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
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
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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