Introduction to Docker

Reseau LoOPS, 2015/12/17

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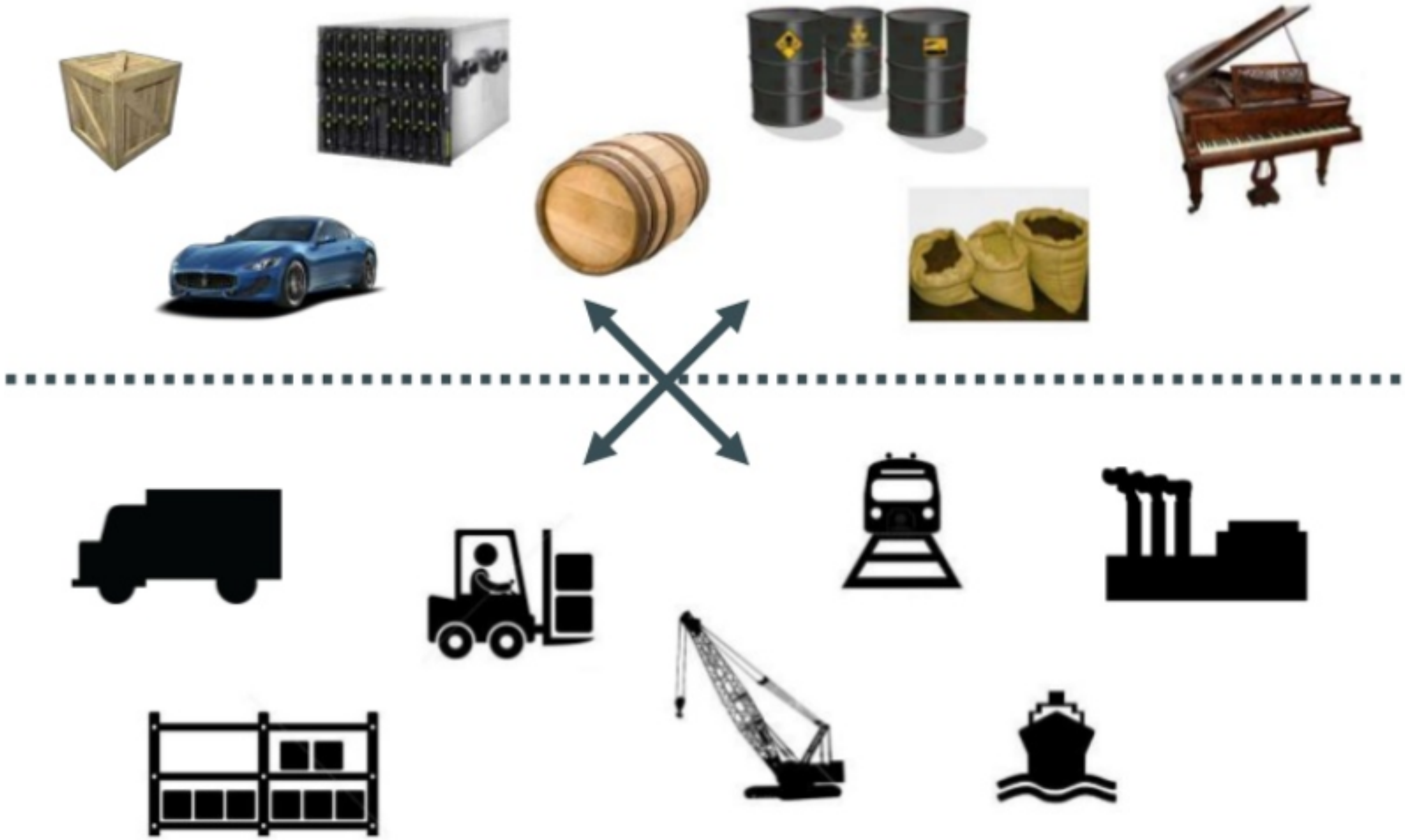
CNRS/IN2P3

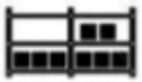
Docker origins

The container revolution

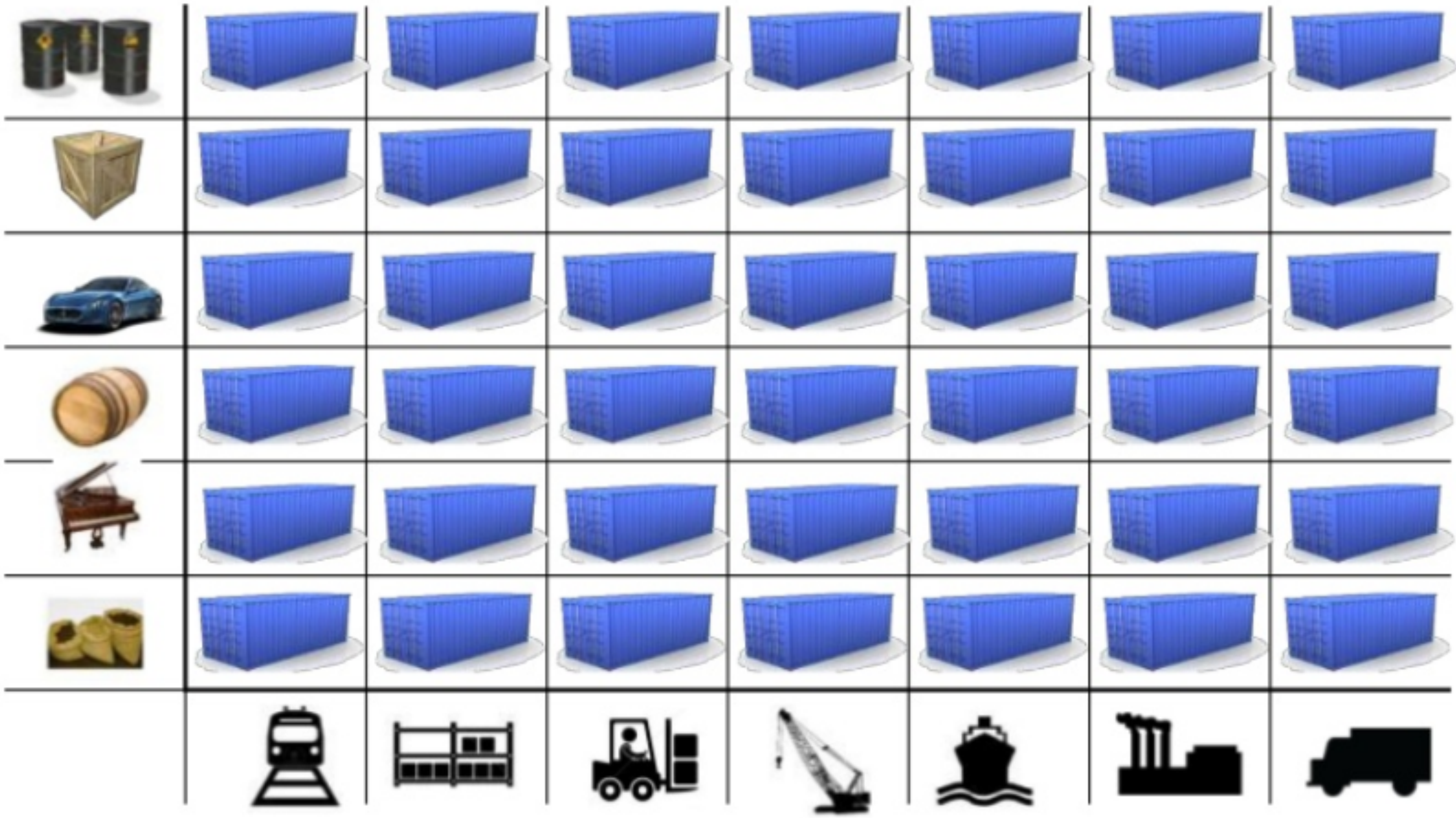
Before 1960, cargo transport looked like:



MxN combinatorics: matrix from Hell

	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
	?	?	?	?	?	?	?
							

Solution: Intermodal shipping container

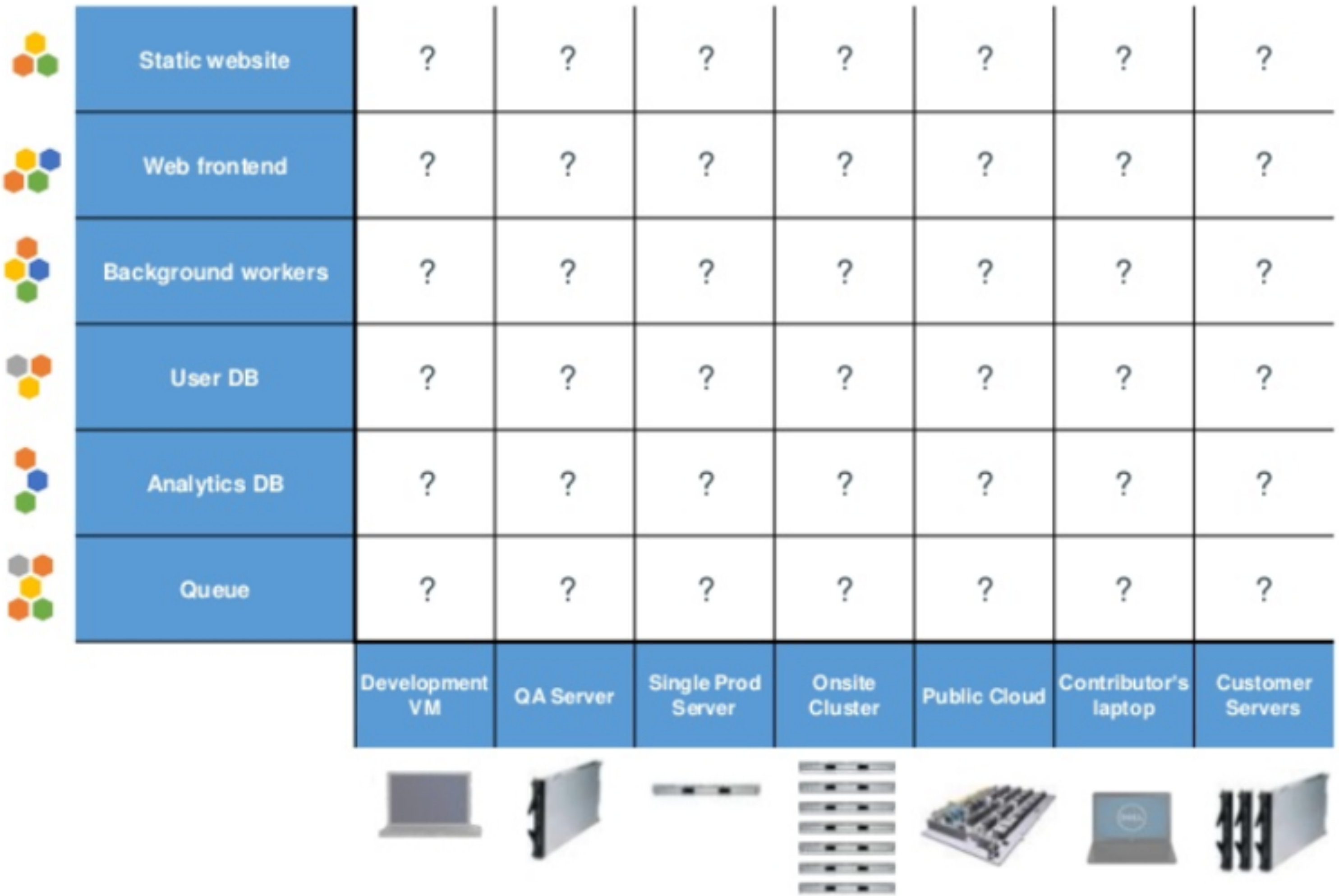


Containers - analysis

- enables seamless shipping on roads, railways and sea (intermodal)
- standardized dimensions
- opaque box convenient for all types of goods (privacy)

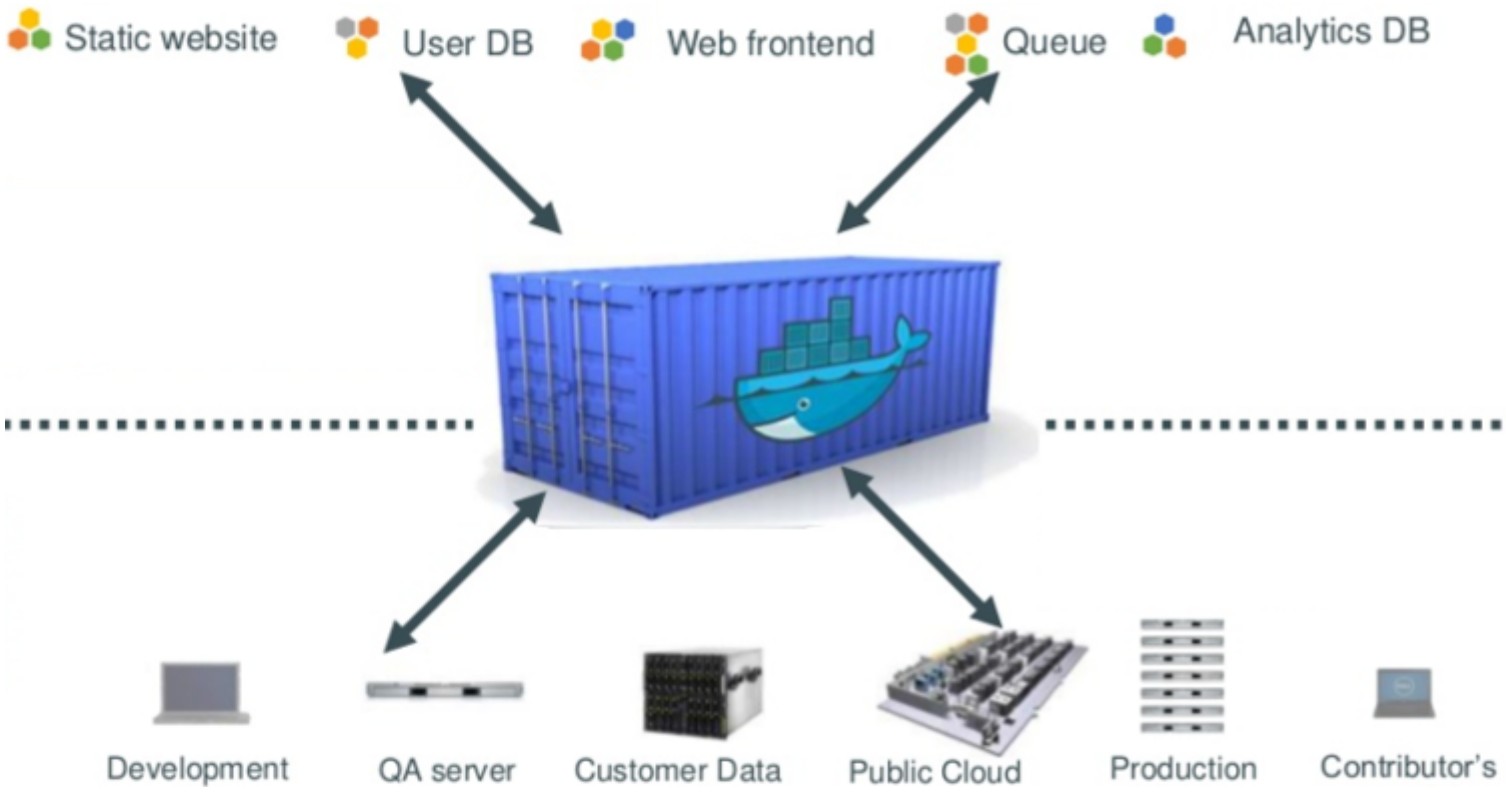
What is Docker?

Application deployment

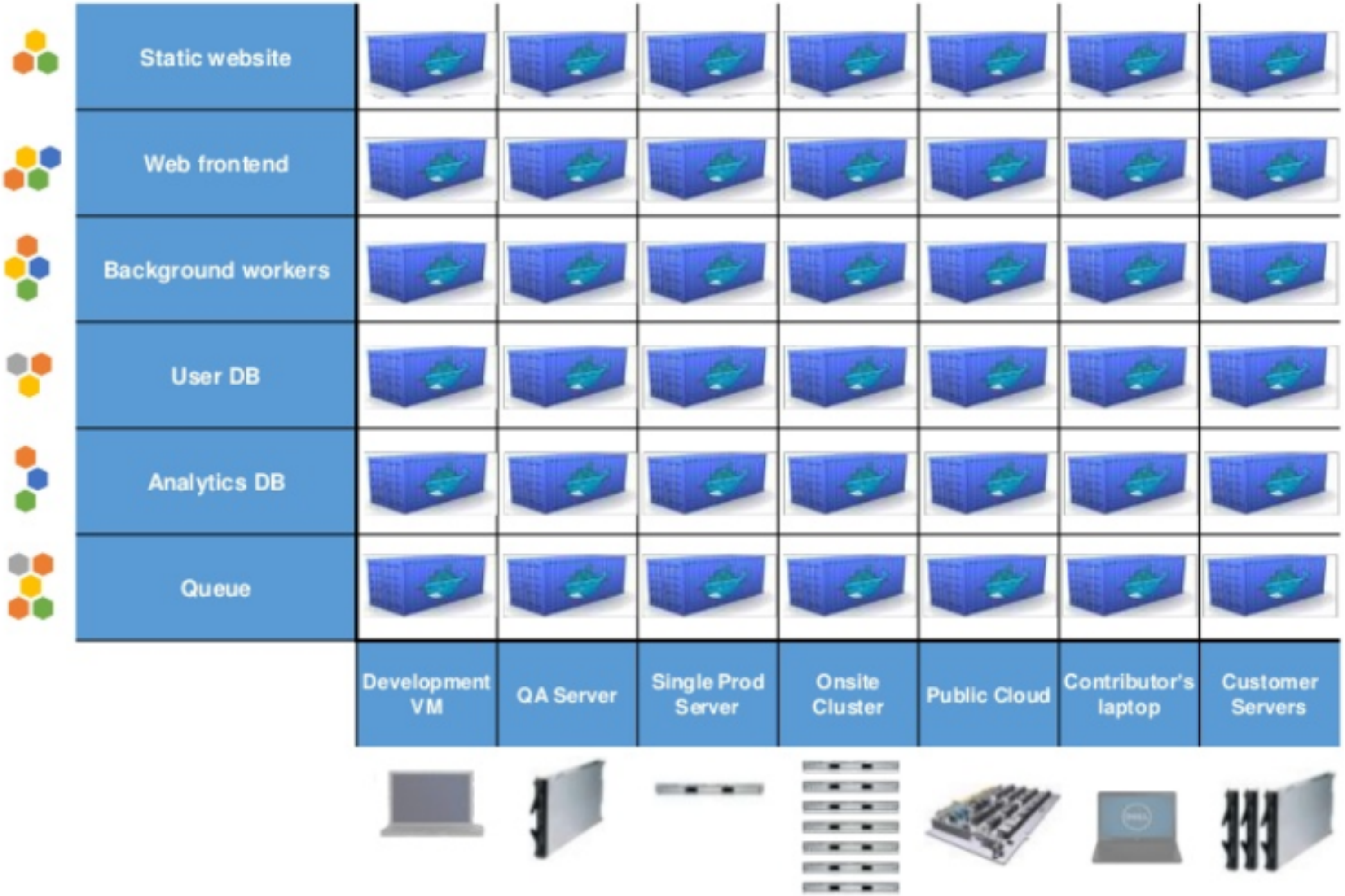


Note: a 3rd dimension (OS/platform) could be considered

Docker: an application container



Docker: no combinatorics no more



Docker

`Docker` is an open source project to pack ship and run any application as a lightweight container: docker.io (http://www.docker.io)

Note: Although `docker` is primarily (ATM) Linux-oriented, it supports other OSes (Windows+MacOSX) at the price of a thin `Linux` VM which is automatically installed (and managed) on these systems.
See docker installation (https://docs.docker.com/installation/)

Docker

`Docker` is an open source project to pack ship and run any application as a lightweight container: [docker.io](http://www.docker.io) (http://www.docker.io)

High-level description:

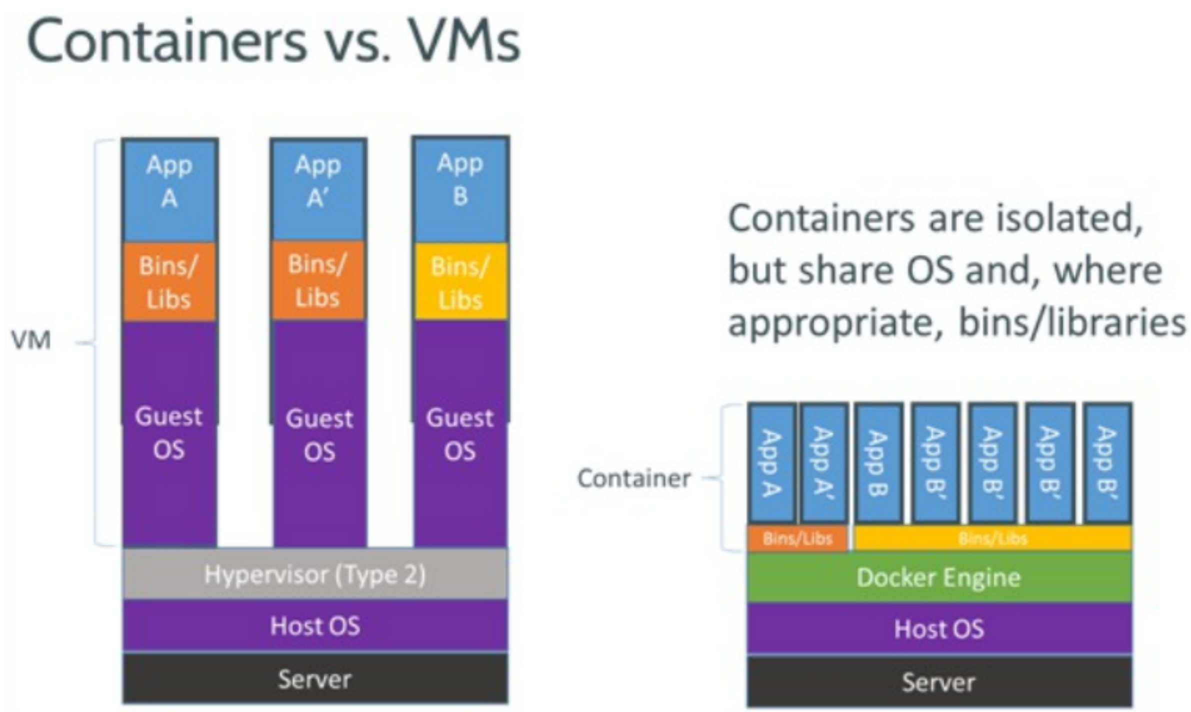
- kind of like a lightweight VM
- runs in its own process space
- has its own network interface
- can run stuff as `root`

Low-level description:

- `chroot` on steroids
- container == isolated process(es)
- share kernel with host
- no device emulation

Docker: why?

- same use cases than for VMs (for `Linux` centric workloads)
- **speed**: boots in (milli)seconds
- **footprint**: 100-1000 containers on a single machine/laptop, small disk requirements



Docker: why?

Efficiency: *almost* no overhead

- processes are isolated but run straight on the host
- CPU performance = **native** performance
- memory performance = a few % shaved off for (optional) accounting
- network performance = small overhead

Docker: why?

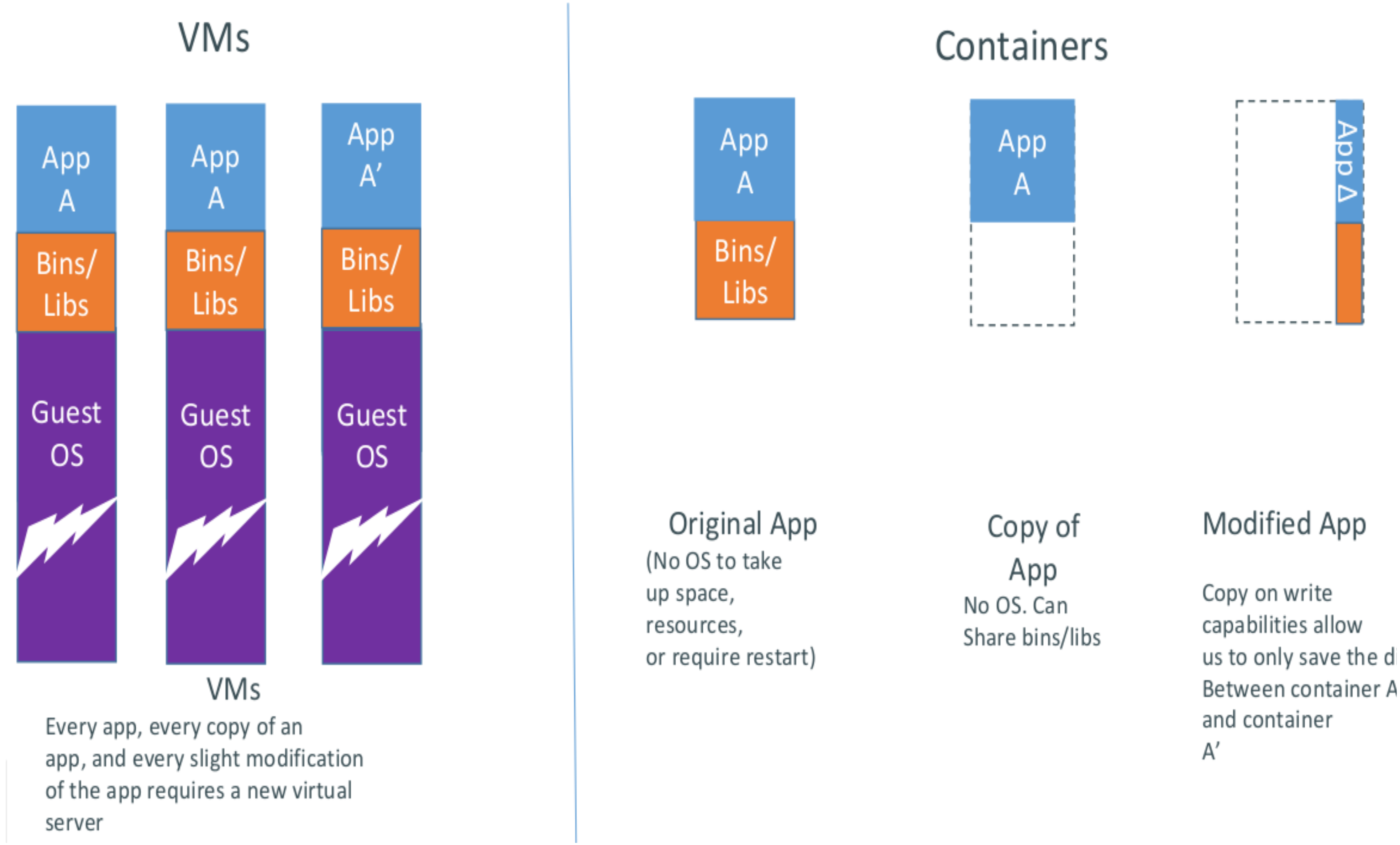
Efficiency: storage friendly

- unioning filesystems
- snapshotting filesystems
- copy-on-write

Docker: why?

- provisionning takes a few milliseconds
- ... and a few kilobytes
- creating a new container/base-image takes a few seconds

Why are Docker containers lightweight?


VMs
App
A
Bins/
Libs
Guest
OS
App
A
Bins/
Libs
Guest
OS
App
A’
Bins/
Libs
Guest
OS
VMs
Every app, every copy of an
app, and every slight modification
of the app requires a new virtual
server
Containers
App
A
Bins/
Libs
App
A
App Δ
Original App
(No OS to take
up space,
resources,
or require restart)
Copy of
App
No OS. Can
Share bins/libs
Modified App
Copy on write
capabilities allow
us to only save the di
Between container A
and container
A’

Separation of concerns

Tailored for the dev team:

- my code
- my framework
- my libraries
- my system dependencies
- my packaging system
- my distro
- my data

Don't care where it's running or how.

Separation of concerns

Tailored for the ops team:

- logs
- backups
- remote access
- monitoring
- uptime

Don't care what's running in it.

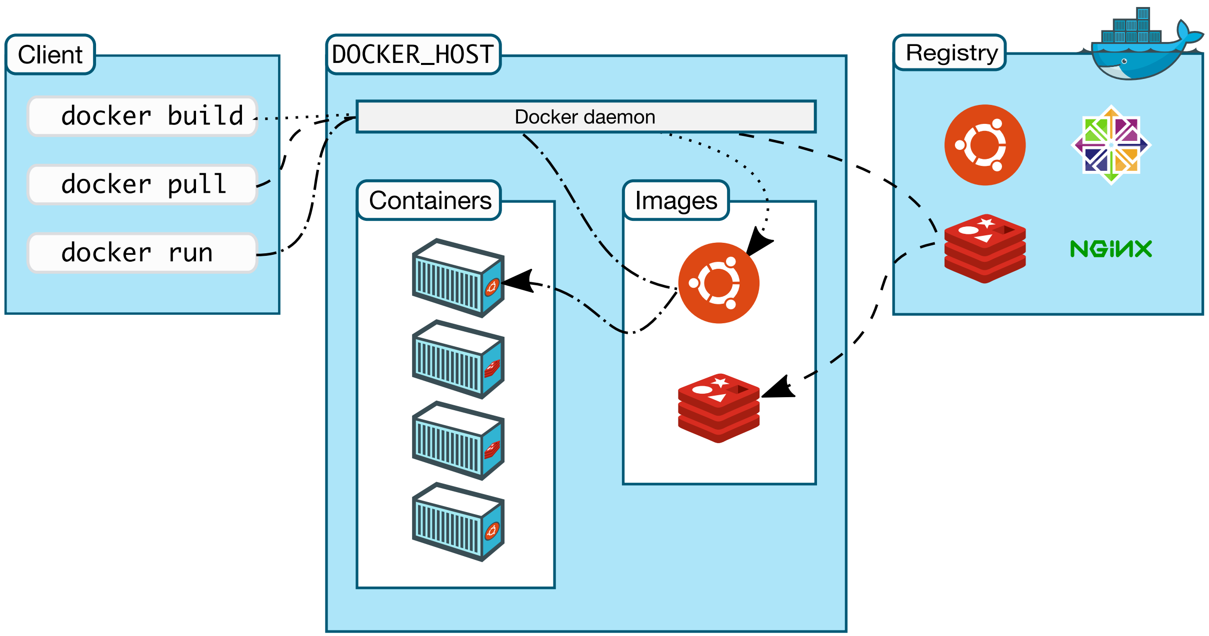
Docker: blueprint

Docker: blueprint

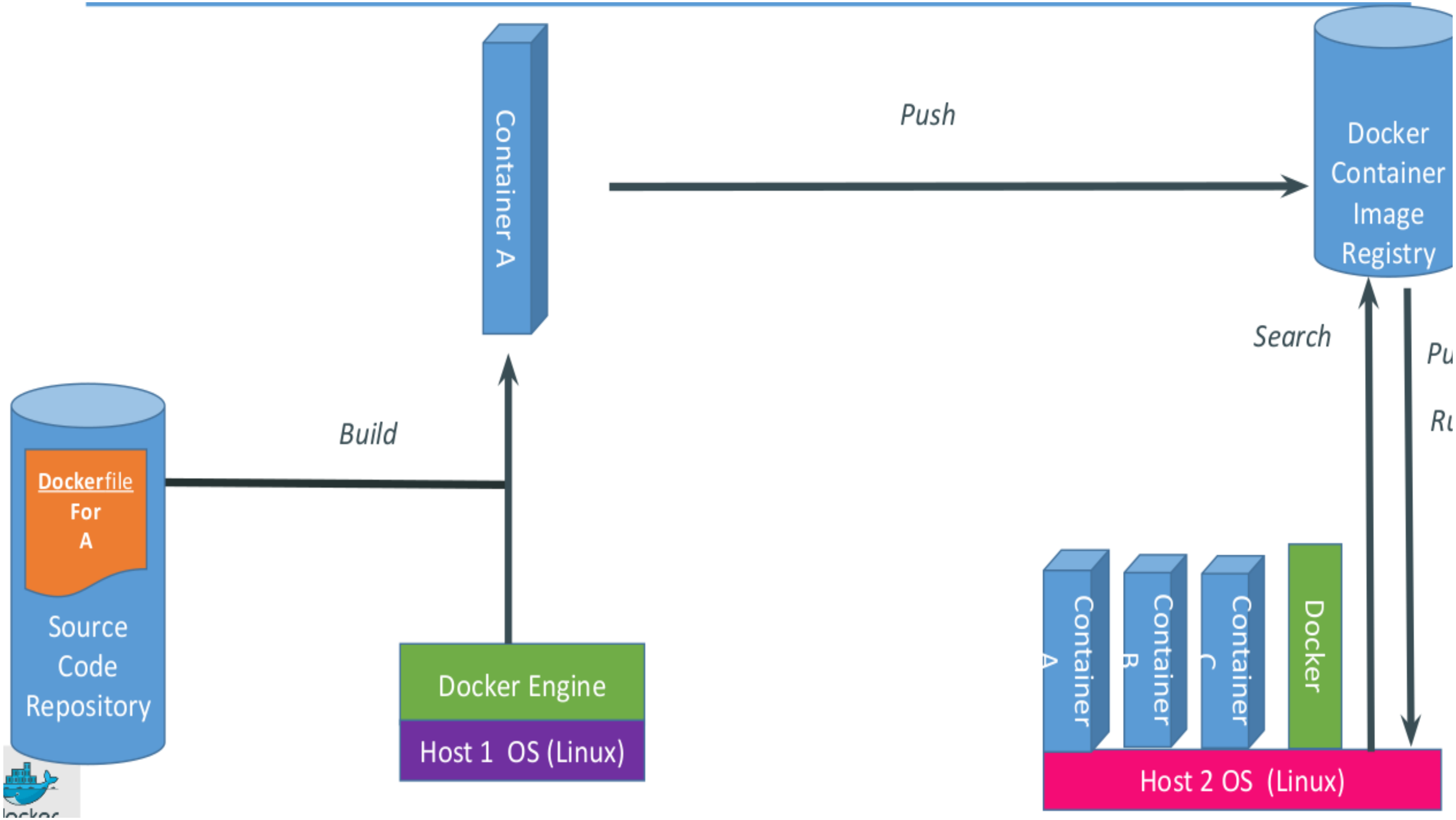
Build, ship and *run* any application, *anywhere*.

`Docker` uses a client/server architecture:

- the `docker` *client* talks to
- a `docker` *daemon* via sockets or a RESTful API.



Docker: basics of the system



Docker: the CLI

The docker client ships with many a subcommand:

```
$ docker help
Usage: docker [OPTIONS] COMMAND [arg...]
       docker daemon [ --help | ... ]
       docker [ -h | --help | -v | --version ]

A self-sufficient runtime for containers.

[...]

Commands:
    attach    Attach to a running container
    build     Build an image from a Dockerfile
    commit    Create a new image from a container's changes
    cp        Copy files/folders from a container to a HOSTDIR or to STDOUT
    images    List images
    import    Import the contents from a tarball to create a filesystem image
    info      Display system-wide information
[...]
```

Docker: the CLI

```
$ docker version
Client:
 Version:      1.9.1
 API version:  1.21
 Go version:   go1.5.1
 Git commit:   a34a1d5-dirty
 Built:        Sun Nov 22 00:15:15 UTC 2015
 OS/Arch:      linux/amd64

Server:
 Version:      1.9.1
 API version:  1.21
 Go version:   go1.5.1
 Git commit:   a34a1d5-dirty
 Built:        Sun Nov 22 00:15:15 UTC 2015
 OS/Arch:      linux/amd64
```

Whirlwind tour of docker features

Hello World

Fetch a docker image from the docker registry:

```
$ docker pull busybox
Using default tag: latest
latest: Pulling from library/busybox
cf2616975b4a: Pull complete
6ce2e90b0bc7: Pull complete
8c2e06607696: Already exists
library/busybox:latest: The image you are pulling has been verified. Important: image verification
Digest: sha256:38a203e1986cf79639cfb9b2e1d6e773de84002feea2d4eb006b52004ee8502d
Status: Downloaded newer image for busybox:latest

$ docker images
REPOSITORY            TAG                 IMAGE ID            CREATED             VIRTUAL SIZE
busybox               latest              8c2e06607696        4 months ago        2.43 MB
```

Now, run a command inside the image:

```
$ docker run busybox echo "Hello World"
Hello World
```

Docker basics

- Run a container in detached mode:

```
$ docker run -d busybox sh -c \
  'while true; do echo "hello"; sleep 1; done;'
```

- Retrieve the container id:

```
$ docker ps
CONTAINER ID        IMAGE               COMMAND                  CREATED             STATUS
321c1aa5bcd4        busybox             "sh -c 'while true; d"   3 seconds ago       Up 2 seconds
```

- Attach to the running container:

```
$ docker attach 321c1aa5bcd4
hello
hello
[...]
```

- Start/stop/restart container

```
$ docker stop 321c1aa5bcd4
$ docker restart 321c1aa5bcd4
```

Docker: public index (aka registry, aka the Hub)

Docker containers may be published and shared on a public registry, the Hub.

- It is searchable:

```
$ docker search apache2
NAME                              STARS     OFFICIAL   AUTOMATED
rootlogin/apache2-symfony2        7                    [OK]
reinblau/php-apache2              6                    [OK]
tianon/apache2                    4                    [OK]
[...]
$ docker pull tianon/apache2
```

- Run the image and check the ports

```
$ docker run -d -p 8080:80 tianon/apache2
$ docker ps
CONTAINER ID        IMAGE               COMMAND                 PORTS
49614161f5b7        tianon/apache2      "apache2 -DFOREGROUND"   0.0.0.0:8080->80/tcp
```

The registry is also available from the browser:

- hub.docker.com (https://hub.docker.com)

Docker: creating a customized image

- run docker interactively:

```
$ docker run -it ubuntu bash
root@524ef6c2e4ce:/# apt-get install -y memcached
[...]
root@524ef6c2e4ce:/# exit

$ docker commit `docker ps -q -l` binet/memcached
4242210aba21641013b22198c7bdc00435b00850aaf9ae9cedc53ba75794891d

$ docker run -d -p 11211 -u daemon binet/memcached memcached
a84e18168f1473a338f9ea3473dd981bf5e3dc7e41511a1252f7bb216d875860

$ docker ps
CONTAINER ID        IMAGE               COMMAND                  PORTS
a84e18168f14        binet/memcached     "memcached"              0.0.0.0:32768->11211/tcp
```

Docker: creating a customized image

- interactive way is fine but not scalable
- enter `Dockerfiles`
- recipes to build an image
- start `FROM` a base image
- `RUN` commands on top of it
- easy to learn, easy to use

Docker: Dockerfile

```
FROM ubuntu:14.04

RUN apt-get update
RUN apt-get install -y nginx
ENV MSG="Hi, I am in your container!"
RUN echo "$MSG" > /usr/share/nginx/html/index.html

CMD nginx -g "daemon off;"

EXPOSE 80
```

Docker: Dockerfile-II

- run in the directory holding that `Dockerfile`

```
$ docker build -t <myname>/server .
$ docker run -d -P <myname>/server
```

- retrieve the port number:

```
$ docker ps
34dc03cdbae8        binet/server         "/bin/sh -c 'nginx -g"   0.0.0.0:32770->80/tcp
```

or:

```
$ docker inspect -f '{{.NetworkSettings.Ports}}' 34dc03cdbae8
```

and then:

```
$ curl localhost:32770
Hi, I am in your container!
```

Docker: Dockerfile-III

NOTE: for Windows(TM) and MacOSX(TM) users, a thin `Linux` VM is sitting between your machine and the container.
The container is running inside that VM so you need to replace `localhost` with the `IP` of that VM:

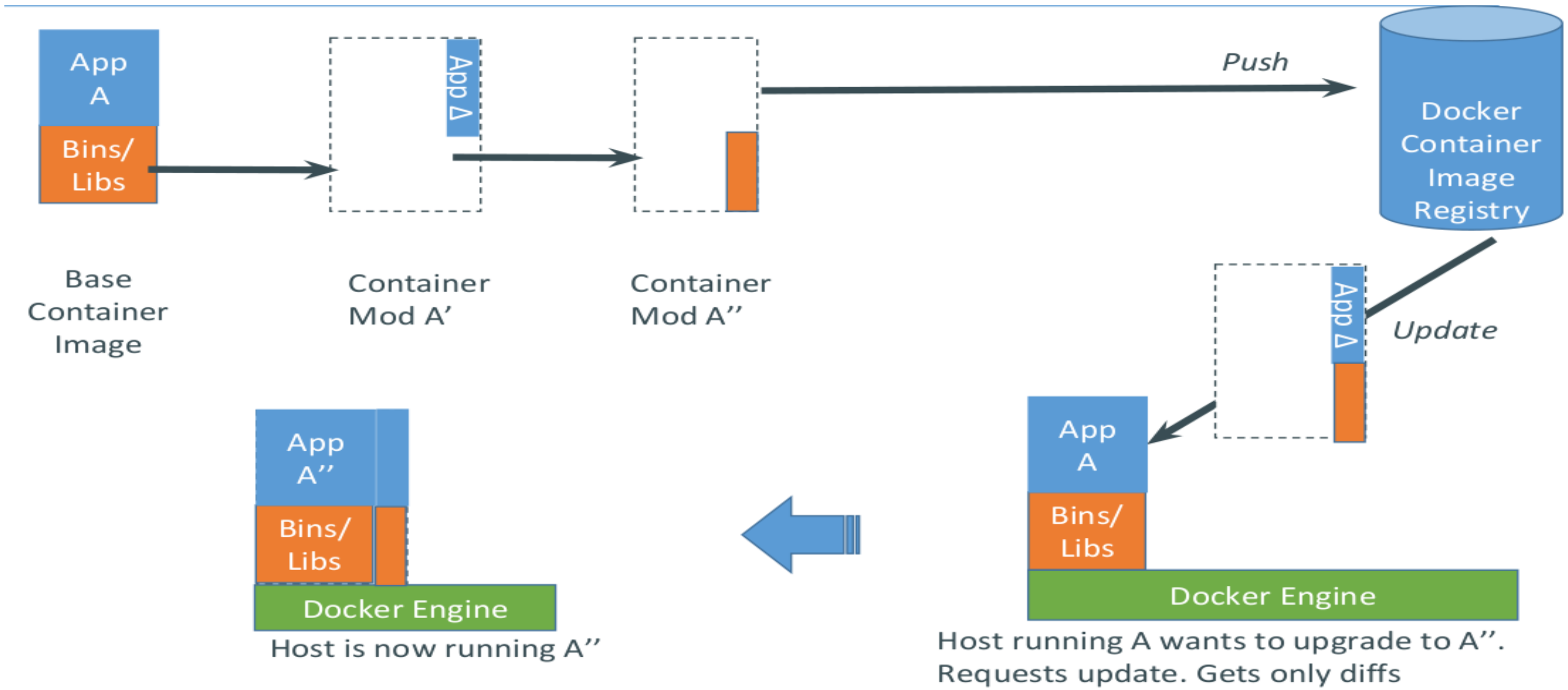
```
$ docker-machine ip default
192.168.59.103
```

and then:

```
$ curl 192.168.59.103:32770
Hi, I am in your container!
```

docker build

- takes a snapshot after each step
- re-uses those snapshots in future builds
- doesn't re-run slow steps when it isn't necessary (cache system)



Docker Hub

- `docker` push an image to the Hub
- `docker pull` an image from the Hub to any machine

This brings:

- reliable deployment
- consistency
- images are self-contained, independent from host
- if it works locally, it will work on the server
- *exact same behavior*
- regardless of versions, distros and dependencies

Docker for the developer

- manage and **control** dependencies
- if it works on my machine, it works on the cluster
- reproducibility
- small but durable recipes

Never again:

- juggle with 3 different incompatible FORTRAN compilers
- voodoo incantations to get that exotic library to link with IDL
- figure out which version of LAPACK works with that code
- ... and what obscure flag coaxed it into compiling last time

Development workflow

- Fetch code (`git`, `mercurial`, ...)

```
$ git clone git@github.com:sbinet/loops-20151217-tp
$ cd loops-20151217-tp
```

- Edit code
- Mount code inside a `build` container
- Build+test inside that container

We'll test this workflow in the remainder of the hands-on session...

Deployment workflow

- Pull binary (possibly from a private registry), packaged as a container
- Deploy container on cloud or local cluster

Many tools exist to ease the deployment of multi-containers applications
eg: an application consisting of a web-server and a database, where each binary is packaged as a single container.
Each container needs to communicate with the other.
Configuration(s) also need to be provided to these containers...

kubernetes.io/ (http://kubernetes.io/)

mesos.apache.org/ (http://mesos.apache.org/)

coreos.com/etcd/docs/latest/ (https://coreos.com/etcd/docs/latest/)

docs.docker.com/compose/ (https://docs.docker.com/compose/)

Conclusions

- `docker` is a rather good tool to deploy applications in containers
- eases the life of developers and sysadmins (devops)
- `docker` isn't the only game in town
- rkt (https://coreos.com/rkt/docs) (`rocket`) from `CoreOS`
- systemd-nspawn (http://0pointer.de/public/systemd-man/systemd-nspawn.html), now part of `systemd`

References

www.slideshare.net/jpetazzo/introduction-to-docker-december-2014-tour-de-france-bordeaux-special-edition (http://www.slideshare.net/jpetazzo/introduction-to-docker-december-2014-tour-de-france-bordeaux-special-edition)

www.slideshare.net/dotCloud/docker-intro-november (http://www.slideshare.net/dotCloud/docker-intro-november)

sif.info-ufr.univ-montp2.fr/docker-talk (https://sif.info-ufr.univ-montp2.fr/docker-talk)

docs.docker.com/introduction/understanding-docker/ (https://docs.docker.com/introduction/understanding-docker/)

wiki.jenkins-ci.org/display/JENKINS/Docker+Plugin (https://wiki.jenkins-ci.org/display/JENKINS/Docker+Plugin)

kubernetes.io/ (http://kubernetes.io/)

mesos.apache.org/ (http://mesos.apache.org/)

coreos.com/rkt/docs (https://coreos.com/rkt/docs)

Hands-on session

Development workflow

- Fetch the code from `github`:

```
$ git clone git://github.com/sbinet/loops-20151217-tp
$ cd loops-20151217-tp
```

We'll see *a* use of `docker` as part of a development workflow:

- Edit code
- Mount code inside a `build` container
- Build+test inside that container

We'll test this workflow in the remainder of the hands-on session...

Create a base container

- create a directory `docker-web-base` to hold the `Dockerfile` for the base container
- create the `Dockerfile` and choose your favorite `Linux` distro (say, `debian`) as a base image,
- install the needed dependencies for the web-app (go and `pkg-config`)
- run:

```
$ docker build -t <myname>/web-base .
```

Hint: The image `golang`, an official image from Docker Inc., is based on `debian` and has go installed...

Create a base container - solution

(see next slide)

Create a base container - II

```
## base environment w/ deps for the web-app
FROM golang
MAINTAINER binet@cern.ch

## dependencies already contained in `golang`
## but we need 'pkg-config'
RUN apt-get update -y && apt-get install -y pkg-config

## prepare for web server
EXPOSE 8080
```

Base container for development

- One could create a new container with all the development tools (editor, completion, ...)
- But you'd need to carry over the configuration (`ssh` keys, editor, ...)

Probably easier to just mount the sources **inside** the base container:

```
$ docker run -it -v `pwd`:/go/src/github.com/sbinet/loops-20151217-tp \
   -p 8080:8080 <myname>/web-base bash
[root@48b2c74a5004 /go]# go run ./src/github.com/sbinet/loops-20151217-tp/web-app/main.go
2015/12/16 14:13:13 listening on: http://localhost:8080
```

In another terminal:

```
$ curl localhost:8080
hello LoOPS 20151217!



--- running external command...

>>> pkg-config --cflags python2
Package python2 was not found in the pkg-config search path.
Perhaps you should add the directory containing `python2.pc'
```

```
to the PKG_CONFIG_PATH environment variable
No package 'python2' found
error: exit status 1
```

Base container for dev - II

- On windows, the correct `-v` syntax is like:

```
$ docker run -it -v //c/Users/username/some/path:/go/src/ ...
```

github.com/docker/docker/issues/12590#issuecomment-96767796 (https://github.com/docker/docker/issues/12590#issuecomment-96767796)

Create the final container

Now that we know the base image "works", we'll automatize the build part as yet another `Dockerfile`:

- create a new `Dockerfile` file (at the root of the `git` repository) based on the `web-base` image, with the correct build+run instructions
- make sure you can `docker build` it and tag it as `web-app`
- make sure that you can still access the web server when you run:

```
$ docker run -d -p 8080:8080 <myname>/web-app
```

Hint: `ADD`

Hint: `CMD`

docs.docker.com/reference/builder/ (https://docs.docker.com/reference/builder/)

Create the final container - solutions

(see next slide)

Create the final container - II

```
## image for the web-app
FROM binet/web-base

MAINTAINER binet@cern.ch

## add the whole git-repo
ADD . /go/src/github.com/sbinet/loops-20151217-tp

RUN go install github.com/sbinet/loops-20151217-tp/web-app

CMD web-app
```

Create the final container - III

- `CMD` describes the command to be run by default when the container is started
- `ADD` copies files, directories or URLs into the container's filesystem
- `VOLUME` creates a volume mount point inside the container which can contain data from the host or from other containers
- `USER` defines the user (or `UID`) with whom to run the various commands inside the container

Create multiple versions of an image

At times, it might be very useful to test 2 versions of an application and run them concurrently (to debug discrepancies.)

Let's do just that.

- tag the last `web-app` image as v1

```
$ docker tag \
    <myname>/web-app \
    <myname>/web-app:v1
```

- modify `sbinet/loops-20151217-tp/web-app/main.go` to print a different welcome message
- containerize the new version as `.../web-app:v2`

Create multiple versions of an image - II

- run the container v2 on port 8082

```
$ docker run -p 8082:8080 \
    --name=web-app-v2     \
    <myname>/web-app:v2
```

- run the container v1 on port 8080

```
$ docker run -p 8080:8080 \
    --name=web-app-v1     \
    <myname>/web-app:v1
```

- make sure the servers on ports 8080 and 8082 display the correct welcome messages.

Sharing images

Up to now, the images you've been creating have been put on your local disk.
But there is this public registry instance available at:

hub.docker.com (https://hub.docker.com)

Let's try to package the previous `web-app:v2` and `web-app:v1` images and put them on that registry:

```
$ docker push <myname>/web-app:v1
$ docker push <myname>/web-app:v2
```

Now, try to `pull` the `web-app` image of your friend and run it.

Inspecting logs

`docker` is nice enough to let us inspect what (running) containers are generating as logs.

For a single container, it is as simple as:

```
$ docker logs <some-container-id>
$ docker logs <some-container-name>
```

- inspect the logs of your `web-app-v2` container

e.g.:

```
$ docker logs web-app-v2
2015/12/16 14:53:56 listening on: http://localhost:8080
```

Inspecting logs - II

- launch a container in interactive mode
- start a bash shell
- run inside that container:

```
docker> logger -i -s plop
```

- in another terminal:

```
$ docker logs <container-id>
```

Creation of a build+target container pair

So far, we have been building containers where the intermediate results leading to the final binary (or set of binaries) are left inside the image.

This might not be completely efficient if these intermediate steps are (disk) resource heavy.

The usual solution is to have a 2-step process:

- a container in which the binaries are built
- a container in which the binaries are directly copied from the first

Let's do that.

Hint: `docker export`
Hint: `docker import`
Hint: `docker cp`

Creation of a build+target container pair

(solution on next slide)

Creation of a build+target container pair

Extract the root fs from the build image:

```
$ mkdir rootfs && cd rootfs
$ docker run -d -p 8080:8080 --name=web-app-v2 \
    <myname>/web-app:v2
$ docker export web-app-v2 | tar xf -
$ ls go/src/github.com/sbinet/loops-20151217-tp/
Dockerfile  docker-web-base  hello  README.md web-app
$ ls go/bin
web-app
```

Another way is to use `docker cp`:

```
$ docker cp web-app-v2:/go/bin/web-app web-app
```

The binaries are under `/go/bin`.
As go usually creates static libraries, you can just create a very slim container with them, using `docker import`.

Creation of a build+target container pair

```
$ mkdir rootfs && cd rootfs
$ docker cp web-app-v2:/go/bin/web-app web-app
$ cat > Dockerfile << EOF
FROM ubuntu
ADD web-app /usr/bin/web-app
CMD web-app
EOF
$ docker build -t slim-web-app .
```

Compare the size:

```
$ docker images
ubuntu                 14.04               187.9 MB
slim-web-app           latest              196.6 MB
binet/web-app          latest              749.3 MB
golang                 1.5.2               703.8 MB
```

Running GUIs

The application we have been currently "dockerizing" doesn't need any graphics per se.
Many do, though.

Let's try to run a simple graphics-enabled application from within a `docker` container:

```
$ docker run -it --rm ubuntu bash
docker> apt-get update -y && apt-get install -y x11-apps
docker> xclock
```

Running GUIs - II

Running GUIs is a bit more involved than just running your simple "from the mill" CLI application.

There are many options to enable graphics:

- `ssh` into a container with X11 forwarding
- VNC
- sharing the X11 socket

fabiorehm.com/blog/2014/09/11/running-gui-apps-with-docker/ (http://fabiorehm.com/blog/2014/09/11/running-gui-apps-with-docker/)

blog.docker.com/2013/07/docker-desktop-your-desktop-over-ssh-running-inside-of-a-docker-container/ (https://blog.docker.com/2013/07/docker-desktop-your-desktop-over-ssh-running-inside-of-a-docker-container/)

wiki.ros.org/docker/Tutorials/GUI (http://wiki.ros.org/docker/Tutorials/GUI)

Running GUIs - III

Let's try the most direct (albeit a bit insecure) one: sharing the X11 socket.

First, allow all X11 connections (that's the insecure part):

```
$ xhost +
```

Then:

```
$ docker run -ti --rm \
      -e DISPLAY=$DISPLAY \
      -v /tmp/.X11-unix:/tmp/.X11-unix \
      ubuntu bash
docker> apt-get update -y && apt-get install -y xclock && xclock
```

Don't forget to re-enable X11 access control afterwards:

```
$ xhost -
```

Conclusions

- `docker` is a rather good tool to deploy applications in containers
- eases the life of developers and sysadmins (devops)
- `docker` isn't the only game in town
- rkt (https://coreos.com/rkt/docs) (`rocket`) from `CoreOS`
- systemd-nspawn (http://0pointer.de/public/systemd-man/systemd-nspawn.html), now part of `systemd`

References

www.slideshare.net/jpetazzo/introduction-to-docker-december-2014-tour-de-france-bordeaux-special-edition (http://www.slideshare.net/jpetazzo/introduction-to-docker-december-2014-tour-de-france-bordeaux-special-edition)

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Thank you

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