Recent advances in the Linux kernel resource management

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Agenda

- Resources to account and control
- Some background on containers
- Existing functionality, shortcomings
- Control Groups a.k.a. cgroups
- Memory Controller
- Future work
Resources
Why?

- All resources are finite
- Multiple tasks and users
- Need usage statistics / bookkeeping
- Need Denial of Service protection
- Need Quality of Service level (not only limits but guarantees)
What?

- CPU
- Memory (RAM)
- Swap
- Disk space
- Disk I/O
- Network
Resources: CPU

CPU is given to tasks in time slices

- CPU shares/weights
- CPU limits
- for SMP: CPU affinity
Resources: Memory & swap

- User memory
  - Virtual and physical (RSS) memory
  - Dirty page cache
- Kernel memory
  - Various objects, different allocators
  - Special case: network buffers
- Swap space
Resources: disk

• Disk space
• Disk I/O bandwidth
  – read/write
  – mmap()
  – swapin/swapout
  – Problem: most of I/O is async
Resources: networking

• Network bandwidth: solved by tc
• Traffic Control:
  – Shaping
  – Scheduling
  – Policies
  – Dropping
Containers
What are containers?

- Multiple isolated userspace instances
- Running on top of a single kernel
- Like VMs but very lightweight, native performance, low overhead
Containers Implementations

- OpenVZ
- Parallels Virtuozzo Containers
- FreeBSD jails
- Linux-VServer
- Solaris 10 Containers/Zones
- IBM AIX6 WPARs (Workload Partitions)
Containers cont'd

- Multiple containers should peacefully co-exist, need DoS protection
- From the resource management point of view, containers are just groups of processes.
Existing mechanisms
Disk Quota

- Per mount point disk quota for users and groups
- Soft limits, hard limits, grace periods
- Can see the current usage
- Can be inc'd/dec'd on-the-fly
- Applications are expecting disk space shortage (or at least should be)
CPU

- Per-process nice value which can be changed on-the-fly (nice, renice)
- Real-time priority queue
- Hard CPU time limit (ulimit -c)
ulimit

• setrlimit()/getrlimit() syscalls

• Controls 16 different resources:
  core file size, data seg size, scheduling priority, file size, pending signals,
  max locked memory, max memory size, number of open files, pipe size,
  POSIX message queues, real-time priority, stack size, cpu time, max user processes,
  virtual memory, file locks

• Soft limits and hard limits
ulimit: problems

- Not all resources are covered
- Ulimits set in the current context
  - the only good place to set is login
  - some can only be decreased run-time
- All limits are per-process
  - only NPROC is per-UID
- Current usage values are unknown
- Memory limits are mostly ignored
Control Groups
Control Groups

- A generic mechanism for grouping tasks into hierarchical groups
- Multiple resource controllers
- Possible to have different groups for different controllers
- Managed via cgroup filesystem
Control Groups: interface

Managed via cgroup filesystem:

```bash
mkdir /dev/cgroup
mount -t cgroup none /dev/cgroup
mkdir /dev/cgroup/0
cd /dev/cgroup/0
echo $$ > tasks
cat /proc/self/cgroup
/etc/init.d/httpd start
```
Control Groups: history

- A feature known as cpusets was developed by big iron Bull/SGI guys
- Used to maintain process groups to NUMA nodes affinity
- Paul Menage generalized it
- Now cpusets is just one of the resource controllers
Memory Controller
Memory controller

- User memory:
  - RSS
  - Page cache
- Reclamation
  - Same as `try_to_free_pages()`
- OOM killer
VMAs classification

- unreclaimable: private and anonymous
- reclaimable: shared file mappings

Pages classification

- unused: parts of mapped regions
- used: touched pages
MemCtrl: interface

# echo 4M > memory.limit_in_bytes
# cat memory.limit_in_bytes
4194304
# cat memory.usage_in_bytes
172032
# cat memory.max_usage_in_bytes
294912
# cat memory.failcnt
0
# cat memory.stat
....
Shared Pages accounting

- Shared code/library segments
- Approaches:
  - Charge to the first user only (unfair)
  - Charge to all users (incorrect totals)
  - Charge a fraction to every user
Page fractions accounting

Algorithm benefits

- $O(1)$ algorithm of adding and removing

The sum of RSS on all beancounters is an amount of all actually used pages
Future
Future a.k.a. TODO

- Shared pages accounting
- VMA (user mappings) length ctrl
- Kernel memory controller
- cgroups checkpoint/restart
- per-cgroup I/O priorities
- All that is available in OpenVZ; needs to be ported to mainstream
More Info

/usr/src/linux/Documentation/cgroups/*

/usr/src/linux/Documentation/controllers/*

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Questions? Comments?

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OpenVZ
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