Porting bhyve on ARM

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About me

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  - Teaching Assistant: operating systems, systems architecture, networks
- BSD world
  - DragonFly BSD: SMT aware scheduler - 2012, Intel EPT for vkernels - 2013
  - FreeBSD - bhyve: instruction caching - 2014, coordinating students in bhyve projects - current, porting bhyve on ARM

FreeBSD

Hardware Assisted Virtualization

- a new CPU privilege level
  - on Intel/AMD: extends the current kernel mode (root/non-root)
  - on ARM: a brand new level called Hyp-mode

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Hardware Assisted Virtualization

- a new CPU privilege level
  - on Intel/AMD: extends the current kernel mode (root/non-root)
  - on ARM: a brand new level called Hyp-mode
- Type-2 hypervisor on ARM is more difficult to achieve
  - have to rewrite significant parts of the base OS to use the new registers
  - even then you can't run userspace apps directly over it

FreeBSD

Type-2 hypervisor on ARM

- We need to leverage the FreeBSD management mechanisms
- Don't want to write a full hypervisor from scratch

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  - bridge between the Host-OS and the hardware
  - it's called when doing hypervisor operations

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- Insert only a small code into Hyp-mode
  - bridge between the Host-OS and the hardware
  - it's called when doing hypervisor operations
- Other type-2 implementation - KVM
  - VirtualOpenSystems did the same thing

FreeBSD

Current status work

- running with bhyve a FreeBSD virtual machine
- output through a paravirtualized serial console
- it's getting to interrupt controller initialization

FreeBSD

Steps I've taken

- boot FreeBSD on FastModels (Fixed Virtual Platform)
  - $\tilde{2}$ weeks
  - different bugs in the FDT/OFW subsystem
  - accommodation with the code base

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  - different bugs in the FDT/OFW subsystem
  - accommodation with the code base
- crafted an init code placed in `locore`
  - it jumps to a routine where it checks if the platform booted in Hyp-mode
  - install some stub exception vector for Hyp-mode
  - marks the virtualization available

Steps I've taken (2)

- created a new `sys/arm/vmm`
- copied the VMM interface from `sys/amd64/vmm`
  - the VMM code should stay in generic
  - there is an amount of code still arch dependent
  - after stabilizing the ARM implementation we can make a common interface

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- created some low-level routines for installing the exception vector for Hyp-mode
  - the most important entry is the `Hypervisor` one
  - it jumps there whenever `hyp` instruction is called or a VM raises an exception

FreeBSD

How the Host-OS is making hypervisor calls?

- executes the `hyp` instruction
- first parameter indicates the address of a routine
- in Hyp-mode the code checks that the call came from the Host-OS

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- New translation level (Stage-2 translation) for VM isolation
- Issue: only LPAE is supported for both translations
- FreeBSD doesn't support LPAE and we cannot leverage on its memory management

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LPAE support

- Implement LPAE support in the VMM code
- Support for 40bit PA
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- Issue: On 32-bit we don't have the DMAP mechanism (we need the virtual address of each entry to be able to write on it)
- Created a shadow pagetable for each level 1 and level 2 pagetables which have the VAs

FreeBSD

Steps I've taken (3)

- Mapped the hypervisor code at the same address in Hyp-Mode and in Host-OS
  - all the pointers passed between modes needs to be consistent
  - note: the Hyp-mode works with the MMU enabled using a normal stage-1 translation using it's own pagetables

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  - all the pointers passed between modes needs to be consistent
  - note: the Hyp-mode works with the MMU enabled using a normal stage-1 translation using it's own pagetables
- Implement the low-level code which is doing context switching between the Host-OS and the VM
  - Save and restore the context (e.g. registers, co-proc registers)

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- Implement the paravirtualized serial console
- Started virtualizing interrupts

FreeBSD

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  - I plan to complete the GIC virtualization in the next two weeks

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- Try to run other Guest OSes
- Unify VMM code (amd64/arm)
- I'll try to promote this to my students (diploma and master projects)

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Conclusions

- Porting bhyve on ARM showed that the VMM interface design almost fits our needs
- The VMM still has some arch dependent code
- Lack of the LPAE in the FreeBSD base (hard-wire memory for VM)
- Type-2 hypervisor needs special care on ARM (for now)

Thank you for your attention!

ask questions

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