U-Boot

porting and maintaining a bootloader for a multimedia SoC family
Who?

- **14y Kernel & Firmware Hacker**
  - Entirely Ported Linux & custom boot chain on custom ARM SoCs
  - Worked with SoC design team

- **5y BayLibre Engineer**
  - Writes support for Amlogic Mainline Linux & U-Boot

- **2y1/2 Amlogic U-Boot Custodian Maintainer**
  - 47 Pull Requests since January 2019
What?

- Amlogic provides a line of Multimedia SoCs
  - Originally designed for low-cost Digital TV / Set-top-box market
- First Single Board Computer with the Odroid-C1
- The following Odroid-C2 became Famous
  - 4xCortex-A53 up to 1.6GHz
  - USB2, Ethernet 10/100/1000
  - HDMI 2.0
  - eMMC, SDCard, 40pin header
  - 2GiB DDR
- The last Odroid-N2+ is much better!
  - 2xCortex-A53@1.8GHz + 4xCortex-A73@2.2GHz
  - USB3.0
  - HDMI 2.1
  - 4GiB DDR
Software Support Status

Amlogic provides an open source vendor kernel tree

- Was 3.14 for Odroid-C2
- The latest is 4.9 for Odroid-N2+
- Driver code doesn’t follow kernel frameworks
  - There is a clock driver, almost unused
  - Since 2017, Amlogic re-used some mainline drivers (with some heavy changes)
  - Display & Decoder/Encoder code is completely custom
  - Drivers are almost not reusable
- DT is completely custom, not reusable
  - Hard to understand for newcomers
Software Support Status

- U-boot is derived from v2015.01 (!!!!!!!)
  - But with a lot of code backported from recent u-boot
  - Melting pot of firmware code and DM code
  - Custom eMMC partition format based on NAND
  - Custom multi-DT boot flow
  - Custom USB Device flash protocol
    - For curious people: https://github.com/superna9999/pyamlboot/blob/master/PROTOCOL.md
  - Drivers are not reusable
Software Support Status

- Amlogic has now a v2019.01 based U-Boot
  - Supports only new SoCs
  - Still too old
  - Vendor code is the same as the v2015.01 version
  - Still not usable as maintainable codebase
Software Support Status

- **SoC Boot flow**
  - Amlogic uses TF-A, PSCI & SCPI since S905
    - Was mandated by ARM for new Armv8 platforms
    - They used a custom boot flow for their Armv7 platforms
  - Amlogic provides binaries only for:
    - BL2: DDR controller and system PLLs Inits
    - BL30: SCP Firmware running on the Cortex-M3
    - BL31: EL3 Runtime Firmware
    - BL32: Secure-EL1 Payload (optional)
  - Build from Amlogic U-Boot Source
    - ACS: DDR controller and system PLLs Settings
    - BL21: Board specific power Init
    - BL301: BL301 open-source loadable part of BL30
Software Support Status

- SoC Boot flow
  - The provided boot flow handle full scrambled and signed secure boot
  - Used for Digital TV products
  - Not Documented...
Software Support Status

● Upstream Status of ARMv8 SoCs (S905 to A311d)
  ○ Great Linux coverage
  ○ Great U-Boot coverage
  ○ Partial TF-A (BL31) is upstream
    ■ BL2/BL30 are very complex to reverse-engineer
    ■ Complex undocumented DDR init
    ■ Tricky and undocumented system PLL init
    ■ Would need documentation to do a clean job
Software Support Status

● Great Linux coverage
  ○ See my other talks
  ○ TL;DW(atch)
    ■ Basic system support is complete
    ■ Basic I/O support is complete
    ■ Partial Multimedia support
      ● Lacks all advanced Digital TV features (HDR, 3D, ...)
      ● Entirely lack Video Encoders support
      ● Partial Video Decoder support (basic H264, VP9, no HEVC)
  ○ → http://linux-meson.com
### Software Support Status

- **Great U-Boot coverage**
  - System support is complete
  - Basic I/O is complete
    - PWM has been merged
  - Advanced I/O is partial
    - Ethernet OK
    - USB OK
    - SD/eMMC OK
    - NAND is missing
    - PCIe/NVMe is missing
  - Video Output is partial
    - DSI output is Ongoing

<table>
<thead>
<tr>
<th>Boards</th>
<th>S905</th>
<th>S905X</th>
<th>S905XK</th>
<th>S912</th>
<th>S905D</th>
<th>A111X</th>
<th>S905K2</th>
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Software Support Status

- **Great U-Boot coverage**
  - All known Amlogic Single Board Computers are supported
    - Except ARMv7 ones… (Odroid-C1)
    - Waiting for Banana Pi BPI-M5 samples :-)
  - Generic Reference Designs are also supported
    - Permits booting products based on Reference Designs
    - P200 (S905)
    - P212 (S905X)
    - Q200 (S905D, S912)
    - W400 (S905X2, S905D2, S905X3, S905D3, S922X, A311D)
    - S400 (A113D)
Software Support Status

- **Great U-Boot coverage**
  - Most drivers were ported from Linux
  - The U-Boot Driver Model helped a lot!
  - NAND driver is missing, the Linux driver exists
  - PCIe driver for NVMe support is missing
  - A few tweaks subsist
    - Ethernet PHY config is still static, this need to be cleaned
    - PHY Mux driver between Internal & external is missing
Software Support Status

- Great U-Boot coverage
  - HDMI Output is supported
  - Display framework is pretty basic but works fine
  - MIPI-DSI Output is implemented
  - U-Boot dm-display EDID handling is primitive
    - Only handles detailed timings
    - Doesn’t have Standard & established timings tables like Linux
    - Doesn’t support HDMI VIC timings
  - Some monitors EDID don’t have their native timing in the detailed timings table
  - → Can’t support HDMI1.4 4K & HDMI2.0 4K timings
Software Support Status

● Great U-Boot coverage
  ○ UEFI support comes for free!
  ○ Great motivation to maintain support upstream
  ○ RNG is supported for Linux KASLR boot
  ○ Runtime Variables are still missing....
    ■ This could need per-board implementation (is possible)
    ■ Only a few board has an on-board SPI NOR flash
Software Support Status

- Used in Real products!
- Example:

La Frite | AML-S805X-AC
https://libre.computer

La Frite default SPI Flash bootloader is Mainline U-Boot!
Supports UEFI boot & eMMC flashing via USB Gadget
Software Support Status

- **U-Boot Upstream Development**
  - Initial support was done by Beniamino Galvani (Thanks !)
  - Only a few non-Baylibre contributors
  - U-Boot process is close to Linux
    - Due to fewer reviewers, non-core patches are less reviewed
    - Has a dedicated mailing-list, easier to track patches
  - U-boot has a handy test suite to validate core code
    - “Sandbox” is U-boot as linux application
    - Can communicate with other Linux process
    - Can run unit tests coordinated from Python
  - U-Boot has a very complete CI
    - Test using Sandbox, only build-tests for other platforms
Software Support Status

- U-Boot binary must be packaged
- U-Boot is part of the TF-A boot chain (Bl33)
- Amlogic used a variant of TF-A FIP format for GXBB
- Since GXL (S905X), Amlogic has their own format
  - Because they have to load numerous firmware
  - They added DDR init firmwares for the lastest SoCs
- Packaging tools are closed source
- Packaging process is not documented
GXL/G12A/G12B/SM1 packaging

$ blx_fix.sh fip/bl30.bin fip/zero_tmp fip/bl30_zero.bin fip/bl301.bin fip/bl301_zero.bin fip/bl30_new.bin bl30
$ acs_tool.pyc fip/bl2.bin fip/bl2_acs.bin fip/acs.bin 0
$ blx_fix.sh fip/bl2_acs.bin fip/zero_tmp fip/bl2_zero.bin fip/bl21.bin fip/bl21_zero.bin fip/bl2_new.bin bl2
$ aml_encrypt --bl3enc --input fip/bl30_new.bin
$ aml_encrypt --bl3enc --input fip/bl31.img
$ aml_encrypt --bl3enc --input fip/bl33.bin
$ aml_encrypt --bl2sig --input fip/bl2_new.bin --output fip/bl2.n.bin.sig
$ aml_encrypt --bootmk --output fip/u-boot.bin --bl2 fip/bl2.n.bin.sig --bl30 fip/bl30_new.bin.enc --bl31 fip/bl31.img.enc --bl33 fip/bl33.bin.enc

Pretty ugly...
Software Support Status

- **GXBB packaging tools has been reverse-engineered**
  - [https://github.com/afaerber/meson-tools](https://github.com/afaerber/meson-tools)
  - Until last year, only supported GXBB (S905)
- **GXL later on**
  - [https://github.com/repk/gxlimg](https://github.com/repk/gxlimg)
- **G12A/G12B/SM1 recently**
  - [https://github.com/angerman/meson64-tools](https://github.com/angerman/meson64-tools)
  - New SoCs has loadable DDR init code
Software Support Status

GXL/G12A/G12B/SM1 packaging

acs.bin
- DDR timings
- PLL settings

bl2.bin
- Board power init

acs_tool
- Power Settings
- Resume code

b2x_fix

bl301.bin
- Power Settings
- Resume code

bl30.bin

bl31.bin

bl32.bin

Optional

Python 2.7 binary (!!!)

bl33.bin
- U-Boot!

bl3enc

bootmk

Bootable Binary

Modifiable Source
In Vendor U-Boot Tree

Bash Script
Software Support Status

- Building bootable binary could trigger legal issues
  - bl2/bl30/bl32 binaries has finally a licence
    - Buildroot rejected due to lack of earlier licence terms
  - Acs.bin, bl21.bin & bl301.bin are part of the Vendor U-Boot source
    - arch/arm/cpu/armv8/gxl/firmware/bl21 → bl21.bin
    - arch/arm/cpu/armv8/gxl/firmware/acs → acs.bin
    - Now have a clear licence: GPL2+
  - Still no clear licence terms for bl301.bin
    - Some has GPL2+ headers, some none

- These could be moved out of vendor U-Boot
  - In a separate repo ? in Mainline U-Boot ?
Software Support Status

Amlogic Binary Distribution Licence

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Software Support Status

GXL/G12A/G12B/SM1 packaging

- **acs.bin**: DDR timings, PLL settings
- **bl2.bin**: Board power init
- **bl21.bin**: Board power init
- **bl2.sign**: Python 2.7 binary (!!!)
- **bl301.bin**: Power settings, Resume code
- **bl2.sign**: Python 2.7 binary (!!!)
- **bl30.bin**: Bootable Binary
- **bl31.bin**: Bootable Binary
- **bl32.bin**: Bootable Binary
- **bl33.bin**: U-Boot!
- **blix_fix**: Amlogic Binary Licence

- **GPL2+ Source**
- **Either Amlogic Binary Licence Or GPL2+ (Partial) Implementation**
Software Support Status

- Partial TF-A (BL31) is upstream for GXBB (S905)
  - First ArmV8 SoC
  - AES/SHA Accelerator are non-functional
  - Boot ROM has flaws
  - "Amlogic S905 SoC: bypassing the (not so) Secure Boot to dump the BootROM"
  - Upstream TF-A is partial
    - Doesn’t support Suspend/Resume
    - Doesn’t support Secure Boot (AFAIK untested)
Software Support Status

- Partial TF-A (BL31) is upstream for GXL (S905X/S905D)
  - Third generation ArmV8 SoC (GXTVBB for TVs is second)
  - AES/SHA Accelerator are functional, secure boot should be secure
  - Upstream TF-A is partial
    - Doesn't support Suspend/Resume
    - Doesn't support Secure Boot (AFAIK untested)
    - Doesn't support GXM (S912) variant for 8xCortex-A53
      - Doesn't support enabling second Cortex-A53 cluster
Software Support Status

- Partial TF-A (BL31) is upstream for AXG (A113D)
  - Fourth generation ArmV8 SoC, variant for Audio Applications
  - AES/SHA Accelerator are functional, secure boot should be secure
  - Upstream TF-A is partial
    - Doesn't support Suspend/Resume
    - Doesn't support Secure Boot (AFAIK untested)
Software Support Status

- Partial TF-A (BL31) is upstream for G12A (S905X2/S905D2)
  - Modern(ish) generation ArmV8 SoC
  - AES/SHA Accelerator are functional, secure boot should be secure
  - Upstream TF-A is partial
    - Doesn't support Suspend/Resume
    - Doesn't support Secure Boot (AFAIK untested)
    - Doesn't support G12B (S922X/A311d) variant
      - Doesn't support enabling second Cortex-A73 cluster
    - Doesn't support (yet) SM1 variant
      - Only difference from BL1 is the CPU model: Cortex-A55
Missing Features

• Secure Boot
  ○ These SoCs are designed for Secure products
  ○ Real-World secure boot is really complex
  ○ Tools are private, closed source & undocumented
  ○ Secure eFuse Map is undocumented, **bad fuse map could brick the device**
  ○ eFuse programming sequence is undocumented
  ○ But, only BL33 trusted boot would be enough!

• Unified Open Source boot tools
  ○ Today 3 different tools

• Full Open Source TF-A
  ○ Not sure this will happen one day...
Missing Features

- **U-Boot Support**
  - NAND
  - PCIe
  - Old ARMv7 SoCs support
  - EFI Runtime Variables

- **Testing**
  - Regular and complete boot testing is missing
  - We need a true CI to boot-test on major boards