Manage Performance with Cgroups and Projects

David Collier-Brown

Agenda

- Introduction
- Resource Managers for Linux and Unix
- Containers, cgroups and the Completely Fair Scheduler
  - > CPU management
  - > Memory management
  - > I/O
  - > Network
- Cgroups in Practice
- Conclusions

Some Things Won't Fit

- For example, a fridge in a French minicar
- Or an ad-hoc reporting program in a small, fast website

Imagine for a Moment

- You're the sysadmin for a successful LAMP-based web site
- Management has just gifted you with a new ad-hoc reporting program.
- You now have to somehow shoehorn it in
  - Without affecting the performance

- Insoluble problem?
- Not a bit of it!

Limit Reporting to Spare Cycles

- Production is more important, so reporting should take a second place
- It should only get CPU, I/O or network bandwidth when production doesn't need it

Add Resource Management

- What's needed is a resource manager like cgroups
- Assign most of the CPU, memory or I/O bandwidth to the more important programs
- And then give any other programs, including reporting, a fair share of what's left.

A Classic Capacity problem

- This is the performance *management* problem.
- Make sure non-critical programs don't interfere with important ones,
- And ensure there is a bit of CPU for root to use to stop and diagnose runaway programs.

- You can't create resources out of nothing
- You can do a lot more than you'd think

My Laptop is Too Slow!

- As a practical example,I have a CPU- and disk-hog Solaris data-analysis batch program.
- My laptop is just a bit too slow for it
- Whenever I run it, even with nice -20, it takes 100% of the CPU and a big chunk of the disk bandwidth.
- That's so much that I can't keep up with my everyday work.
  - I can't even read email when it's hogging the machine.

So I Ration It

- To solve this, I give
  > one share of the CPU to the background program,
  > three shares to everything else.
- Now I can run the job and the only indication is the Gnome perfmeter is pegged at 100%:
- my interactive programs run at full speed.

What's Happening

- The background program is cut to 25% whenever other programs need CPU,
- But is allowed to use all the CPU it wants when I'm thinking and neither typing nor moving the mouse.
- This keeps it from issuing enough I/Os to make my disk non-responsive.
  - That's a lucky side-effect
- It's enforcing a least upper bound

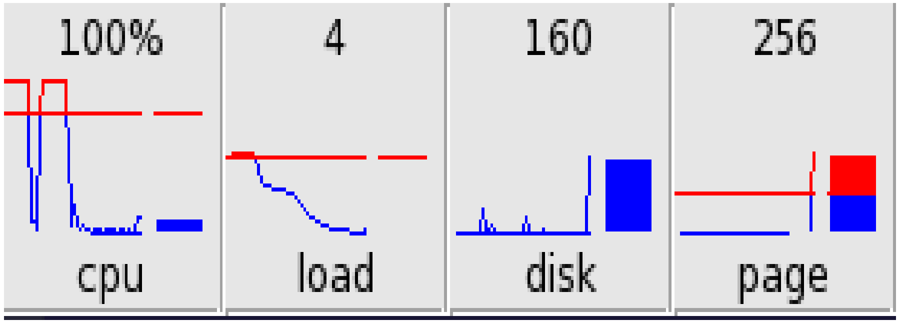
My process status looked like this:

PROJID	NPROC	SIZE	RSS	MEMORY	TIME	CPU	PROJECT
100	2	2304K	1232K	0.2%	00:02:26	92.0%	bg
101	32	919M	277M	56%	00:02:54	6.5%	user.davecb
0	39	164M	62M	13%	00:00:28	0.1%	system
3	2	14M	3264K	1%	00:00:00	0.00%	default

- The project containing the background job averaged 92% of the CPU, and I averaged only 6.5% over 10 seconds,
- But whenever user davecb ran anything, *that* program got at least 25% of the CPU.
- That was far more than I needed for

Interactive editing was fast...

- Well, as fast as OO ever is.
- I literally needed to keep checking the perfmeter to see when the batch job was done.



Resource Managers for Linux and Unix

- Back in the days of the IBM mainframes, resource management was critical: hundreds of users need to be able to get their fair share a single machine.
- Nor could they afford to let a program with a memory leak steal all the memory from everyone else.

Minis and Micros

- For many years, mini and microcomputers had so little performance that you only ran one program per machine, and didn't have to worry about sharing.
- Now, however, the average Linux machine
  - has the power of an older mainframe and
  - will be running seventy-odd processes by the time the first user has logged on.

Resource Managers Redux

- Because of this, resource managers are coming back, starting with the commercial Unixes like Solaris and AIX.
- The 2.6 kernel has a fair-share scheduler and "cgroups", the performance management infra-structure for Linux containers.
- Linux is now a hotbed of resource management research

Control Groups and the CF Scheduler

- Cgroups are “control groups”, an elegant extension to ordinary groups to allow resource management.
  - If a program is in a particular control group, it will given a specific share of the resources of the machine
- For example, consider an overloaded disk
  - all the programs in a group with a guarantee of 10% of the bandwidth of a particular disk will share that 10 percent whenever the disk is busy.
  - When no-one else is using the disk, the members of that same group could take

Control Groups

- Control groups are the low-level mechanism in Linux to provide resource guarantees to containers and virtual machines.
- They are artifacts of the “Completely Fair Scheduler”, CFS.
- Like many Unix constructs, they are organized in a virtual filesystem under /cgroups (or /containers, this is still being debated)

A Container Example

- Assuming you're creating containers, you write and read files to define them
- For example:

  # mount -t container -o cpu /containers/cpu

  # mount -t container -o net /containers/net

  # mkdir /containers/*new_container*

  # echo $$ >/containers/*new_container*/tasks

And They're Recursive

- They started out as a way to manage resources for
  - containers (lightweight virtual machines) or
  - conventional VMs,
- They allow you to give VMs shares of the real physical machines.
- They aren't restricted to virtual machines though:
  - they can manage resources and therefor the performance of ordinary processes, too.
  - Either inside VMs or under the native OS

CPU Management

- CPU Management is pretty easy
  - > done by scheduling the CPU
  - > Hierarchical or recursive
- Strengths & weaknesses
  - > Very simple and low-cost
  - > Only affects other resources by accident
- My Solaris example “works by accident”
  - > It prevents the programs from issuing enough reads
  - > Nice -40 would have worked, if it existed
  - > But this trick works for diets, so it's not

Memory Management

- Open Office could use this feature
  > It keeps pushing everything else out of memory
  > It really doesn't need to
- Current Linux experiments:
  > keep RSS at a specified level
  > weakly tracks shared libraries, first cgroup to use one gets billed for it
  > Don't use least upper bound
- Future experiments may do it differently
  > "soft limits" are least upper bounds

I/O Management

- Done via the Linux I/O scheduler
  - > Solaris lacks this (and I really want it)
  - > Doesn't dispatch I/Os if it will exceed the cgroup's ration of bandwidth
  - > Equivalent to adding think time (Z)
  - > Can set a bound on total bandwidth
    - – We'll see this in a moment...
- Uses a virtual filesystem too

```
# /bin/echo <device>:<bandwidth> \
  <cgroup>/blockio.bandwidth
```

I/O Management II [Updated]

- Solaris lacks a scheduler
- But ZFS has one now
  - > Implemented the same way as the Linux I/O bandwidth management, by adding sleeps before the write attempts

A Extended Example

- Mount the cgroup filesystem (blockio subsystem):

  ```
  # mkdir /mnt/cgroup
  # mount -t cgroup -oblockio blockio /mnt/cgroup
  ```

  - Note that this developer put them under a different directory

- Instantiate the new cgroup "foo":

  ```
  # mkdir /mnt/cgroup/foo
  ```

- Add the current shell process to the cgroup "foo":

  ```
  # /bin/echo $$ > /mnt/cgroup/foo/tasks
  ```

I/O Example II

- +Give maximum 1MB/s of I/O bandwidth on /dev/sda1 to the cgroup "foo":

  ```
  # /bin/echo /dev/sda1:1M \
  >/mnt/cgroup/foo/blockio.bandwidth
  ```

- And 8MB/s of I/O bandwidth on /dev/sdb f

  ```
  # /bin/echo /dev/sda5:8M \
    >/mnt/cgroup/foo/blockio.bandwidth
  ```

- Start a subshell in cgroup "foo" for the test
  - it can use a maximum I/O bandwidth of 1MB/s on /dev/sda1 and 8 MB/s on sda5

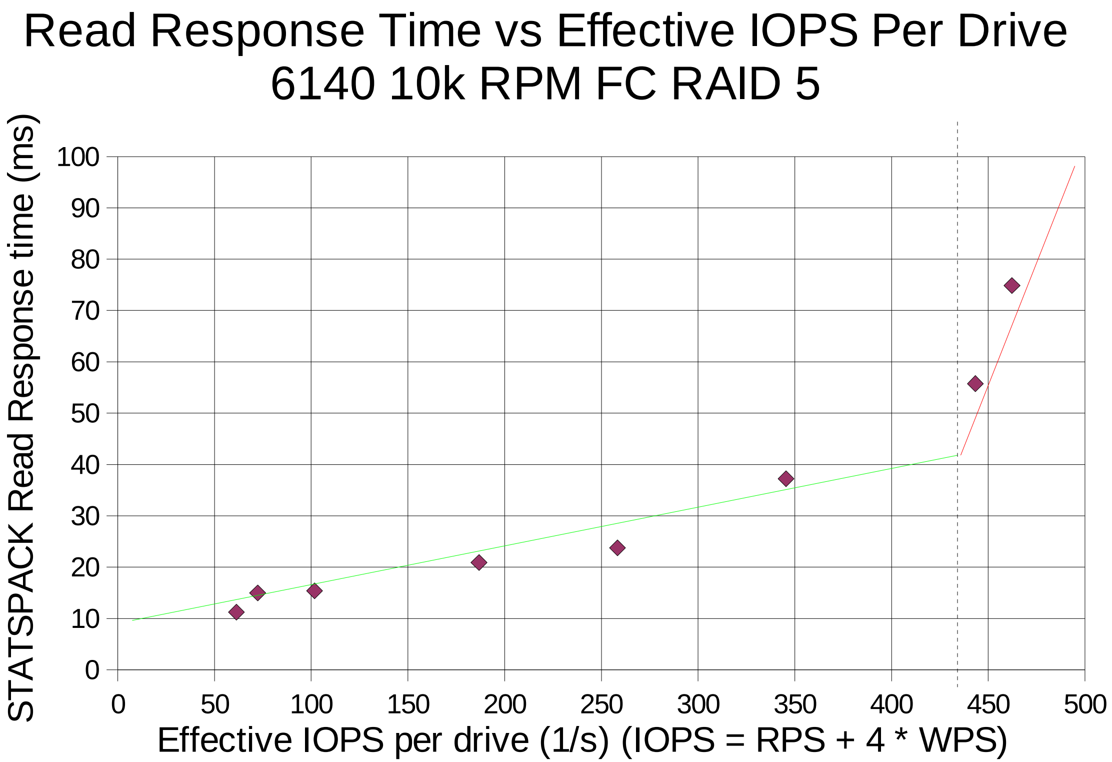
I/O Example III

- Now run a benchmark doing I/O on sda1 and 5
- I/O limits and usage are readable from the VFS:

```
# cat /mnt/cgroup/foo/blockio.bandwidth
=== device (8,1) ===
    bandwidth limit: 1024 KiB/sec
  current i/o usage: 819 KiB/sec
=== device (8,5) ===
    bandwidth limit: 1024 KiB/sec
  current i/o usage: 3102 KiB/sec
```

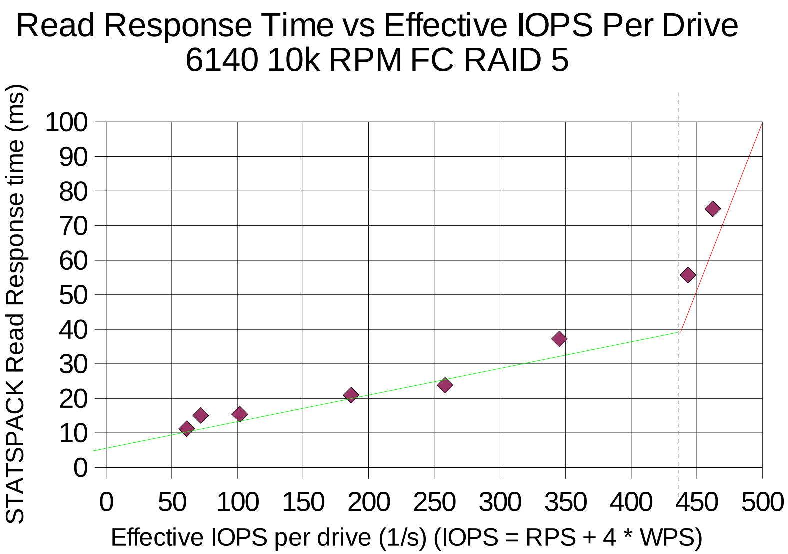
- Default units are KB/S

Why I/O Limiting Works



- This is the measured performance of a disk array
  - > Note the degradation after 400 start-I/Os per second

Why I/O Limiting Works II



- At 400 start-IOs/S
  - 40 milliseconds
- At 500
  - 80 milliseconds
- This disk is in *pain*
- So insert 10 milliseconds delay
  - Same as reducing demand to 400 IOPS
  - Service time falls back to 40 milliseconds
  - 30 milliseconds better than without the delay

This Applies to Most Limits

- Anything that can build up a queue
- That's why Apache has a tunable to reject more than N connections
  - N at 40 milliseconds is better than n+25% at 80 Milliseconds
- CPU, Disk and I/O apply
- Memory and caches don't
  - until they're full and degrade to the speed of the paging disk or the bus

Networks Too

- Make a cgroup of file transfer processes and assign it a unique classid # of 0x1234
  - mkdir -p /dev/cgroup
  - mount -t cgroup tc -otc /dev/cgroup
  - mkdir /dev/cgroup/file_transfer
  - echo 0x1234 > /dev/cgroup/file_transfer/tc.classid
  - echo $$ > /dev/cgroup/file_transfer/tasks

Networks Too, II

- Now create a HTB class that rate limits traffic to 100mbits and filter to direct all traffic from cgroup file_transfer to this new class.

  ```
  # tc qdisc add dev eth0 root handle 1: htb
  # tc class add dev eth0 parent 1: classid 1:2 htb rate 100mbit ceil 100mbit
  # tc filter add dev eth0 parent 1: protocol ip prio 1 handle 800 cgroup value 0x1234 classid 1:2
  ```

- Yet another variant on the syntax...

Networks Too [Updated]

- Solaris added “Virtual NIC Cards”
  - December 4th, 2008
  - Can be assigned to any zone/VM
- They can limit & prioritize “flows”
  - Where a flow is a group of port and IP adresses
- You could have a priority flow for all https
  - And a low-priority one for http & ftp

Cooperative Networking with Trickle

- Already available for OpenBSD, Linux i386, Solaris SPARC, NetBSD/Alpha and FreeBSD
- Implemented as a shared library
  - Doesn't require OS support
  - Can't impose itself, though
  - The BOFH can, though
- Has a management daemon
  - You can trickle all the machine in your home net
- http://monkey.org/~marius/pages/?page=trickle

This is an Immature Area

- Measurement tools are missing
  - No pmap -x
  - No by-cgroup stats
- To find libraries, for example,
  - # strace -p <pid> | grep 'open.*\.so'
- But give them about a week (;-))

Cgroups in Practice

- Already in Fedora
- There, you can:
  - Set up CPU groups for main apps
  - Create a new one for reporting
- See what it bottlenecks -
  - it may be I/O
  - set limits
- Stress-test the new program
  - with normal production unaffected
- This is also handy for developers

Conclusions

- Cgroups are here now, in Fedora
  - > There are upsides and downsides
  - > There's LOTS of room to improve

Downsides

- Least upper bounds are weird
  - They're not well-studied, so they can be contra-intuitive
- It's hard to measure per-cgroup CPU
  - This week, anyway
- Users WILL get it wrong
  - The Bob Sneed story

Upsides

- Containers and application to VMs coming
- IBM is doing magic with “goal mode”
  > A daemon manages whole mainframe VMs
- You can guarantee
  > production gets 3 second response time minimums
  > Reporting gets 40 seconds minimum
- If the production VM falls below it's goal,
  > it gets more resources at the expense of

Do Try This At Home

- Try Trickle almost anywhere
  - Especially for those &#$%! downloads
- Or if you're running Fedora
  - At the very least, it will make your laptop or desktop survive CPU hogs
- Reccommend it to any production folks running Solaris

Sun microsystems

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David Collier-Brown
davecb@sun.com
davecb@spamcop.net