# Embedded systems 5/7

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# Previous session

A driver defines the low-level functionalitites and is called by a device definition matching the `.name` attribute:

```
static struct platform_driver gpio_simple_driver = {
        .probe = gpio_simple_probe,
        .remove = gpio_simple_remove,
        .driver = { .name = "simple",
        },
};

static int __init gpio_simple_init(void)
{ret =platform_driver_register(&gpio_simple_driver);
 pdev=platform_device_register_simple("simple",0,NULL,0);
                                        // no argument: NULL,0
}
```

# Passing parameters to the driver

On the platform device: resource[1] definition

```
static struct resource jmf_res[] = {
        {.start  = 0x378,
         .end    = 0x379,
         .flags  = IORESOURCE_IO, // NOT IORESOURCE_MEM
         .name   = "io-memory1"
        },
        {.start  = 0x37a,
         .end    = 0x37b,
         .flags  = IORESOURCE_IO,
         .name   = "io-memory2"
        },
    };

static struct platform_device *pdev1;

static int __init gpio_simple_init(void)
{pdev1=platform_device_register_simple("jmf",0,jmf_res,→
    ↪ARRAY_SIZE(jmf_res));
...
```

The last two arguments of `platform_device_register_simple()` provide the arguments to the driver.

[1] definition in `include/linux/ioport.h`

# Passing parameters to the driver module

In the driver:

```
static int gpio_simple_probe(struct platform_device *pdev)
{struct resource *r1,*r2;
 r1= platform_get_resource(pdev, IORESOURCE_IO, 0);
 r2= platform_get_resource(pdev, IORESOURCE_IO, 1);
 printk(KERN_ALERT "jmf %d %x %x\n",pdev->id,(int)r1->→
     ↪start,(int)r2->start);
...
```

leads to (dmesg)

```
[  331.353399] jmf 0 378 37a
```

and

```
# cat /proc/ioports
  0378-0379 : io-memory1
  037a-037b : io-memory2
```

⇒ multiple configurations can be provided for a same peripheral

# Passing parameters to the driver module

⇒ a driver is given multiple configurations for a same peripheral type located at different addresses:

In the device module:

```
static struct resource jmf_resources1[] = {
  {.start=0x378, .end=0x379, .flags=IORESOURCE_IO, .name="io-memory1"},
  {.start=0x37a, .end=0x37b, .flags=IORESOURCE_IO, .name="io-memory2"},
 };
static struct resource jmf_resources2[] = {
  {.start=0x37c, .end=0x37d, .flags=IORESOURCE_IO, .name="io-memory3"},
 };

static struct platform_device *pdev1,*pdev2;

static int __init gpio_simple_init(void)
{pdev1=platform_device_register_simple("jmf",0,jmf_resources1,ARRAY_SIZE(jmf_resources1));
 pdev2=platform_device_register_simple("jmf",1,jmf_resources2,ARRAY_SIZE(jmf_resources2));
...
```

and in the driver

```
static int gpio_simple_probe(struct platform_device *pdev)
{struct resource *r1,*r2;
 printk("resources: %d",pdev->num_resources);
 r1= platform_get_resource(pdev, IORESOURCE_IO, 0);
 printk(KERN_ALERT "start1 %d %x\n",pdev->id,(int)r1->start);
 if (pdev->num_resources>1)
   {r2= platform_get_resource(pdev, IORESOURCE_IO, 1);
    printk(KERN_ALERT "start2 %d %x\n",pdev->id,(int)r2->start);
   } // $LINUX/Documentation/driver-model/platform.txt
...
```

dmesg :

```
[ 187.705199] resources: 2
[ 187.705200] start1 0 378
[ 187.705653] start2 0 37a
[ 187.706333] resources: 1
[ 187.706334] start1 1 37c
```

and these entries are found in `/sys/bus/platform/devices/jmf*`

# Challenge of peripheral description

- for enumerated buses (USB, PCI, firewire), a driver is loaded when the peripheral is detected
- for other buses (SPI, I$^2$C, ISA/PC104), hardware must be explictly described
- inserting hardware description in the kernel ⇒ source code growth (one driver for each peripheral implementation) and redundancy [2]

```
/* SPI */
static struct spi_board_info pcm037_spi_dev[] = {
        {
                .modalias       = "dac124s085",
                .max_speed_hz   = 400000,
                .bus_num        = 0,
                .chip_select    = 0,            /* Index in pcm037_spi1_cs[] */
                .mode           = SPI_CPHA,
        },
};

/* Platform Data for MXC CSPI */
static int pcm037_spi1_cs[] = {MXC_SPI_CS(1), IOMUX_TO_GPIO(MX31_PIN_KEY_COL7)};

static const struct spi_imx_master pcm037_spi1_pdata __initconst = {
        .chipselect = pcm037_spi1_cs,
        .num_chipselect = ARRAY_SIZE(pcm037_spi1_cs),
};

int __init pcm037_eet_init_devices(void)
{[...]
        /* SPI */
        spi_register_board_info(pcm037_spi_dev, ARRAY_SIZE(pcm037_spi_dev));
        imx31_add_spi_imx0(&pcm037_spi1_pdata);
```

[2] linux-4.4.2/arch/arm/mach-imx/mach-pcm037_eet.c

# Challenge of peripheral description

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```
From Linus Torvalds <>
Date Thu, 17 Mar 2011 19:50:36 -0700
Subject Re: [GIT PULL] omap changes for v2.6.39 merge window

On Thu, Mar 17, 2011 at 11:30 AM, Tony Lindgren <tony@atomide.com> wrote:
> Please pull omap changes for this merge window from:

Gaah. Guys, this whole ARM thing is a f*cking pain in the ass.

You need to stop stepping on each others toes. There is no way that
your changes to those crazy clock-data files should constantly result
in those annoying conflicts, just because different people in
different ARM trees do some masturbatory renaming of some random
device. Seriously.
[...]
```

https://lkml.org/lkml/2011/3/17/492

# Challenge of peripheral description

- for enumerated buses (USB, PCI, firewire), a driver is loaded when the peripheral is detected
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- inserting hardware description in the kernel ⇒ source code growth (one driver for each peripheral implementation) and redundancy
- **Solution** provided by PowerPC & SPARC architectures ported to ARM: the *devicetree* [3] for describing peripheral and their dependencies

⇒ a human readable ASCII file describing the peripherals and their dependencies, converted to a binary file used by the Linux kernel upon starting or while being executed (overlay) [4] [5]

[3] `www.kernel.org/doc/Documentation/devicetree/usage-model.txt`

[4] T. Petazzoni, *Introduction au "device tree" sur ARM*, Opensilicium Janvier-Février-Mars 2016, pp. 46-59, à `jmfriedt.free.fr/devicetree_os19.pdf`

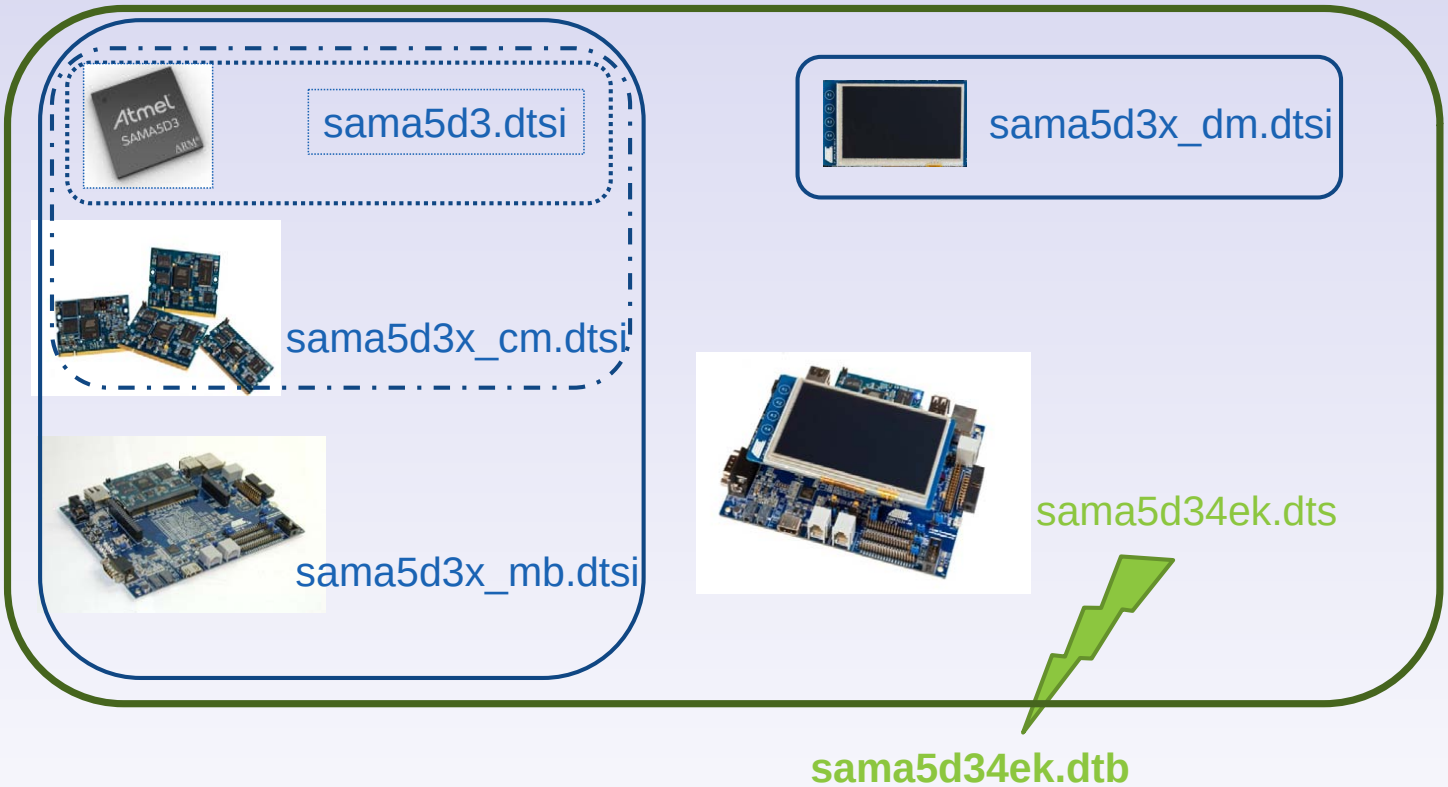
[5] T. Petazzoni, *Device Tree for dummies*, ELC 2014 `events.linuxfoundation.org/sites/events/files/slides/petazzoni-device-tree-dummies.pdf`, talk at `www.youtube.com/watch?v=uzBwHFjJ0vU`

# *devicetree* architecture

Peripheral hierarchy: SoC=CPU+interfaces, fitted on a development board [6]

**Device Tree Implementation**

Layers




14 © 2014 Atmel Corporation Linux Device Tree Introduction 5/20/2014 Atmel

**Not** valid on a PC (x86/amd64 architectures)

[6] Atmel AN-8481, *Linux Device Tree Introduction* (2014), http://atmel.force.com/support/servlet/fileField?id=0BEG0000000PDgm

# Hardware description

Example of `linux-4.4.2/arch/arm/boot/dts/sun5i-a13-olinuxino-micro.dts`
1. in the devicetree:

```
#include "sun5i-a13.dtsi"
#include <dt-bindings/pinctrl/sun4i-a10.h>
[...]

&spi2 {   // surchage la definition de SPI precedente
  pinctrl-0 = <&spi2_pins_a>, <&spi2_cs0_pins_a>;
  status = "okay";
  ad9834@0 {
    compatible = "ad9834_2";
    spi-max-frequency = <50000000>; // 5 MHz
    spi-cpol;
    reg = <0>;
    vcc-supply = <&reg_ad9834_vref>;
    freq0 = <136727>;
  };
};

reg_ad9834_vref: vref-reg@1 {
  compatible = "regulator-fixed";
  regulator-max-microvolt = <3300000>;
  [...]
  }
};
```

# Link with the driver

Example of `linux-4.4.2/arch/arm/boot/dts/sun5i-a13-olinuxino-micro.dts`

1. in the devicetree:

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[...]

&spi2 {   // surchage la definition de SPI precedente
  pinctrl-0 = <&spi2_pins_a>, <&spi2_cs0_pins_a>;
  status = "okay";
  ad9834@0 {
    compatible = "ad9834_2";
    spi-max-frequency = <50000000>; // 5 MHz
    spi-cpol;
    reg = <0>;
    vcc-supply = <&reg_ad9834_vref>;
    freq0 = <136727>;
  };
};
```

2. and in the driver:

```
static const struct spi_device_id ad9834_id[] = {
        {"ad9834_2", ID_AD9834}, {}
};
MODULE_DEVICE_TABLE(spi, ad9834_id);
```

# Devicetree compilation

1. The "original" devicetress is located in
   `output/build/linux-*/arch/arm/boots/dts/zynq-red_pitaya.dts`
   $\Rightarrow$ modify this file and compile the kernel (requires write access to the bruildroot directory)
2. binary$\rightarrow$ ASCII of an existing devicetree [7]

   ```
   dtc -I dtb -O dts filename.dtb
   ```
3. or `fdtdump zynq-red_pitaya.dtb`
4. ASCII $\rightarrow$ binary:

   ```
   dtc -O dtb -o filename.dtb filename.dts
   ```

OF=OpenFirmware[8]

[7] script `https://git.kernel.org/cgit/utils/dtc/dtc.git` or `buildroot/output/host/usr/bin/dtc` : remember to use the `dtc` **provided by buildroot** and not the one from the host

[8] `https://www.openfirmware.info/Welcome_to_OpenBIOS`

# Adding a new entry to the devicetree

Loading the driver

```
# insmod composant.ko
```

does not trigger any action as long as we have not

```
# insmod dummy_platform.ko
```

which inserts the platform device requesting the driver support.

```
[  838.108990] . Entering probe
[  838.111930] . Registering
[  838.114825] . Registered
```

⇒ adding an entry to call the driver from the *devicetree*

# Adding a new entry to the devicetree

⇒ adding an entry to call the driver from the *devicetree*

1. fetch the current *devicetree* in the boot partition

```
# mount /dev/mmcblk0p1 /mnt/
# ls /mnt/
...  zImage  zynq-red_pitaya.dtb
```

2. binary → ASCII
3. add a node calling the driver (`compatible` = description that was taken care of by the device previously)

```
dummy_entry {compatible="composant1";};
```

4. ASCII → binary
5. reboot the Redpitaya to load the new configuration

# Driver-devicetree link

Check that the new node has been inserted: the tree structure of the *devicetree* can be accessed in /sys/firmware/devicetree/base:
⇒ dummy_entry is now present

```
$ cat compatible
composant1
```

In the driver, the structures associating with the *devicetree* entry is [9] :

```
static const struct of_device_id composant_id_of[] = { // for devicetree
  { .compatible="composant1",
  },{} };
MODULE_DEVICE_TABLE(of, composant_id_of);          // for devicetree

static struct platform_driver composant_driver = {
  .driver = {
     .name = "composant",
     .owner = THIS_MODULE,
     .of_match_table=of_match_ptr(composant_id_of), // for devicetree
  },
  .probe = composant_probe,
  .remove = composant_remove,
  .id_table = composant_id,   // for platform device
};
module_platform_driver(composant_driver);
```

[9] http://events.linuxfoundation.org/sites/events/files/slides/dt_internals_0.pdf

# Driver-devicetree link

This time, the messages printed by `probe()` are displayed as soon as the driver is loaded

```
[ 5804.151642] . Entering probe
[ 5804.154560] . Registering
[ 5804.158091] . Registered
```

without requiring explictly loading the platform device.

$\Rightarrow$ the devicetree describes the hardware and the drivers are loaded dynamically while fetching their configuration

# Passing parameters

Parameter passing to the driver upon being loaded by the *devicetree* to describe the peripheral configuration.

- in the devicetree:

```
dummy_entry {compatible="composant1";toto32=<56>;};
```

- in the driver:

```
static int composant_probe(struct platform_device *pdev)
{u32 val32=42;u16 val16=42;
 struct device_node *np = pdev->dev.of_node;
 of_property_read_u32(np, "toto32", &val32);
 of_property_read_u16(np, "toto16", &val16);
 printk(KERN_ALERT ". Entering probe %u %u\n",val32,val16);
...
```

- check that the variable value has been loaded

```
/sys/firmware/devicetree/base/dummy_entry
# ls
compatible  name        toto32

# hexdump toto32
0000000 0000 3800
0000004

# insmod composant_comm.ko
[  232.968359] . Entering probe 56 42
```

# Devicetree overlay

- Dynamically adding entries in the devicetree: overlays [10] [11]
- Not yet supported in the official Linux kernel
- Documentation in `SRC_LINUX/Documentation/devicetree/overlay-notes.txt`
- Useful when dynamically adding peripherals: FPGA IPs and associated resources described in the *devicetree* [12]
- $\Rightarrow$ useful for architectures combining CPU + FPGA (Armadeus Systems, Xilinx Zynq, Intel/Altera SoC)

[10] M. Fischer, *FPGA Manager & devicetree overlays*, FOSDEM 2016, `https://archive.fosdem.org/2016/schedule/event/fpga_devicetree/`

[11] P. Antoniou, *Transactional Device Tree & Overlays – Making Reconfigurable Hardware Work*, ELC 2015 `http://events.linuxfoundation.org/sites/events/files/slides/dynamic-dt-elce14.pdf` et conférence `https://www.youtube.com/watch?v=3Ag7ZBC_Nts`

[12] `https://git.kernel.org/cgit/linux/kernel/git/next/linux-next.git/tree/Documentation/devicetree/bindings/fpga/fpga-region.txt?id`

# Devicetree overlay

Adding an overlay to the devicetree triggers the probe method of the corresponding driver:

```
/dts-v1/;
/plugin/;
/ { compatible = "xlnx,zynq-7000";
    fragment@0
        {target-path = "/";
          __overlay__
          {  #address-cells = <1>;
             #size-cells = <1>;
             pilote_drv {compatible = "pilote_ctl";};
          };
        };
  };
```

is compiled with

```
BUILDROOT/output/host/usr/bin/dtc -@ -I dts -o pl_ovl.dtbo pl_ovl.dts
```

where "@" indicates that an overlay is being compiled
Adding the overlay

```
mkdir /sys/kernel/config/device-tree/overlays/pilote
cat pl_ovl.dtbo > /sys/kernel/config/device-tree/overlays/pilote/dtbo
cd /sys/firmware/devicetree/base/pilote_drv/
cat compatible # > pilote_ctl
```

# Devicetree overlay

The driver compatible with the overlay is informed with

```
static const struct of_device_id composant_id_of[] = { // for devicetree
        { .compatible="pilote_ctl", },
        {}
};
MODULE_DEVICE_TABLE(of, composant_id_of);           // for devicetree

static struct platform_driver pilote_driver = {
        .driver = {.name = "pilote_de_jmf",.owner = THIS_MODULE,
                   .of_match_table=of_match_ptr(composant_id_of),
                   },
        .probe = gpio_simple_probe,
        .remove= gpio_simple_remove,
};

module_platform_driver(pilote_driver);
// creates init() and exit() including platform_register and platform_unregister

static int gpio_simple_remove(struct platform_device *pdev)
{printk("driver Good Bye\n");return 0;}

static int gpio_simple_probe(struct platform_device *pdev)
{printk("driver Hello\n");return 0;}
```

⇒ loading the driver immediately calls the `probe` method, without having the explictly load a platform (the devicetree did it for us)

Removing the overlay

```
rmdir /sys/kernel/config/device-tree/overlays/pilote/
```

# Linux and FPGA bitstreams

- `fpga_manager` (Linux) provides a unified interface for all SoC
- Vivado (Xilinx) provides bitstreams in `.bit` format to be converted to `.bit.bin` with the Xilinx SDK:

  ```
  $VIVADO_SDK/bin/bootgen -image my_bif_file.bif -arch zynq \
  -process_bitstream bin
  ```

  using the following `.bif` configuration file:

  ```
  all: {nom_bitstream.bit}
  ```

  $\rightarrow$ .bit.bin file
- the `bit.bin` file is copied to `/lib/firmware` of the (Redpitaya) Zynq.
- Transfering to the FPGA:

  ```
  echo "bitstream_name.bit.bin" > /sys/class/fpga_manager/fpga0/firmware
  ```

# Overlay associated to a bitstream

- for each overlay: consistent description of the bitstream, the driver and the resources

```
/dts-v1/;
/plugin/;
/ { compatible = "xlnx,zynq-7000";
    fragment@0 {
        target = <&fpga_full>;
        #address-cells = <1>;
        #size-cells = <1>;
        __overlay__ {
            #address-cells = <1>;
            #size-cells = <1>;
            firmware-name = "top_redpitaya_axi_gpio_ctl.bit.bin";
            gpio1: gpio@43C00000 {
                compatible = "gpio_ctl";
                reg = <0x43C00000 0x0001f>;
                gpio-controller;
                #gpio-cells = <1>;
                ngpio= <8>;
            };
        };
    };
};
```

# Conclusion and laboratory session

**Exercise**: modify the devicetree so that an associated driver is automatically loaded when inserting the module

Functions related to the devicetree are declared in

```
#include <linux/of.h>
#include <linux/of_device.h>
```

Compatibility of platform device + devicetree [13]

```
static int composant_probe(struct platform_device *pdev)
{struct composant_state *st;
 if (pdev->dev.of_node)
     st->chip_info=of_match_device(composant_id_of,&pdev->dev)->data; // dt
 else
     st->chip_info =                                              // plateforme
       &composant_chip_info_tbl[platform_get_device_id(pdev)->driver_data];
```

**Adapt** the driver unblocking the `read` function on a timer condition so that the period of the timer is given as a parameter in the *devicetree*.

Read `LINUX/Documentation/devicetree`

[13] `http://lxr.free-electrons.com/source/drivers/iio/adc/at91_adc.c` l.1142 : `static int at91_adc_probe(struct platform_device *pdev)`

# Overlay example

```
/dts-v1/;
/plugin/;
/ { compatible = "xlnx,zynq-7000";
    fragment@0
        {target-path = "/";
          __overlay__ {
             le_timer_de_jmf {
                mon_timer2=<2>;
                compatible="mon_pilote";
             };
          };
        };
  };
```

will generate after
`cat /tmp/demo.dtbo > /sys/kernel/config/device-tree/overlays/demo/dtbo`
a directory named `le_timer_de_jmf` in `/sys/firmware/devicetree/base` whose content are the "compatible" and variable fields.