Private vs. Common
Reflections on Cross-Architecture Commonality

—

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Motivation

Maintainer for s390 KVM (IBM Z)

Mostly focused on that platform

Also try to keep up2date with kvm in general

I have seen many opportunities for improvement regarding cross-architecture work

Often challenging due to the details

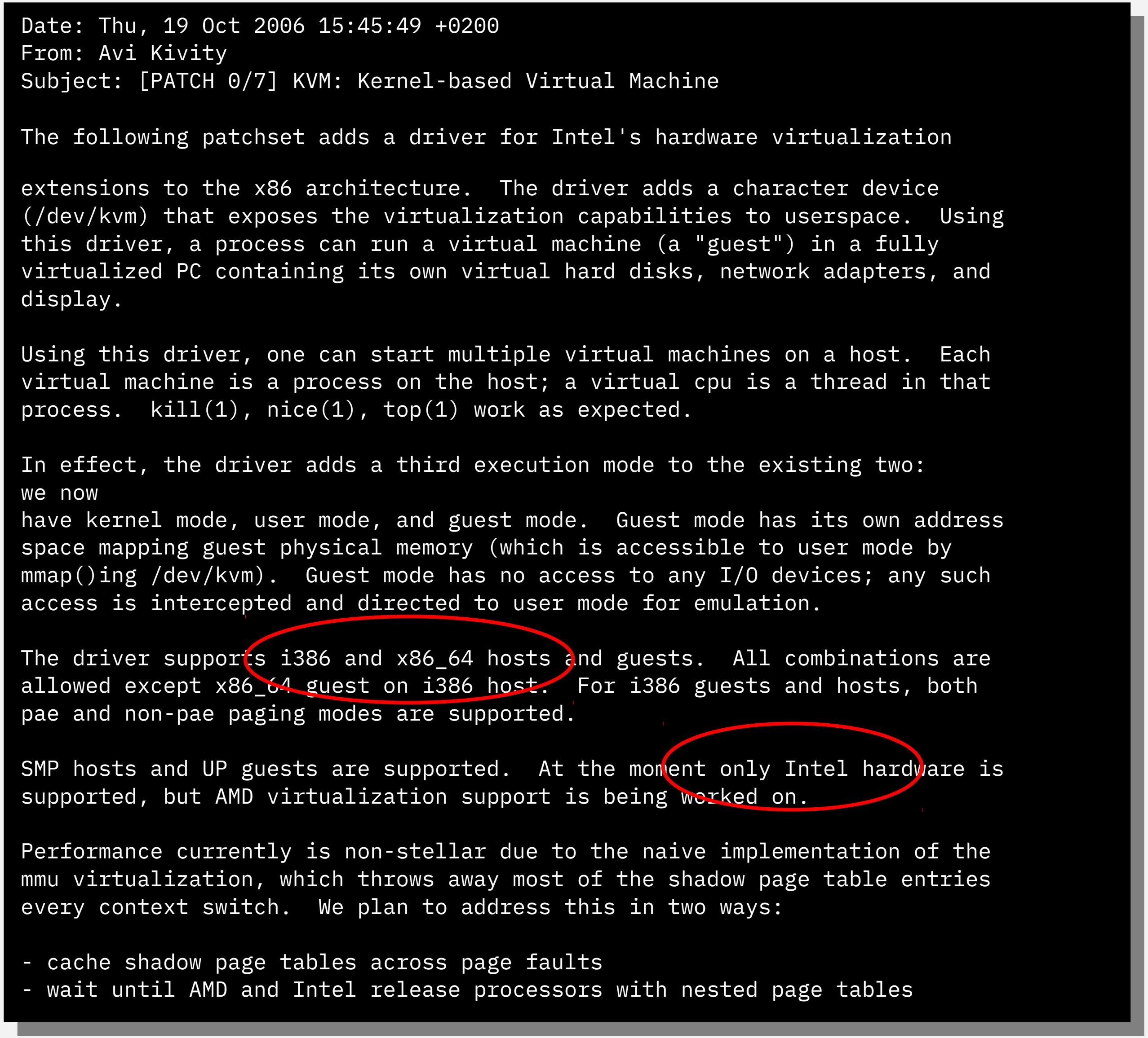
Some history and some examples

Outlook and Future

History

First Steps

KVM started as Intel only
AMD support drove first factorization



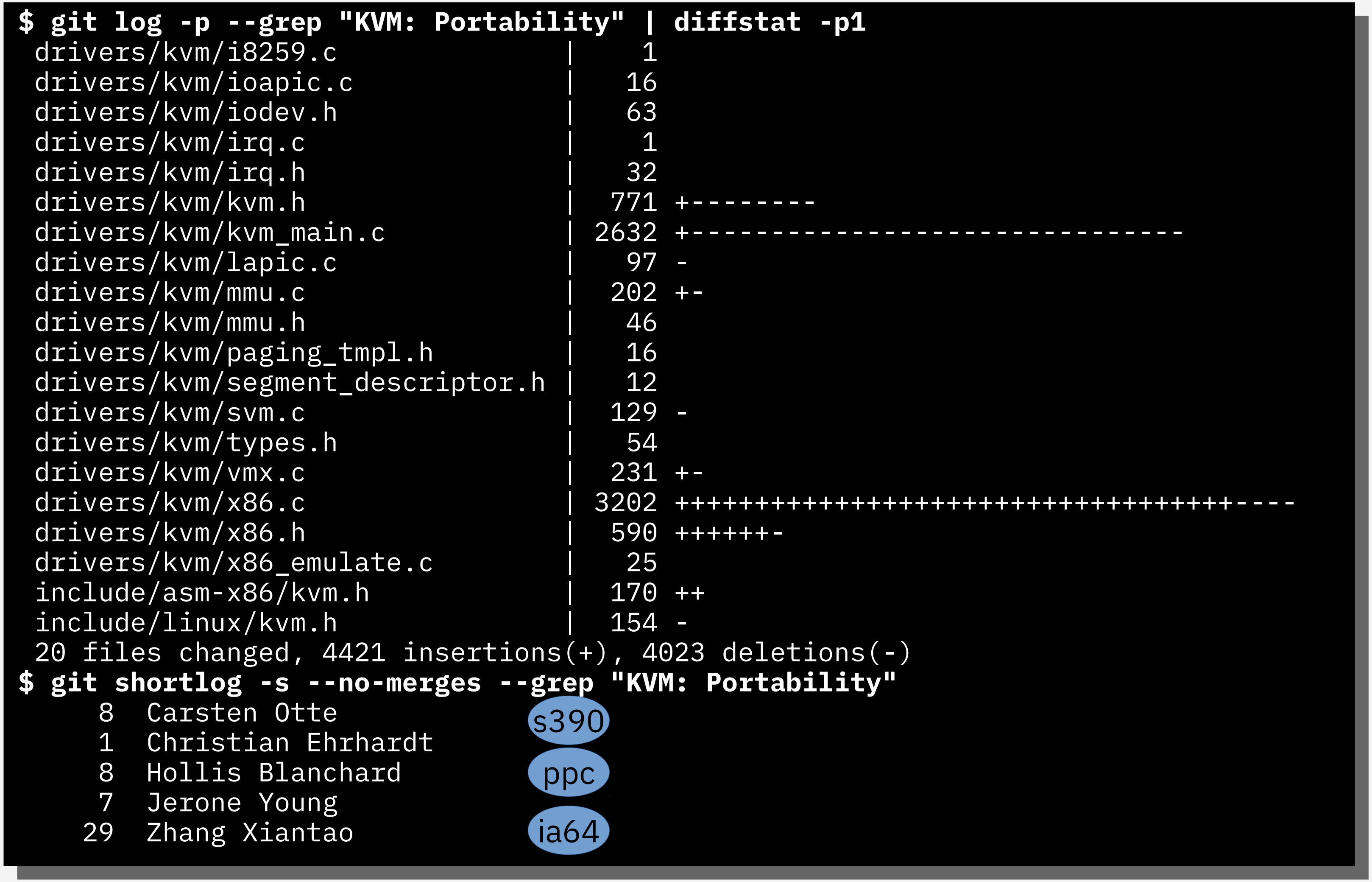
```
Date: Thu, 19 Oct 2006 15:45:49 +0200
From: Avi Kivity
Subject: [PATCH 0/7] KVM: Kernel-based Virtual Machine

The following patchset adds a driver for Intel's hardware virtualization

extensions to the x86 architecture.  The driver adds a character device
(/dev/kvm) that exposes the virtualization capabilities to userspace.  Using
this driver, a process can run a virtual machine (a "guest") in a fully
virtualized PC containing its own virtual hard disks, network adapters, and
display.

Using this driver, one can start multiple virtual machines on a host.  Each
virtual machine is a process on the host; a virtual cpu is a thread in that
process.  kill(1), nice(1), top(1) work as expected.

In effect, the driver adds a third execution mode to the existing two:
we now
have kernel mode, user mode, and guest mode.  Guest mode has its own address
space mapping guest physical memory (which is accessible to user mode by
mmap()ing /dev/kvm).  Guest mode has no access to any I/O devices; any such
access is intercepted and directed to user mode for emulation.

The driver supports i386 and x86_64 hosts and guests.  All combinations are
allowed except x86_64 guest on i386 host.  For i386 guests and hosts, both
pae and non-pae paging modes are supported.

SMP hosts and UP guests are supported.  At the moment only Intel hardware is
supported, but AMD virtualization support is being worked on.

Performance currently is non-stellar due to the naive implementation of the
mmu virtualization, which throws away most of the shadow page table entries
every context switch.  We plan to address this in two ways:

- cache shadow page tables across page faults
- wait until AMD and Intel release processors with nested page tables
```

Enabling Other Architectures

Refactoring of code end of 2007

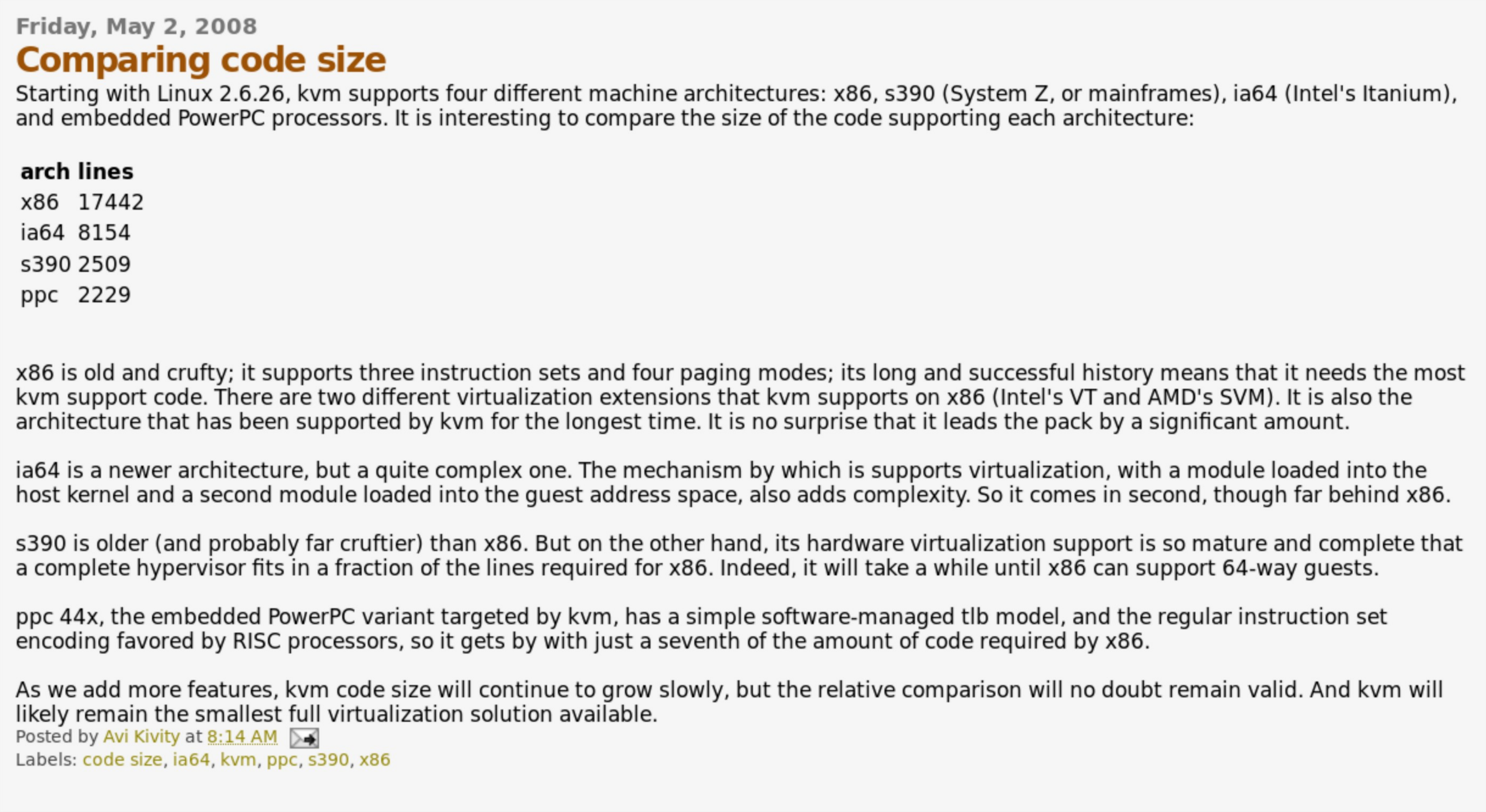
Intel: IA64

IBM: POWER, s390



```
$ git log -p --grep "KVM: Portability" | diffstat -p1
 drivers/kvm/i8259.c              |    1
 drivers/kvm/ioapic.c             |   16
 drivers/kvm/iodev.h              |   63
 drivers/kvm/irq.c                |    1
 drivers/kvm/irq.h                |   32
 drivers/kvm/kvm.h                |  771 +--------
 drivers/kvm/kvm_main.c           | 2632 +-------------------------------
 drivers/kvm/lapic.c              |   97 -
 drivers/kvm/mmu.c                |  202 +-
 drivers/kvm/mmu.h                |   46
 drivers/kvm/paging_tmpl.h        |   16
 drivers/kvm/segment_descriptor.h |   12
 drivers/kvm/svm.c                |  129 -
 drivers/kvm/types.h              |   54
 drivers/kvm/vmx.c                |  231 +-
 drivers/kvm/x86.c                | 3202 +++++++++++++++++++++++++++++++++++----
 drivers/kvm/x86.h                |  590 ++++++-
 drivers/kvm/x86_emulate.c        |   25
 include/asm-x86/kvm.h            |  170 ++
 include/linux/kvm.h              |  154 -
 20 files changed, 4421 insertions(+), 4023 deletions(-)
$ git shortlog -s --no-merges --grep "KVM: Portability"
     8  Carsten Otte
     1  Christian Ehrhardt
     8  Hollis Blanchard
     7  Jerone Young
    29  Zhang Xiantao
```

KVM “Everywhere”



Friday, May 2, 2008

Comparing code size

Starting with Linux 2.6.26, kvm supports four different machine architectures: x86, s390 (System Z, or mainframes), ia64 (Intel's Itanium), and embedded PowerPC processors. It is interesting to compare the size of the code supporting each architecture:

arch	lines
x86	17442
ia64	8154
s390	2509
ppc	2229

x86 is old and crufty; it supports three instruction sets and four paging modes; its long and successful history means that it needs the most kvm support code. There are two different virtualization extensions that kvm supports on x86 (Intel's VT and AMD's SVM). It is also the architecture that has been supported by kvm for the longest time. It is no surprise that it leads the pack by a significant amount.

ia64 is a newer architecture, but a quite complex one. The mechanism by which is supports virtualization, with a module loaded into the host kernel and a second module loaded into the guest address space, also adds complexity. So it comes in second, though far behind x86.

s390 is older (and probably far cruftier) than x86. But on the other hand, its hardware virtualization support is so mature and complete that a complete hypervisor fits in a fraction of the lines required for x86. Indeed, it will take a while until x86 can support 64-way guests.

ppc 44x, the embedded PowerPC variant targeted by kvm, has a simple software-managed tlb model, and the regular instruction set encoding favored by RISC processors, so it gets by with just a seventh of the amount of code required by x86.

As we add more features, kvm code size will continue to grow slowly, but the relative comparison will no doubt remain valid. And kvm will likely remain the smallest full virtualization solution available.

Posted by Avi Kivity at 8:14 AM

Labels: code size, ia64, kvm, ppc, s390, x86

http://avikivity.blogspot.com/2008/05/comparing-code-size.html

Components

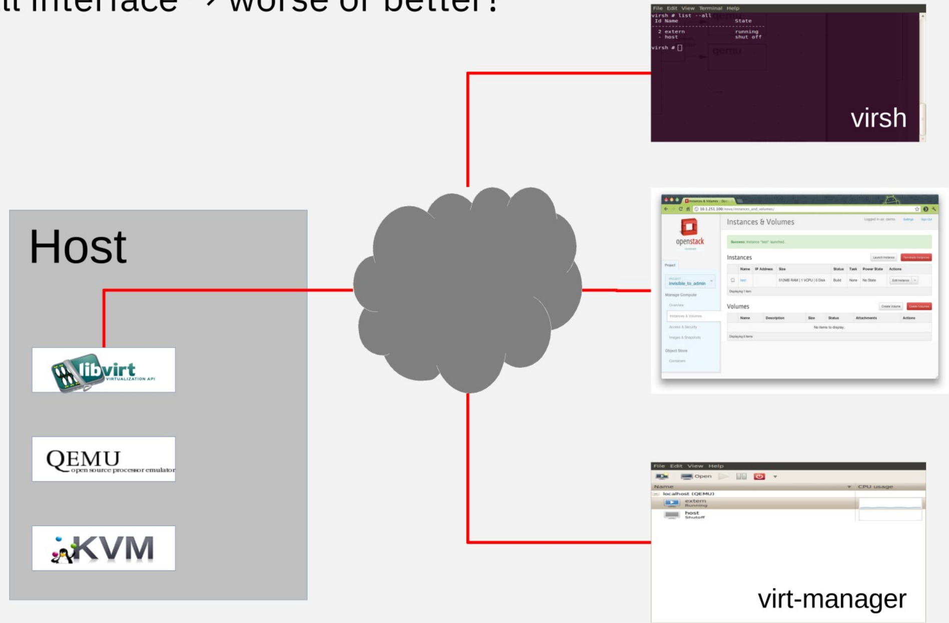
Structure of a KVM Installation

KVM kernel module
Closest to the hardware → does that mean least commonality?

QEMU userspace
Also close to hardware, but uses abstract system call interface → worse or better?

Libvirt
Far away from hardware → should be easy, no?

Management stack beyond libvirt
Is there anything platform specific at all?



```
virsh # list --all
 Id Name                 State
----------------------------------
  2 extern               running
  - host                 shut off

virsh #
```

QEMU, libvirt

QEMU vs Kernel

target/*/kvm*

vs

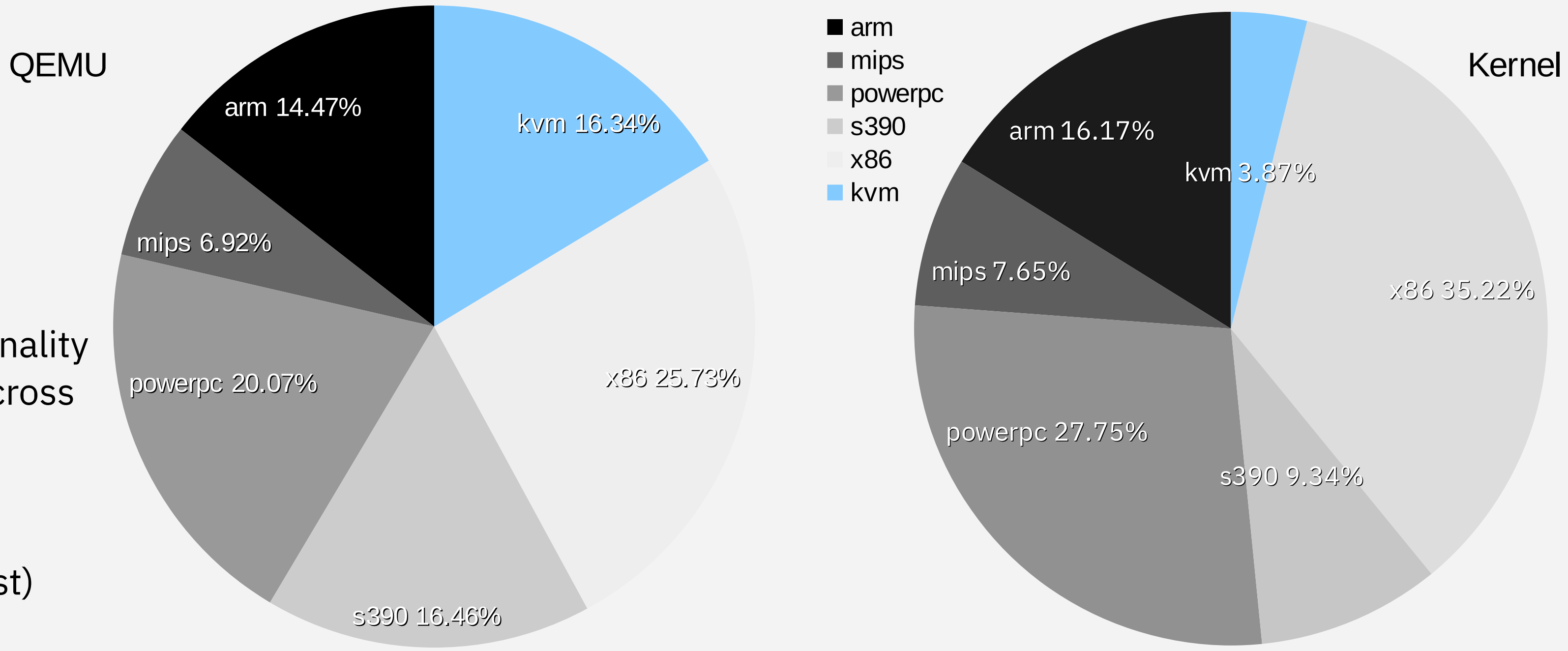
accel/kvm/

As expected: more commonality

Unexpected: similar size across architecture

libvirt

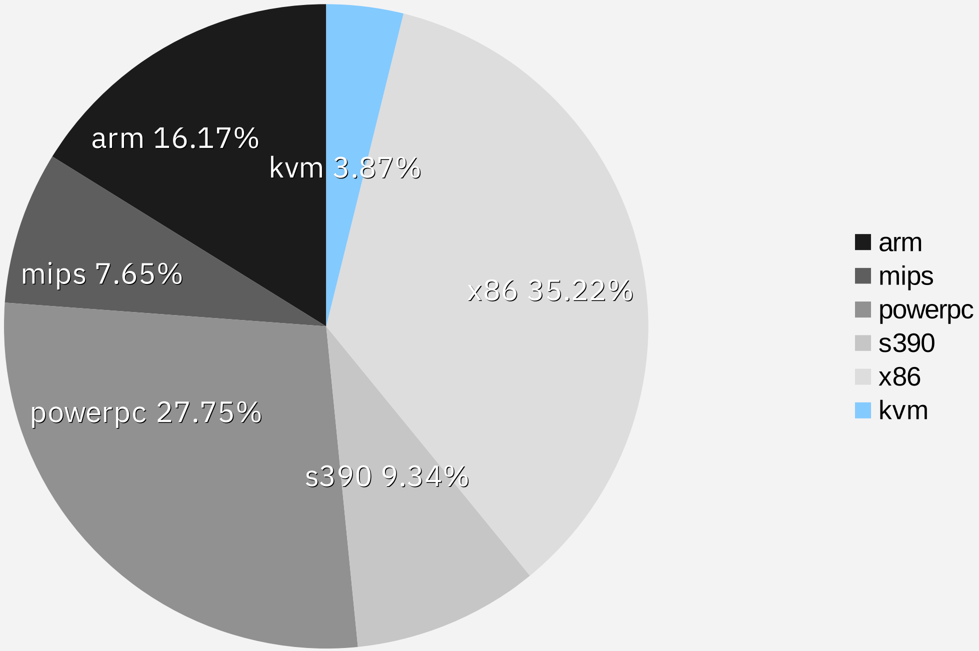
Not even arch-specific folders/files (apart from test)

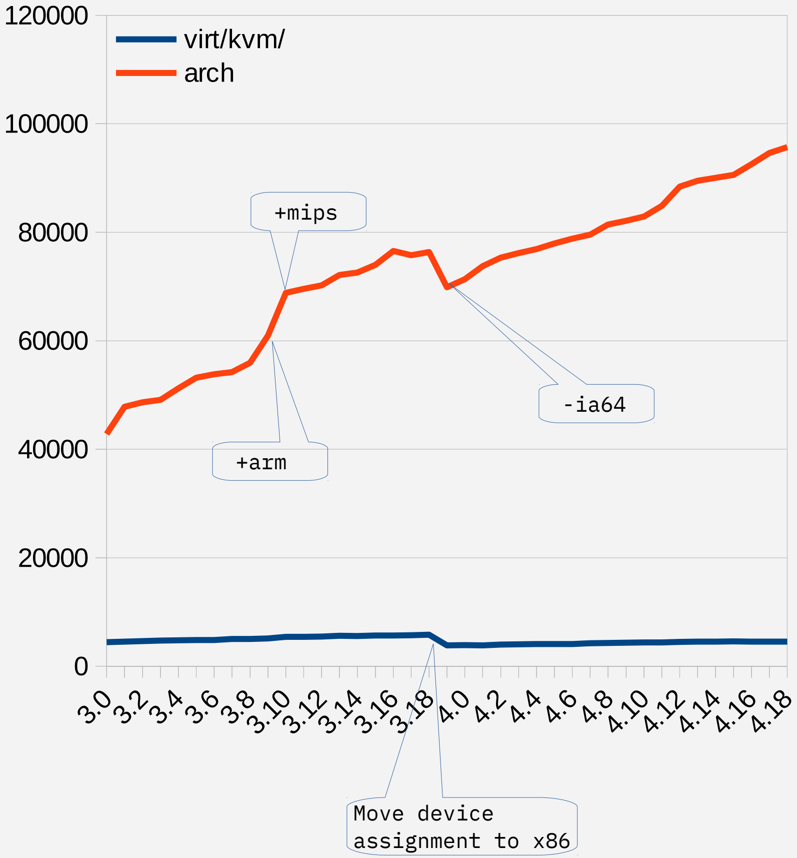


KVM Kernel Module

Lines of Code (sloccount) 4.18

```
arch/arm64/kvm/   = 4,792
arch/arm/kvm/     = 2,458
arch/mips/kvm/    = 9,005
arch/s390/kvm/    = 10,984
arch/powerpc/kvm/ = 32,651
arch/x86/kvm/     = 41,439
virt/kvm/ = 16,327  (- virt/kvm/arm/ = 11,776) == 4551
```





KVM Kernel Module

What is common?
Basic IOCTLs
VM lifecycle
VCPU lifecycle
Eventfd/IRQFD handling
Debugfs
kvm_stat base functions
What is partially common?
RCU handling
Wait state
Cpu request handling
Polling
Time accounting
Vfio kvm bridge

What is arch specific?
Hardware setup
Nested virtualization
MMU emulation
Instruction emulation
kvm_stat counters
Arch tracepoints
Guest state interfaces
Basically any hardware specific guest feature enablement
….

What Kind of Problems?

Kernel perspective

Halt Polling

Wait a bit when guest CPU is going idle

Lots of heuristics: Uses hystereris to adapt, check for system load...

Does one size fits all?

Problem 1: Local and floating interrupts

If there is an interrupt, consider the poll successful

I/O interrupts on s390 are floating (pending for all CPU, first come first serve)

Polling was overly optimistic

Solution: Add arch callback to filter wakeups

Problem 2: SMT variants

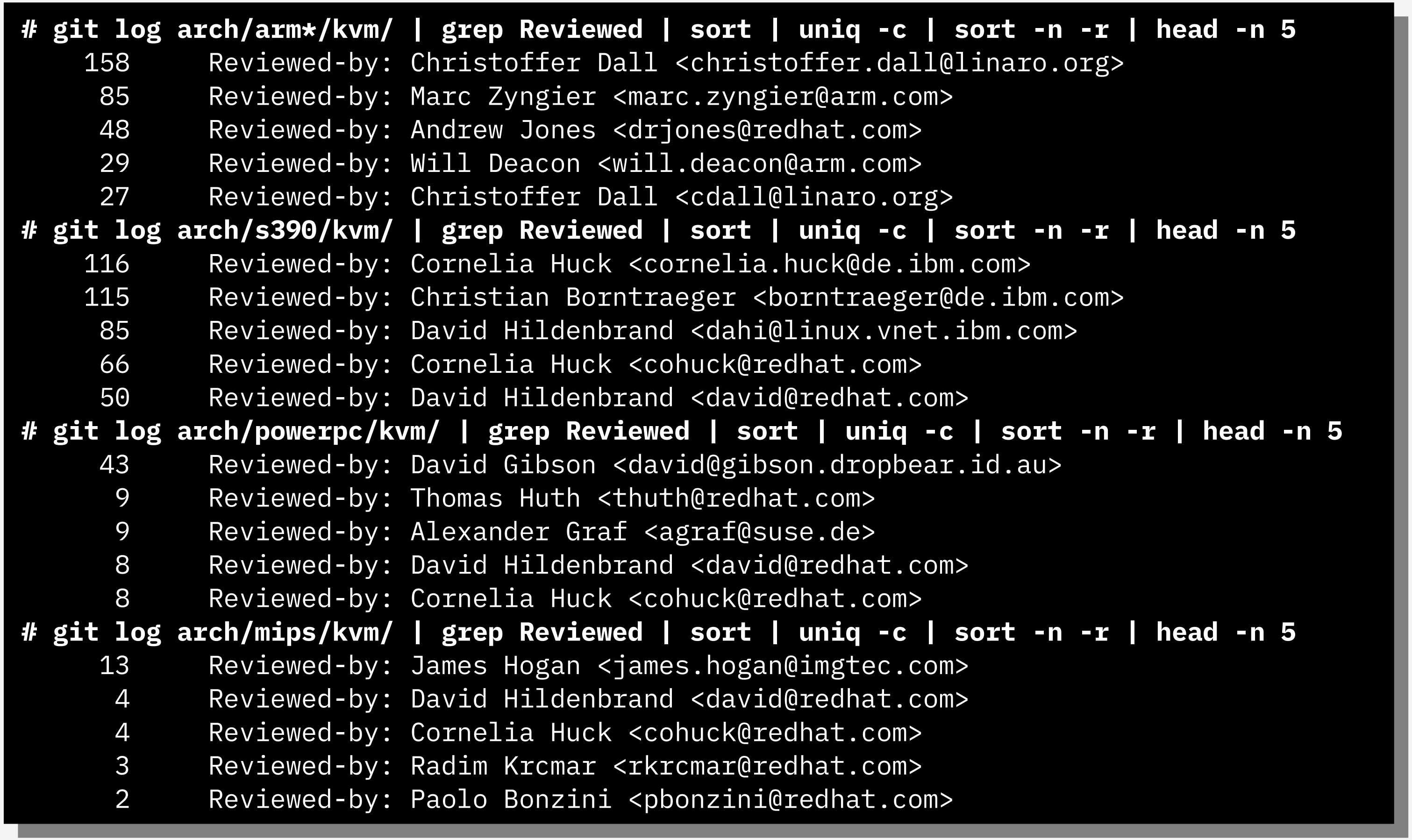
Solution: Private implementation for power

```
commit 0cda69dd7cd64fdd54bdf584b5d6ba53767ba422
    KVM: PPC: Book3S HV: Implement halt polling

    This patch introduces new halt polling functionality into the kvm_hv kernel
    module. When a vcore is idle it will poll for some period of time before
    scheduling itself out.
[..]
    There exists generic halt_polling code in virt/kvm_main.c, however on
    powerpc the polling conditions are different to the generic case. It would
    be nice if we could just implement an arch specific kvm_check_block()
    function, but there is still other arch specific things which need to be
    done for kvm_hv (for example manipulating vcore states) which means that a
    separate implementation is the best option.
```

So what about cross architecture review?

Reviews

Reviews are often inside the silo



```
# git log arch/arm*/kvm/ | grep Reviewed | sort | uniq -c | sort -n -r | head -n 5
    158     Reviewed-by: Christoffer Dall <christoffer.dall@linaro.org>
     85     Reviewed-by: Marc Zyngier <marc.zyngier@arm.com>
     48     Reviewed-by: Andrew Jones <drjones@redhat.com>
     29     Reviewed-by: Will Deacon <will.deacon@arm.com>
     27     Reviewed-by: Christoffer Dall <cdall@linaro.org>
# git log arch/s390/kvm/ | grep Reviewed | sort | uniq -c | sort -n -r | head -n 5
    116     Reviewed-by: Cornelia Huck <cornelia.huck@de.ibm.com>
    115     Reviewed-by: Christian Borntraeger <borntraeger@de.ibm.com>
     85     Reviewed-by: David Hildenbrand <dahi@linux.vnet.ibm.com>
     66     Reviewed-by: Cornelia Huck <cohuck@redhat.com>
     50     Reviewed-by: David Hildenbrand <david@redhat.com>
# git log arch/powerpc/kvm/ | grep Reviewed | sort | uniq -c | sort -n -r | head -n 5
     43     Reviewed-by: David Gibson <david@gibson.dropbear.id.au>
      9     Reviewed-by: Thomas Huth <thuth@redhat.com>
      9     Reviewed-by: Alexander Graf <agraf@suse.de>
      8     Reviewed-by: David Hildenbrand <david@redhat.com>
      8     Reviewed-by: Cornelia Huck <cohuck@redhat.com>
# git log arch/mips/kvm/ | grep Reviewed | sort | uniq -c | sort -n -r | head -n 5
     13     Reviewed-by: James Hogan <james.hogan@imgtec.com>
      4     Reviewed-by: David Hildenbrand <david@redhat.com>
      4     Reviewed-by: Cornelia Huck <cohuck@redhat.com>
      3     Reviewed-by: Radim Krcmar <rkrcmar@redhat.com>
      2     Reviewed-by: Paolo Bonzini <pbonzini@redhat.com>
```

Redhat as the exception (and overall KVM maintainer)

More Cross-Team Education and Review

There have been several talks about educating about architecture specifics

Nested Virtualization on ARM - Christoffer Dall - KVM Forum 2017
To EL2, and Beyond! - Christoffer Dall – KVM Forum 2017
Nesting KVM on s390x - David Hildenbrand – KVM Forum 2016
KVM on System z: The Good, the Bad and the Weird - Cornelia Huck – KVM Forum 2016
QEMU Hotplug Infrastructure and Implementing PCI Hotplug for PowerKVM - Michael Roth – KVM Forum 2015
KVM on IBM POWER8 Machines - Paul Mackerras – KVM Forum 2014
[…]

There are more talks this time

Arm Timers; and Fire! - Christoffer Dall
Secure Virtual Machines on Power - Ram Pai & Guerney Hunt
Protect Data of Virtual Machines with Memory Encryption on KVM - Kai Huang
s390 KVM Memory Management and its Pitfalls - Janosch Frank
…

Do we need more discussion across architecture teams?

Each architecture has its own pile of oddities
Most HW company have some non-yet-public in-house developments
BOF Session proposal
(see https://www.linux-kvm.org/page/KVM_Forum_2018_BOF)

Successful Changes

Time Accounting

Linux systems have the notion of system time, user time, idle time, softirq time etc
For KVM a guest time was added
Support available in sysstat and others

```
sar -A
[...]
Average:        CPU     %usr     %nice      %sys   %iowait    %steal      %irq     %soft    %guest    %gnice     %idle
Average:        all     0.06      0.00      0.05      0.00      0.01      0.00      0.00      1.13      0.00     98.75
[...]
```

Generic callbacks that handle this across all architectures
Now wrapped in guest_enter/exit_irqoff
Does work for all variants of virt cpu accounting
Can we build upon this to influence and enhance others?
No support in top (procps-ng)

Many more successful common parts

Idea sharing

Are we good in sharing ideas?

Lazy FPU

Registers are often shared between guest and host

For example the hypervisor must reload the floating point registers on guest entry/exit

Does it?

The kernel does not use floating point (most of the time)

First stage

preempt notifier

Light-weight exits (e.g. a virtio notify bound to eventd) have no need of fp reloading

Second stage

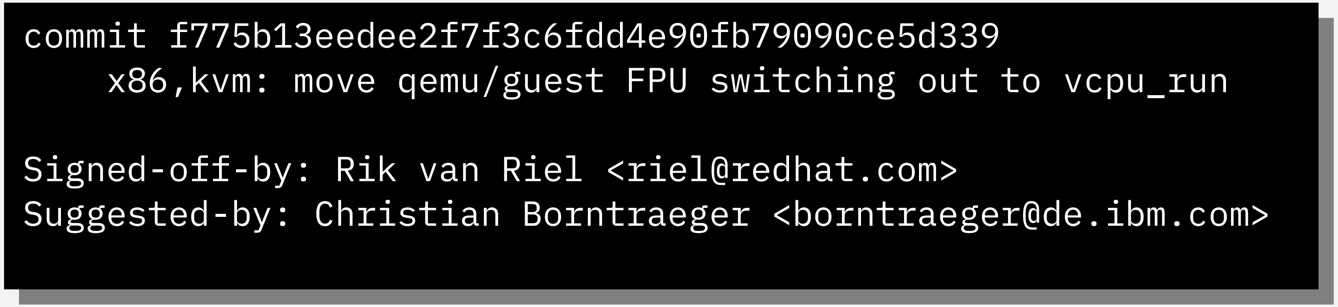
On reschedule: save guesta, load hosta → schedule → save hosta, load hostb →schedule → save hostb, load hosta → save hosta,load guesta

Do the guest/host reloading in ioctl path instead

Now on reschedule: save guesta, load hostb →schedule → save hostb, load guesta

Last year I talked about that with Rik van Riel

See what happened afterwards



```
commit f775b13eedee2f7f3c6fdd4e90fb79090ce5d339
    x86,kvm: move qemu/guest FPU switching out to vcpu_run

Signed-off-by: Rik van Riel <riel@redhat.com>
Suggested-by: Christian Borntraeger <borntraeger@de.ibm.com>
```

Asynchronous Pagefault

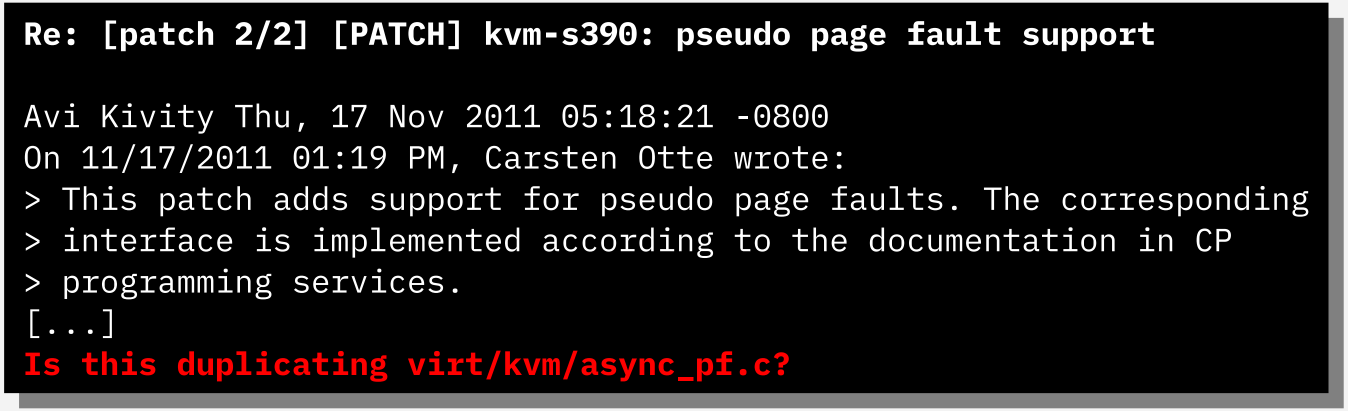
IBM Z had asynchronous page fault for a long time in z/VM

KVM on z tried to implement the same on KVM

Meanwhile KVM on x has implemented a similar scheme

https://www.linux-kvm.org/images/a/ac/2010-forum-Async-page-faults.pdf

Sometimes it needs review feedback to state the obvious



```
Re: [patch 2/2] [PATCH] kvm-s390: pseudo page fault support

Avi Kivity Thu, 17 Nov 2011 05:18:21 -0800
On 11/17/2011 01:19 PM, Carsten Otte wrote:
> This patch adds support for pseudo page faults. The corresponding
> interface is implemented according to the documentation in CP
> programming services.
[...]
Is this duplicating virt/kvm/async_pf.c?
```

Implementation was not fully identical but we were able to factor out things

Protected by CONFIG_KVM_ASYNC_PF_SYNC

Interestingly enough there is no sharing in the guest handlers

Guest Page Hinting

Tell the host, which guest pages are no longer necessary

Implemented for IBM Z with z/VM since ~2005 as CMMA (collaborative memory management assist)

Available for KVM on Z since ~2014

Guest has callbacks in arch_alloc_page and arch_free_page

Callbacks use hardware instructions that sets special bits in the host page table

Several possible optimization

On swapout: discard unused pages

On swapin: discard swap slot and use empty zero page

During runtime: drop existing mappings to avoid page out

For x86 under discussion for a while

Similar scheme – guest page hinting

See Guest Free Page Hinting - Nitesh Narayan Lal, Red Hat, Inc., Friday, October 26 • 16:15 – 16:45

Any chance to collaborate? Are the implementations too different?

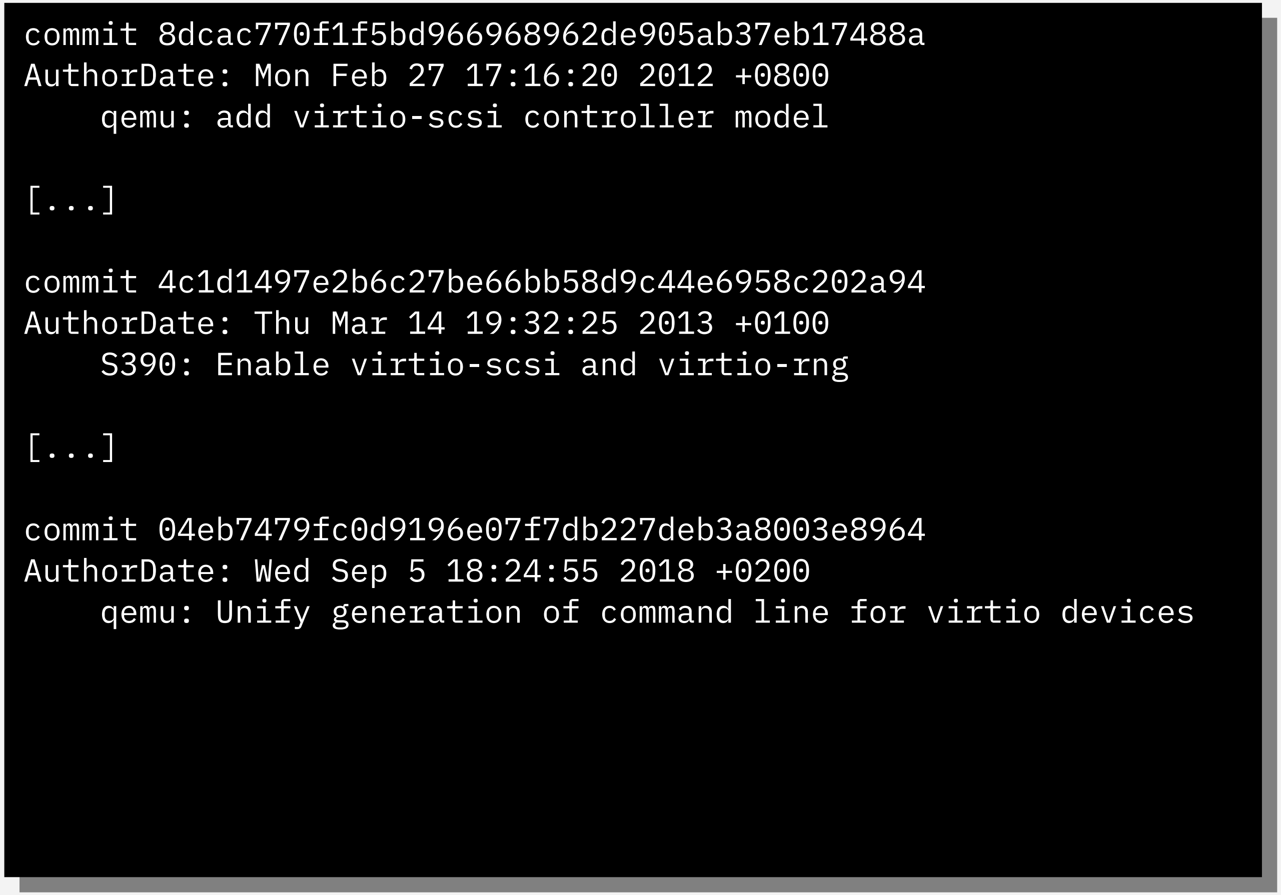
Interfaces

VIRTIO

Devices are platform specific
SATA,IDE,SCSI,DASD.....
Must be platform specific
Virtio defines fully virtual I/O interface
This can clearly be made platform independent!
First implementation allowed anything (virtio over pigeon carriers)
Unfortunately, no so:
During SPECing things became more specific
A Windows driver was considered important
It was much easier to add a PCI driver than to add a new access method
So it was PCI
Now, s390 had no PCI back then...
S390 implemented an lguest like scheme (with queues above main memory)
Refactoring started
Later virtio-ccw was added → hotplug, hot unplug up to 256k devices etc.
Later virtio-mmio was added
Does that cause problem?

Virtio in Libvirt

Implementation start on one platform
Usually PCI
Other platforms add thing later
CCW,MMIO and previously S390
It becomes obvious that we can refactor

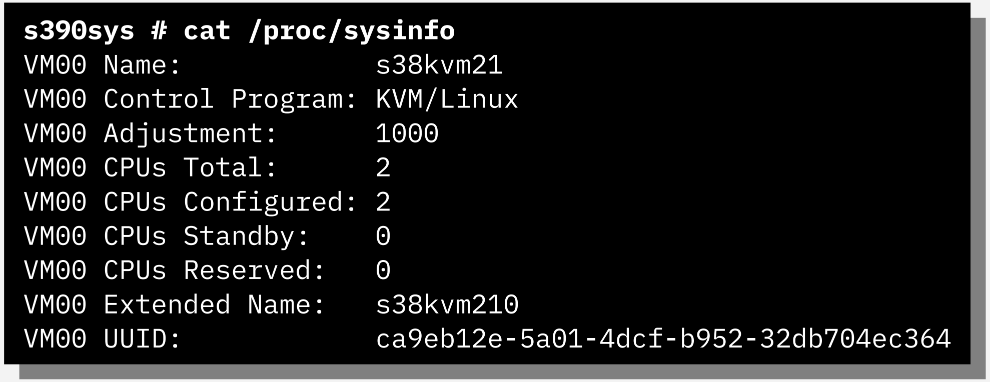


```
commit 8dcac770f1f5bd966968962de905ab37eb17488a
AuthorDate: Mon Feb 27 17:16:20 2012 +0800
    qemu: add virtio-scsi controller model

[...]

commit 4c1d1497e2b6c27be66bb58d9c44e6958c202a94
AuthorDate: Thu Mar 14 19:32:25 2013 +0100
    S390: Enable virtio-scsi and virtio-rng

[...]

commit 04eb7479fc0d9196e07f7db227deb3a8003e8964
AuthorDate: Wed Sep 5 18:24:55 2018 +0200
    qemu: Unify generation of command line for virtio devices
```

Future Development

Upcoming Guest User Interfaces

Every architecture has ways of exposing that you run a hypervisor



```
s390sys # cat /proc/sysinfo
VM00 Name:            s38kvm21
VM00 Control Program: KVM/Linux
VM00 Adjustment:      1000
VM00 CPUs Total:      2
VM00 CPUs Configured: 2
VM00 CPUs Standby:    0
VM00 CPUs Reserved:   0
VM00 Extended Name:   s38kvm210
VM00 UUID:            ca9eb12e-5a01-4dcf-b952-32db704ec364
```

Dmidecode

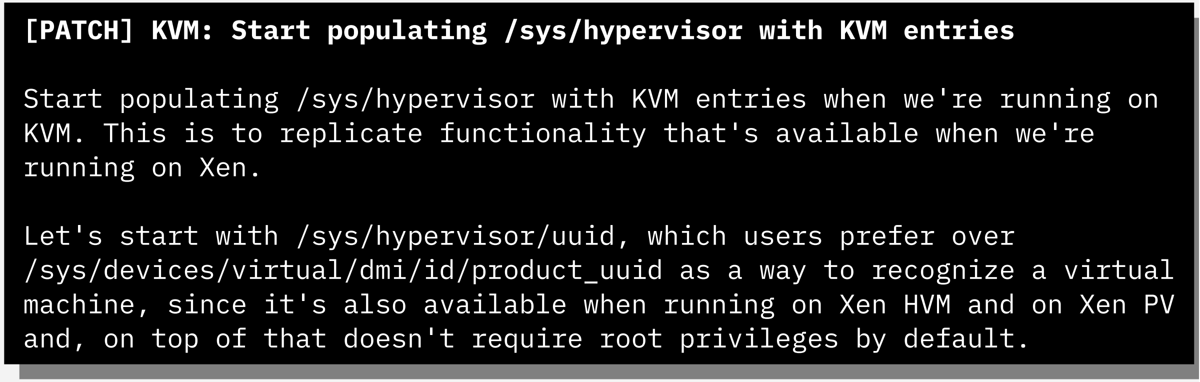
etc

New patch for /sys/hypervisor

Commonality with XEN

X86 specific

Can be fixed to be cross-architecture



```
[PATCH] KVM: Start populating /sys/hypervisor with KVM entries

Start populating /sys/hypervisor with KVM entries when we're running on
KVM. This is to replicate functionality that's available when we're
running on Xen.

Let's start with /sys/hypervisor/uuid, which users prefer over
/sys/devices/virtual/dmi/id/product_uuid as a way to recognize a virtual
machine, since it's also available when running on Xen HVM and on Xen PV
and, on top of that doesn't require root privileges by default.
```

Upcoming Guest User Interfaces

Read Only Enforcement patches V4 [VMM based kernel hardening]
X86 only
Any chance of making this generic?

A steady flow of such new interfaces

Summary

Improve inter-architectural discussion

That implies understanding what this is all about

Do not assume that anything is x86

Most people know ARM, but there are others: mips, POWER,s390

Sometimes it even possible to share interfaces with other hypervisors

XEN guest interfaces, z/VM interfaces, PowerVM?

Sometimes sharing hurts and private implementations are better

Try, but do not go too far

Interested in doing something? See my BoF Session

THANK YOU!

borntraeger@de.ibm.com

What else if I had more time?

Problems when doing common code

Over-Generalization

Sometimes people do the right thing and implement things across architecture
This can go wrong as well
People makes assumptions and base their implementation on those
Example
Postcopy transfers empty pages to the target and marks them as transferred
Second requests for that page are being ignored
Should not fault
Guest page hinting might now throw away this page
And then the guest reuses that page and accesses it
Fault!
The host will then resolve the fault.....
Userfaultd is responsible.....
Postcopy thinks: already transmitted – return and do nothing
Fault!
Everything was fixed by disabling the problematic cases during postcopy
Something to learn from both sides, sometimes assumptions break
Before enabling a feature on a platform

MMU Notifier

How do handle host paging and similar thing

Ideally just allow everything that a normal process has

Provide callbacks for page table primitives

mm gets a callback structure for primitives:

ptep_test_and_clear_young → ptep_clear_young_notify

[...]

  ptep_test_and_clear_young

  mmu_notifier_clear_young

KVM will register for operations

S390 does not use mmu notifier

Storage keys as a per physical page entity

Update needs to be in sync for host and guest

Solution: not use mmu_notifier, do the guest part in the base architecture primitives

Other challenges: need to implement large page support separately

See “s390 KVM Memory Management and its Pitfalls - Janosch Frank, IBM” at this KVM Forum