University of Applied Sciences and Arts Northwestern Switzerland
School of Computer Science

member of swissuniversities

Cloud Computing (cloud)

Module 2: Form Virtualization to IaaS Platforms

Prof. Dr. Sebastian Graf (sebastian.graf@fhnw.ch)
Norwin Schnyder (norwin.schnyder@fhnw.ch)

Input of this Module

- https://learning.oreilly.com/playlists/43827098-7a87-435e-823e-736586b5694c (03-iaasplatforms):
  - Shrivastwa et al., OpenStack: Building a Cloud Environment (2016)
  - Kumar and Stankowic, VMware vSphere Essentials (2015)
  - Eri and Monroy, Cloud Computing: Concepts, Technology, Security, and Architecture (2023)

- Several Blogposts

- Openstack Documentation: https://docs.openstack.org/install-guide/get-started-logical-architecture.html
- Proxmox Documentation: https://pve.proxmox.com/pve-docs/pve-admin-guide.html

NIST Definition of Cloud Computing

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

This cloud model is composed of **five essential characteristics**, which are:

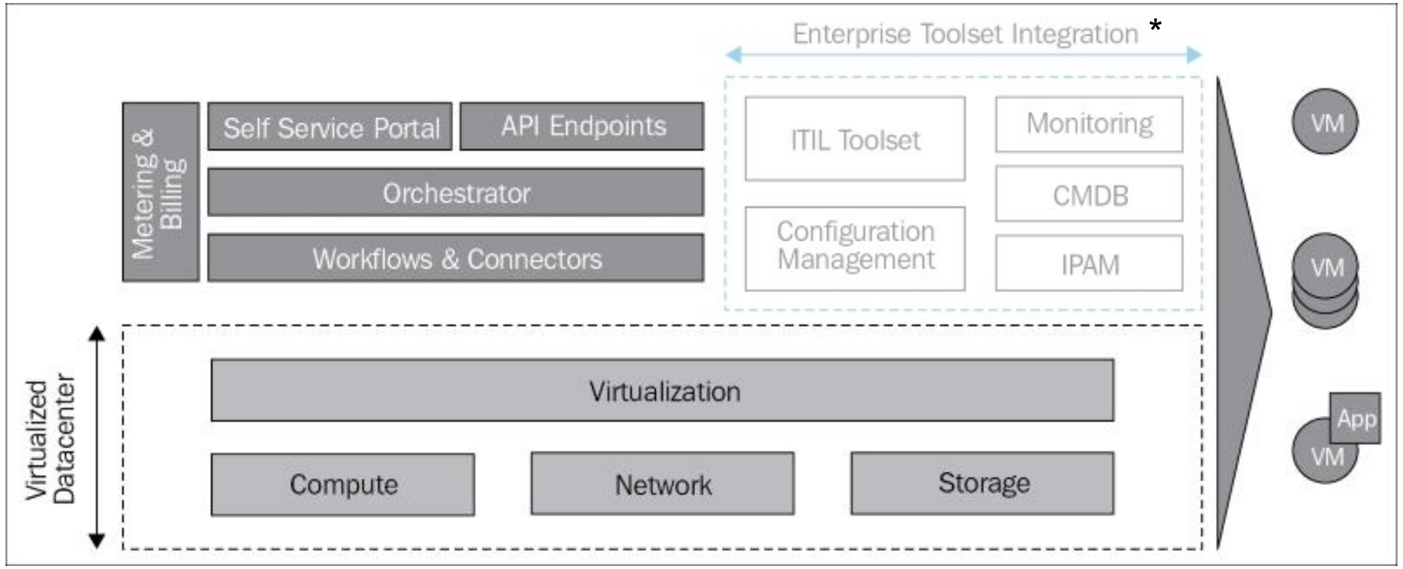
- **On-demand self-service**: Resources are provisioned automatically without human interaction.
- **Broad network access**: The cloud must be accessible via network.
- **Resource pooling**: Resources are shared among multiple customers → *Virtualization* ✓
- **Rapid elasticity**: Existing resource can be adapted to shrink and to increase dynamically.
- **Measured service**: All usage of the cloud is metered in a transparent matter to enable pay-as-you-go

Example: OpenStack

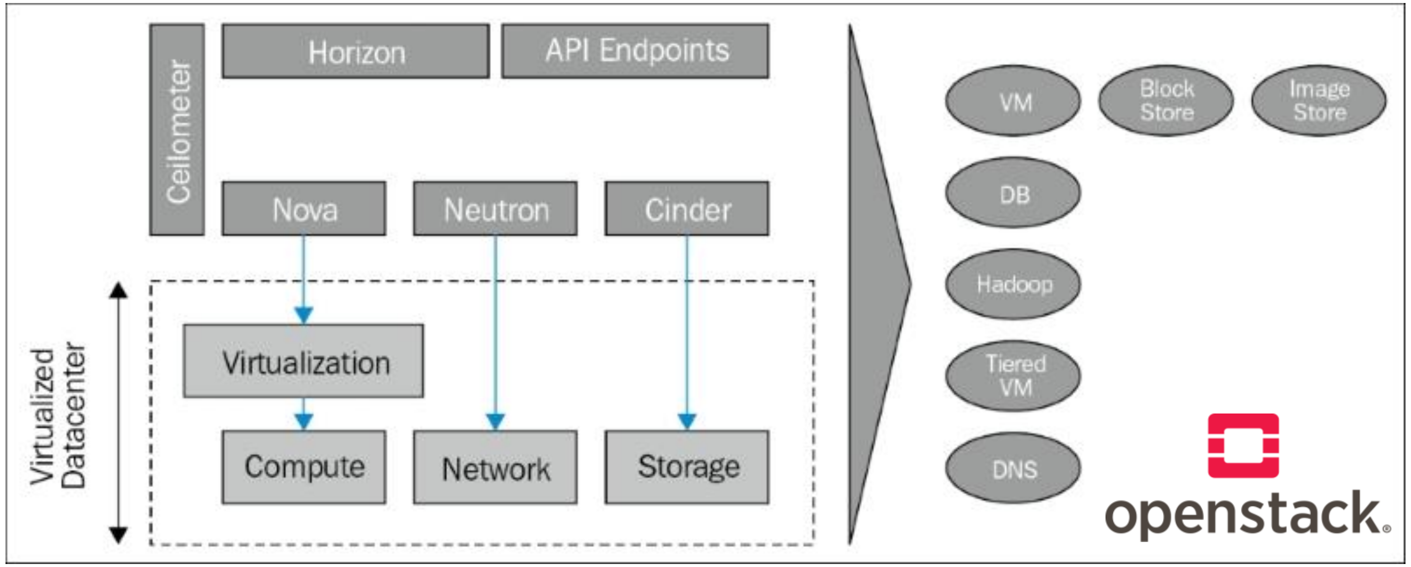
Large-scale virtualization orchestrators are in need to satisfy Self Service & API Endpoints.

OpenStack boils down to necessary cloud features and offers baseline functionality with modular services:

- **Horizon**: Dashboard
- **Keystone**: Authentication
- **Glance**: Images
- **Ceilometer**: Monitoring & Billing
- **Neutron**: Networking
- **Nova**: Computing
- **Cinder**: (Block)Storage
- **Swift**: (Object)Storage

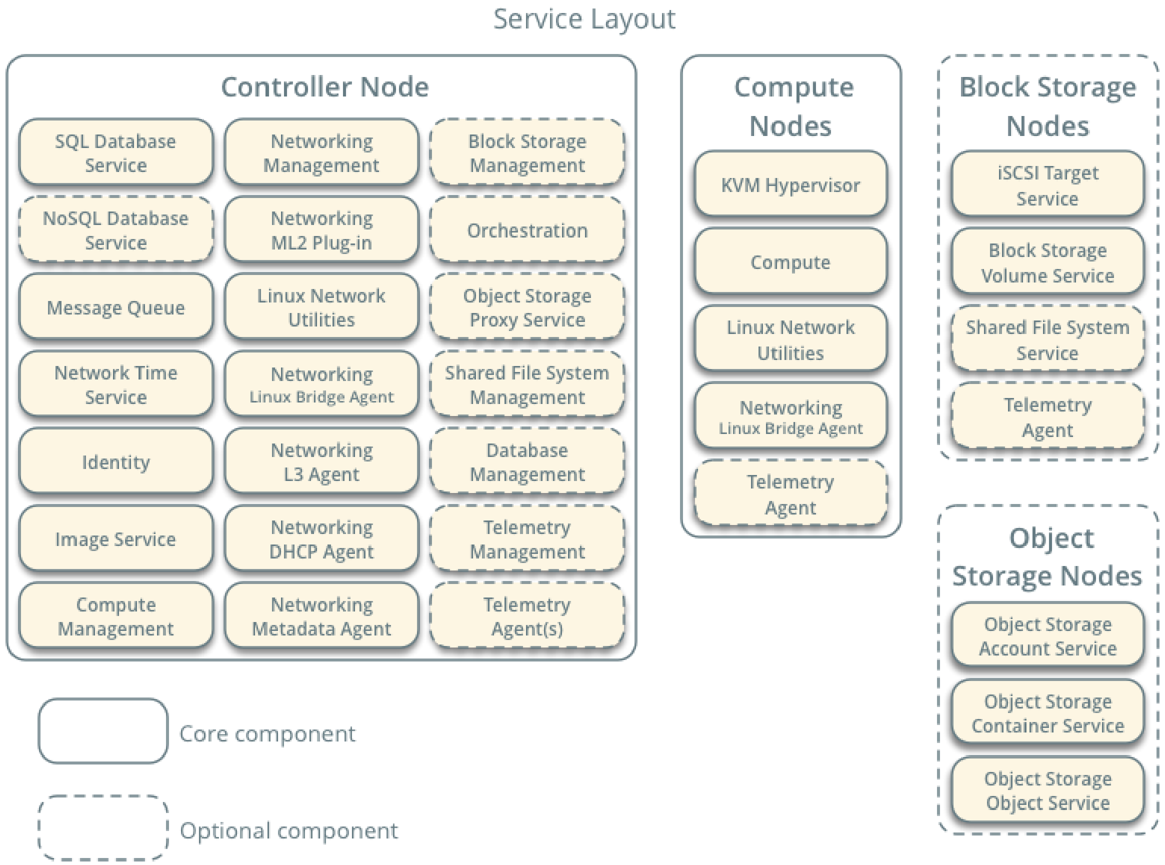


* Enterprise integration usually only provided by commercial orchestrators



Example: OpenStack Architecure

- **Controller Node**: Hosting all manager services like *keystone*, *neutron management*, *nova management*
- **Computer Node**: Hosts network agents and machines
- **Network Node**: Network components like DHCP Agent, the L3 Agent, and Open vSwitch
- **Storage Node**: Block and Object Storage accessible via iSCSI to other nodes



Service Layout

Controller Node

SQL Database Service
NoSQL Database Service
Message Queue
Network Time Service
Identity
Image Service
Compute Management

Networking Management
Networking ML2 Plug-in
Linux Network Utilities
Networking Linux Bridge Agent
Networking L3 Agent
Networking DHCP Agent
Networking Metadata Agent

Block Storage Management
Orchestration
Object Storage Proxy Service
Shared File System Management
Database Management
Telemetry Management
Telemetry Agent(s)

Compute Nodes

KVM Hypervisor
Compute
Linux Network Utilities
Networking Linux Bridge Agent
Telemetry Agent

Block Storage Nodes

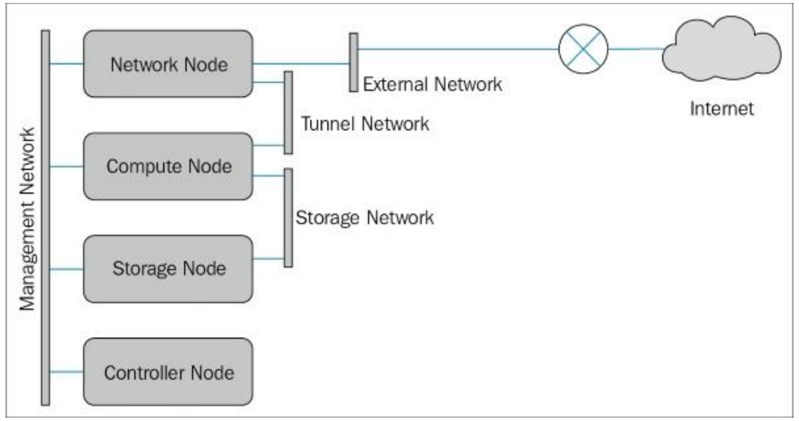
iSCSI Target Service
Block Storage Volume Service
Shared File System Service
Telemetry Agent

Object Storage Nodes

Object Storage Account Service
Object Storage Container Service
Object Storage Object Service

Core component

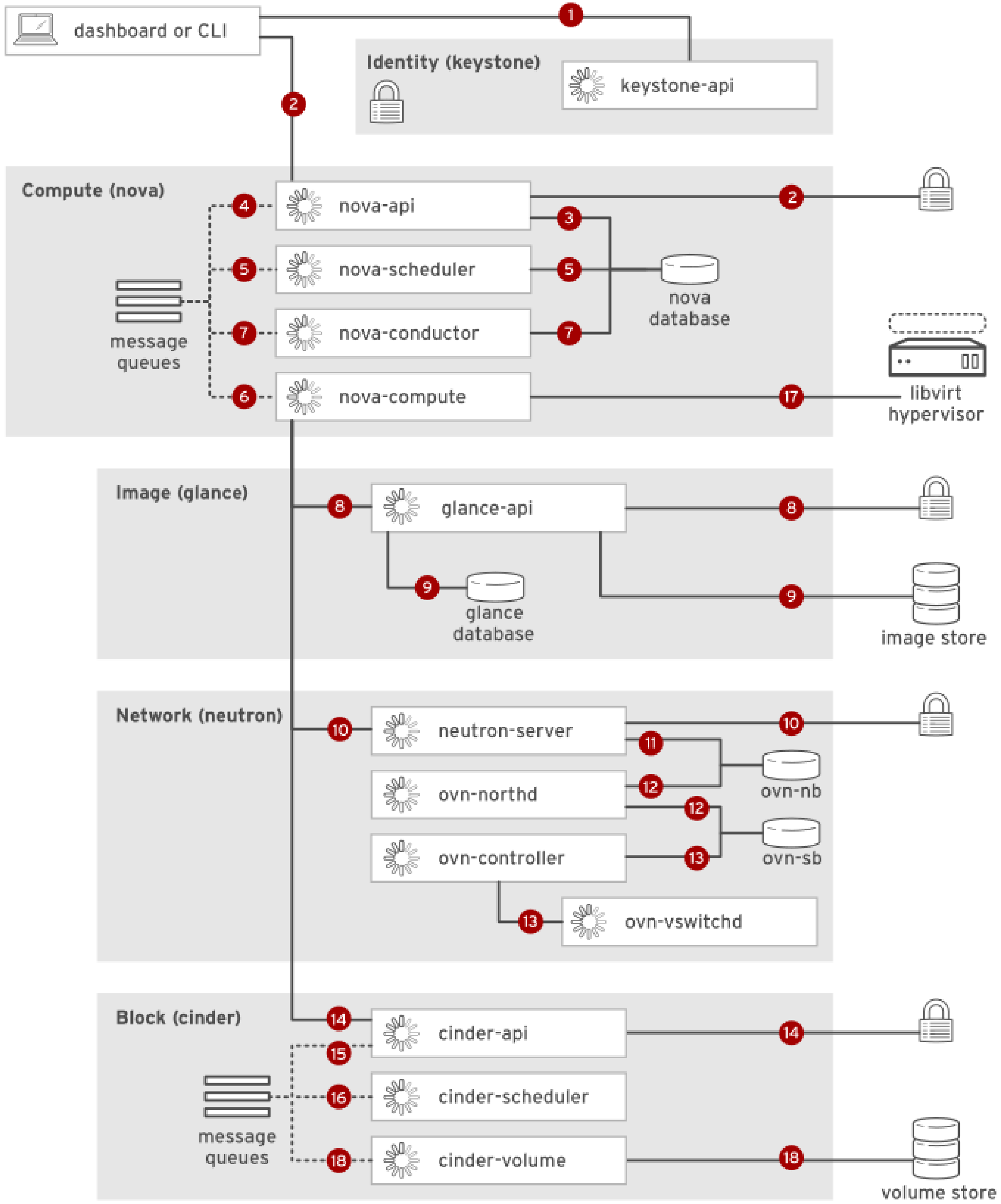
Optional component



Network can be encapsulated based on use to minimize side effects.

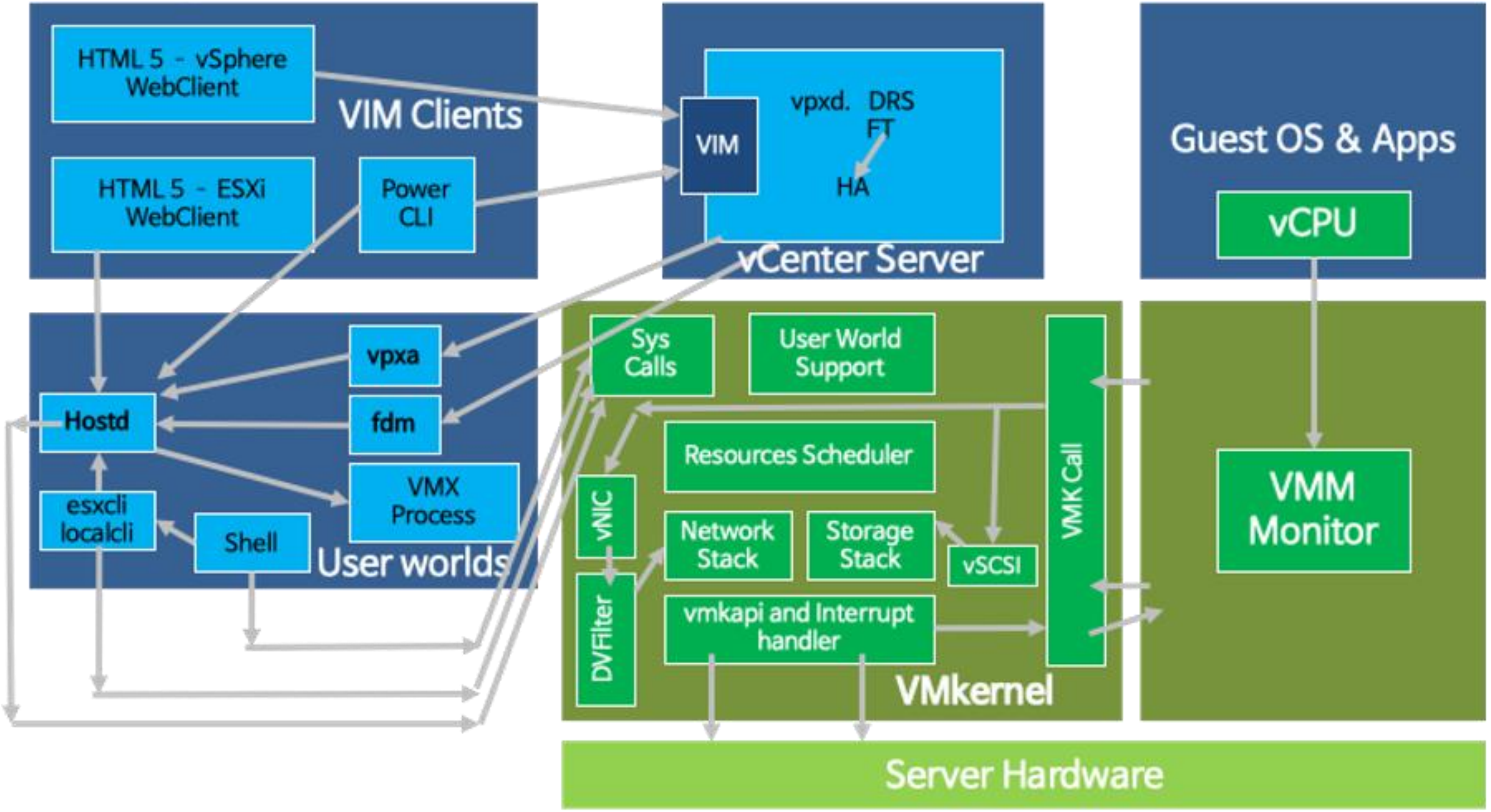
Example: OpenStack Workflow

- 1. Authorize
- 2. Trigger
- 3. Add Request to database
- 4. Schedule the creation in the scheduler
- 5. Reading data for node from database
- 6. Nova_compute subscribes to creation process
- 7. Nova_conductor subscribes to process reading resources
- 8. Revalidating from glance of the authorization
- 9. Triggering nova_compute with the imageid
- 10. Nova_compute triggering network re-authorizing
- 11.-13.: Open Network Integration: not needed over here
- 14. Trigger block device service including auth
- 15. Triggering new block device / reusing existing block device
- 16. Trigger creation of new block device, returning block device
- 17. Creating Instance
- 18. Mounting Volume

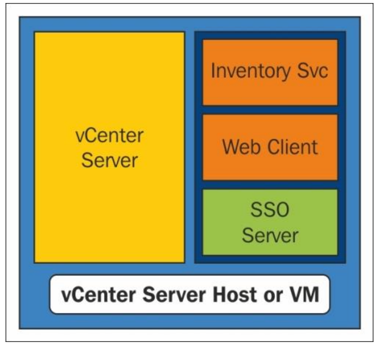


Example: VMware vSphere / ESXi

VIM (Virtual Infrastructure Manager) creates and manages multiple instances of a hypervisor across different physical servers.



VMware vCenter



A single vCenter can manage:

- up to 2500 ESXi hosts
- up to 40000 virtual machines

Different services coordinate any actions between the ESXi hosts and the vCenter:

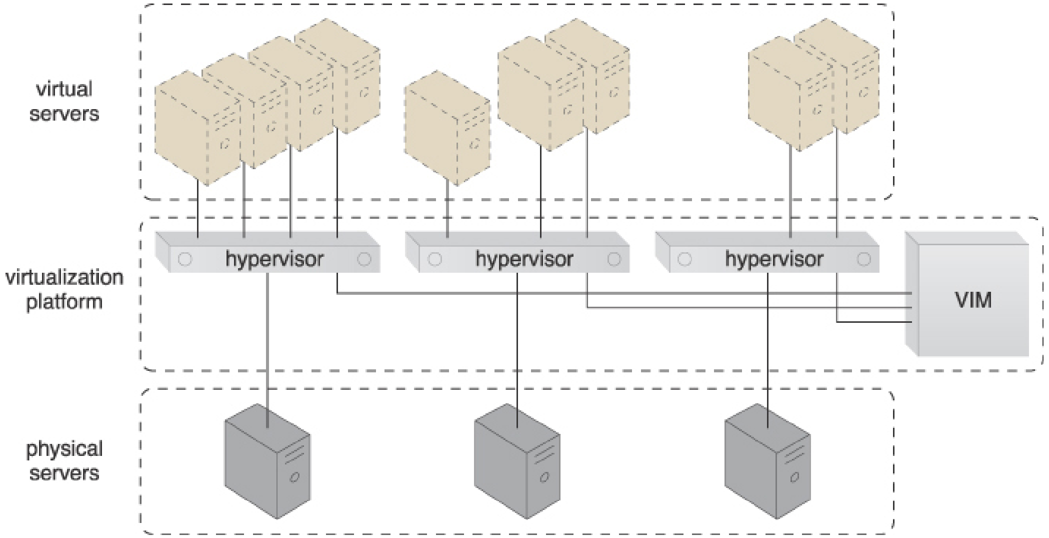
- **vpxd**: VMware Virtual Server service
- **vpxa**: intermediate service installed on all hosts acting as endpoint on host
- **hostd**: service managing the host itself

» It is hard to get insight in VMware vSphere because of closed source, however nowadays one of the main providers.

VIM (Virtual Infrastructure Manager)

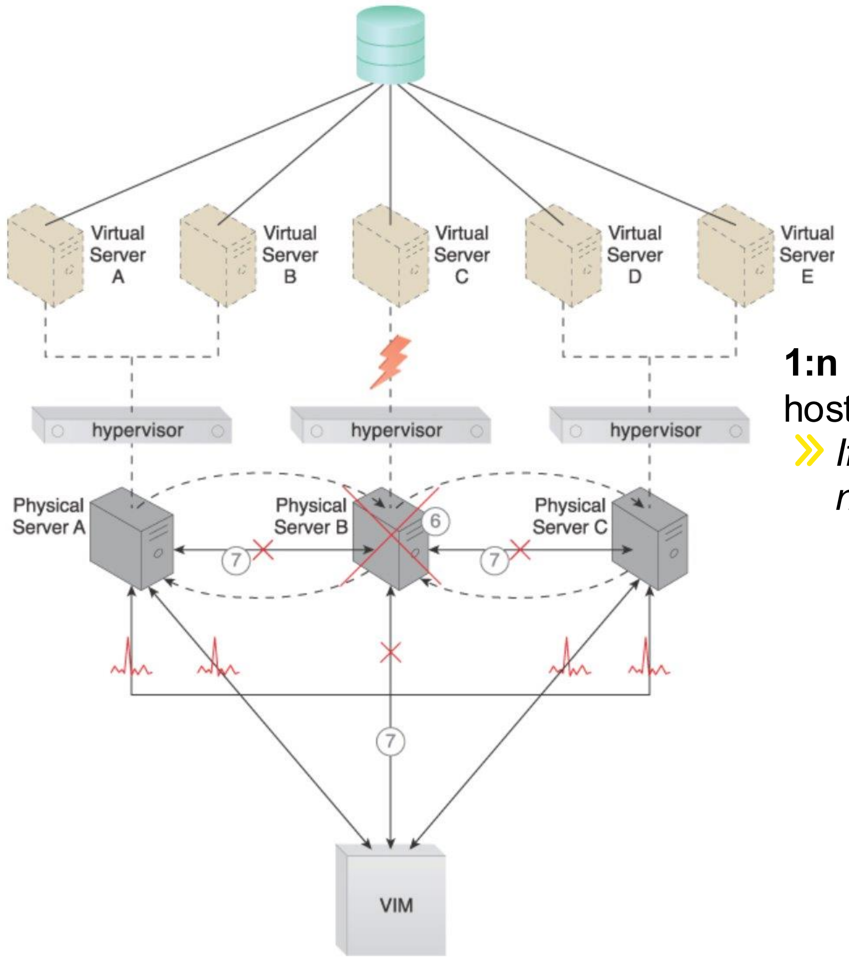
Tasks that are typically automated and implemented through the VIM system include:

- **managing templates** that are used to create prebuilt instances, such as virtual server images
- **allocating and releasing** virtual resources into the available physical infrastructure in response to the starting, pausing, resuming, and termination of virtual instances
- coordinating resources in relation to the involvement of other mechanisms, such as resource **replication**, **load balancer**, and **failover system**
- enforcing usage and security policies throughout the lifecycle of instances
- **monitoring** operational conditions of virtual/physical resources



VIM (Virtual Infrastructure Manager)

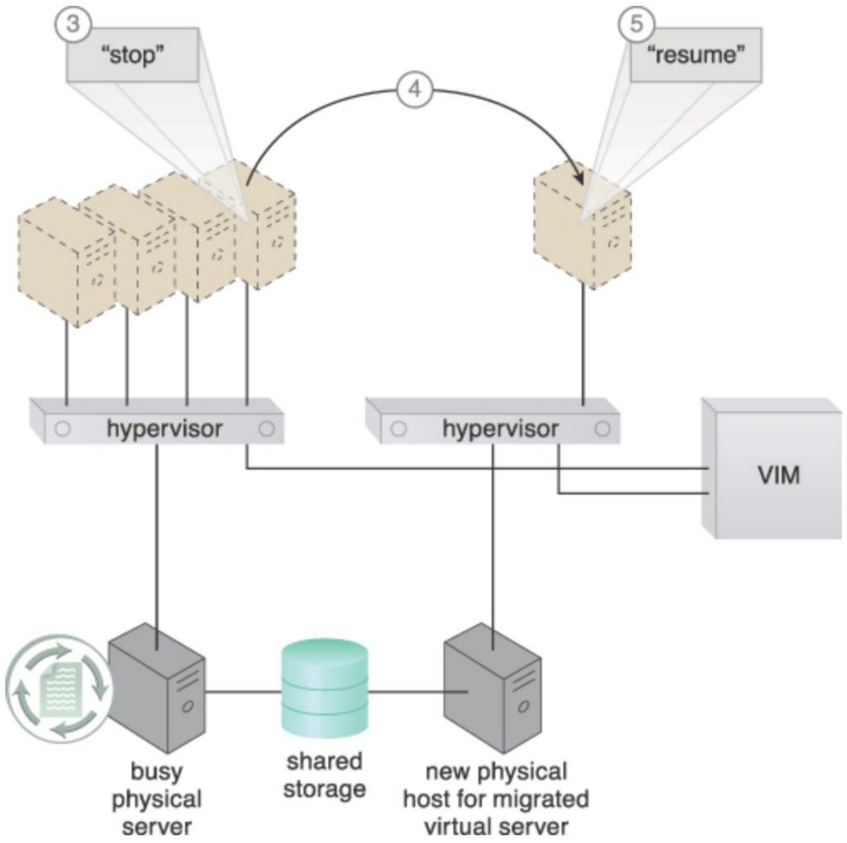
Failover System (Evacuation)



1:n relationship between host and guests.

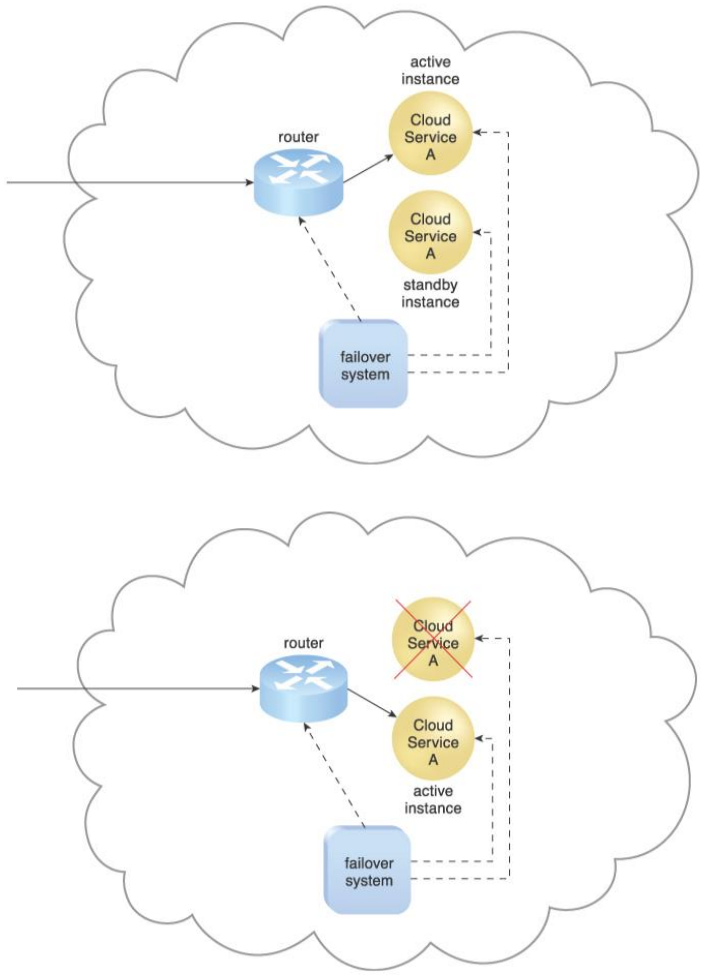
» *If host goes down, n guests are affected*

Load Balancing

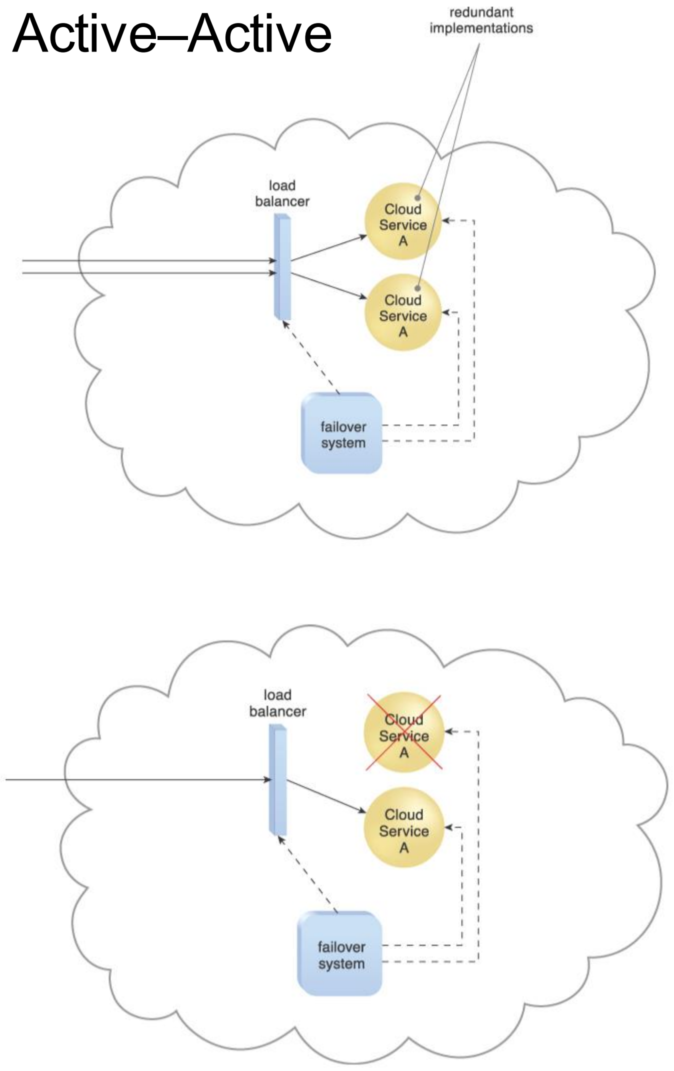


Failover System

Active–Passive



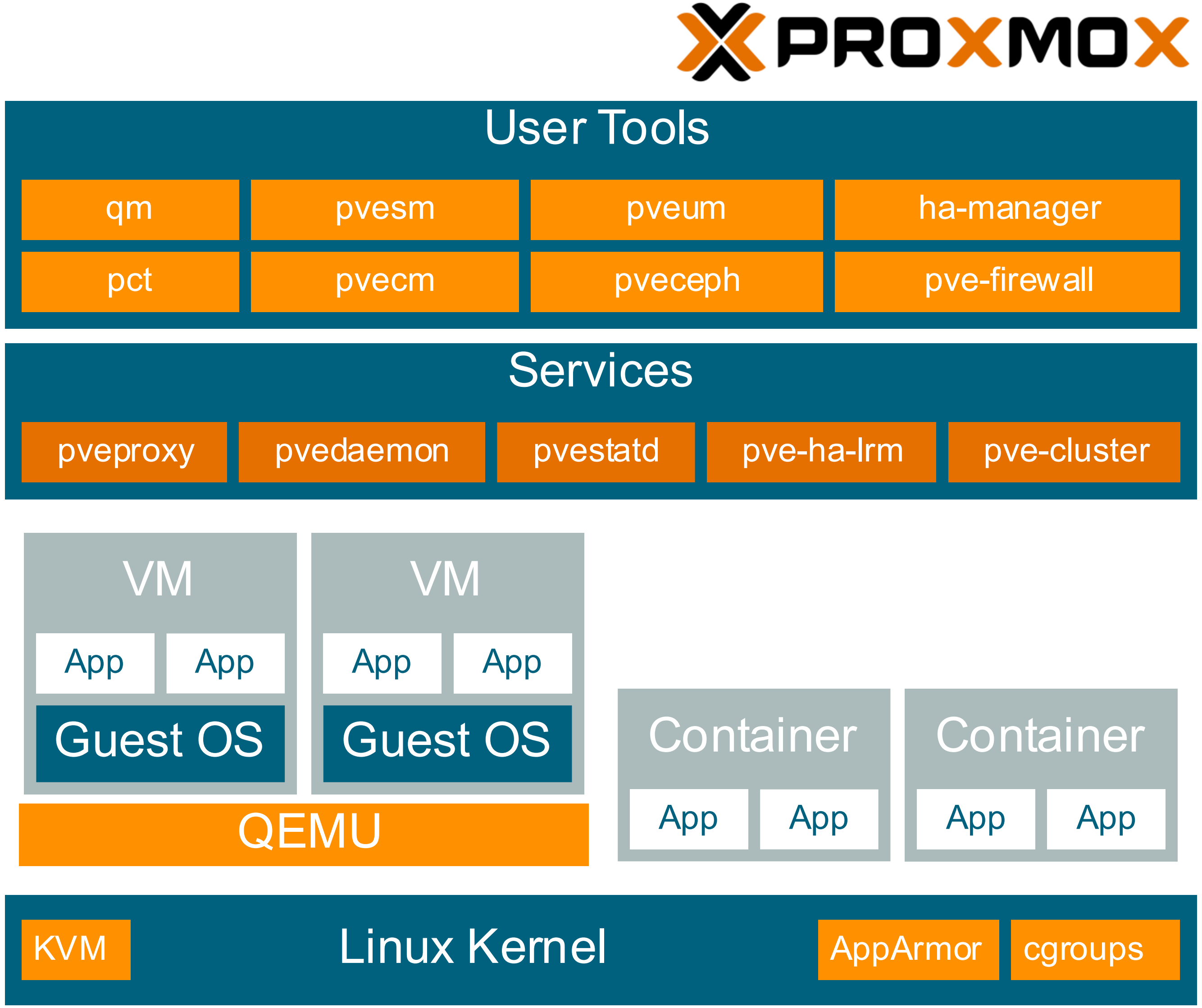
Active–Active



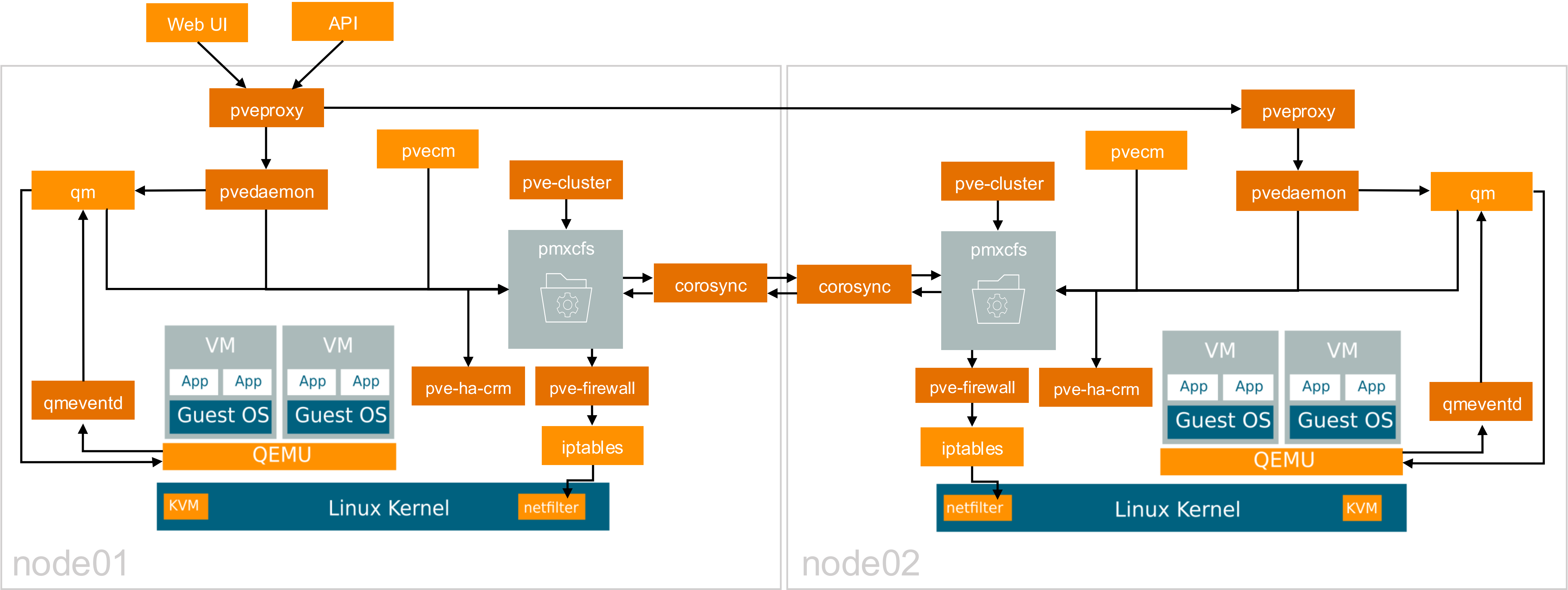
Example: Proxmox VE

Proxmox VE is a platform to run virtual machines and containers. It is written in Perl, C & Rust, based on Debian Linux, and completely open source, relying entirely on Linux methods / software itself.

An integrated web interface or CLI can be used to manage virtual machines, containers, highly available clusters, storage and network.



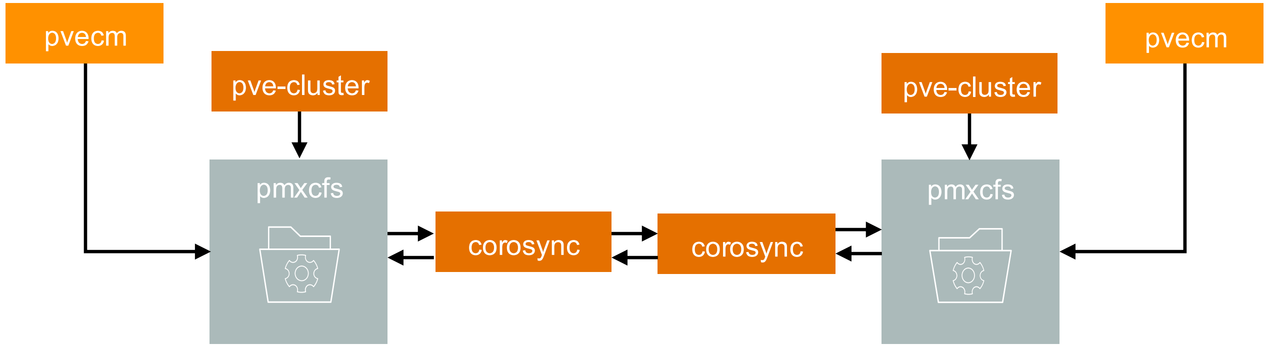
Example: Proxmox VE Cluster Architecture



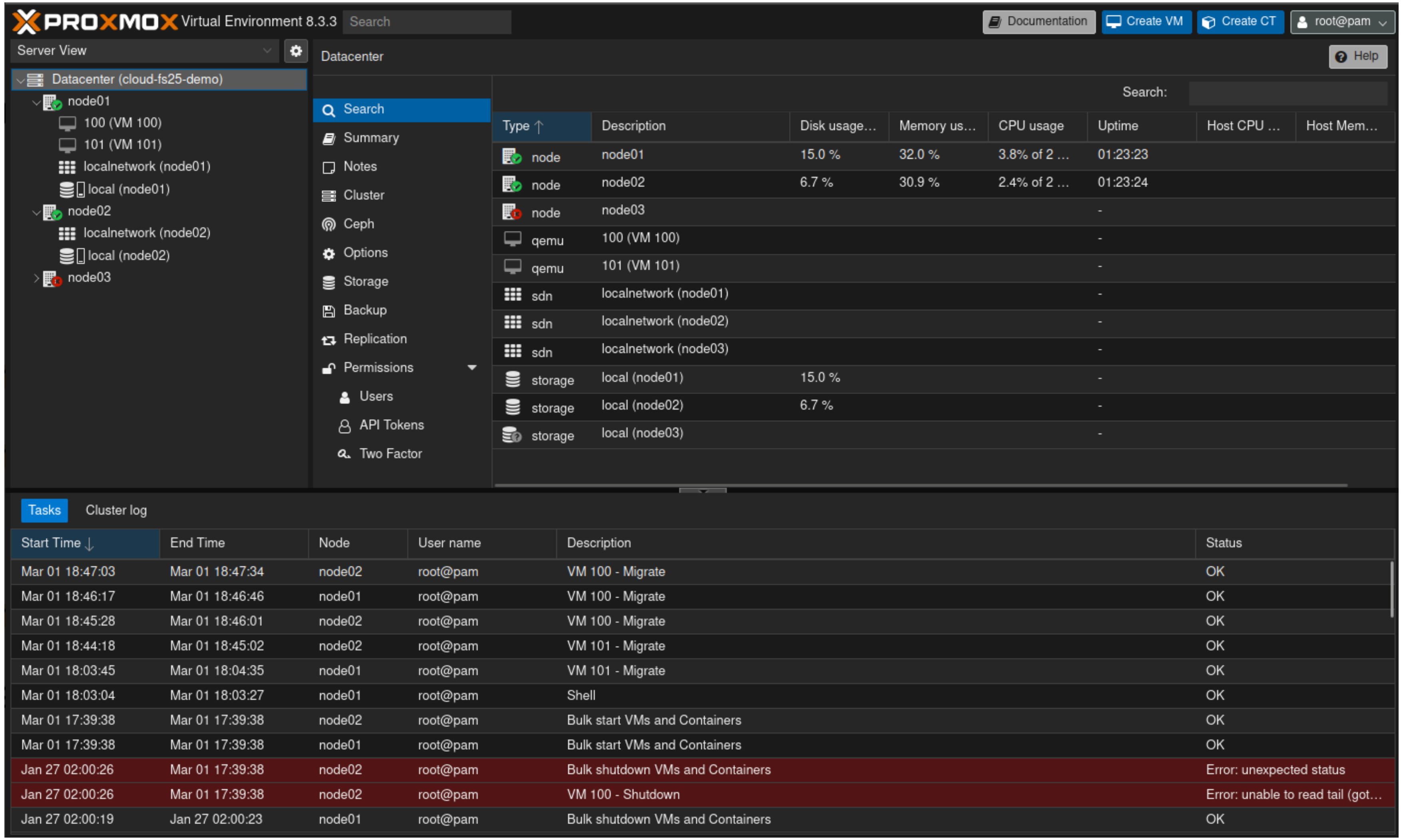
Example: Proxmox VE Cluster Manager

The **pvecm** (Proxmox VE cluster manager) is a CLI tool to create a group of physical servers into a cluster. It can be used to create a new cluster, join nodes to a cluster, leave the cluster, get status information.

The **pmxcfs** (Proxmox Cluster File System) is a database-driven file system (`/etc/pve`) for storing configuration files, (e.g., certificates, ssh keys, firewall config, (ha) status, ...), which are replicated in real-time on all nodes using **corosync**.



Demo: Proxmox VE Manager (Web UI)



Type ↑	Description	Disk usage…	Memory us…	CPU usage	Uptime	Host CPU …	Host Mem…
node	node01	15.0 %	32.0 %	3.8% of 2 …	01:23:23		
node	node02	6.7 %	30.9 %	2.4% of 2 …	01:23:24		
node	node03				-		
qemu	100 (VM 100)				-		
qemu	101 (VM 101)				-		
sdn	localnetwork (node01)				-		
sdn	localnetwork (node02)				-		
sdn	localnetwork (node03)				-		
storage	local (node01)	15.0 %			-		
storage	local (node02)	6.7 %			-		
storage	local (node03)				-		

Start Time ↓	End Time	Node	User name	Description	Status
Mar 01 18:47:03	Mar 01 18:47:34	node02	root@pam	VM 100 - Migrate	OK
Mar 01 18:46:17	Mar 01 18:46:46	node01	root@pam	VM 100 - Migrate	OK
Mar 01 18:45:28	Mar 01 18:46:01	node02	root@pam	VM 100 - Migrate	OK
Mar 01 18:44:18	Mar 01 18:45:02	node02	root@pam	VM 101 - Migrate	OK
Mar 01 18:03:45	Mar 01 18:04:35	node01	root@pam	VM 101 - Migrate	OK
Mar 01 18:03:04	Mar 01 18:03:27	node01	root@pam	Shell	OK
Mar 01 17:39:38	Mar 01 17:39:38	node02	root@pam	Bulk start VMs and Containers	OK
Mar 01 17:39:38	Mar 01 17:39:38	node01	root@pam	Bulk start VMs and Containers	OK
Jan 27 02:00:26	Mar 01 17:39:38	node02	root@pam	Bulk shutdown VMs and Containers	Error: unexpected status
Jan 27 02:00:26	Mar 01 17:39:38	node02	root@pam	VM 100 - Shutdown	Error: unable to read tail (got…
Jan 27 02:00:19	Jan 27 02:00:23	node01	root@pam	Bulk shutdown VMs and Containers	OK

Summary

- **On-demand self-service**

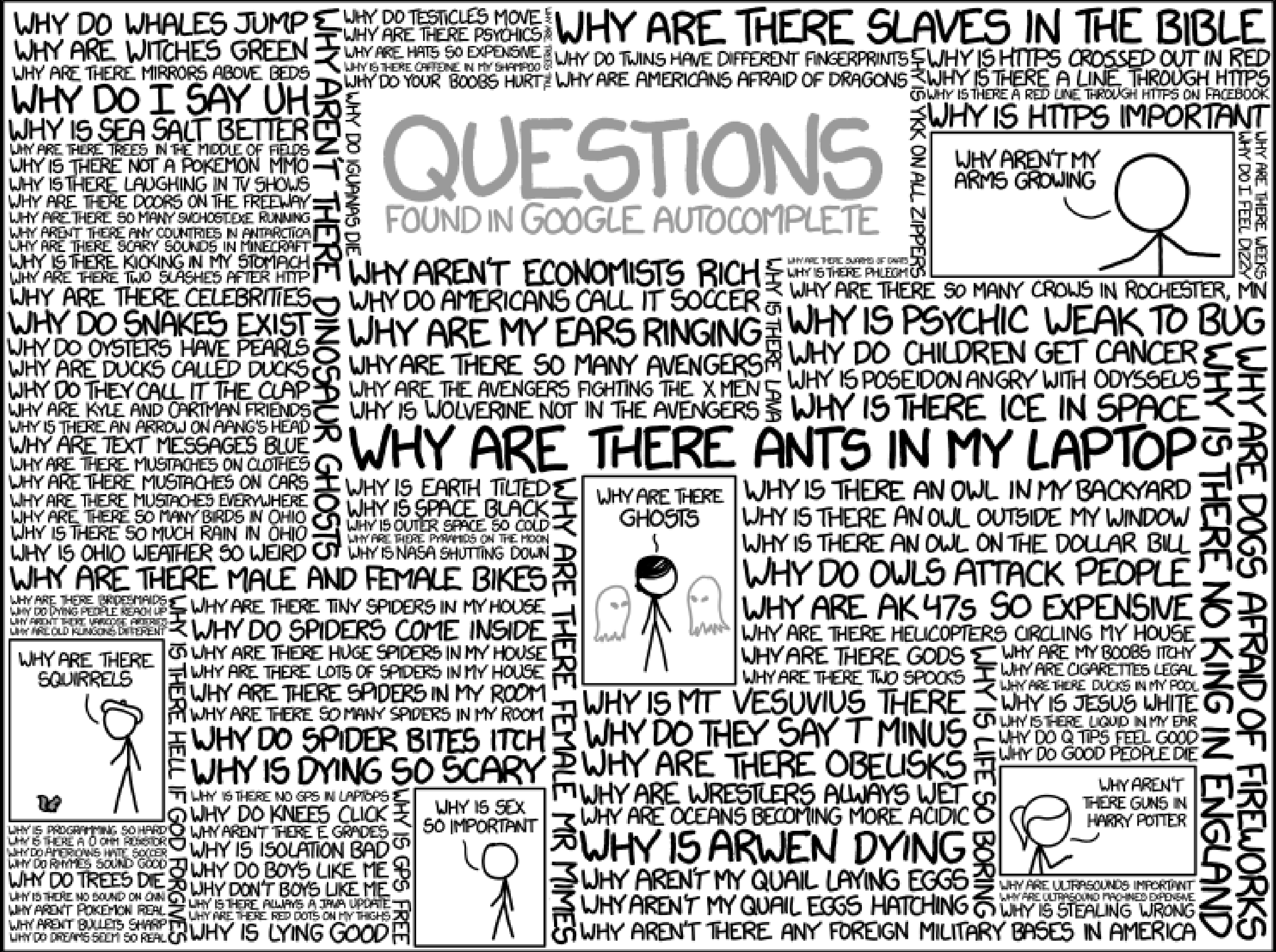
  →Creation with help of dedicated tool (Web UI), CLI (e.g., *VMware vCenter*)
- **Broad network access**

  → Network creation and management (e.g., *OpenStack neutron service*)
- **Resource pooling**

  →Creation of multiple machines on multiple nodes (e.g., *KVM*)
- **Rapid elasticity**

  →API-driven creation / deletion of machines (e.g., *VMware VIM Protocol*)
- **Measured service**

  →VIM monitors usage (e.g., *OpenStack ceilometer service*)


QUESTIONS
FOUND IN GOOGLE AUTOCOMPLETE
WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SVCHOST.EXE RUNNING
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES ON CARS
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY AREN'T THERE DINOSAUR GHOSTS
WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE CAFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT
WHY DO IGUANAS DIE
WHY ARE THERE SLAVES IN THE BIBLE
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS YKK ON ALL ZIPPERS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT
WHY AREN'T MY ARMS GROWING
WHY ARE THERE WEEKS
WHY DO I FEEL DIZZY
WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS
WHY IS THERE LAVA
WHY ARE THERE SWARMS OF GNATS
WHY IS THERE PHLEGM
WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY ARE THERE ANTS IN MY LAPTOP
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE GHOSTS
WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOCKS
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE VARICOSE ARTERIES
WHY ARE OLD KLINGONS DIFFERENT
WHY IS THERE HELL IF GOD FORGIVES
WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY ARE THERE SQUIRRELS
WHY IS PROGRAMMING SO HARD
WHY IS THERE A 0 OHM RESISTOR
WHY DO AMERICANS HATE SOCCER
WHY DO RHYMES SOUND GOOD
WHY DO TREES DIE
WHY IS THERE NO SOUND ON CNN
WHY AREN'T POKEMON REAL
WHY AREN'T BULLETS SHARP
WHY DO DREAMS SEEM SO REAL
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A JAVA UPDATE
WHY ARE THERE RED DOTS ON MY THIGHS
WHY IS LYING GOOD
WHY IS GPS FREE
WHY IS SEX SO IMPORTANT
WHY ARE THERE FEMALE MR MIMES
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA
WHY IS LIFE SO BORING
WHY ARE MY BOOBS ITCHY
WHY ARE CIGARETTES LEGAL
WHY ARE THERE DUCKS IN MY POOL
WHY IS JESUS WHITE
WHY IS THERE LIQUID IN MY EAR
WHY DO Q TIPS FEEL GOOD
WHY DO GOOD PEOPLE DIE
WHY AREN'T THERE GUNS IN HARRY POTTER
WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG
WHY IS THERE NO KING IN ENGLAND
WHY ARE DOGS AFRAID OF FIREWORKS

Summarizing Questions

- Why is simple virtualization not sufficient to withstand the NIST-Definition of Cloud Computing?
- What is the difference between a VMM and a VIM?
- Why is a HA-setup consisting of different nodes important related to virtualized environments?
- What is the difference between an active-active and an active-passive architecture?
- Explain why Keystone is neuralgic in OpenStack to exist.
- Explain how the Proxmox VE Cluster synchronizes the configuration between nodes.