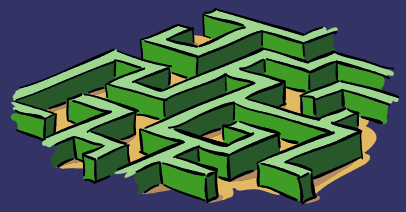
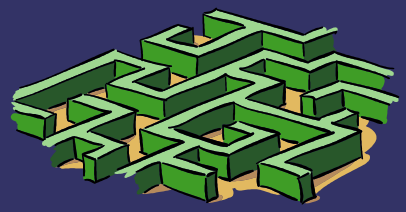
Virtualization and BSD

- Approaches to Virtualization
- Benefits of Virtualization
- Para-virtualization in depth
- Para-virtualization on x86 and sparc64



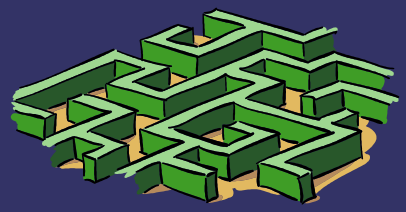
Virtualization Approaches

- Process Virtualization
  - Jails
  - Vservers (Linux)
  - Zones (Solaris)
- OS Virtualization (para-virtualization)
  - Xen (Cambridge, UK)
  - T1 hypervisor (Sun)
  - VMI (VMware)
  - Phype (IBM)
- CPU Virtualization (emulation)
  - VMware
  - Virtual PC (Microsoft)



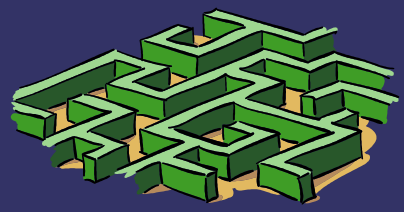
OS Virtualization Benefits for Development

- MMU interface can be decoupled from the OS
  - Provides future sun4v processors with the backward compatibility (on x86 by design)
- Debugging / fault isolating drivers by running them in their own domain
  - Faulty devices / drivers don't bring down the whole system



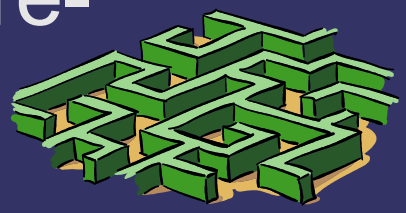
Virtualization Benefits for Administration

- Server Consolidation
  - Servers typically average 10-20% utilization
  - Large potential impact on power, space, and network ports
- Simplified Provisioning
  - Allocating a new system can be just allocating an IP address and storage



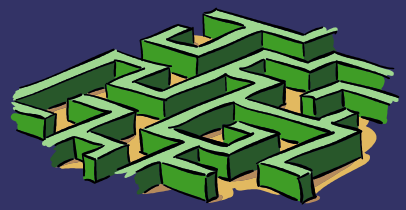
OS Virtualization Benefits for Administration

- Reduction in planned downtime
  - Running virtual machines can be migrated across the network – actual “down time” determined by the size of the writable working set
- Consolidating different operating systems or different versions of the same operating system
- “Reboot” virtual machines independently of each other
- Natural interfaces for QoS across all resources



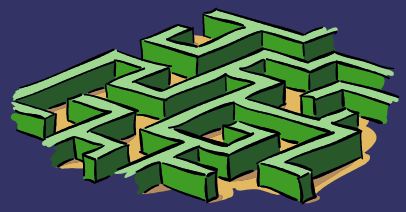
Paravirtualization In-Depth

- Memory Partitioning
- CPU Time
- CPU Privilege
- Devices / Interrupts
- Virtual Memory



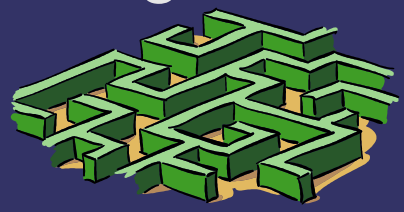
Memory Allocation

- Real / Physical
  - Each guest is given a subset of the memory on the machine
  - Sun uses the traditional terminology for the distinction -- real addresses are addresses that guest can access and physical are the actual hardware addresses
  - Guests
- Physical / Machine
  - Xen makes the same distinction but uses the terms from the earlier “Disco” papers
- Balloon driver

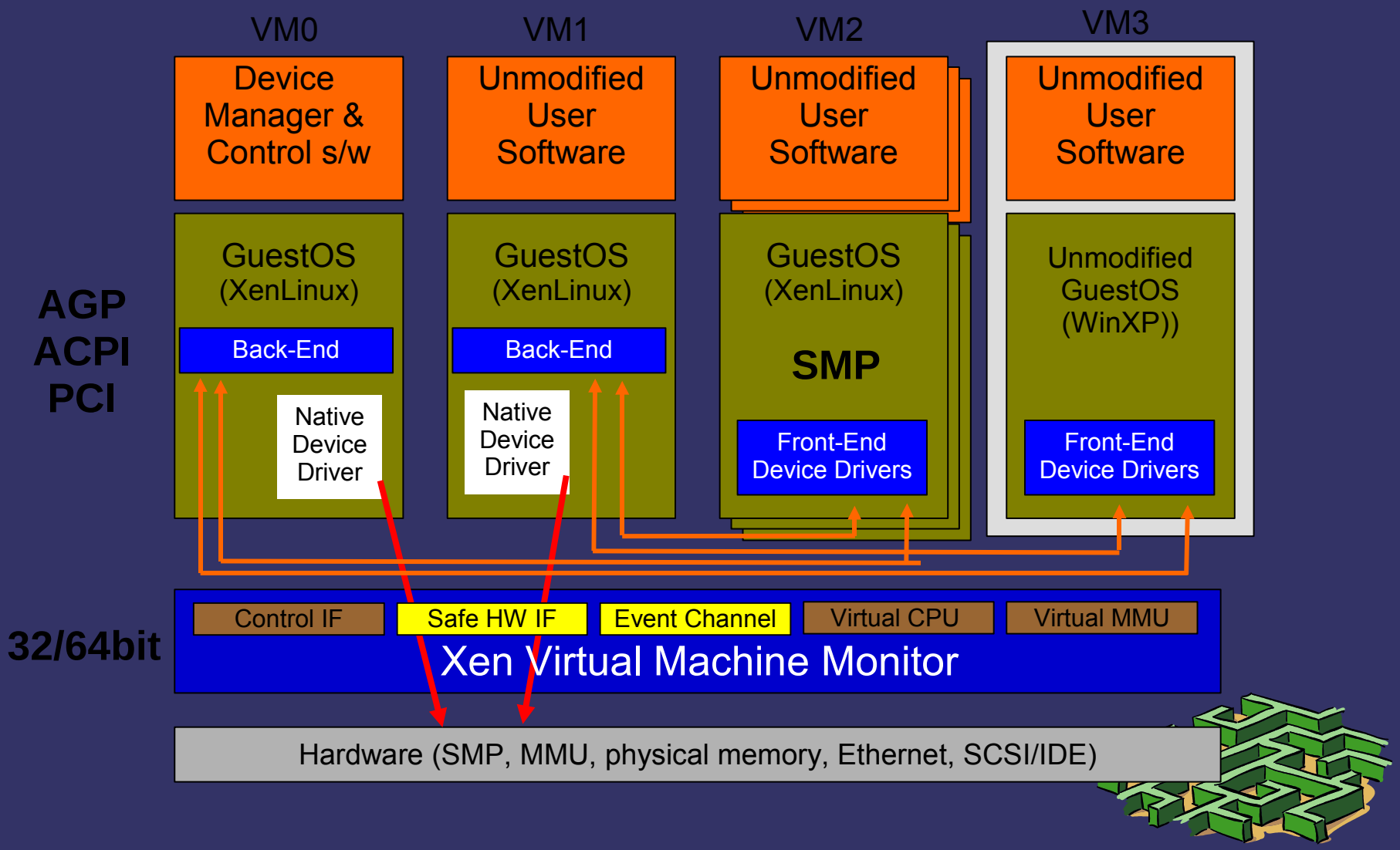


CPU Time

- Xen schedulers
  - Guest operating systems are multiplexed on the CPUs by a scheduler
  - A number of different schedulers exist
  - Difficult to get right, awkward interaction with driver domains, to work well with SMP requires some form of gang scheduling
- Sun4v strands
  - The T1 exposes 32 “strands”, the strands can be dynamically added to/removed from running domains

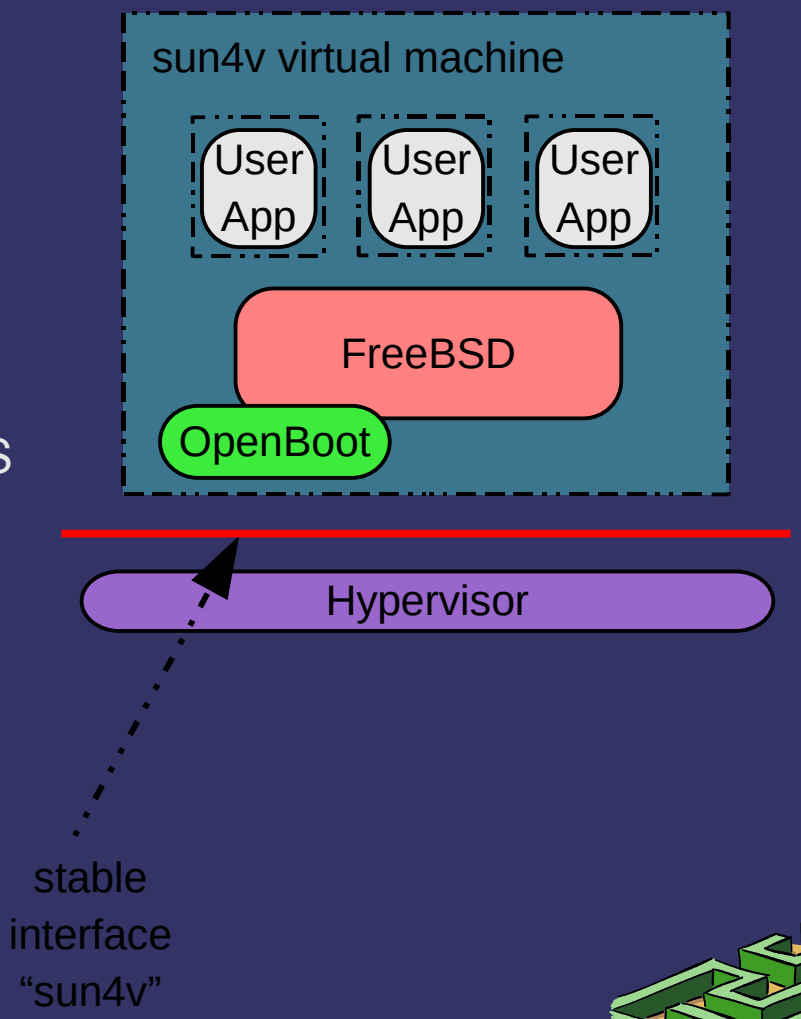


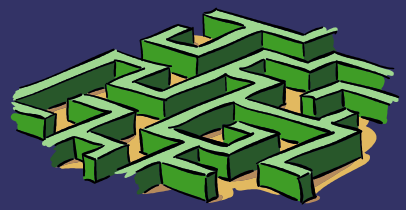
Xen 3.0 Architecture



Virtual Machine for SPARC

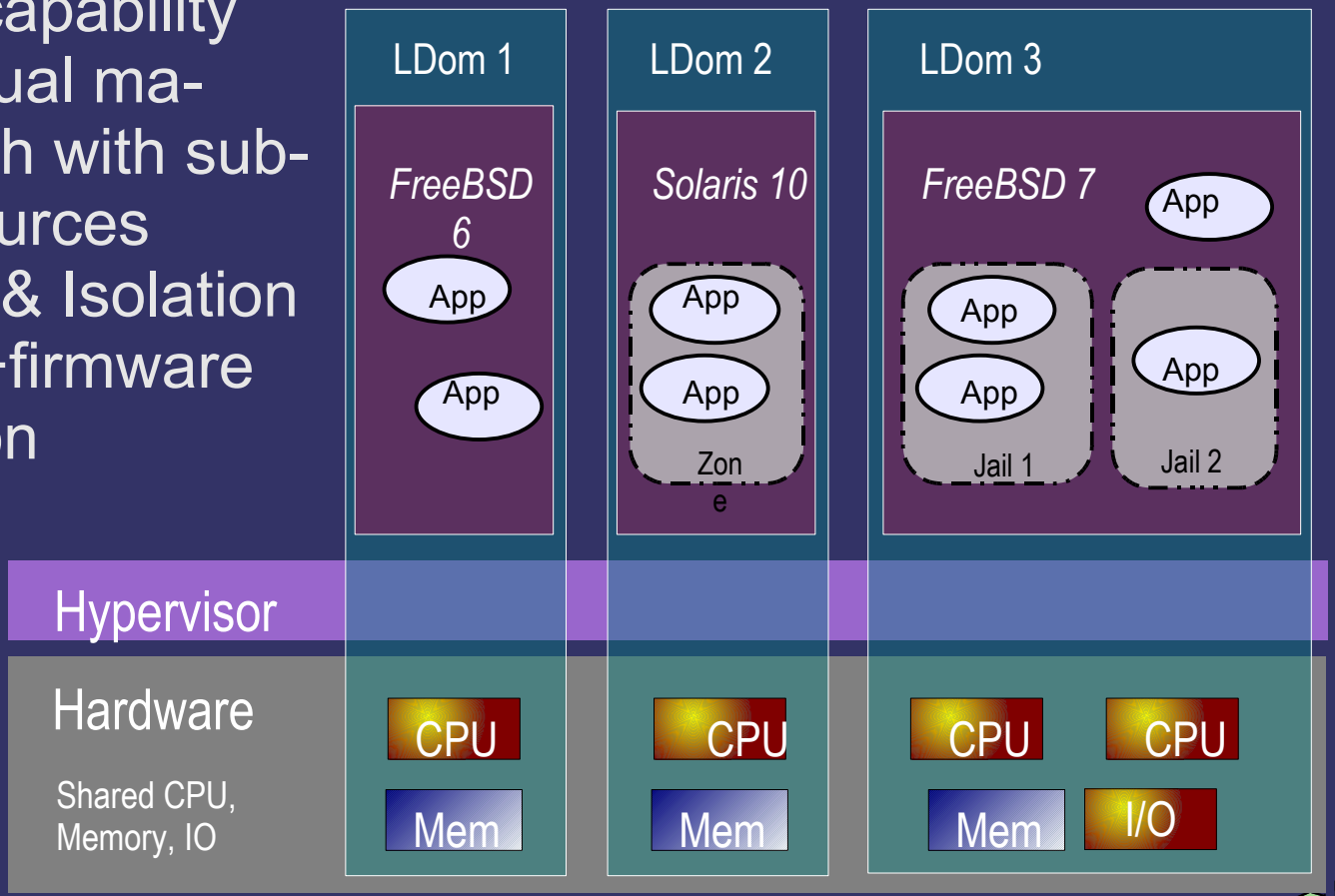
- Thin software layer between OS and platform hardware
- Para-virtualised OS
- Hypervisor + sun4v interface
  - Virtualises machine HW and isolates OS from register-level
  - Delivered with platform not OS
  - Not itself an OS

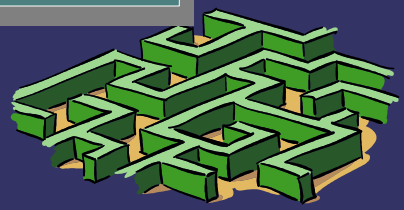




Sun4v Logical Domains Architecture

- Partitioning capability
  - Create virtual machines each with subset of resources
  - Protection & Isolation using HW+firmware combination



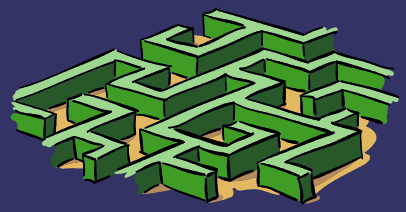


CPU Privilege

- Xen ring/segment usage
  - i386: Xen runs in ring 0, guest OS runs in ring 1
  - x86_64: most models lack segment checks in long mode – Xen runs in ring 0, guest OS runs in ring 3 with a different page directory from guest
- Sun4v adds a hyperprivileged mode
  - Sun4v adds a hpstate register (hyperprivileged pstate) some events that would previously cause a switch to privileged mode now switch to hyper-privileged
  - all guest state lives in the guest allowing the HV to be updated in place

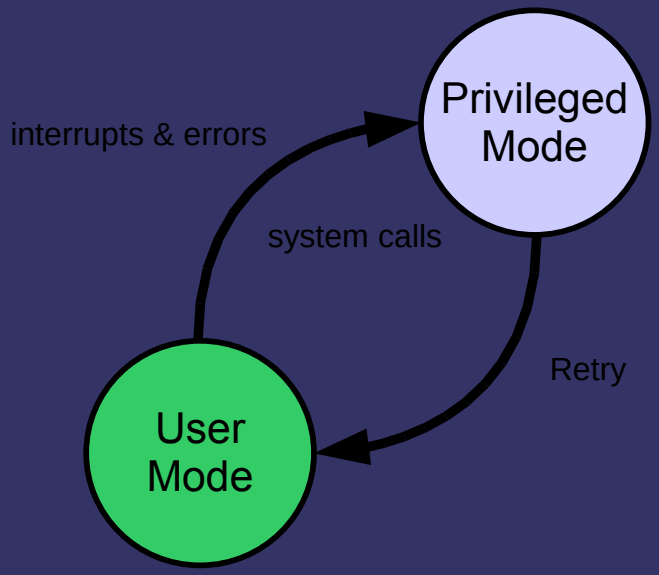
Privileged mode constrained

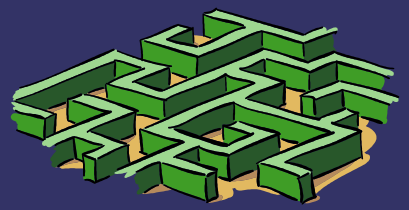
- Close derivative of legacy privileged mode, but:
  - No access to diagnostic registers
  - No access to MMU control registers
  - No access to interrupt control registers
  - No access to I/O-MMU control registers
  - All replaced by Hypervisor API calls
- UltraSPARCness remains with minor changes
  - timer tick registers
  - softint registers etc.
  - trap-levels & global registers etc.
  - register window spill/fill



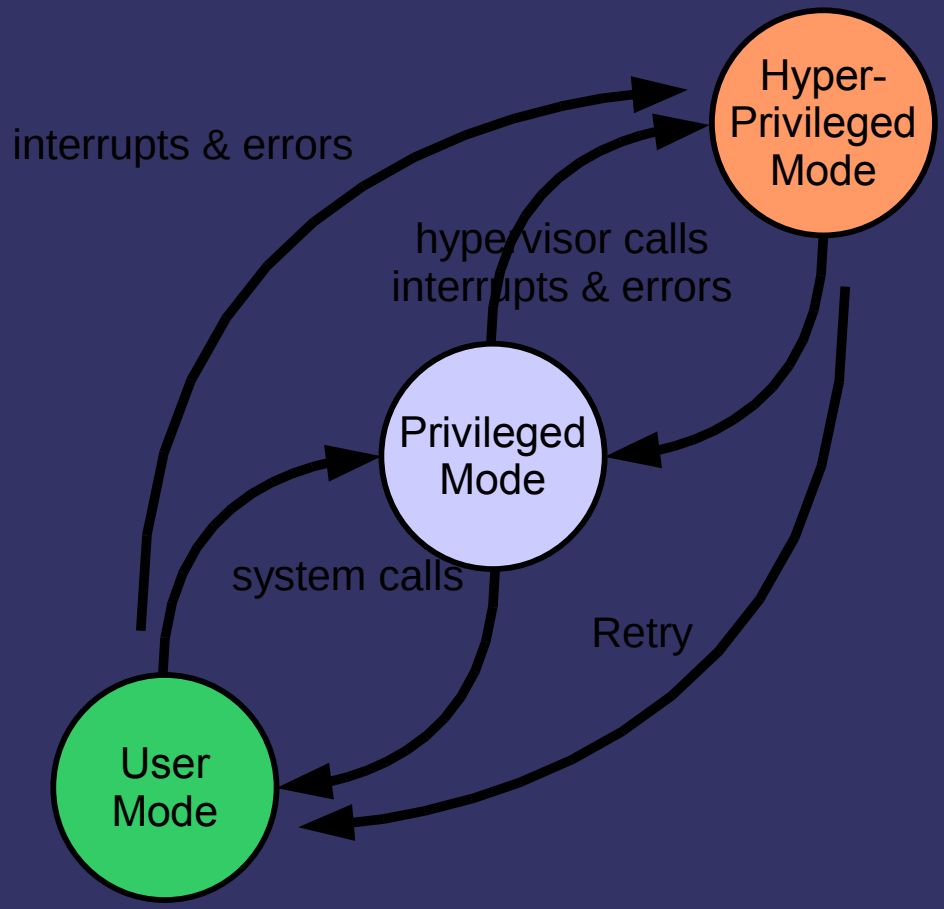
Legacy SPARC execution mode

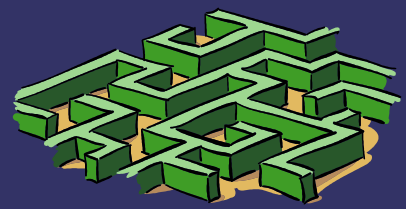
- Existing sun4u chips



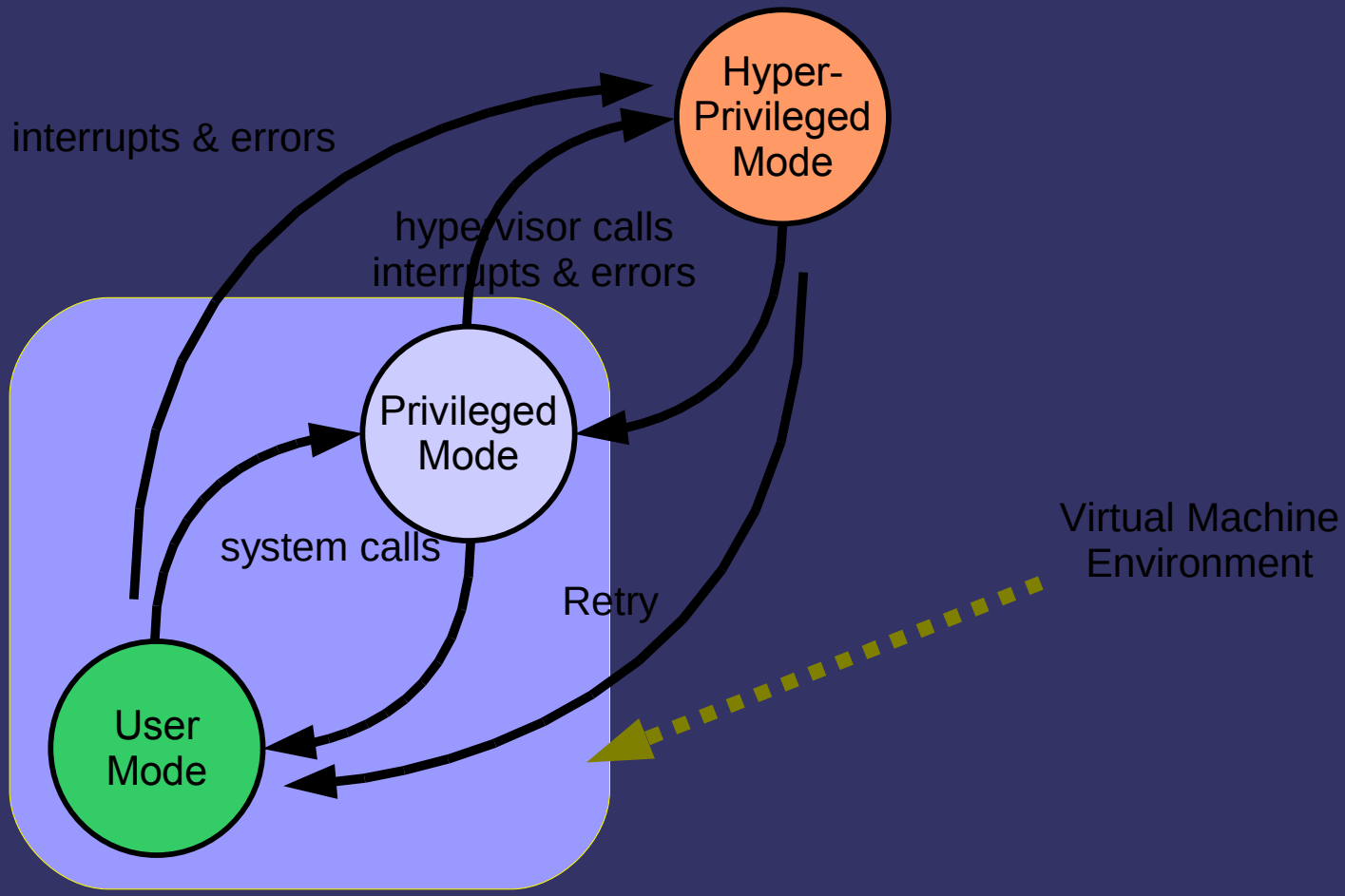


New SPARC Execution mode



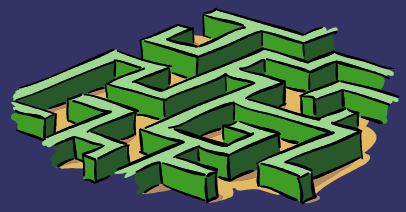


New SPARC Execution mode



Devices / Interrupts

- DOM0 driver domains
- Allocating PCI-e nexus
- Virtual network and block devices
- Interrupt handling

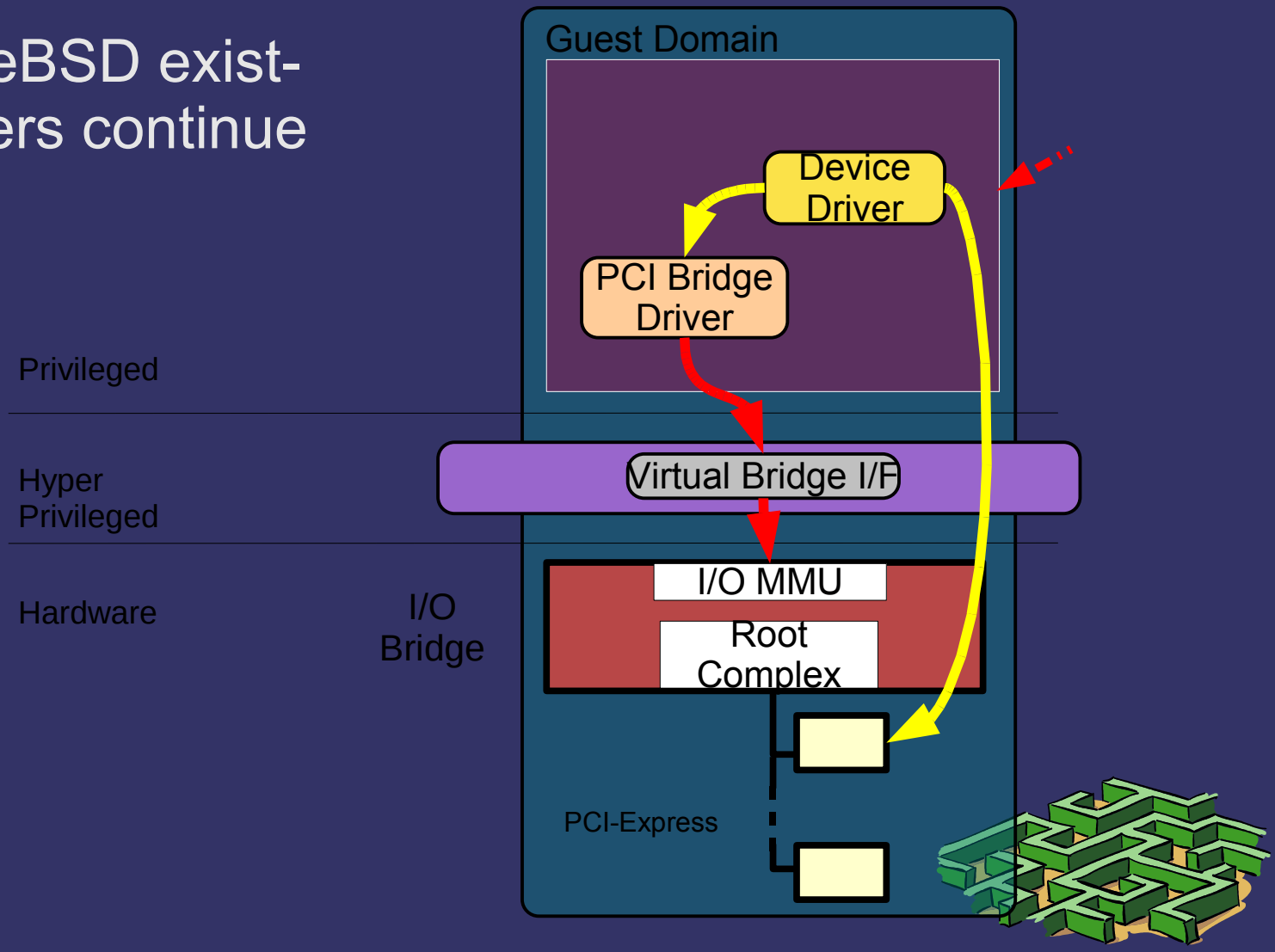


Xen I/O Architecture

- Xen *IO-Spaces* delegate guest OSes protected access to specified h/w devices
  - Virtual PCI configuration space
  - Virtual interrupts
- Devices are virtualised and exported to other VMs via *Device Channels*
  - Safe asynchronous shared memory transport
  - ‘Backend’ drivers export to ‘frontend’ drivers
  - Net: use normal bridging, routing, iptables
  - Block: export any blk dev e.g. sda4,loop0,vg3

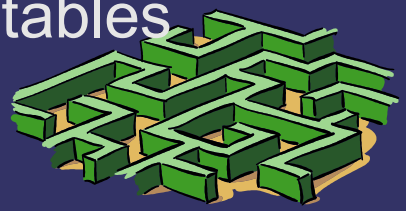
Sun4v direct I/O model

- For FreeBSD existing drivers continue to work



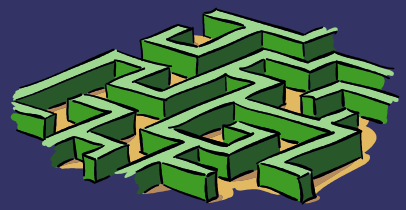
Virtual Memory x86

- Architected Page Tables
  - Difficult to abstract – pages are stateful can't allow guest to update directly to prevent guest from mapping other guests memory
    - (L3 vs. L2 etc. page tables)
    - Other global resources that can't be manipulated directly (GDT, LDT, etc.)
  - Xen directly exposes page tables to the guest
    - Upside – relatively few changes to MD VM
    - Downside – large amounts of state required for tracking type of each page, exposing super-pages is more difficult, batching updates requires writable page tables which frequently don't work outside of Linux



Virtual Memory x86 II

- Page table updates are all made via hyper-calls
  - Setting cr3
  - Writes to page directories and page tables
    - Page table updates can be batched by means of “writable page tables”, but their use precludes the use of linear page tables.



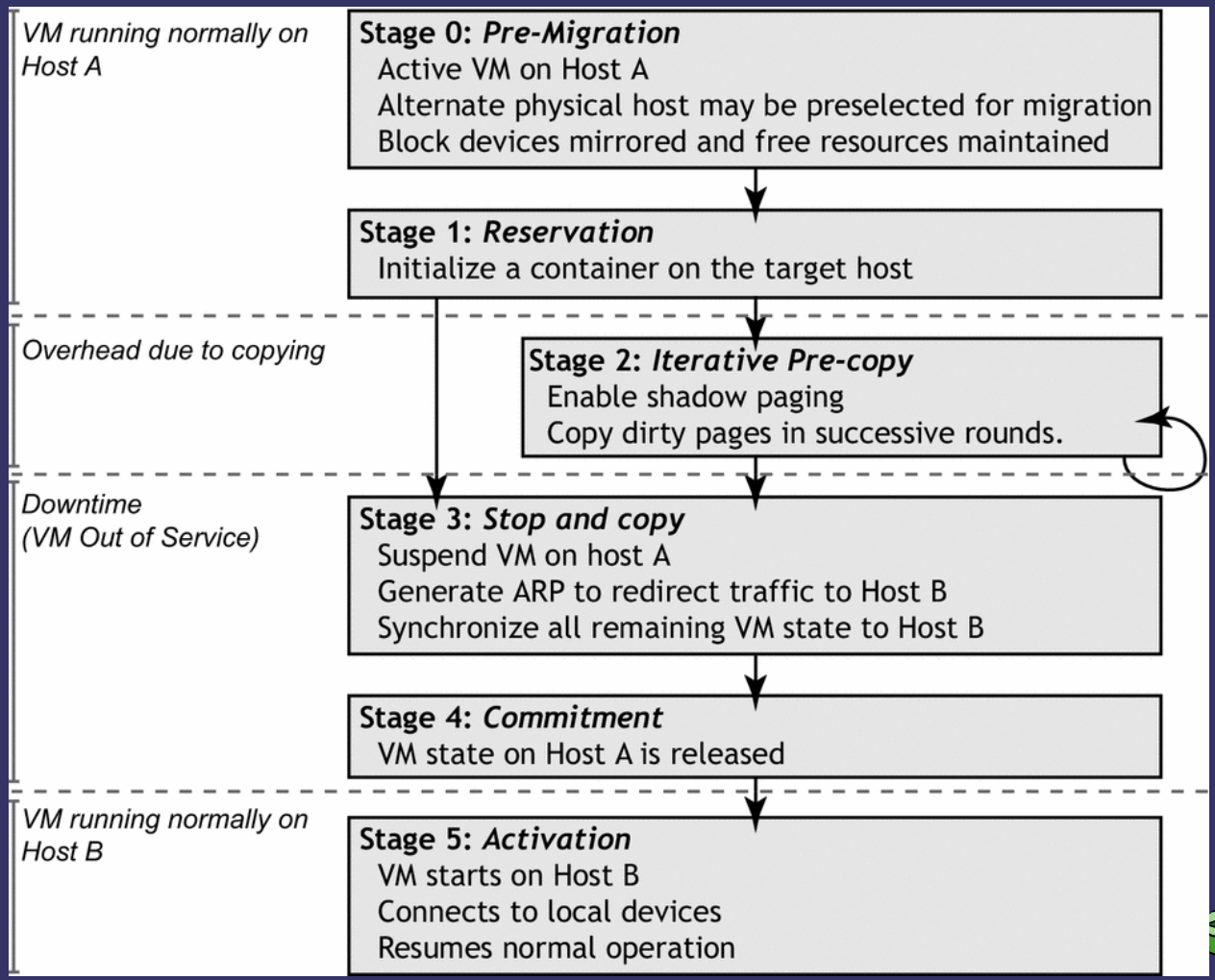
Virtual Memory Sparc

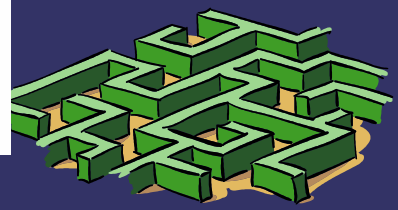
- Software loaded TLB
  - Sparc v8 and v9 relied on a TSB (translation storage buffer) as a direct mapped secondary TLB
    - Benefits of TSB over page tables:
      - allows for arbitrary page sizes
      - Single memory access for lookup
      - Lookups can be done in parallel for set associative TSBs
      - Flat structure avoids typing issues
  - Happily this also makes for a good interface with the hypervisor
    - Guest now registers TSB with the hypervisor on context context switch – hypervisor services TLB misses from the TSB

Live VM Relocation

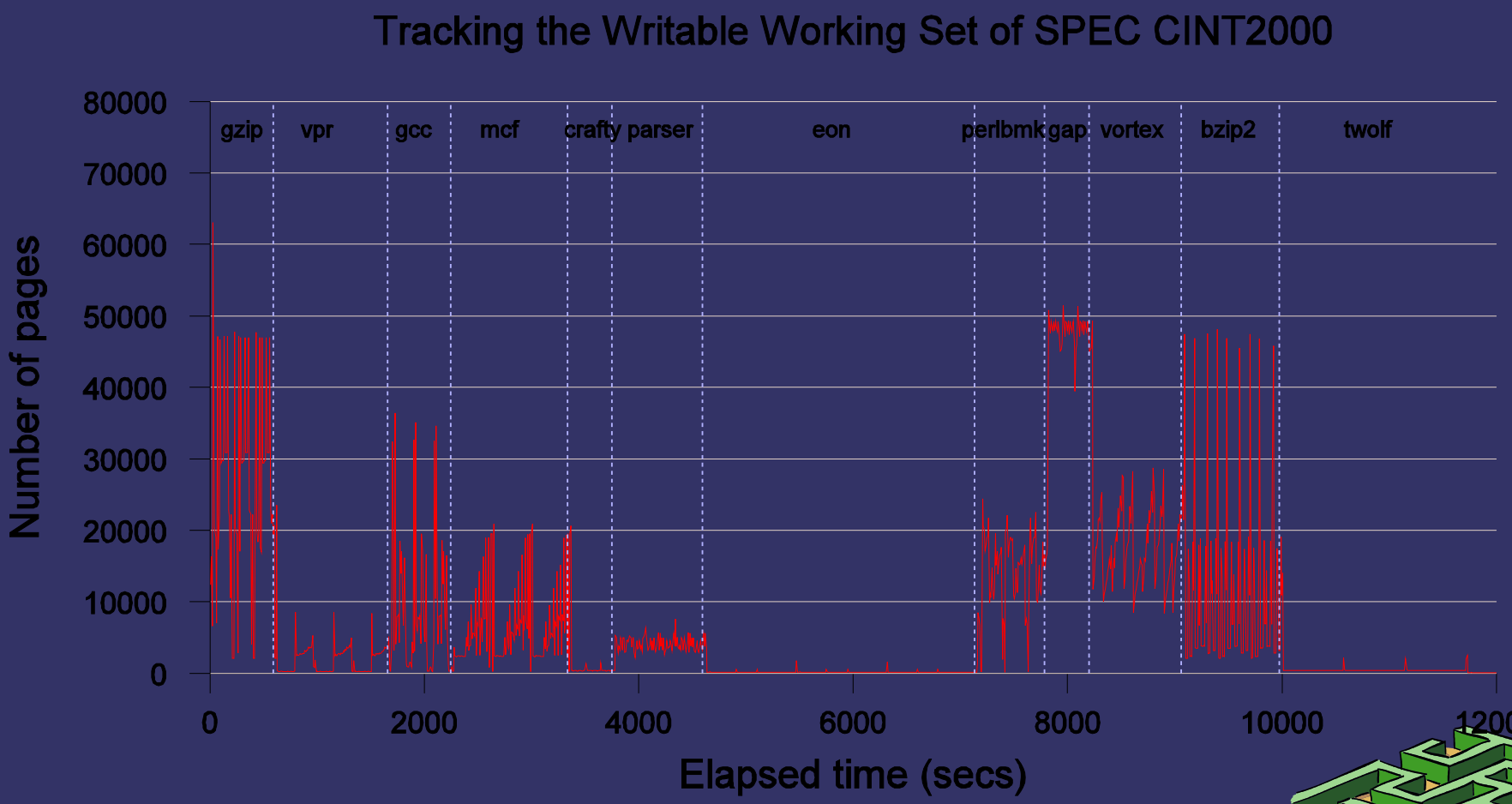
- Why is VM relocation useful?
  - Managing a pool of VMs running on a cluster
  - Taking nodes down for maintenance
  - Load balancing VMs across the cluster
- Why is it a challenge?
  - VMs have lots of state
  - Some VMs will have soft real-time require-ments
    - E.g. web servers, databases, game servers
  - Can only commit limited resources to migration

VM Relocation Strategy



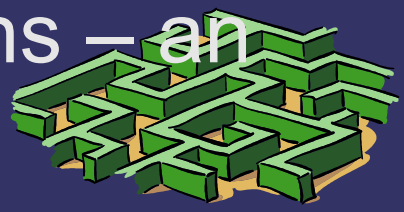


Writeable Working Set



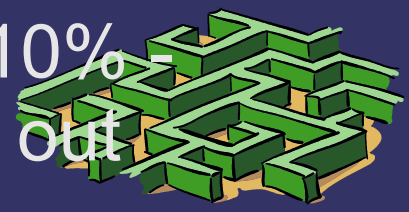
Xen and the BSDs

- NetBSD had full dom0 support for Xen 2 – full support for Xen3 a work in progress
- OpenBSD has seen no effort on Xen support to date – but Chris Jones has proposed it as an SoC project
- FreeBSD 7.0 has 3.x support for unprivi-leged guests and some extra “driver domain” functionality
- Some work has been done on dom0 – but has been neglected for several months – an SoC project is being pushed



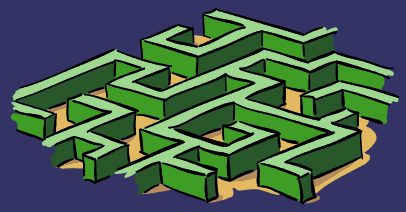
Xen and FreeBSD

- Large amounts of work required to integrate the Xen toolset into the FreeBSD environment and make Xen usable for the average user
- Xen appears to have no thought given to incremental versioning – FreeBSD will likely support point versions
- Less compelling now that Vmware Server is free and VMI is available
  - If performance difference is less than 10% - Vmware's polish and ease of use wins out



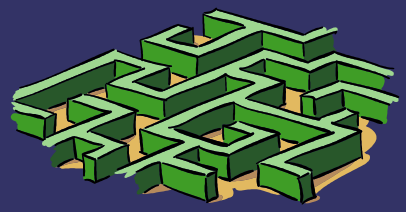
Sun4v and FreeBSD

- Sun's hypervisor has a thoroughly documented API and an established versioning interface
- The challenge is more general and lies largely in FreeBSD's scaling bottlenecks and the lack of a maintainer for sparc64



VMI and FreeBSD

- Not as Linux-centric
- FreeBSD will ultimately seek a unified interface for Xen and VMI
- Objective of VMI is to have a non-disruptive P2V by having the same binary support both native and virtual



What's next?

- Xen
  - DomU support (unprivileged guest)
    - Complete balloon driver
    - Make sleep work prior to interrupts being enabled for xenbus
  - Dom0 support (initial domain)
    - Stabilization
    - Drivers to support domU (netback, blkback)
- VMI
  - Need further investigation
- Sun4v
  - Dom0 support
    - Pmap stabilization
  - DomU support
    - Virtual drivers