EE Live! Featuring esc The Embedded Systems Conference

Device Trees – A Database Approach to Describing Hardware

Doug Abbott

Intellimetrix
COMPUTING FOR SCIENCE AND INDUSTRY

#eelive

Produced by EE Times

esc EMBEDDED SYSTEMS CONFERENCE | BLACK HAT EMBEDDED | INTERNET OF THINGS | HARDWARE STARTUP | ANDROID ENGINEERING | FPGA ENGINEERING | SUPER C++ TUTORIAL | UBM Tech

EE Live! Featuring esc The Embedded Systems Conference

Problem

- How to describe hardware to OS?
  - Build description into drivers
    - CONFIG_ variables
  - Create a "Board Support Package"
    - mach-* and plat-* directories in arch/arm/
  - Database approach
- OS and bootloader may have different views of hardware

"Gaah! Guys, this whole ARM thing is a _____ pain in the ass."

Linus Torvalds

esc | BLACK HAT EMBEDDED | INTERNET OF THINGS | HARDWARE STARTUP | ANDROID ENGINEERING | FPGA ENGINEERING | SUPER C++ TUTORIAL | UBM Tech

EE Live! Featuring esc The Embedded Systems Conference

The Linux Device Driver Model

- Busses
  - How devices connect to the processor
  - Need not be physical
- Devices
  - Connect to a bus
- Drivers
  - Represent a device
  - Must identify device

EE Live! Featuring esc The Embedded Systems Conference

Platform vs. “discoverable” devices

- Discoverable devices
  - Connected to well-defined bus like PCI or USB
  - Can be interrogated to determine what they are
- Platform devices
  - Generally connect directly to the CPU
  - Lack ability to be interrogated
  - These are the tough ones!

EE Live! Featuring esc The Embedded Systems Conference

Device Tree Background

- Came from Open Firmware standard
  - IEEE 1275
  - Replaced by UEFI (Unified Extensible Firmware Interface)
- Widely used in Power PC world
  - Now required for all PPC Linux implementations
- Gaining traction in ARM world
  - See linux/arch/arm/boot/dts

EE Live! Featuring esc The Embedded Systems Conference

Device Tree

- Data Structure for Describing Hardware Configuration
  - Standard interface between bootloader and OS
  - Avoid hard coding platform details
- Open Firmware specification
- Framework that can support multiple SoC devices with single kernel image

Device Tree Syntax

```
/ memreserve / 0 x20000000 -0 x21FFFFFF ;
/ {
        model = " MyBoard ";
        compatible = " acme, MyBoard";
        #address - cells = <1>;
        #size - cells = <1>;
        interrupt-parent = <&intc>;

        cpus {
       #address - cells = <1>;
       #size - cells = <0>;
            cpu@0 {

            };
       };
       intc: Interrupt_controller @10140000 {
       };
};
```


Device Tree Elements

- Tree -- hierarchy of nodes beginning at /
- Node -- name { properties };
- Name
  - Up to 31 characters
  - Represents *type* of device, not specific implementation
  - Format: <string>[@<unit_address>]
    - <unit_address>: how the node is referenced

Node Properties

- name = value;
- Value:
  - String -- “MyBoard”
  - Cells -- <0 8000 f0000000>
  - Bytestring – [1234abcdef]
  - Reference -- &/path_to_node
  - Empty

EE Live! Featuring esc The Embedded Systems Conference

Memory-mapped Device Node

```
serial@101f0000 {
    compatible = "arm, pl011";
        reg = <0x101f0000 0x1000 >;
    interrupts = <3 0>;
}
```

esc UBM Tech

Bus-mapped Device Node

```
external-bus {
    #address-cells = <2>;
    #size-cells = <1>;

    i2c@1,0 {
        compatible = "acme, a1234-i2c-bus";
        #address-cells = <1>;
        #size-cells = <0>;
        reg = <1 0 0x1000>;
        rtc@58 {
            compatible = "maxim, ds1338";
            reg = <58>;
        };
    };
};
```


Interrupt controller Device Node

```
intc: interrupt-controller@10140000 {
    compatible = "arm, pl190";
    reg = <0x10140000 0x1000 >;
    interrupt-controller;
    #interrupt-cells = <2>;
};
```

EE Live! Featuring esc The Embedded Systems Conference

"aliases" node

- Associate short name with full path to node
- Must be at root level

```
aliases {
    i2c = "/external_bus/i2c@1,0";
    rtc = "/external_bus/i2c@1,0/rtc@58";
};
```

EE Live! Featuring esc The Embedded Systems Conference

"chosen" node

- Doesn't represent a device
- Used to pass variable data from bootloader to kernel
  - Often left blank in dts. Filled in at boot time
- Must be at root level

```
chosen {
    bootargs = "root=/dev/nfs rw nfsroot=192.168.1.50
      console=ttyS0, 115200";
};
```

compatible Property

- Link between device and driver
- In device tree
  - compatible = “device_name”;
- In driver code
  - struct of_device_id my_of_match[] = {
  - {.compatible = “device_name”}
  - }
  - MODULE_DEVICE_TABLE (of, my_of_match)

Property Names

- Defined by “bindings”
- Bindings defined by:
  - Original IEEE 1275 specification
    - Not available free
  - ePAPR
    - See References slide at end
  - Kernel source tree
    - linux/Documentation/devicetree/bindings

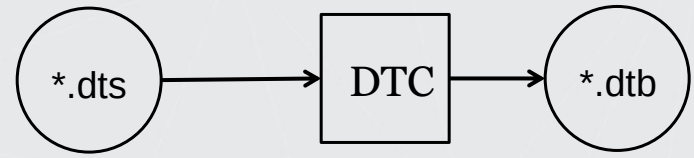
EE Live! Featuring esc The Embedded Systems Conference

Device Tree and Linux

- Configuration: Boot Options
  - Device Tree Support
    - CONFIG_USE_OF
- /proc/device-tree
  - Node -> directory
  - Property -> file
- On entry to kernel (ARM)
  - R2 -> device tree blob
- Device tree support code in drivers/of

EE Live! Featuring esc The Embedded Systems Conference

Flattened Device Tree



Device Tree Source | Device Tree Compiler | Flattened Device Tree Blob

DTC at linux/scripts/dtc
DTS files in arch/<arch>/boot/dts

make <board_name>.dtb

EE Live! Featuring esc The Embedded Systems Conference

FDT and u-boot

- #define CONFIG_OF_LIBFDT
- fdt command
  - List tree
  - Make new nodes
  - Set properties
  - Remove nodes or properties
- bootm <kernel_addr> <initrd_addr> <dtb_addr>

EE Live! Featuring esc The Embedded Systems Conference

Accessing the dtb

```
#include of.h

struct device_node – Represents a node in the device tree. Linked list
struct property – Represents a property of a device node.  Linked list

struct device_node *of_find_node_by_name (struct device_node *from,
      const char *name);
struct device_node *of_find_node_by_type (struct device_node *from,
      const char *type);
struct device_node *of_get_parent (const struct device_node *node);

struct property *of_find_property (const struct device_node *np,
      const char *name, int *lenp);
int of_n_addr_cells (struct device_node *np);
int of_n_size_cells(struct device_node *np);
```

Device Tree Does Not…

- Replace board-specific code
  - Handles the common case
  - Odd hardware still requires special treatment
- Add features
- Boot fast
  - Increases kernel footprint

EE Live! Featuring esc The Embedded Systems Conference

Example

- linux/drivers/tty/serial/of_serial.c
- linux/arch/arm/boot/dts/kirkwood.dtsi
- linux/arch/arm/boot/dts/kirkwood-dns320.dts

esc UBM Tech

Summary

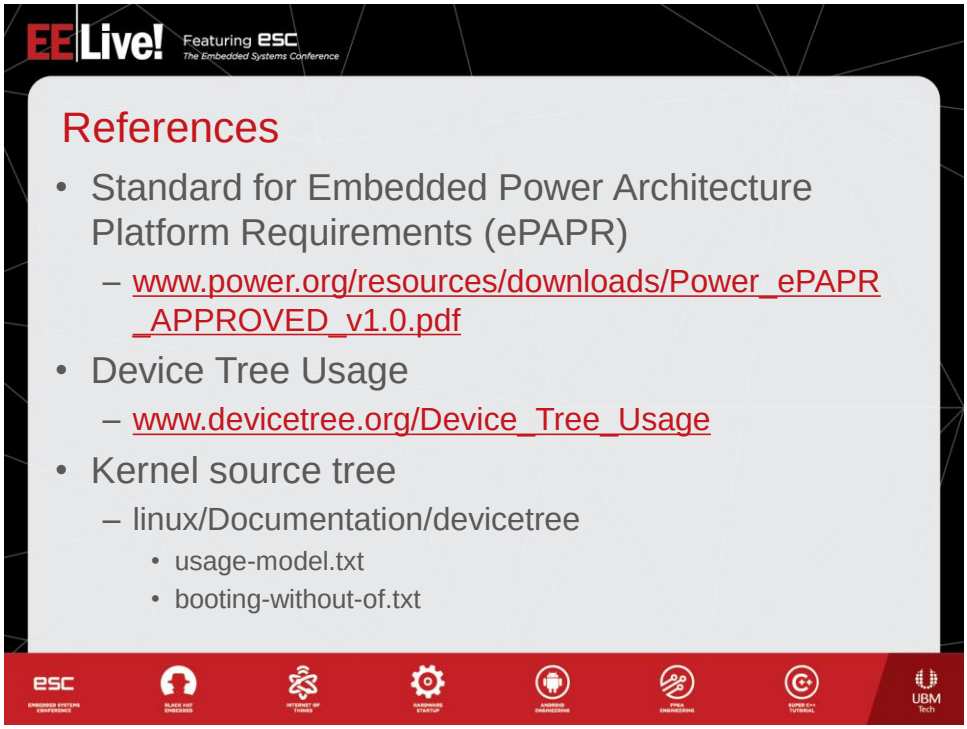
- Problem: how to describe system hardware to the OS?
  - Make sure bootloader and OS have consistent view
- Device tree = database for describing hardware
  - Device Tree Compiler (DTC) translates source to binary “blob”

EE Live! Featuring esc The Embedded Systems Conference

Summary II

- Bootloader passes blob to OS at boot time
- Kernel and device drivers interrogate blob to determine configuration
  - Kernel and drivers can now be “generic” rather than unique to each board

esc UBM Tech


EE Live! Featuring esc
The Embedded Systems Conference
References
• Standard for Embedded Power Architecture Platform Requirements (ePAPR)
– www.power.org/resources/downloads/Power_ePAPR_APPROVED_v1.0.pdf
• Device Tree Usage
– www.devicetree.org/Device_Tree_Usage
• Kernel source tree
– linux/Documentation/devicetree
• usage-model.txt
• booting-without-of.txt
esc
UBM Tech