An introduction to cgroups and cgroupspy

tags = [‘python’, ’docker’, ‘coreos', ‘systemd']

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CloudSigma

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About CloudSigma

- Public Infrastructure-as-a-Service (IaaS)
- PoPs in Europe and North America
- Support (almost) all operating systems
- Virtual data center
- Trusted by CERN, ESA and many more

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Talk outline

- Introduction to cgroups
- Using cgroups
  - Examples
- Cgroup tools
  - Filesystem
  - libcgroup
  - cgroupspy
  - systemd
  - Docker

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1. Introduction

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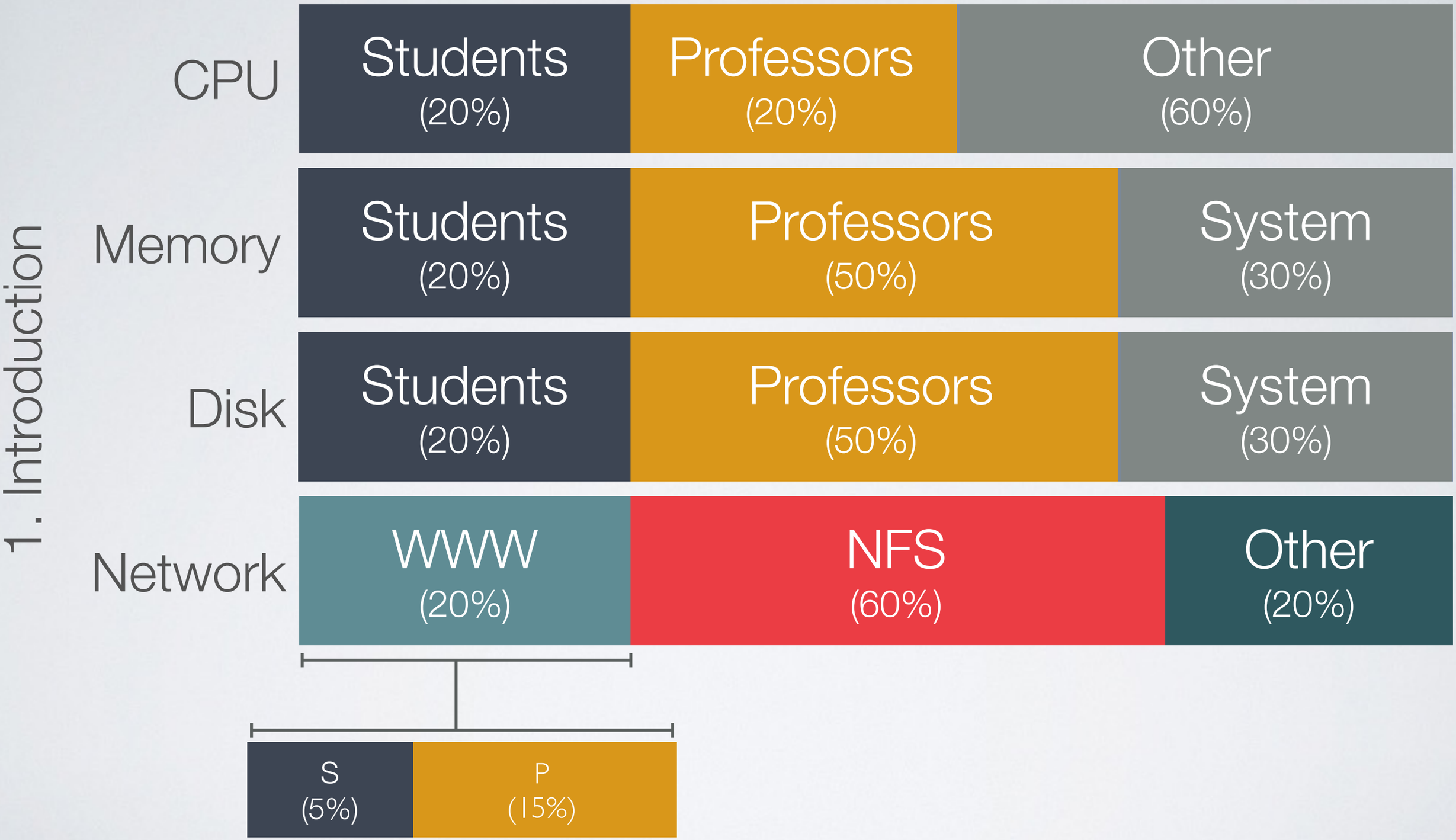
What are cgroups?

- Control groups
- Resource accounting
- A file system
- Much more sophisticated than `ulimit`

Example (from the Kernel docs)



What can you do with cgroups?

- Limit and prioritize
  - CPU consumption
  - Memory consumption
  - Disk I/O consumption
  - Network consumption
  - Device limitations
- Classify network packets
- Freeze processes
- Set up resource accounting

Terminology

- Resource class or Controller
- Group or Slice (in systemd)
- CPU Schedulers
  - Completely Fair Scheduler (CFS)
  - Real-Time scheduler (RT)

Resource classes

- **Block IO** (blkio)
- **CPU Set** (cpuset)
- CPU Accounting (cpuacct)
- **CPU** (cpu)
- Devices (devices)
- Freezer (freezer)
- **Memory** (memory)
- Network Classifier (net_cls)
- Network Priority (net_prio)

Universal elements

- tasks
- notify_on_release
- release_agent

Distro	Cgroups	Systemd
CentOS/RHEL	Yes	Yes
CoreOS	Yes	Yes
Debian	Yes	Yes
Fedora	Yes	Yes
Ubuntu	Yes	Optional

Zero to cgroups on Ubuntu 14.04

```
$ apt-get install -y cgroup-lite
$ mkdir /sys/fs/cgroup/cpuset/test
$ echo 0 > /sys/fs/cgroup/cpuset/test/cpuset.cpus
```

2. Using cgroups

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2.1 CPU Resources

CPU resources

- cpu
- cpuset

2.1 CPU Resources

cpu	cpuset
cpu.stat	cpuset.memory_pressure_enabled
cpu.cfs_period_us	cpuset.memory_spread_slab
cpu.cfs_quota_us	cpuset.memory_spread_page
cpu.shares	cpuset.memory_pressure
cgroup.sane_behavior	cpuset.memory_migrate
cgroup.clone_children	cpuset.sched_relax_domain_level
cgroup.event_control	cpuset.sched_load_balance
cgroup.procs	cpuset.mem_hardwall
	cpuset.mem_exclusive
	cpuset.cpu_exclusive
	cpuset.mems
	cpuset.cpus
	cgroup.sane_behavior
	cgroup.clone_children
	cgroup.event_control
	cgroup.procs

Limit a process to a specific CPU core

```
# Create a group
$ cd /sys/fs/cgroup
$ mkdir -p cpuset/group1

# Limit ‘group1’ to core 0 and enroll the current shell
$ echo 0 > cpuset/group1/cpuset.cpus
$ echo $$ > cpuset/group1/tasks
```

Limit a process to a specific CPU core

```
# Before
$ cat /proc/$$/status | grep '_allowed'
Cpus_allowed:  3
Cpus_allowed_list:     0-1
Mems_allowed:   00000000,00000001
Mems_allowed_list:     0

# After
$ cat /proc/$$/status | grep '_allowed'
Cpus_allowed:  1
Cpus_allowed_list:     0
Mems_allowed:   00000000,00000001
Mems_allowed_list:     0
```

Allocate “CPU Shares” across two groups

```
# Create two groups
$ cd /sys/fs/cgroup
$ mkdir -p cpu/group1 cpu/group2

# Allocate CPU shares
$ echo 250 > cpu/group1/cpu.shares
$ echo 750 > cpu/group2/cpu.shares

# Fire off the workload
$ burnP6 --group1 & echo $! > cpu/group1/tasks
$ burnP6 --group2 & echo $! > cpu/group2/tasks
```

2. vagrant@vagrant-ubuntu-trusty-64: ~ (ssh)

```
CPU[||||||||||||||||||||||||100.0%]     Tasks: 54, 17 thr; 3 running
Mem[|||||||||||              174/2001MB]     Load average: 0.05 0.07 0.10
Swp[                           0/0MB]     Uptime: 01:40:35

  PID USER      PRI  NI  VIRT   RES   SHR S CPU% MEM%   TIME+  Command
 2792 root       20   0   148     4     0 R 80.7  0.0  0:03.75 burnP6 --group1
 2793 root       20   0   148     4     0 R 20.0  0.0  0:00.93 burnP6 --group2
 2789 vagrant    20   0 24456  2004  1464 R  0.7  0.1  0:00.07 htop
 1716 vagrant    20   0 24516  1376   724 S  0.0  0.1  0:18.55 htop
 2243 vagrant    20   0 24516  2132  1472 S  0.0  0.1  0:08.42 htop
 2364 root       20   0 21860  4472  1888 S  0.0  0.2  0:00.24 -su
 1663 vagrant    20   0 25692  2592   820 S  0.0  0.1  0:06.24 tmux
 1201 root       20   0  227M   376    44 S  0.0  0.0  0:02.12 /usr/sbin/VBoxSer
 2089 vagrant    20   0  105M  2384  1376 S  0.0  0.1  0:01.33 sshd: vagrant@pts
 1208 root       20   0  227M   376    44 S  0.0  0.0  0:00.90 /usr/sbin/VBoxSer
    1 root       20   0 33648  1676   188 S  0.0  0.1  0:00.90 /sbin/init
  282 root       20   0 23660   808   568 S  0.0  0.0  0:00.03 /sbin/cgmanager -
  446 root       20   0 19472   300     4 S  0.0  0.0  0:00.06 upstart-udev-brid
  451 root       20   0 51440   704     4 S  0.0  0.0  0:00.03 /lib/systemd/syst
  529 root       20   0 10220  2292     0 S  0.0  0.1  0:00.00 dhclient -1 -v -p
  611 root       20   0 23416   312     4 S  0.0  0.0  0:00.02 rpcbind
  683 statd      20   0 21540   464     4 S  0.0  0.0  0:00.00 rpc.statd -L
  688 root       20   0 15388   380     0 S  0.0  0.0  0:00.03 upstart-socket-br
F1Help  F2Setup F3SearchF4FilterF5Tree  F6SortByF7Nice -F8Nice +F9Kill  F10Quit
```

'cpu.shares' in action

2.2 Memory Resources

Resources

2.1 Memory

Memory

memory.kmem.tcp.max_usage_in_bytes
memory.kmem.tcp.failcnt
memory.kmem.tcp.usage_in_bytes
memory.kmem.tcp.limit_in_bytes
memory.kmem.slabinfo
memory.kmem.max_usage_in_bytes
memory.kmem.failcnt
memory.kmem.usage_in_bytes
memory.kmem.limit_in_bytes
memory.numa_stat
memory.pressure_level
memory.oom_control
memory.swappiness
memory.force_empty
memory.stat
memory.failcnt
memory.soft_limit_in_bytes
memory.limit_in_bytes
memory.max_usage_in_bytes
memory.usage_in_bytes
cgroup.sane_behavior
cgroup.clone_children
cgroup.event_control
cgroup.procs
memory.move_charge_at_immigrate
memory.use_hierarchy

Setting up memory policies

```
# Create a group
$ cd /sys/fs/cgroup
$ mkdir -p memory/group1

# Set a memory limit of 150M
$ echo 150M > memory/group1/memory.limit_in_bytes

# Add shell to group
$ echo $$ > blkio/group1/tasks

# Fire off a memory eating task
$ ./memhog
```

2. root@vagrant-ubuntu-trusty-64: /sys/fs/cgroup (ssh)

```
  CPU[|||                                    3.3%]     Tasks: 59, 17 thr; 1 running
  Mem[|||||||                              169/2001MB]     Load average: 0.26 0.13 0.08
  Swp[                                       0/0MB]     Uptime: 02:54:25

  PID USER      PRI  NI  VIRT   RES   SHR S CPU% MEM%   TIME+  Command
 3177 root       20   0 24468  1148   592 R  0.7  0.1  0:00.23 htop
 2243 vagrant    20   0 24516  1268   608 S  0.7  0.1  0:24.78 htop
  770 messagebu  20   0 39224   572   172 S  0.7  0.0  0:00.50 dbus-daemon --system --fork
 1207 root       20   0  227M   332     0 S  0.7  0.0  0:00.34 /usr/sbin/VBoxService
 1716 vagrant    20   0 24516  1264   612 S  0.0  0.1  0:34.98 htop
 1663 vagrant    20   0 25692  2228   456 S  0.0  0.1  0:11.49 tmux
 2089 vagrant    20   0  105M  1500   488 S  0.0  0.1  0:02.47 sshd: vagrant@pts/0
  909 syslog     20   0  251M   744     0 S  0.0  0.0  0:00.01 rsyslogd
  893 syslog     20   0  251M   744     0 S  0.0  0.0  0:00.03 rsyslogd
 3162 root       20   0 21836  3108   552 S  0.0  0.2  0:00.03 -bash
F1Help  F2Setup F3SearchF4FilterF5Tree  F6SortByF7Nice -F8Nice +F9Kill  F10Quit

root@vagrant-ubuntu-trusty-64:/sys/fs/cgroup# mkdir -p memory/group1
root@vagrant-ubuntu-trusty-64:/sys/fs/cgroup# echo 150M > memory/group1/memory.limit_in_bytes
root@vagrant-ubuntu-trusty-64:/sys/fs/cgroup# echo $$ > blkio/group1/tasks
root@vagrant-ubuntu-trusty-64:/sys/fs/cgroup# /vagrant/bin/memhog
Killed
root@vagrant-ubuntu-trusty-64:/sys/fs/cgroup#

[0] 0:bash*                                   "vagrant-ubuntu-trusty-" 12:58 04-Apr-15
```

'memory.limit_in_bytes' in action

2.3 Block I/O Resources

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2.3 Block I/O Resources

Block IO	
blkio.io_queued_recursive	blkio.time
blkio.io_merged_recursive	blkio.leaf_weight
blkio.io_wait_time_recursive	blkio.leaf_weight_device
blkio.io_service_time_recursive	**blkio.weight**
blkio.io_serviced_recursive	blkio.weight_device
blkio.io_service_bytes_recursive	blkio.throttle.io_serviced
blkio.sectors_recursive	blkio.throttle.io_service_bytes
blkio.time_recursive	**blkio.throttle.write_iops_device**
blkio.io_queued	**blkio.throttle.read_iops_device**
blkio.io_merged	**blkio.throttle.write_bps_device**
blkio.io_wait_time	**blkio.throttle.read_bps_device**
blkio.io_service_time	blkio.reset_stats
blkio.io_serviced	cgroup.sane_behavior
blkio.io_service_bytes	cgroup.clone_children
blkio.sectors	cgroup.event_control

Setting up I/O policies

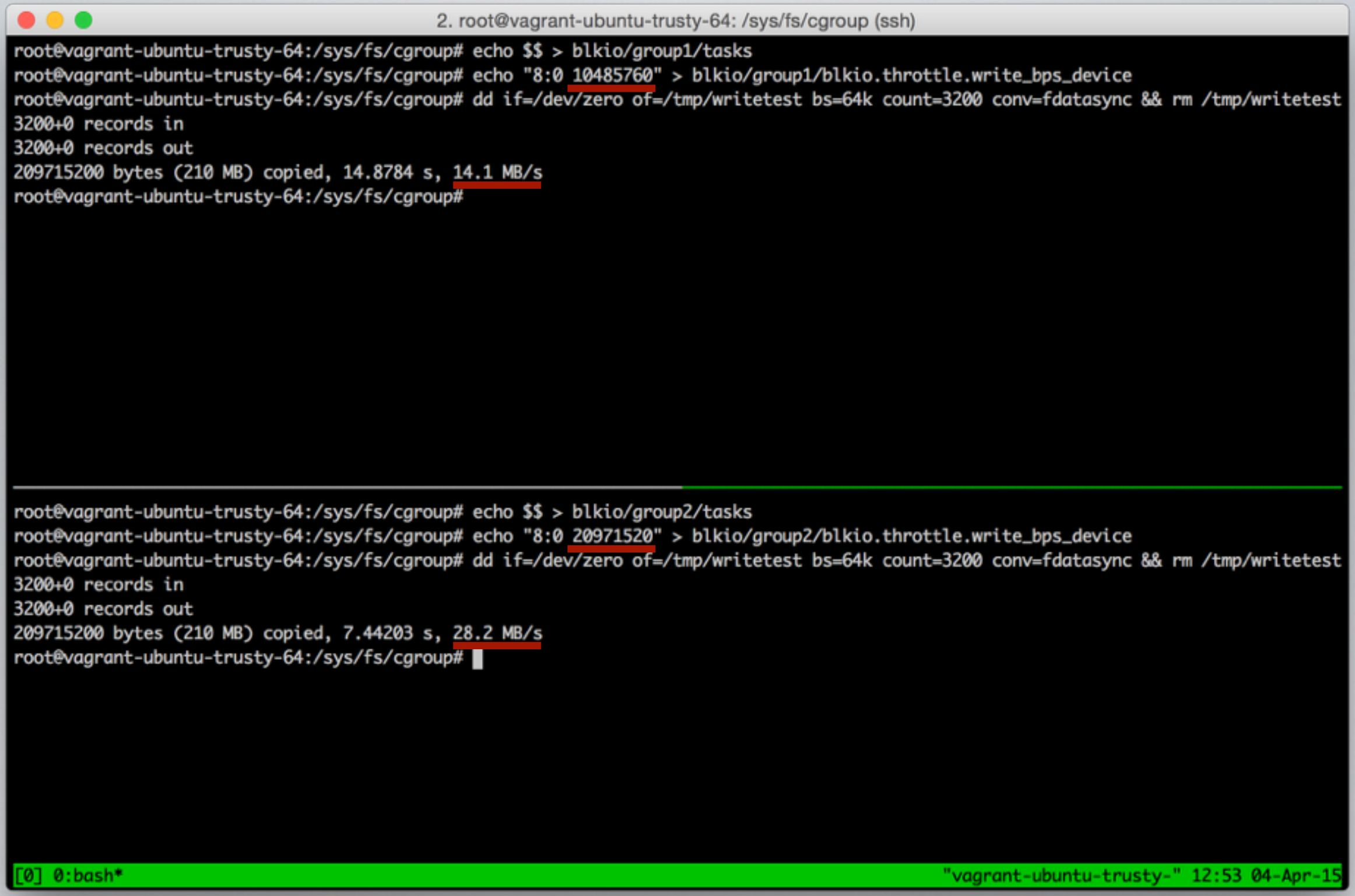
```
# Find the device
$ lsblk
NAME   MAJ:MIN RM SIZE RO TYPE MOUNTPOINT
sda      8:0    0  40G  0 disk
└─sda1   8:1    0  40G  0 part /

# Create the groups
$ cd /sys/fs/cgroup
$ mkdir blkio/group1 blkio/group2
```

Setting up I/O policies

```
# Group 1 and shell 1
$ echo "8:0 10485760" > blkio/group1/blkio.throttle.write_bps_device
$ echo $$ > blkio/group1/tasks
$ dd if=/dev/zero of=/tmp/writetest bs=64k count=3200 conv=fdatasync && \
      rm /tmp/writetest

# Group 2 and shell 2
$ echo "8:0 20971520" > blkio/group1/blkio.throttle.write_bps_device
$ echo $$ > blkio/group2/tasks
$ dd if=/dev/zero of=/tmp/writetest bs=64k count=3200 conv=fdatasync && \
      rm /tmp/writetest
```



‘blkio.throttle.write_bps_device’ in action

3. Cgroup tools

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Overview

- Filesystem
- libcgroup
- cgroupspy
- systemd
- Docker

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Using the filesystem

```
$ cd /sys/fs/cgroup

# Create a CPU group
$ mkdir -p cpu/group1

# Set a CPU Share
$ echo 250 > cpu/group1/cpu.shares

# Enroll [PID] in ‘group1’
$ echo [PID] > cpu/group1/tasks
```

3.2 Libcgroup

Using libcgroup

```
# On Debian and Ubuntu
$ apt-get install -y cgroup-bin

# Create a group
$ cgcreate -g cpu:foobar

# Set values
$ cgset -r cpu.shares=6 foobar

# Run a command
$ cgexec -g cpu:foobar bash
^D

# Delete group
$ cgdelete cpu:foobar
```

Cgroupspy

- Python wrapper for cgroups
- Integration with libvirt for interacting with VMs
- Developed by and used at CloudSigma

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3.3 cgroupspy

Getting started with cgroupspy

```
$ pip install cgroupspy

$ python
>>> from cgroupspy import trees
>>> t = trees.Tree()
>>> cset = t.get_node_by_path(‘/cpuset/')
>>> cset.controller.cpus
set([0, 1])
>>> test = cset.create_cgroup(‘test')
>>> test.controller.cpus
set([0, 1])
>>> test.controller.cpus = [1]
>>> test.controller.cpus
set([1])
>>> cset.delete_cgroup('test')
```

3.3 cgroupspy

Controlling VMs with cgroupspy

```
>>> from cgroupspy.trees import VMTree
>>> vmt = VMTree()
>>> print vmt.vms
{u'1ce10f47-fb4e-4b6a-8ee6-ba34940cdda7.libvirt-qemu': <NodeVM 1ce10f47-
fb4e-4b6a-8ee6-ba34940cdda7.libvirt-qemu>,
 u'3d5013b9-93ed-4ef1-b518-a2cea43f69ad.libvirt-qemu': <NodeVM
3d5013b9-93ed-4ef1-b518-a2cea43f69ad.libvirt-qemu>,
}
>>> vm = vmt.get_vm_node("1ce10f47-fb4e-4b6a-8ee6-ba34940cdda7")
>>> print vm.cpu.shares
1024

>>> print vm.cpuset.cpus
{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15}

>>> print vm.memory.limit_in_bytes
25603080192
```

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3.3 cgroupspy

Controlling VMs with cgroupspy (cont'd)

```
>>> print vm.children
[<NodeControlGroup vcpu1>,
 <NodeControlGroup vcpu0>,
 <NodeControlGroup emulator>]

>>> print vm.path
/machine/grey/1ce10f47-fb4e-4b6a-8ee6-ba34940cdda7.libvirt-qemu

>>> vcpu1 = vm.children[0]
>>> print vcpu1.cpuset.cpus
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15}

>>> vcpu1.cpuset.cpus = {1,2,3}
>>> print vcpu1.cpuset.cpus
{1, 2, 3}
```

Systemd and cgroups

- Resource control unit settings
- Pre-configured slices
  - system
  - machine
  - user

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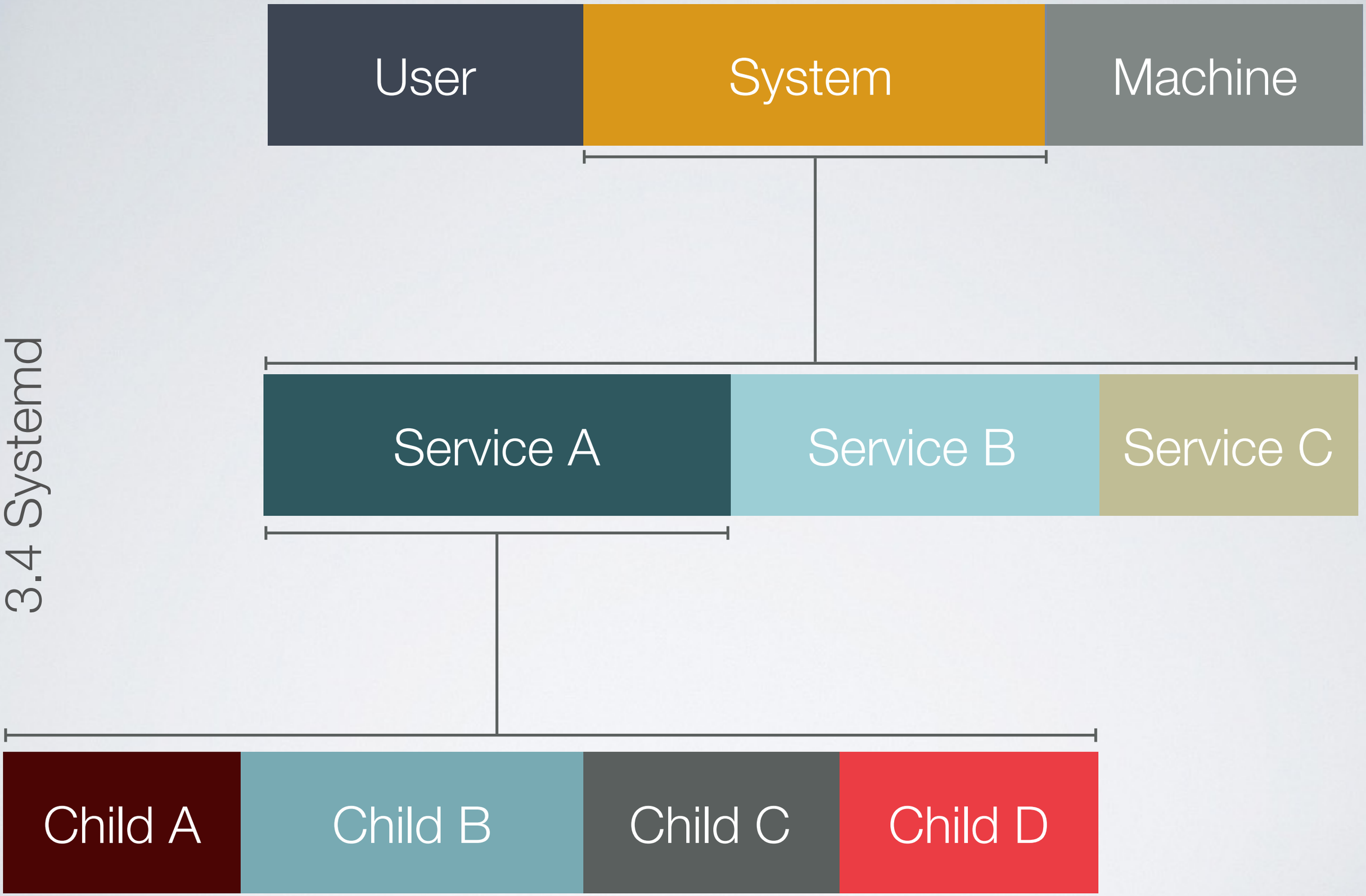
3.4 Systemd



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3.4 Systemd

Slices on CoreOS

```
$ cat cpu/system.slice/system-apache.slice/tasks
730
733
734
735
736
737
```

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3.4 Systemd

Unit file for locksmithd on CoreOS

```
[Unit]
Description=Cluster reboot manager
Requires=update-engine.service
After=update-engine.service
ConditionVirtualization=!container
ConditionPathExists=!/usr/.noupdate

[Service]
CPUShares=16
MemoryLimit=32M
PrivateDevices=true
EnvironmentFile=-/usr/share/coreos/update.conf
EnvironmentFile=-/etc/coreos/update.conf
ExecStart=/usr/lib/locksmith/locksmithd
Restart=always
RestartSec=10s

[Install]
WantedBy=multi-user.target
```

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Docker and cgroups

- Based on LXC
- Built-in support for cgroups via LXC
  - LXC driver must be activated

3.5 Docker

Notes for Ubuntu 14.04

```
$ apt-get install -y lxc
$ echo 'DOCKER_OPTS="--exec-driver=lxc"' \
    >> /etc/default/docker
$ service docker restart
```

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Using cgroups in Docker

```
$ docker run -d --name='low_prio' \
    --lxc-conf="lxc.cgroup.cpu.shares=250" \
    --lxc-conf="lxc.cgroup.cpuset.cpus=0" \
    busybox md5sum /dev/urandom
```

```
$ docker run -d --name='high_prio' \
    --lxc-conf="lxc.cgroup.cpu.shares=750" \
    --lxc-conf="lxc.cgroup.cpuset.cpus=0" \
    busybox md5sum /dev/urandom
```

2. vagrant@vagrant-ubuntu-trusty-64: ~ (ssh)

```
  1  [||||||||||||||||||||||100.0%]     Tasks: 48, 25 thr; 3 running
  2  [|                       1.3%]     Load average: 1.20 0.42 0.25
  Mem[|||||||||              193/2001MB] Uptime: 05:51:59
  Swp[                         0/0MB]

  PID USER      PRI  NI  VIRT   RES   SHR S CPU% MEM%   TIME+  Command
11682 root       20   0  3156    72    36 R 75.3  0.0  0:38.38 md5sum /dev/urand
11601 root       20   0  3156    72    36 R 24.0  0.0  0:21.55 md5sum /dev/urand
 7894 vagrant    20   0 24580  2212  1472 S  1.3  0.1  0:03.08 htop
  813 messagebu  20   0 39212  1516  1056 S  0.7  0.1  0:02.18 dbus-daemon --sys
 1220 root       20   0  227M  1092   764 S  0.7  0.1  0:10.25 /usr/sbin/VBoxSer
 6868 vagrant    20   0  105M  2368  1356 S  0.0  0.1  0:02.75 sshd: vagrant@pts
11900 vagrant    20   0 24488  1996  1456 R  0.0  0.1  0:00.02 htop
    1 root       20   0 33640  3000  1504 S  0.0  0.1  0:02.06 /sbin/init
  300 root       20   0 23660  1472  1216 S  0.0  0.1  0:00.59 /sbin/cgmanager -
  458 root       20   0 19472   656   468 S  0.0  0.0  0:00.37 upstart-udev-brid
  462 root       20   0 51212  1544  1008 S  0.0  0.1  0:00.14 /lib/systemd/syst
  593 root       20   0 10220  2404   116 S  0.0  0.1  0:00.00 dhclient -1 -v -p
  649 root       20   0 23416  1104   800 S  0.0  0.1  0:00.09 rpcbind
  691 statd      20   0 21540  1376   920 S  0.0  0.1  0:00.00 rpc.statd -L
  705 root       20   0 15388   808   416 S  0.0  0.0  0:00.26 upstart-socket-br
  887 root       20   0 43448  1852  1488 S  0.0  0.1  0:00.46 /lib/systemd/syst
  890 root       20   0 25540   428   212 S  0.0  0.0  0:00.00 rpc.idmapd
F1Help  F2Setup F3SearchF4FilterF5Tree  F6SortByF7Nice -F8Nice +F9Kill  F10Quit
```

cgroups with Docker

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Resources

- Red Hat's Resource Management Guide
  - http://goo.gl/tqh6l1
- Cgroup in kernel docs - http://goo.gl/MOX0xH
- SUS15: LXC, Cgroups and Advanced Linux Container Technology Lecture - http://goo.gl/6jb71g
- Systemd's Resource Control - http://goo.gl/dwUotd
- Docker Run reference for LXC - http://goo.gl/dmBIMK
- Cgroupspy - http://goo.gl/ahKvgs