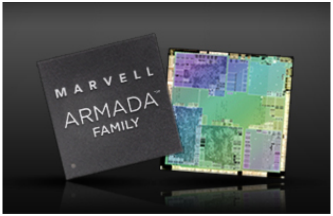
ARM support in the Linux kernel



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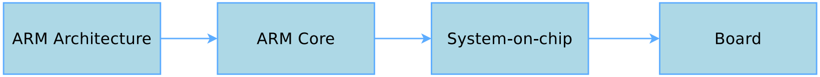
Thomas Petazzoni

- Embedded Linux engineer and trainer at Free Electrons since 2008
  - Embedded Linux **development**: kernel and driver development, system integration, boot time and power consumption optimization, consulting, etc.
  - Embedded Linux **training**, Linux driver development training and Android system development training, with materials freely available under a Creative Commons license.
  - `http://free-electrons.com`
- Contributing the **kernel support for the new Armada 370 and Armada XP** ARM SoCs from Marvell.
- Major contributor to **Buildroot**, an open-source, simple and fast embedded Linux build system
- Living in **Toulouse**, south west of France

Agenda

- Background on the ARM architecture and Linux support
- The problems
- Changes in the ARM kernel support
- Getting the support for a SoC in mainline, story of Armada 370/XP

From the ARM architecture to a board



Defines the instruction set, interface with the MMU, interrupts, etc.

It is just a specification.

Is a specific implementation of a given ARM architecture.

Delivered in the form of a netlist or Verilog code to licensees.

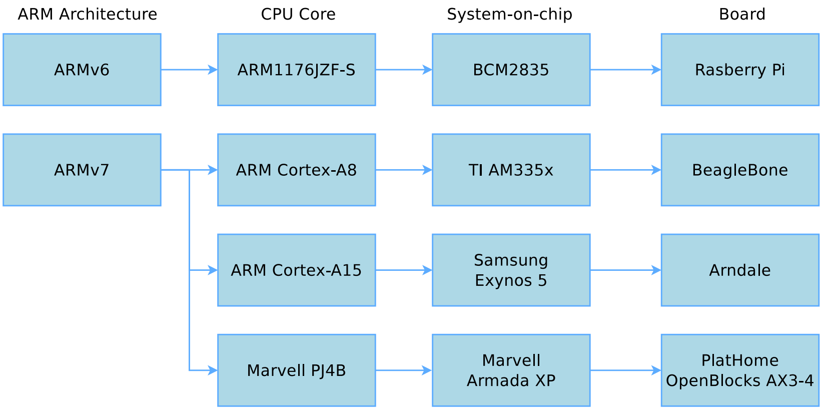
Integrates the ARM core with a number of peripherals around it.

Done by silicon vendors, sold in the form of a chip.

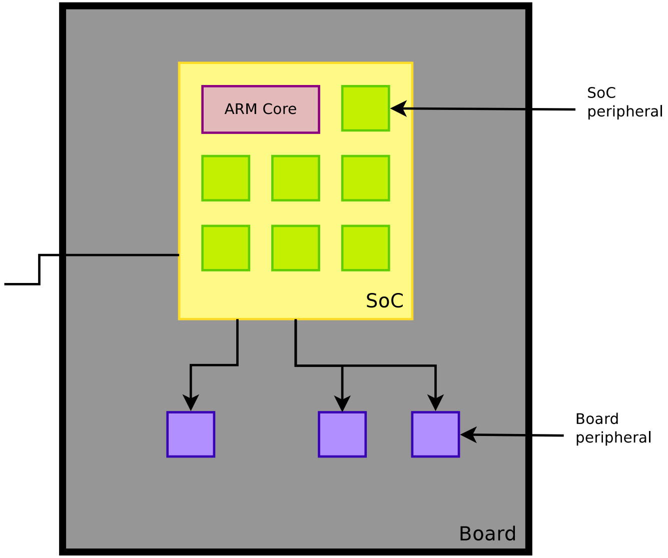
Integrates the SoC on a PCB with other components around it.

Done by board and system makers.

From the ARM architecture to a board, examples



Schematic view of a board



No standardization

- Beyond the ARM core itself, a lot of freedom is left to the SoC vendor.
- There is **no standard** for the devices, the management of clocks, pinmuxing, IRQ controllers, timers, etc.
  - Note: some things like IRQ controllers and timers are now standardized.
- There **isn't a mechanism** to enumerate the devices available inside the SoC. All devices have to be known by the kernel.

“Old” ARM code organization in the Linux kernel

- `arch/arm/`
  - `arch/arm/{kernel,mm,lib,boot}/`
    The core ARM kernel. Contains the code related to the ARM core itself (MMU, interrupts, caches, etc.). Relatively small compared to the SoC-specific code.
  - `arch/arm/mach-<foo>/`
    The SoC-specific code, and board-specific code, for a given SoC family.
    - `arch/arm/mach-<foo>/board-<bar>.c`.
      The board-specific code.
- `drivers/`
  The device drivers themselves.

Issue #1: too much code, lack of review

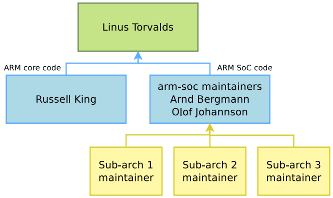
- **Exploding number of ARM SoC**, from different vendors
- The historical maintainer, Russell King, got **overflowed by the amount of code** to review.
- Code started to flow directly from sub-architecture maintainers directly to Linus Torvalds.
- Focus of each sub-architecture teams on **their own problems**, no vision of the other sub-architectures.
- Consequences: lot of code **duplication**, **missing common infrastructures**, maintenability problems, etc.
- Linus, March 2011: *Gaah. Guys, this whole ARM thing is a f*cking pain in the ass*.

Issue #2: the need for multiplatform kernel

- On x86 PC, one can build a **single kernel image** (with many modules) that boots and work on all PCs
- Good for distributions: they can ship a single kernel image.
- On ARM, it was **impossible to build a single kernel** that would boot on systems using different SoCs.
- Issue for distributions: they have to build and maintain a kernel image almost for each ARM hardware platform they want to support.
- Need for **ARM multiplatform support** in the kernel.

Change #1: *arm-soc* and maintainers

- A new maintainer team for the ARM sub-architectures: Arnd Bergmann (Linaro) and Olof Johansson (Google)
- All the ARM SoC-specific code goes through them, in a tree called **arm-soc**
  - They send the changes accumulated in **arm-soc** to Linus Torvalds.
  - Those maintainers have a cross-SoC view: detection of things that should be factorized, consistency accross SoC-specific code.
  - Core ARM changes continue to go through Russell King.



Change #2: Device Tree

- Most devices inside an ARM SoC and on the board cannot be dynamically enumerated: they have to be **statically described**.
- The old way of doing this description was by using **C code**, registering `platform_device` structures for each hardware device.
- This has been replaced by a hardware description done in structure separated from the kernel, called the **Device Tree**.
  - Also used on PowerPC, Microblaze, ARM64, Xtensa, OpenRisc, etc.
- The *Device Tree Source*, in text format, gets compiled into a *Device Tree Blob*, in binary format, thanks to the *Device Tree Compiler*.
  - Sources are stored in `arch/arm/boot/dts`
- At boot time, the kernel parses the *Device Tree* to instantiate the available devices.

Change #2: Before the Device Tree...

From `arch/arm/mach-at91/at91sam9263_devices.c`

```
static struct resource udc_resources[] = {
        [0] = {
                .start  = AT91SAM9263_BASE_UDP,
                .end    = AT91SAM9263_BASE_UDP + SZ_16K - 1,
                .flags  = IORESOURCE_MEM,
        },
        [1] = {
                .start  = NR_IRQS_LEGACY + AT91SAM9263_ID_UDP,
                .end    = NR_IRQS_LEGACY + AT91SAM9263_ID_UDP,
                .flags  = IORESOURCE_IRQ,
        },
};

static struct platform_device at91_udc_device = {
        .name           = "at91_udc",
        .id             = -1,
        .dev            = {
                                .platform_data          = &udc_data,
        },
        .resource       = udc_resources,
        .num_resources  = ARRAY_SIZE(udc_resources),
};

some_init_code() {
        platform_device_register(&at91_udc_device);
}
```

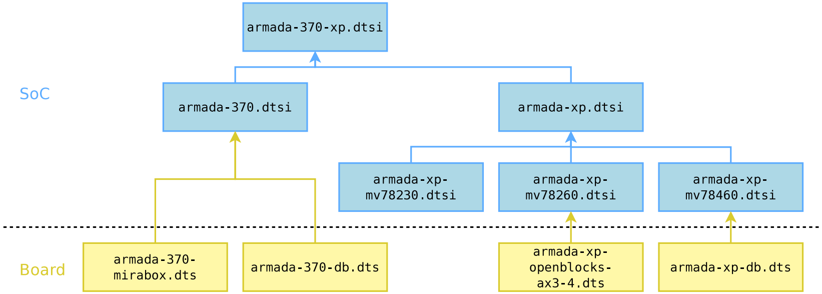
Change #2: SoC Device Tree example

```
/include/ "skeleton.dtsi"
/ {
        compatible = "brcm,bcm2835";
        model = "BCM2835";
        interrupt-parent = <&intc>;

        chosen {
                bootargs = "earlyprintk console=ttyAMA0";
        };

        soc {
                compatible = "simple-bus";
                #address-cells = <1>;
                #size-cells = <1>;
                ranges = <0x7e000000 0x20000000 0x02000000>;

                [...]
                intc: interrupt-controller {
                        compatible = "brcm,bcm2835-armctrl-ic";
                        reg = <0x7e00b200 0x200>;
                        interrupt-controller;
                        #interrupt-cells = <2>;
                };
                uart@20201000 {
                        compatible = "brcm,bcm2835-pl011", "arm,pl011", "arm,primecell";
                        reg = <0x7e201000 0x1000>;
                        interrupts = <2 25>;
                        clock-frequency = <3000000>;
                        status = "disabled";
                };
        };
};
```

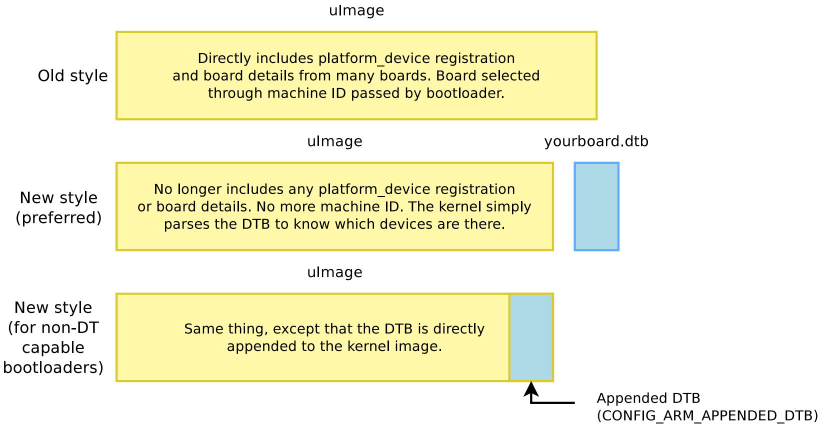
Change #2: Board Device Tree example

```
/dts-v1/;
/memreserve/ 0x0c000000 0x04000000;
/include/ "bcm2835.dtsi"

/ {
        compatible = "raspberrypi,model-b", "brcm,bcm2835";
        model = "Raspberry Pi Model B";

        memory {
                reg = <0 0x10000000>;
        };
        soc {
                uart@20201000 {
                      status = "okay";
                };
        };
};
```

Change #2: Device Tree inheritance



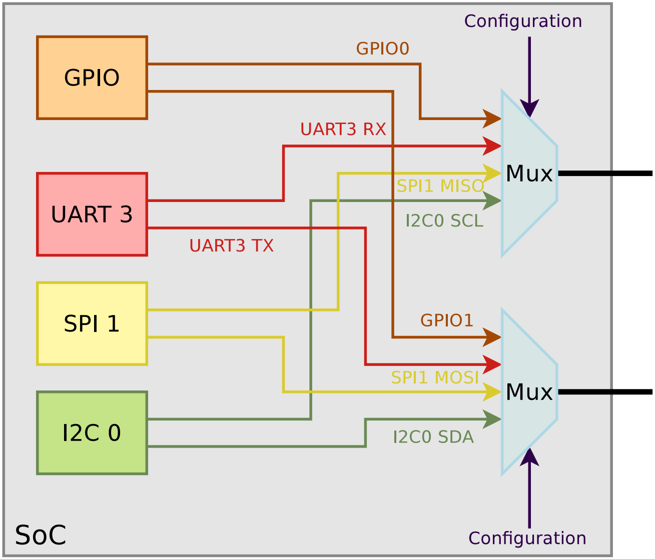
Change #2: Booting with a Device Tree


uImage
Old style
Directly includes platform_device registration and board details from many boards. Board selected through machine ID passed by bootloader.
uImage
yourboard.dtb
New style (preferred)
No longer includes any platform_device registration or board details. No more machine ID. The kernel simply parses the DTB to know which devices are there.
uImage
New style (for non-DT capable bootloaders)
Same thing, except that the DTB is directly appended to the kernel image.
Appended DTB (CONFIG_ARM_APPENDED_DTB)

Change #3: Multiplatform kernel

- Fits the need of distributions willing to build a single kernel image that works on many ARM platforms.
- The SoC choice now contains a **Allow multiple platforms to be selected** option, and all the SoC families that are compatible with this can be compiled together in the same kernel.
  - There is still a split between ARMv4/ARMv5 on one side, and ARMv6/ARMv7 on the other side.
- A **lot of changes** have been done in the ARM kernel to make this possible: avoid two different platforms from defining the same symbol, from using the same header names, no more `#ifdef` but runtime detection instead.
- The support for all new SoCs **must use the multiplatform** mechanism.

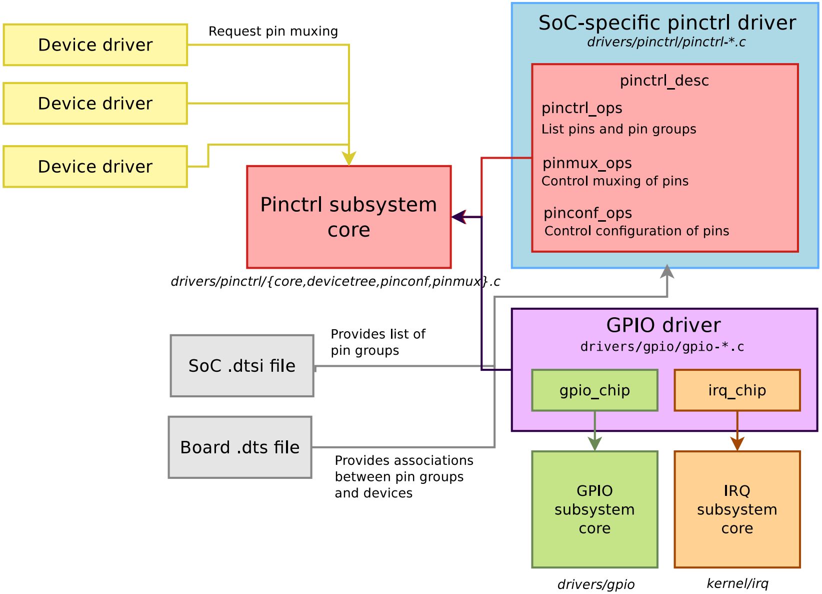
Change #4: Pinctrl subsystem, introduction



Change #4: Pinctrl subsystem, old code

- Each ARM sub-architecture had its own pin-muxing code
- The API was specific to each sub-architecture
- A lot of similar functionality implemented in different ways
- The pin-muxing had to be done at the SoC level, and couldn't be requested by device drivers

Change #4: Pinctrl subsystem, new subsystem



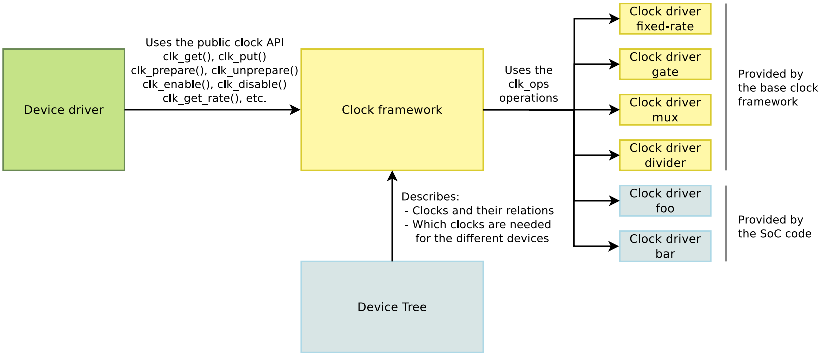
Change #5: Clocks

- In a System-on-Chip, all peripherals are driven by one or more **clocks**.
- Those clocks are organized in a **tree**, and often are **software configurable**.
- Since quite some time, the kernel had a simple API: `clk_get`, `clk_enable`, `clk_disable`, `clk_put` that were used by device drivers.
- Each ARM sub-architecture had its **own implementation** of this API.
- Does not work for **multiplatform** kernels.
- Does not allow **code sharing**, and common mechanisms.

Change #5: Common clock framework

- A proper **common clock framework** has been added in kernel 3.4, released in May 2012
- This framework:
  - Implements the `clk_get`, `clk_put`, `clk_prepare`, `clk_unprepare`, `clk_enable`, `clk_disable`, `clk_get_rate`, etc. **API for usage by device drivers**
  - Implements **some basic clock drivers** (fixed rate, gatable, divider, fixed factor, etc.) and allows the implementation of **custom clock drivers** using `struct clk_hw` and `struct clk_ops`
  - Allows to declare the available clocks and their association to devices in the Device Tree (preferred) or statically in the source code (old method)
  - Provides a *debugfs* representation of the clock tree
  - Is implemented in `drivers/clk`

Change #5: Common clock framework architecture



Change #6: More things in `drivers/`

- Another goal of the ARM cleanup is to have less code in `arch/arm` and create proper drivers and related infrastructures.
- For example

IRQ controller drivers	`drivers/irqchip/`
Timer drivers	`drivers/clocksource/`
PCI host controller drivers	`drivers/pci/host/`
Clock drivers	`drivers/clk/`
Pinmux drivers	`drivers/pinctrl/`

Armada 370/XP, step 1

Device Tree
(SoC and board)

`arch/arm/boot/dts/`

Basic
"initialization"
C file
+
basic header
files

`arch/arm/mach-mvebu/`

Timer
driver

`drivers/clocksource/`

IRQ controller
driver

`drivers/irqchip/`

earlyprintk
support

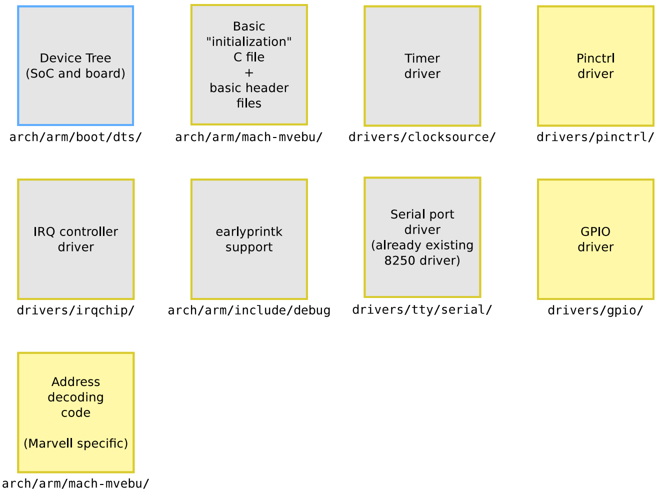
`arch/arm/include/debug`

Serial port
driver
(already existing
8250 driver)

`drivers/tty/serial/`

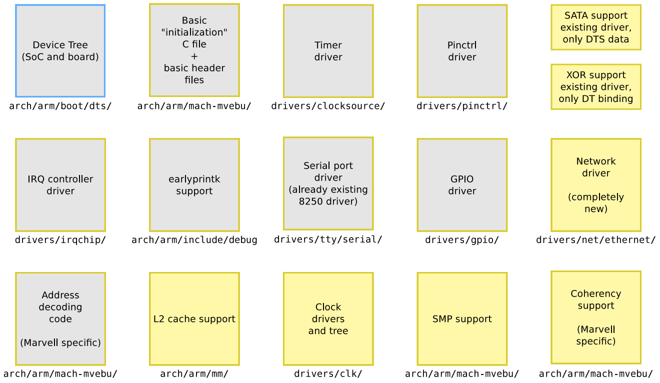
Went into Linux 3.6, 10 patches

Armada 370/XP, step 2



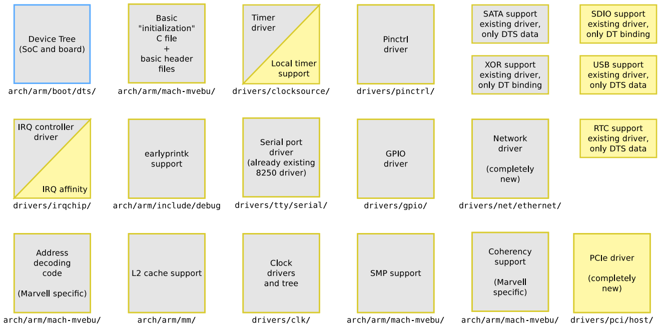
Went into Linux 3.7, 35 patches

Armada 370/XP, step 3



Went into Linux 3.8, 99 patches

Armada 370/XP, step 4



Device Tree (SoC and board)
arch/arm/boot/dts/
Basic "initialization" C file + basic header files
arch/arm/mach-mvebu/
Timer driver
Local timer support
drivers/clocksource/
Pinctrl driver
drivers/pinctrl/
SATA support existing driver, only DTS data
XOR support existing driver, only DT binding
SDIO support existing driver, only DT binding
USB support existing driver, only DTS data
IRQ controller driver
IRQ affinity
drivers/irqchip/
earlyprintk support
arch/arm/include/debug
Serial port driver (already existing 8250 driver)
drivers/tty/serial/
GPIO driver
drivers/gpio/
Network driver (completely new)
drivers/net/ethernet/
RTC support existing driver, only DTS data
Address decoding code (Marvell specific)
arch/arm/mach-mvebu/
L2 cache support
arch/arm/mm/
Clock drivers and tree
drivers/clk/
SMP support
arch/arm/mach-mvebu/
Coherency support (Marvell specific)
arch/arm/mach-mvebu/
PCIe driver (completely new)
drivers/pci/host/

Hopefully going in 3.9 :-)

Getting an ARM SoC in mainline

- **Throw away the vendor BSP code**. Most likely it is completely crappy. You have to start from scratch.
- **Start small**, and send code piece by piece. Don't wait to have everything fully working.
- **Comply with the latest infrastructure changes**: Device Tree, clock framework, pinctrl subsystem. They are mandatory.
- **Read and post to the LAKML**, Linux ARM Kernel Mailing List
- **Listen to reviews and comments**, and repost updated versions regularly.

Questions?

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Thanks to Gregory Clement (Free Electrons, working with me on Marvell mainlining), Lior Amsalem and Maen Suleiman (Marvell)