Docker resource management

ACA Student Presentation

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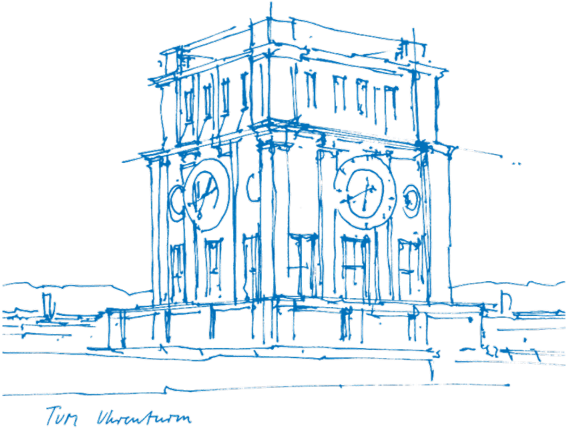


Quick questions

- Who has ever heard of Docker?
- Who used Docker at least once?
- Who uses Docker in their daily life?
- Who knows that tools similar to Docker exist? (or focusing on subtasks)
- Who has seen this slide at least 5 times?

Containers vs VMs (once again)

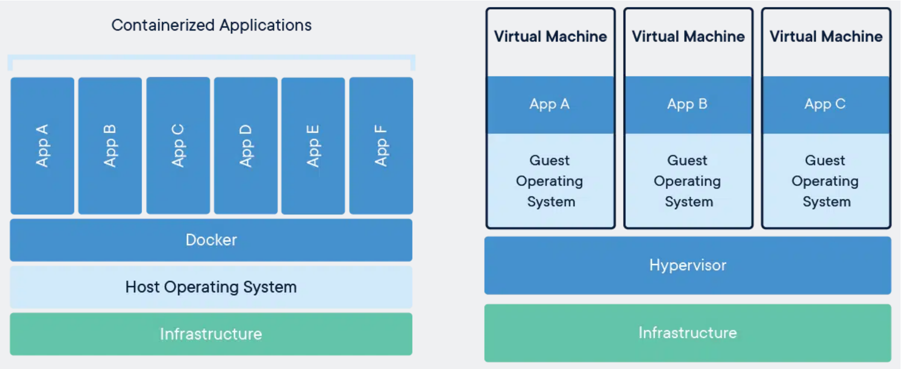


Figure 1 from: https://www.docker.com/resources/what-container/

"Docker"

The Open Container Initiative is an open governance structure for the express purpose of creating open industry standards around container formats and runtimes.

docker
podman
buildah
skopeo
HashiCorp
Packer
Kaniko
containerd
Finch

How do containers provide isolation?

”Applications are safer in containers and Docker provides the strongest default isolation capabilities in the industry” [1]

- linux namespaces (limits what you see)
- cgroups (limits what you can use use)

[1] https://www.docker.com/resources/what-container/

Linux Namespaces

Namespaces are a feature of the Linux kernel that partitions kernel resources such that one set of processes sees one set of resources while another set of processes sees a different set of resources.... Examples of such resources are process IDs, hostnames, user IDs, file names, and some names associated with network access, and interprocess communication.[2]

- inspired by the wider namespace functionality used heavily throughout Plan 9 from Bell Labs.
- 2002: initial work on namespaces introduced in Linux mainline kernel 2.4.19
- February 2013: user namespaces are introduced in Linux mainline kernel 3.8 (we now have adequate container support functionality)

[2] https://en.wikipedia.org/wiki/Linux_namespaces

Type of Linux Namespaces

- **User** namespaces isolate User and group IDs
- **PID** namespaces isolate process IDs (nested trees; PID 1 in a subtree)
- **Mount** namespaces isolate mount points
- **Network** namespaces isolate Network devices, stacks, ports
- some others, check `man` page

Let’s get our hands dirty, user namespace(1/2)

```
# outside the namespace
rc@s369 ~/t/aca> whoami
rc
rc@s369 ~/t/aca> id
uid=1000(rc) gid=1000(rc) groups=1000(rc), ...
rc@s369 ~/t/aca> sudo unshare --user
# inside the namespace
nobody@s369:/home/rc/tum-exams/aca$ whoami
nobody
nobody@s369:/home/rc/tum-exams/aca$ id
uid=65534(nobody) gid=65534(nogroup) groups=65534(nogroup)
nobody@s369:/home/rc/tum-exams/aca$
```

Who is nobody? ”If a user ID has no mapping inside the namespace, then system calls that return user IDs return the value defined in the file `/proc/sys/kernel/overflowuid`, which on a standard system defaults to the value 65534.”[3]

[3] https://lwn.net/Articles/532593/

Let’s get our hands dirty, user namespace (2/2)

```
# outside the namespace
rc@s369 ~/t/aca> whoami
rc
rc@s369 ⇝ id
uid=1000(rc) gid=1000(rc) groups=1000(rc), ...
rc@s369 ⇝ sudo unshare --user --map-root-user
# inside the namespace
root@s369:/home/rc# whoami
root
root@s369:/home/rc# id
uid=0(root) gid=0(root) groups=0(root)
```

This is probably what you need if you are creating a user namespace.

Let’s get our hands dirty, mount namespace

```
rc@s369 ⇝ sudo unshare --mount
# inside the namespace
root@s369:/home/rc# mount -t tmpfs tmpfs /mnt
root@s369:/home/rc# echo "I love ACA student presentations!" > /mnt/aca.txt
root@s369:/home/rc# cat /mnt/aca.txt
I love ACA student presentations!
root@s369:/home/rc#
logout
# outside of namespace
rc@s369 ⇝ ls -l /mnt/aca.txt
ls: cannot access '/mnt/aca.txt': No such file or directory
rc@s369 ~ [2]>
```

Let’s get our hands dirty, net namespace (1/2)

```
# outside the namespace
rc@s369 ⇝ ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: enp0s31f6: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc fq_codel state DOWN group defau
    link/ether 54:e1:ad:5d:1c:6e brd ff:ff:ff:ff:ff:ff
.... i should probably clean this up :)
rc@s369 ⇝ ip route
default via 131.159.223.254 dev wlp4s0 proto dhcp metric 600
131.159.192.0/19 dev wlp4s0 proto kernel scope link src 131.159.218.200 metric 600
169.254.0.0/16 dev br-0d5fb61239aa scope link metric 1000
172.17.0.0/16 dev docker0 proto kernel scope link src 172.17.0.1 linkdown
172.18.0.0/16 dev br-0d5fb61239aa proto kernel scope link src 172.18.0.1
```

Let’s get our hands dirty, net namespace (2/2)

```
rc@s369 ⇝ sudo unshare --net  /bin/bash
# inside the namespace
root@s369:/home/rc# ip a
1: lo: <LOOPBACK> mtu 65536 qdisc noop state DOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
root@s369:/home/rc# iptables --list-rules
-P INPUT ACCEPT
-P FORWARD ACCEPT
-P OUTPUT ACCEPT
root@s369:/home/rc# ip route
root@s369:/home/rc#
```

Let’s get our hands dirty, pid namespace (1/2)

```
rc@s369 ⇝ ps -aux | head -2
USER         PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root           1  0.0  0.0 168412 13844 ?        Ss   09:56   0:04 /sbin/init splash
rc@s369 ⇝ ps -aux | wc -l
324
rc@s369 ⇝ sudo unshare --fork --pid   /bin/bash
root@s369:/home/rc# ps -aux | wc -l
328
root@s369:/home/rc# ps -aux | head -2
USER         PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root           1  0.0  0.0 168412 13844 ?        Ss   09:56   0:04 /sbin/init splash
rc@s369 ⇝ sudo unshare --fork --pid --mount-proc  /bin/bash
root@s369:/home/rc# ps -aux
USER         PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root           1  0.0  0.0  10236  4132 pts/4    S    18:53   0:00 /bin/bash
root           8  0.0  0.0  12940  3720 pts/4    R+   18:53   0:00 ps -aux
```

Why this happens?

Let's get our hands dirty, pid namespace (2/2)

The ps program uses the procfs virtual file system to obtain information about the current processes in the system. This filesystem is mounted in the /proc directory. However, in the new namespace this mountpoint describes the processes from the root PID namespace.

```
rc@s369:~$ echo $$
45460
rc@s369:~$ ls /proc/45460
arch_status          cwd        mem            patch_state    stat
attr                 environ    mountinfo      personality    statm
autogroup            exe        mounts         projid_map     status
auxv                 fd         mountstats     root           syscall
cgroup               fdinfo     net            sched          task
clear_refs           gid_map    ns             schedstat      timens_offsets
cmdline              io         numa_maps      sessionid      timers
comm                 limits     oom_adj        setgroups      timerslack_ns
coredump_filter      loginuid   oom_score      smaps          uid_map
cpu_resctrl_groups   map_files  oom_score_adj  smaps_rollup   wchan
cpuset               maps       pagemap        stack
rc@s369:~$ ls /proc/45460/ns
cgroup  mnt  pid                time               user
ipc     net  pid_for_children   time_for_children  uts
```

Cgroups

Cgroups is a Linux kernel feature that limits, accounts for, and isolates the resource usage (CPU, memory, disk I/O, network, etc.) of a collection of processes.[4]

- 2006: engineers at Google start working of this feature
- January 2008: cgroups functionality is merged in the Linux mainline kernel (2.6.24)
- December 2016: cgroups v2 is merged in Linux mainline kernel (4.5) with some improvements

[4] https://en.wikipedia.org/wiki/Cgroups

Cgroup controllers

- **cpu**: grants a minimun number of ”CPU shares” when system is busy
  - from 3.2: CPU ”bandwidth” control
- **devices**: supports controlling which processes may create (mknod) devices as well as open them for reading or writing.
- **cpuacct**: provides accounting for CPU usage by groups of processes.
- **pids**: permits limiting the number of process that may be created in a cgroup (and its descendants).
- **net_cls**: places a classid on network packets created by a cgroup.
- **memory**: supports reporting and limiting of process memory, kernel memory, and swap used by cgroups.
- **blkio**: controls and limits access to specified block devices.
- **hugetlb**, **rdma**, **cpuset**, **cpu_prio**, **net_prio**, **perf_event**, **freezer**

Memory controller hands on

```
root@s369:/# mkdir /sys/fs/cgroup/memory/cgtest
root@s369:/# echo 5000 > /sys/fs/cgroup/memory/cgtest/memory.limit_in_bytes
root@s369:/# cat /sys/fs/cgroup/memory/cgtest/memory.limit_in_bytes
4096
```

now let's create a simple script test.sh

```
#!/bin/bash

while [ 1 ]; do
        echo "I love Advanced Computer Networking Student Presentations!"
        sleep 20
done
```

Memory controller hands on

```
rc@s369:~$ sh ~/test.sh &
[1] 9668
root@s369:/# echo 9668 > /sys/fs/cgroup/memory/cgtest/cgroup.procs
rc@s369 ⇝ ps  9668
    PID TTY      STAT   TIME COMMAND
   9668 pts/2    S      0:00 sh /home/rc/test.sh
rc@s369 ⇝ ps  -o cgroup 9668
CGROUP
13:memory:/cgtest,11:pids:/user.slice/user-1000.slice/user@1000.service...
```

after some time... test.sh

```
rc@s369 ⇝ ps  9668
    PID TTY      STAT   TIME COMMAND
```

What happened?

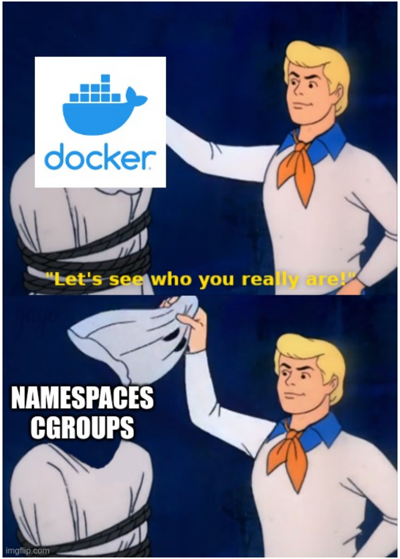
Memory controller hands on

```
rc@s369:~$ sh ~/test.sh &
[1] 9668
root@s369:/# echo 9668 > /sys/fs/cgroup/memory/cgtest/cgroup.procs
rc@s369 ⤳ ps  9668
    PID TTY      STAT   TIME COMMAND
   9668 pts/2    S      0:00 sh /home/rc/test.sh
rc@s369 ⤳ ps  -o cgroup 9668
CGROUP
13:memory:/cgtest,11:pids:/user.slice/user-1000.slice/user@1000.service...
```

after some time... test.sh

```
rc@s369 ⤳ ps  9668
    PID TTY      STAT   TIME COMMAND
```

What happened? There is a new sheriff in town! oom-killer!


docker
"Let's see who you really are!"
NAMESPACES
CGROUPS
imgflip.com

further readings/talks

- https://github.com/containerd/containerd/blob/main/docs/getting-started.md
- https://lwn.net/Articles/531114/ (the entire series)
- https://blog.quarkslab.com/digging-into-linux-namespaces-part-1.html
- `man` {namespaces,cgroups}
- https://drewdevault.com/2022/11/12/In-praise-of-Plan-9.html
- @jpetazzo - Cgroups, namespaces, and beyond: what are containers made from?
- Containers unplugged: Linux namespaces - Michael Kerrisk
- https://docs.kernel.org/admin-guide/cgroup-v1/cgroups.html