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BHyVe

BSD Hypervisor

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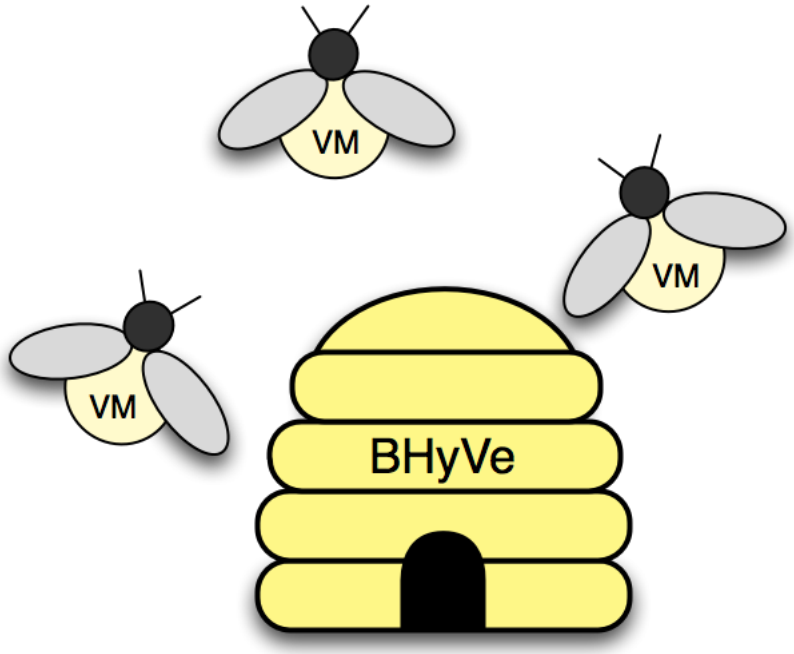


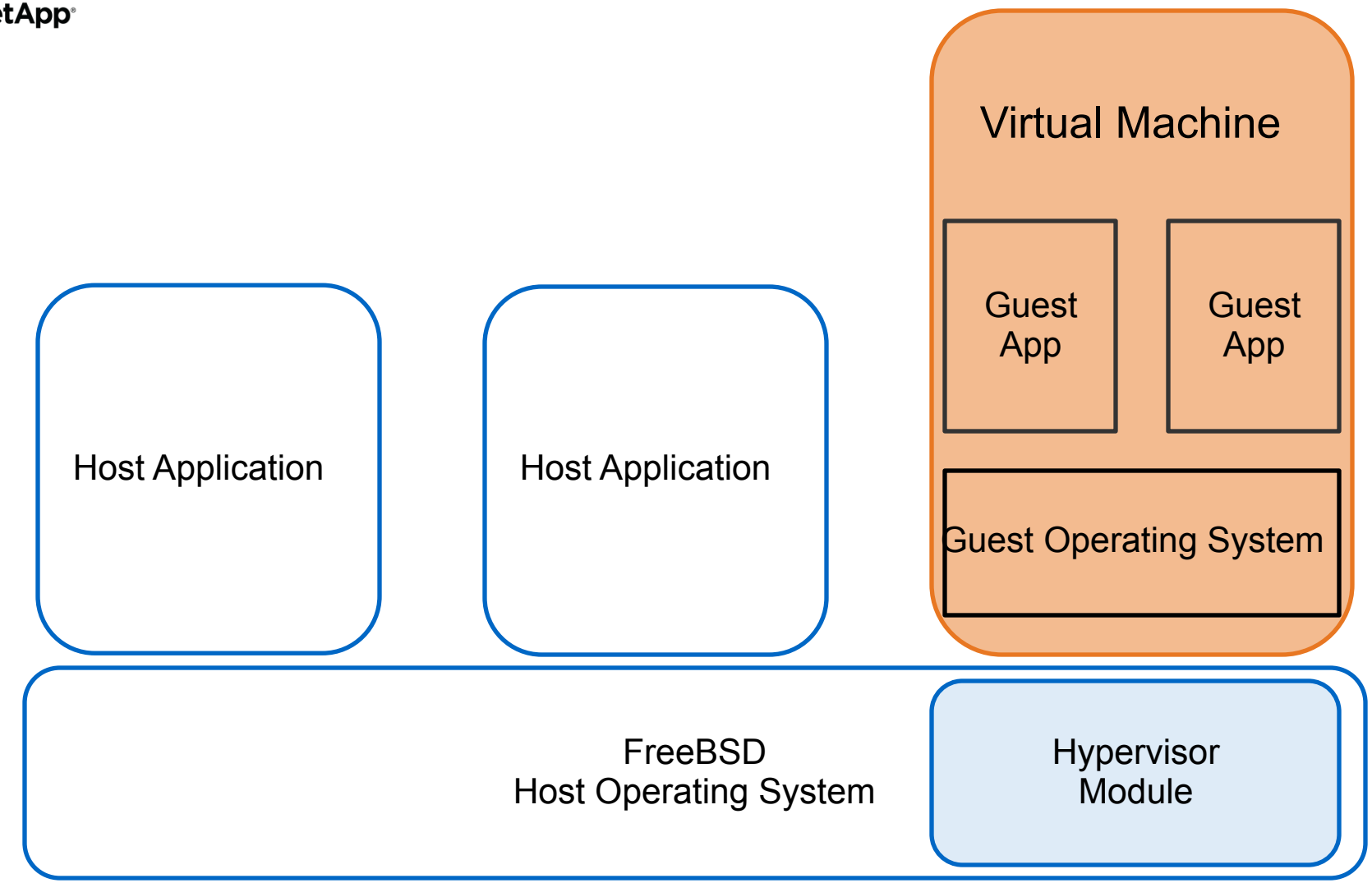
Introduction

- 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

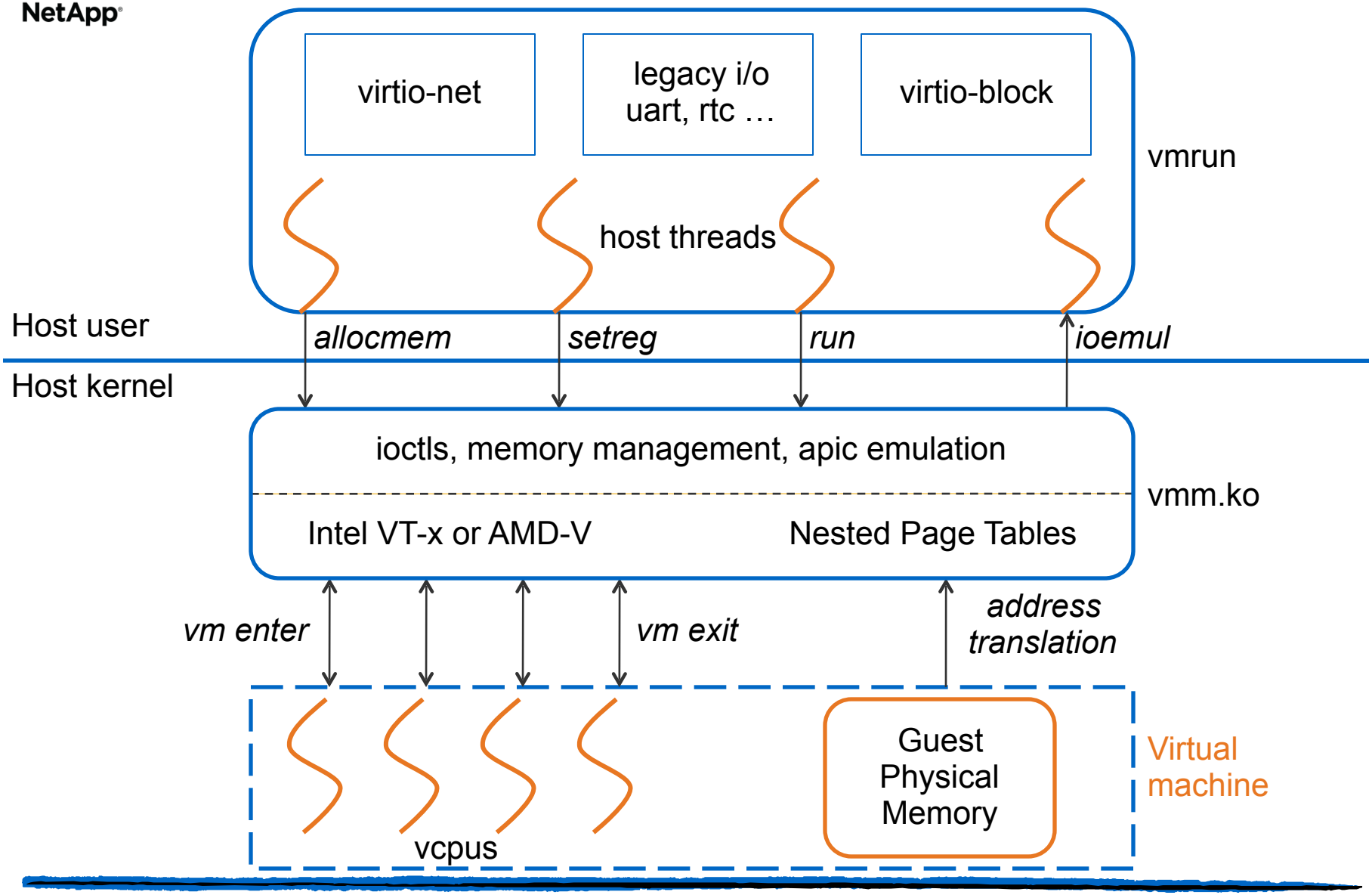
Status

- 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



BHyVe: Implementation



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
  - http://ozlabs.org/~rusty/virtio-spec/virtio-paper.pdf
- FreeBSD virtio block and net drivers from 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

Configuration	Build time in seconds
Bare Metal	1308
Partitioned	1336
Virtualized	1446

Future Opportunities

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

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Thank you