U-Boot bootloader port done right – 2018 edition

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Structure of the talk

- What is U-Boot bootloader
- News in U-Boot in 2018
- U-Boot basics
- Device Tree and U-Boot
- U-Boot Driver Model
- Barebones U-Boot port 101
- Low-memory system optimization
- Conclusion

U-Boot bootloader

- Boot loader
  - First[1]-ish code that runs on a system
  - Responsible for some HW initialization and starting OS
- Boot monitor
- Debug tool

[1] There are exceptions, ie. Boot ROMs

U-Boot example

```
U-Boot 2017.11 (Nov 19 2017 - 22:43:25 +0100)

CPU: Renesas Electronics CPU rev 1.0
Model: Renesas Salvator-X board based on r8a7795 ES2.0+
Board: Salvator-X
I2C:   ready
DRAM:  3.9 GiB
Flash: 64 MiB
MMC:   sd@ee100000: 0, sd@ee140000: 1, sd@ee160000: 2
In:    serial@e6e88000
Out:   serial@e6e88000
Err:   serial@e6e88000
Net:   eth0: ethernet@e6800000
Hit any key to stop autoboot:  0
=>
=> md 0xe6e88000 4
e6e88000: 00000000 11111111 00300030 00000000 ........0.0.....
=>
```

U-Boot news and highlights – 2018 edition

- Device Tree control
- Driver Model conversion
- EFI support
- Distro boot command
- DTO application with fitImage
- CI

U-Boot sources

- Git master at:
  `http://git.denx.de/?p=u-boot.git;a=summary`
- Custodian subtrees at:
  `http://git.denx.de/?p=u-boot.git;a=forks`
- Available via Git and HTTP protocols

Building the sources

```
$ git clone git://git.denx.de/u-boot.git
$ cd u-boot
$ export ARCH=plat                      # optional, set target architecture
$ export CROSS_COMPILE=plat-none- # optional, set cross compiler
$ make board_defconfig                  # ie. sandbox_defconfig
$ make
```

U-Boot source tree structure

- arch/ – Architecture specific code
  - arch/nnn/mach-foo – foo CPU specific code
  - arch/nnn/dts – U-Boot device trees
- board/ – Board specific code
- config/ – Per-board U-Boot configurations
- include/ – Header files for all global things
  - include/configs/ – Legacy per-board configs
- drivers/ – U-Boot drivers
- cmd/ – U-Boot commands
- common/ lib/ – Common code
- net/ – Network stack
- fs/ – Filesystems implementation

`Kconfig` and `Makefile` permeate the entire structure

Configuring U-Boot

- U-Boot uses Kconfig for configuration
- Some configuration macros still not converted: `./scripts/config_whitelist.txt`
- All new config options are Kconfig-only!
- Example, `drivers/net/Kconfig`:

```
source "drivers/net/phy/Kconfig"

config DM_ETH
        bool "Enable Driver Model for Ethernet drivers"
        depends on DM
        help
          Enable driver model for Ethernet.

          The eth_*() interface will be implemented by the UC_ETH class
          This is currently implemented in net/eth.c
          Look in include/net.h for details.
```

- Example, `drivers/net/Makefile`:

```
obj-$(CONFIG_ALTERA_TSE) += altera_tse.o
obj-$(CONFIG_AG7XXX) += ag7xxx.o
```

Adding configuration option

Adding configuration option means

- Patch matching Kconfig file
- Patch matching Makefile if applicable
- Add code.c sources

unless this is a hardware-related configuration

- Use Device Tree to describe hardware
- Do NOT hardcode hardware topology into U-Boot

Device Tree

- Data structure describing hardware
- Usually passed to OS to provide information about HW topology where it cannot be detected/probed
- Tree, made of named nodes and properties
  - Nodes can contain other nodes and properties
  - Properties are a name-value pair
  - See https://en.wikipedia.org/wiki/Device_tree
- DT can contain cycles by means of phandles
- More on DT at: https://www.devicetree.org/
- ePAPR specification of DT: https://elinux.org/images/c/cf/Power_ePAPR_APPROVED_v1.1.pdf

Device Tree example

```
#include <dt-bindings/power/r8a7795-sysc.h>
/ {
    model = "Renesas Salvator-X board based on r8a7795 ES2.0+";
    compatible = "renesas,salvator-x", "renesas,r8a7795";
[...]
    cpus {
        a57_0: cpu@0 {
            compatible = "arm,cortex-a57", "arm,armv8";
            reg = <0x0>;
            device_type = "cpu";
            power-domains = <&sysc R8A7795_PD_CA57_CPU0>;
            next-level-cache = <&L2_CA57>;
            enable-method = "psci";
        };
[...]
    soc: soc {
        pmu_a57 {
            compatible = "arm,cortex-a57-pmu";
            interrupts = <GIC_SPI 72 IRQ_TYPE_LEVEL_HIGH>,
                         <GIC_SPI 73 IRQ_TYPE_LEVEL_HIGH>,
                         <GIC_SPI 74 IRQ_TYPE_LEVEL_HIGH>,
                         <GIC_SPI 75 IRQ_TYPE_LEVEL_HIGH>;
            interrupt-affinity = <&a57_0>, <&a57_1>, <&a57_2>, <&a57_3>;
```

Device Tree in U-Boot

Two ways U-Boot uses DT:

- Patch DT and pass it to kernel
- Understand HW topology
  - CONFIG_OF_CONTROL
  - U-Boot needs early access to DT!

U-Boot early stages

- Platform-specific reset vector code
- crt0.S
- common/board_f.c
  - U-Boot running from FLASH
  - First item is fdtdec_setup()
- common/board_r.c
  - U-Boot running from RAM
- Hint: lib/initcall.c is nice debug aid

U-Boot DT access

- fdt_*() functions in include/fdt_support.h
  Very rudimentary
- fdtdec_*() functions in include/fdtdec.h
  Convenience wrappers around fdt_() functions
- dev_read_*() functions in include/dm/read.h
  DM-specific DT access functions
- Parsing DT by hand can be useful in early stages, but later we use DM

U-Boot Driver Model

- Harbinger of order within all the ifdef chaos
- Consists of:
  - Classes – Groups of devices which operate the same, ie. GPIO uclass, I2C controller uclass...
  - Drivers – Code which talks to device and presents standard higher-level interface for Class
  - Devices – Each device with a fitting driver gets an instance

U-Boot DM core

- Responsible for handling device life-cycle
- Inherently lazy to reduce boot time
- Upon init, creates root driver
- Everything else is under the root driver

U-Boot DM example

```
=> dm tree
 Class      Probed  Driver      Name
----------------------------------------
 root        [ + ]   root_drive  root_driver
 clk         [ + ]   fixed_rate  |-- extal
 simple_bus  [ + ]   generic_si  |-- soc
 gpio        [   ]   rcar-gpio   |   |-- gpio@e6051000
 gpio        [ + ]   rcar-gpio   |   |-- gpio@e6052000
 pinctrl     [ + ]   sh_pfc_pin  |   |-- pin-controller@e6060000
 pinconfig   [   ]   pinconfig   |   |   |-- scif1
 pinconfig   [ + ]   pinconfig   |   |   |-- scif2
 pinconfig   [ + ]   pinconfig   |   |   |-- scif_clk
 pinconfig   [   ]   pinconfig   |   |   |-- usb1
 pinconfig   [   ]   pinconfig   |   |   |   |-- mux
 pinconfig   [   ]   pinconfig   |   |   |   |-- ovc
 pinconfig   [   ]   pinconfig   |   |   |   `-- pwen
 pinconfig   [   ]   pinconfig   |   |   `-- usb2
 serial      [   ]   serial_sh   |   |-- serial@e6e68000
 serial      [ + ]   serial_sh   |   |-- serial@e6e88000
 usb         [   ]   xhci_rcar   |   |-- usb@ee000000
 usb         [   ]   ehci_gener  |   `-- usb@ee0c0100
 regulator   [   ]   fixed regu  |-- regulator-vbus0-usb2
 clk         [   ]   fixed_rate  `-- x23-clock
```

U-Boot Driver life-cycle

- Driver is statically defined by `U_BOOT_DRIVER` macro
- Upon instantiation, the following are done:
  - (optional) – Preallocation of private data
  - .ofdata_to_platdata – Convert OF data to platdata
  - .bind – Bind the driver with DM, device not active
  - .probe – Upon first request, device activated
  - .remove – Counterpart to probe
  - .unbind – Counterpart to bind

Porting U-Boot to a new board 101

- Start small – boot and get serial console
- But serial console is hard, it needs
  - clock – we need clock driver
  - pinmux – we need pinmux driver
  - serial – we need serial driver
- Most parts can be done separately

Starting new port

- Populate `arch/foo/mach-bar` if applicable
  - Add DTS to `arch/foo/dts/`
  - Add at least one board
- Populate board/mymfg/myboard if applicable
  - Add `configs/myboard_defconfig`
  - Add `include/configs/myboard.h`
  - Add `board/mymfg/myboard/Kconfig`
  - Add `board/mymfg/myboard/Makefile`
  - Add `board/mymfg/myboard/myboard.c`
  - Add `arch/foo/mach-bar/Kconfig` entry
- For arch and board specific hooks, see: `common/board_f.c` and `common/board_r.c`
- Most of the code should be in drivers/

U-Boot DM serial driver

```
U_BOOT_DRIVER(serial_sh) = {
	.name	= "serial_sh",
	.id	= UCLASS_SERIAL,
	.ops	= &sh_serial_ops,

	.of_match = of_match_ptr(sh_serial_id),

	.probe = sh_serial_probe,
	.priv_auto_alloc_size = sizeof(struct uart_port),

	.ofdata_to_platdata =
		of_match_ptr(sh_serial_ofdata_to_platdata),
	.platdata_auto_alloc_size =
		sizeof(struct sh_serial_platdata),

	.flags = DM_FLAG_PRE_RELOC,
};
```

U-Boot DM serial driver II

DT matching is done for you!

```
static const struct udevice_id sh_serial_id[] ={
        {.compatible = "renesas,sci", .data = PORT_SCI},
        {.compatible = "renesas,scif", .data = PORT_SCIF},
        {.compatible = "renesas,scifa", .data = PORT_SCIFA},
        {}
};
static int sh_serial_ofdata_to_platdata(struct udevice *dev)
{
        struct sh_serial_platdata *plat = dev_get_platdata(dev);
[...]
        addr = fdtdec_get_addr(gd->fdt_blob, dev_of_offset(dev), "reg");
        if (addr == FDT_ADDR_T_NONE)
                return -EINVAL;
        plat->base = addr;
[...]
}
U_BOOT_DRIVER(serial_sh) = {
    .of_match = of_match_ptr(sh_serial_id),
    .ofdata_to_platdata = of_match_ptr(sh_serial_ofdata_to_platdata),
    .platdata_auto_alloc_size = sizeof(struct sh_serial_platdata),
};
```

U-Boot DM serial driver III

Serial ops, getc, putc, etc. . .

```
static int sh_serial_getc(struct udevice *dev)
{
        struct uart_port *priv = dev_get_priv(dev);

        return sh_serial_getc_generic(priv);
}

static const struct dm_serial_ops sh_serial_ops = {
        .putc = sh_serial_putc,
        .pending = sh_serial_pending,
        .getc = sh_serial_getc,
        .setbrg = sh_serial_setbrg,
};

U_BOOT_DRIVER(serial_sh) = {
    .ops    = &sh_serial_ops,
};
```

Early serial console

Sometimes serial is needed before DM is available:

- Special-purpose code allowing very early prints
- Special-purpose custom print functions:
  - printch(), printascii(), printhex2()...
- CONFIG_DEBUG_UART=y
- Resides in include/debug_uart.h

U-Boot early serial console with DM

See ie. drivers/serial/serial_ar933x.c :

```
#ifdef CONFIG_DEBUG_UART_AR933X
#include <debug_uart.h>

static inline void _debug_uart_init(void)
{
[...]
        writel(val, regs + AR933X_UART_CLK_REG);
}
static inline void _debug_uart_putc(int c)
{
        void __iomem *regs = (void *)CONFIG_DEBUG_UART_BASE;
        u32 data;

        do {
                data = readl(regs + AR933X_UART_DATA_REG);
        } while (!(data & AR933X_UART_DATA_TX_CSR));

        data  = (u32)c | AR933X_UART_DATA_TX_CSR;
        writel(data, regs + AR933X_UART_DATA_REG);
}
DEBUG_UART_FUNCS
#endif
```

Clock framework

Clock provider:

- uses UCLASS_CLK
- implements clk_ops to enable/disable/get/set clock
- Resides in include/clk-uclass.h

Clock consumer:

- Uses clk_*() clock framework functions

U-Boot clock consumer

SH UART driver consumes clock:

```
[...]
    struct sh_serial_platdata *plat = dev_get_platdata(dev);
    struct clk sh_serial_clk;
    int ret;
[...]
    ret = clk_get_by_name(dev, "fck", &sh_serial_clk);
    if (!ret) {
        ret = clk_enable(&sh_serial_clk);
        if (!ret)
            plat->clk = clk_get_rate(&sh_serial_clk);
                                    "clock", 1);
[...]
```

Pinctrl framework

- One framework handles two roles
- uses UCLASS_PINCTRL
- implements pinctrl_ops to configure pins
- operates per-pin, per-group, per-function
- PINMUX – configures pin multiplexing
- PINCONF – configures pin properties (voltage, pull,...)

Pinctrl consumer:

- Can select pin configuration from multiple options
- DM sets default pin configuration based on DT
- Useful ie. when selecting eMMC IO voltage

U-Boot pinctrl consumer

DT node lists two possible pin configurations:

```
&sdhi0 {
        pinctrl-0 = <&sdhi0_pins>;
        pinctrl-1 = <&sdhi0_pins_uhs>;
        pinctrl-names = "default", "state_uhs";
}
```

Uniphier SD driver sets IO voltage:

```
static void uniphier_sd_set_pins(struct udevice *dev)
{
    struct uniphier_sd_priv *priv = dev_get_priv(dev);
    struct mmc *mmc = mmc_get_mmc_dev(dev);
[...]
    if (mmc->signal_voltage == MMC_SIGNAL_VOLTAGE_180)
        pinctrl_select_state(dev, "state_uhs");
    else
        pinctrl_select_state(dev, "default");
}
```

Other frameworks

- Block layer is fully DM capable
- MTD layer needs DM conversion
- DM can trigger size limits!

Low-memory systems

U-Boot SPL – Secondary Program Loader

- Reduced U-Boot build which loads subsequent payload: U-Boot, Linux (falcon mode), ...
- May be very board specific
- DM support is optional
- DT support is optional
- Special CONFIG_SPL_* Kconfig options
  - Allow controlling what goes into SPL vs U-Boot

U-Boot TPL – Tertiary Program Loader

- If SPL is too big, TPL loads SPL
- Full-on custom solution
- Try to avoid this
- For TPL, CONFIG_TPL_* also exists

DT compaction

Standard DT blob is too big

- Unused nodes can be removed
  - Done for U-Boot SPL by default
  - Nodes with special DT property are retained: `u-boot,dm-pre-reloc`
  - LibFDT has `fdtgrep` tool for this
  - Same marker used for drivers that must be started early
- Driver instantiation with platform data
  - DT nodes replaced with C structures linked with U-Boot
  - Useful in size-limited U-Boot SPL
  - LibFDT support can be droppped from SPL (saves quite a bit of .text area)

Conclusion

- Use DT and DM in new U-Boot ports
- Reuse code and drivers as much as possible
- Read the documentation, see `doc/`
- Submit patches
- Reach out to U-Boot community for help:
  IRC: `irc.freenode.net` #u-boot
  ML: `u-boot@lists.denx.de`

The End

Thank you for your attention!

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