SCALE 14X

The Bare-Metal Hypervisor as a Platform for Innovation

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About the Old, Fat Geek Up Front

- Linux user since 1995; became a Linux advocate immediately
- Delivered many early talks on Open Source Advocacy
- Former Open Source columnist for Infoworld, Processor magazines
- Former weekly panelist on “The Linux Show”
- Wrote one of the first books on Open Source: Embracing Insanity: Open Source Software Development
- 30 years in the industry; 20+ years in software services consulting
- Recently Evangelist for the Xen Project (until tomorrow; now looking for other opportunities)
- Over 100 FOSS talks delivered; over 200 FOSS pieces published

About Innovation...

- A favorite buzzword for marketing purposes
- Many things in our industry labeled "Innovation" are nothing more than hackneyed placid tripe
- Innovation calls for thinking of the world in a different way and seeing it come to life
- Simply changing the shade of lipstick on a pig does not qualify

About Innovation...

- Real innovation can borrow from the known to create the unknown
- Many innovations are reassemblies of known objects in a new way
  - Example: many cloud concepts resemble similar concepts in mainframes, but they've been reapplied to a multi-server environment
  - But the net result needs to be something significantly different than what existed before

Some of the More Interesting Advances

- Xen Automotive: the effort to craft an embedded automotive infotainment system
- Realtime virtualization: work to facilitate applications which need realtime processing
- ARM-based hypervisor: enabling a new breed of applications, from servers to cell phones, on the ARM architecture
- MirageOS and other unikernel systems: creating highly-dense farms of ultra-small and secure cloud appliances

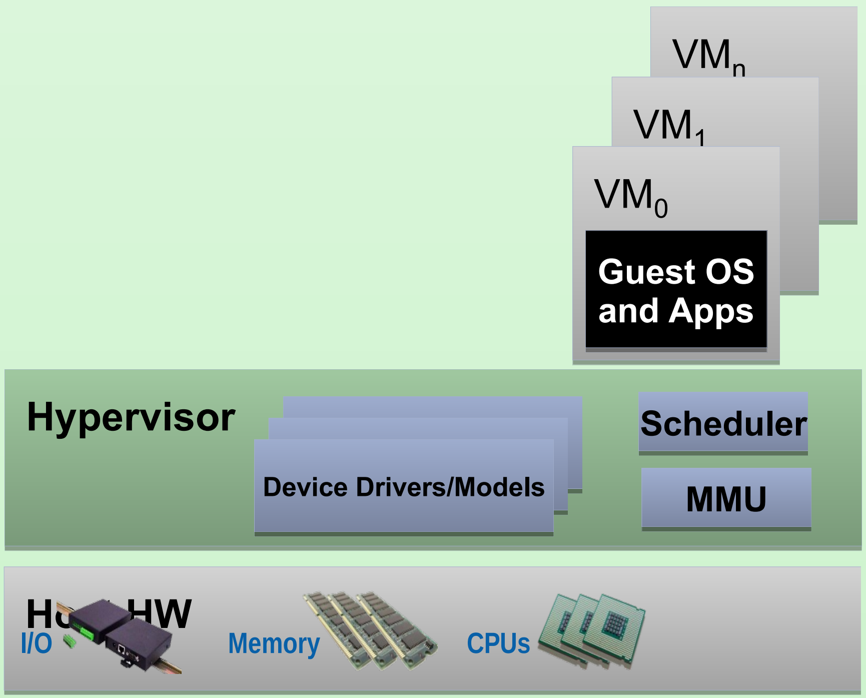
But First...

What exactly is a “Bare-Metal Hypervisor”?

Hypervisor Architectures

Type 1: Bare metal Hypervisor

A pure Hypervisor that runs directly on the hardware and hosts Guest OS's.



Provides partition isolation + reliability,
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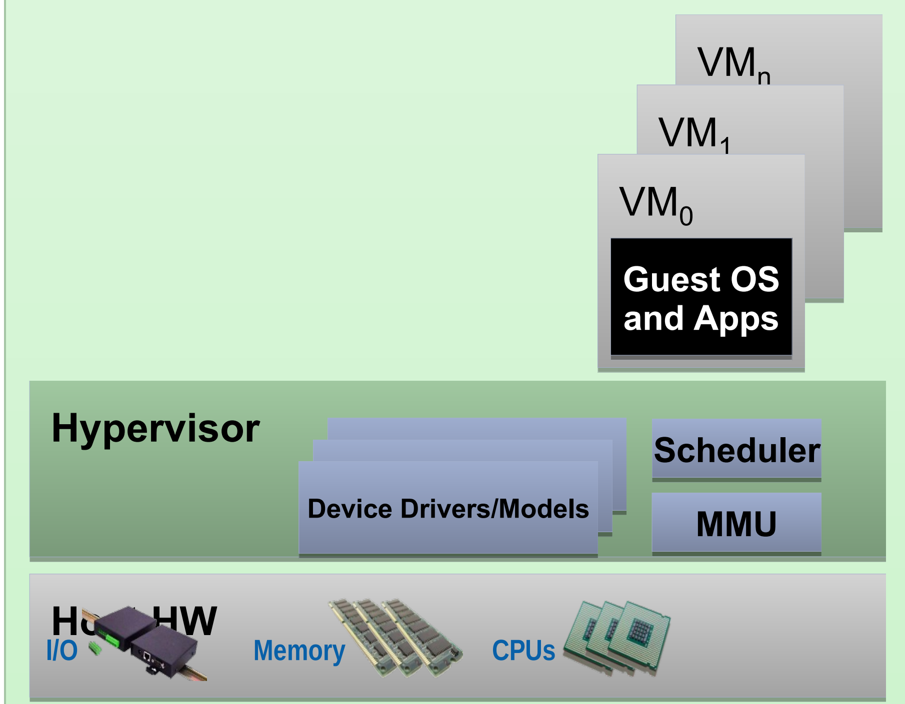
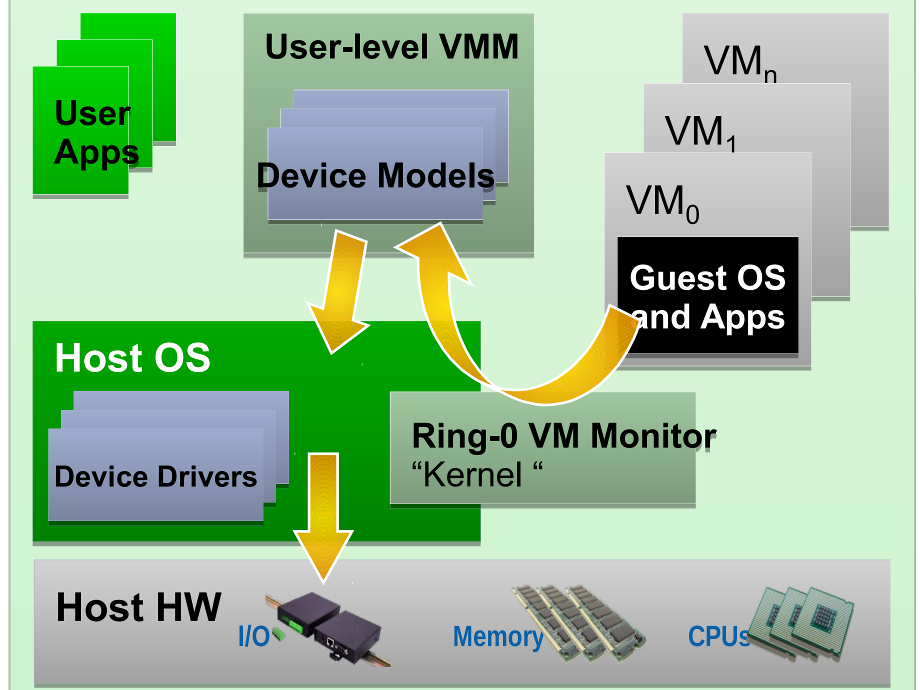


Provides partition isolation + reliability, higher security

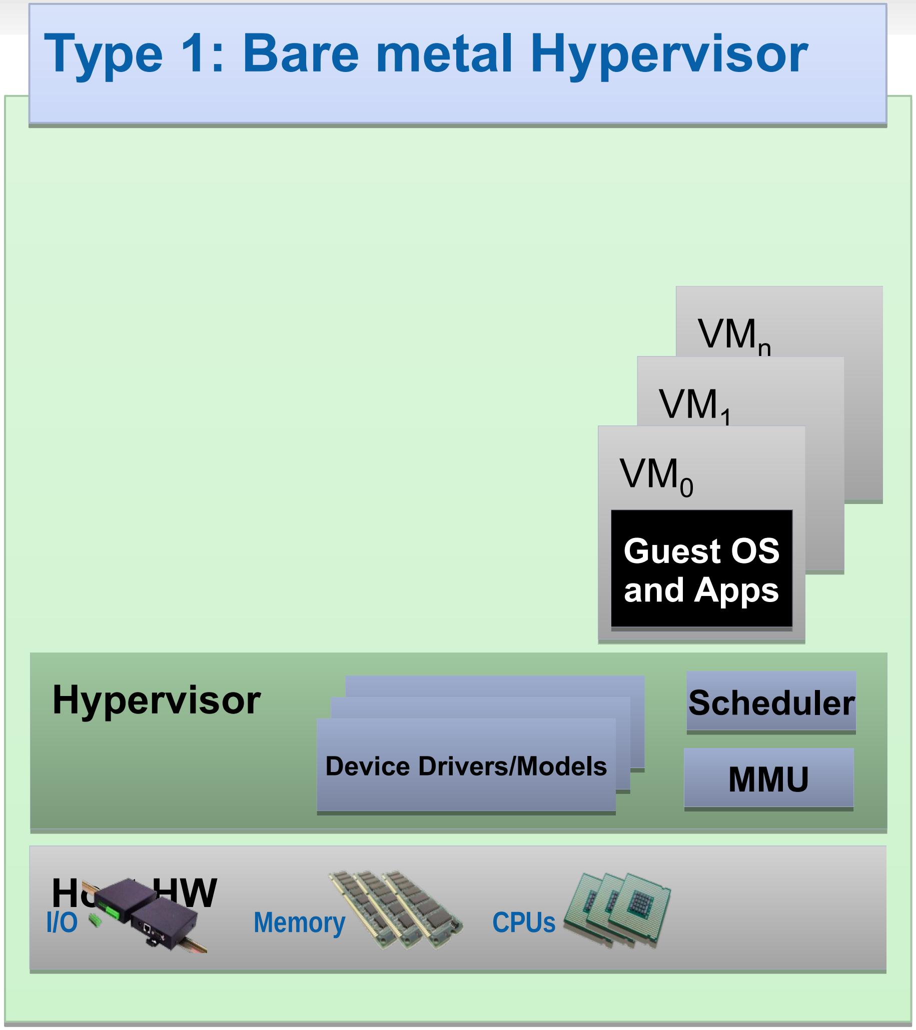
Type 2: OS 'Hosted'

A Hypervisor that runs within a Host OS and hosts Guest OS's inside of it, using the host OS services to provide the virtual environment.



Low cost, no additional drivers
Ease of use & installation

Xen Project: Type 1 with a Twist



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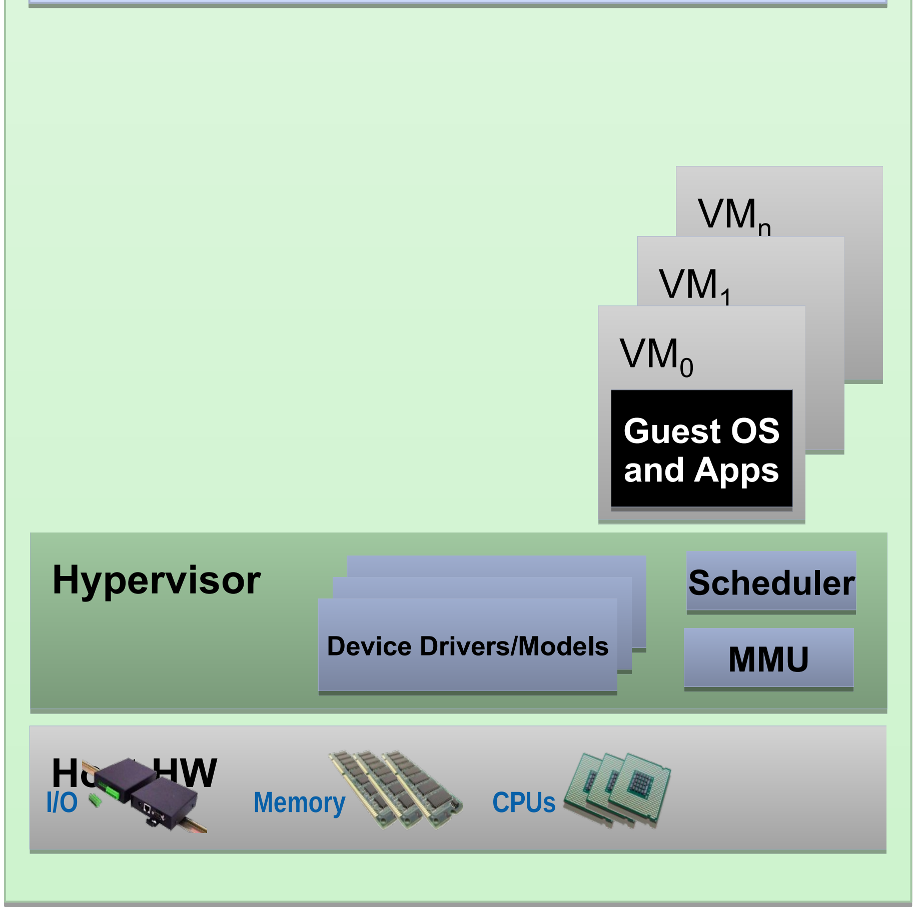
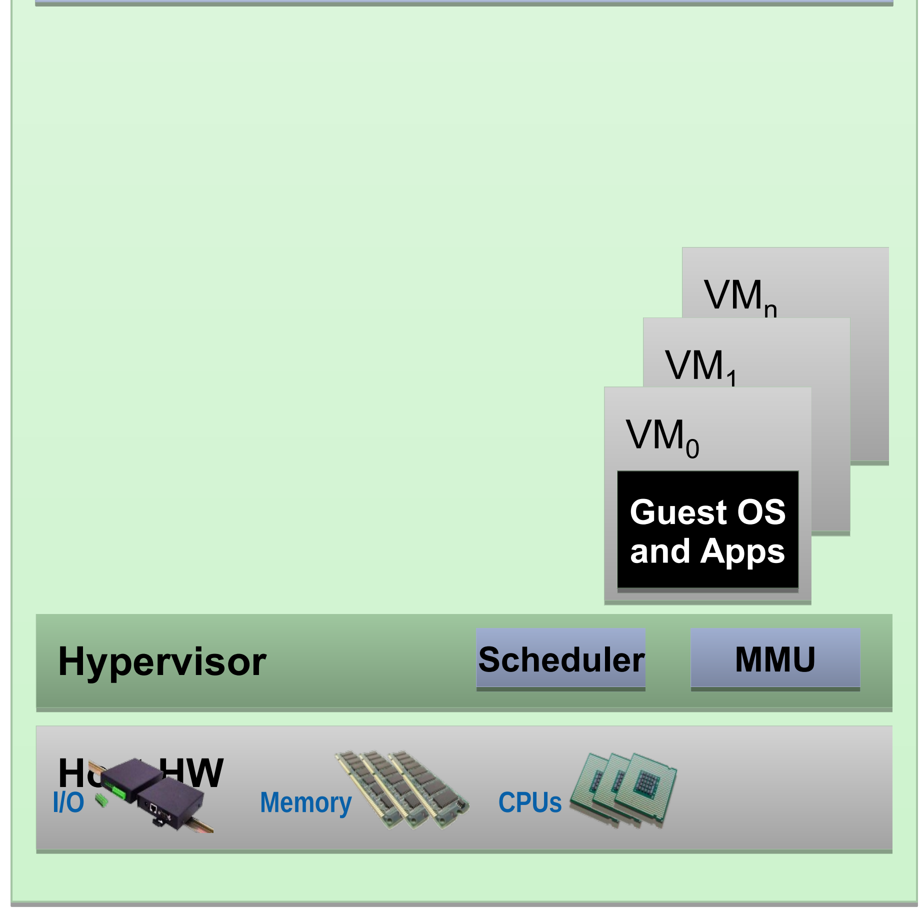


Xen Project Architecture



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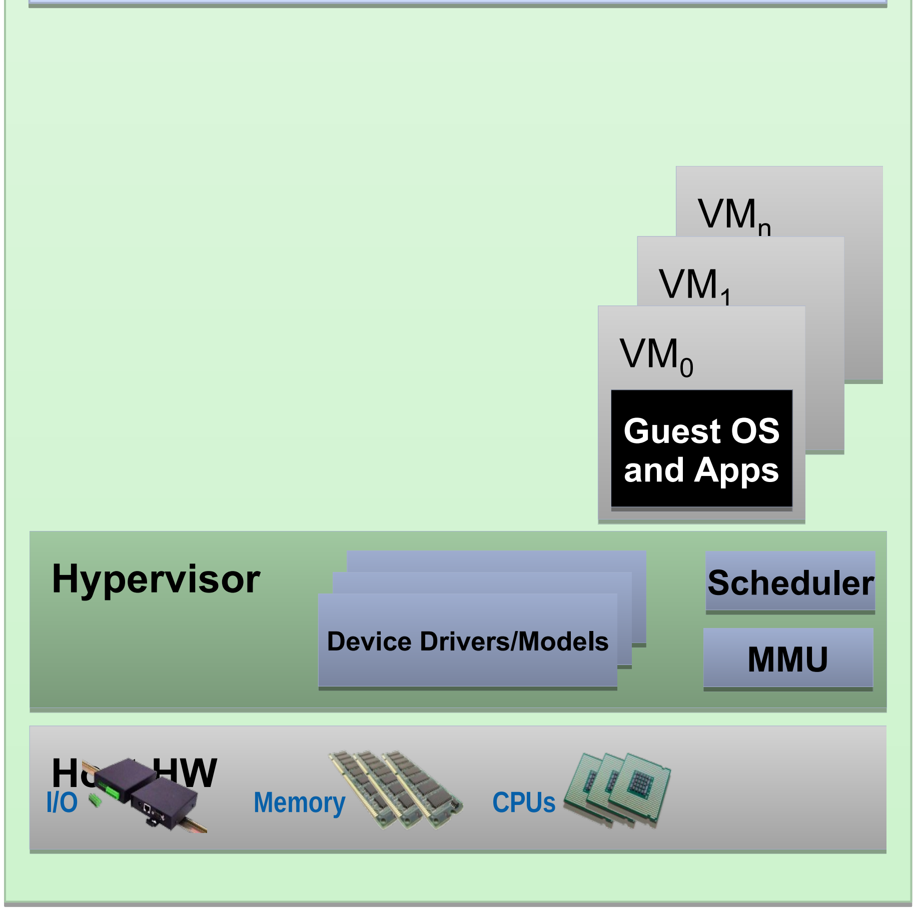
Type 1: Bare metal Hypervisor



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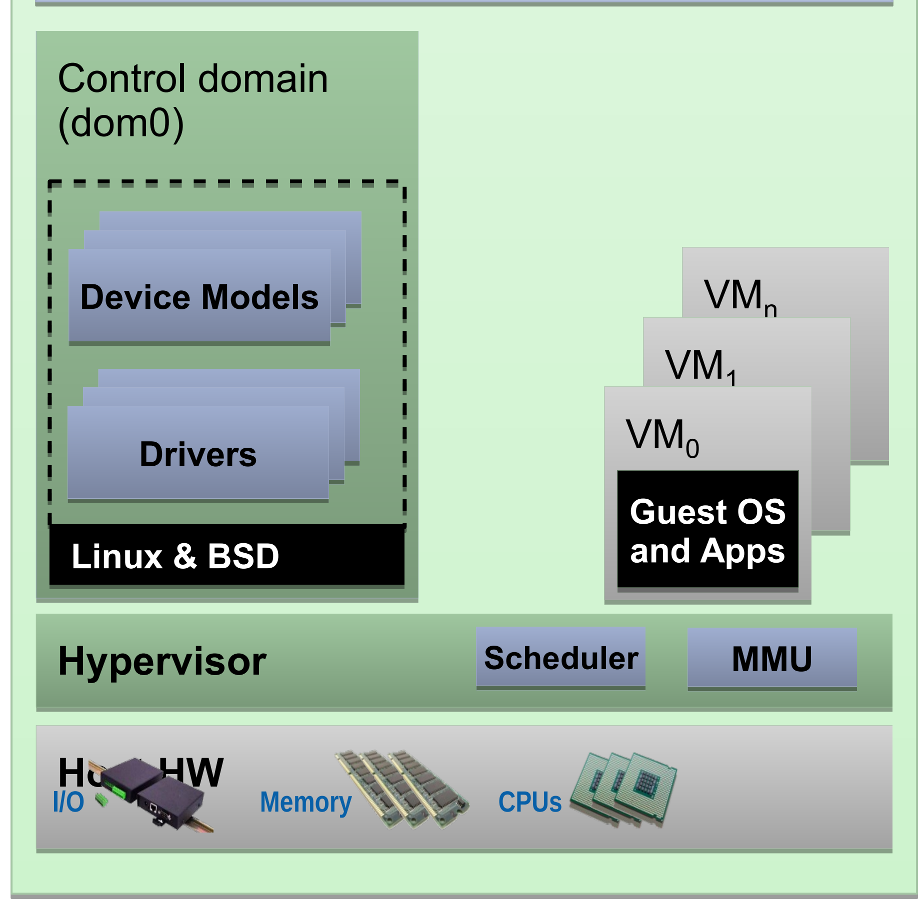


Some Bare-Metal Advantages

- What are the advantages of a Bare-Metal Hypervisor?
  - Density: It's thin
    - Excellent for supporting very small workloads
  - Scalability: It can support huge numbers of VMs
    - Terrific for highly dense workloads
  - Security: No host OS
    - It has no host OS layer to attack
  - Scheduling: Can use dedicated scheduler
    - Needed for specialized workload profiles where a host OS scheduler just won't do
  - Paravirtualization: Simplified interface
    - Easier to code to when no OS is present
- And now some of the innovations they enable...

#1: Xen Automotive

- A subproject of the Xen Project
- Proposed by community member GlobalLogic
- Support for infotainment systems (for now...)
- Eliminates multiple discreet systems needing sourcing, installation, and testing
- ARM-based

Automotive Challenges

- Soft-Real-time support
- Hard-Real-time support
- GPU virtualization
- Other co-processor (DSP, IPU, etc.)
- Certification
- Driver support for Android, e.g. Backend ION memory allocator and Linux User Space Device Drivers for Graphics, Sound, USB, Giros, GPS, etc.
- Driver support for operating systems such as QNX and other guest operating systems that are relevant for these use-cases

A Focused Hypervisor

- Automotive requires extreme focus
- Simply repurposing a server-based hypervisor won't cut it
- A Bare-Metal hypervisor can add and modify pieces as needed
  - There is no legacy Host Operating System to be accommodated
  - Bare-Metal can do what the situation requires

#2: Realtime Virtualization

- Support for Xen Automotive and beyond
- RT-Xen
- Streaming video, etc. cannot wait for next time slice
- Leverages a custom scheduler

Custom Schedulers

- Type 2 (Hosted) Hypervisors use the scheduler of the host (e.g., Linux)
  - That scheduler is designed for the host operating system, not for special needs
- Type 1 (Bare Metal) Hypervisors use schedulers designed for the needs of the hypervisor itself
  - It is possible to change the scheduler to meet the needs of the hypervisor
  - That's the way to handle Realtime Scheduling

A Scheduler for Every Need

- Current schedulers in Xen Project:
  - Credit
    - General Purpose
    - Default scheduler in 4.5
  - Credit2
    - Optimized for low latency & high VM density
    - Currently Experimental
    - Expected to become supported and default in future

A Scheduler for Every Need

- Current schedulers in Xen Project (continued):
  - RTDS
    - Soft & Firm Realtime scheduler
    - Multicore
    - Currently Experimental
    - Embedded, Automotive, Graphics, Gaming in the Cloud
  - ARINC 653
    - Hard Realtime
    - Single Core
    - Currently Experimental
    - Avionics, Drones, Medical

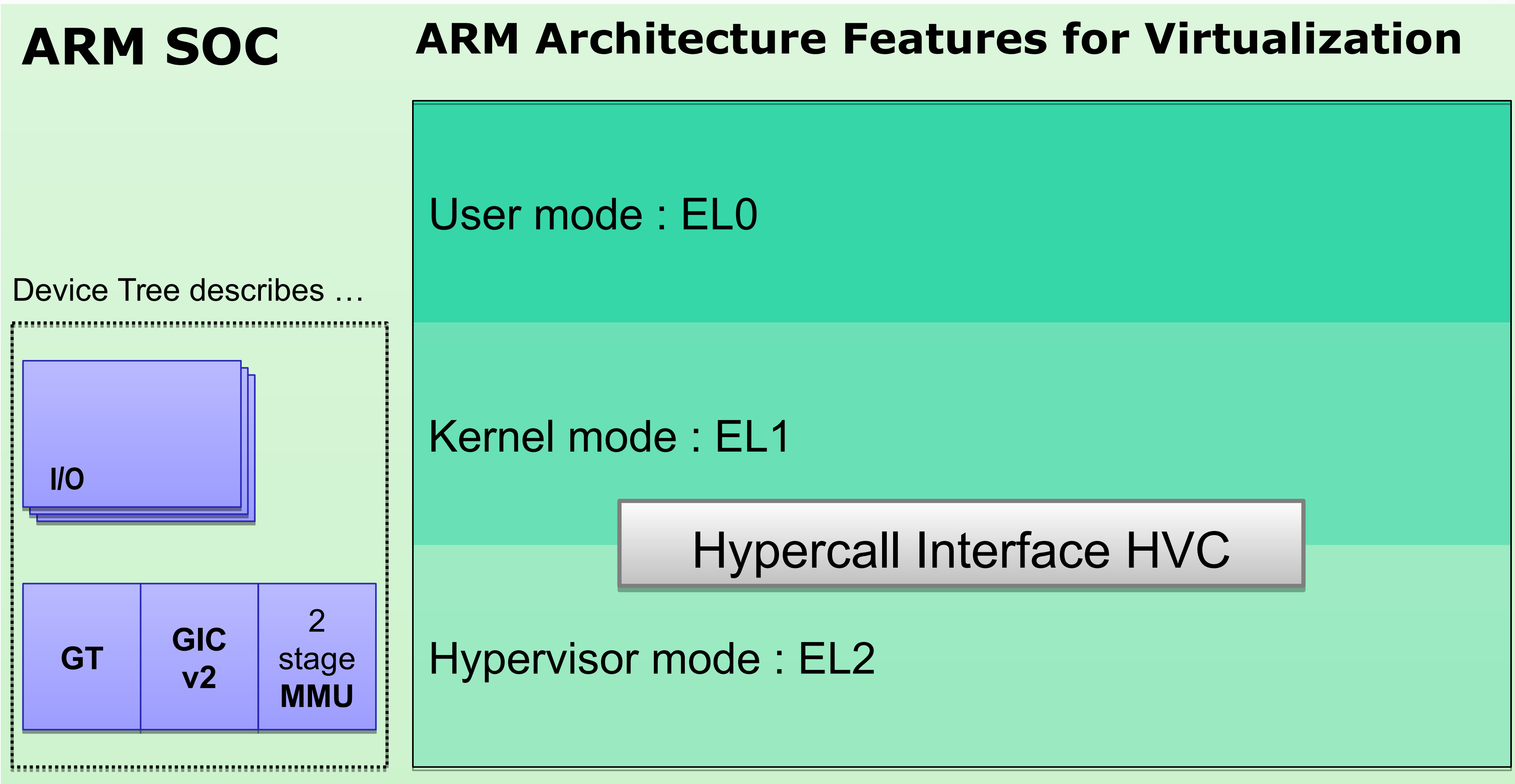
A Scheduler for Every Need

- Past schedulers in Xen Project:
  - Borrowed Virtual Time
  - Atropos
  - Round Robin
  - SEDF (removed in Xen Project 4.6)
- For more information:
  - http://wiki.xenproject.org/wiki/Xen_Project_Schedulers

#3: ARM-based Hypervisor

- ARM expanding from handhelds to servers
- Virtualization extensions added to ARM V7
- Architecture is hand-in-glove fit for Bare-Metal hypervisor
- No mode changes means greater speed and security

Xen + ARM = a perfect Match



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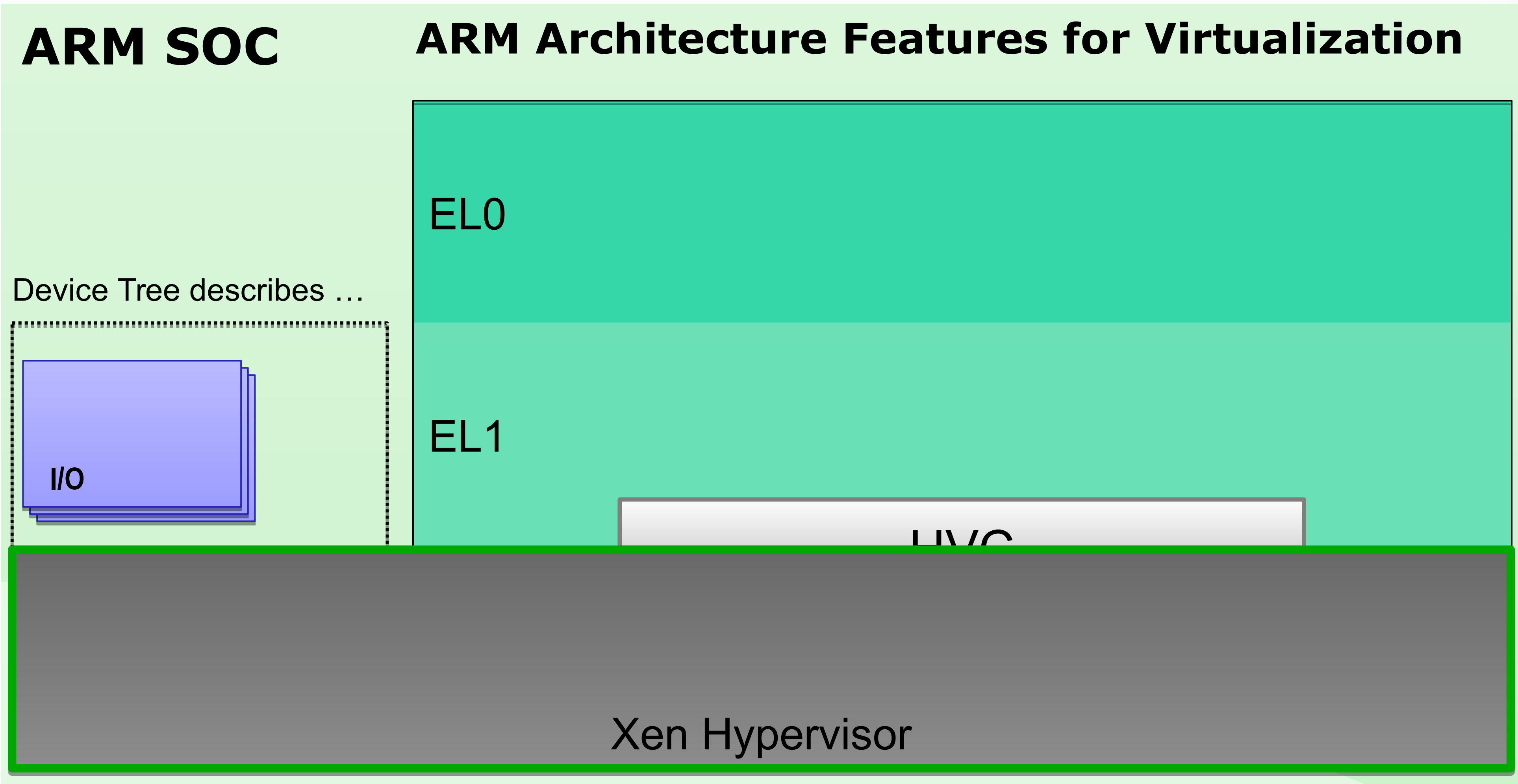

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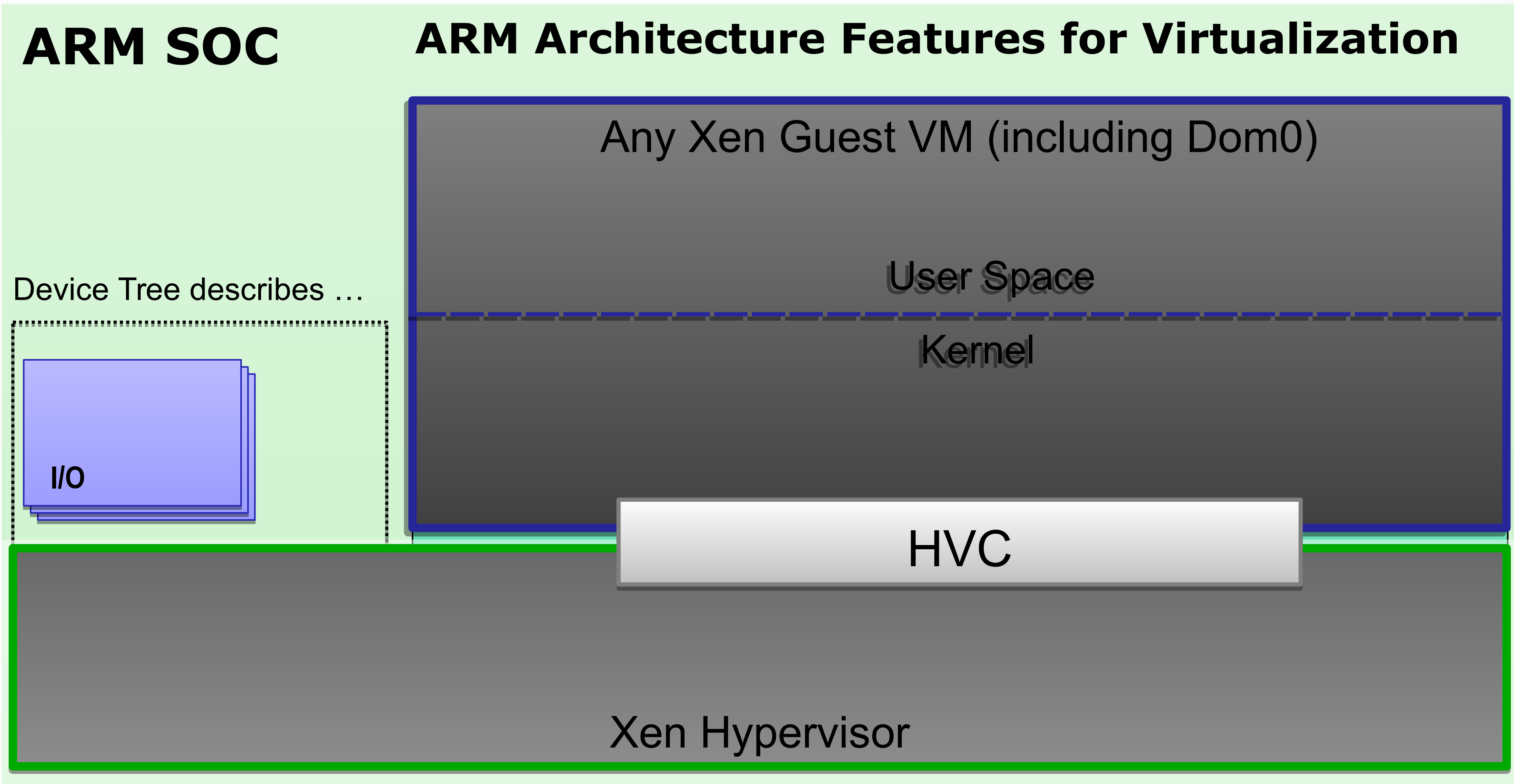

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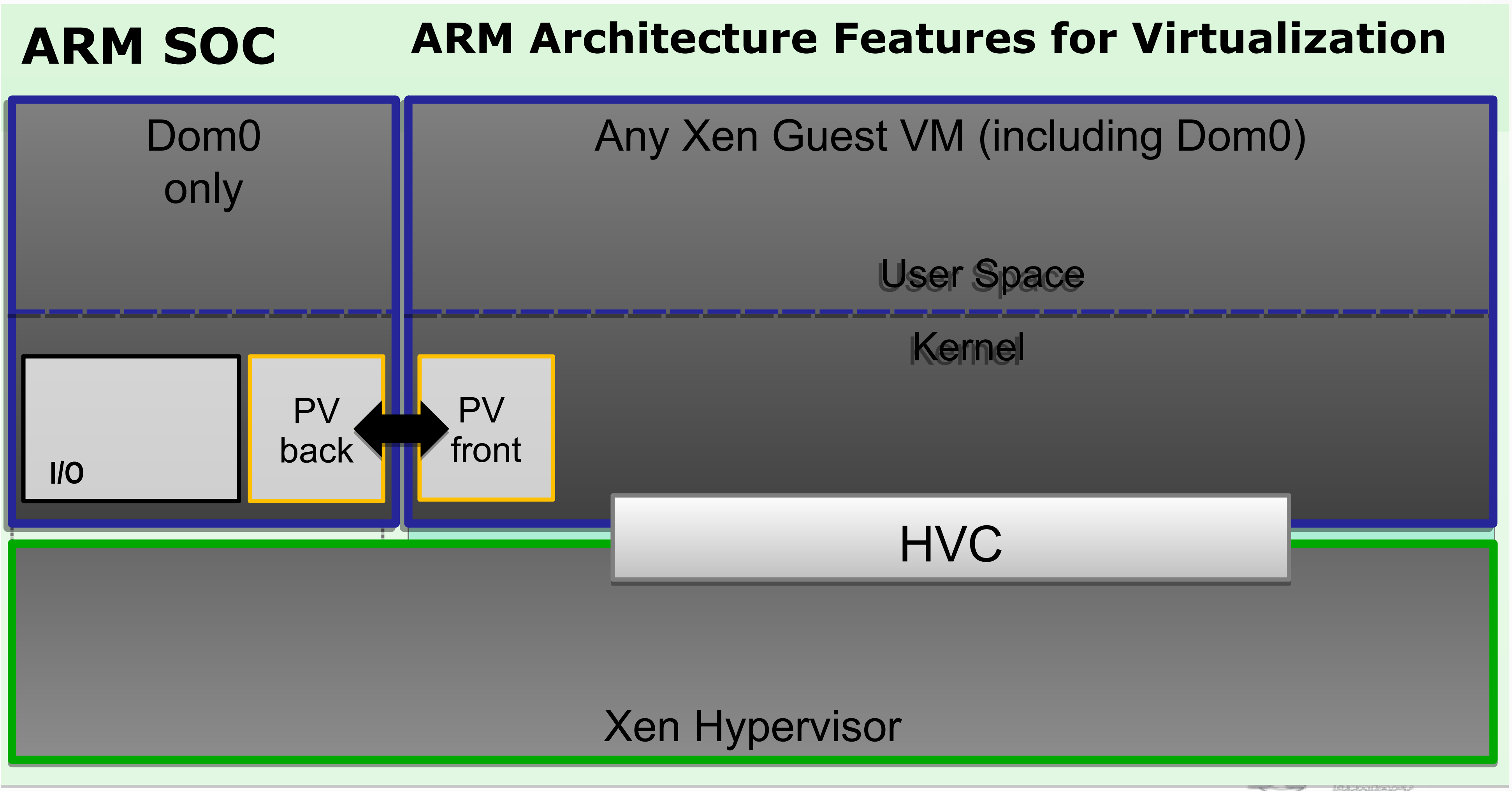


Where Will an ARM Hypervisor Play?

- You name it...
  - Cell phones
    - Multiple personalities are possible
  - Embedded systems
    - Automotive is just the beginning; Trains are already here!
  - Internet of Things (IoT)
    - Lots of little things means lots of responses needed
  - Servers
    - Lower power footprint
    - Real green technology

#4: The Unikernel

- Super-small VMs
- Quick booting
- Enhanced security
- Easy deployment
- Enables transient services
  - Services that appear when needed and disappear when done

The Cloud We Know

- Field of innovation is in the orchestration
  - The Cloud Engine is paramount (OpenStack, CloudStack, etc.)
  - Workloads adapted to the cloud strongly resemble their non-cloud predecessors
    - Some basic adaptations to facilitate life in the cloud, but basically the same stuff that was used before the cloud
    - Applications with full stacks (operating system, utilities, languages, and apps) which could basically run on hardware, but are run on VMs instead.
    - VMs are beefy; large memory footprint, slow to start up
    - It all works, but its not overly efficient
    - 10s of VMs per physical host

The Next Generation Cloud

- Turning the scrutiny to the workloads
  - Should be easier to deploy and manage
  - Smaller footprint, removing unnecessary duplication
  - Faster startup
  - Transient microservices
  - Higher levels of security
  - 1000s of VMs per host

The New Stuff: Docker & Containers

- Makes deployment easier
- Smaller footprint by leveraging kernel of host
- Less memory needed to replicate shared kernel space
- Less disk needed to replicate shared executables
- Really fast startup times
- Higher number of VMs per host

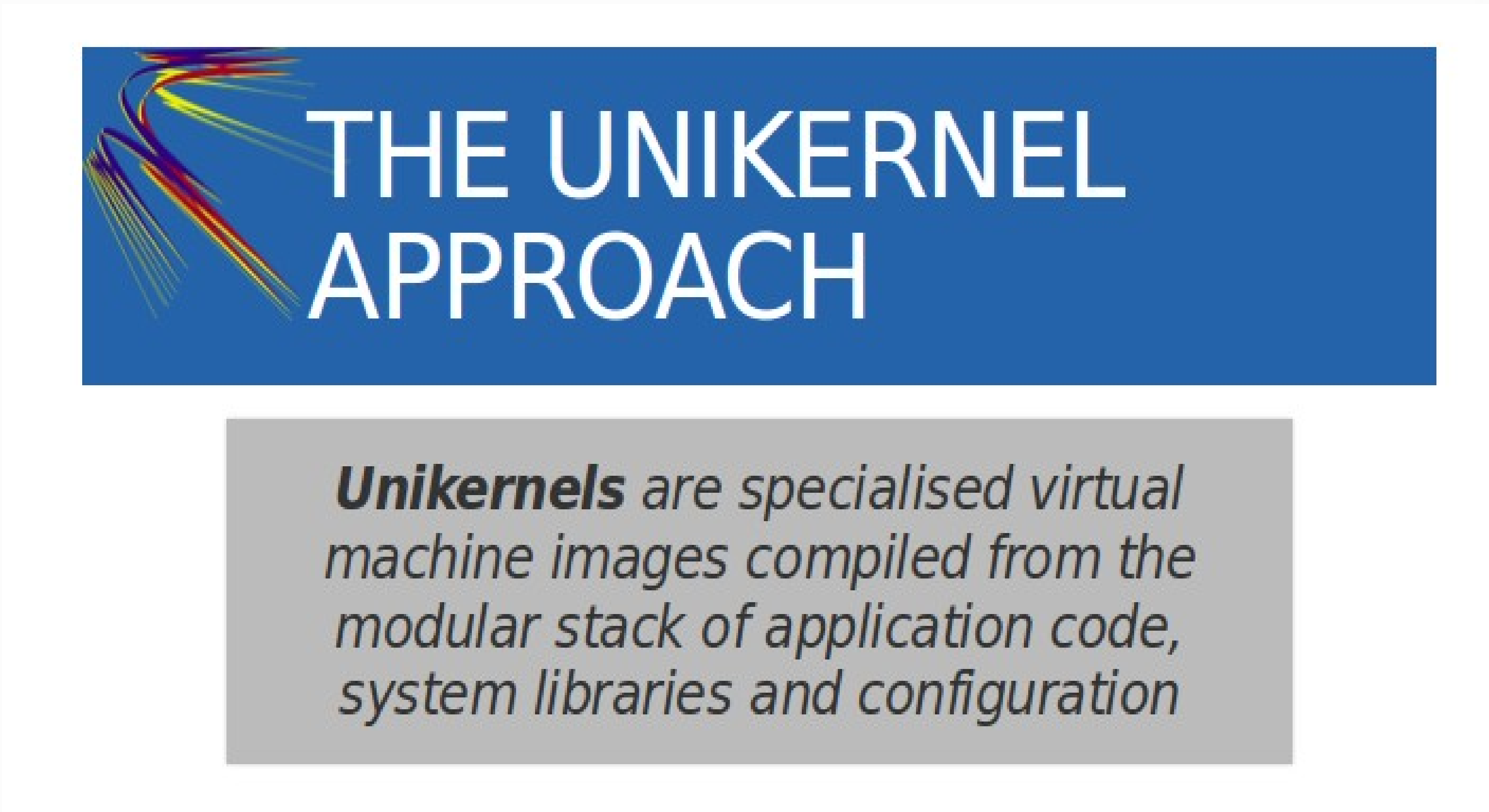
Docker Downsides

- Improvements, yes; but not without issues
  - Can't run any payload that can't use host kernel
  - Potential limits to scaleability
    - Linux not really optimized for 1000s of processes
  - Security
    - Security is a HUGE issue in clouds
    - Still working on security mechanisms
    - Will users employ the security mechanisms or pick the quick-and-easy deployment which has made Containers popular?

The Unikernel: A Real Cloud Concept

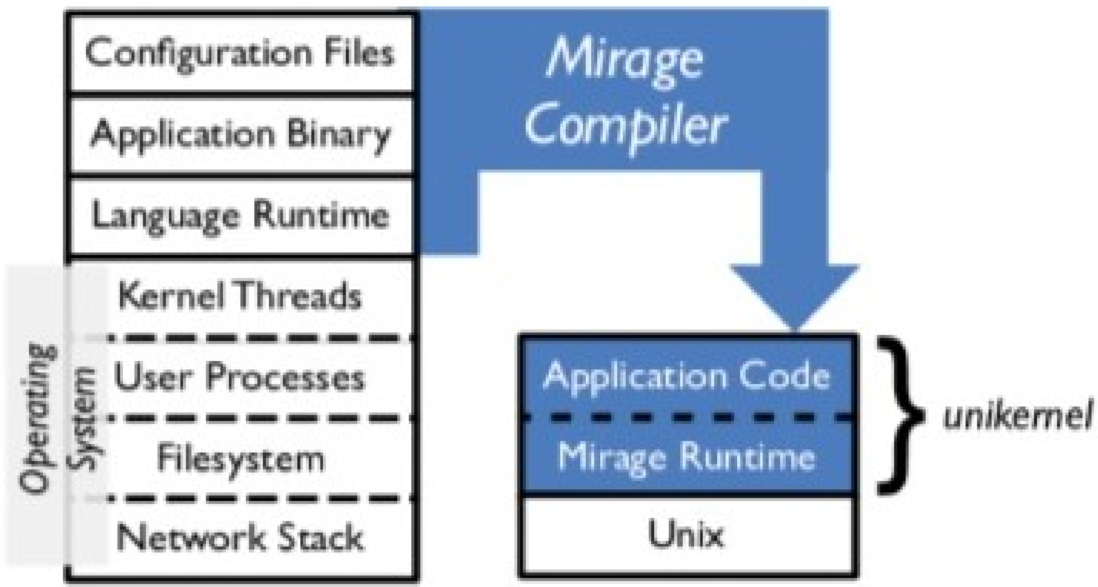
- Very small
- Very efficient
- Very quick to boot
- And very, VERY secure!
- It's a Green (energy) technology which saves you green (cash); extremely important to foster adoption
- Many unikernels already exist, including Mini-OS and MirageOS, a Xen Project Incubator Project

What is a Unikernel? From MirageOS



Unikernel Approach: MirageOS

Swap system libraries to target different platforms:
develop application logic using native Unix.



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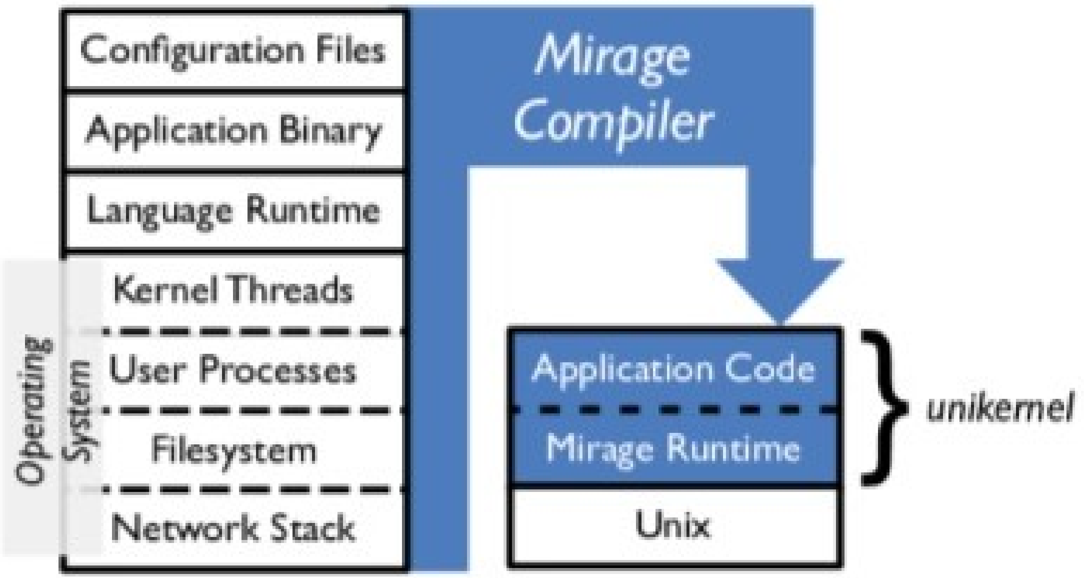
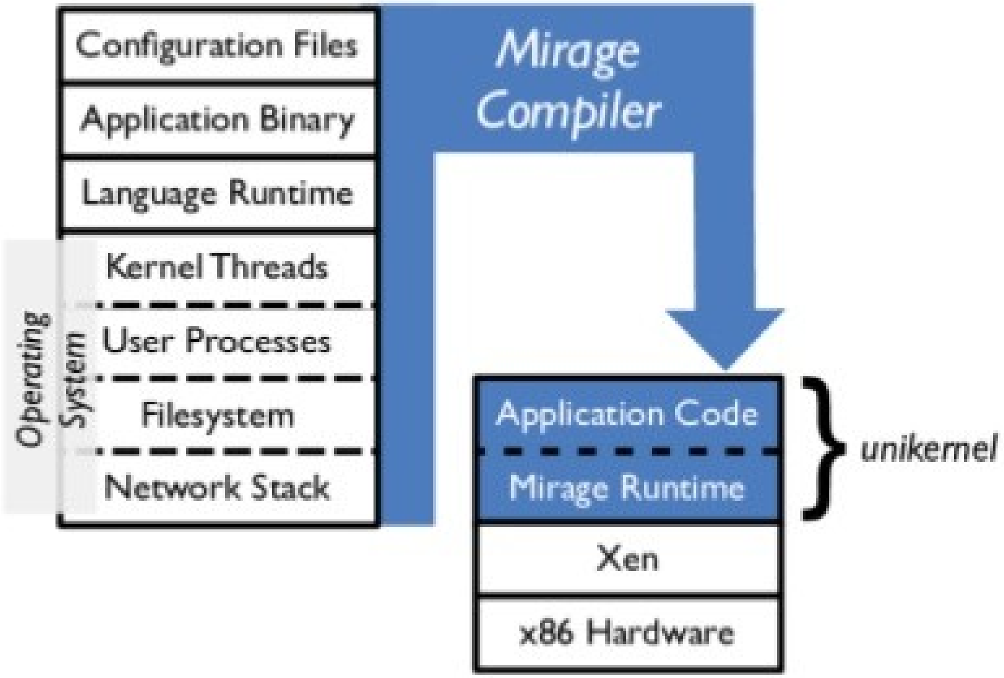
Swap system libraries to target different platforms:

test unikernel using Mirage system libraries.



Unikernel Approach: MirageOS

Swap system libraries to target different platforms:
deploy by specialising unikernel to Xen.



Unikernel Concepts

- Use just enough to do the job
  - No need for multiple users; one VM per user
  - No need for a general purpose operating system
  - No need for utilities
  - No need for a full set of operating system functions
- Lean and mean
  - Minimal waste
  - Tiny size

Unikernel Concepts

- Similar to an embedded application development environment
  - Limited debugging available for deployed production system
  - Instead, system failures are reproduced and analyzed on a full operating system stack and then encapsulated into a new image to deploy
  - Tradeoff is required for ultralight images

What Do the Results Look Like?

- MirageOS examples:
  - DNS Server: 449 KB
  - Web Server: 674 KB
  - OpenFlow Learning Switch: 393 KB
- LING metrics:
  - Boot time to shell in under 100ms
  - Erlangonxen.org memory usage: 8.7 MB
- ClickOS:
  - Network devices processing >5 million pkt/sec
  - 6 MB memory with 30 ms boot time

What About Security?

- Type-Safe Solution Stack
  - Can be certified
  - Certification is crucial for certain highly critical tasks, like airplane fly-by-wire control systems
- Image footprints are unique to the image
  - Intruders cannot rely on always finding certain libraries
  - No utilities to exploit, no shell to manipulate

What's Out There Right Now?

- MirageOS, from the Xen Project Incubator
- HaLVM, from Galois
- LING, from Erlang-on-Xen
- ClickOS, from NEC Europe Labs
- OSv, from Cloudius Systems
- Rumprun, from the Rump Kernel Project
- And that's just the beginning...

How Does Xen Project Enable Unikernels?

- No Host OS means it's lean and mean
  - A tiny VM can sit on a thin hypervisor layer on the hardware
  - Attack surface is small
  - Scale out support
    - Can currently support about 600 concurrent VMs per host without losing performance
    - Current target: 2000-3000 concurrent VMs per host
  - Enhanced scheduler (Credit2)
  - ARM as an option

Innovation: Is This All?

- By no means!
- The list of other subprojects & capabilities continues to grow:
  - Virtualized GPUs
  - Enhanced NUMA
  - COLO: Coarse-grained lockstepping of VMs
  - Native VMware VMDK support
  - And so on...
- http://xenproject.org/users/innovations.html

In Review...

- Some advantages of a Bare-Metal Hypervisor
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  - Paravirtualization: Simplified interface
    - Easier to code to when no OS is present

The Xen Project Difference

- Tomorrow's workloads are not yesterday's workloads
  - If your hypervisor is just focused on yesterday's payloads, it is suffering from planned obsolescence
  - Select a hypervisor which is innovating – and Open Source
- Xen Project is busy enabling the next generation in virtualization

Questions?

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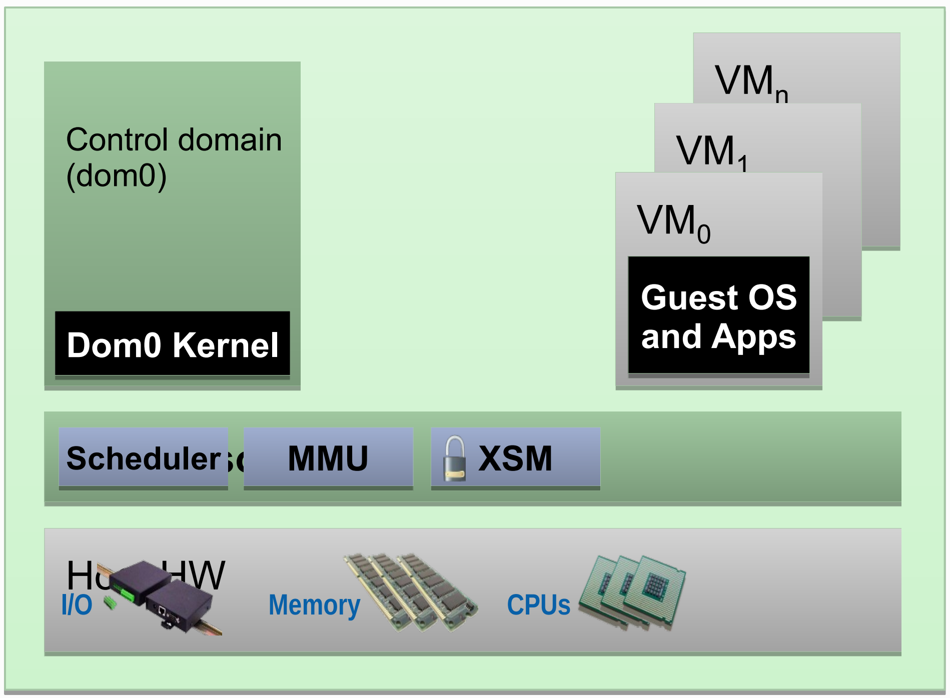
Actively looking for a new opportunity

This presentation is available in the Presentations Section of XenProject.org

Basic Xen Project Concepts



Trusted Computing Base

Console

- Interface to the outside world

Control Domain aka Dom0

- Dom0 kernel with drivers
- Xen Management Toolstack

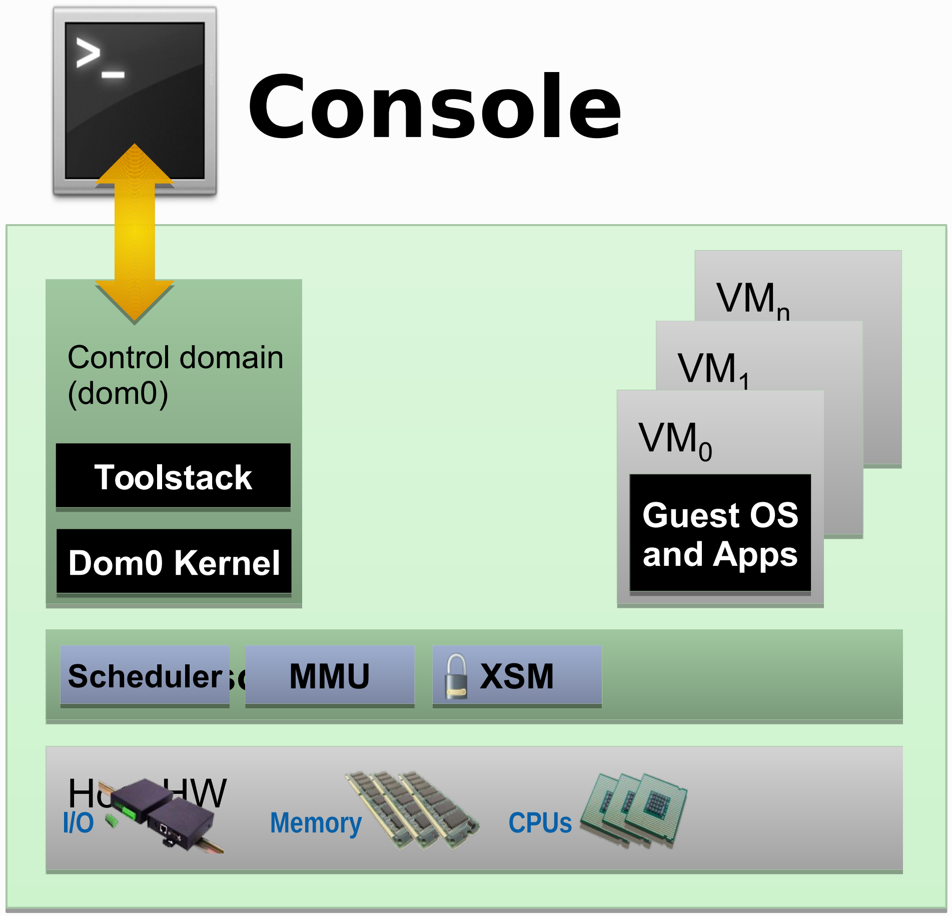
Guest Domains

- Your apps

Driver/Stub/Service Domain(s)

- A "driver, device model or control service in a box"
- De-privileged and isolated
- Lifetime: start, stop, kill

Basic Xen Project Concepts: Toolstack+



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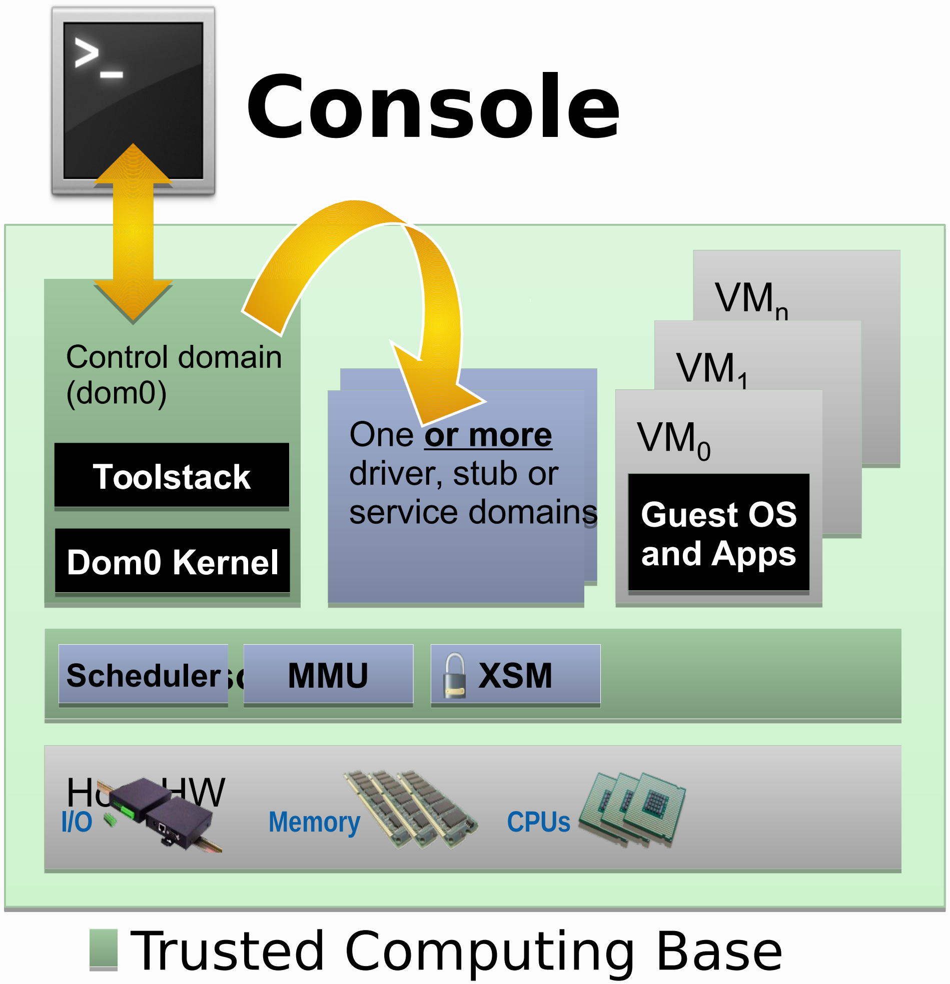
Basic Xen Project Concepts: Disaggregation



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