BHyVe
BSD Hypervisor

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Introduction

- BHyVe stands for “BSD Hypervisor”
  - Pronounced like beehive

- Type 2 Hypervisor (aka hosted hypervisor)
  - FreeBSD is the Host OS

- Availability
  - NetApp is releasing the source code under the BSD license!
  - Snapshot against 8.1 in svn repository: /projects/bhyve_ref

- Work In Progress
Status

- **Guest**
  - FreeBSD/amd64 releases 7.2 and 8.1
  - SMP - up to 8 virtual cpus
  - I/O - virtio or pci passthru
  - Minor kernel patches required

- **Host**
  - FreeBSD/amd64 release 8.1
  - Unmodified GENERIC kernel

- **Hardware**
  - Requires hardware virtualization assist with Nested Page Tables
  - Intel VT-x is supported
  - AMD-V support in progress
BHyVe: Logical View

- FreeBSD Host Operating System
- Hypervisor Module
- Virtual Machine
  - Guest Operating System
  - Guest App
  - Guest App
- Host Application
- Host Application
BHyVe: Implementation

- virtio-net
- legacy i/o (uart, rtc …)
- virtio-block

Host user
- allocmem
- setreg
- run
- ioemul

Host kernel
- IOCTLs, memory management, apic emulation

- Intel VT-x or AMD-V
- Nested Page Tables

Guest Physical Memory
- Virtual machine
- vcpus

- vm enter
- vm exit
- address translation

vmrun

vmm.ko
CPU Virtualization

- Requires Intel VT-x or AMD-V virtualization assists

- Trap into the hypervisor for a variety of reasons
  - Instructions like RDMSR, OUTB, CPUID, HLT, PAUSE
  - Hardware interrupts

- Local APIC is emulated
  - x2APIC mode
  - Accessed by the guest using RDMSR/WRMSR
  - Startup IPI is handled in user-space
    - Creates a thread context for the virtual cpu
    - IPIs between virtual cpus map to a fast host IPI
Memory Virtualization

- Requires hardware support for Nested Page Tables
  - Guest Physical to Host Physical translation

- Memory is allocated and pinned to virtual machines
  - No sharing between virtual machines
  - No allocate-on-demand
  - Hard allocation makes pci passthru a lot easier

- Memory allocated to virtual machines is hidden from the host
  - Kernel config option MAXMEM
  - hw.physmem tunable
PCI I/O Virtualization

- PCI bus topology and configuration emulated in user-space
  - Intercept access to PCI config address and data registers

- Two types of PCI devices on the virtual PCI bus
  - virtio
  - passthru

- Interrupt delivery through MSI only
  - Single as well as multi-vector MSI is supported
  - Legacy is hard because it requires IOAPIC emulation
  - MSI-X is hard because it requires instruction emulation
virtio

- Paravirtualized device specification

- FreeBSD virtio block and net drivers from [deboomerang@gmail.com](mailto:deboomerang@gmail.com)
  - Not publicly available under a BSD license

- Backend virtio-net and virtio-block devices in user-space
  - virtio-net uses /dev/tapN to send and receive ethernet frames
  - virtio-block reads/writes to a file on the host filesystem
PCI Passthru

- Guest has direct access to a PCI device
- Some configuration registers are still emulated
  - BAR registers
  - MSI capability
- DMA transfers will target guest physical addresses
  - IOMMU translates from guest physical to host physical addresses
- Stub driver in the host forwards interrupts from the device to the guest
- Virtual MSI capability for passthru devices that only support legacy interrupts
- ‘blackhole’ driver prevents the host from attaching to passthru devices
Guest Modifications

- Custom console and debug port
  - Done for expediency
  - Not necessary if we have a 16550 device model

- Local APIC access via x2APIC MSRs

- AP bringup changed to start execution directly in 64-bit mode
  - Required if real-mode guest execution is not supported
User-space API

- A virtual machine appears in the host filesystem as a device node

- ioctls used to control and configure the virtual machine
  - 20 in total
  - For e.g. setreg, pincpu, run, interrupt, getstats

- Can read(), write() and mmap() the virtual machine device node
  - Useful to inspect the virtual machine's memory
  - `dd if=/dev/vmm/testvm of=memdump bs=1024 count=1024`
Performance

- **Features**
  - Address space identifiers for virtual cpus
  - Minimal overhead host IPIs
  - Some guest state is lazily saved only on “slow” trap to user-space
    - Guest floating point registers
    - System call related MSRs

- “make buildworld”
  - 4 cores, 2GB memory, 1GbE NIC, 1 SATA disk
  - /usr/src is mounted over NFS
  - /usr/obj is mounted on a block device

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Build time in seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Metal</td>
<td>1308</td>
</tr>
<tr>
<td>Partitioned</td>
<td>1336</td>
</tr>
<tr>
<td>Virtualized</td>
<td>1446</td>
</tr>
</tbody>
</table>
Future Opportunities

- Support Windows, Linux and *BSD guests
- Support AMD’s hardware virtualization assist
- Guest suspend/resume and live migration
- BIOS emulation
Thank you