Instruction caching for bhyve

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Who we are?

- Mihai Carabas
  - PhD Student and Teaching Assistant at the University POLITEHNICA of Bucharest, Romania
  - DragonFly BSD (SMT aware scheduler - 2012 / Intel EPT for vkernels - 2013)
  - FreeBSD - bhyve (instruction caching - 2014 / coordinating students in bhyve projects - current)

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- Neel Natu
  - principal contributor for the bhyve project (together with Peter Grehan)
  - started as a FreeBSD/mips committer

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  - a new CPU privilege level
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- What about controlling the APIC from the VM?
  - each control register access traps in the hypervisor
  - the hypervisor needs to emulate that access

Steps for handling a trap in the hypervisor

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- Any solution to jump over some of them?

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- Unique identifier (key)
  - VM ID: `struct vm *`
  - instruction address (RIP)
  - pointer to the page table (CR3)
- Stored in `struct vie_cached`

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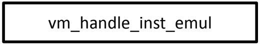
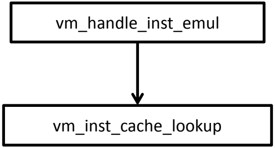
- `vm_inst_cache_lookup`

Caching flow



vm_handle_inst_emul

Caching flow



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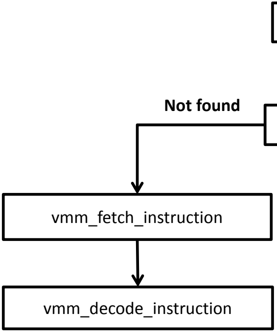

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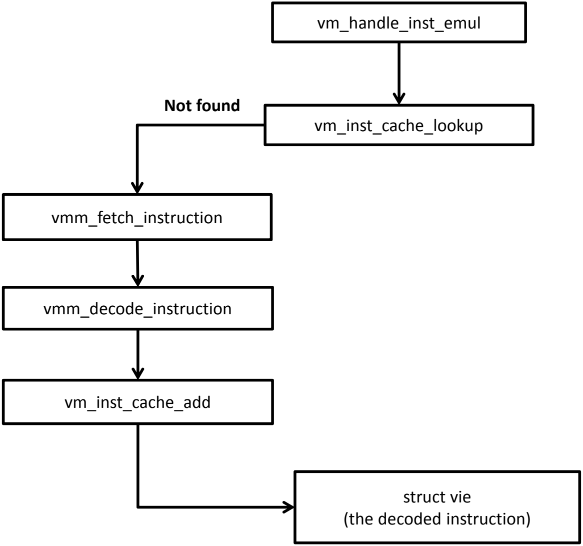

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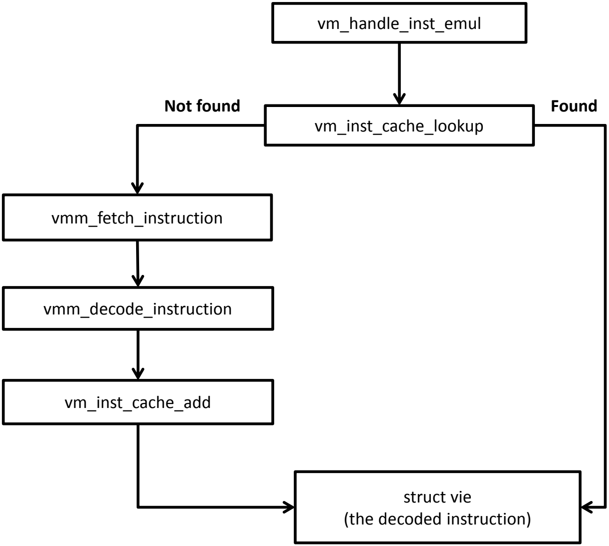

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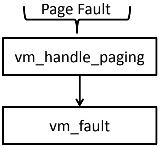

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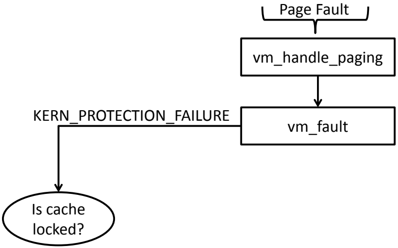

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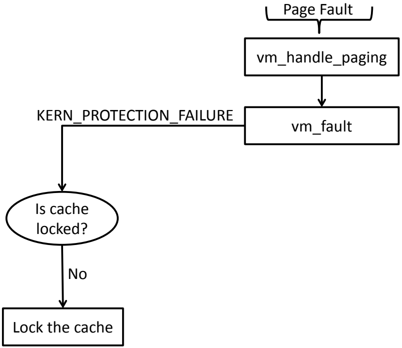

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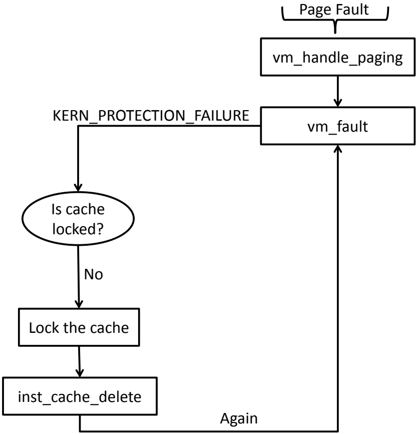

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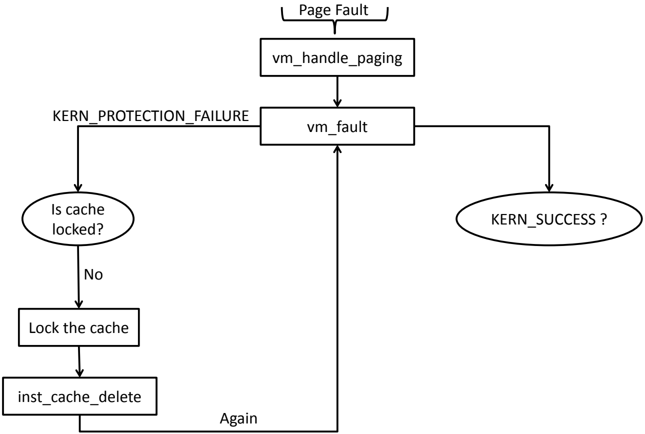

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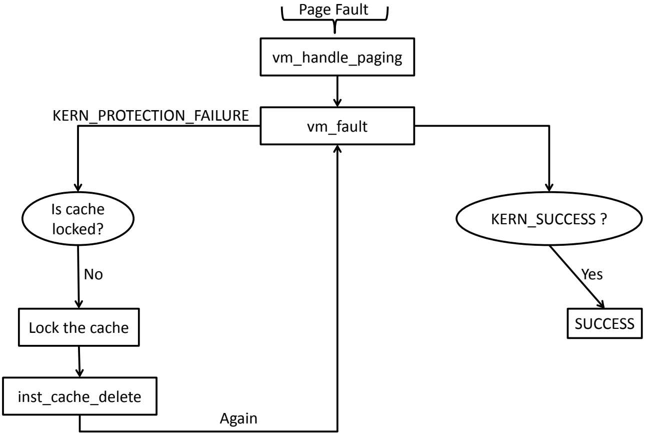

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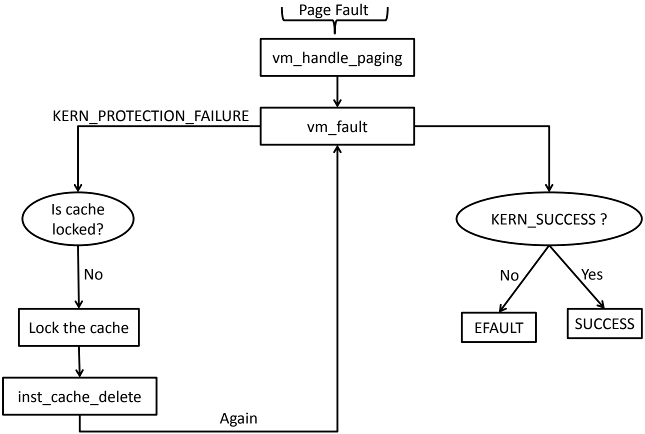

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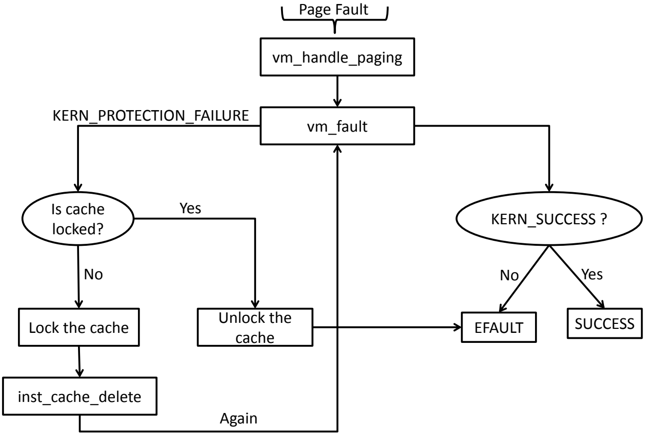

Efficiency evaluation

- Micro-benchmarking
  - kernel module accessing the LAPIC ID in a tight loop
  - measure the average access time
  - 10500 ticks without instruction caching
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- Real world workloads
  - simple loop running in user space and `make buildworld` in VM
  - measure the time that needs to finish the workload (`time` command)
  - measure the cache efficiency (hits, misses) (`VMM_STAT_*` custom counters)

Real world cache efficiency

Table: CPU intensive bash script

Number of instruction cache	vCPU0	vCPU1
hits	699.519	840,485
insertions	10.395	5,743
evictions[0]	7.139	8.926
evictions[1]	0	0
evictions[2]	0	0
evictions[3]	0	0

Table: make buildworld -j2

Number of instruction cache	vCPU0	vCPU1
hits	19.204.630	12.930.500
insertions	8.688.733	9.051.295
evictions[0]	8.563.694	9.173.381
evictions[1]	1.131	1.457
evictions[2]	0	0
evictions[3]	0	0

Speed-up for running time

Table: CPU intensive bash script

hw.vmm.instruction_cache	time spent in execution (s)
1	225
0	230

Table: make buildworld -j2

hw.vmm.instruction_cache	time spent in execution (s)
1	13900
0	13938

Related work

- KVM driver isn't using any caching technique
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  - all the interrupt handling in hardware (virtualize the APIC without VM exists)
  - a VM exit is too expensive

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- KVM community opinion as stated in a KVM-Intel presentation from 2012
  - they want to rely on the hardware only
  - all the interrupt handling in hardware (virtualize the APIC without VM exists)
  - a VM exit is too expensive
- instruction emulation will still be used for other devices models (e.g. HPET, AHCI)

Conclusions

- Cache the emulated instructions in order to decrease the time spent in the hypervisor
- Handled corner cases like contention on the VM page table without using a big lock
- Theoretical good results (e.g. 30% improvement of the average access time)
- Didn't find a real world workload to benefit from this mechanism

Thank you for your attention!

ask questions