# OS Virtualization

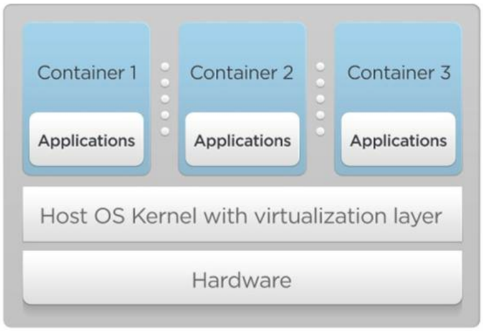
- Part 1: OS Virtualization
- Part 2: Fair share allocation
- Part 3: Docker and linux containers

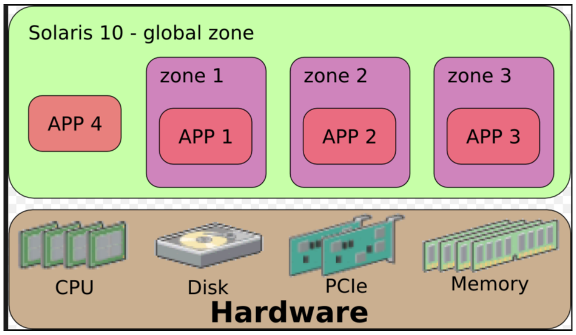
# Part 1: OS Virtualization

- Recall virtualization: use native interface to emulate another one
- Broader view of OS virtualization:
  - OS interface (e.g., sys call interface) can emulate another OS interface
    - E.g., Solaris zone can emulate older kernel version
- Modern view of OS virtualization
  - **OS paradigm where kernel allows multiple isolated user space instances**
  - Each instance looks like real machine running OS
  - Outside processes can see all resources; processes inside isolated instances see a restricted set

# Part 1: OS Virtualization

- Emulate OS-level interface with native interface
- "Lightweight" virtual machines
  - No hypervisor, OS provides necessary support

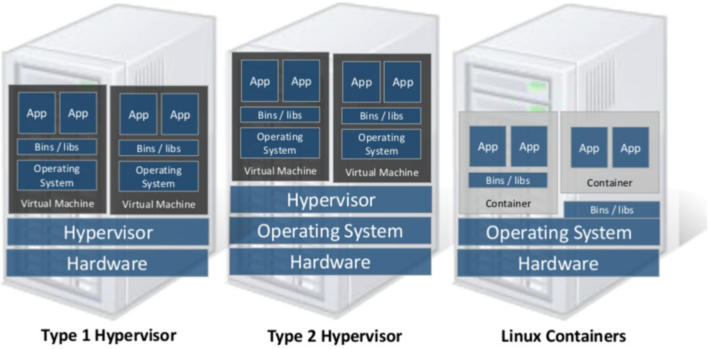




- Referred to as *containers* ("isolated set of processes")
  - Solaris containers, BSD jails, Linux containers

# Linux Containers (LXC)

- Containers share OS kernel of the host
  - OS provides resource isolation
- Benefits
  - Fast provisioning, bare-metal like performance, lightweight



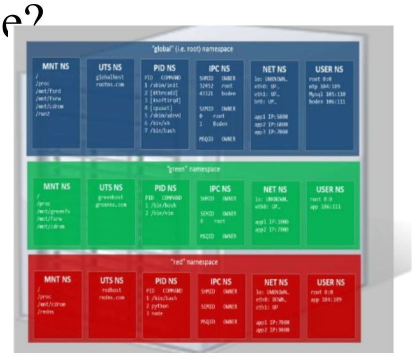
Material courtesy of "Realizing Linux Containers" by Boden Russell, IBM

# OS Mechanisms for LXC

- OS mechanisms for resource isolation and management
- namespaces: process-based resource isolation
- Cgroups: limits, prioritization, accounting, control
- chroot: apparent root directory
- Linux security module, access control
- Tools (e.g., docker) for easy management

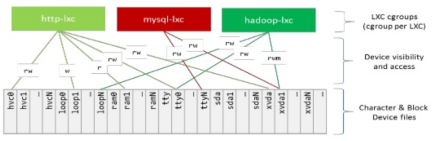
# Linux Namespaces

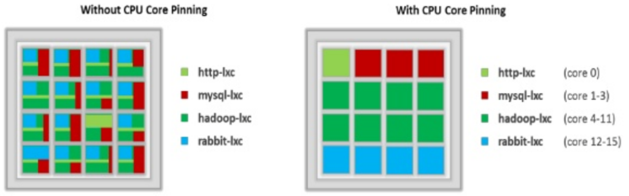
- Namespace: restrict what can a container see?
  - Provide process level isolation of global resources
- Processes have illusion they are the only processes in the system
- MNT: mount points, file systems (what files, dir are visible)?
- PID: what other processes are visible?
- NET: NICs, routing
- Users: what uid, gid are visible?
- chroot: change root directory



# Linux cgroups

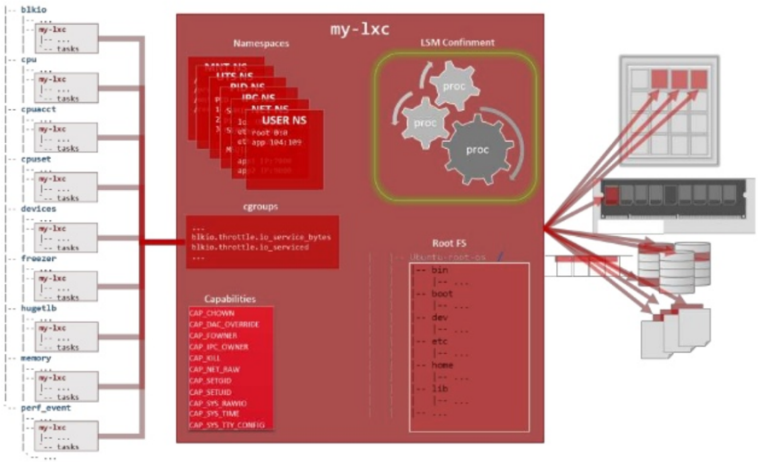
- Resource isolation
  - what and how much can a container use?
    - Set upper bounds (limits) on resources that can be used
    - Fair sharing of certain resources
- Examples:
  - cpu: weighted proportional share of CPU for a group
  - cpuset: cores that a group can access
  - block io: weighted proportional block IO access
  - memory: max memory limit for a group





# Putting it all together

- Images: files/data for a container
  - can run different distributions/apps on a host
- Linux security modules and access control
- Linux capabilities: per process privileges



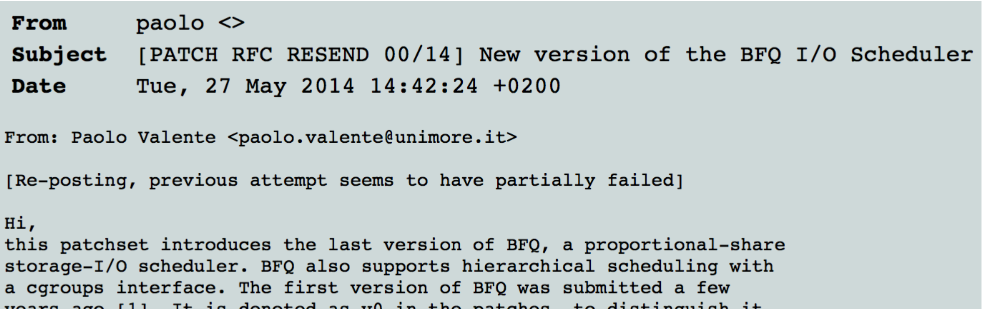
# Part 2: Proportional Share Scheduling

- Proportional-share scheduling: allocate a fraction (“slice/share”) of the resource
  - allocate CPU capacity to containers, VM, or a process
  - allocate network bandwidth to an application, container
- *Share-based* scheduling:
  - Assign each process a weight w_i (a “share”)
  - Allocation is in proportional to share
  - fairness: reused unused cycles to others in proportion to weight
  - Examples: fair queuing, start time fair queuing
- *Hard limits*: assign upper bounds (e.g., 30%), no reallocation

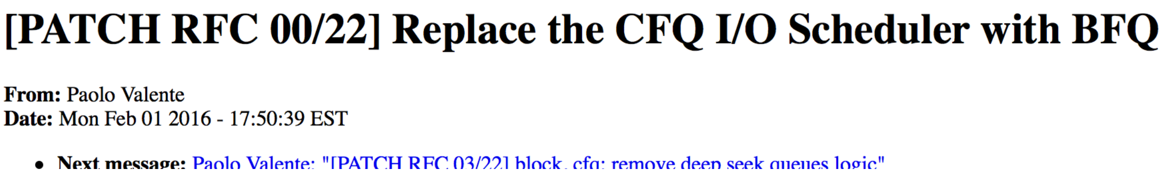
# Weighted Fair Queuing (WFQ)

- One of the original proportional share schedulers
- Each process /container assigned a weight $w_i$
  - each receives $w_i + \sum_j w_j$ fraction of resource
- OS keep a counter for each process $s_i$
  - Tracks how much CPU service the process has received
  - After each quantum, $s_i = s_i + \frac{q}{w_i}$ where q is quantum length
  - Scheduler schedules task with min $s_i$
  - what happens when process blocks: accumulates “credit” and can starve others
    - Track $s_{min} = min(s_1, s_2, ..)$ and $s_i = max(s_{min}, s_i + \frac{q}{w_i})$

# Share-based Schedulers



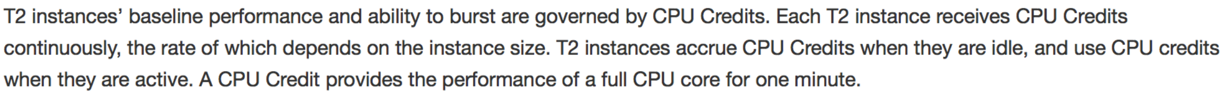
```
From      paolo <>
Subject   [PATCH RFC RESEND 00/14] New version of the BFQ I/O Scheduler
Date      Tue, 27 May 2014 14:42:24 +0200

From: Paolo Valente <paolo.valente@unimore.it>

[Re-posting, previous attempt seems to have partially failed]

Hi,
this patchset introduces the last version of BFQ, a proportional-share
storage-I/O scheduler. BFQ also supports hierarchical scheduling with
a cgroups interface. The first version of BFQ was submitted a few
years ago [1]. It is denoted as v0 in the patches, to distinguish it
```



**[PATCH RFC 00/22] Replace the CFQ I/O Scheduler with BFQ**

**From:** Paolo Valente
**Date:** Mon Feb 01 2016 - 17:50:39 EST

- **Next message:** Paolo Valente: "[PATCH RFC 03/22] block, cfq: remove deep seek queues logic"



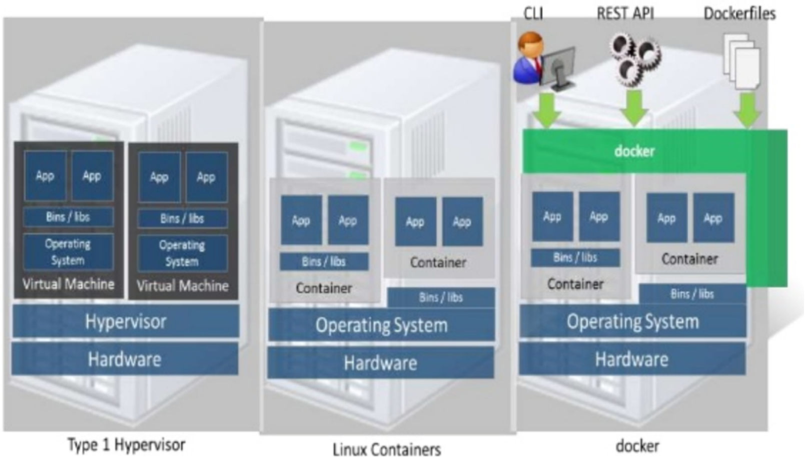
T2 instances' baseline performance and ability to burst are governed by CPU Credits. Each T2 instance receives CPU Credits continuously, the rate of which depends on the instance size. T2 instances accrue CPU Credits when they are idle, and use CPU credits when they are active. A CPU Credit provides the performance of a full CPU core for one minute.

# Part 3: Docker and Linux Containers

- Linux containers are a set of kernel features
  - Need user space tools to manage containers
  - Virtuozo, OpenVZm, VServer,Lxc-tools, Docker
- What does Docker add to Linux containers?
  - Portable container deployment across machines
  - Application-centric: geared for app deployment
  - Automatic builds: create containers from build files
  - Component re-use
- Docker containers are self-contained: no dependencies

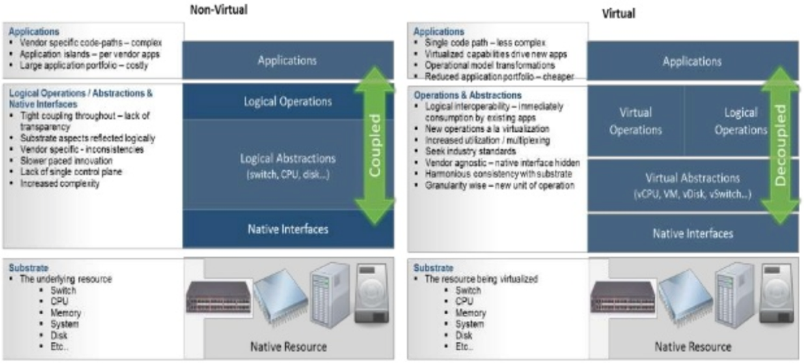
# Docker

- Docker uses Linux containers



# LXC Virtualization Using Docker

- Portable: docker images run anywhere docker runs
- Docker decouples LXC provider from operations
  - uses virtual resources (LXC virtualization)
    - fair share of physical NIC vs use virtual NICs that are fair-shared



Non-Virtual

Applications
- Vendor specific code-paths – complex
- Application islands – per vendor apps
- Large application portfolio – costly

Logical Operations / Abstractions & Native Interfaces
- Tight coupling throughout – lack of transparency
- Substrate aspects reflected logically
- Vendor specific - inconsistencies
- Slower paced innovation
- Lack of single control plane
- Increased complexity

Substrate
- The underlying resource
  - Switch
  - CPU
  - Memory
  - System
  - Disk
  - Etc..

Virtual

Applications
- Single code path – less complex
- Virtualized capabilities drive new apps
- Operational model transformations
- Reduced application portfolio – cheaper

Operations & Abstractions
- Logical interoperability – immediately consumption by existing apps
- New operations a la virtualization
- Increased utilization / multiplexing
- Seek industry standards
- Vendor agnostic – native interface hidden
- Harmonious consistency with substrate
- Granularity wise – new unit of operation

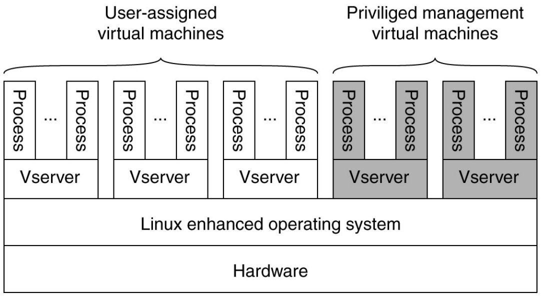
Substrate
- The resource being virtualized
  - Switch
  - CPU
  - Memory
  - System
  - Disk
  - Etc..

# Docker Images and Use

- Docker uses a union file system (AuFS)
  - allows containers to use host FS safely
- Essentially a copy-on-write file system
  - read-only files shared (e.g., share glibc)
  - make a copy upon write
- Allows for small efficient container images
- Docker Use Cases
  - "Run once, deploy anywhere"
  - Images can be pulled/pushed to repository
  - Containers can be a single process (useful for microservices) or a full OS

# Case Study: PlanetLab

- Distributed cluster across universities
  - Used for experimental research by students and faculty in networking and distributed systems
- Uses a virtualized architecture
  - Linux Vservers
  - Node manager per machine
  - Obtain a "slice" for an experiment: slice creation service


User-assigned virtual machines
Priviliged management virtual machines
Process
...
Process
Vserver
Linux enhanced operating system
Hardware