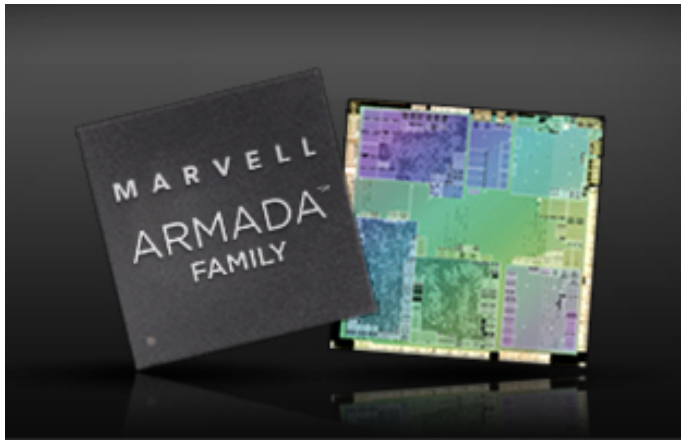
ARM support in the Linux kernel



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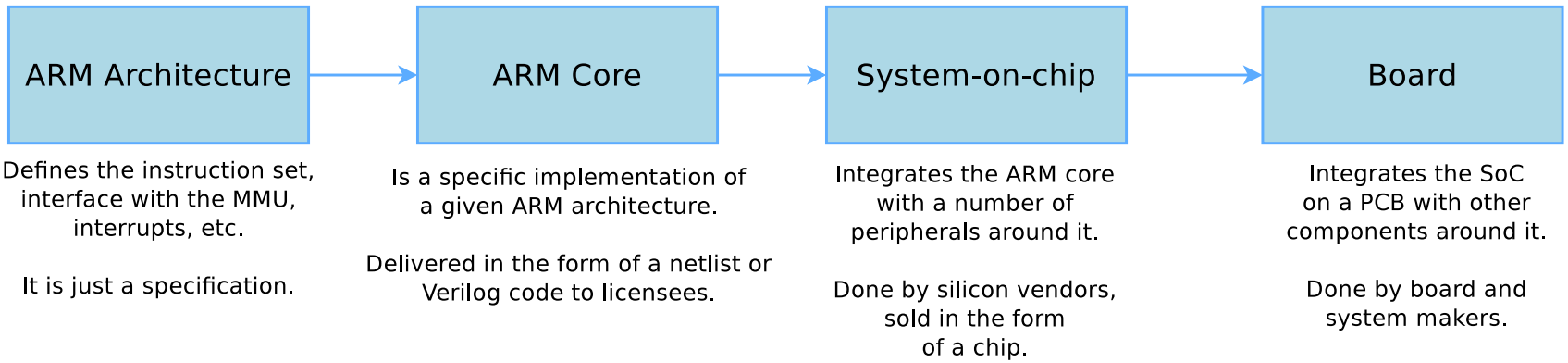
Thomas Petazzoni

- 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, under contract with Marvell.
- Major contributor to **Buildroot**, an open-source, simple and fast embedded Linux build system
- Living in **Toulouse**, south west of France

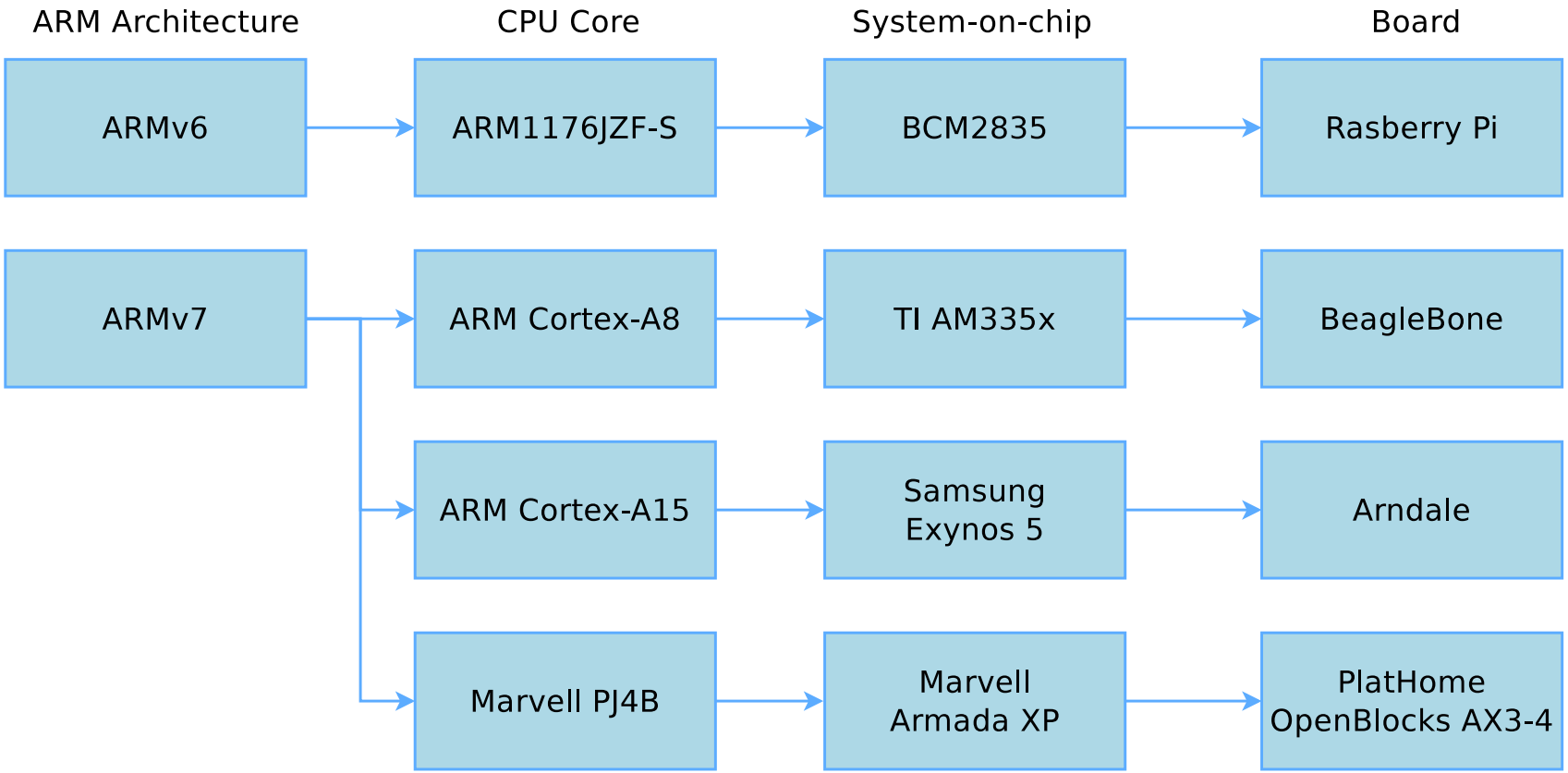
Agenda

- 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

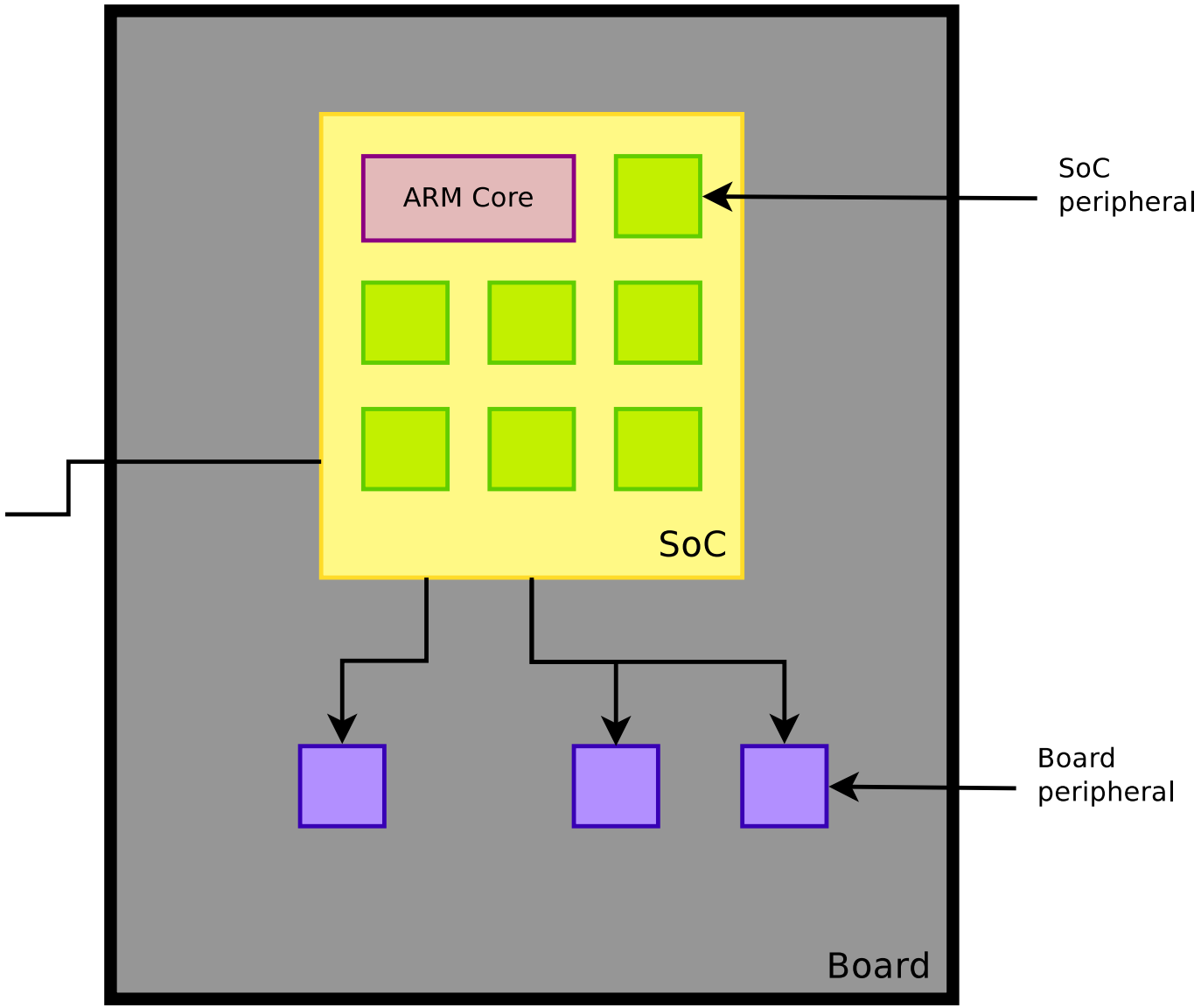
From the ARM architecture to a board



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

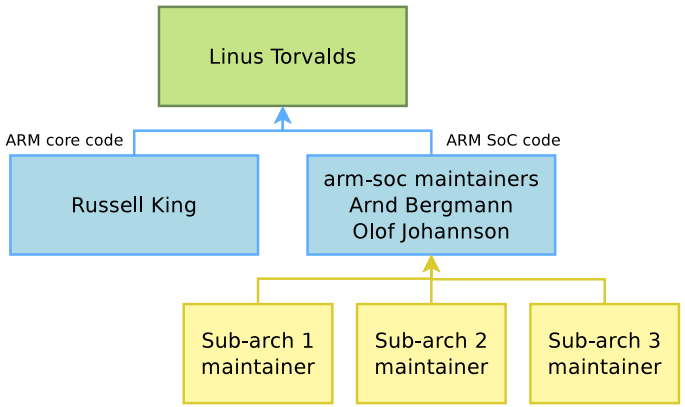
- **Exploding number of ARM SoC**, from different vendors
- The historical maintainer, Russell King, got **overflowed by the amount of code** to review.
- Code started to flow directly from sub-architecture maintainers directly to Linus Torvalds.
- Focus of each sub-architecture teams on **their own problems**, no vision of the other sub-architectures.
- Consequences: lot of code **duplication**, **missing common infrastructures**, maintenability problems, etc.
- Linus Torvalds, 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**.
  - Role of the **Linaro** consortium



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);
}
```

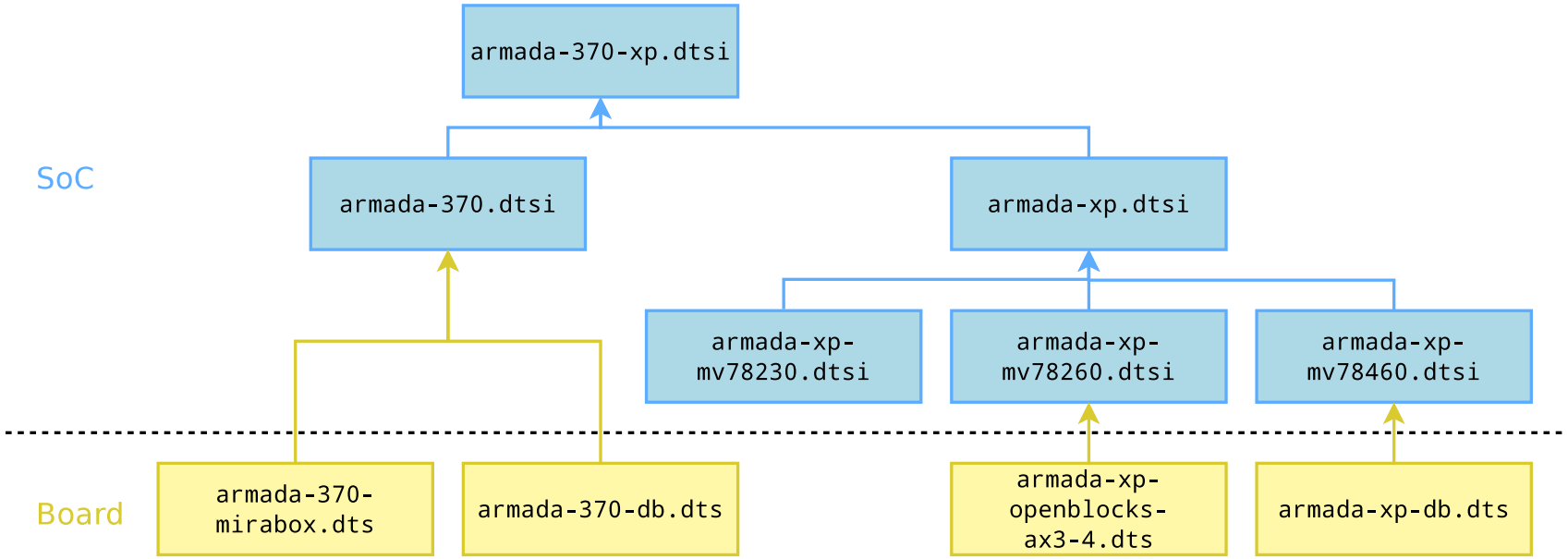
Change #2: SoC Device Tree example

```
/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";
                };
        };
};
```

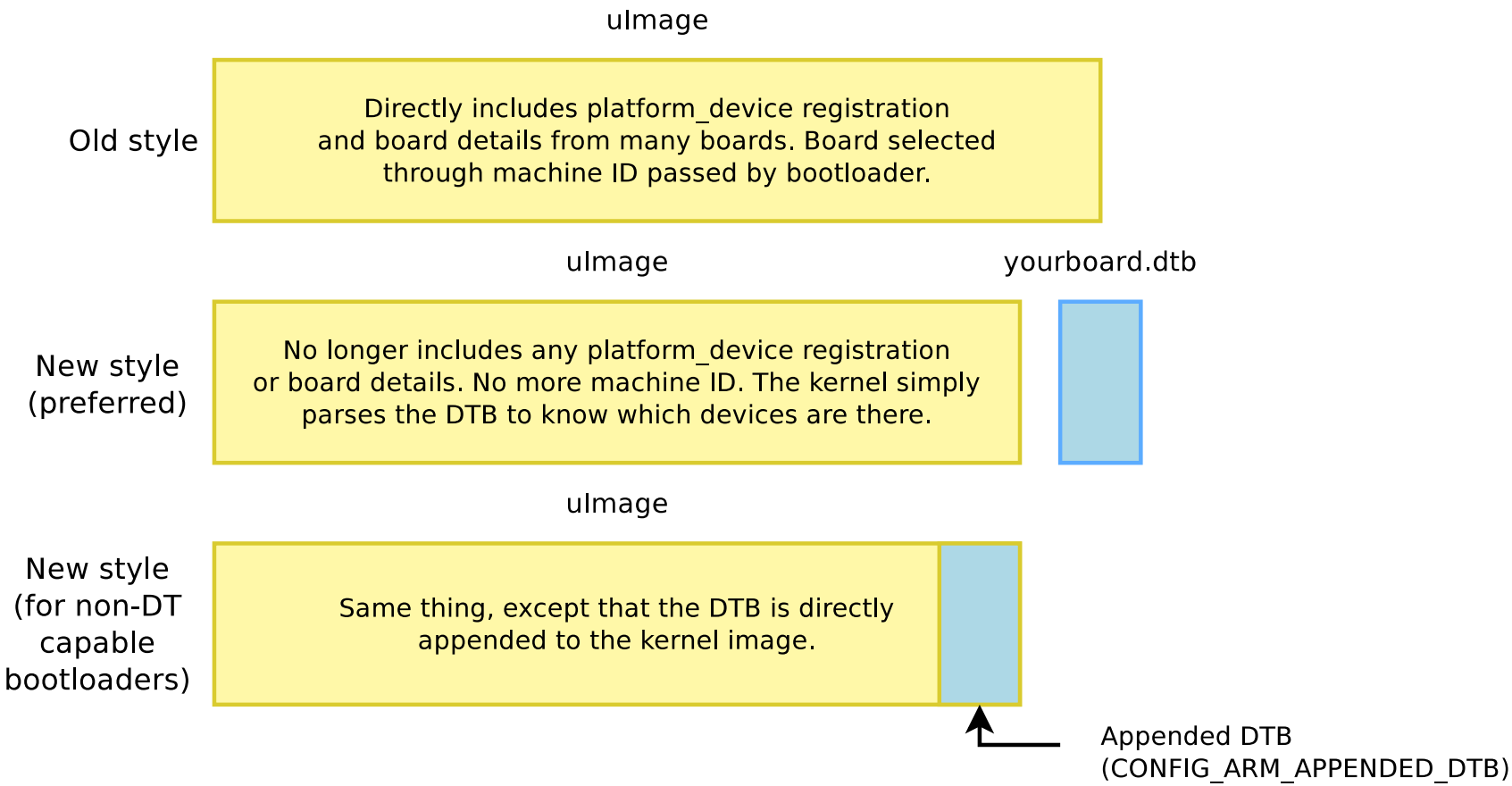
Change #2: Board Device Tree example

```
/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



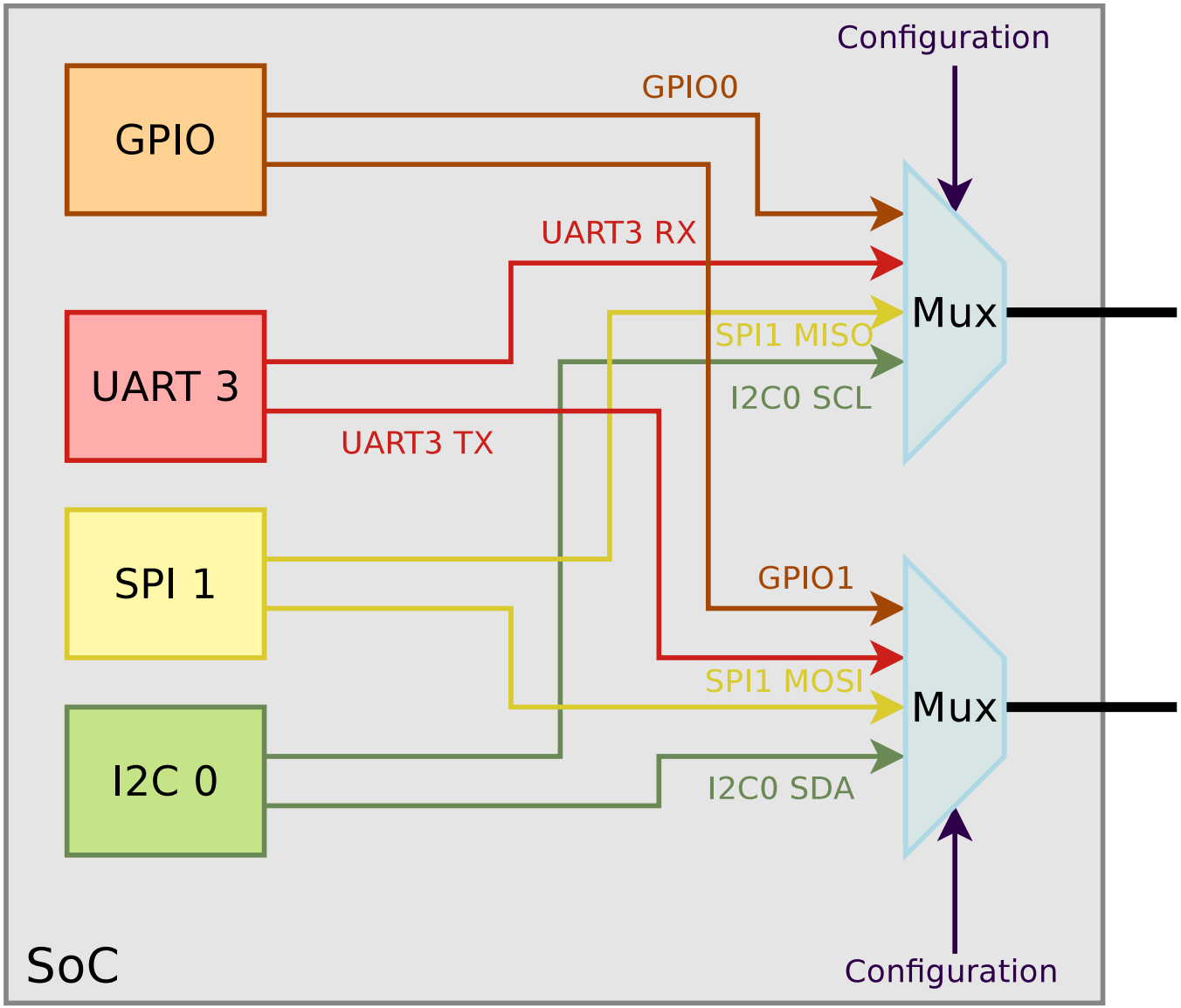
Change #2: Booting with a Device Tree



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.

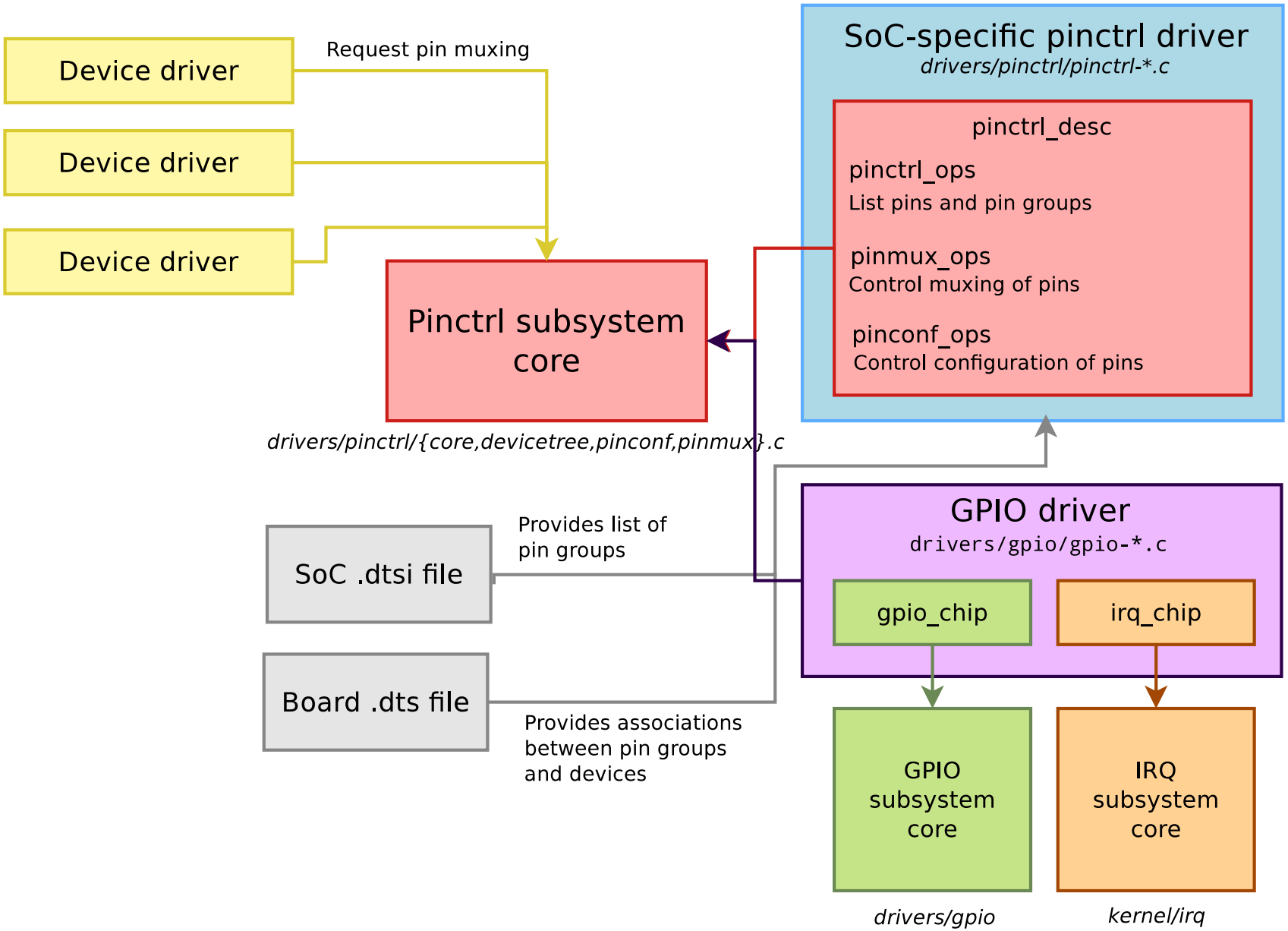
Change #4: Pinctrl subsystem, introduction



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



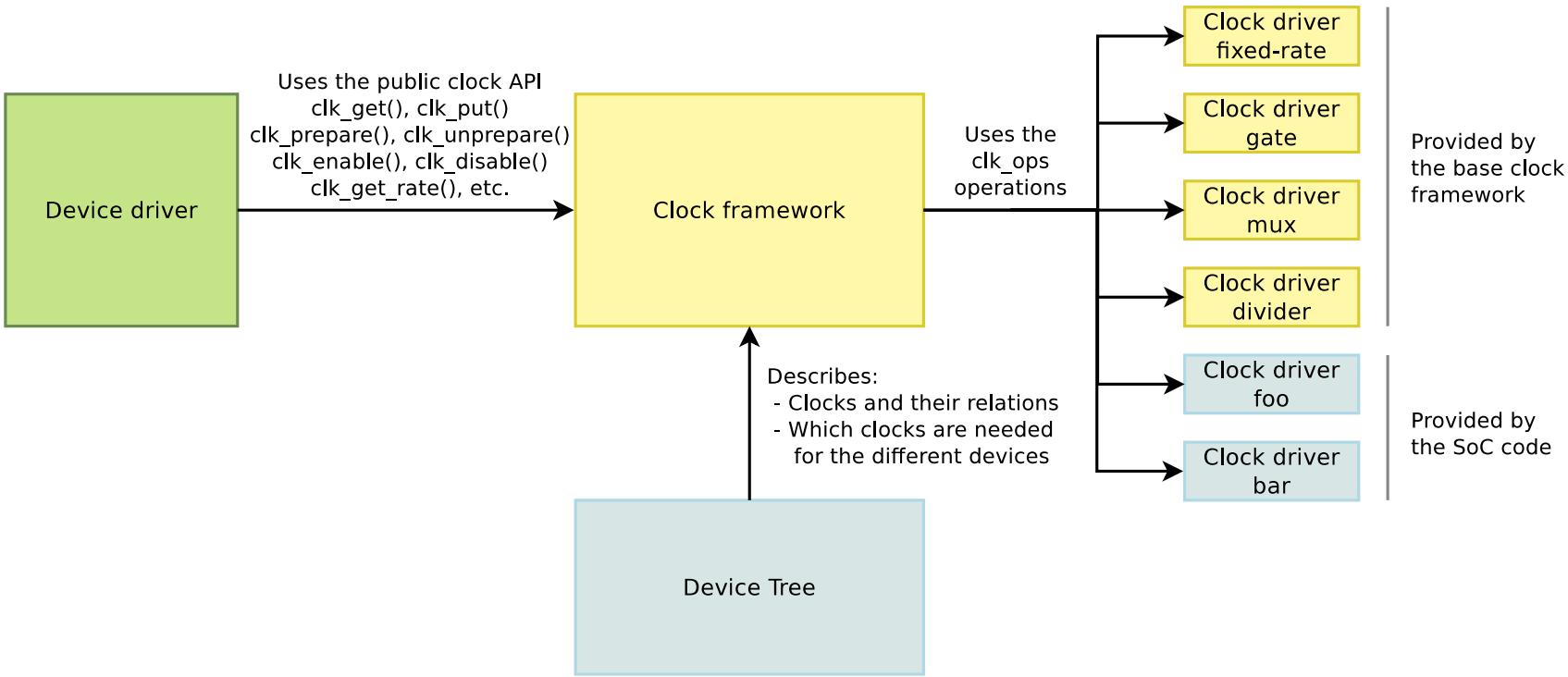
Change #5: Clocks

- 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)

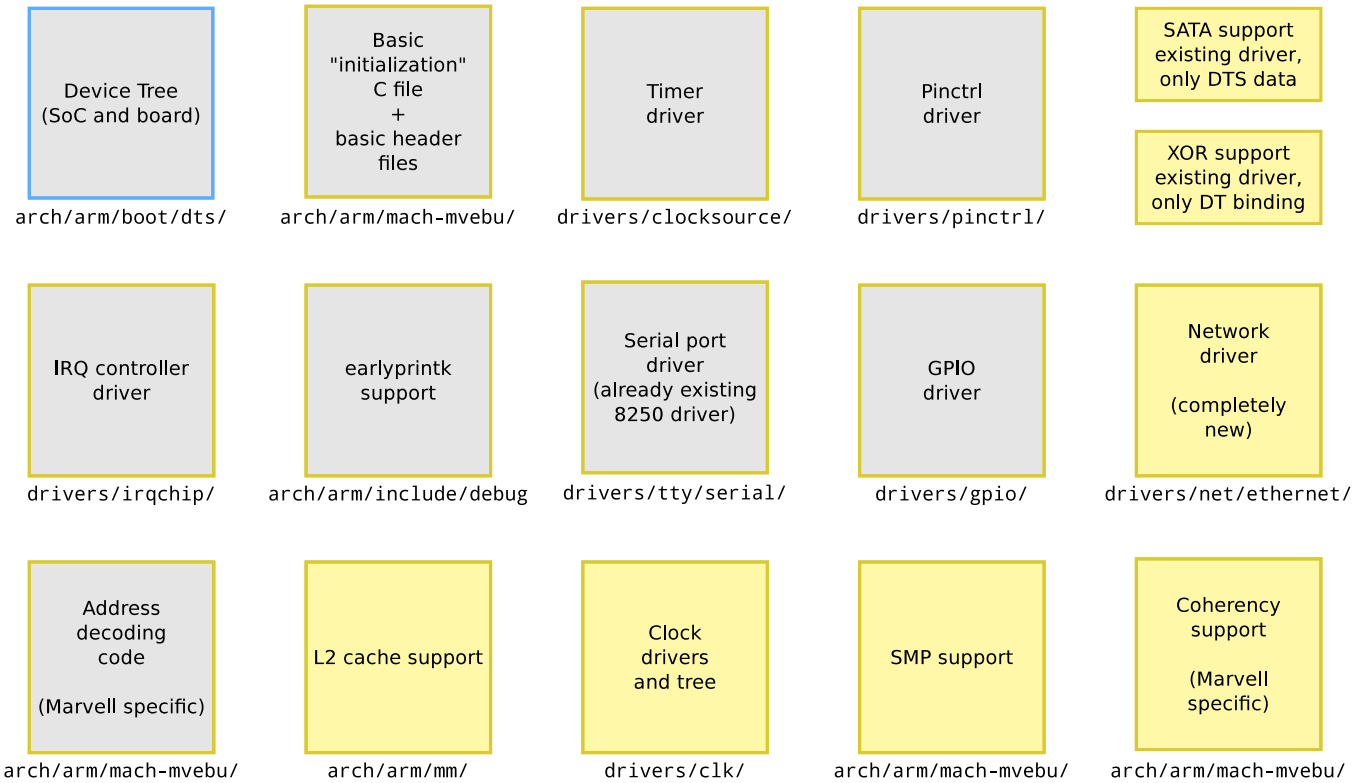
`drivers/tty/serial/`

Went into Linux 3.6, 10 patches

Armada 370/XP, step 2

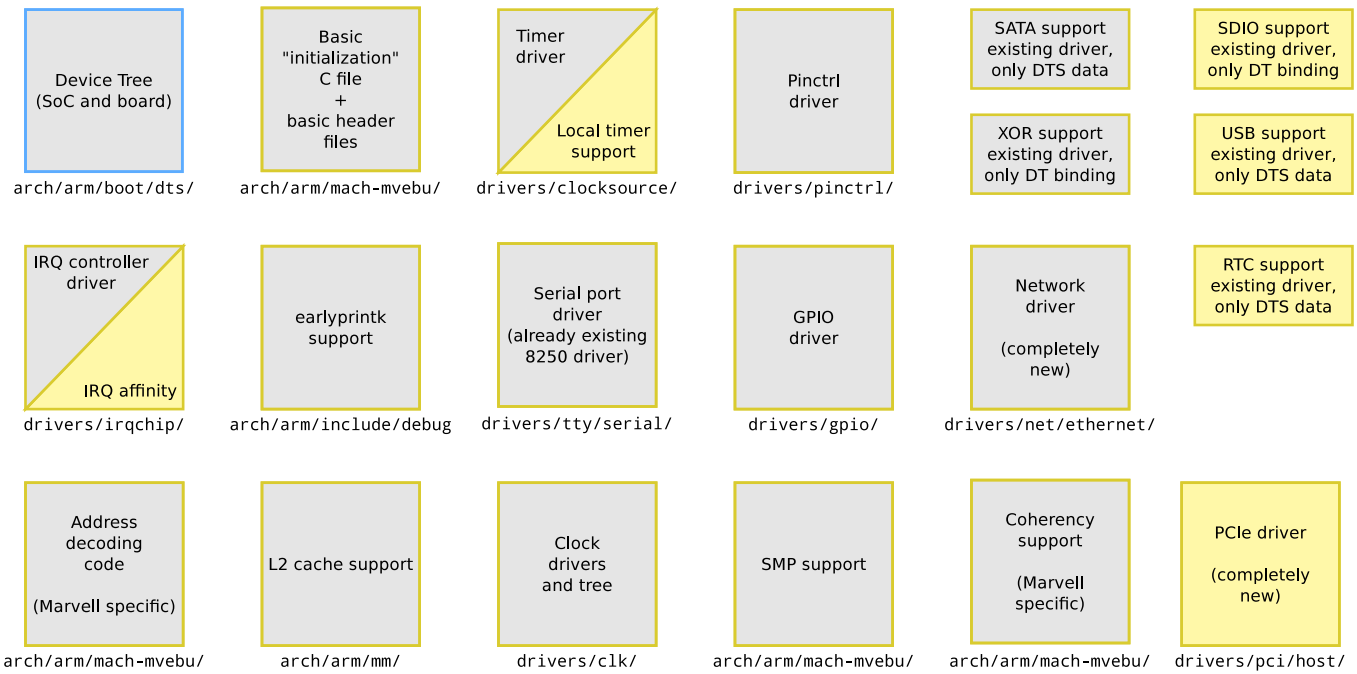
Went into Linux 3.7, 35 patches

Armada 370/XP, step 3



Went into Linux 3.8, 99 patches

Armada 370/XP, step 4



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.
- **Look at recently merged sub-architectures**: highbank, mvebu, sunxi, bcm2835, socfpga, etc.

And now...

Over the last year, ARM has gone from a constant headache every merge window to an outstanding citizen in the Linux community

Linus Torvalds, August 2012

Questions?

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

http://free-electrons.com/pub/conferences/2013/fosdem/arm-support-kernel/