XDF XILINX DEVELOPER FORUM

Heterogeneous Real-Time SoC Software Architecture

Presented By

Stefano Stabellini
Principal System Software Engineer

XILINX

Introduction

- **Stefano Stabellini**
  - Xen Project:
    - Founder of the Xen on Arm effort in late 2011
    - Xen on ARM Maintainer and Committer, Linux Maintainer
    - Develops Xen Project features on Zynq UltraScale+ MPSoC
  - Xilinx:
    - System Software Architect focusing on heterogeneous systems
    - Upstreaming Xilinx support to Xen and OpenAMP projects

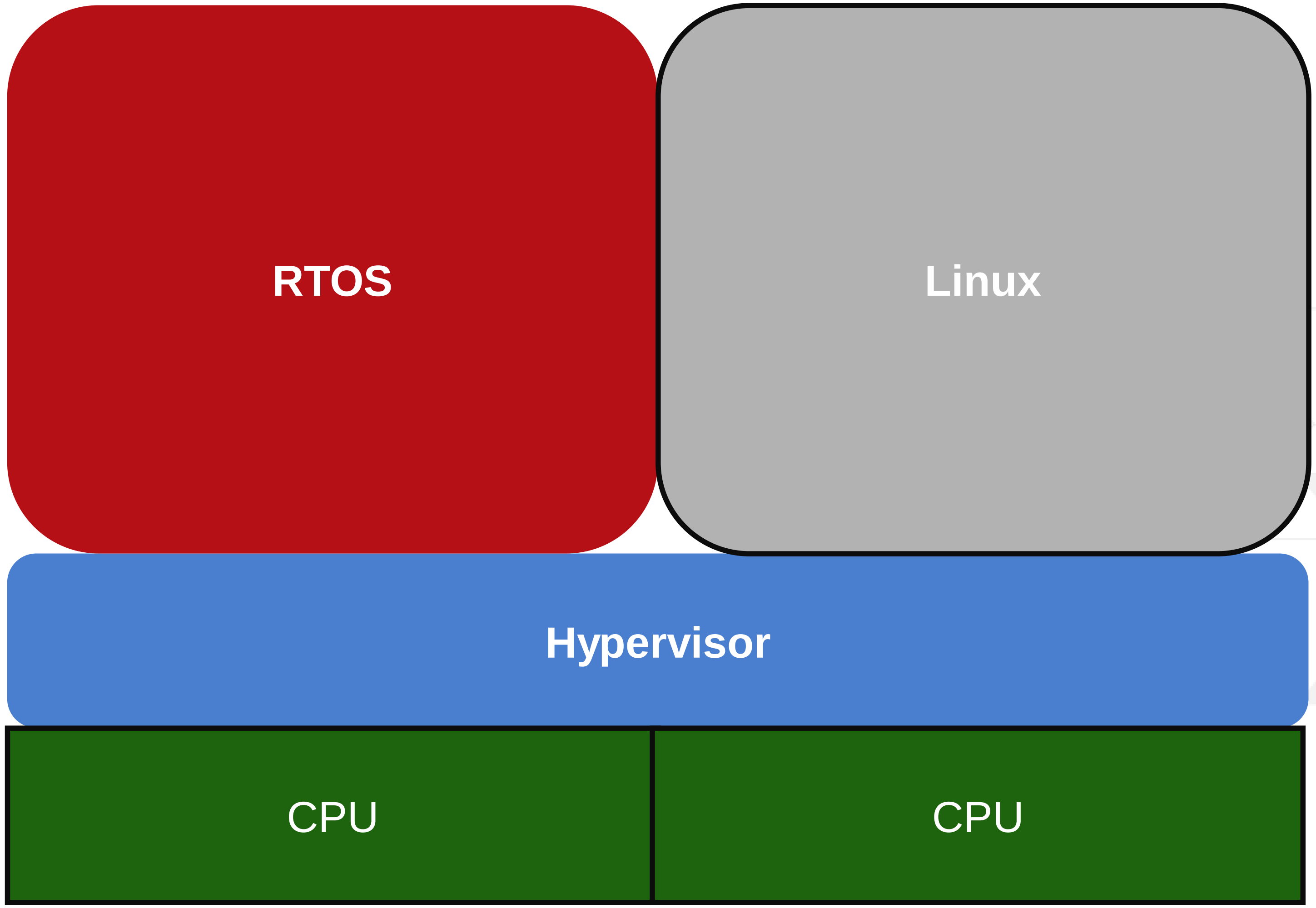
Virtualization Basics

Virtualization – The Concept

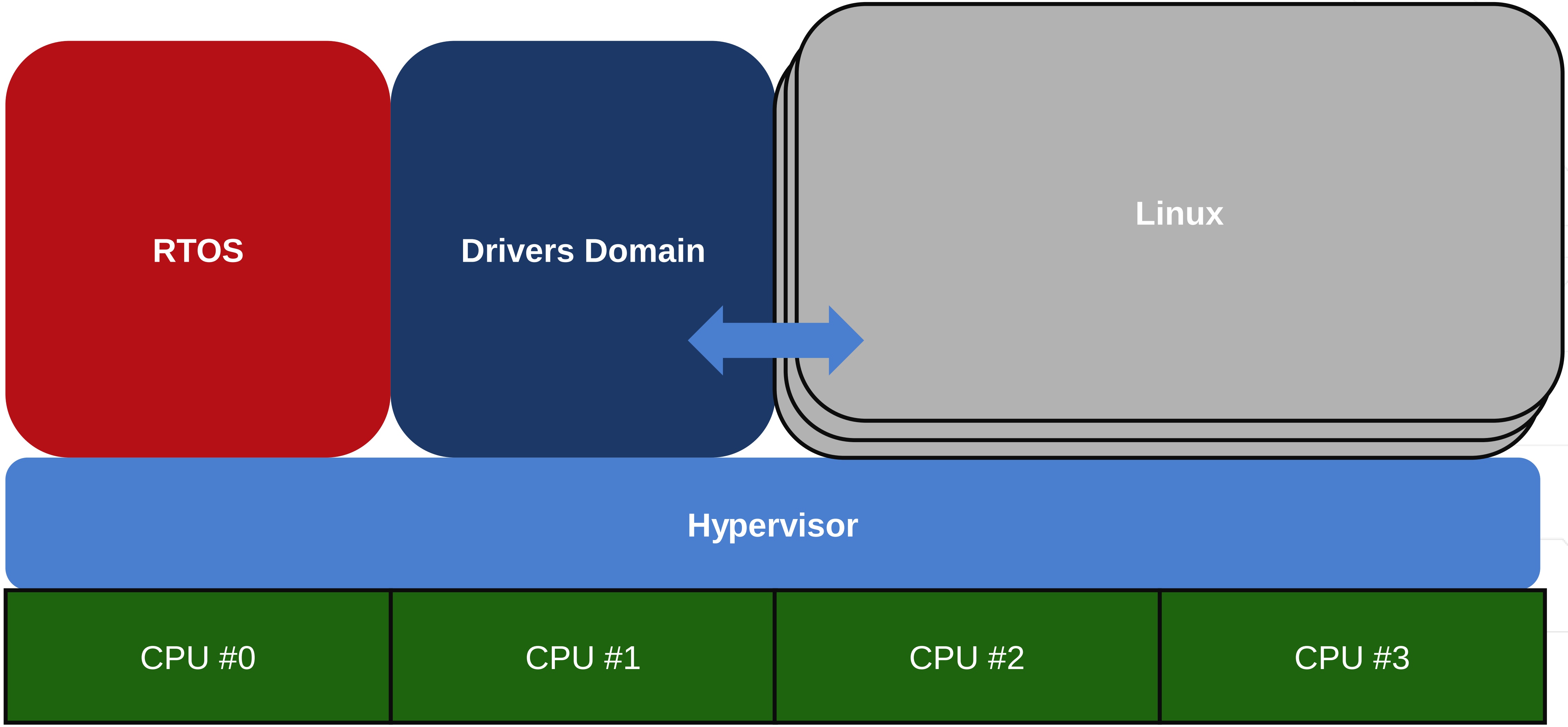
- **“Virtualization”**
  - *The act of creating a virtual version of something, including virtual computer hardware platforms, storage devices, and computer network resources.*
  - Allows the deployment of multiple operating systems and independent workloads on one or more processors
- **“Hypervisor”**
  - *A hypervisor or virtual machine monitor is computer software, firmware or hardware that creates and runs virtual machines.*

- **Why Virtualize?**
  - OS/Workload consolidation
  - Lower system cost
  - Lower power consumption
  - Improved resource utilization
    - Mixed Criticality Systems
  - Fault tolerance
  - Multi-tenancy
  - Portability

Why Virtualize?



Why Virtualize?



Embedded Hypervisor Requirements

- **Short Boot Times**
- **Real time**
  - Low, deterministic IRQ latency
  - Real time schedulers
  - Static CPU partitioning
- **Device Virtualization**
  - Device Assignment
  - Device Sharing
  - Driver Domains
  - VM to VM communication
- **Security, Isolation and Partitioning**
  - Memory
  - Devices
  - CPU
  - SLCRs
- **Operating System Support**
  - Linux, bare-metal, other RTOS support
- **Certifications**
  - Small code base
  - Type-1

Xen Project

Xen Project

> **Xen Project**

- Open source hypervisor
- Small code base implementing a micro-kernel design
- Xen Project hosted by the Linux Foundation

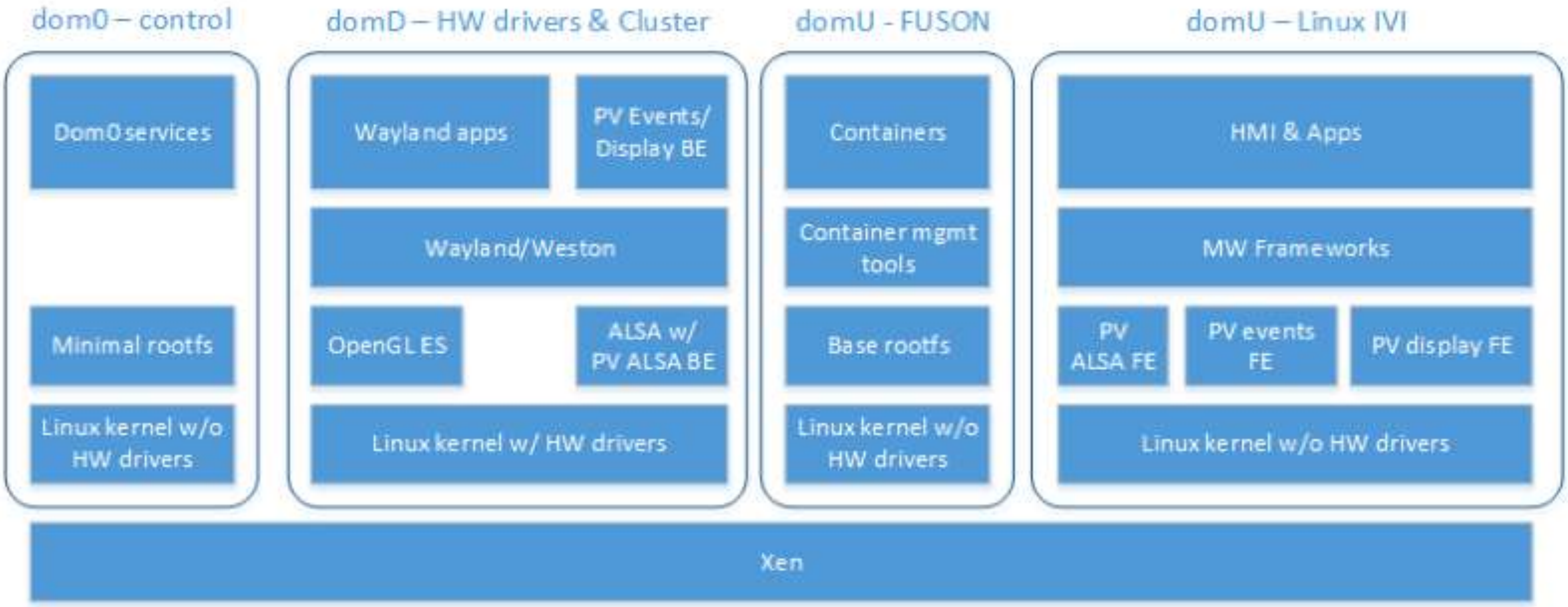
> **Broad, Customizable Feature Set**

- From servers to embedded
- Out of box “real time” schedulers and enhancements
- Advanced device management, partitioning, assignment
- Independent user, control, and driver domains

> **Linux, BSDs or other OSes used for bootstrap (dom0)**

- Linux is the most widely used but other OSes are possible

Example Xen Architecture



dom0 – control

- Dom0 services
- Minimal rootfs
- Linux kernel w/o HW drivers

domD – HW drivers & Cluster

- Wayland apps
- PV Events/ Display BE
- Wayland/Weston
- OpenGL ES
- ALSA w/ PV ALSA BE
- Linux kernel w/ HW drivers

domU - FUSON

- Containers
- Container mgmt tools
- Base rootfs
- Linux kernel w/o HW drivers

domU – Linux IVI

- HMI & Apps
- MW Frameworks
- PV ALSA FE
- PV events FE
- PV display FE
- Linux kernel w/o HW drivers

Xen

XDF XILINX DEVELOPER FORUM

XILINX

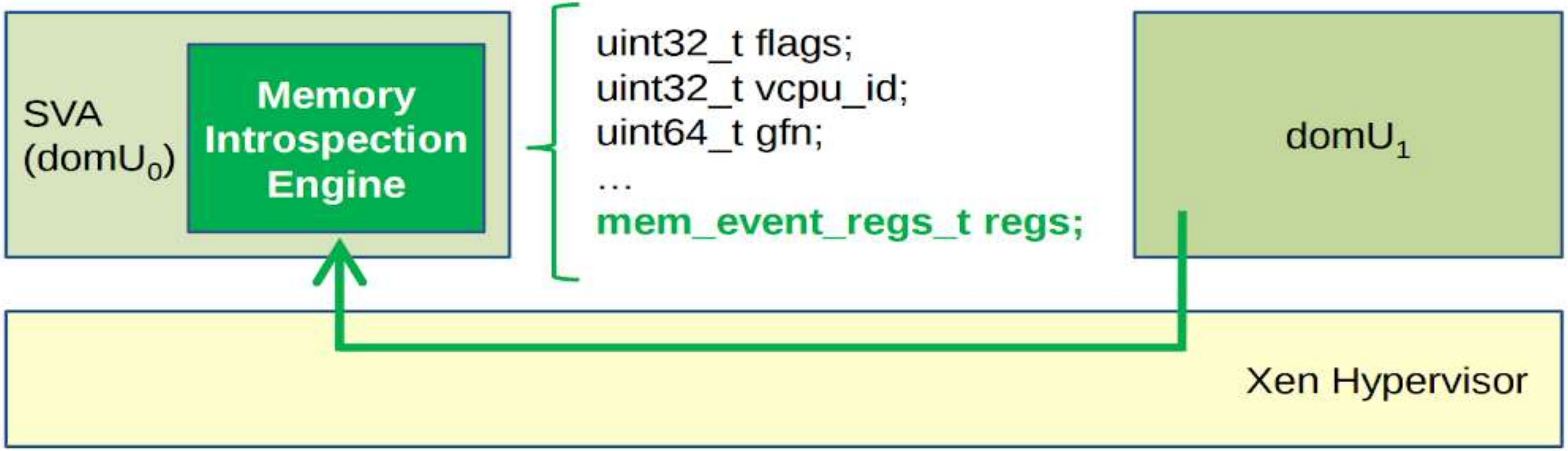
Xen Project 4.11

- **Highlights**
  - Regression testing and hardware validation completed successfully
  - Enormous work for the Meltdown and Spectre mitigations
  - Configurable SErrors handling
  - Many reliability fixes, especially in the interrupt handling path (GIC, vGIC)
  - SMCCC 1.1

- **Highlights (cont.)**
  - RTDS scheduler improvements
  - "null" scheduler improvements: tracing, soft affinity
  - VPL011
  - Mem_Access improvements
  - new PV Drivers: PV Display, PV Audio, PVCalls, PV 9pfs

- **Features and Status**
  - Xen Project 4.11 Feature List

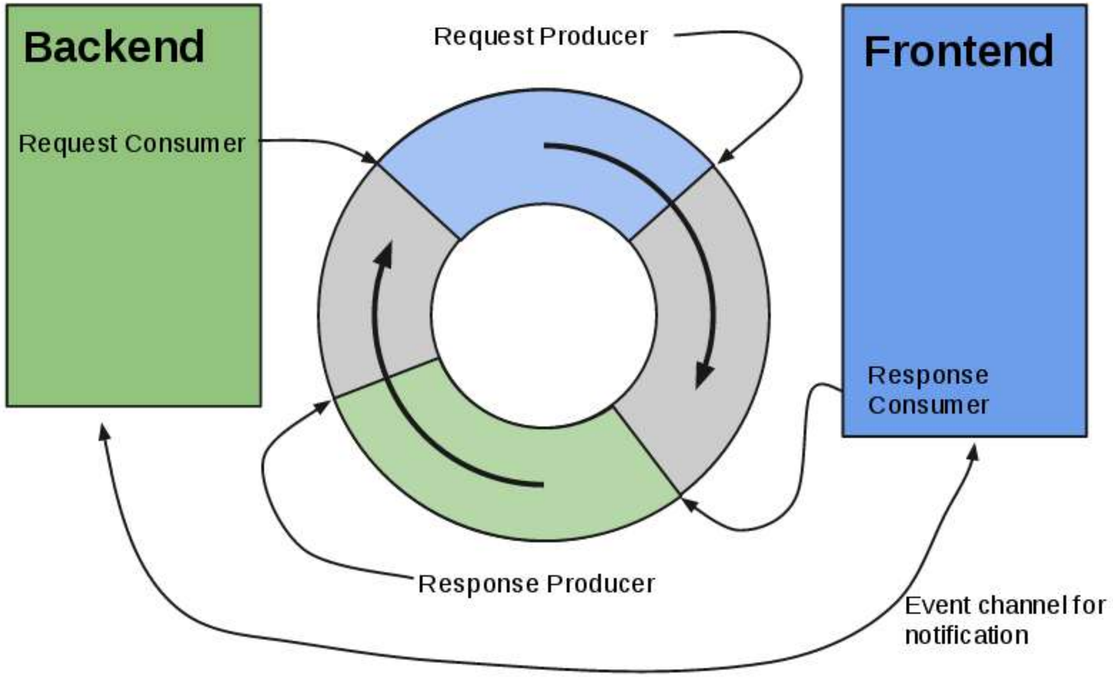
Mem_Access



```
uint32_t flags;
uint32_t vcpu_id;
uint64_t gfn;
…
mem_event_regs_t regs;
```

PV Drivers

- Existing: net, block, console, keyboard, mouse, framebuffer
- New: 9pfs, PVCalls, Multi Touch, Sound, Display
- Prerequisites: xenstore, grant table and event channels support (BSD code available)



Static Partitioning Use-Case

sched=null vwfi=native

Static Partitioning Use-Case

sched=null vwfi=native

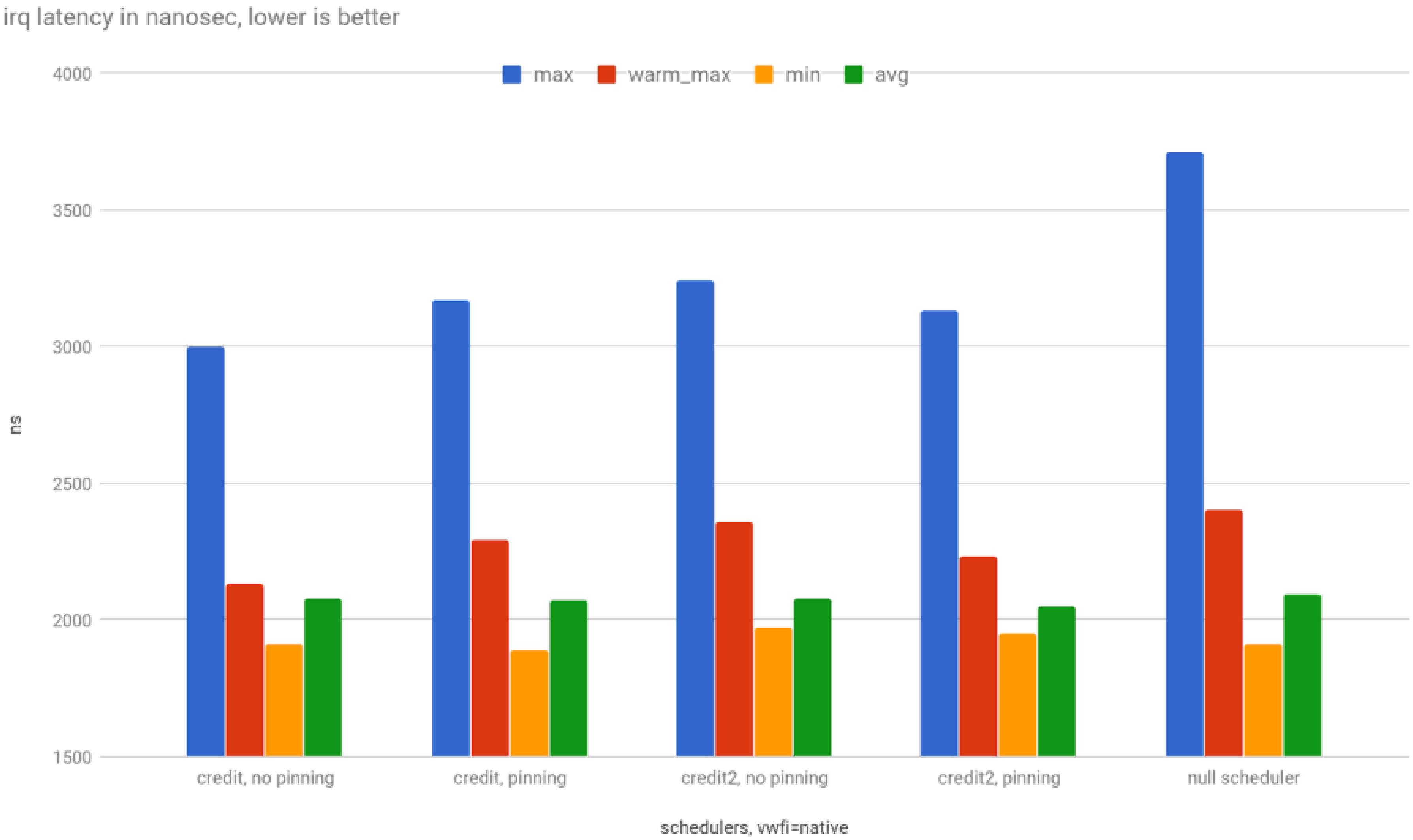
2.5 us

Static Partitioning Latency

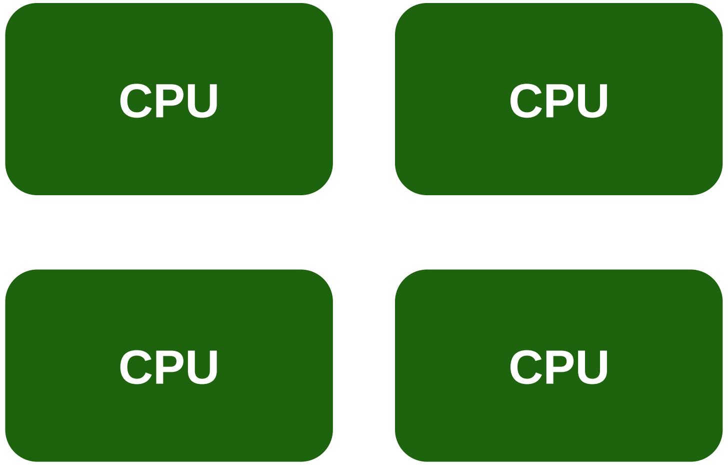
Xilinx Zynq Ultrascale+ MPSoC
Physical Timer

Xen with phys_timer patch
vwfi=native

dom0_mem=1G
max_dom0_vcpus=2
1 vcpu TBM ctest



Xen Schedulers



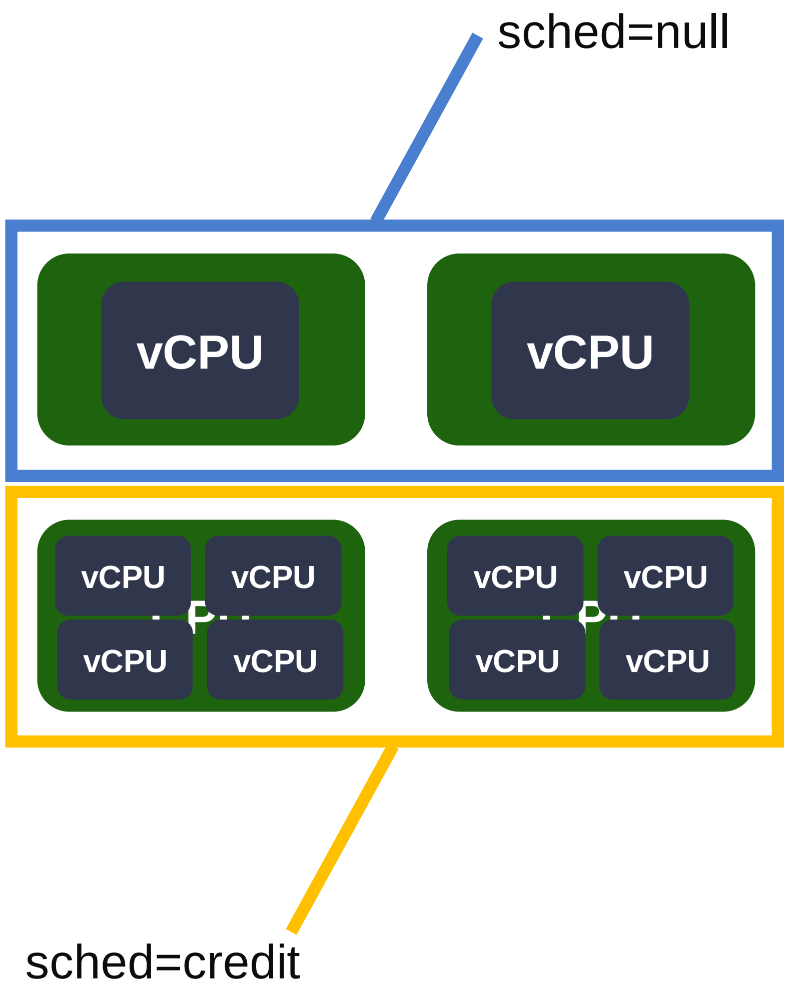
CPU

CPU

CPU

CPU

Xen Schedulers



sched=null

vCPU

vCPU

vCPU

vCPU

vCPU

vCPU

vCPU

vCPU

vCPU

vCPU

sched=credit

Xen VM-to-VM communication mechanisms

- **Libvchan**
  - Linux library
    - Direct VM to VM communication channel based on a ring on shared memory
    - libxenvchan_send and libxenvchan_recv
- **PVCalls**
  - Socket API virtualization
    - VM to VM communication mediated by the backend domain (typically dom0)
    - "lo" becomes a inter-VMs communication namespace
- **V4V**
  - Linux library and hypercall, kernel space and user space
  - VM to VM communication mediated by Xen
    - Trivial to implemented on your own kernel
    - Not fully upstream

Brand New Features

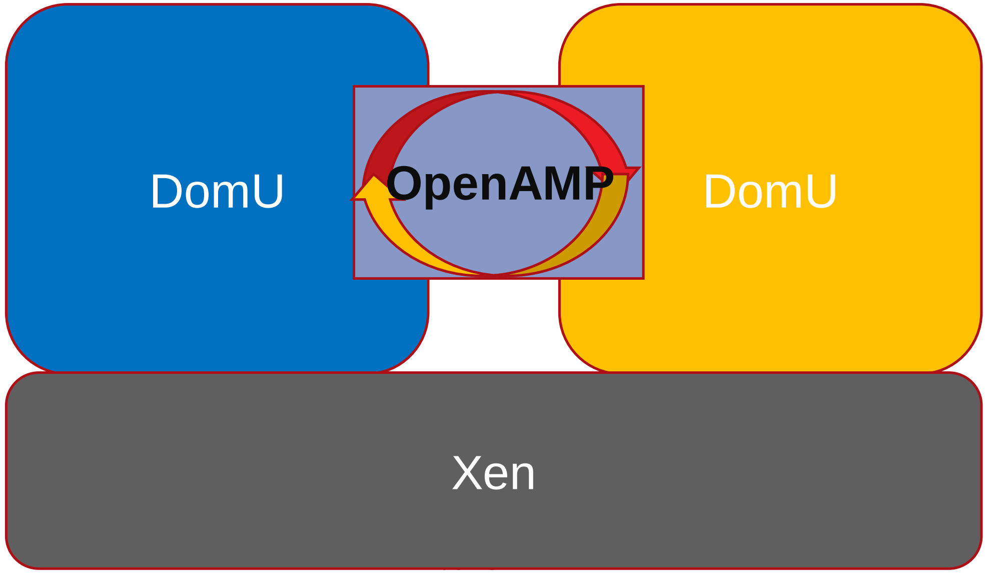
Introduction Slide

Shared Memory

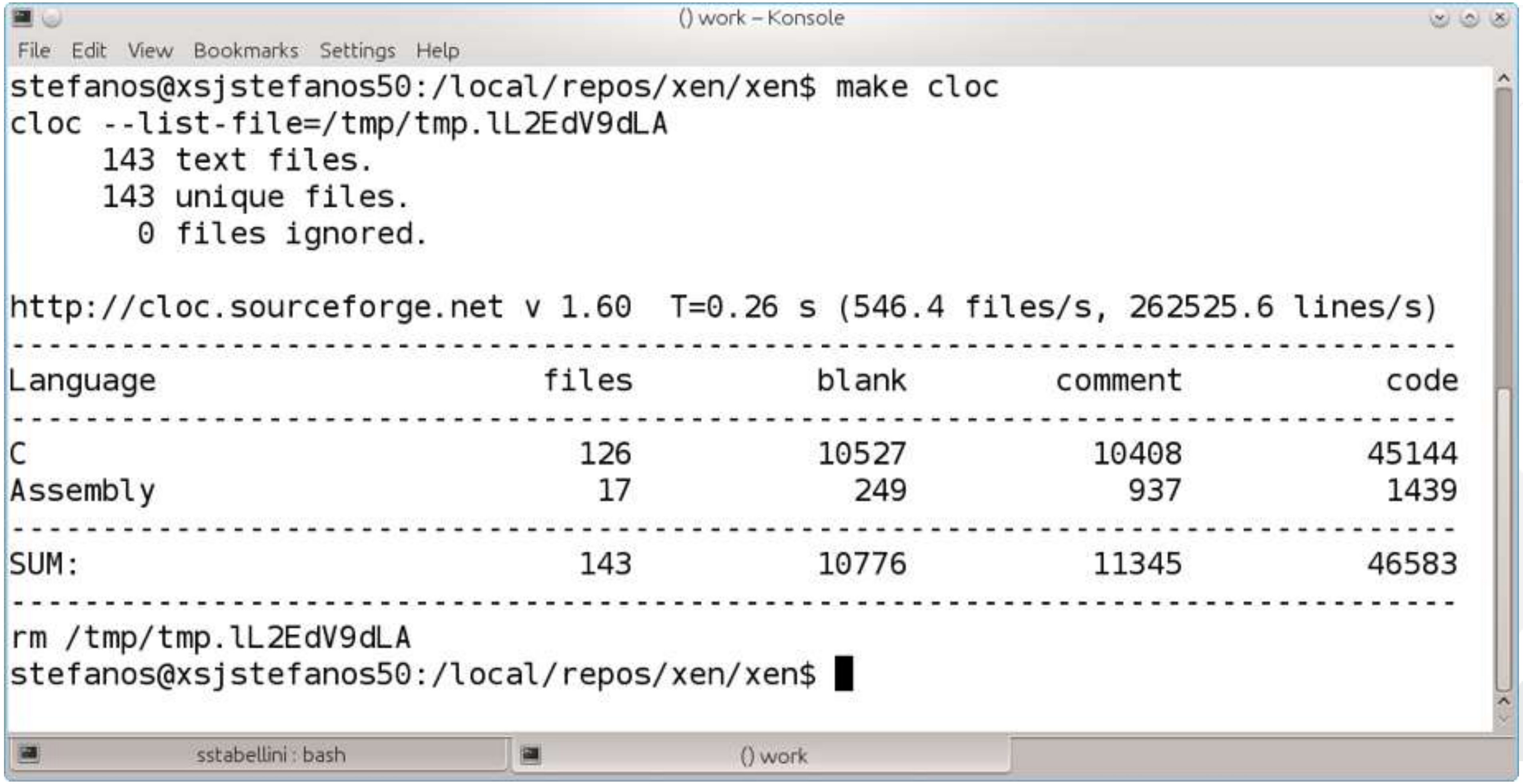
- **Completely Configurable**
  - Support any memory attributes, including cacheable memory (default)
- **No need for Xen support to use it**
- **Can export the memory to Linux userspace and use OpenAMP**

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

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



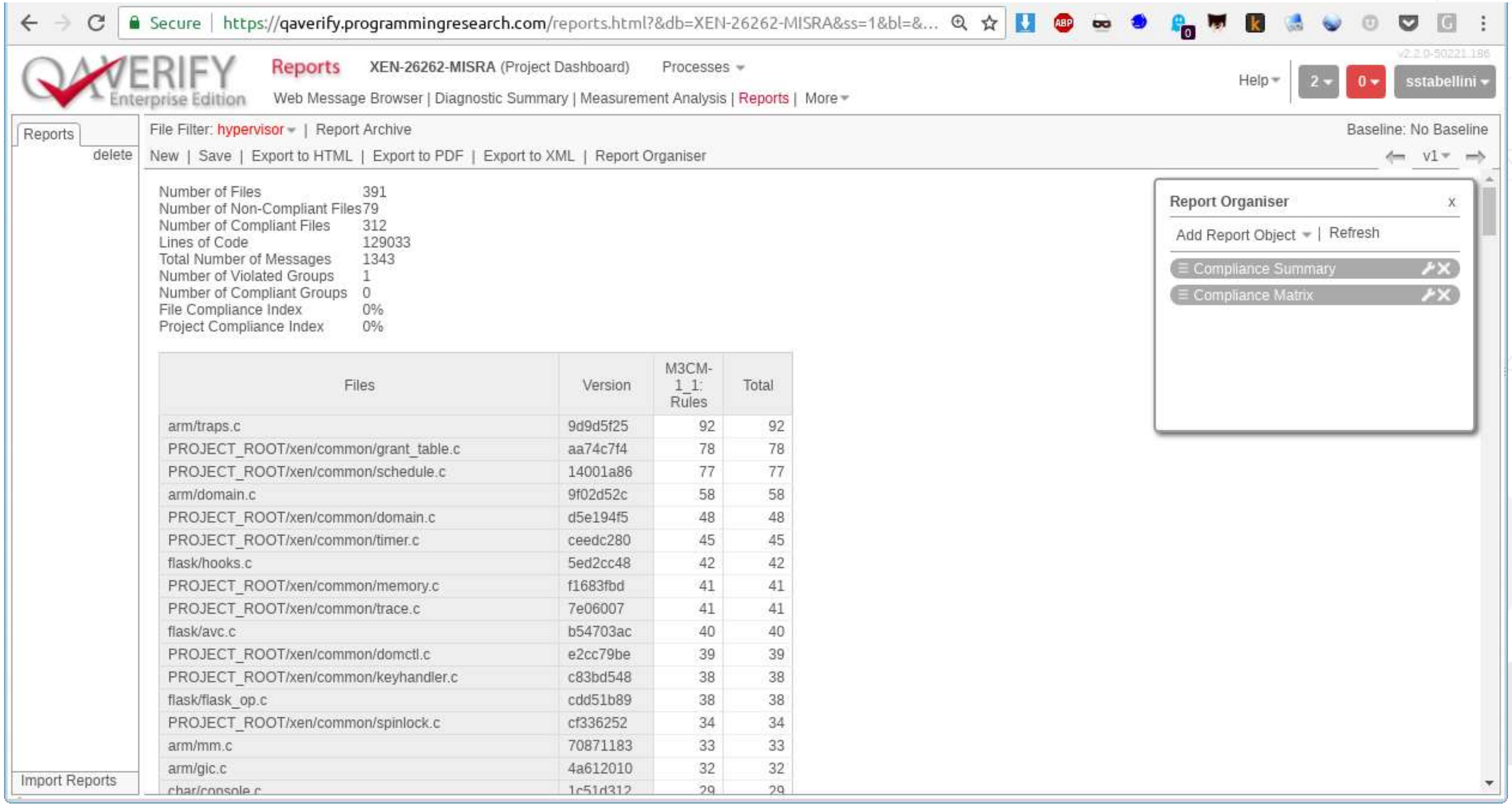
Reducing Code Size



```
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$ █
```

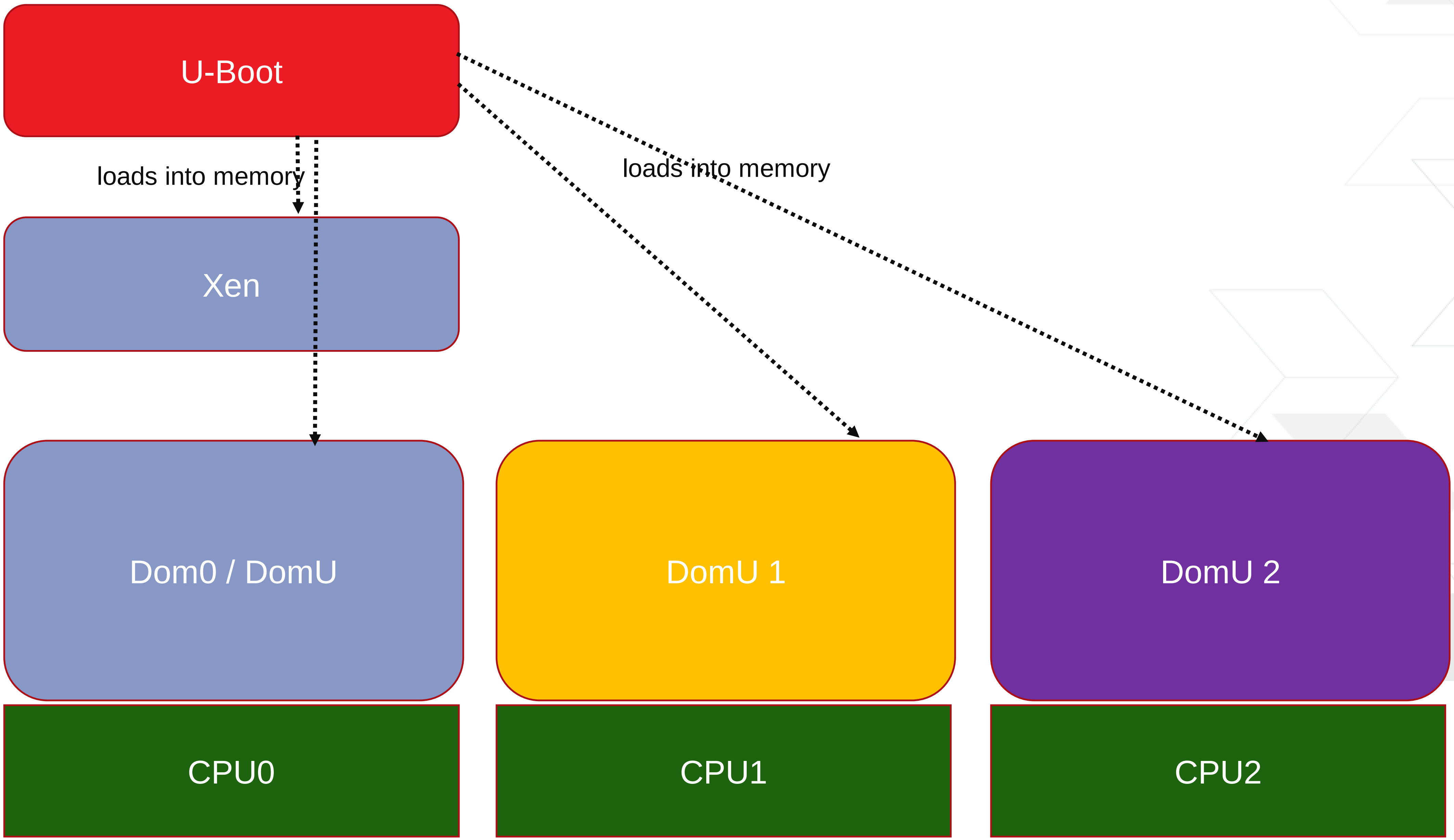
Certifications


Secure
https://qaverify.programmingresearch.com/reports.html?&db=XEN-26262-MISRA&ss=1&bl=&...
QA VERIFY Enterprise Edition
Reports
XEN-26262-MISRA (Project Dashboard)
Processes
Web Message Browser | Diagnostic Summary | Measurement Analysis | Reports | More
Help
2
0
sstabellini
Reports
delete
Import Reports
File Filter: hypervisor | Report Archive
New | Save | Export to HTML | Export to PDF | Export to XML | Report Organiser
Baseline: No Baseline
v1
Report Organiser
x
Add Report Object | Refresh
Compliance Summary
Compliance Matrix

Number of Files	391
Number of Non-Compliant Files	79
Number of Compliant Files	312
Lines of Code	129033
Total Number of Messages	1343
Number of Violated Groups	1
Number of Compliant Groups	0
File Compliance Index	0%
Project Compliance Index	0%

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

Dom0-less



U-Boot

loads into memory

loads into memory

Xen

Dom0 / DomU

DomU 1

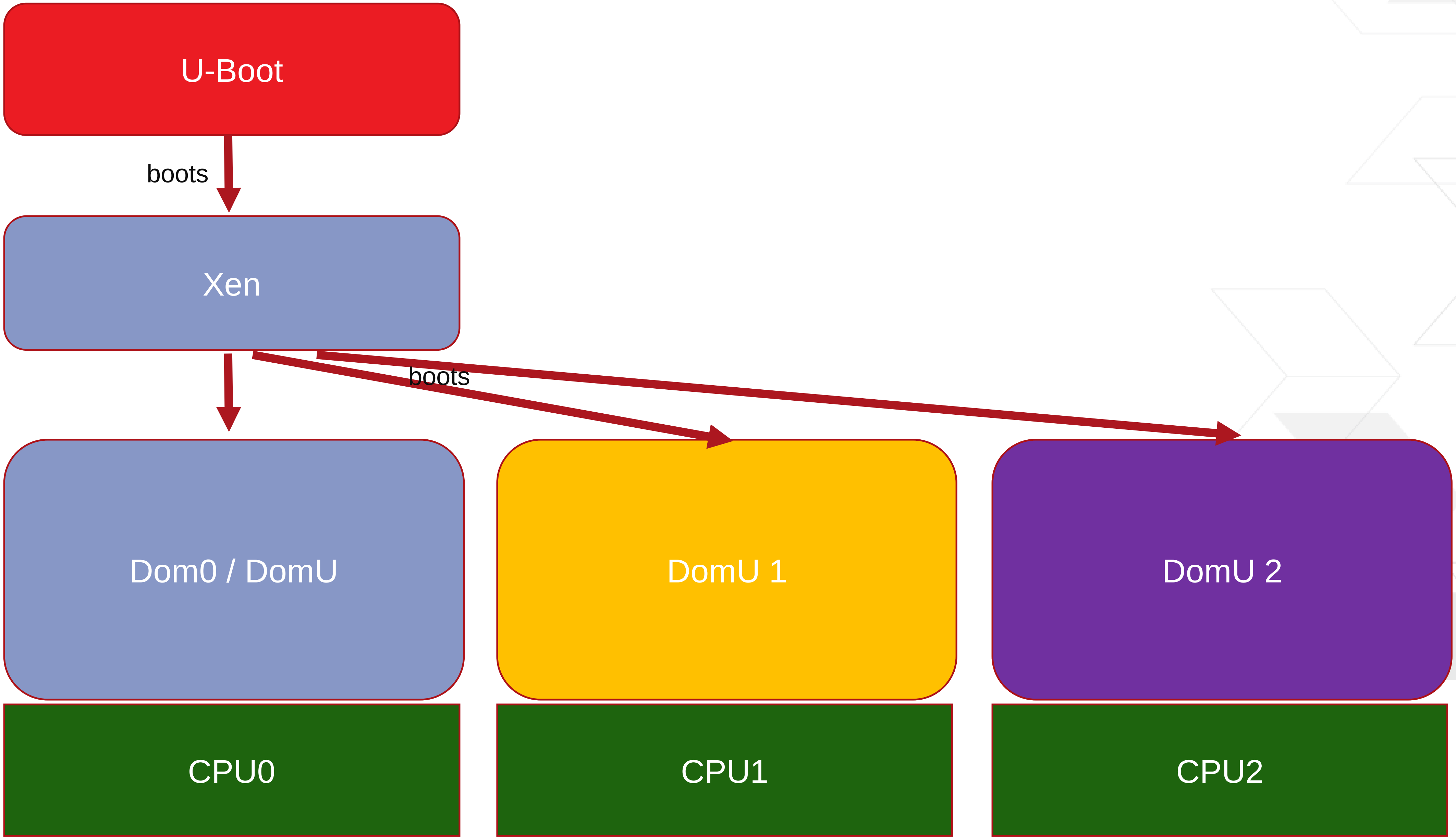
DomU 2

CPU0

CPU1

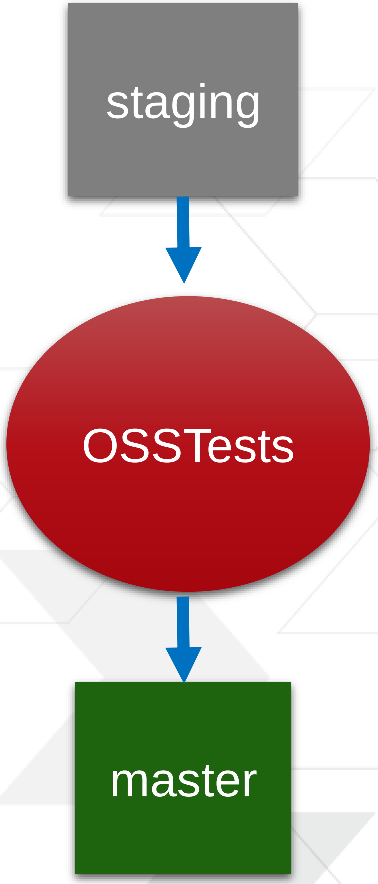
CPU2

Dom0-less



Xen Project "OSSTests"

- **OSSTests: Xen Project official CI-loop**
  - Run 24/7
  - Commits move to master only after passing the CI-loop tests
  - Based in Boston, MA
  - Only accept off-the-shelf hardware
- **Xilinx MPSoC ZCU102 coming to Xen Project!**
  - Will validate master on Xilinx hardware
  - Every Xen release will be checked against Xilinx hardware
  - Increase overall quality
  - Reduce risks of rebasing Xen in Petalinux



"The best security process in the industry"

- A very transparent process
- Responsible disclosure
- Only few security issues for Xen on ARM
- Xen stable trees maintained for security for 3 years

Commercial Xen Support

- **DornerWorks**
  - Xilinx Premier Design Services Partner
  - Hardware, software and systems expertise
  - Xilinx partner for Xen support and design customization services
- **Community Support**
  - Free [Community Support](#)is available to the entire Zynq UltraScale+ MPSoC community.
  - This support includes all software for Virtuosity™, plus all supported configurations or workflows that are documented by the distribution.

- **DornerWorks Xen commercial support**
  - Custom hardware porting
  - New guest OS support
  - Custom device drivers
  - Programmable Logic integration
  - System architecture design
  - Scheduling and partitioning for ARINC 653 and FACE
- **http://dornerworks.com/xen**

Other Hypervisors

Jailhouse

- **Open source hypervisor**
  - https://github.com/siemens/jailhouse
- **Lightweight implementation**
  - Focus on resource partitioning and not on virtualization
    - No schedulers, no PV devices, no Driver Domains, etc.
- **Features**
  - Optimized for simplicity rather than feature richness
  - Relatively new ARM64 support
- **Linux used for bootstrap and control of partitions**
- **Commercially supported on Zynq UltraScale+ MPSoC by Enea**

Commercial Hypervisors

- DornerWorks (Xen, seL4)
- General Dynamics Mission Systems (OKL4 Microvisor®)
- Green Hills Multivisor®
- Lynx LynxSecure®
- Mentor Embedded Hypervisor
- BlackBerry QNX® Hypervisor
- Sysgo PikeOS® Hypervisor
- Wind River Virtualization Profile

XDF XILINX
DEVELOPER
FORUM