Linaro connect
San Francisco 2015

SFO15-TR9: ACPI, PSCI (and UEFI to boot)

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v2.0

Presented by
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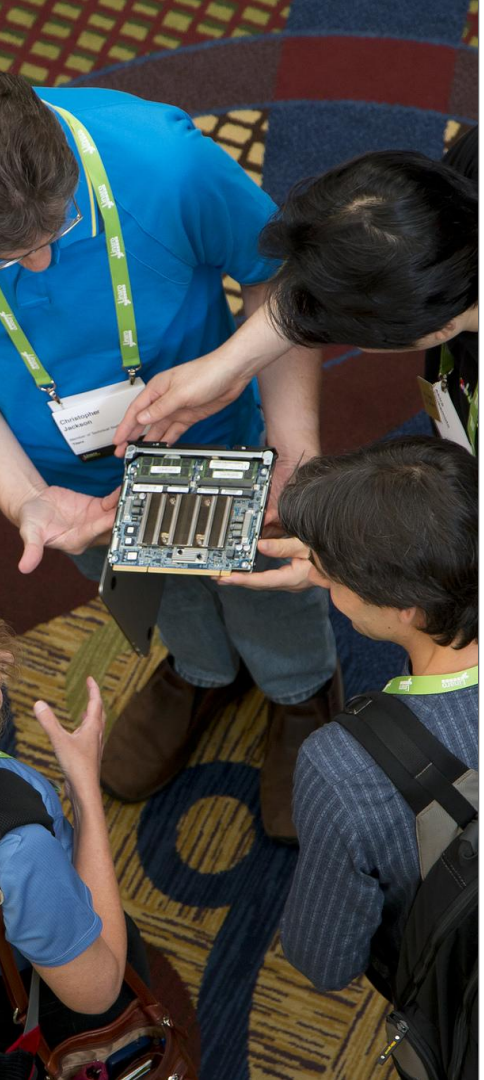
Date
Thursday 24 September 2015

Event
SFO15



Overview

- An introductory look at ACPI infrastructure
- How a platform (qemu), a bootloader (uefi) and the kernel work together to set up the ACPI configuration
- There's an explanation of what’s been upstreamed in Linux kernel 4.1
- A simple aarch64 demo based on qemu
- A brief look at what's new

Caveats. This is not ...

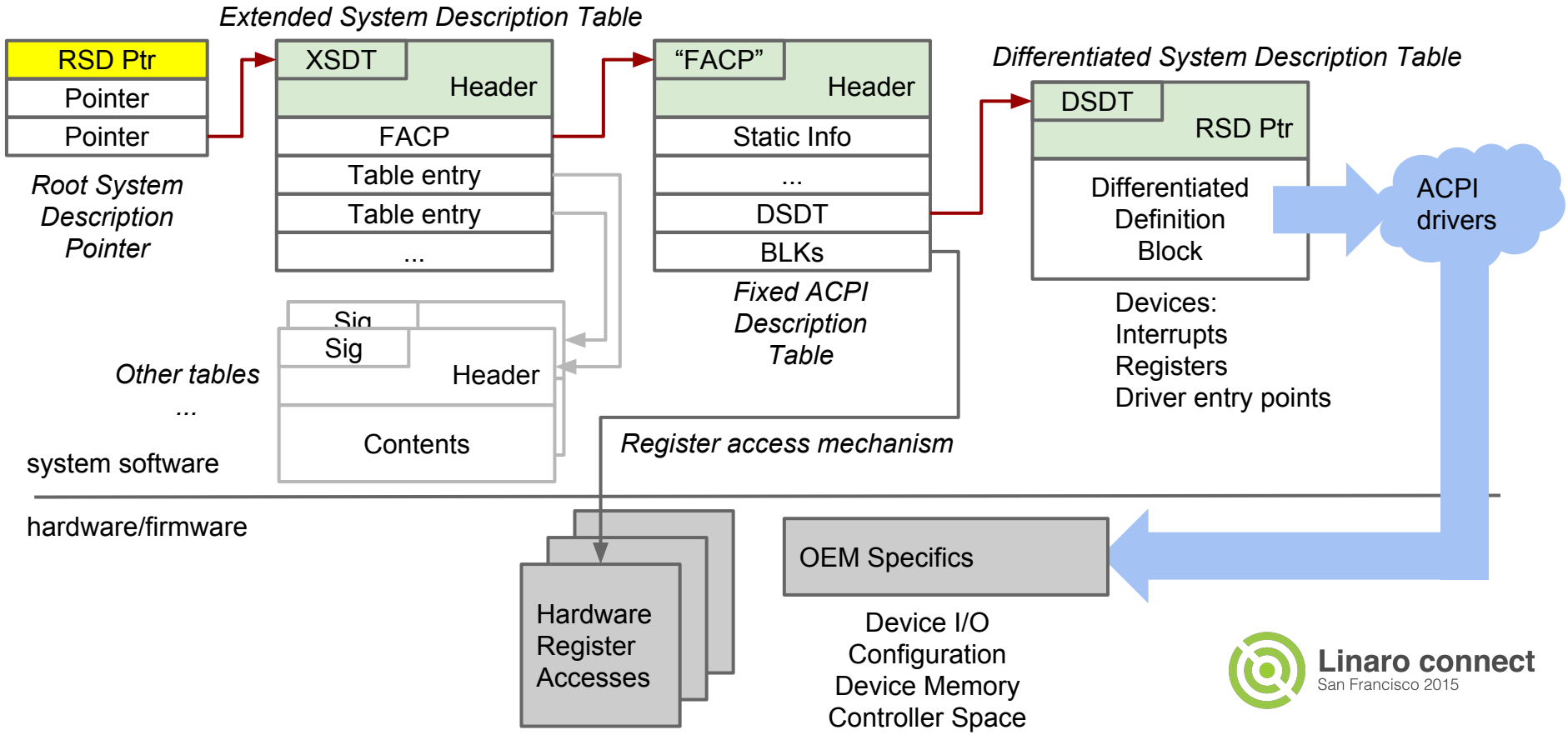
- An exhaustive tutorial on ACPI
- A reference implementation for PSCI
- “Why to use ACPI instead of device trees”
- “Why to favour UEFI instead of UBoot”
- ...

ACPI and PSCI (briefly)

ACPI - One Pager

- "Advanced Configuration and Power Interface" Specification (Currently v6.0: http://www.uefi.org/acpi/specs)
- *"Industry-standard interfaces enabling OS-directed configuration, power management, and thermal management (since 1996)"*
- ACPI is important because hardware and OS vendors have already worked out the mechanisms for supporting a general purpose computing ecosystem
- Hence it's non-negotiable in the Enterprise environment, standardized with UEFI
- Has three main components: Tables, Drivers and Registers.
- There's an interpreted element in ACPI Machine Language (AML) bytecode stored in the ACPI tables.

What ACPI looks like - a chain of tables

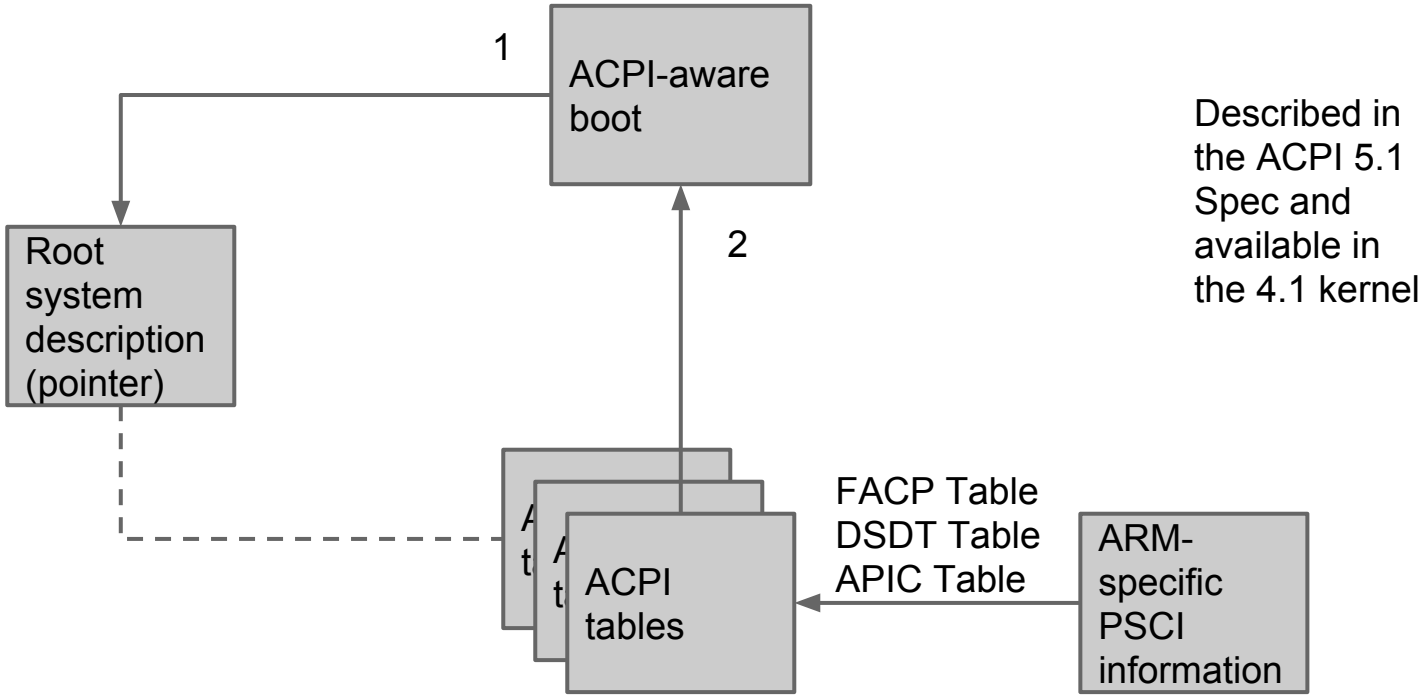


"Power State Coordination Interface"

- It’s an ARM standard
- The official/only way for power management on ARM64
- A generic interface that low-level supervisory software can use to manage power
- Lives under CPU Ops, which itself lives under CPU Idle and the CPU Governors
- Covers: Core idle management, dynamic addition and removal of cores, and secondary core boot, core migration, system shutdown and reset
- Has both Device Tree and ACPI bindings

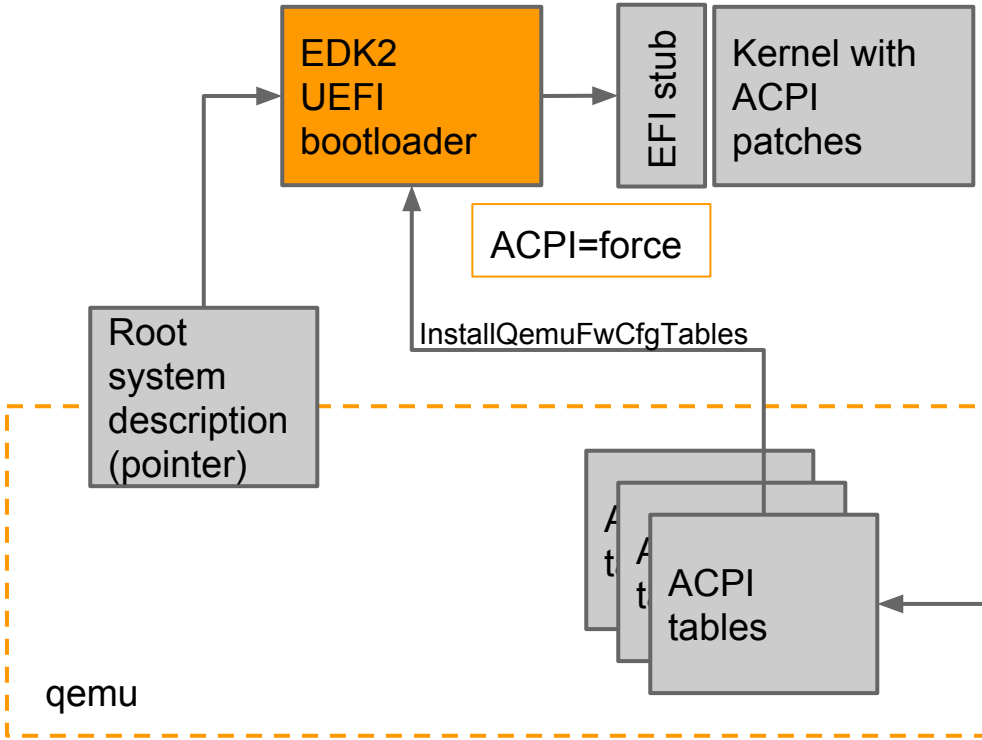
Booting

Basic Boot and ACPI/PSCI Discovery



Described in the ACPI 5.1 Spec and available in the 4.1 kernel

Practical boot and ACPI/PSCI discovery



"The generic interface for discovering ACPI tables is to boot as an EFI application and then to query the tables from UEFI. That is the interface others are likely to follow, and ACPI without UEFI is unlikely to be of much use to anyone else (ARM)"

What about dtb?

- The EFI stub loader makes the Linux kernel image into a UEFI application.
- This application uses the Flattened Device-Tree (FDT) format to pass information about how to access UEFI to the Linux kernel.
- If no device-tree blob (using dtb=) is available as in our case when using ACPI for hardware description the loader stub will create a new dtb containing only this information.

See: https://wiki.linaro.org/LEG/Engineering/Kernel/UEFI/Architecture and *drivers/firmware/efi/libstub/fdt.c (leading to efi.h)*

Basic Feature Set

Having booted successfully and loaded the ACPI tables … what functionality do we have?

4.1 ARM ACPI Kernel functionality

- Basic support to run ACPI on ARM64
- ARM SMP and GICv2 init using MADT
- PSCI announced in the FADT table
- ARM timer init using GTDT
- Kernel documentation why/how to use ACPI on ARM64

Why talk about this now?

- The ACPI Spec (5.1) supported ARM specifically for the first time this year
- ACPI on ARM is a major and continuing LEG collaboration between ARM and Linaro
- "*There is no longer any reason to feel that ACPI only belongs to Windows or that Linux is in any way secondary to Microsoft in this arena*" (kernel arm-acpi.txt)

ACPI Boot Demo

Comprises:

- qemu built from sources
- kernel with ACPI 5.1 built from source
- UEFI built from EDK2 source
- uefi-tools
- ***iasl***, the ACPI table assembler/disassembler

Allows to:

- Boot UEFI as a guest in aarch64 qemu
- Boot the Linux image from the UEFI shell
- Confirm ACPI is enabled
- Dump and read (via *iasl*) the ACPI tables
- Modify the ACPI data in qemu, rinse and repeat …

ACPI in the booting/running system

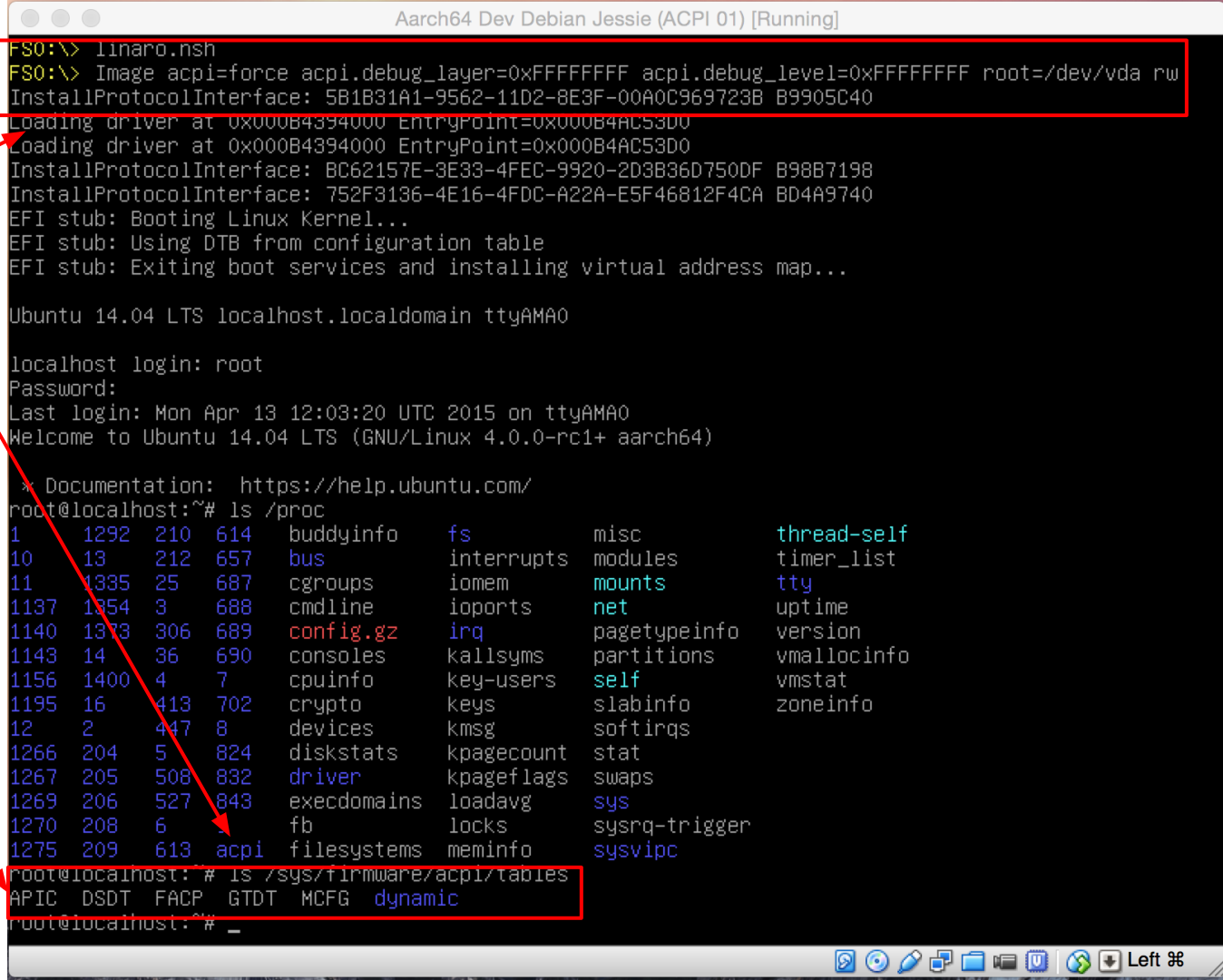
UEFI Booting and reading the ACPI tables

```
InstallProtocolInterface: 30CFE3E7-3DE1-4586-BE20-DEABA1B3B793 0
OnPciEnumerated: PCI enumeration complete, installing ACPI tables
InstallQemuFwCfgTables: installed 5 tables
InstallProtocolInterface: 09576E91-6D3F-11D2-8E39-00A0C969723B B9908518
InstallProtocolInterface: 4CF5B200-68B8-4CA5-9EEC-B23E3F50029A B9946028
[1] Linux (EFI stub) on virtio31:hd0:part0
        - VenHw(837DCA9E-E874-4D82-B29A-23FE0E23D1E2,003E000A00000000)/HD(1,MBR,0x00000000,0x3F,0x19
FC0)/Image
        - Arguments: root=/dev/vda2 console=ttyAMA0 earlycon uefi_debug
[2] Shell
[3] Boot Manager
Start: _
```

- UEFI has platform-specific functionality to load the tables - in this case to interface with qemu
- Notice that PCI enumeration blocks ACPI table loading

Linux Boot

- Boot from UEFI with *ACPI=force*
- ACPI entry in */proc*
- ACPI tables in */sys/firmware/acpi/tables*



Some more about the tables

Devices are reported - CPUs, Comms (DSDT table)

PSCI is present (FADT/FACP table)

Way to access PSCI is stated as HVC (FADT/FACP table)

Interrupt structures are reported (APIC table)

All tables in AML bytecode - disassembled with *iasl*

AML data generated by qemu - see ./hw/arm/virt-acpi-build.c

DSDT

Differentiated System Description Table

System & peripherals, memory mapping, IRQs, driver entry points

```
DefinitionBlock ("DSDT.aml", "DSDT", 1, "BOCHS ", "BXPCDSDT", 0x00000001)
{
    Scope (\_SB)
    {
        Device (CPU0)
        {
            ...
        }

        Device (COM0)
        {
            Name (_HID, "ARMH0011")  // _HID: Hardware ID
            ...
            {
                Memory32Fixed (ReadWrite,
                    0x09000000,         // Address Base
                    0x00001000,         // Address Length
                    )
                Interrupt (ResourceConsumer, Level, ActiveHigh, Exclusive, ,, )
                {
                    0x00000021,
```

FADT

Fixed ACPI Description Table (“FACP”)
Part of the chain that gets to the DSDT
Register blocks relating to power management … and PSCI

```
[000h 0000   4]                    Signature : "FACP"    [Fixed ACPI Description Table (FADT)]

<snip>

[074h 0116  12]                Reset Register : [Generic Address Structure]
[074h 0116   1]                     Space ID : 00 [SystemMemory]
[075h 0117   1]                    Bit Width : 00
[076h 0118   1]                   Bit Offset : 00
[077h 0119   1]          Encoded Access Width : 00 [Undefined/Legacy]
[078h 0120   8]                      Address : 0000000000000000

[080h 0128   1]           Value to cause reset : 00
[081h 0129   2]     ARM Flags (decoded below) : 0003
                              PSCI Compliant : 1
                         Must use HVC for PSCI : 1
```

The full table dumps are reproduced here:
http://people.linaro.org/~bill.fletcher/SFO15-TR9_ACPI_PSCI_and_UEFI_To_Boot_supporting_material/

MADT

Multiple APIC Description Table (“APIC”)

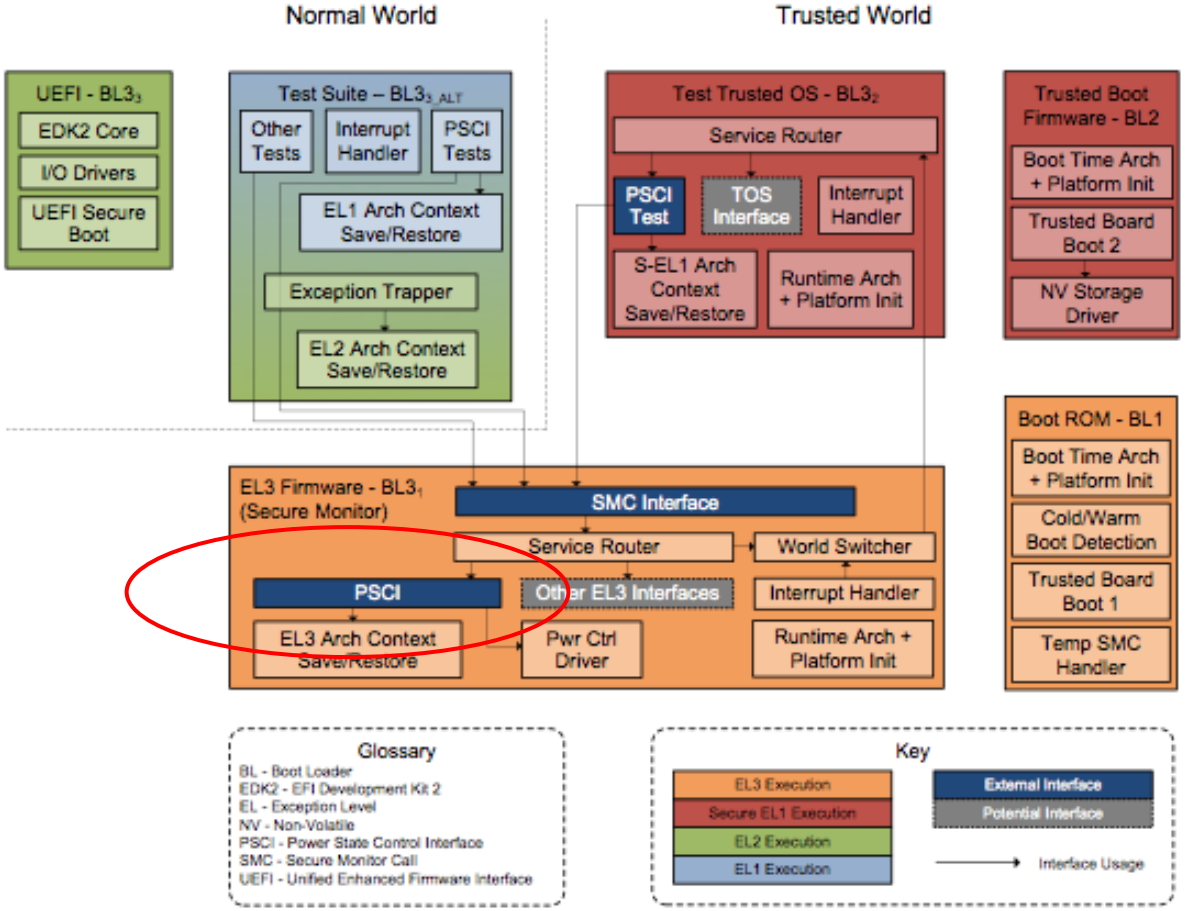
APIC = Advanced Programmable Interrupt Controller (8259+)
Interrupt controllers and CPU affinity

```
[000h 0000   4]                    Signature : "APIC"    [Multiple APIC Description Table (MADT)]

<snip>

[02Ch 0044   1]                Subtable Type : 0B [Generic Interrupt Controller]
...
[038h 0056   4]         Flags (decoded below) : 00000001
                            Processor Enabled : 1
          Performance Interrupt Trigger Mode : 0
          Virtual GIC Interrupt Trigger Mode : 0
[03Ch 0060   4]     Parking Protocol Version : 00000000
[040h 0064   4]         Performance Interrupt : 00000000
...
[070h 0112   8]                    ARM MPIDR : 0000000000000000
```

There can be a system MADT referenced from the XSDT
Peripherals with their own interrupt controllers can have a method in their DSDT entry for you to get a local MADT

Usage outside qemu

ATF PSCI functionality (it's the reference)

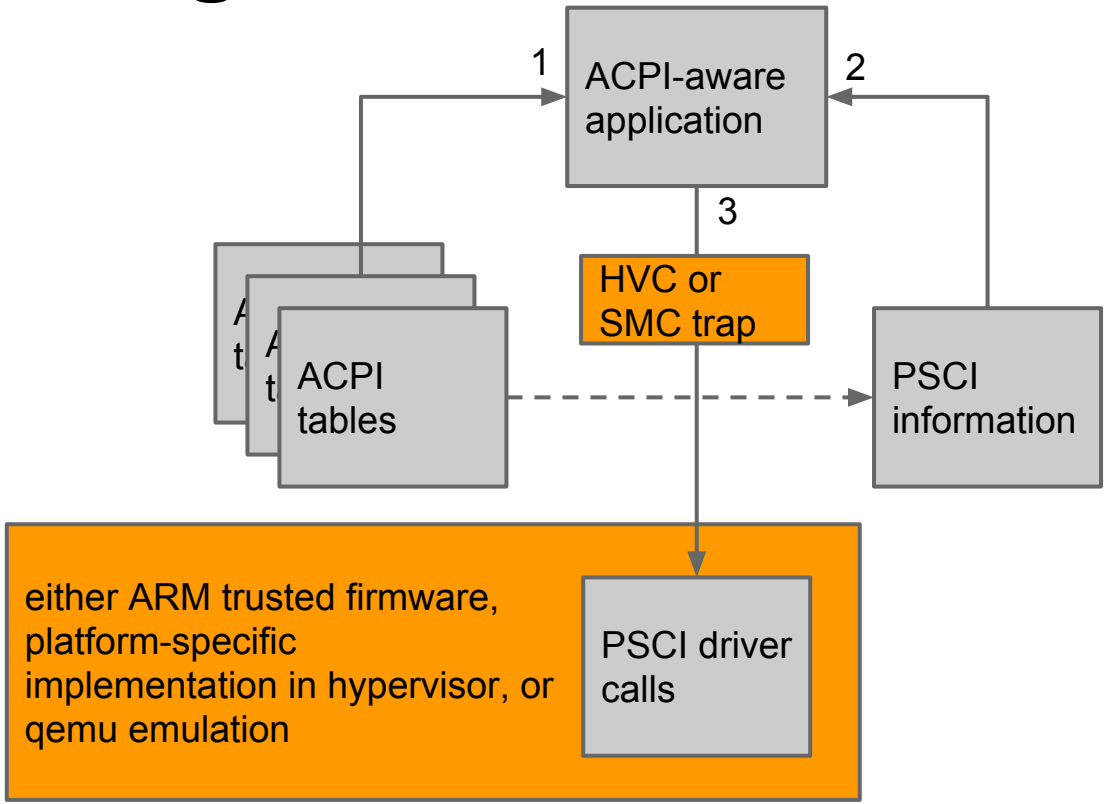


Handles SMCs (Secure Monitor Calls) conforming to the [SMC Calling Convention PDD]

There's extensive design documentation available.

Source is published under a BSD license.

Calling PSCI from an ACPI context



PSCI implementation assumes either a Hypervisor running at EL2 or a Secure Monitor running at EL3

Requires a platform running the Secure Monitor at EL3, which implements PSCI.

Alternatively if there's no EL3 but a hypervisor instead you can emulate this with a HVC call

This HVC mechanism is also emulated in qemu

What’s New and What’s Next?

What arrived in the latest ACPI 6.0 spec?

Enough in ACPI "to boot a server, support ARM’s latest IP (GICv2m, GICv3, SMMUv2) and do decent idle management."

What’s next? DVFS performance management ...

… for an ARM server to implement DVFS in an architecture agnostic way via “CPPC” (CPPC - Collaborative Processor Performance Control)

ARM Low Power Idle (LPI) states

ACPI 6.0 introduces Low Power Idle states, which allows an operating system to manage the power states of the processor power domain hierarchy.

The ACPI FFH* mechanism is used in ARM-based systems to allow the operating system to discover: the entry method into a low power state; how to collect power state residency, and statistics

This ACPI register-based interface is defined in ARM DEN0048A available on ARM Infocentre portal

*FFH = *Functional Fixed Hardware* Interface - an ACPI name for the register address space used for power management)

Back to DVFS → CPPC & PCC (1)

CPPC (Collaborative Processor Performance Control)

Provides more autonomy to the CPU subsystem to control power/perf

An abstract interface where the OS specifies performance bounds and leaves the underlying subsystem some latitude in how it achieves them.

"CPPC implementation designed as shim which allows Cpufreq drivers to plug into existing governors or alternately implement inbuilt ones"

PCC (Platform Communication Channel)

PCC (Platform Communication Channel) is a generic means for PCC Clients such as CPPC, to talk to the firmware.

CPPC & PCC (2)

- CPPC has been used on ARM64 servers successfully. Some ARM vendors may not have feedback counters (workaroundable). Missing in CPPC at the moment is the power-to-performance level mapping. This is to be addressed in the near future once EAS is upstream
- This patchwork is part of LEG activity. See https://git.linaro.org/people/ashwin.chaugule/leg-kernel.git
- V9 patches picked up for v4.3 - hoping to upstream by v4.4

Wrap Up

Wrap-Up

- UEFI is a requirement for ACPI
- Upstream qemu can emulate an aarch64 ACPI platform (with elementary PSCI)
- You can build a simple ARM64 ACPI-aware system with 4.1
- ARM idle management arrived in the ACPI 6.0 spec
- Interfaces to ARM DVFS (via CPPC) are still "works in progress".
- Once these arrive, a demonstrator will need more than qemu’s emulation of PSCI
- ARM trusted firmware is the reference implementation for PSCI

References

- PSCI spec: http://infocenter.arm.com/help/topic/com.arm.doc.den0022c/DEN0022C_Power_State_Coordination_Interface.pdf
- ACPI standard: http://www.uefi.org/sites/default/files/resources/ACPI_5_1release.pdf
- Basic ACPI info: http://www.acpi.info/over.htm

Resources

- The full table dumps are reproduced here: http://people.linaro.org/~bill.fletcher/SFO15-TR9_ACPI_PSCI_and_UEFI_To_Boot_supporting_material
- Useful primer on PSCI (ARM doc): http://events.linuxfoundation.org/sites/events/files/slides/lp-linuxcon14.pdf
- LEG wiki: https://wiki.linaro.org/LEG/Engineering/Kernel/ACPI
- For a comparison of ACPI and FDT, google the presentation done by Graeme Gregory at Linux Plumbers 2013.
- See http://article.gmane.org/gmane.linux.ports.arm.kernel/382864/match=cppc for an explanation of how to use ACPI
- Ashwin's V8 patch set including CPPC via PCC http://thread.gmane.org/gmane.linux.power-management.general/63697

Q&A?

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