How I survived to a SoC with a terrible Linux BSP

Working with jurassic vendor kernels, missing pieces and buggy code

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About me

- Embedded Linux engineer at AIM Sportline
  `http://www.aim-sportline.com/`
  - Develop real products on custom hardware
  - Kernel, bootloader, drivers
  - Integration, build system
- Open source enthusiast
  - Contributor to Buildroot and a few other projects

Introduction

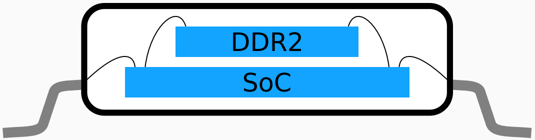
The ideal BSP

- BSP = Board Support Package
- The ideal BSP
  - Mainline kernel
  - Mainline U-Boot or Barebox
  - Good hardware documentation

The System on Chip

Nuvoton N32926

- ARM926EJ-S @ 240 MHz
- Peripherals: H.264 en/decoder, Ethernet MAC, USB, CMOS sensor interface, video out, LCD controller, sound, ...
- 64 MB DDR2 *in package*
- LQFP package
- Ideal application: low cost IP camera



Source: `https://www.nuvoton.com/hq/products/microprocessors/arm9-mpus/n3292-h.264-codec-series/n32926u1dn`

My Quest

My quest

- Documentation
- Linux kernel
- Booting
- Tools
- Customer support

Documentation

Public documentation

- An 8-page datasheet (mostly a list of features)

From: https://www.nuvoton.com/hq/products/microprocessors/arm9-mpus/n3292-h.264-codec-series/n32926u1dn

Documentation for customers

- Only under NDA

Accessible documentation

- A "low-cost" devkit is available from chinese online stores
- Contains a DVD-ROM with a subset of the BSP for customers
  - Documentation and software
  - Contains the N3292x Design Guide
    - SoC peripherals (registers)

Linux kernel

Vendor kernel VS mainline kernel

Base kernel: Linux 2.6.35.4 (2010)

2.6.35.4 → 2.6.35.14
(latest stable)

- 11 months
- 1382 bugfix commits
- Merged with minimal conflicts

2.6.35.14 → 4.13.y
(latest mainline)

- A countless number of fixes, improvements, new features
- Security
- Device Tree
- New device drivers!

Vendor kernel additions

- Total: 170.000 lines changed
- Provided as patches:
  - `w55fa92-kernel-2.6.35-000.patch` (3.6 MB)
  - `w55fa92-kernel-2.6.35-001.patch` (1.4 MB)
  - `w55fa92-kernel-2.6.35-002.patch` (0.4 MB)
  - `do_kernel_patch.sh`

Vendor kernel issues

1. Bugs
2. Missing features
3. Code quality

Bugs

Examples:

- Sound Processing Unit ALSA driver
  - `arecord myfile.wav` $\rightarrow$ kernel crash
    - `NULL` pointer dereference
- H.264 decoder driver
  - Works with sample streams
  - Kernel crash on streaming packet loss
    - Several `NULL` pointer dereferences

Missing features

Examples:

- GPIO
  - Basic functionality is implemented
  - No interrupt handling
- Power Management
  - Implemented with a proprietary API
  - Also implemented the Linux standard way, but incomplete and not working

Code quality

- Average quality of additions: generally bad
- Trivial metric: +521 lines starting with `#if 0`
- A few examples follow

Code quality: driver model

drivers/video/w55fa92_fb.c:

```
#ifdef  CONFIG_GIANTPLUS_GPM1006D0_320X240
#include "w55fa92_GIANTPLUS_GPM1006D0.c"
#endif

#ifdef  CONFIG_TOPPLY_320X240
#include "w55fa92_TOPPLY_320x240.c"
#endif

/* ...5 more displays... */

#if 0
  #ifdef  CONFIG_SHARP_LQ035Q1DH02_320X240
  #include "w55fa92_Sharp_LQ035Q1DH02.c"
  #endif

  #ifdef  CONFIG_WINTEK_WMF3324_320X240
  #include "w55fa92_Wintek_WMF3324.c"
  #endif

  /* ...5 more displays... */
#endif
```

Code quality: H.264 codec memory allocation

drivers/misc/codec264/favc_module.c:

```
unsigned int get_avc_buffer_size(void)
{
  /* ...~90 lines... */
  return TOTAL_VDE_BUF_SIZE;
}
EXPORT_SYMBOL(get_avc_buffer_size);
```

From arch/arm/mm/mmu.c:

```
extern unsigned int get_avc_buffer_size(void);
void __init reserve_node_zero(pg_data_t *pgdat)
{
  /* ... */
  buffer_size = get_avc_buffer_size();
  printk("AVC Buffer Size: 0x%x\n",buffer_size);
  w55fa92_vde_v = alloc_bootmem_low_pages (buffer_size);
  /* ... */
}
```

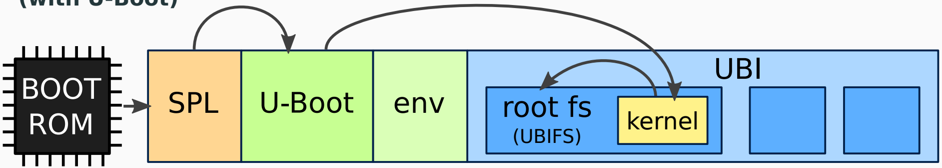
Booting

Bootloaders in the BSP

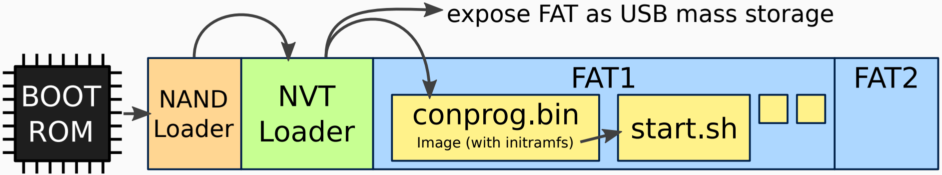
- No U-Boot
- No Barebox
- Some proprietary bootloaders
  - Sources provided, but not open source (“All rights reserved”)
  - Tied to the SoC

Vendor booting scheme (NAND example)

A common booting scheme
(with U-Boot)



Nuvoton N32926



Vendor booting scheme pros

- Easy deployment of demos provided by vendor
    1. Press a button during boot
    2. Mount mass storage on PC
    3. Replace files

Vendor booting scheme issues /1

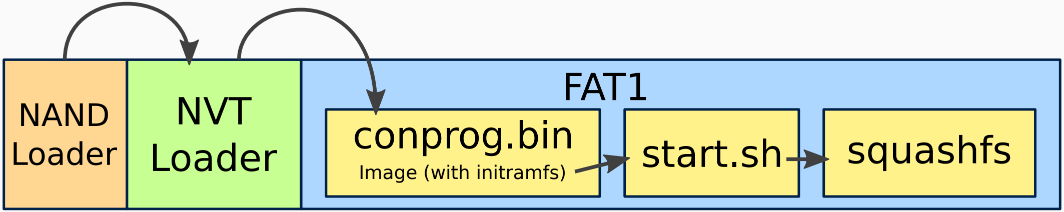
- FAT
  - Unreliable on power loss
  - It just cannot contain a UNIX-like rootfs
- NAND FTL (Flash Translation Layer)
  - FAT-on-NAND emulation (with FTL) is in a binary module
  - NVT Loader cannot mount UBIFS
- No provision for redundancy
- Data may be accessble to users *in production*

Vendor booting scheme issues /2

- Root filesystem is an initramfs
  - Volatile
  - Uses RAM
- NVT Loader does not pass cmdline to kernel
  - it must be hard-coded in the kernel (`CONFIG_CMDLINE`)
- NFS booting
  - Needs cmdline parameters $\rightarrow$ must rebuild and reflash the kernel
- Cannot load kernel via TFTP

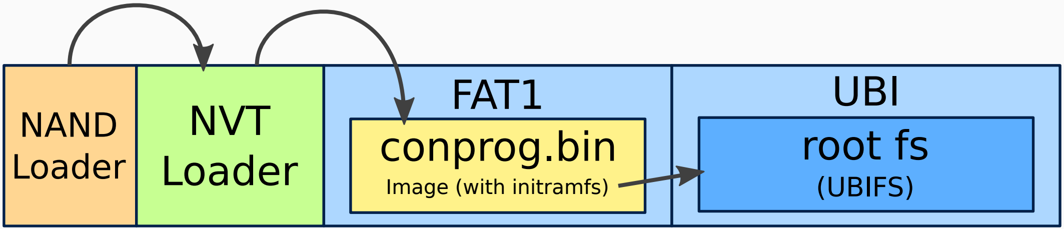
Alternative booting options?

Option 1: add a SquashFS layer on top of FAT



- Keep the existing structure untouched
- Remove initramfs constraints
- Still read-only
  - ext2 or any other rw filesystem over FAT over NAND is crazy
- The device cannot atomically upgrade itself

Option 2: jump from FAT to UBIFS



- UBI and UBIFS are designed for NAND!
- Tweaks needed
  - Change the initramfs `/init` to mount UBIFS and `switch_root`
  - Tweak NVT Loader not to use all space for FAT
- USB mass storage can only update kernel
- FAT area atrophied, NVT Loader almost useless

Option 3: skip NVT Loader

- NAND Loader loads `Image` to address `0` and jumps there
- No more NVT Loader and FAT
- Kernel still on bare NAND and without cmdline
- Replacement for the U-Boot environment?

Option 4: Port U-Boot

- Port U-Boot or Barebox to the SoC
  - Maybe keeping the vendor NAND Loader (SPL)
- Unleashes all the known advantages
  - Environment, boot-time scripting, prompt
  - cmdline, TFTP boot, kernel loading from rootfs
  - Redundancy for all/most components on bare NAND
- Time to market?

Tools

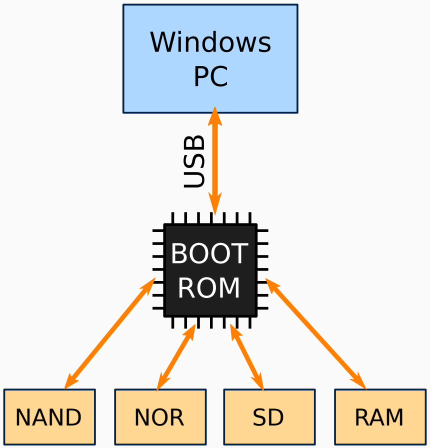
Vendor tools

- Ideally, no vendor-specific tools are needed
- Flashing an empty memory is different
  - Boot ROM protocol is not standardized
  - Vendor-specific tools

Flashing tools

- Tool provided to write memory
- Quite flexible
  - Can write NAND, SPI, SD, SDRAM (and execute)
  - Over USB
- GUI, not scriptable
- For Windows only
- Proprietary, binary only
- Protocol to Boot ROM not documented

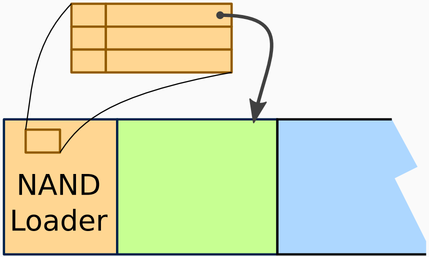
→ You're locked to it



NAND partition table

- Proprietary partition table in the NAND Loader area
- The proprietary tool writes only this format
- Not a bad idea
  - but standard tools work differently

→ You can't get rid of the table



Customer support

A real e-mail exchange (short form)

Me The proprietary tool doesn't work

A real e-mail exchange (short form)

Me The proprietary tool doesn’t work

CS Works on my PC, see screenshot

A real e-mail exchange (short form)

Me The proprietary tool doesn't work

CS Works on my PC, see screenshot

Me Not on mine; can it log errors so you can diagnose it?

A real e-mail exchange (short form)

Me The proprietary tool doesn't work

CS Works on my PC, see screenshot

Me Not on mine; can it log errors so you can diagnose it?

CS Adding logging would not be practical

Concluding remarks

The result

Comparison with a well-supported SoC

- Higher development cost
- Longer time-to-market
- Final product quality is lower
  - The hardware would allow to do better

What can I do to improve things?

- As an embedded Linux engineer
  - Assess potential problems early while evaluating a SoC
- As a hobbyist or a hacker
  - Pick boards with good mainline support, or...
  - Improve existing support and mainline it

What can vendors do to ship better BSPs?

- Don't reinvent the wheel
- Write good docs, no NDA, no registration
  - Including your Boot ROM protocol
    - And let people write the tools they want
- Push your code to mainline
- Leverage the community
  - Let your engineers use mailing-lists, IRC etc
  - Make cheap, hacker-friendly boards

A possible idea?

A possible idea?

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A possible idea?

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Questions?

Thank you for your attention!

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References

- Stuck in 2009 — How I Survived
  Will Sheppard, Embedded Bits Limited
  ELC-E 2016
  `https://elinux.org/ELC_Europe_2016_Presentations`
- How I survived to a SoC with a terrible Linux BSP
  Luca Ceresoli
  FOSDEM 2016
  (Previous version of this talk)
  `https://archive.fosdem.org/2017/schedule/event/terrible_bsp/`

Extra Slides

Kernel code quality — Extra examples

Kernel code quality — example 1

Changes to Makefile:

```
-ARCH?= $(SUBARCH)
-CROSS_COMPILE?=
-CROSS_COMPILE?= $(CONFIG_CROSS_COMPILE:''%''=%)
+#ARCH?= $(SUBARCH)
+ARCH= arm
+#CROSS_COMPILE?=
+#CROSS_COMPILE?= $(CONFIG_CROSS_COMPILE:''%''=%)
+CROSS_COMPILE= arm-linux-
```

- Prevents using toolchains with a different prefix
- Any advantage?

Kernel code quality — example 2

Changes to `arch/arm/boot/Makefile`:

```
 $(obj)/Image: vmlinux FORCE
         $(call if_changed,objcopy)
         @echo '  Kernel: $@ is ready'

+ifeq ($(CONFIG_ARCH_W55FA92),y)
+        cp $@   ../image/conprog.bin
+endif
```

- `../image/` does not make sense in any buildsystem

Kernel code quality — example 3

`sound/soc/w55fa92/w55fa92_spu.c`:

```
if (nChannels ==1)
{
    DrvSPU_EnableInt(_u8Channel0, DRVSPU_ENDADDRESS_INT);
    DrvSPU_EnableInt(_u8Channel0, DRVSPU_THADDRESS_INT);
}
else
{    /* just open one channel interrupt */
    DrvSPU_EnableInt(_u8Channel0, DRVSPU_ENDADDRESS_INT);
    DrvSPU_EnableInt(_u8Channel0, DRVSPU_THADDRESS_INT);
}
```

- Find the differences between the *then* and the *else* branch

Kernel code quality — example 4

sound/soc/w55fa92/w55fa92_spu.c:

```
static int DrvSPU_EnableInt(u32 u32Channel, u32 u32InterruptFlag)
{
  if ( (u32Channel >=eDRVSPU_CHANNEL_0) && (u32Channel <=eDRVSPU_CHANNEL_31) )
  {
    /* ... */
    if (u32InterruptFlag & DRVSPU_USER_INT)
    {
      AUDIO_WRITE(REG_SPU_CH_EVENT, AUDIO_READ(REG_SPU_CH_EVENT) | EV_USR_EN);
    }
    if (u32InterruptFlag & DRVSPU_SILENT_INT)
    {
      AUDIO_WRITE(REG_SPU_CH_EVENT, AUDIO_READ(REG_SPU_CH_EVENT) | EV_SLN_EN);
    }
    /* ...a few more times... */

    /* ... */
    return E_SUCCESS;
  }
  else
    return E_DRVSPU_WRONG_CHANNEL;
}
```

Kernel code quality — example 5

arch/arm/mach-w55fa92/include/mach/w55fa92_gpio.h:

```
static inline int w55fa92_gpio_configure(int group, int num) {
  /* ... */
    case GPIO_GROUP_B:
      if(num <= 7)
        writel(readl(REG_GPBFUN0) &~ (0xF << (num<<2)), REG_GPBFUN0);
      else
        writel(readl(REG_GPBFUN1) &~ (0xF << ((num%8)<<2)), REG_GPBFUN1);
      break;

    case GPIO_GROUP_C:
      if(num <= 7)
        writel(readl(REG_GPCFUN0) &~ (0xF << (num<<2)), REG_GPCFUN0);
      else
        writel(readl(REG_GPCFUN1) &~ (0xF << ((num%8)<<2)), REG_GPCFUN1);
      break;
  /* ...similarly fo other GPIO ports... */
}
```

- A little refactoring would help

Toolchain

Vendor toolchain

- The BSP provides a toolchain.
  - Why?
- What's inside
  - gcc 4.2.1 (July 2007)
    - No C++11 support
    - gcc 4.2.x got fixes until 4.2.4 (May 2008)
  - uClibc 0.9.29 (2007)
    - What if I need glibc or musl?
    - Bugfixes and improvements in later versions?
  - A few other libraries (libcurl, libpng ...)
  - A hand-crafted script to install it at a hard-coded location

Toolchain selection

- Don't use the provided toolchain
- You could use a pre-built toolchain
  - If it has been built with kernel headers <= 2.6.35
  - So it's probably quite old itself
- Build your own
  - crosstool-NG, Buildroot, Openembedded...

Using an old gcc — an example

A C++ program using libconfuse 3.0

```
#include <confuse.h>
//...
cfg_opt_t opts[] =
{
  CFG_STR("my-param", "defval", CFGF_NONE),
  CFG_END()
};
```

With gcc $<=$ 4.8 fails building due to designated initializers not being implemented:

```
error: expected primary-expression before '.' token
```