Scheduling in Xen: Present and Near Future

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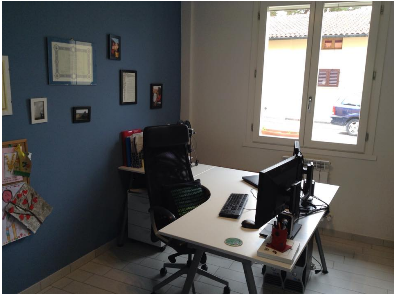
Introduction

Welcome

- Hello, my name is Dario
- I'm with Citrix since 2011 (in the Xen Platform Team)

Welcome (cont.)

Not often around here in 101... Because I work from home!



A bit of a Background (Check ;-)

- Computer Engineering MSc $\rightarrow$ Ph.D on Real-Time Scheduling
- Scheduling already... but OS scheduling!
- What about virtualization:

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- Computer Engineering MSc $\rightarrow$ Ph.D on Real-Time Scheduling
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"I'm not a virtualization kind of guy.
I think virtualization is evil"[*]

[*] a well known benevolent dictator

Me and Scheduling

- Not too good at nonsensical math

$$\forall R_j \mid \tau_i \in \Gamma_j, I_i^j = \sum_{k \mid \tau_k \in \Phi_i^j} \xi_k(R_j) + \biguplus^{m-1} \Omega_i^j \qquad (2)$$

and

$$I_i = \sum_{j \mid \tau_i \in \Gamma_j} I_i^j \qquad (3)$$

- Focused on implementing Real-Time scheduling algo-s in real-world OSes, such as Linux
- Tried to implement Earliest Deadline First (EDF) algorithm and have it merged upstream
- Attempted by 'academicians' a few times, just to blame the Linux community upon failure!

Me and Scheduling (cont.)

- Real-Time scheduling: *"a solution to the wrong problem"*:
  - most of the time, there even is no overbooking
  - when there's overbooking, not all activities are equally important
  - I/O is a bigger issue

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*"Real-Time is bul1$*it!"*[*]

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Scheduling in Xen's World

Scheduling and Xen

- There is **pretty much always** overbooking
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- I/O is **still** more important!

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We are **special**!

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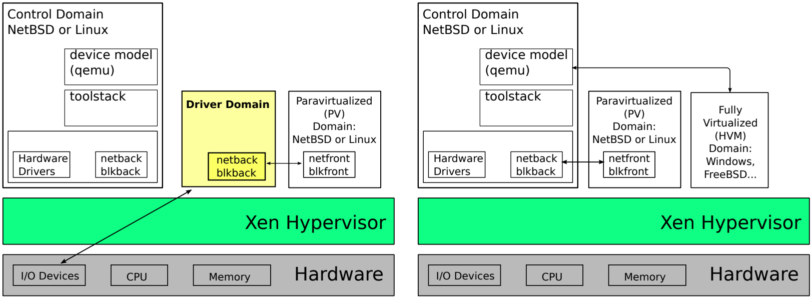
"I already told you, this isn't ever going to happen. You do _NOT_ put a for_each_online_cpu() loop in the middle of schedule().

You also do not call stop_one_cpu(migration_cpu_stop) in schedule to force migrate the task you just scheduled to away from this cpu.
That's retarded.

Nacked-by: Peter Zijlstra <a.p.zijlstra@chello.nl>"

Wait a Second... (cont.)

Our I/O needs (CPU) scheduling!



Xen's Scheduler Features

Hard and Soft Affinity

- pinning: you can run `there` and `only` there!
  `#xl vcpu-pin vm1 0 2`
- hard affinity: you can't run outside of that spot
  `# xl vcpu-pin vm1 all 8-12`
- soft affinity: you can't run outside of that spot and, *preferably*, you should ru there
  `# xl vcpu-pin vm1 all - 10,11`

Same achieved with `cpus=` and `cpus_soft=` in config file.

`cpus=` or `cpus_soft=` in config file control where memory is allocated

Hard and Soft Affinity (cont.)

```
root@tg03:~# xl vcpu-pin vm1 0 2
root@tg03:~# xl vcpu-list vm1
Name                    ID  VCPU   CPU State   Time(s) Affinity (Hard / Soft)
vm1                      5     0    2   -b-       1.5  2 / all
vm1                      5     1   15   -b-       1.9  all / all
vm1                      5     2   13   -b-       0.8  all / all
vm1                      5     3   23   -b-       0.8  all / all
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Name                    ID  VCPU   CPU State   Time(s) Affinity (Hard / Soft)
vm1                      5     0    8   -b-       1.5  8-12 / all
vm1                      5     1    9   -b-       1.9  8-12 / all
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root@tg03:~# xl vcpu-pin vm1 all - 10,11
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vm1                      5     1   10   -b-       1.9  8-12 / 10-11
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```

for Dom0

- dom0_max_vcpu: makes sense
- dom0_vcpus_pin: **bleah!!**
- dom0_nodes: **new** parameter. Place Dom0's vCPUs and memory on one or more nodes
  - strict (default) uses hard affinity
  - relaxed uses soft affinity

More about NUMA

Automatic placement policy in libxl (since Xen 4.2)

- acts at domain creation time
- easy to tweak (at libxl build time, for now) heuristics:
  - use the smallest possible set of nodes (ideally, just one)
  - use the (set of) node(s) with fewer vCPUs bound to it ([will] consider both hard and soft affinity)
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Coming: node distances, IONUMA, vNUMA

Workin' On

Exploiting Intel PSR

Intel Platform Shared Resource Monitoring (PSR):

- Cache Monitoring Technology (CMT)
- Memory Bandwidth Monitoring (MBM)

Tells how much cache/mem. bandwidth is being consumed by a certain 'activity' running on a CPU. E.g., about CMT:

- `https://software.intel.com/en-us/blogs/2014/06/18/benefit-of-cache-monitoring`
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Cool, eh? Oh, well:

- moderately accurate and fast:
  hey, it's done in hardware after all! :-)
- limited in scope and not very flexible:
  heh, it's done in hardware after all! :-(

Exploiting Intel PSR (cont.)

Current CMT support:

- in Linux (and hence KVM): cache usage stats for tasks and group of tasks
- in Xen: cache usage stats for domains (`http://wiki.xenproject.org/wiki/Intel_Cache_Monitoring_Technology`)

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Can it be used in more clever ways, e.g., in the scheduler?

- in Linux: Yes... **as soon as hell freezes!**
- in Xen: **Yes!** (Or, at least, nothing stops us trying)

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Biggest limitations:

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What I'm thinking to:

- use one monitoring ID per pCPU. This gives:
  - how 'cache hungry' a pCPU is being
  - how much free chace there is on each socket/NUMA node
- sample periodically and use for mid-level load balancing decisions
- ... ideas welcome!!

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What's missing:

- SMT awareness (done, missing final touches)
- hard and soft affinity support (someone working on it)
- tweaks and optimization in the load balancer (someone looking at it)
- cap and reservation (!!!)

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Plan: mark it as !experimantal for 4.6, make it default for 4.7 (let's see...)

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  - any addition, at this stage, would fall into this (e.g., load balancing based on historical load)

Credit2: Why? (cont.)

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Complexity:

- in `Credit` we have:
  - credits and weights
  - 2 priorities
  - oh, actually, it's 3
  - active and non active state of vCPUs
  - flipping between active/non-active means flipping between burning/non-burning credits, which in turns means wandering around among priorities

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- in `Credit2` we have:
  - credits burned basing on weights

Credit2: Why? (cont. II)

Complexity (II):

- in `Credit` we have:
  - credits-per-msec, timeslice, ticks-per-timeslice
  - can we change the timeslice? Yes, of course... **in theory!**

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Complexity (II):

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- in `Credit2` we have:
  - no timeslice at all (just min-timer, max-timer)

Credit2: Why? (cont. II)

Complexity (an example): `start_time`

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s_time_t start_time; /* When we were scheduled (used for credit) */
svc->start_time += (credits * MILLISECS(1)) / CSCHED_CREDITS_PER_MSEC;
scurr->start_time -= now;
snext->start_time += now;
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```

in `Credit2` we have:

```
s_time_t start_time; /* When we were scheduled (used for credit) */
svc->start_time = now;
delta = now - svc->start_time;
svc->start_time = now;
snext->start_time = now;
```

Credit2: Why? (cont. III)

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Scalability:

- in `Credit`
  - periodic runqueue sorting. *Freezes* a runqueue
  - periodic accounting. *Freezes* the whole scheduler!

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- in `Credit2` we have:
  - "global" lock only for load balancing
    (looking at improving it)

Credit2: Why (cont. IV)

In general, more advanced, a lot of potential:

- historical load based load balancing
- runqueue kept in order of credit (instead than Round-Robin as in `Credit1`)
- configurable runqueue arrangement

Credit2: Why (cont. V)

Performance?

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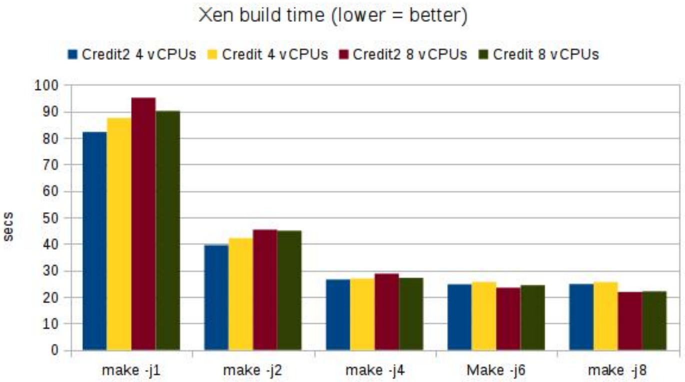

Driver Domain Aware Scheduling

Suppose:

- vCPU x is top priority (higher credits, whatever)
- vCPU x issues an I/O operation. It **has some remaining timeslice (or credit, or whatever) available**, but it blocks waiting for results
- some other domains' vCPUs y, w and z have higher priority than I/O's vCPUs (Dom0 or driver domain)

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Schedule: v_x, v_y, v_w, v_z, v_{drv_dom} $\longrightarrow$ only now v_x can resume

Driver Domain Aware Scheduling (cont.)

What if, v_x could *donate* its timeslice to the entity that is blocking it?

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Schedule: v_x, v_{drv_dom}, v_x, v_w, v_z $\longrightarrow$ v_x unblocks right away (this, assuming servicing I/O to be quick, and does not even exhaust v_x timeslice)

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Schedule: v_x, v_{drv_dom}, v_x, v_w, v_z $\longrightarrow$ v_x unblocks right away (this, assuming servicing I/O to be quick, and does not even exhaust v_x timeslice)

- avoids priority inversion (no, we're not the Mars Pathfinder, but still...)
- makes v_x sort of "pay", from the CPU load it generates with its I/O requests (fairness++)

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However:

- we should assess whether that is the case or not (for as many workloads as we possibly can)
- even if yes, we should do even better!

Q&A

Thanks again,

Questions?