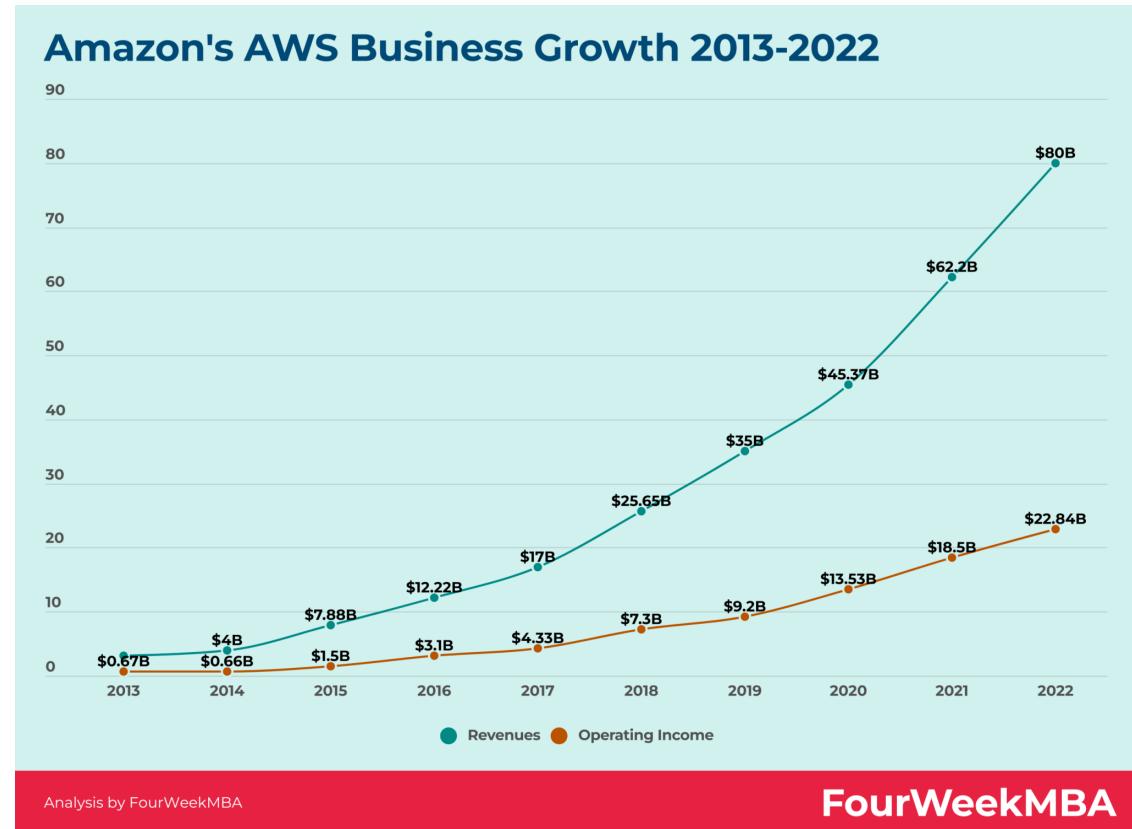
AWS vs OpenStack

NOTE: This chart does not represent the true relationship between AWS and OpenStack, and the exact services they are offering.





- A subsidiary of Amazon, founded in 2002
- Provides on-demand cloud computing platforms and APIs
- PAYG basis
- Makes tons of \$\$\$





- AWS Free Tier: <https://aws.amazon.com/free> (NOT FREE!)
 - Free trials
 - 12 months free
 - Always free

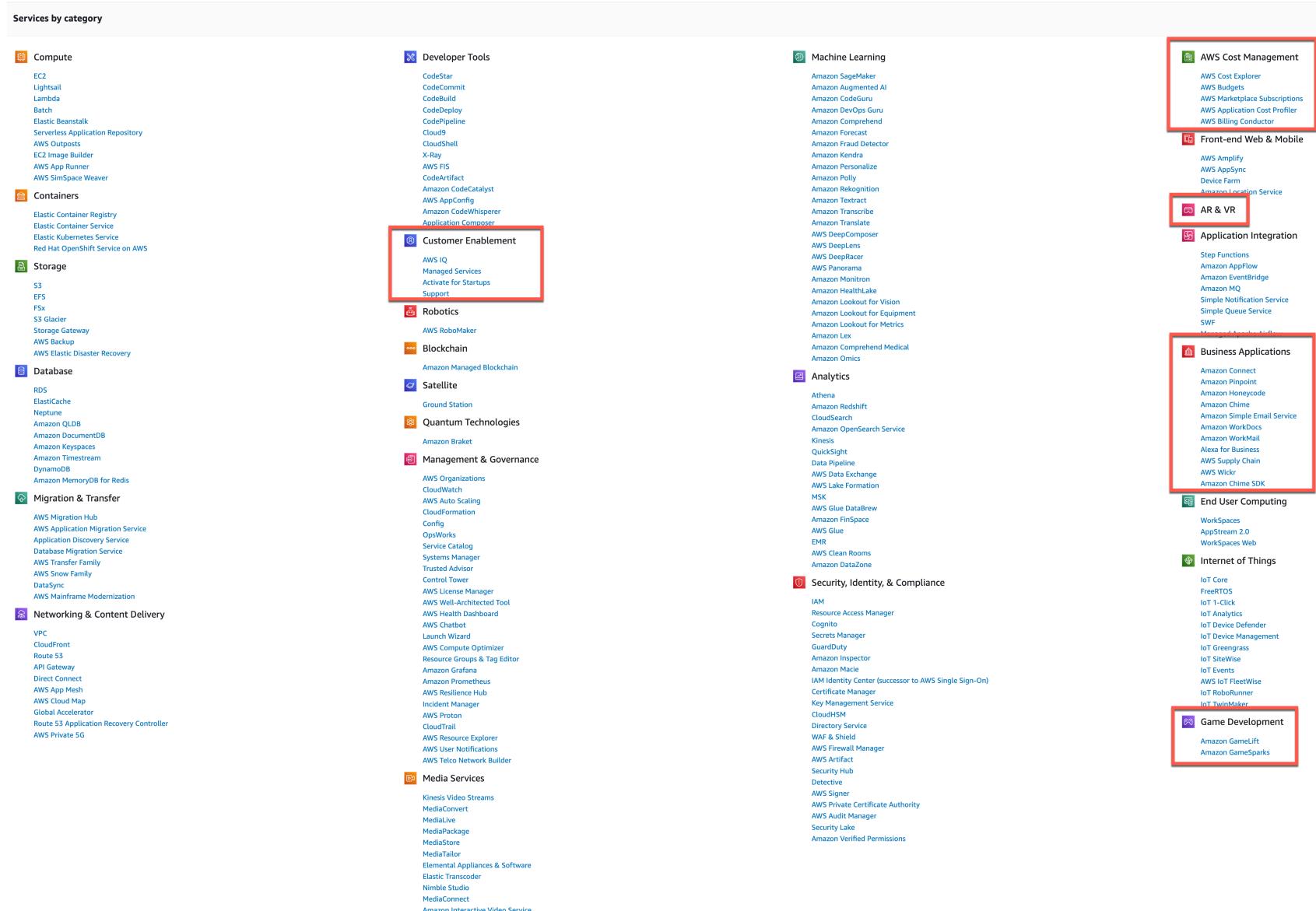
The screenshot shows the AWS Console Home page with the following sections:

- Recently visited:** A list of recently used services including Amazon Simple Email Service, VPC, Support, CloudWatch, IAM, RDS, S3, and EC2.
- Welcome to AWS:** A section with three cards:
 - Getting started with AWS**: Learn the fundamentals and find valuable information to get the most out of AWS.
 - Training and certification**: Learn from AWS experts and advance your skills and knowledge.
 - What's new with AWS?**: Discover new AWS services, features, and Regions.
- AWS Health:** Shows 0 open issues and 0 scheduled changes.
- Cost and usage:** A blurred section showing cost and usage data over the past 7 days.



Services: All AWS Services

- AWS currently offers ~~226~~ **216** services across ~~21~~ **24** categories



Services: AWS vs OpenStack

- AWS service alternatives in OpenStack (Short)

Service Category	AWS Service	OpenStack Service
Compute	Amazon EC2 (Elastic Compute Cloud)	Nova
Storage	Amazon S3 (Simple Storage Service)	Swift
Block Storage	Amazon EBS (Elastic Block Store)	Cinder
Object Storage	Amazon S3 (Simple Storage Service)	Swift
Networking	Amazon VPC (Virtual Private Cloud)	Neutron
Load Balancing	Elastic Load Balancing (ELB)	Octavia
DNS	Amazon Route 53	Designate
Database	Amazon RDS (Relational Database)	Trove
NoSQL Database	Amazon DynamoDB	Trove
Caching	Amazon ElastiCache	Not a direct equivalent
Orchestration	AWS CloudFormation	Heat (MRC does not support scaling)
Containers	Amazon ECS (Elastic Container Service)	Zun (Container Service)
Serverless	AWS Lambda	OpenStack Function (Project Qinling)
Content delivery Network (CDN)	CloudFront	No Content Distribution Network
Managed Hosting Platform	Elastic Beanstalk	There is no Managed Hosting Platform



- AWS service alternatives in OpenStack (Long)

Offered Service	AWS	OpenStack
Elasticity	Auto Scaling is a part of AWS	Autoscaling with Heat
Virtual servers	based on EC2	Based on Instance in Nova
Workflow Service	Follows Simple Workflow Service (SWF)	It has the Mistral – Workflow Service
Business Productivity Tools	Amazon WorkDocs	None
Workload Management	ELB (Elastic Load Balancer)	Load Balancer as a Service (LBaaS)
Billing	AWS Usage and Billing Report	Ceilometer – Telemetry based billing, resource tracking etc
Enterprise Messaging:	Simple Queue Service (SQS)	Zaqar, a multi-user cloud messaging service for Mobile and Web
Search Service	Elasticsearch Service	Searchlight
Allotted Network	DirectConnect	No Dedicated Network
Database (NoSQL)	DynamoDB	Trove
Serverless Framework	Lambda	OpenStack Function (Project Qinling)
SAN Data Storage	EBS(Elastic Block Storage)	Cinder
Cache (InMemory)	ElastiCache	No In memory Caching
Script project deployment	CodeDeploy Code Commit Code Pipeline	No Application Deployment with Scripts
Microservices based Dockers or Containers:	ECS(EC2 Container Service)	Magnum
RDB (Database)	RDS	Trove
Domain Name System Administration	Route 53	Designate
Content delivery Network (CDN)	CloudFront	No Content Distribution Network
Templates or Image	AMI(Amazon Machine Image)	Glance
Cloud Data Storage Architecture	S3(Simple Storage Service)	Swift
Data Warehouse or Database	Redshift	Trove



- AWS service alternatives in OpenStack (Long)

Offered Service	AWS	OpenStack
Orchestration or Job Scheduler	AWS Batch	Heat
Data Archiving	Glacier	Swift
Big Data	EMR (Elastic Map Reduce)	Sahara
Identity and Access Management	IAM	KeyStone
Collaborated File Sharing	EFS (Elastic File System)	Manila
Private Cloud in Public Cloud	VPC (Virtual Private Cloud)	Neutron
Managed Hosting Platform	Elastic Beanstalk	There is no Managed Hosting Platform
Key/Encryption Management	KMS (Key Management Service)	Barbican
Mail Service	Simple Email Service (SES)	There is no Mail Service unless created
Speech or Voice recognition	Lex	No Speech or Voice recognition solution
Text to Speech Tool	Amazon Polly	No Text to Speech Tool
Personal Voice Assistant	Alexa	No Personal Voice Assistant
Application development Platforms	Mobile HUB, Mobile SDK, Cognito	No Application development Platforms
Machine Learning/NLP	Possible	ML & NLP are not readily available
Internet of Things or Connected Smart Systems	AWS IoT	No Internet of Things or Connected Smart Systems
Streaming Analytics or Data	Kinesis	No Streaming Analytics or Data feature

- MRC only offers a subset of OpenStack services:
 - No Designate (DNS as a Service)
 - No HEAT with Scaling
 - No ...

- Some services are available in MRC, but not to your project:
 - Trove (Relation Database as a Service)
 - LBaaS (Load Balancer as a Service)
 - ...



AWS Cost

Cost and usage [Info](#)

Current month costs
\$45,439.27

Forecasted month end costs
\$70,371.13 Down 71% from last month

Last month costs
\$239,033.92

Costs shown are unblended. [Learn more](#)

[Go to AWS Cost Management](#)

Top costs for current month

Service	Cost
Amazon Elastic Compute Cloud (Amazon EC2)	\$5,984.48
Amazon Elastic MapReduce	\$2,583.16
EC2 - Other	\$1,843.37
Tax	\$1,212.25
AmazonCloudWatch	\$397.84

Cost and usage [Info](#)

Current month costs
\$7,791.70

Forecasted month end costs
\$9,571.40 Down 22% from last month

Last month costs
\$12,316.50

Costs shown are unblended. [Learn more](#)

[Go to AWS Cost Management](#)

Top costs for current month

Service	Cost
Amazon Elastic Compute Cloud (Amazon EC2)	\$5,984.48
Amazon Elastic MapReduce	\$2,583.16
EC2 - Other	\$1,843.37
Tax	\$1,212.25
AmazonCloudWatch	\$397.84

Cost and usage [Info](#)

Current month costs
\$13,334.77

Forecasted month end costs
\$16,461.61 Up 14% over last month

Last month costs
\$14,477.46

Costs shown are unblended. [Learn more](#)

[Go to AWS Cost Management](#)

Top costs for current month

Service	Cost
Amazon Elastic Compute Cloud (Amazon EC2)	\$5,984.48
Amazon Elastic MapReduce	\$2,583.16
EC2 - Other	\$1,843.37
Tax	\$1,212.25
AmazonCloudWatch	\$397.84

Cost and usage [Info](#)

Current month costs
\$8,624.91

Forecasted month end costs
\$10,738.03 Down 4% from last month

Last month costs
\$11,133.28

Costs shown are unblended. [Learn more](#)

[Go to AWS Cost Management](#)

Top costs for current month

Service	Cost
AmazonCloudWatch	\$6,649.77
Amazon Elastic Compute Cloud (Amazon EC2)	\$691.16
Amazon Relational Database Service (Amazon RDS)	\$557.03
AWS Support (Developer)	\$250.24

Cost and usage breakdown

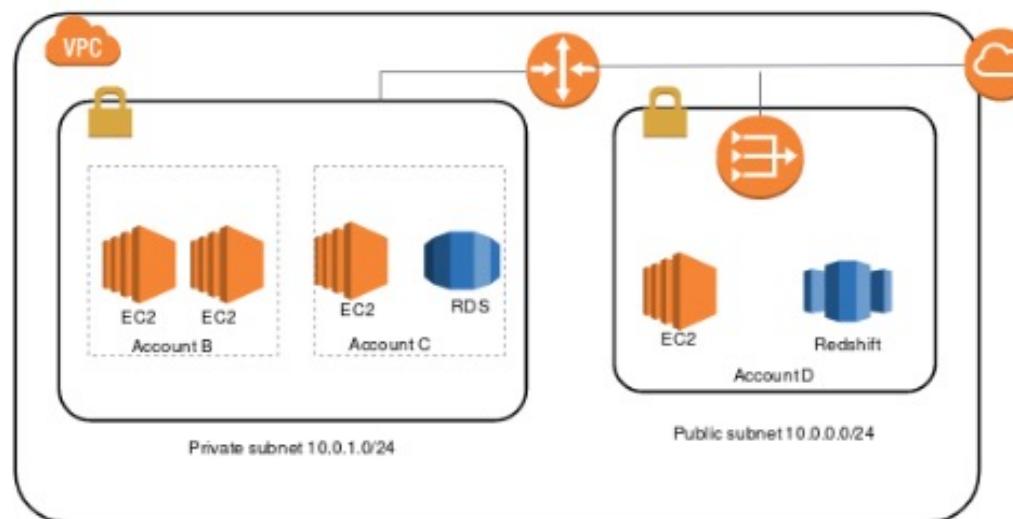
	Total	Mar-01	Mar-02	Mar-03	Mar-04	Mar-05	Mar-06	Mar-07	Mar-08	Mar-09	Mar-10
Total costs	\$8,682.44	\$273.46	\$279.09	\$280.16	\$279.30	\$280.06	\$279.62	\$279.70	\$279.47	\$279.54	\$279.42

[Download as CSV](#)

< 1 >



- Amazon VPC - Virtual Private Cloud
 - Launch AWS resources into a virtual network you've defined
- Subnets
 - A range of IP addresses in your VPC
- Common use case
 - VPC with public and private subnets





- EC2 – Elastic Cloud Computing
 - Instance
 - Security group
 - Elastic IP (Floating IP)
 - Elastic Load Balancer
 - Secured way to connect to a EC2 instance
 - SSH via a bastion host (SSH Forward Agent)
 - Session Manager via Web Interface
 - Session Manager via CLI



- S3 – Simple Storage Service
 - Object storage service offering industry-leading scalability, data availability, security, and performance.
 - Store any data for any purpose
 - Upload and retrieve data via web interface, CLI, API, and many third-party libraries and clients
 - Host a static website with S3 bucket
 - Data versioning and lifecycle policy



- Fleet Manager
 - Manage nodes remotely
 - View health and performance status, gather data from nodes

AWS Systems Manager > Fleet Manager > Node ID: i-0a6a4f1029a5ac348

Node ID: i-0a6a4f1029a5ac348 Running Node actions ▾

Node overview		
Node ID	i-0a6a4f1029a5ac348	OS name
Platform type	Linux	SSM Agent version
Node type	t2.micro	IP address
Source type	EC2 instance	Source ID
		-
		Availability Zone ap-southeast-2a
		SSH key name comp90024-demo
		SSM Agent ping status Online
		IAM role arn:aws:iam::027195712236:instance-profile/AmazonSSMRoleForInstancesQuickSetup

Tags Inventory Associations Patch Configuration compliance

Tags Edit

You can use tags to group and filter your managed nodes. A tag consists of a case-sensitive key-value pair.

Key	Value
Name	ec2-demo
SSMSessionRunAs	ubuntu



- Session Manager
 - Provide secure and auditable node management without the need to open inbound port
 - Interactive browser-based shell or AWS CLI
- Run Command
 - Automate common admin tasks
 - Perform one-time configuration changes at scale
- Patch Manager
 - Automate the process of patching managed nodes
 - For both OS and applications



- Amazon RDS
 - Managed relational database service
 - Support: MySQL, PostgreSQL, MariaDB, Oracle, MS SQL
- Amazon DocumentDB
 - A scalable, highly durable, and fully managed database service for operating mission-critical MongoDB
 - Compatible with the open-source MongoDB 3.6 and 4.0 APIs?
 - MongoDB Atlas?
- Amazon ElasticCache
 - Managed, in-memory data store services
 - Compatible with Redis or Memcached



- GuardDuty

- Protect your AWS accounts with intelligent threat detection
- Continuously monitors your AWS accounts and workloads for malicious activity and delivers detailed security findings for visibility and remediation

The screenshot shows the AWS GuardDuty 'Findings' page. At the top, there are buttons for 'Suppress Findings' and 'Info'. To the right are 'Actions' and a 'Saved rules' section indicating 'No saved rules'. Below this is a filter bar with 'Current' and 'Add filter criteria' options. The main table lists findings with columns for 'Finding type', 'Resource', 'Last seen', and 'Count'. The findings listed are:

Finding type	Resource	Last seen	Count
Recon:EC2/PortProbeUnprotectedPort	Instance: [REDACTED]	4 hours ago	186
Recon:EC2/PortProbeUnprotectedPort	Instance: [REDACTED]	6 days ago	180
Impact:EC2/PortSweep	Instance: [REDACTED]	19 days ago	28
CryptoCurrency:EC2/BitcoinTool.B	Instance: [REDACTED]	20 days ago	6



- WAF – Web Application Firewall
 - Monitor web requests forwarded to an API Gateway, CloudFront distribution, or an Application Load Balancer.
 - Protect resources based on conditions that you specify, such as the IP addresses that the requests originate from.

Sampled requests						
Samples of requests from the past 3 hours.						
Metric name	Source IP	URI	Rule inside rule group	Action	Time	
AWS-AWSManagedRulesCommonRuleSet	213.226.123.30 (PL)	/Autodiscover/Autodiscover.xml	AWS#AWSManagedRulesCommonRuleSet#CrossSiteScripting_BODY	BLOCK	Wed Apr 27 2022 00:42:18 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	212.50.99.121 (CY)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Wed Apr 27 2022 00:43:25 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	167.248.133.45 (US)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Tue Apr 26 2022 23:24:05 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	162.142.125.211 (US)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Wed Apr 27 2022 00:07:28 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	184.105.247.254 (US)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Tue Apr 26 2022 23:00:41 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	109.237.103.118 (RU)	.aws/credentials	AWS#AWSManagedRulesCommonRuleSet#GenericLFI_URIPATH	BLOCK	Wed Apr 27 2022 00:57:54 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	65.49.20.68 (US)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Tue Apr 26 2022 22:22:15 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	139.162.33.92 (SG)	/	AWS#AWSManagedRulesCommonRuleSet#UserAgent_BadBots_HEADER	BLOCK	Wed Apr 27 2022 00:05:50 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	190.189.55.170 (AR)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Tue Apr 26 2022 22:24:59 GMT+1000 (Australian Eastern Standard Time)	
AWS-AWSManagedRulesCommonRuleSet	164.92.67.17 (US)	/	AWS#AWSManagedRulesCommonRuleSet#NoUserAgent_HEADER	BLOCK	Wed Apr 27 2022 00:42:13 GMT+1000 (Australian Eastern Standard Time)	



- AWS Certificate Manager
 - Provision, manage and deploy public and private SSL/TLS certificates
 - Free public certificates! 😊
 - Free for real? Only for ACM-integrated services 😐
- Route 53
 - Domain name registration
 - DNS management
 - DNS health check
- Many more services...

