Brave new world of unified cgroups

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Why this talk?

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Unified hierarchy (a.k.a.) cgroups v2 is the default default in systemd 243 (Sept. 2019)

`https://fedoraproject.org/wiki/Changes/CGroupsV2` (for F31+)

Version two is just nicer!

Control groups

Control groups (cgroups) is a Linux subsystem that has two main purposes:

- Process tracking
- Resource distribution

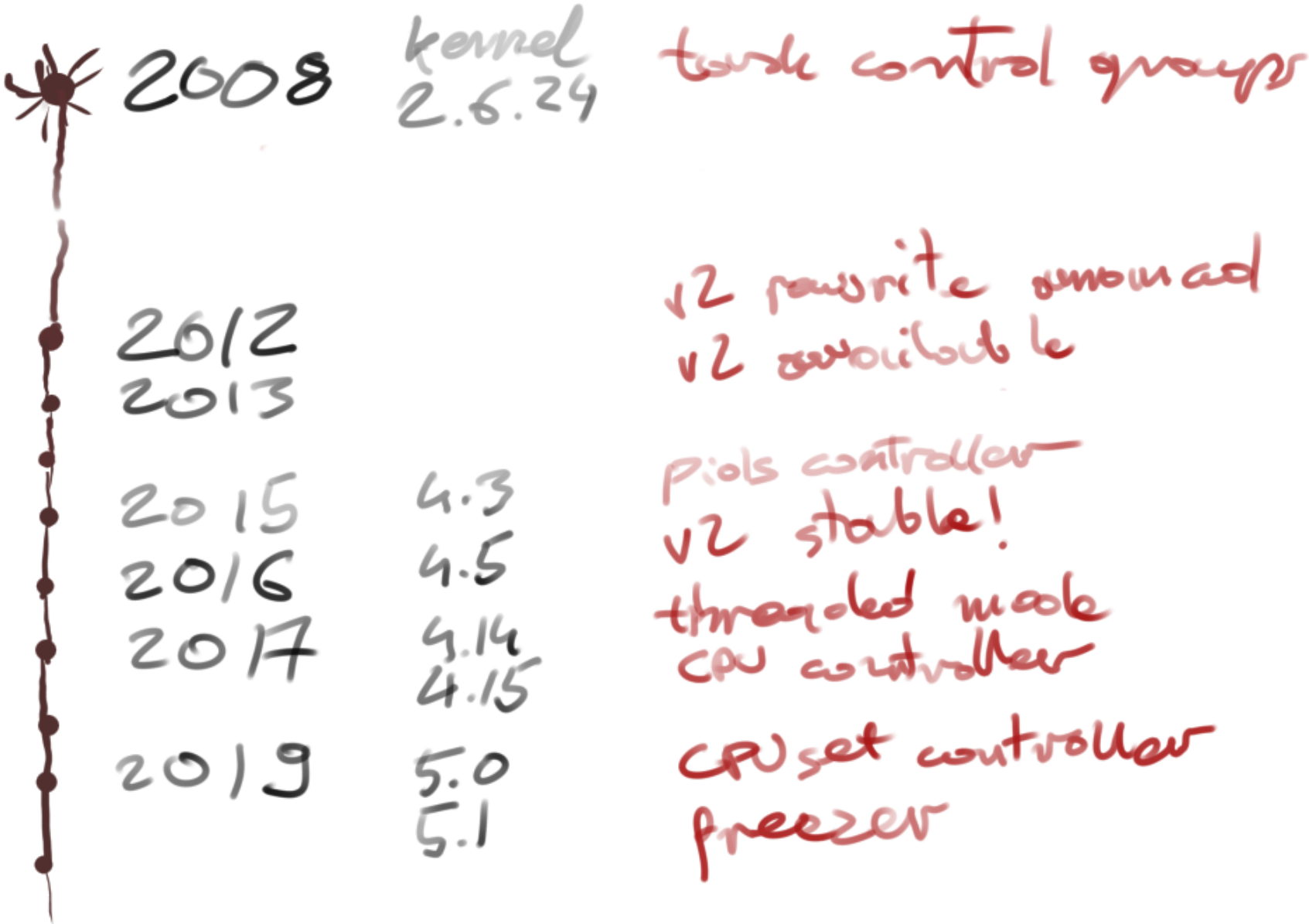
Control groups

Cgroup – associates a set of tasks with a set of parameters for one or more controllers

Controller – schedules a resource or applie per-cgroup limits

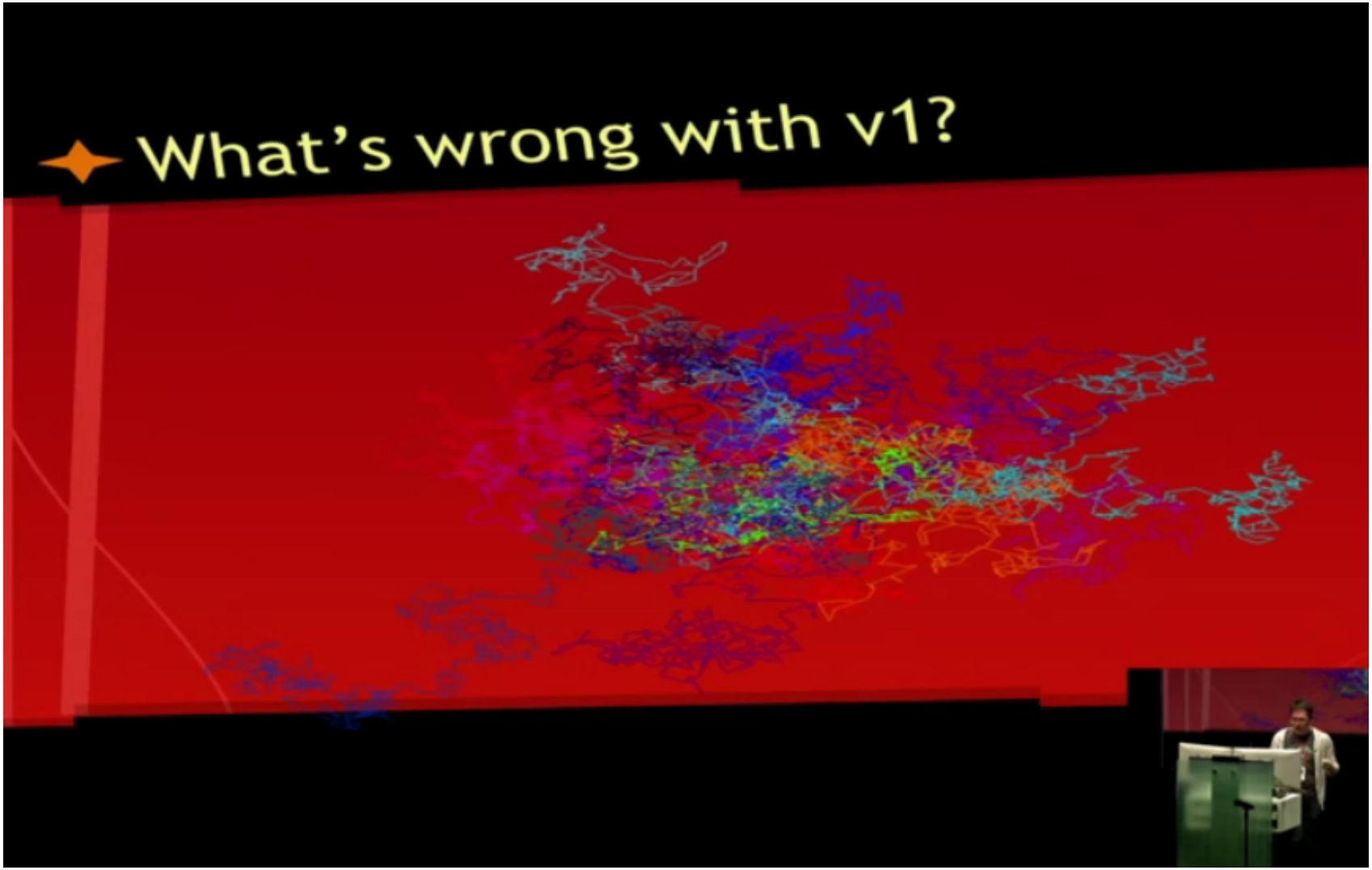
Hierarchy – set of cgroups arranged in a tree, every process is in exactly one cgroup

Brief history of cgroups in the linux kernel



Why?

What's wrong with v1



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- no cooperation between contollers
- threads not processes
- no secure delegation

```
$ ls /sys/fs/cgroup/memory/
...
memory.limit_in_bytes       memory.kmem.tcp.limit_in_bytes
memory.usage_in_bytes       memory.kmem.tcp.usage_in_bytes
memory.max_usage_in_bytes   memory.kmem.tcp.max_usage_in_bytes
memory.soft_limit_in_bytes

memory.kmem.limit_in_bytes     memory.memsw.limit_in_bytes
memory.kmem.usage_in_bytes     memory.memsw.usage_in_bytes
memory.kmem.max_usage_in_bytes memory.memsw.max_usage_in_bytes

memory.kmem.slabinfo              memory.use_hierarchy
memory.move_charge_at_immigrate   cgroup.sane_behavior
...
```

inconsistent interface

v1	default	range
`cpu.shares`	1024	2-262144
`blkio.bfq.weight`	500	10–1000
v2		
`cpu.weight`	100	1–10000
`io.weight`[1]	100	1–10000

[1] `https://github.com/systemd/systemd/pull/13335`

v2

Design:

- single hierarchy
- consistent interface
- small number of controllers: memory, io, pids, cpu, cpuset
- controllers are fully hierarchical
- (controllers can be turned off midway throught the tree)
- high-level knobs
- soft limits
- non-hierarchical controllers are gone

Old vs. New

v1 controller	v2 solution
memory	memory
cpu+cpuacct	cpu
cpuset	cpuset
blkio	io
pids	pids
hugetlb	hugetlb (kernel 5.6)

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devices	eBPF filters
net_cls,net_prio	matching by cgroup, eBPF
perf_event	eBPF

Delegation

- Less-privileged process owns a part of the cgroup tree
- Implemented through file system permissions
- Delegate=yes in systemd units
- Cutoff is not at the directory level

$ sudo systemd-cgls

```
Control group /:
-.slice
├─user.slice
│ ├─user-6.slice
│ │ └─user@6.service …
│ │   └─init.scope
│ │     ├─1963 /usr/lib/systemd/systemd --user
│ │     └─2001 (sd-pam)
│ └─user-1000.slice
│   ├─user@1000.service …
│   │ ├─gsd-xsettings.service
│   │ │ └─412129 /usr/libexec/gsd-xsettings
│   │ ├─gvfs-goa-volume-monitor.service
│   │ │ └─412027 /usr/libexec/gvfs-goa-volume-monitor
│   │ ├─gsd-power.service
│   │ │ └─412104 /usr/libexec/gsd-power
│   │ ├─dbus\x2d:1.1\x2dorg.gnome.Epiphany.SearchProvider.slice
│   │ │ └─dbus-:1.1-org.gnome.Epiphany.SearchProvider@0.service
│   │ │   └─415659 /usr/libexec/epiphany-search-provider
│   │ ├─xdg-permission-store.service
│   │ │ └─411997 /usr/libexec/xdg-permission-store
│   │ ├─dbus-broker.service
│   │ │ ├─411532 /usr/bin/dbus-broker-launch --scope user
│   │ │ └─411533 dbus-broker --log 4 --controller 11 --machine-id 08a5690a2eed47cf92ac0a
│   │ ├─xdg-document-portal.service
│   │ │ └─412300 /usr/libexec/xdg-document-portal
│   │ ├─dbus\x2d:1.1\x2dorg.gnome.OnlineAccounts.slice
│   │ │ └─dbus-:1.1-org.gnome.OnlineAccounts@0.service
│   │ │   └─412024 /usr/libexec/goa-daemon
│   │ ├─tracker-store.service
│   │ │ └─468488 /usr/libexec/tracker-store
```

```
$ ls -l .../user.slice/user-1000.slice/user@1000.service
-r--r--r--. root    root    cgroup.controllers
-r--r--r--. root    root    cgroup.events
-rw-r--r--. root    root    cgroup.freeze
-rw-r--r--. root    root    cgroup.max.depth
-rw-r--r--. root    root    cgroup.max.descendants
-r--r--r--. root    root    cgroup.stat
-rw-r--r--. zbyszek zbyszek cgroup.procs
-rw-r--r--. zbyszek zbyszek cgroup.threads
-rw-r--r--. zbyszek zbyszek cgroup.subtree_control
-r--r--r--. root    root    pids.current
-r--r--r--. root    root    pids.events
-rw-r--r--. root    root    pids.max
...
drwxr-xr-x. zbyszek zbyszek pipewire.service/
drwxr-xr-x. zbyszek zbyszek pulseaudio.service/
drwxr-xr-x. zbyszek zbyszek xdg-desktop-portal-gtk.service/
drwxr-xr-x. zbyszek zbyszek xdg-desktop-portal.service/
drwxr-xr-x. zbyszek zbyszek xdg-document-portal.service/
```

Delegation

is not all or nothing

- Delegate=io pids memory ...
- Delegation may be nested
- Resources are divided hierarchically

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`cgroup.threads`

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`cgroup.threads`

Used by libvirt to manage QEMU vCPU threads

Resource management – Resource distribution models

- **Weights**
  - Resource is distributed by adding up the weights of all sub-cgroups and giving each the fraction matching its ratio against the sum.
  - Usually used to distribute stateless resources (CPU time)
  - Example: cpu.weight ([1-10000], default 100)

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- **Protections**
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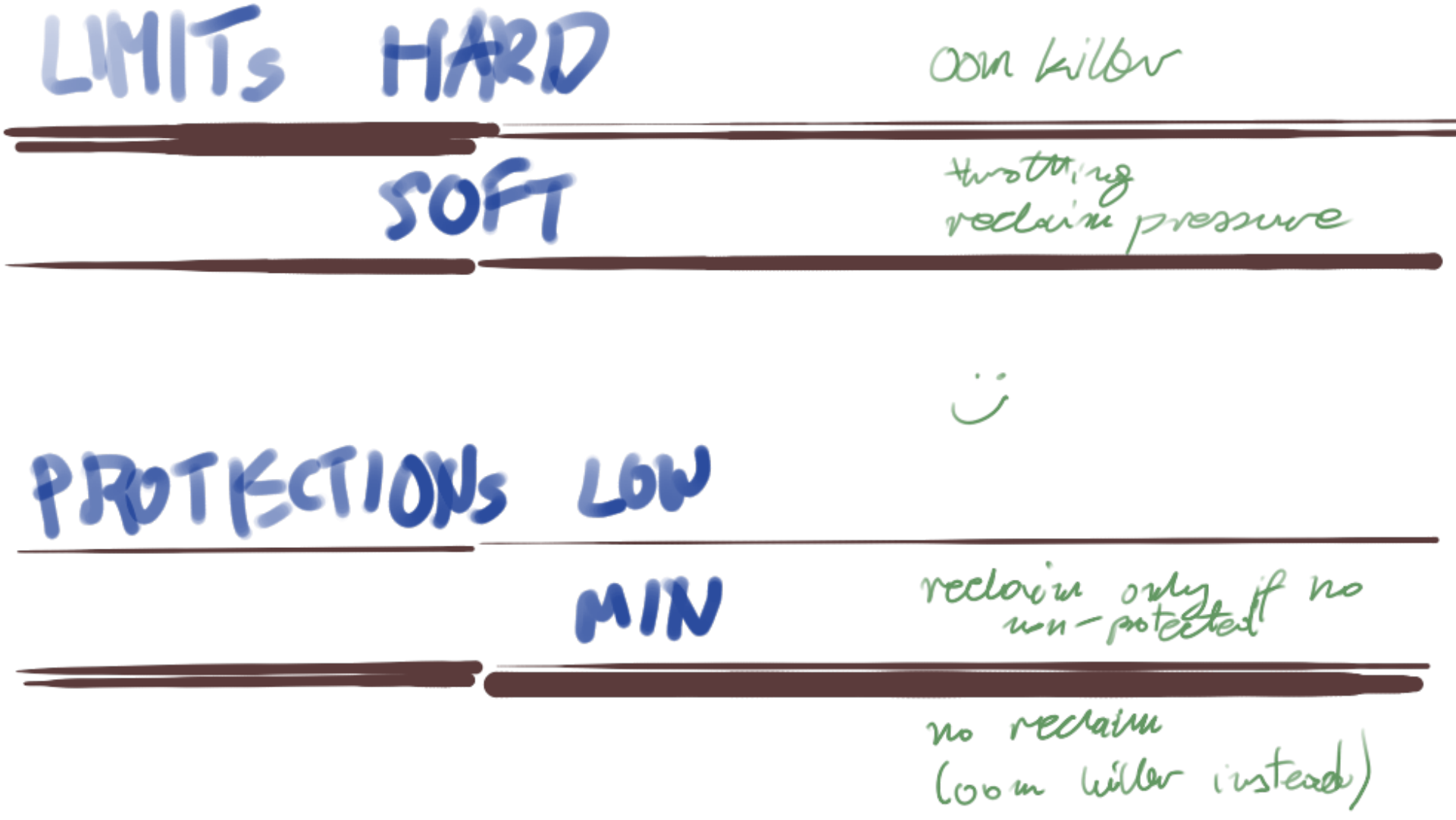
- **Allocations**
  - Exclusive allocations of the absolute amount of a finite resource (e.g. real-time budget)

Memory protections and limits



Resource management – Memory

cgroup v2 memory controller implements memory usage limits but also very useful protections (not available in cgroup v1),

- **memory.min** – Hard memory protection. If memory usage is below the limit the cg memory won't be reclaimed.
- **memory.low** – Soft memory protection. If memory usage is below the limit the cg memory can be reclaimed only if there is no memory to be reclaimed from unprotected cgroups.
- **memory.high** – Memory throttle limit. If memory usage goes above the limit the processes in the cgroup are throttled and put under heavy reclaim pressure.
- **memory.max** – Hard limit for memory usage (OOM killer is invoked if usage goes above the limit)

Resource management – Block I/O

`io` controller in cgroup v2 allows for very fine grained settings (per device)

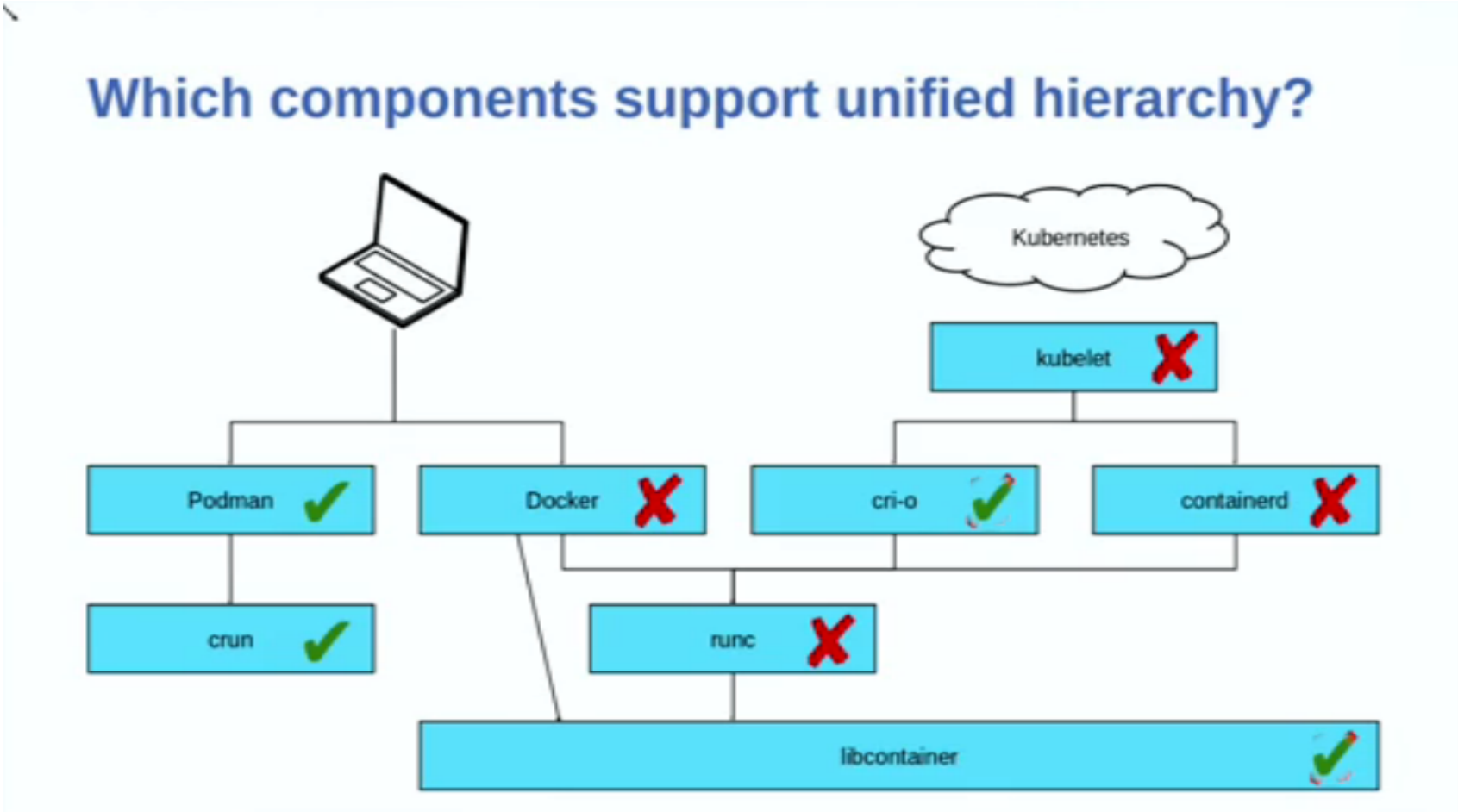
- **io.weight** – IO weight (work-conserving)
- **io.max** – per-device absolute bandwidth limit (e.g. `8:16 rbps=2097152 wiops=120`)
- **io.latency** – per-device latency target protection (e.g. `8:16 target=10000`)

Status quo

v1 only: k8s, CRI-O, Docker, Containerd, runc (in progress), OCI runtime spec

v2 too: Buildah+Podman+skopeo, crun, libvirt, JVM, snapd, systemd

Status of container runtimes



Summary

control groups v2:

- Fully hierarchical with safe delegation
- Consistent inteface
- Efficient and scalable notifications
- Fewer controllers, high-level knobs
- Soft limits
- eBPF!
- Better monitoring: Pressure Stall Information (PSI)

Links

this talk: https://github.com/keszybz/cgroupsv2/raw/master/cgroupsv2.pdf

docs:
https://www.kernel.org/doc/html/latest/admin-guide/cgroup-v1/
https://www.kernel.org/doc/html/latest/admin-guide/cgroup-v2.html
https://facebookmicrosites.github.io/cgroup2/docs/overview
systemd.resource-control(5)
https://systemd.io/CGROUP_DELEGATION.html

recent changes:
https://www.redhat.com/sysadmin/fedora-31-control-group-v2
https://fedoraproject.org/wiki/Changes/CGroupsV2
https://www.youtube.com/watch?v=GznkuTXq8AQ&t=1s
https://medium.com/nttlabs/cgroup-v2-596d035be4d7
https://www.youtube.com/watch?v=yZpNsDe4Qzg (Michael Kerrisk)
freezer for cgroup v2 v5.1-rc3-45-g76f969e894
https://lwn.net/Articles/772377/

https://bugzilla.redhat.com/show_bug.cgi?id=1727149 libvirt support in 5.5.0

https://bugzilla.redhat.com/show_bug.cgi?id=1438079 snapd support in snapd-2.41-1.fc31

https://github.com/opencontainers/runc/pull/2113 for libcontainer

https://github.com/opencontainers/runc/issues/654 for runc

https://github.com/kubernetes/enhancements/pull/1370/files for k8s

codesearch.debian.net/search?q=cgroup.type

https://www.kernel.org/doc/html/latest/accounting/psi.html

Links

history:
https://kernelnewbies.org/Linux_2_6_24#Task_Control_Groups
https://kernelnewbies.org/Linux_3.16#Unified_Control_Group_hierarchy
State of CPU controller in cgroup v2 (2016)
LWN: A milestone for control groups (2017)
Linux 4.15
v4.14-rc2-7-g0d5936344f
https://www.youtube.com/watch?v=PzpG40WiEfM

https://www.youtube.com/watch?v=ikZ8_mRotT4