Linux Containers

Basic Concepts

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Underlying kernel mechanisms

cgroups	manage resources for groups of processes
namespaces	per process resource isolation
seccomp	limit available system calls
capabilities	limit available privileges
CRIU	checkpoint/restore (with kernel support)

cgroups - user space view

low-level filesystem interface similar to sysfs (/sys) and procfs (/proc)

new filesystem type “cgroup”, default location in /sys/fs/cgroup

cgroup hierarchies ← each subsystem can be used at most once* — **subsystems (controllers)**

```
   /sys/fs/cgroup
TL /cpu   [cpu] [cpuacct]
      /high-priority
      /normal
      /experiment_1
TL /mem   [memory]
      /opus
      /normal
      /experiment_1
```

cpuset | cpu | cpuacct

memory | hugetbl

devices | blkio | net_cls ▲ | net_prio ▲

freezer | perf

▲ built as kernel module

TL top level cgroup (mount)

cgroups - user space view

cgroup hierarchies

/sys/fs/cgroup

TL /cpu cpu cpuacct

/high-priority

/normal

/experiment_1

TL /mem memory

/opus

/normal

/experiment_1

common

tasks

cgroup.procs

release_agent **TL**

notify_on_release

cgroup.clone_children

cgroup.sane_behavior

cpuacct

cpuacct.stat

cpuacct.usage

cpuacct.usage_percpu

cpu

cpu.stat

cpu.shares

cpu.cfs_period_us

cpu.cfs_quota_us

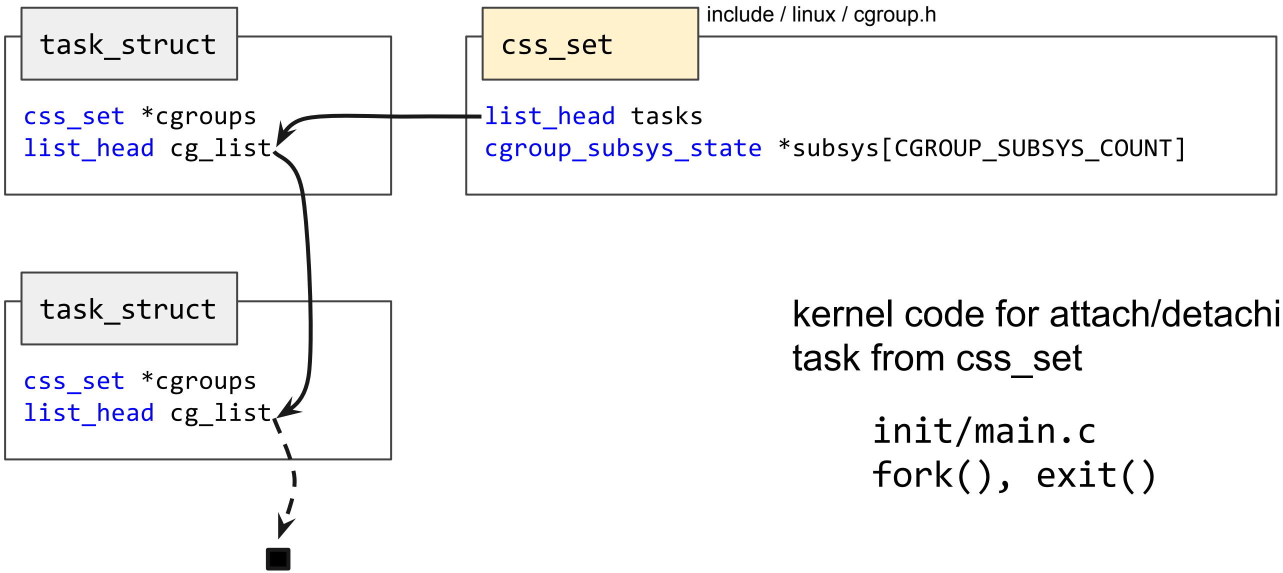
cpu.rt_period_us

cpu.rt_runtime_us

cpuset · memory · hugetbl · devices · blkio

net_cls · net_prio · freezer · perf

cgroups - kernel space view

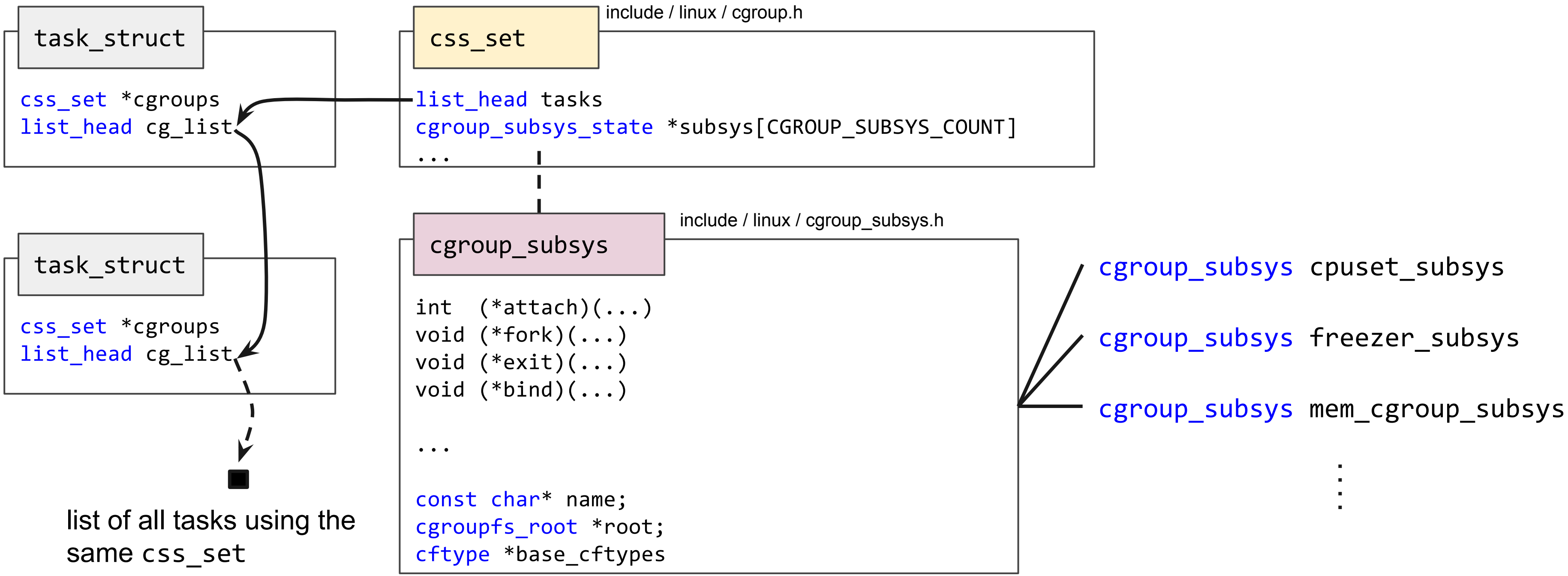


list of all tasks using the same css_set

kernel code for attach/detaching task from css_set

init/main.c
fork(), exit()

cgroups - kernel space view



cgroups - kernel space view

include / linux / cgroup_subsys.h

```
cgroup_subsys

int  (*attach)(...)
void (*fork)(...)
void (*exit)(...)
void (*bind)(...)

...

const char* name;
cgroupfs_root *root;
cftype *base_cftypes
```

```
cgroup_subsys cpuset_subsys
                        .base_cftypes = files
```

```
static struct cftype files[] = {
	{
		.name = "cpus",
		.seq_show = cpuset_common_seq_show,
		.write_string = cpuset_write_resmask,
		.max_write_len = (100U + 6 * NR_CPUS),
		.private = FILE_CPULIST,
	},

	{
		.name = "mems",
		.seq_show = cpuset_common_seq_show,
		.write_string = cpuset_write_resmask,
		.max_write_len = (100U + 6 * MAX_NUMNODES),
		.private = FILE_MEMLIST,
	},

	{
		.name = "cpu_exclusive",
		.read_u64 = cpuset_read_u64,
		.write_u64 = cpuset_write_u64,
		.private = FILE_CPU_EXCLUSIVE,
	},

	{
		.name = "mem_exclusive",
		.read_u64 = cpuset_read_u64,
		.write_u64 = cpuset_write_u64,
		.private = FILE_MEM_EXCLUSIVE,
	},
```

cgroups - summary

cgroup hierarchies ← each subsystem can be used at most once* — **subsystems (controllers)**

```
  /sys/fs/cgroup
TL  /cpu   [cpu] [cpuacct]
      /high-priority
      /normal
      /experiment_1
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cpuset	cpu	cpuacct	
memory	hugetbl		
devices	blkio	net_cls ▲	net_prio ▲
freezer	perf		

▲ built as kernel module

TL top level cgroup (mount)

namespaces - user space view

Namespaces limit the scope of kernel-side **names** and **data structures**

at process granularity

mnt	(mount points, filesystems)	*CLONE_NEWNS*
pid	(processes)	*CLONE_NEWPID*
net	(network stack)	*CLONE_NEWNET*
ipc	(System V IPC)	*CLONE_NEWIPC*
uts	(unix timesharing - domain name, etc)	*CLONE_NEWUTS*
user	(UIDs)	*CLONE_NEWUSER*

namespaces - user space view

Namespaces limit the scope of kernel-side **names** and **data structures**

at process granularity

Three system calls for management

`clone()`	new process, new namespace, attach process to ns
`unshare()`	new namespace, attach current process to it
`setns(int fd, int nstype)`	join an existing namespace

namespaces - user space view

- each namespace is identified by an *inode* (unique)
- six(?) entries (inodes) added to `/proc/<pid>/ns/`

- two processes are in the same namespace if they see the same inode for equivalent namespace types (mnt, net, user, ...)

User space utilities

* IPROUTE (`ip netns add`, etc)
* `unshare`, `nsenter` (part of util-linux)
* `shadow`, `shadow-utils` (for user ns)

namespaces - kernel space view

task_struct

```
struct nsproxy *nsproxy
struct cred *cred
```

nsproxy — include / linux / nsproxy.h

```
atomic_t count
struct uts_namespace *uts_ns
struct ipc_namespace *ipc_ns
struct mnt_namespace *mnt_ns
struct pid_namespace *pid_ns_for_children
struct net           *net_ns
```

cred — include / linux / cred.h

```
...
struct user_namespace *user_ns
```

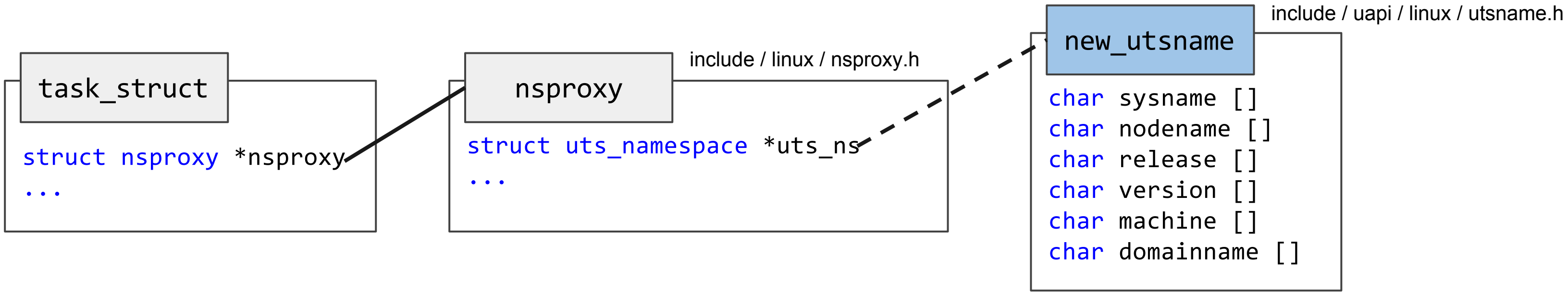
include / linux / nsproxy.h

```
nsproxy* task_nsproxy(struct task_struct *tsk)
```

- For each namespace type, a default namespace exists (the global namespace)
- `struct nsproxy` is shared by all tasks with the same **set** of namespaces

namespaces - kernel space view

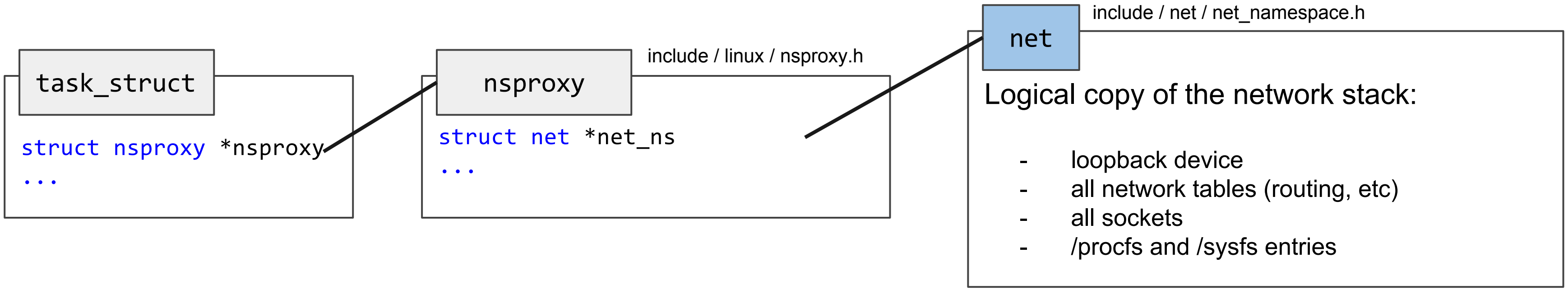
Example for **uts** namespace



- global access to hostname: `system_utsname.nodename`
- namespace-aware access to hostname: `&current->nsproxy->uts_ns->name->nodename`

namespaces - kernel space view

Example for **net** namespace



- a network device belongs to exactly one network namespace
- a socket belongs to exactly one network namespace
- a new network namespace only includes the loopback device
- communication between namespaces using veth or unix sockets

namespaces - summary

Namespaces limit the scope of kernel-side **names** and **data structures**

at process granularity

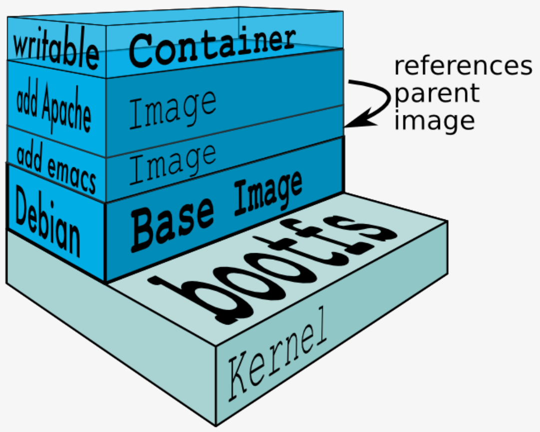
mnt (mount points, filesystems)
pid (processes)
net (network stack)
ipc (System V IPC)
uts (unix timesharing - domain name, etc)
user (UIDs)

Containers

- A light form of resource virtualization based on kernel mechanisms
- A container is a *user-space* construct

- Multiple containers run on top of the same kernel
  - illusion that they are the only one using resources (cpu, memory, disk, network)

- some implementations offer support for
  - container templates
  - deployment / migration
  - union filesystems



taken from the Docker documentation

Container solutions

Mainline

Google containers (lmctfy)

- uses cgroups only, offers CPU & memory isolation
- no isolation for: disk I/O, network, filesystem, checkpoint/restore
- adds some cgroup files: `cpu.lat`, `cpuacct.histogram`

LXC: user-space containerisation tools

Docker

systemd-nspawn

Forks

Vserver, OpenVZ

Container solutions - LXC

An LXC container is a userspace process created with the `clone()` system call

- with its own pid namespace
- with its own mnt namespace
- net namespace (configurable) - lxc.network.type

Offers container templates `/usr/share/lxc/templates`

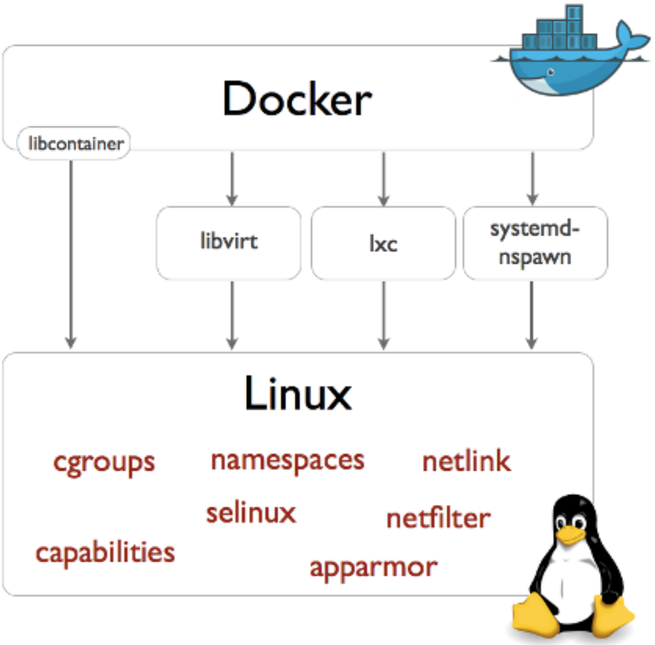
- shell scripts
- `lxc-create -t ubuntu -n containerName`
    - also creates cgroup `/sys/fs/cgroup/<controller>/lxc/containerName`

Container solutions - Docker

A Linux container engine

- multiple backend drivers
- application rather than machine-centric
- app build tools
- diff-based deployment of updates (AUFS)
- versioning (git-like) and reuse

- links (tunnels) between containers



taken from the Docker documentation

Questions?

Thank you!

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More details

cgroups: http://media.wix.com/ugd/295986_d73d8d6087ed430c34c21f90b0b607fd.pdf

namespaces: http://lwn.net/Articles/531114/ (and series)