Lightweight Virtualization

LXC containers & AUFS

SCALE11x — February 2013, Los Angeles

Those slides are available at:

`http://goo.gl/bFHSh`

Outline

- Intro: who, what, why?

- LXC containers
- Namespaces
- Cgroups
- AUFS
- setns

- Future developments

Who am I?

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dotCloud

dotCloud is the first "polyglot" PaaS,
and we built it with Linux Containers!

What is this about?

LXC (LinuX Containers) let you run a Linux system within another Linux system.

A container is a group of processes on a Linux box, put together in an isolated environment.

Inside the box, it looks like a VM.
Outside the box, it looks like normal processes.

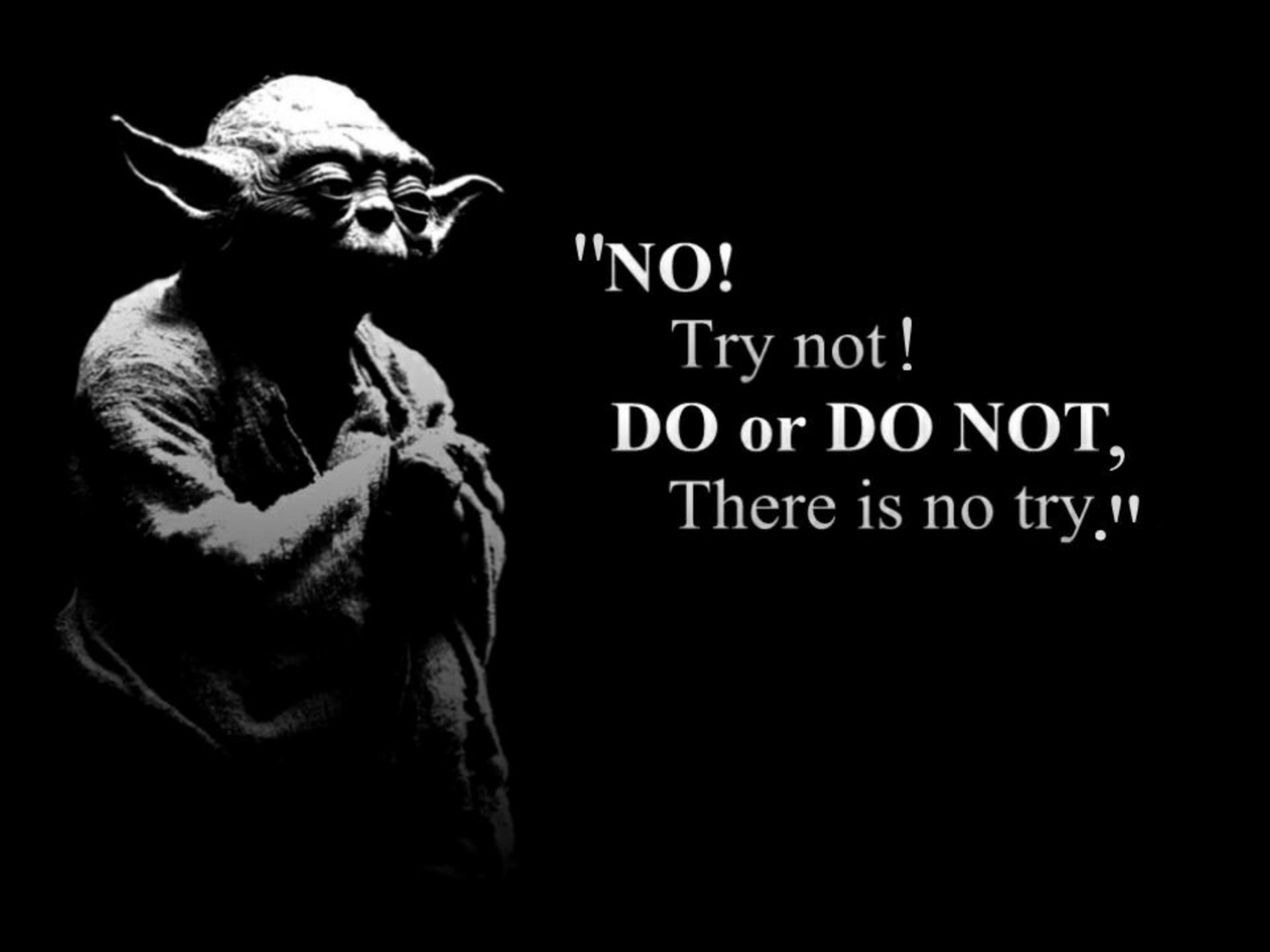
This is "`chroot()` on steroids"

Why should I care?

1. I will try to convince you that it's awesome.

2. I will try to explain how it works.

3. I will try to get you involved!


"NO!
Try not!
DO or DO NOT,
There is no try."

Why should I care?

1. I will convince you that it's awesome.

2. I will explain how it works.

3. You will want to get involved!

Why is it awesome?

The 3 reasons why containers are awesome

Why?
3) Speed!

	Ships within ...	Manual deployment takes ...	Automated deployment takes ...	Boots in ...
Bare Metal	days	hours	minutes	minutes
Virtualization	minutes	minutes	seconds	less than a minute
Lightweight Virtualization	seconds	minutes	seconds	seconds

Why?
2) Footprint!

On a typical physical server, with average compute resources, you can easily run:

- 10-100 virtual machines
- 100-1000 containers

On disk, containers can be very light.

A few MB — even without fancy storage.

Why?
1) It's still virtualization!

Each container has:

- its own network interface (and IP address)
  - can be bridged, routed... just like $your_favorite_vm
- its own filesystem
  - Debian host can run Fedora container (&vice-versa)
- isolation (security)
  - container A & B can't harm (or even see) each other
- isolation (resource usage)
  - soft & hard quotas for RAM, CPU, I/O...

Some use-cases

For developers,
hosting providers,
and the rest of us

Use-cases: Developers

- Continuous Integration
  - After each commit, run 100 tests in 100 VMs
- Escape dependency hell
  - Build (and/or run) in a controlled environment
- Put everything in a VM
  - Even the tiny things

Use-cases: Hosters

- ~~Cheap~~ Cheaper Hosting (VPS providers)
  - I'd rather say "less expensive", if you get my drift
  - Already a lot of vserver/openvz/... around
- Give away more free stuff
  - "Pay for your production, get your staging for free!"
  - We do that at dotCloud
- Spin down to save resources
  - And spin up on demand, in seconds
  - We do that, too

Use-cases: Everyone

- Look inside your VMs
  - You can see (and kill) individual processes
  - You can browse (and change) the filesystem

- Do whatever you did with VMs
  - ... But faster

Breaking news: LXC can haz migration!

This slide intentionally left blank

(but the talk right before mine ~~should have~~ interesting results)
oh yes indeed!

LXC lifecycle

- `lxc-create`
  Setup a container (root filesystem and config)
- `lxc-start`
  Boot the container (by default, you get a console)
- `lxc-console`
  Attach a console (if you started in background)
- `lxc-stop`
  Shutdown the container
- `lxc-destroy`
  Destroy the filesystem created with lxc-create

How does it work?

First time I tried LXC:

```
# lxc-start --name thingy --daemon
# ls /cgroup
... thingy/ ...
```

"So, LXC containers are powered by cgroups?"

Wrong.

Namespaces

Partition essential kernel structures to create virtual environments

e.g., you can have multiple processes with PID 42, in different environments

Different kinds of namespaces

- `pid` (processes)
- `net` (network interfaces, routing...)
- `ipc` (System V IPC)
- `mnt` (mount points, filesystems)
- `uts` (hostname)
- `user` (UIDs)

Creating namespaces

- Extra flags to the `clone()` system call
- CLI tool `unshare`

Notes:

- You don't have to use *all* namespaces
- A new process inherits its parent's ns
- No easy way to attach to an existing ns
  - Until recently! More on this later.

Namespaces: `pid`

- Processes in a `pid` don't see processes of the whole system
- Each `pid` namespace has a PID #1
- `pid` namespaces are actually *nested*
- A given process can have *multiple* PIDs
  - One in each namespace it belongs to
  - ... So you can easily access processes of children ns
- Can't see/affect processes in parent/sibling ns

Namespaces: `net`

- Each `net` namespace has its own…
  - Network interfaces (and its own `lo/127.0.0.1`)
  - IP address(es)
  - routing table(s)
  - iptables rules

- Communication between containers:
  - UNIX domain sockets (=on the filesystem)
  - Pairs of `veth` interfaces

Setting up veth interfaces 1/2

```
# Create new process, <PID>, with its own net ns
unshare --net bash
echo $$

# Create a pair of (connected) veth interfaces
ip link add name lehost type veth peer name leguest

# Put one of them in the new net ns
ip link set leguest netns <PID>
```

Setting up veth interfaces 2/2

```
# In the guest (our unshared bash), setup leguest
ip link set leguest name eth0
ifconfig eth0 192.168.1.2
ifconfig lo 127.0.0.1

# In the host (our initial environment), setup lehost
ifconfig lehost 192.168.1.1

# Alternatively:
brctl addif br0 lehost

# ... Or anything else!
```

Namespaces: `ipc`

- Remember "System V IPC"?
  `msgget`, `semget`, `shmget`
- Have been (mostly) superseded by POSIX alternatives: `mq_open`, `sem_open`, `shm_open`
- However, some stuff still uses "legacy" IPC.
- Most notable example: PostgreSQL

The problem: `xxxget()` asks for a key, usually derived from the inode of a well-known file

The solution: `ipc` namespace

Namespaces: `mnt`

- Deluxe `chroot()`
- A `mnt` namespace can have its own rootfs
- Filesystems mounted in a `mnt` namespace are visible only in this namespace
- You need to remount special filesystems, e.g.:
  - `procfs` (to see *your* processes)
  - `devpts` (to see *your* pseudo-terminals)

Setting up space efficient containers (1/2)

```
/containers/leguest_1/rootfs (empty directory)
/containers/leguest_1/home (container private data)
/images/ubuntu-rootfs (created by debootstrap)

CONTAINER=/containers/leguest_1
mount --bind /images/ubuntu-rootfs $CONTAINER/rootfs
mount -o ro,remount,bind /images/ubuntu-rootfs $CONTAINER/rootfs
unshare --mount bash
mount --bind $CONTAINER/home $CONTAINER/rootfs/home
mount -t tmpfs none $CONTAINER/tmp
# unmount what you don't need ...
# remount /proc, /dev/pts, etc., and then:
chroot $CONTAINER/rootfs
```

Setting up space efficient containers (2/2)

Repeat the previous slides multiple times (Once for each different container.)

But, the root filesystem is read-only...?

No problem, nfsroot howtos have been around since … 1996

Namespaces: `uts`

Deals with just two syscalls: `gethostname()`,`sethostname()`

Useful to find out in which container you are

... More seriously: some tools might behave differently depending on the hostname (`sudo`)

Namespaces: `user`

UID42 in container X isn't UID42 in container Y

- Useful if you *don't* use the `pid` namespace
  (With it, X42 can't see/touch Y42 anyway)
- Can make sense for system-wide, per-user resource limits if you *don't* use `cgroups`
- Honest: didn't really play with those!

Control Groups

Create as many cgroups as you like.
Put processes within cgroups.
Limit, account, and isolate resource usage.

Think `ulimit`*, but for groups of processes*

… and with fine-grained accounting.

Cgroups: the basics

Everything exposed through a virtual filesystem

`/cgroup`, `/sys/fs/cgroup`... YourMountpointMayVary

Create a cgroup:

```
mkdir /cgroup/aloha
```

Move process with PID 1234 to the cgroup:

```
echo 1234 > /cgroup/aloha/tasks
```

Limit memory usage:

```
echo 10000000 > /cgroup/aloha/memory.limit_in_bytes
```

Cgroup: memory

- Limit
  - memory usage, swap usage
  - soft limits and hard limits
  - can be nested
- Account
  - cache vs. rss
  - active vs. inactive
  - file-backed pages vs. anonymous pages
  - page-in/page-out
- Isolate
  - "Get Off My Ram!"
  - Reserve memory thanks to hard limits

Cgroup: CPU (and friends)

- Limit
  - Set `cpu.shares` (defines relative weights)
- Account
  - Check `cpustat.usage` for user/system breakdown
- Isolate
  - Use `cpuset.cpus` (also for NUMA systems)

Can't really throttle a group of process.

But that's OK: context-switching << 1/HZ

Cgroup: Block I/O

- Limit & Isolate
  - blkio.throttle.{read,write}.{iops,bps}.device
  - Drawback: only for sync I/O
    (i.e.: "classical" reads; not writes; not mapped files)
- Account
  - Number of IOs, bytes, service time...
  - Drawback: same as previously

Cgroups aren't perfect if you want to limit I/O.

Limiting the amount of `dirty` memory helps a bit.

AUFS

Writable single-system images

or

Copy-on-write at the filesystem level

AUFS quick example

You have the following directories:

`/images/ubuntu-rootfs`

`/containers/leguest/rootfs`

`/containers/leguest/rw`

```
mount -t aufs \
      -o br=/containers/leguest/rw=rw:/images/ubuntu-rootfs=ro \
      none /containers/leguest/rootfs
```

Now, you can write in `rootfs`:

changes will go to the `rw` directory.

Union filesystems benefits

- Use a single image (remember the `mnt` namespace with read-only filesystem?)
- Get read-writable root filesystem anyway
- Be nice with your page cache
- Easily track changes (`rw` directory)

AUFS layers

- Traditional use
  - one read-only layer, one read-write layer
- System image development
  - one read-only layer, one read-write layer
  - checkpoint current work by adding another rw layer
  - merge multiple rw layers (or use them as-is)
  - track changes and replicate quickly
- Installation of optional packages
  - one read-only layer with the base image
  - multiple read-only layers with "plugins" / "addons"
  - one read-write layer (if needed)

AUFS compared to others

- Low number of developers
- Not in mainstream kernel
  - But Ubuntu ships with AUFS
- Has layers, whiteouts, inode translation, proper support for mmap...
- Every now and then, another Union FS makes it into the kernel (latest is overlayfs)
- Eventually, (some) people realize that it lacks critical features (for their use-case)
  - And they go back to AUFS

AUFS personal statement

AUFS is the worst union filesystems out there; except for all the others that have been tried.

Not Churchill

Getting rid of AUFS

- Use separate mounts for tmp, var, data...
- Use read-only root filesystem
- Or use a simpler union FS
  (important data is in other mounts anyway)

`setns()` The use-case

Use-case: managing running containers
(i.e. "I want to log into this container")

- SSH (inject `authorized_keys` file)
- some kind of backdoor
- spawn a process *directly* in the container

This is what we want!

- no extra process (it could die, locking us out)
- no overhead

`setns()` In theory

- LXC userland tools feature lxc-attach
- It relies on `setns()` syscall…
- …And on some files in `/proc/<PID>/ns/`

```
fd = open("/proc/<pid>/ns/pid")
setns(fd, 0)
```

And boom, the current process joined the namespace of `<pid>`!

`setns()` In practice

Problem (with kernel <3.8):

```
# ls /proc/1/ns/
ipc  net  uts
```

Wait, what?!? (We're missing `mnt pid user`)

~~You need *custom kernel patches*.~~
Linux 3.8 to the rescue!

Lightweight virtualization at dotCloud

- >100 LXC hosts
- Up to 1000 *running* containers per host
- Many more *sleeping* containers
- Webapps
  - Java, Python, Node.js, Ruby, Perl, PHP...
- Databases
  - MySQL, PostgreSQL, MongoDB...
- Others
  - Redis, ElasticSearch, SOLR...

Lightweight virtualization at $HOME

- We wrote the first lines of our current container management code back in 2010
- We learned many lessons in the process (sometimes the hard way!)
- It got very entangled with our platform (networking, monitoring, orchestration...)
- We are writing a new container management tool, for a DevOps audience

Would you like to know more?

Mandatory shameless plug

If you think that this was easy-peasy,
or extremely interesting:
Join us!

jobs@dotcloud.com

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More about containers, scalability, PaaS...

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