Building a Firmware for Virtual Machines using Rust

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Project:
Rust Hypervisor Firmware

Motivation

Why Rust?

- New language with a focus on correctness and performance
- Compiled to native code offering performance similar to C
- Memory management without garbage collection
- Designed for systems programming

Why A New Hypervisor Firmware?

A new hypervisor deserves a new firmware!

Cloud Hypervisor objectives:

- High performance type-2 VMM using KVM
- Minimal hardware emulation → small attack surface
- Suitable for use with Kata Containers
- Suitable as a “pet” virtual machine monitor (with persistent storage, networking and a generic operating system)

Why Not OVMF?

- OVMF is a TianoCore based UEFI firmware – used with NEMU and QEMU
- Experience of OVMF from porting NEMU “virt” machine type:
- “Legacy” hardware expectations
- Full featured → complex
- Linux cloud workloads main focus
- Want compatibility with Linux loader

Linux Loader Compatibility

- All Rust based hypervisors have an ELF loader for the Linux kernel
- Used to load uncompressed vmlinux kernel
- Boots in long mode with identity mapping
- LDT & GDT setup
- Provides an E820 table with the memory layout

Why A Firmware Then?

- If can already load a Linux kernel with the hypervisor…why this project?
- Direct loading is perfect for: container style workloads (e.g. Kata Containers or Firecracker) or full control of the stack (e.g. Crostini on Chrome OS)
- For wider cloud use cases: End-user need to control their own boot (e.g. to update kernel)

Architecture

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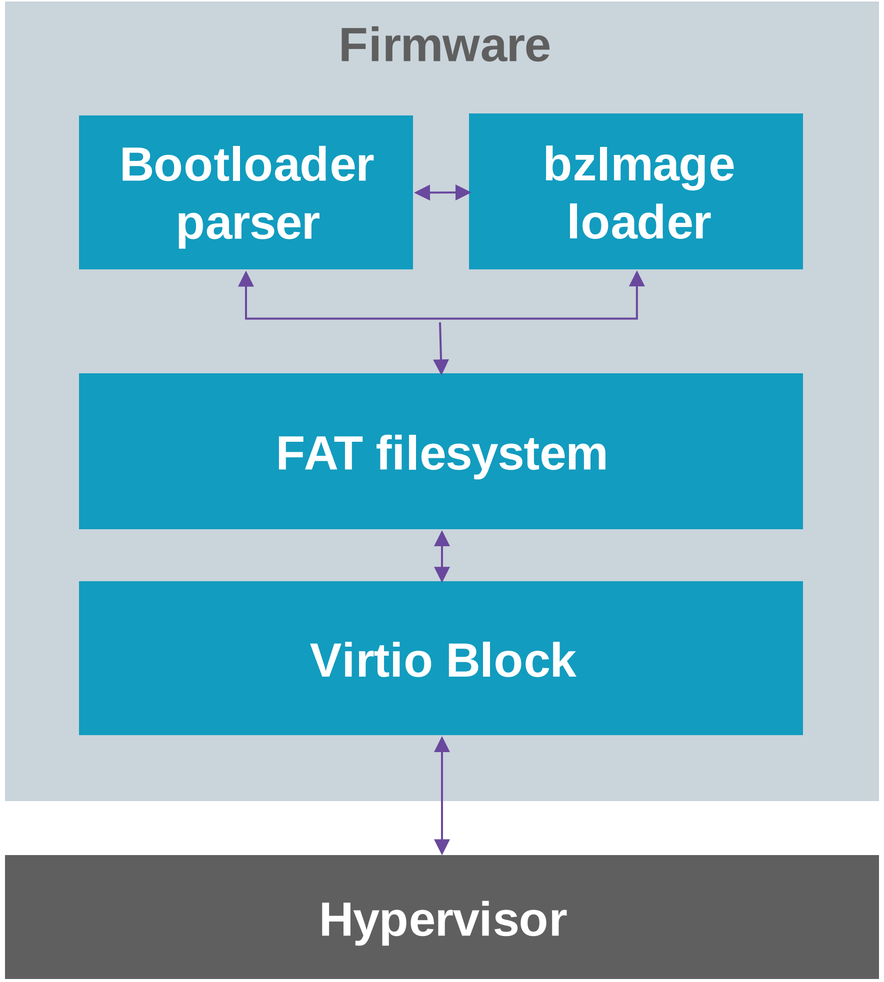
- Two modes of operation:
- FreeDesktop loader
  - Used for ClearLinux
- EFI loading
  - Used for Debian and Ubuntu

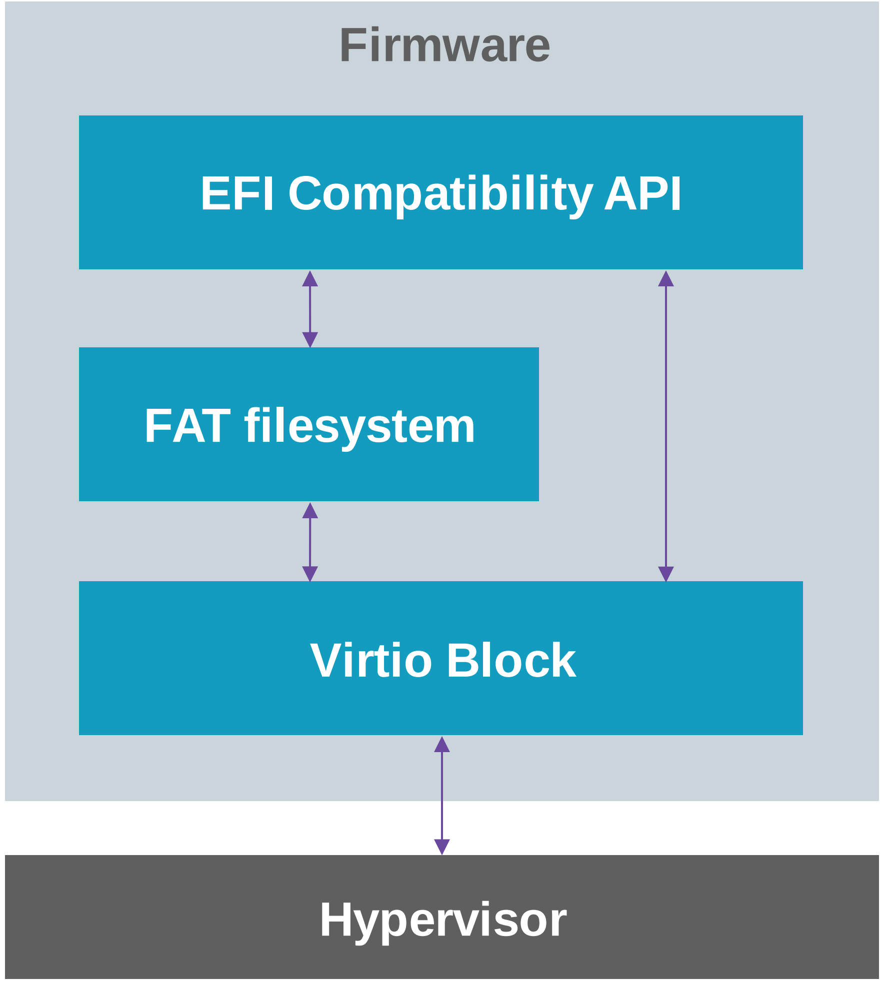
FreeDesktop Loading

- Virtio transport: MMIO and PCI
- Block device driver (virtio-blk)
- GPT partition parsing
- FAT filesystem implementation
- bzImage loader
- FreeDesktop bootloader specification parser



EFI Loading

- Virtio transport: MMIO and PCI
- Block device driver (virtio-blk)
- GPT partition parsing
- FAT filesystem implementation
- PE32+ loader
- "EFI Compatibility" API



Basic setup

- Loaded by hypervisor at 0x100000 (1MiB)
- Establishes wider identity mapping
- Parses kernel command line for MMIO block device details
- Reads E820 table from zero page
- Probes block device and searches for filesystem

FreeDesktop loader

- Parses FreeDesktop bootloader specification configuration
- Loads bzImage via 64-bit bootloader protocol at 0x200000 (2 MiB)
- Loads initrd and populates command line
- Updates zero page with new details per spec (including revised E820)
- Jumps into kernel at 64 bit entry
- No more interaction with firmware

EFI image loader

- PE32+ loader
- “EFI compatibility” layer
- Uses “r-efi” crate – definition of common EFI structures in Rust
- EFI memory allocator
- Filesystem + block abstraction
- Able to boot Linux kernel built with CONFIG_EFI_STUB
- Boots shim + GRUB as used by Ubuntu image
- Not aiming for full EFI functionality

Evaluation

Evaluation of Rust (for Firmware)

Memory safety - *Helps* avoid many classes of security issues

But … firmware needs fine grained control of memory

Ergonomic - great editor support, unit testing in the box, powerful build system

But … custom target for linker script, need to use “core”, “nightly” compiler

Flexible - have control over *some* low-level details

But … firmware patterns pushes Rust language to its limits

High performance - almost native performance

Community - wide community developing firmware, operating systems and other low-level components in Rust

Conclusion

Development Status

- Experiment. Not for production!
- Currently developed and tested against Firecracker and Cloud Hypervisor
- Apache 2.0 licensed
- On GitHub: https://github.com/intel/rust-hypervisor-firmware
- External contributions welcome!

Q&A

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