Xen for Embedded, IoT, Edge

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XILINX

Lightning Xen Update

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Very Embedded Requirements

- Real Time
  - Low Deterministic IRQ Latency
  - Static Partitioning
  - Real Time Schedulers
- Short Boot Times
- Device Virtualization
  - Device Assignment
  - Device Sharing
  - Driver Domains
  - VM to VM communications
- Certifications
  - Small Code Base
  - Type-1

Static Partitioning

sched=null vwfi=native

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sched=null vwfi=native

2.5 us

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VM to VM communication mechanisms

>**Libvchan**

- >>Linux LIbrary
- >>Direct VM to VM channel based on a ring on shared memory
- >>libxenvchan_send and libxenvchan_recv

>**PVCalls**

- >>Socket API virtualization
- >>VM to VM communications mediated by the backend domain (dom0)
- >>“Io” as an inter-VMs communication namespace

>**V4V**

- >>Linux library and hypercall
- >>VM to VM communication mediated by Xen
- >>Trivial to implement in your kernel
- >>Not fully upstream

Shared Memory

>**Completely Configurable**

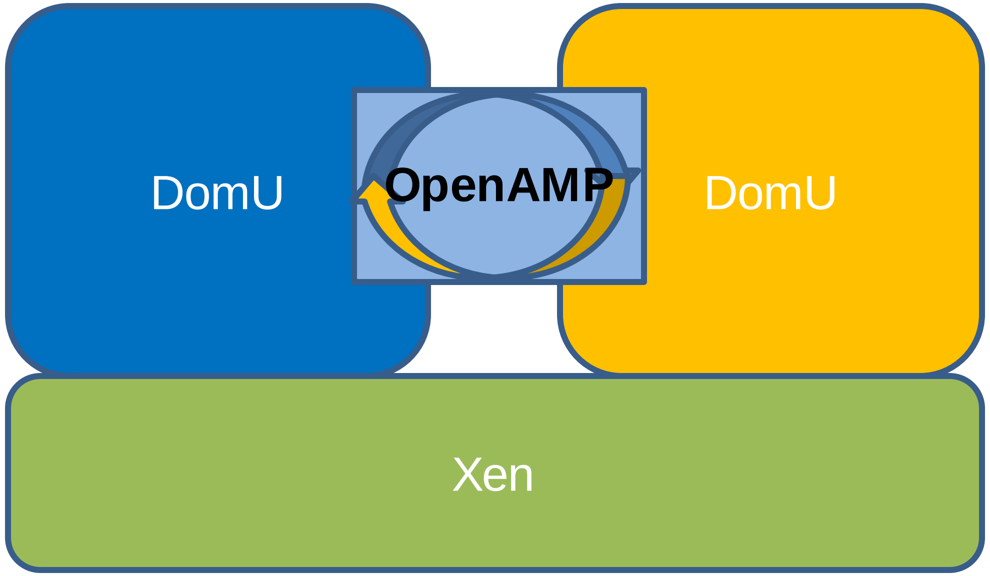
>>Support any memory attributes including cacheable memory

>**No need for Xen support to use it**

>**Can export the memory to Linux userspace and use OpenAMP**

```
static_shm = ["id=ID1, begin=0x40000000, size=0x1000, role=master"]
```

```
static_shm = ["id=ID1, offset=0, begin=0x48000000, size=0x1000, role=slave"]
```

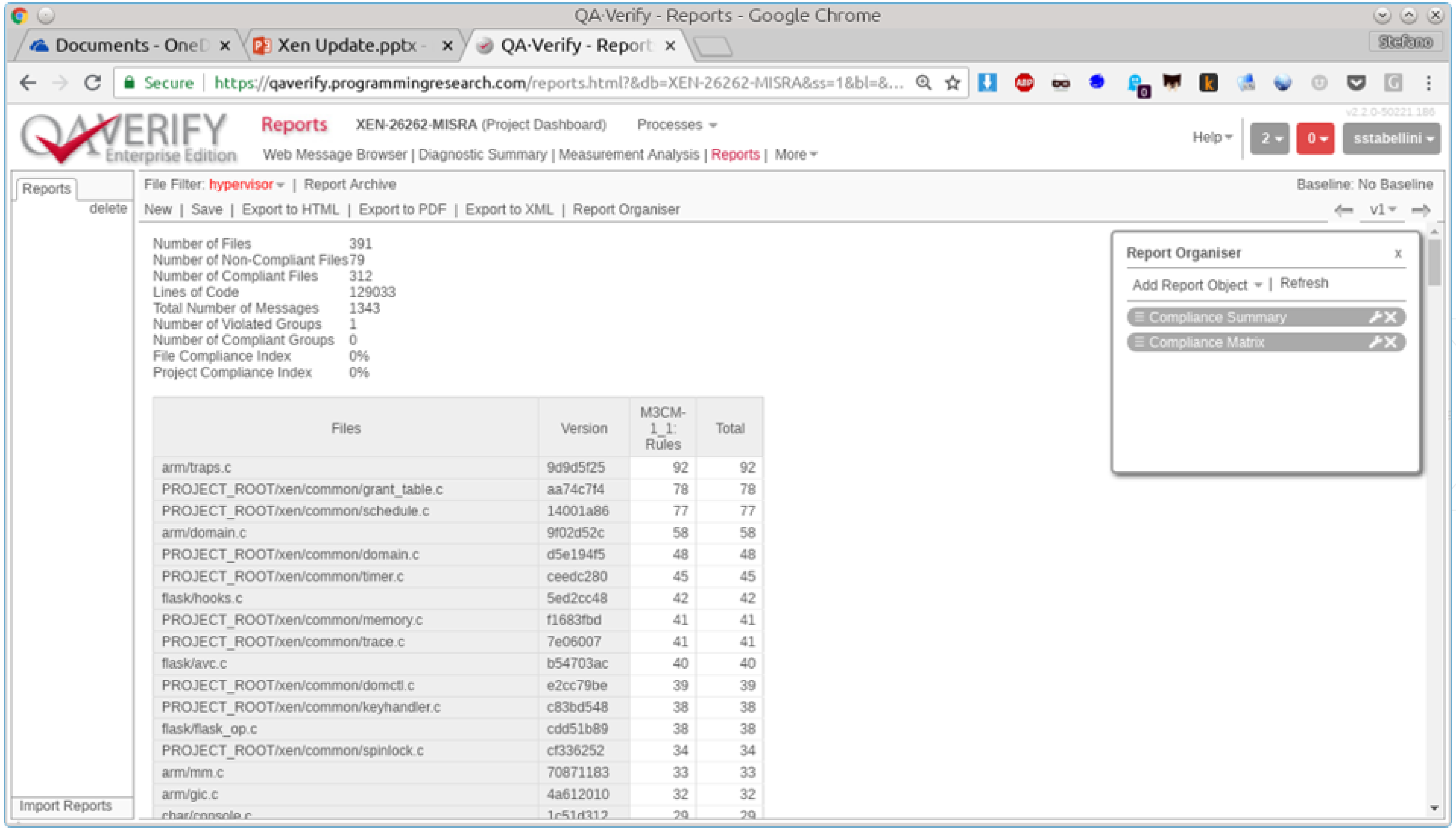


Reducing Code Size

```
() work – Konsole
File  Edit  View  Bookmarks  Settings  Help
stefanos@xsjstefanos50:/local/repos/xen/xen$ make cloc
cloc --list-file=/tmp/tmp.lL2EdV9dLA
     143 text files.
     143 unique files.
       0 files ignored.

http://cloc.sourceforge.net v 1.60  T=0.26 s (546.4 files/s, 262525.6 lines/s)
-------------------------------------------------------------------------------
Language                     files          blank        comment           code
-------------------------------------------------------------------------------
C                              126          10527          10408          45144
Assembly                        17            249            937           1439
-------------------------------------------------------------------------------
SUM:                           143          10776          11345          46583
-------------------------------------------------------------------------------
rm /tmp/tmp.lL2EdV9dLA
stefanos@xsjstefanos50:/local/repos/xen/xen$ 
sstabellini : bash        () work
```

Certifications



Files	Version	M3CM-1_1: Rules	Total
arm/traps.c	9d9d5f25	92	92
PROJECT_ROOT/xen/common/grant_table.c	aa74c7f4	78	78
PROJECT_ROOT/xen/common/schedule.c	14001a86	77	77
arm/domain.c	9f02d52c	58	58
PROJECT_ROOT/xen/common/domain.c	d5e194f5	48	48
PROJECT_ROOT/xen/common/timer.c	ceedc280	45	45
flask/hooks.c	5ed2cc48	42	42
PROJECT_ROOT/xen/common/memory.c	f1683fbd	41	41
PROJECT_ROOT/xen/common/trace.c	7e06007	41	41
flask/avc.c	b54703ac	40	40
PROJECT_ROOT/xen/common/domctl.c	e2cc79be	39	39
PROJECT_ROOT/xen/common/keyhandler.c	c83bd548	38	38
flask/flask_op.c	cdd51b89	38	38
PROJECT_ROOT/xen/common/spinlock.c	cf336252	34	34
arm/mm.c	70871183	33	33
arm/gic.c	4a612010	32	32
char/console.c	1c51d312	29	29

Make xen.git certifiable:

- Reduce code size
- Fix compliance violations reported by PRQA

Ideas on how to do certifications in a Xen Project (Linux Foundation) context

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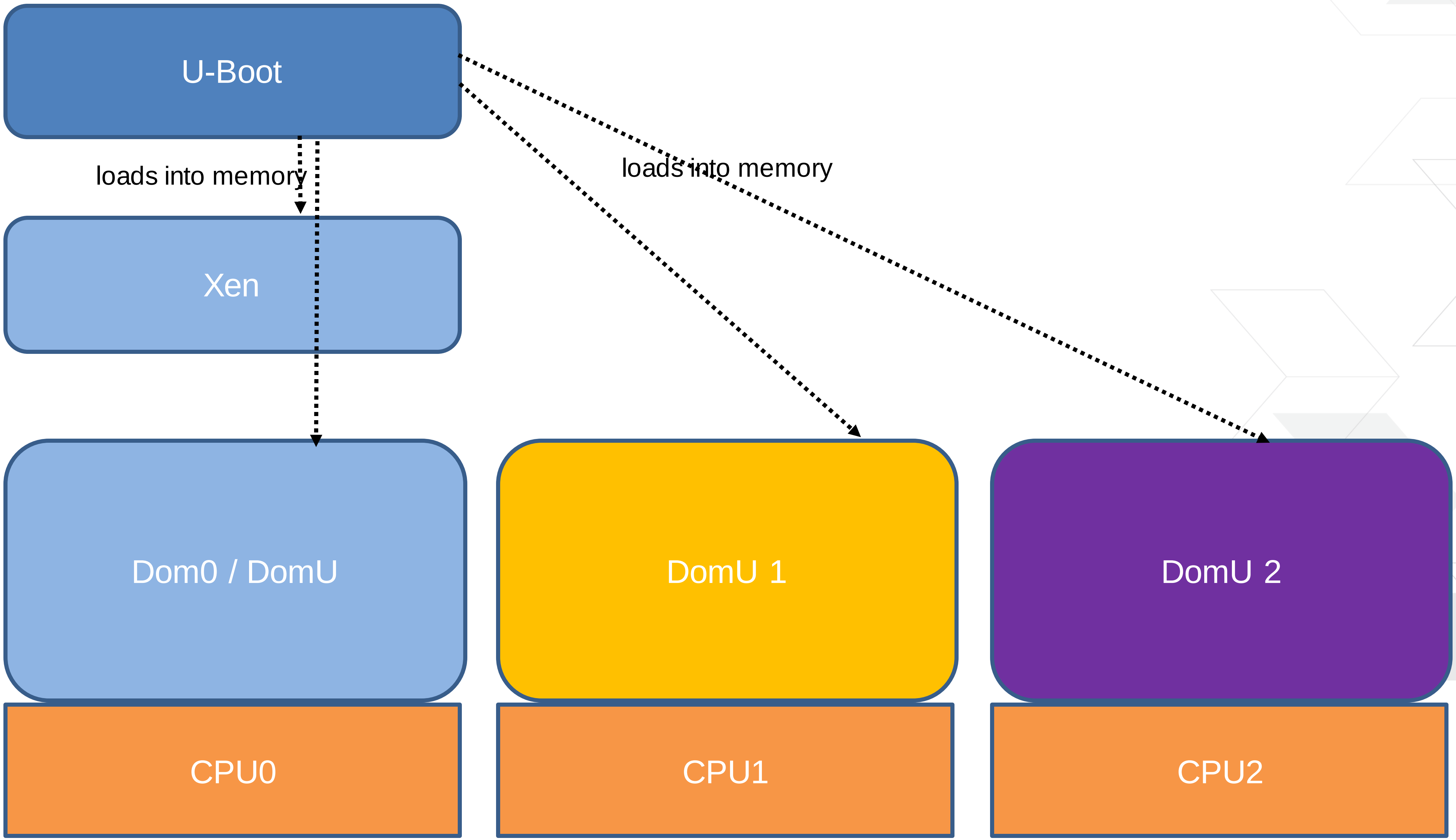
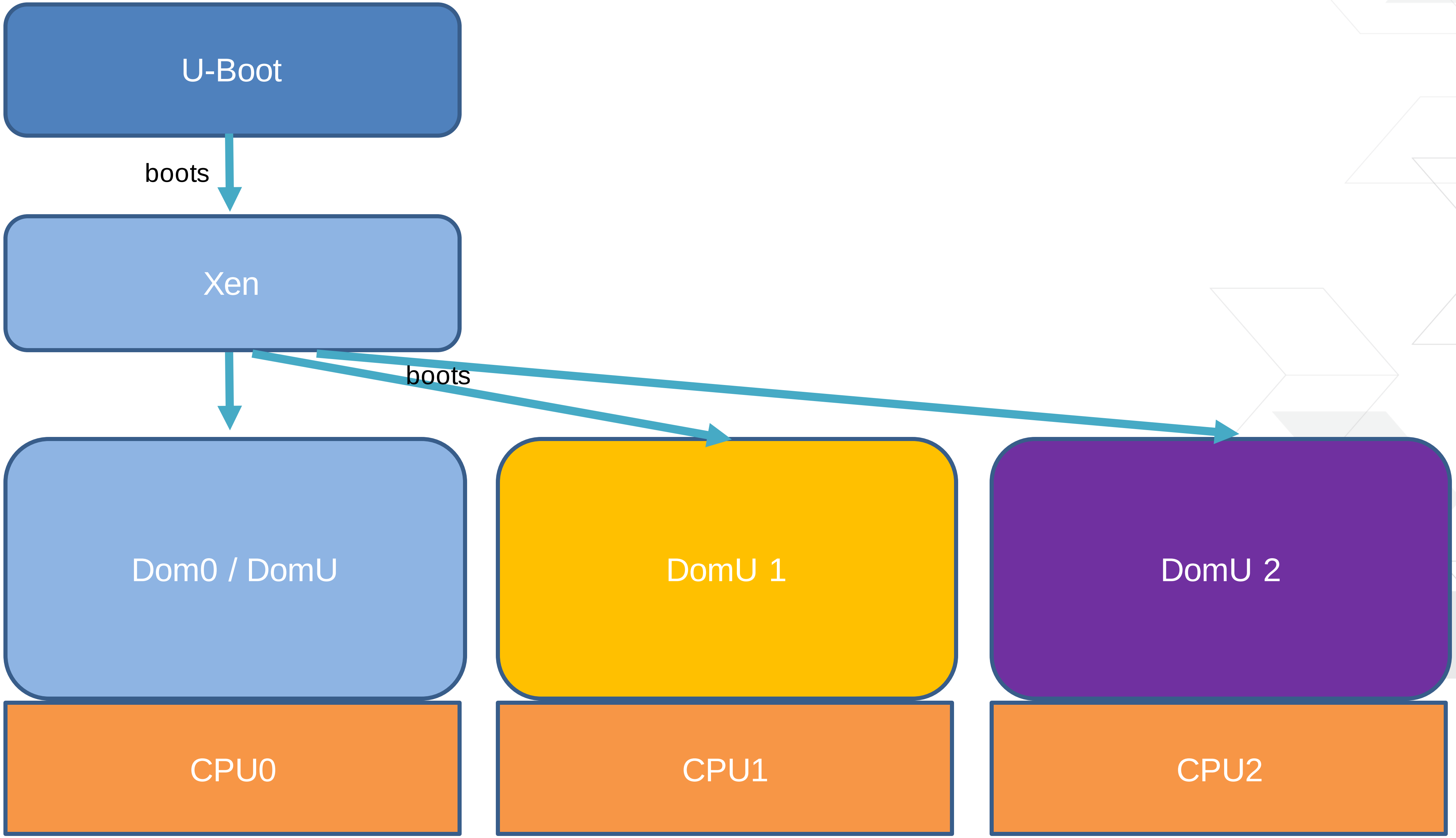
Dom0-less


U-Boot
loads into memory
Xen
loads into memory
Dom0 / DomU
DomU 1
DomU 2
CPU0
CPU1
CPU2

Dom0-less



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Secure Containers at the Edge

The Problem

Package applications for the target

- Contain all dependencies
- Easy to update
- Independent lifecycle

Run applications on the target

- Run in isolation
- No interference between applications

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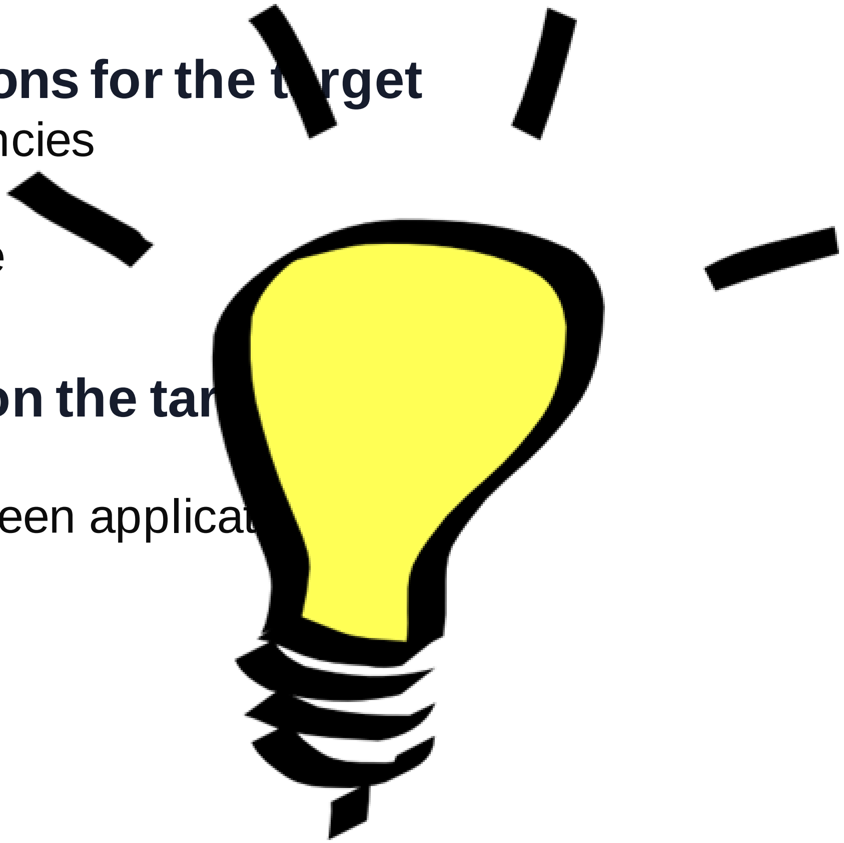

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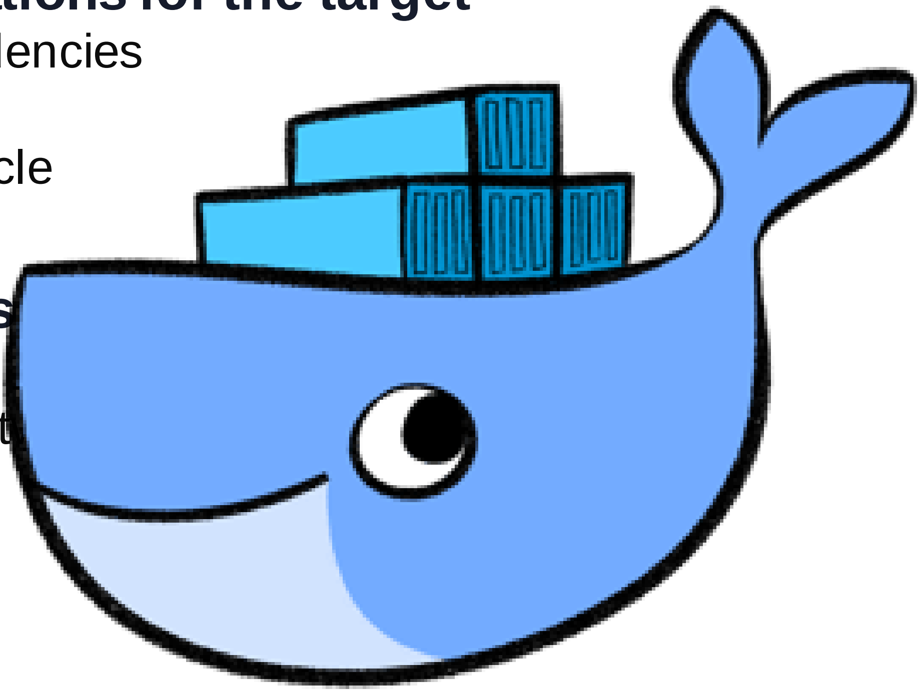

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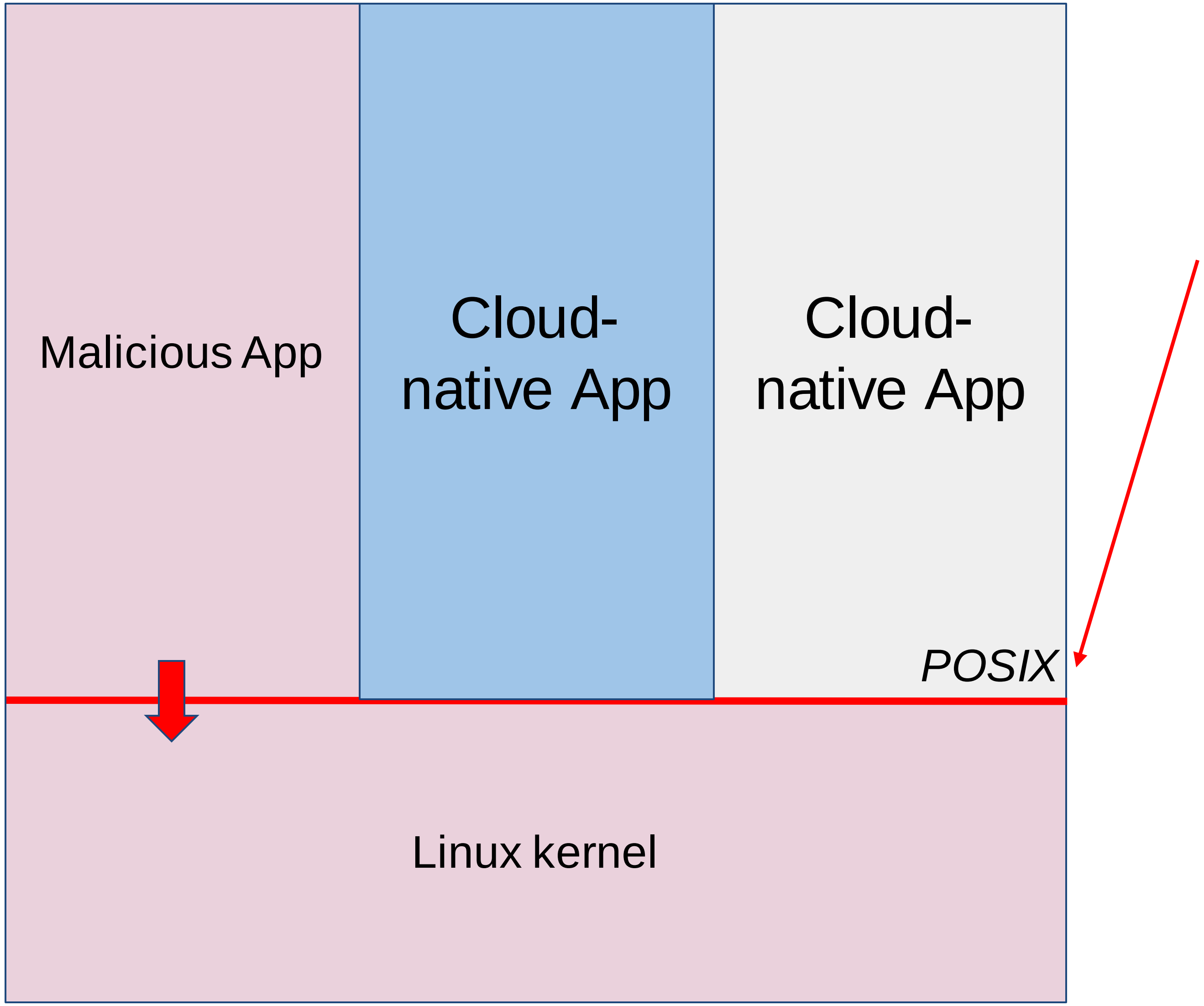
Packaging vs. Runtime

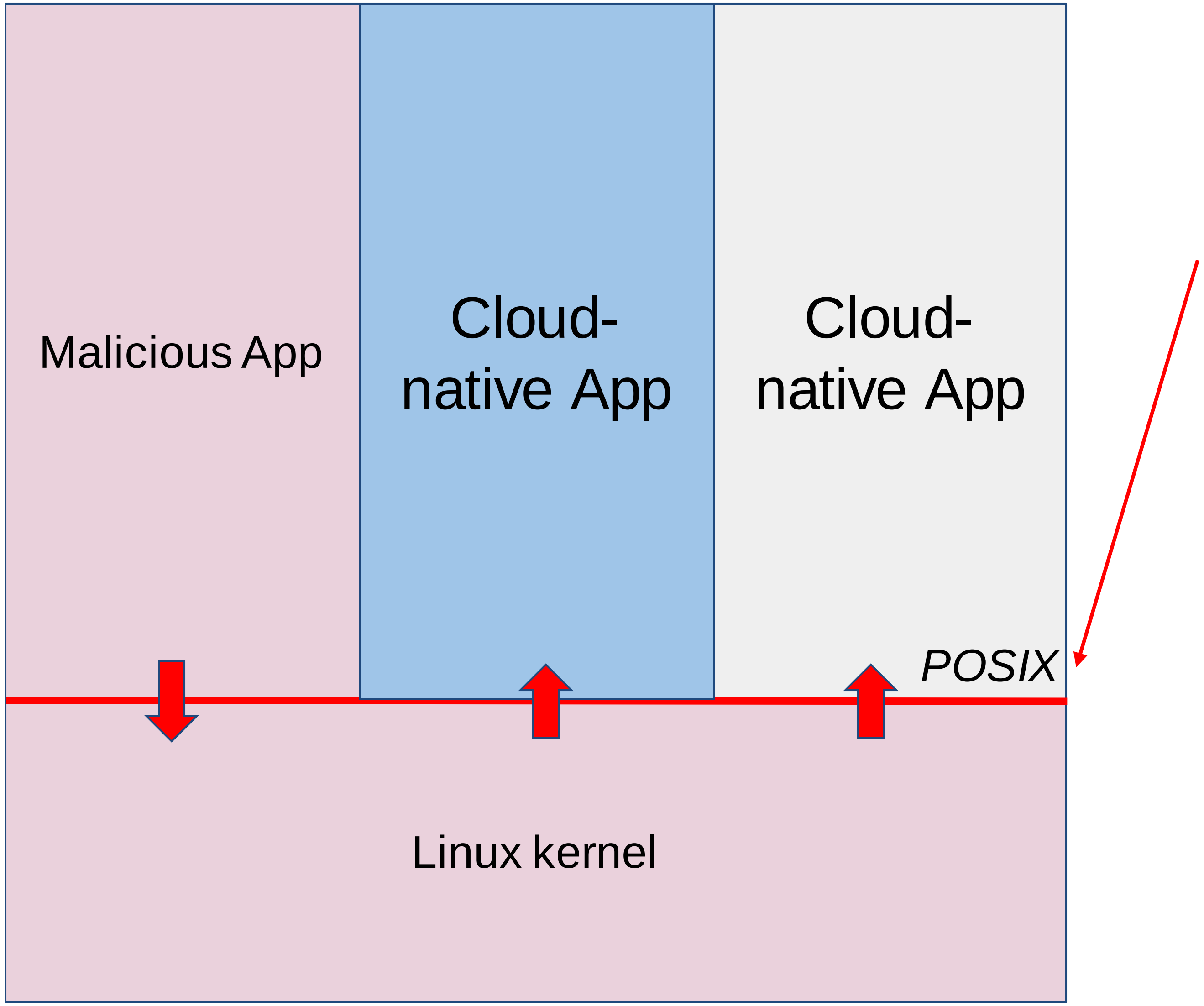
OCI Image Spec vs. OCI Runtime Spec

The problem with Linux namespaces



Large surface of attack

On average, 3 privilege escalation vulnerabilities per Linux release!



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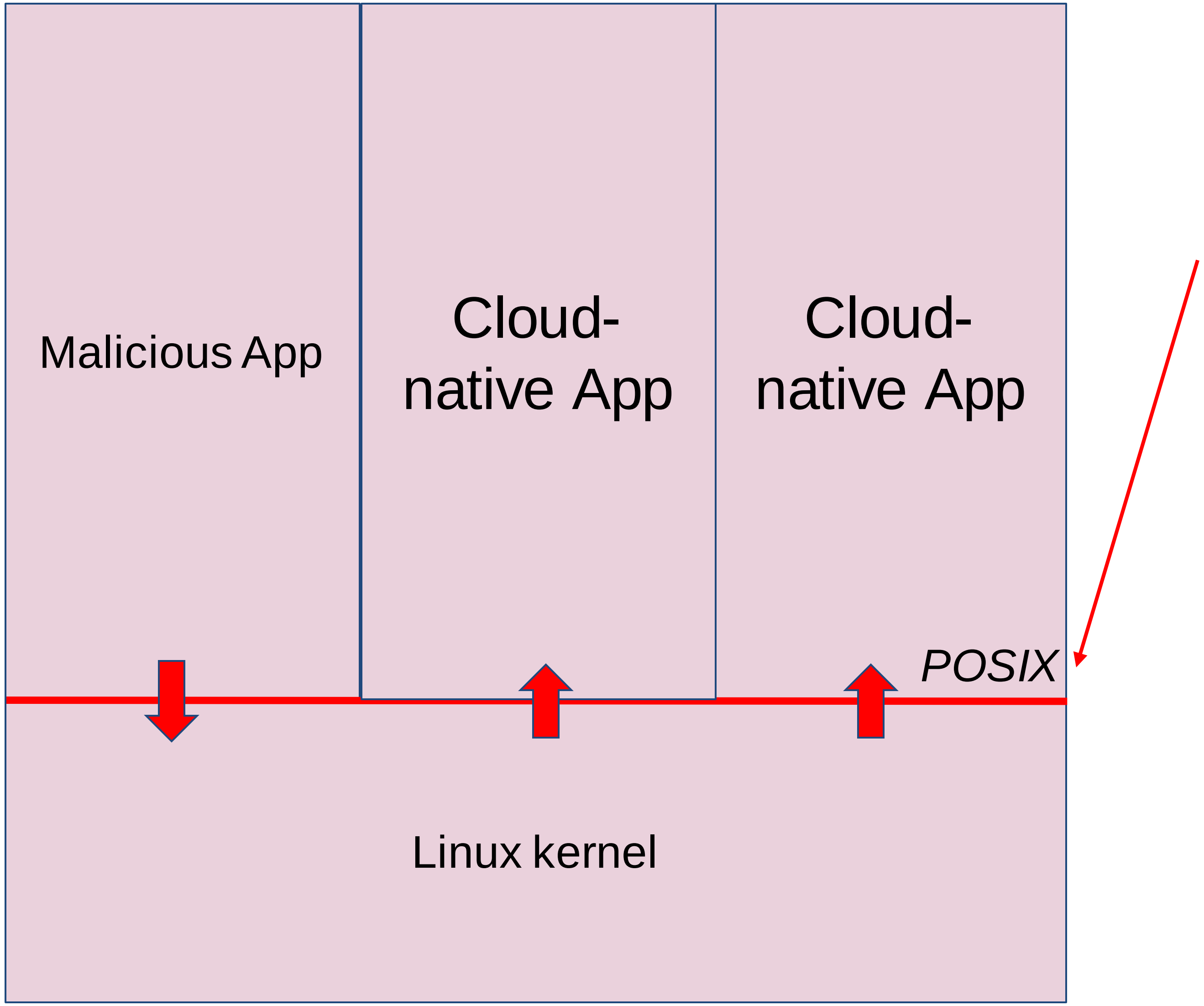

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Security hardening techniques

From “Understanding and Hardening Linux Containers” by NCC Group:

- Run unprivileged containers (user namespaces, root capability, dropping)
- Apply a Mandatory Access Control system, such as SELinux
- Build a custom kernel binary with as few modules as possible
- Apply sysctl hardening
- Apply disk and storage limits
- Control device access and limit resource usage with cgroups
- Drop any capabilities which are not required for the application within the container

[...]

Security hardening techniques

[...]

- Use custom mount options to increase defense in depth
- Apply GRSecurity and PAX patches to Linux
- Reduce Linux attack surface with Seccomp-bpf
- Isolate containers based on trust and exposure
- Logging, auditing and monitoring is important for container deployment
- **Use hardware virtualization along application trust zones**

Security hardening techniques

Securing Linux Namespaces is possible but very difficult

- It requires specific knowledge of the cloud native app
- Auditing and monitoring should performed everywhere

Using virtualization for isolation is still recommended

Linux Namespaces: very embedded problems

>**Mixed-criticality** is not supported

>**Limits** on resource utilization are hard to enforce

>**Real-Time** support is difficult

>**Certifications** are very difficult

The Solution: Xen as Container Runtime

- **Security, Isolation and Partitioning**
  - Multi-Tenancy
  - Mixed-Criticality Workloads
- **Hardware Access to Applications**
- **Real-Time Support**

> ViryaOS: a ready-to-use runtime environment for VMs and Secure Containers

The Problem #2

>Cross-building multiple VMs is difficult

>Assembling the output in a single runnable image is a manual process

Embedded and IoT use pattern

>**Typically users know all the VMs they need beforehand**

>**They still need to:**

- >>Build them all, plus Xen and Dom0
- >>Install all images on target
- >>Partition the hardware using device assignment
  - Edit the Dom0 device tree
  - Generate appropriate device trees for DomUs with device nodes
- >>Plan for images upgrades and security fixes

It’s a lot of work!


You think this is bad enough...
...then you try disaggregation

Current Status

- **Everybody has their own scripts and handcrafted solutions**
  - They are limited
  - Only target one use-case
  - Limited support for driver domains and service domains
  - Only support one hardware platform

- **We would all benefit from a unifying effort**

ViryaOS

A proposal for a new Xen Project sub-project

ViryaOS

>a **Secure** Xen based runtime

>**Containers** supported natively

>a turnkey solution

>a **Flexible** build system

>support aarch64 and x86_64

>Targeted at embedded and IoT

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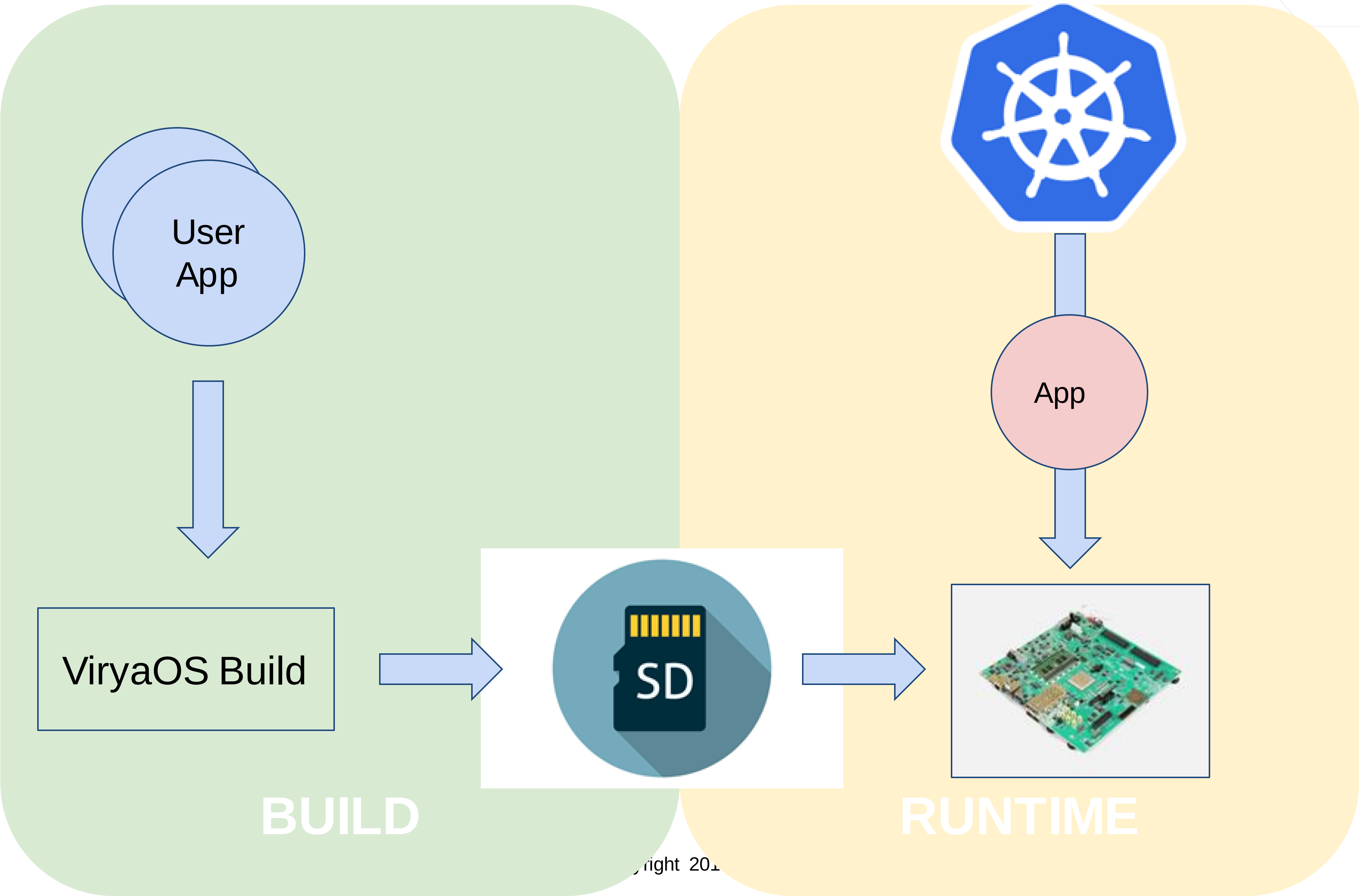
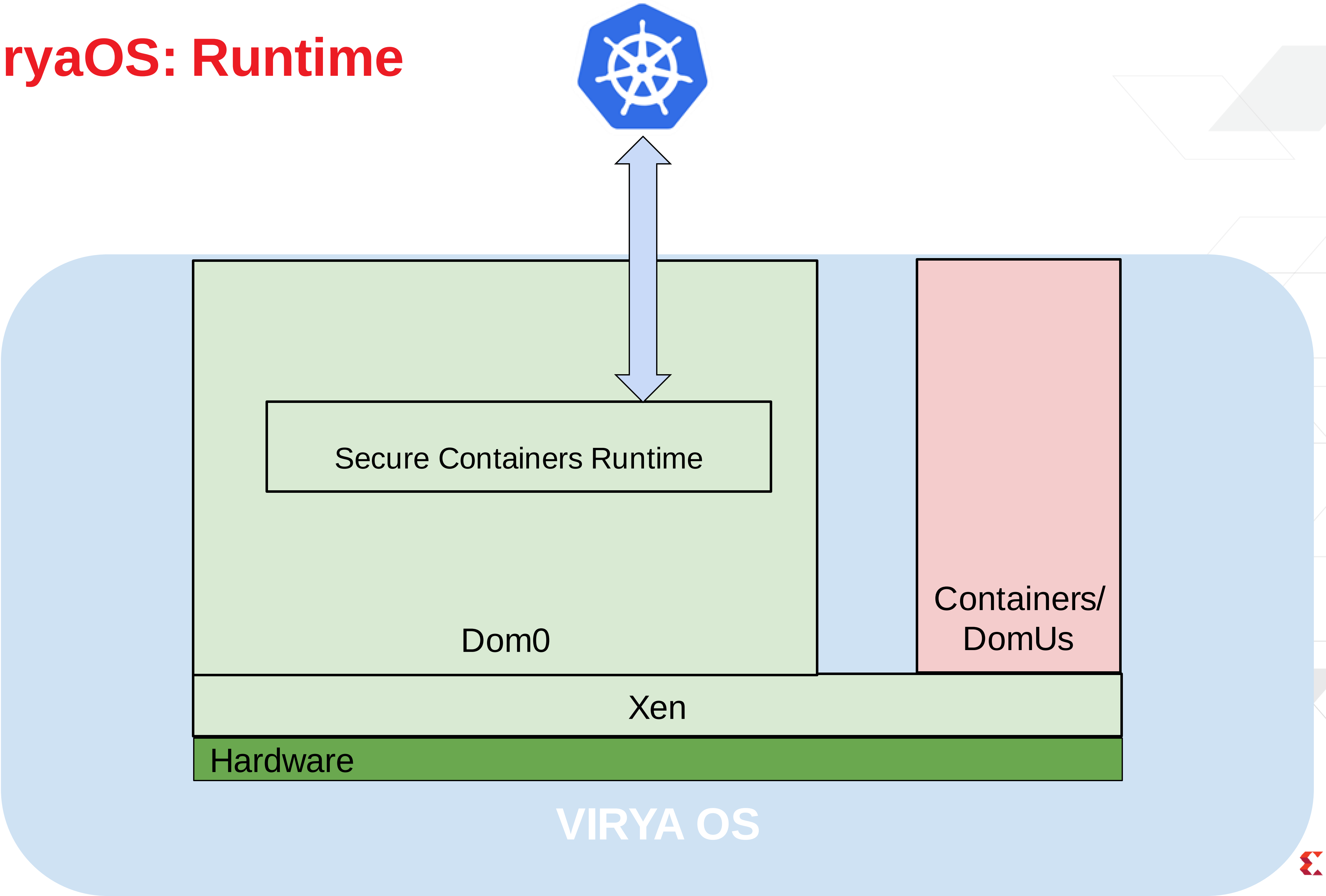
ViryaOS

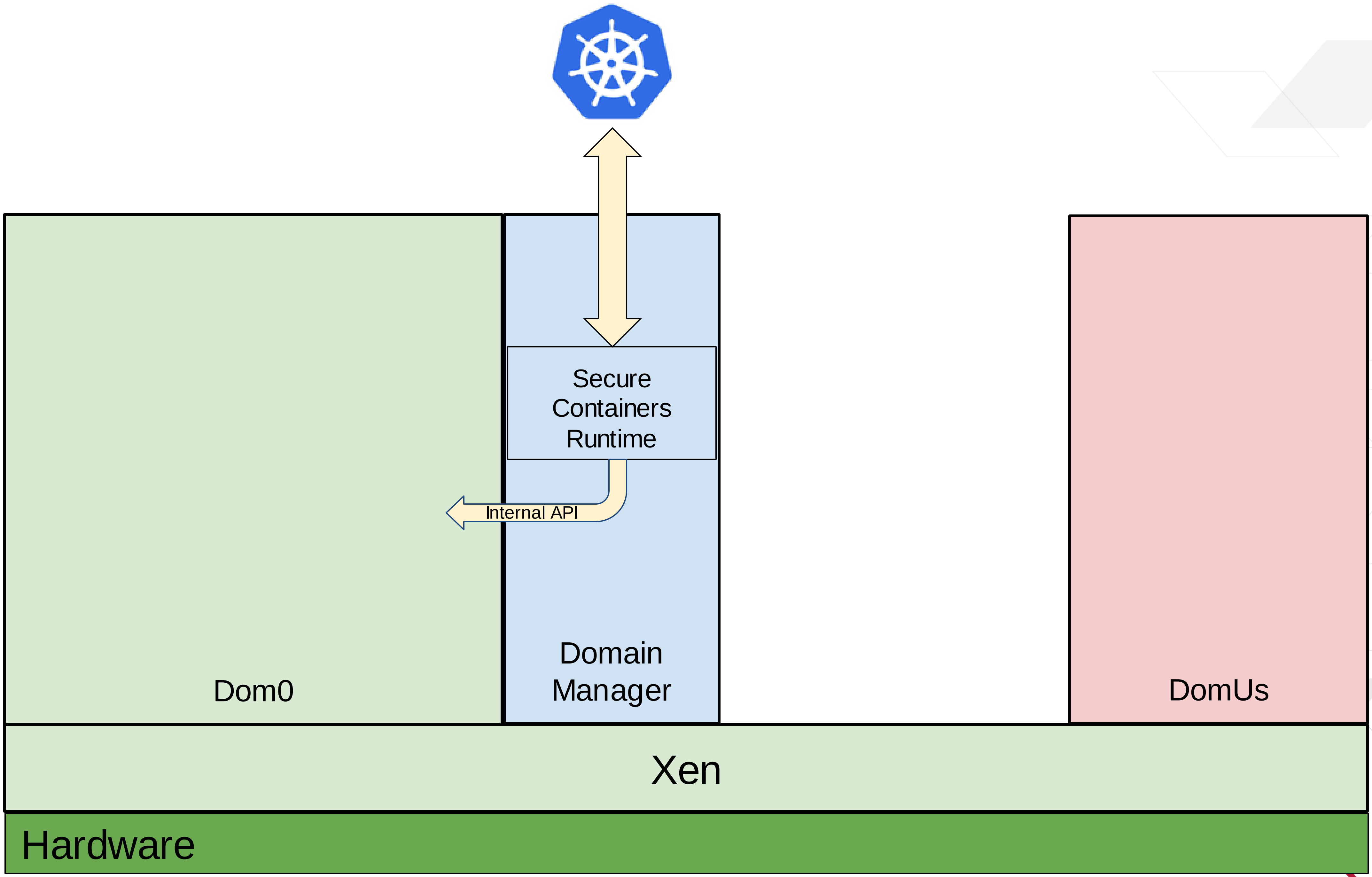


ViryaOS: Runtime

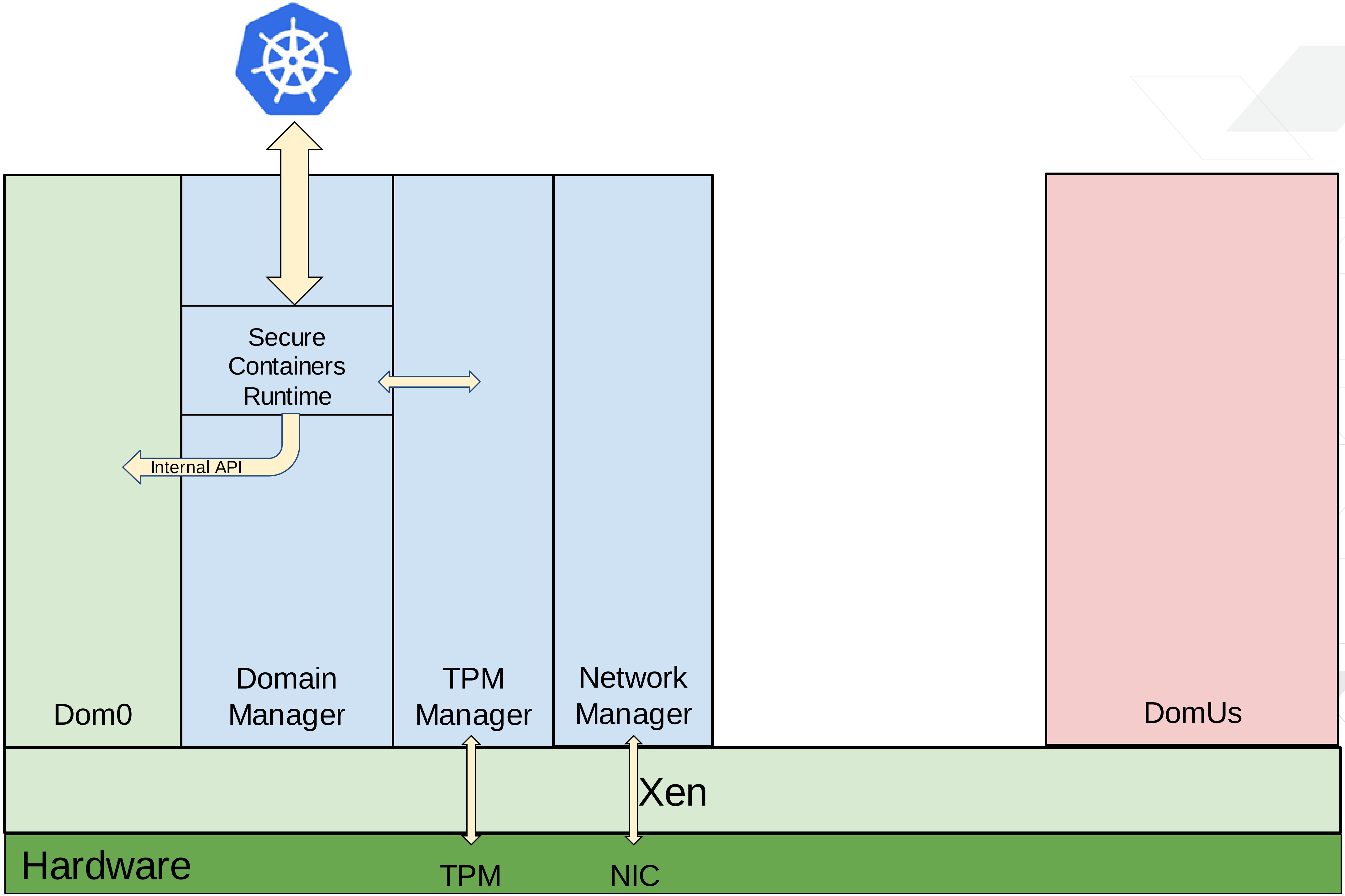
- >**Dynamically deploy VMs and Secure Containers**
- >**Containers are run securely, transparently as Xen VMs**
  - >>1 Kubernetes Pod per VM
  - >>*See KataContainers and stage1-xen*
- >**Measure Boot**
- >**System Software updates and Containers updates**
- >**Uses Disaggregation, Service Domains, and Driver Domains**

ViryaOS: Runtime





Secure Containers Runtime
Internal API
Dom0
Domain Manager
DomUs
Xen
Hardware


Secure
Containers
Runtime
Internal API
Dom0
Domain
Manager
TPM
Manager
Network
Manager
DomUs
Xen
Hardware
TPM
NIC

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ViryaOS: Build

- >a multi-domain build system
  - >>builds multiple domains in one go
- >Create a runnable SD Card image from multiple domain builds
- >Each domain build is independent and run in a Container
- >Pre-configures device assignments to VMs
- >Made for disaggregated architectures

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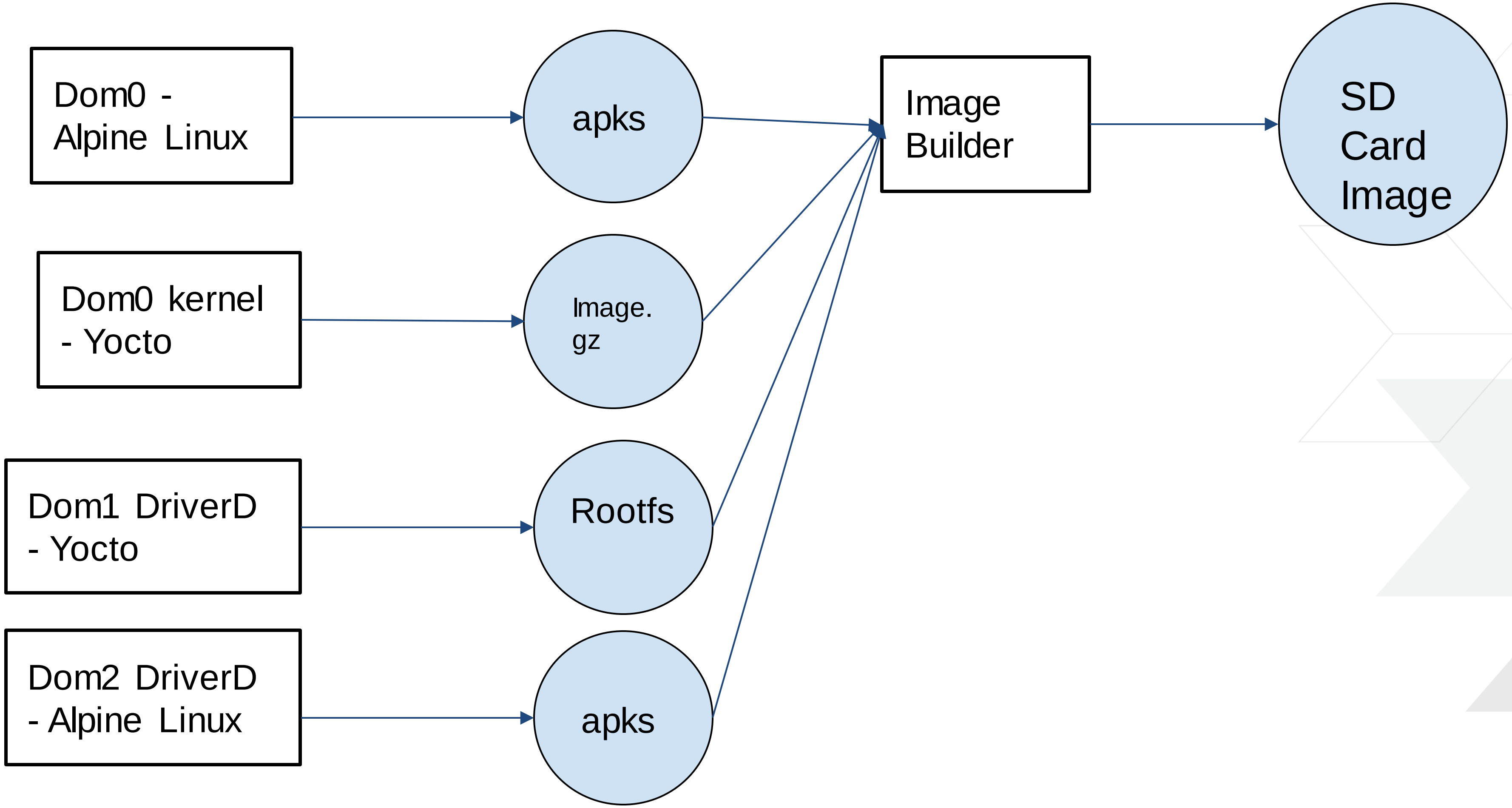
ViryaOS: Build



ViryaOS: Build

- >**Everything builds in a Container**
- >**Support cross-builds (aarch64 on x86) with qemu-user**
- >**Support any build systems for domain builds**
  - >>Enable mixed Alpine Linux / Yocto environments
  - >>Rootfs and kernel can be built independently
- >**Support multiple DomU build output formats**
- >**The DomU build output is stored in a container**
  - >>Intermediate artifacts can be pulled from the Docker Hub to speed up the build

Status

>**Very early stage, experimental**

>**Interest, but no company backers yet, community driver**

>**Subscribe to the mailing list to learn more and participate!**

>**Initial implementation available for:**

- >>SDK
- >>Containers-driven build
- >>Yocto kernel build
- >>Imagebuilder

Adaptable.
Intelligent.

sstabellini@kernel.org
stefanos@xilinx.com

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