

# Private vs. Common Reflections on Cross-Architecture Commonality

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# Motivation

## **Maintainer for s390 KVM (IBM Z)**

Mostly focussed 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	s390
1	Christian Ehrhardt	
8	Hollis Blanchard	ppc
7	Jerone Young	
29	Zhang Xiantao	ia64

# 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 crusty; 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 it 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 cruffier) 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](#)

# Components

# Structure of a KVM Installation

## Kvm kernel module

Closest to the hardware → does that mean least commonality?

## QEMU userspace

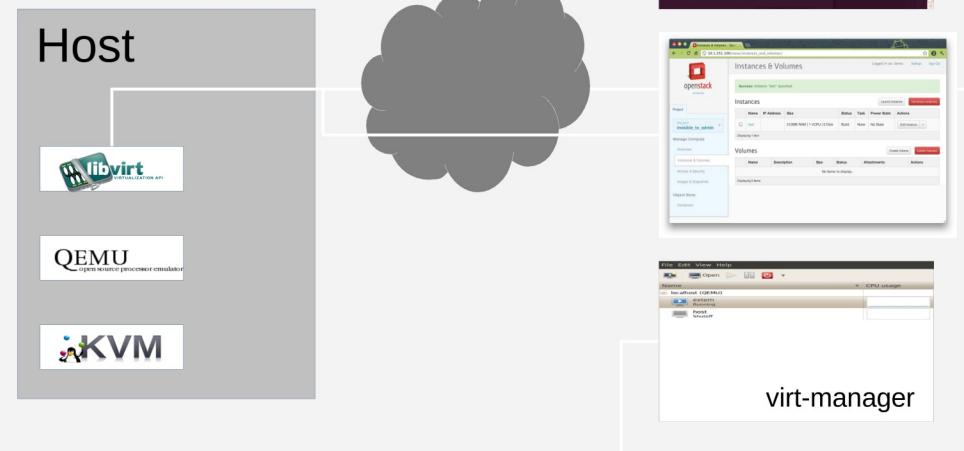
Also close to hardware, but uses abstract system call interface → worse or better?

## Libvirt

Far away from hardware → should be easy, no?

## Management stack beyond libvirt

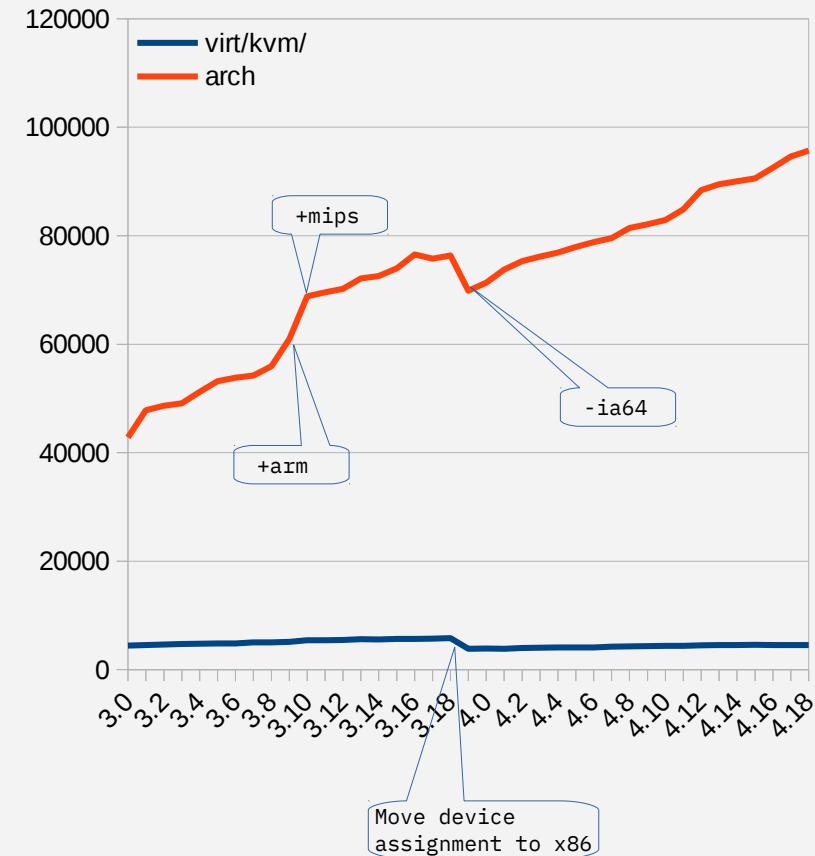
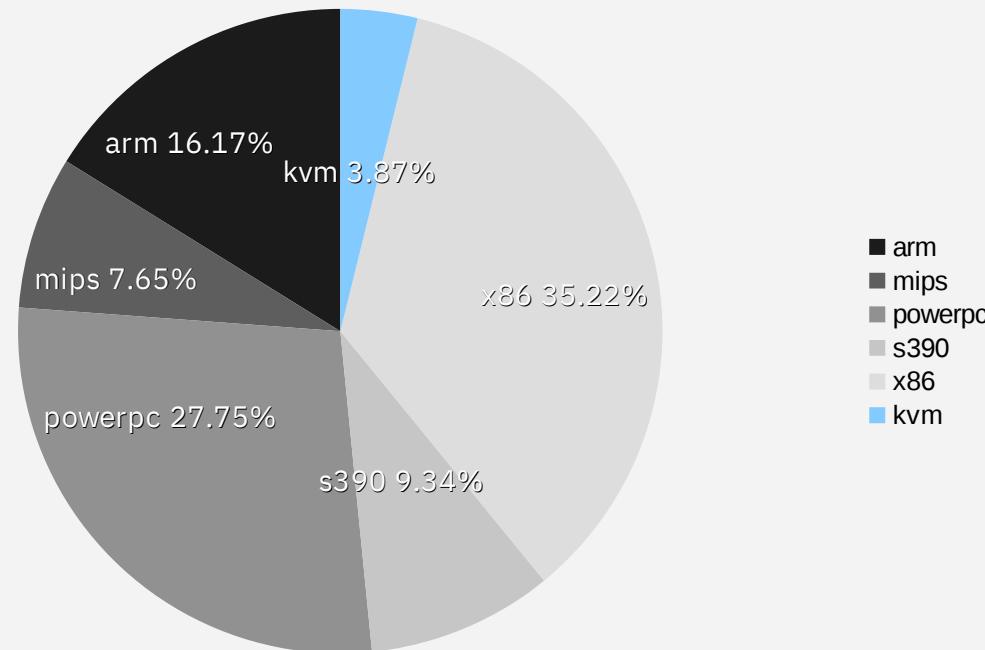
Is there anything platform specific at all?



# 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?**

- VM lifecycle
- VCPU lifecycle
- Eventfd/IRQFD handling
- Debugfs
- kvm\_stat base functions
- Cpu request handling

## **What is partially common?**

- RCU handling
- Wait state
- 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

....

# QEMU, libvirt

## QEMU vs Kernel

target/\*/kvm\*

vs

accel/kvm/

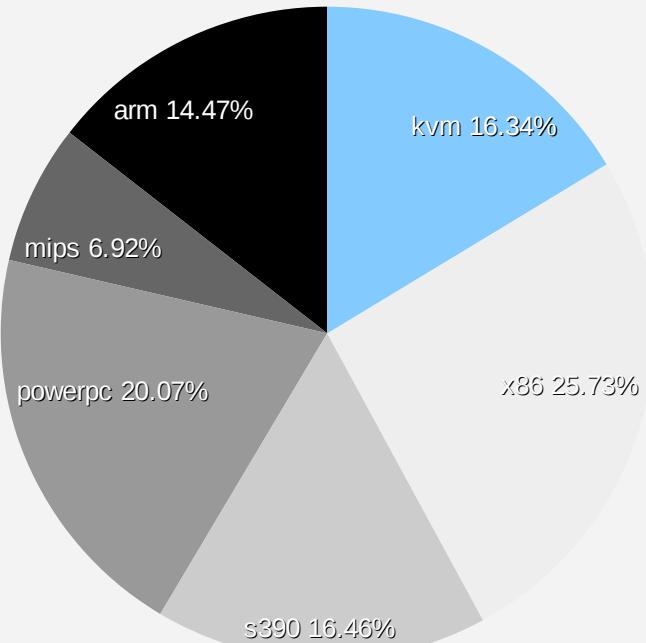
As expected: more commonality

Unexpected: similar size across architecture

## libvirt

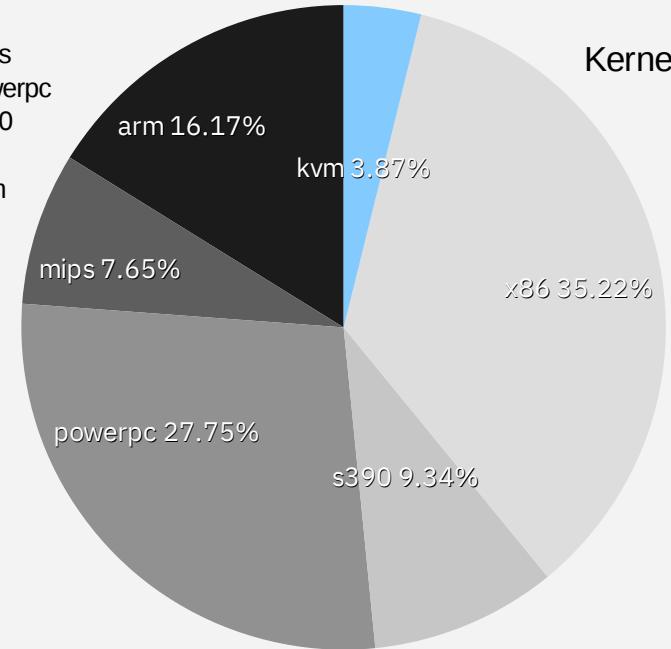
Not even arch-specific  
folders/files (apart from test)

QEMU



■ arm  
■ mips  
■ powerpc  
■ s390  
■ x86  
■ kvm

Kernel



# What Kind of Problems?

# 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.
```

# MMU Notifier

## 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

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 <>
# 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>
```

# 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

[...]

**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

# 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)

# 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 s390 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]**

# 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

**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