

presented by



Multi-ISA Driver Compatibility

What's the future?

UEFI Fall 2023 Developers Conference & Plugfest
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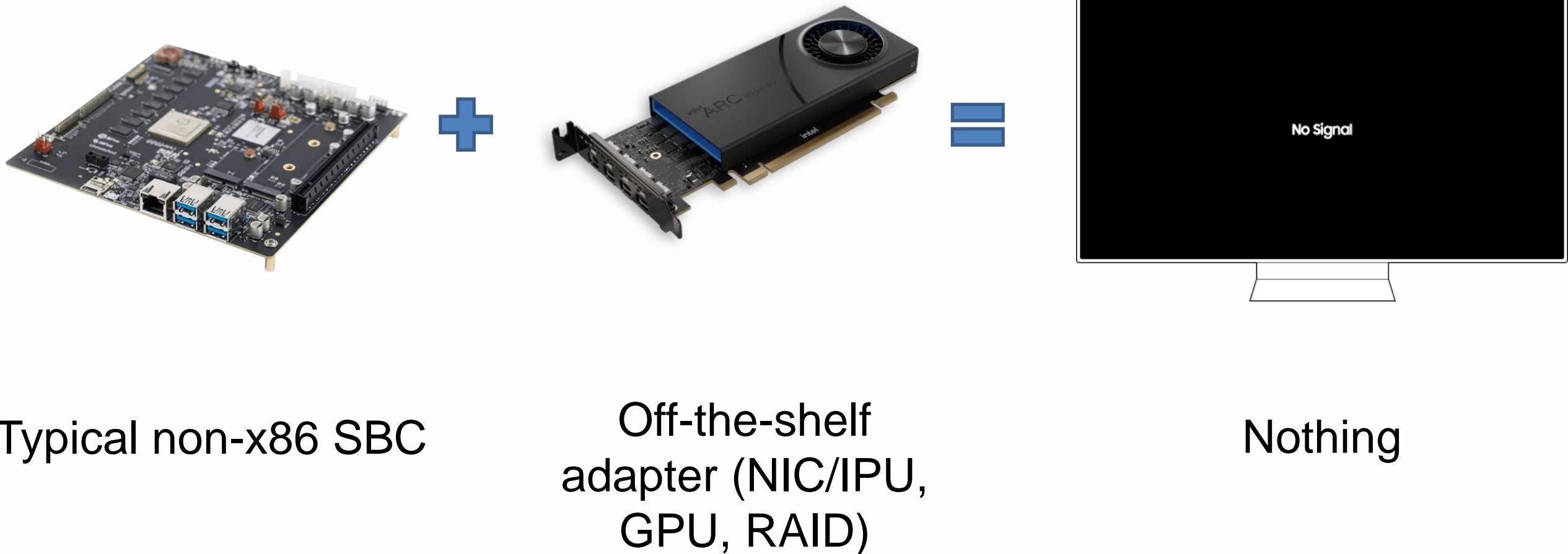
Agenda



- Background
- Past and current approaches
- What's the future?
- Discussion

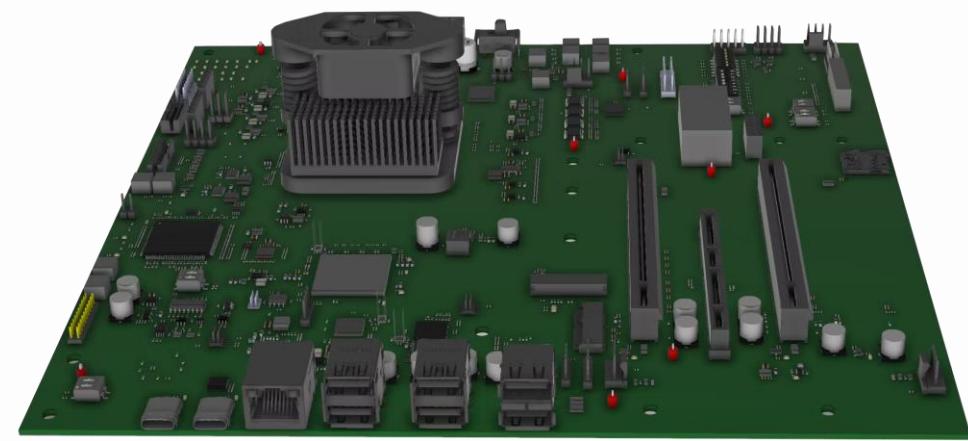


Background

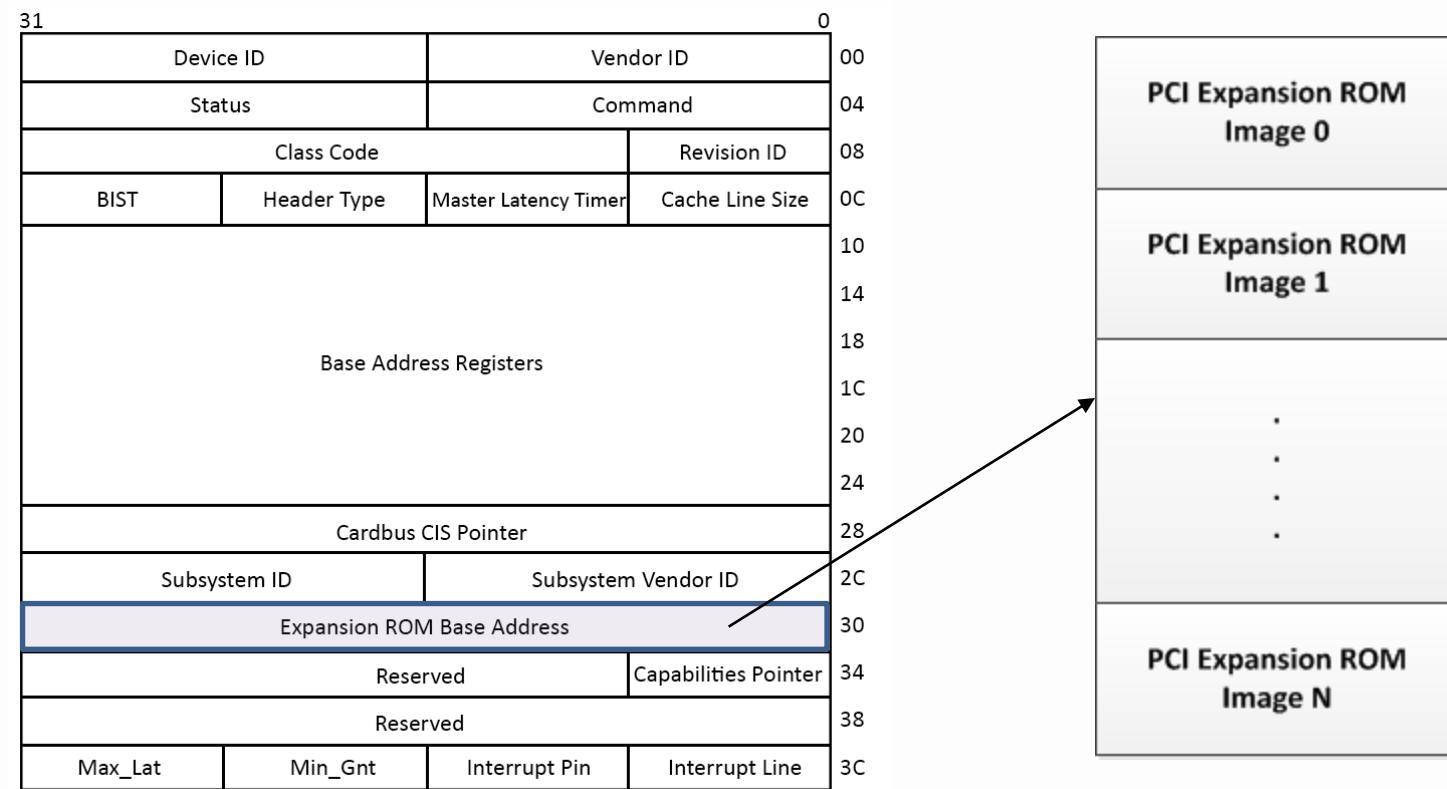


Background

- ❖ **Today → \$GENERIC computer world is already Multi-ISA!**
 - ❖ X64, AArch64 SystemReady, LoongArch64
 - ❖ ACPI + UEFI based servers, PCs, etc.
 - ❖ PCIe/CXL connectivity for off-the-shelf devices, which are not Multi-ISA.
- ❖ **Tomorrow → More architectures and environments.**
 - ❖ RISCV64
 - ❖ RISCV128
 - ❖ CHERI variants (Morello, ...)



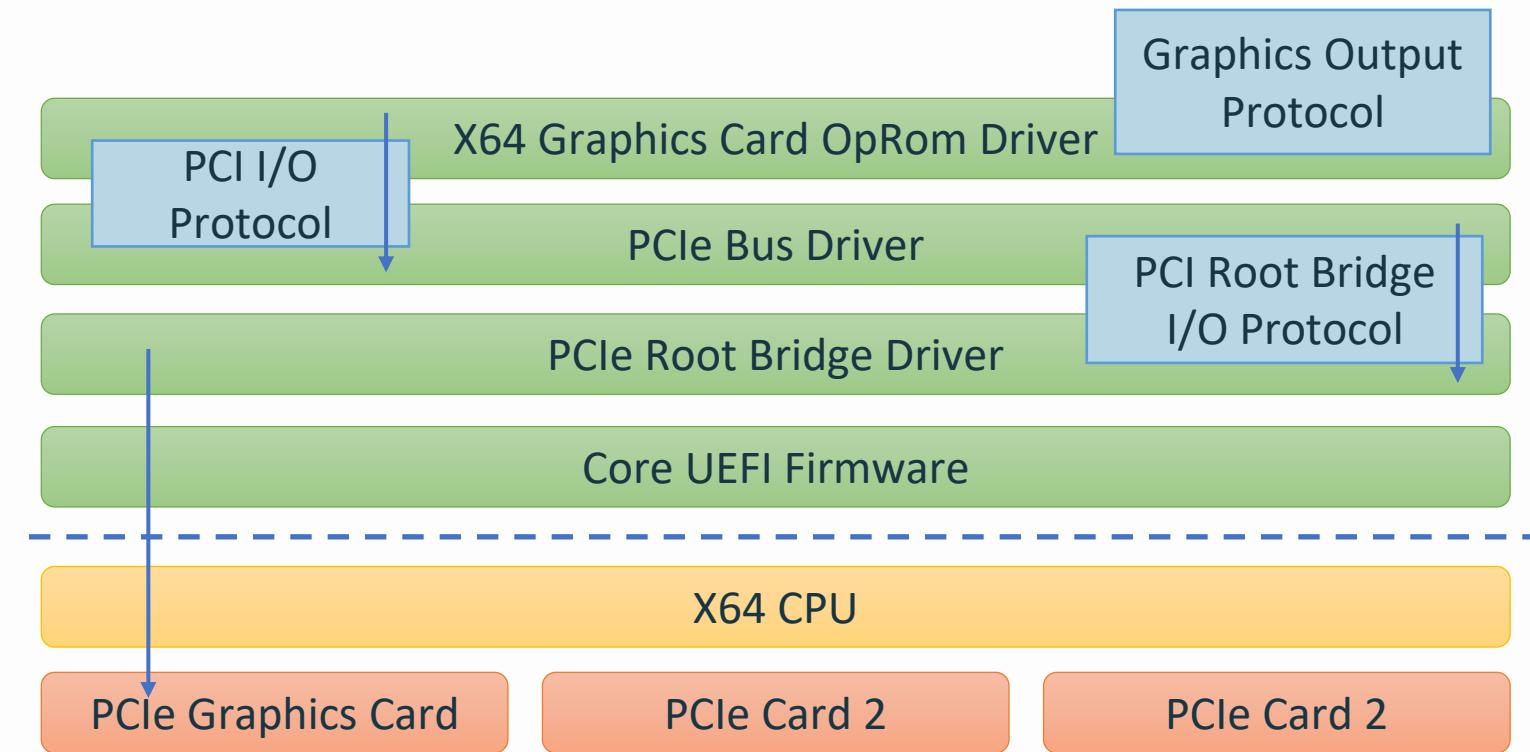
PCIe Firmware Drivers



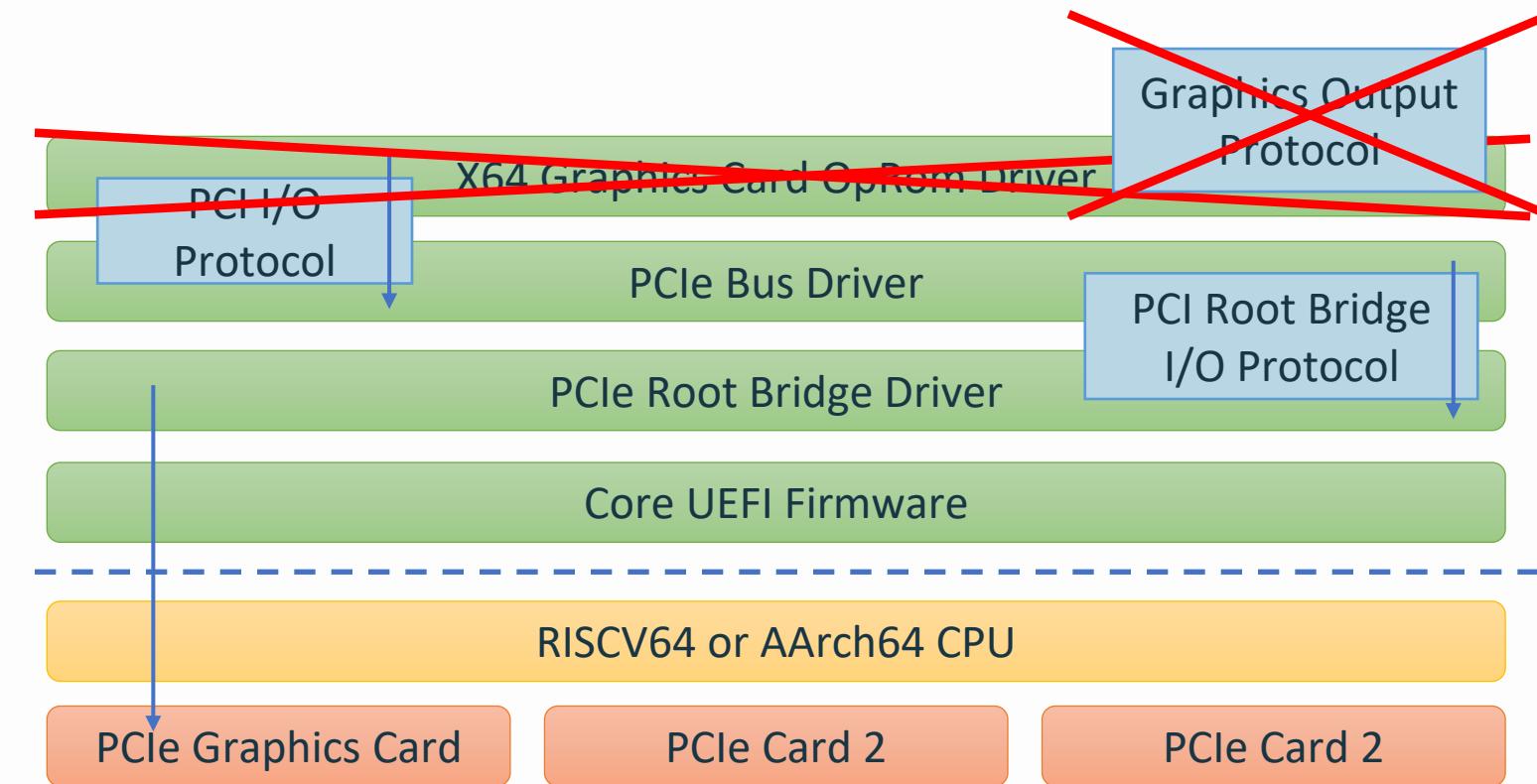
Legacy PC-AT BIOS ROM

X64 UEFI Driver

Life of PCIe in x64 UEFI



Life of PCIe Elsewhere





Past and Current Approaches

Past Approach – EFI Byte Code



PCI Expansion ROM Image 0
PCI Expansion ROM Image 1
.
.
.
.
PCI Expansion ROM Image N

Legacy PC-AT BIOS ROM

X64 UEFI Driver

EBC UEFI Driver

- ❖ Specifically made for this scenario!
- ❖ Processor Independence
 - ❖ `sizeof(VOID*)` is a runtime operation.
 - ❖ VM takes care of 32 vs 64 vs 128-bit issues.
- ❖ TianoCore comes with an interpreter.
- ❖ Not used by the industry!
 - ❖ No tooling – the only supported and proprietary C compiler has been retired.
 - ❖ Some OSS now exists
 - ❖ <https://github.com/yabits/ebcvm> / ELVM
 - ❖ <https://github.com/pbatard/fasmg-ebc>
 - ❖ Different performance profile - interpreted code.
 - ❖ Didn't make a come-back when the Arm ecosystem explored this space

Current AArch64 Approach



X86EmulatorPkg

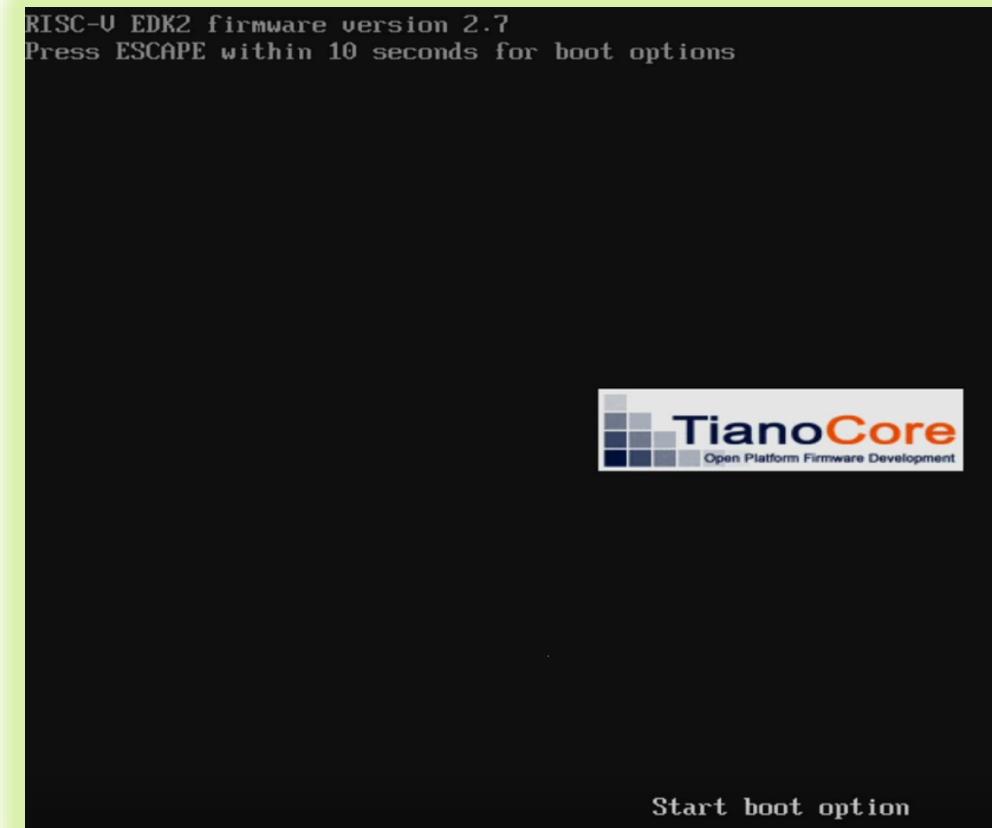
- ❖ Supports x64 OpRoms and UEFI applications on AArch64 systems.
 - ❖ Open Source UEFI Boot Service Driver
 - ❖ Targets 64-bit AArch64 systems (servers, workstations)
 - ❖ Developed by Linaro engineers 6 years ago.
 - ❖ Uses BT (Binary Translation), via Qemu Tiny Code Generator.
 - ❖ <https://github.com/ardbriesheuvel/X86EmulatorPkg>
- ❖ Not trivially portable to RISC-V!
 - ❖ Old TCG code of unknown provenance.
 - ❖ Backporting RISC-V support sounds hard (and time consuming) unless you're a Qemu guru.

BT for Everybody



Rewrite of X86EmulatorPkg

- ❖ Portable: Supports AArch64 and 64-bit RISC-V UEFI hosts.
- ❖ Tested on real hardware
 - ❖ AArch64: Raspberry Pi and Ampere Altra
 - ❖ RISCV64: StarFive VisionFiveV2
- ❖ 64-bit x64 and AArch64 UEFI Boot Service emulation.
- ❖ Clean: Abstracts Qemu/TCG with Unicorn Engine API.
- ❖ <https://github.com/intel/MultiArchUefiPkg>
- ❖ RISE Project in the Firmware WG
- ❖ Correctness, perf, size.

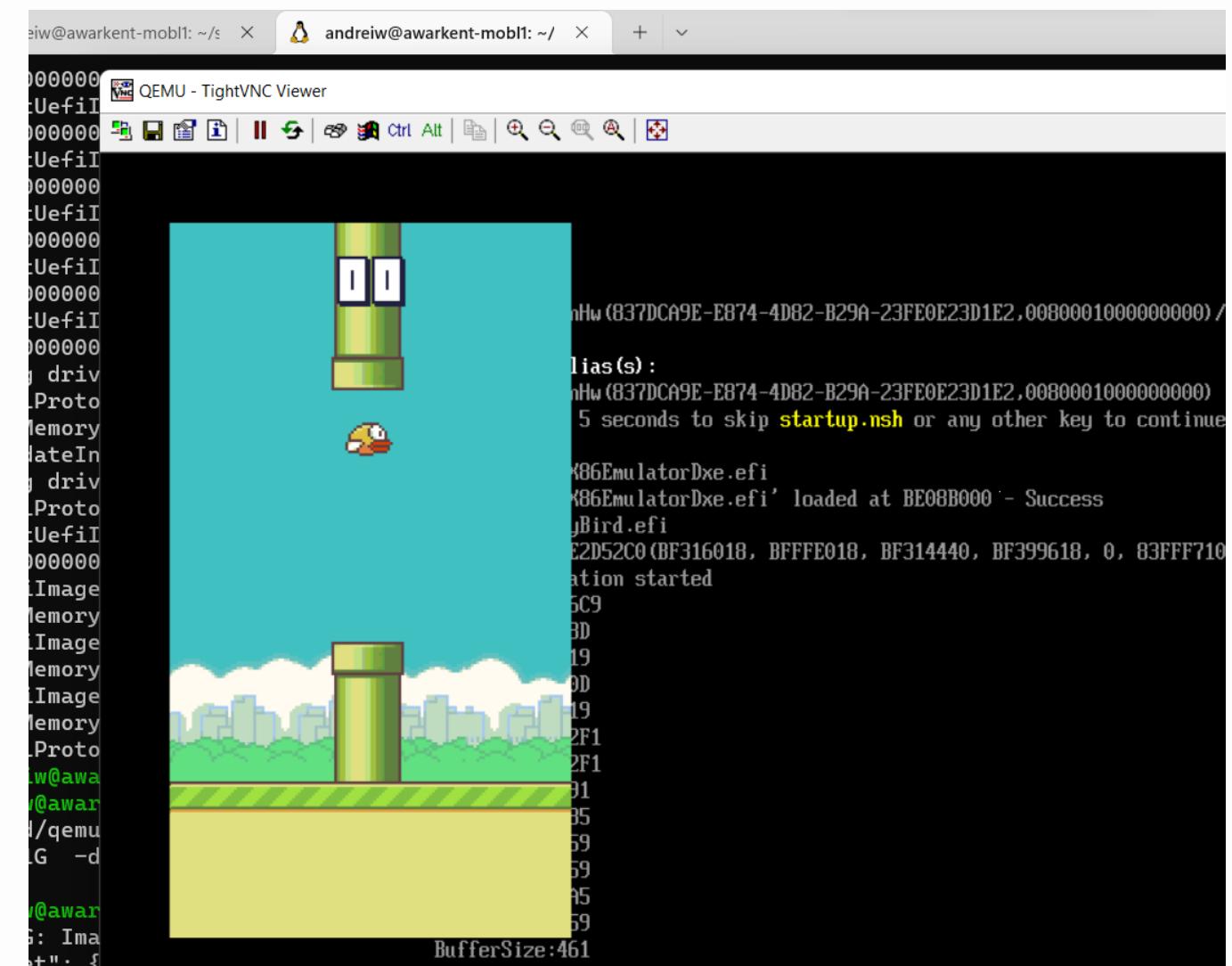


```
7D 0000000H B - - 1 6 USB Bus Driver          UsdBusDxe
7E 0000000A D - - 1 - Usb Keyboard Driver    UsbKbDxe
7F 00000011 D - - 1 - Usb Mass Storage Driver UsbMassStorageDxe
82 00014300 B - - 1 1 AMD GOP X64 Release Driver Rev.1.67 Offset(0x10000,0x1E5FF)
Shell> -
```

BT for Everybody



MultiArchUefiPkg



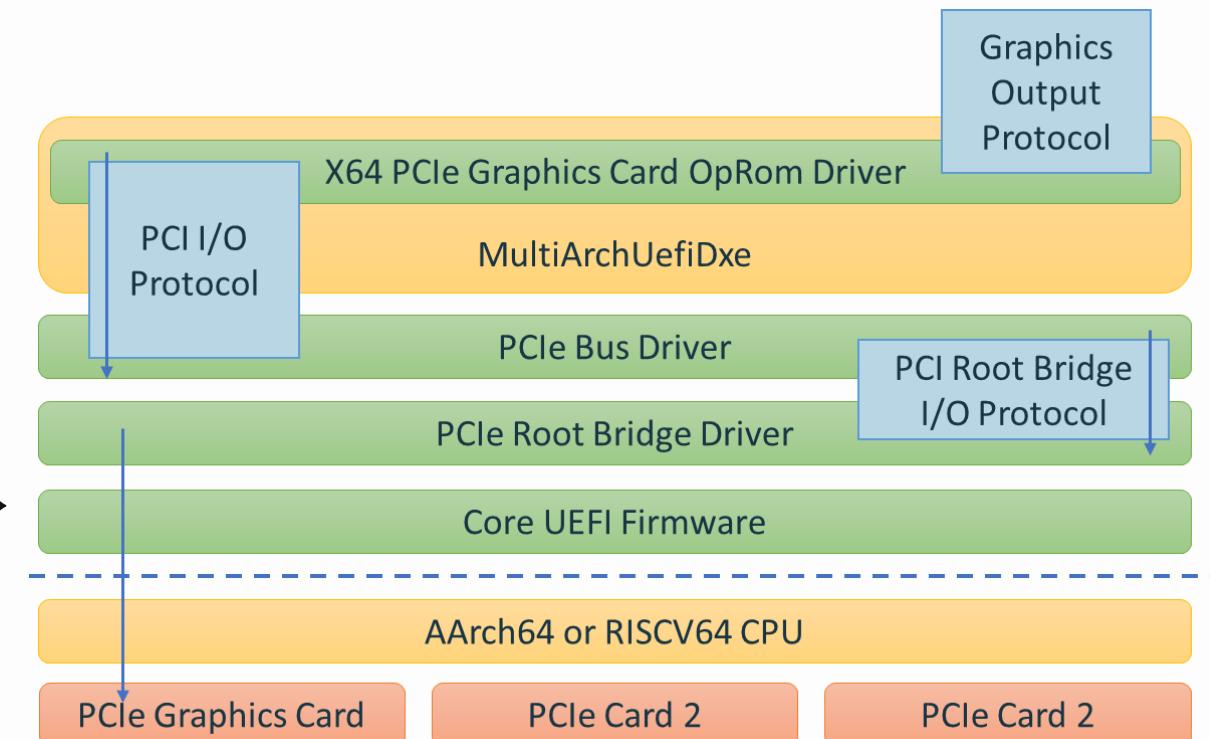
BT for Everybody



MultiArchUefiPkg

- ❖ Possible entirely due to narrowly-defined EFI ABI
- ❖ Models Boot Services environment, with certain services filtered or disabled.
- ❖ Tiano support for foreign binaries - **EDKII_PECOFF_IMAGE_EMULATOR_PROTOCOL**
- ❖ Emulation is only interesting if thunking goes both ways!
 - ❖ No-Execute handler traps for native → emulated.
 - ❖ Unicorn No-Execute handler traps for emulated → native.

```
UINT64  
EFIAPI  
Fn(UINT64, UINT64, UINT64, UINT64,  
    UINT64, UINT64, UINT64, UINT64,  
    UINT64, UINT64, UINT64, UINT64,  
    UINT64, UINT64, UINT64, UINT64);
```



Price of Binary Translation



Good enough for OpRoms on cards out there, but you need testing and qualification. And you're always one OpRom upgrade from a non-POSTing system.

❖ Complexity

- ❖ 500KiB for x64, ~1.7MiB for x64 + AArch64 BT
- ❖ Tiano deps, BT bugs
- ❖ Modelling certain BS calls without leaks is complex (Image Exit, SetJmp/LongJmp across native or across BT code)

❖ Technical debt

❖ 128-bit support requires sandboxing

❖ Fragility

- ❖ ISAs are a moving target
- ❖ “logic bombs” due to tooling or programmer error – very real
 - ❖ Code that must be loaded > 4GiB
 - ❖ Stack that must be below 4GiB

❖ Fragility Cont’d

- ❖ OpRom environment unconstrained
 - ❖ Allocating, manipulating and executing memory of type BootServiceCode?
 - ❖ Using self-modifying code?
 - ❖ Manipulating privileged state or set a CPU exception handler?
 - ❖ Changing page protection attributes (e.g. marking itself executable).
 - ❖ CallsingExitBootServices?

❖ Licensing headaches

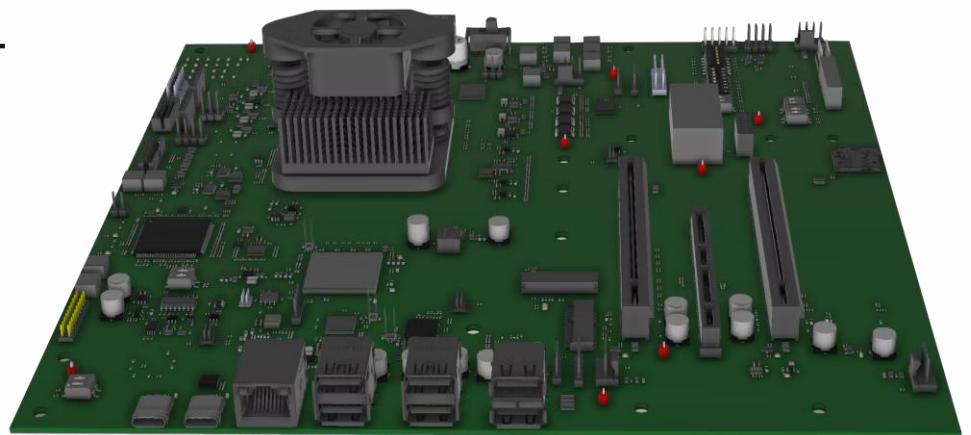
- ❖ MultiArchUefiPkg is approved for release under GPLv2 and LGPLv2.1+. EmulatorDxe itself is covered by the [LGPL v2.1+](#), but it is statically linked to the [Unicorn Engine](#) library, which has a mix of LGPL and GPLv2 code.
- ❖ X86EmulatorPkg is similar due to similar ancestry.



What's the future?

An IHV-only problem?

- ❖ It's not reasonable to support every useful architecture
 - ❖ How many adapters ship with x64 + AArch64 today?
 - ❖ How many will additionally bundle RISCV64, RISCV128 and LOONGARCH support?
- ❖ Most cards only bother with x64



Embracing Emulation via EBC



- ❖ EBC was ahead of its time, and it is technically still the soundest option.
 - ❖ For example, it just disallows SetJmp/LongJmp.
 - ❖ 1 driver to support x64, AArch64, LoongArch64, RISCV64 and anything else.
 - ❖ Will support 128-bit ISAs.
- ❖ Tooling can be fixed
 - ❖ LLVM for EBC?
 - ❖ <https://speakerdeck.com/retrage/llvm-backend-development-for-efi-byte-code>
 - ❖ Development discouraged by deprecation of EBC from spec.
- ❖ Performance can be fixed
 - ❖ EBC JIT

Embracing Emulation via WASM



- ❖ Tooling is great, but... not for the scenario.
- ❖ ISA abstraction not so much
 - ❖ WASM32 vs WASM64?
 - ❖ What about 128-bit?
- ❖ UEFI is single address space, WASM is meant to be sandboxed.
 - ❖ Relocations?
 - ❖ Common memory?
 - ❖ Unique function IDs and thunking?

Embracing Emulation via eBPF



- ❖ Tooling is great.
- ❖ eBPF in the Linux kernel comes with a security model and validation.
 - ❖ Enforces size, complexity, lack of looping, “safe” accesses.
 - ❖ Doesn’t apply to UEFI.
- ❖ 64-bit register size not future-proof.

Embracing Constrained x64?



- ❖ IHVs build X64 code. Let's meet them half-way!
- ❖ Reduce X64 ISA down to a minimum non-privileged set of instructions.
 - ❖ Fixed ISA, not a moving target.
 - ❖ Much simpler and smaller BT.
 - ❖ An additional –march= flag to a compiler.
- ❖ Compiled OpRoms continue to work on existing x64 systems.
- ❖ Plenty of existing tools for static analysis, etc. No need to upset an existing flow.



Let's discuss the approach to invest in?

Thanks for attending the UEFI Fall 2023
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For more information on UEFI Forum and UEFI
Specifications, visit <http://www.uefi.org>

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