GARDENA IoT Gateway

A Journey from Anxiety to Collaboration

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Introduction

About Us

Reto Schneider

- Embedded Developer GARDENA in Zurich
- little prior experience with Embedded Linux

Andreas Müller

- Embedded Developer (and Head of Embedded) GARDENA in Zurich
- no prior experience with Yocto Linux

GARDENA

GARDENA smart system

Gateway/Project Background

Project Goals

- lower hardware costs
- maintainability for 10+ years
- open-source compliance

Challenges

- distributed part-time team
- no backup plan
- timeline: 1 year from project start to sale

Goals Of This Talk

We would like to talk about

- the technical aspects of our gateway
- GARDENA's open-source journey
- mainlining: status, benefits & how to convince your boss
- (our pitfalls and how to avoid them)
- (hacking our gateway)

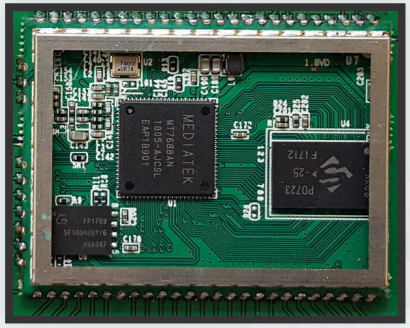
Caveats

- the journey is ongoing; a lot is still left to do
- we are neither Yocto nor Embedded Linux experts


Technical Background

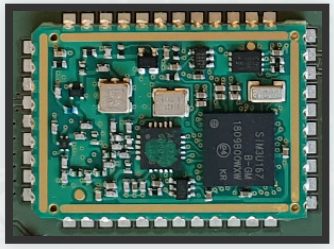
Hardware

Semi-custom Linux module with



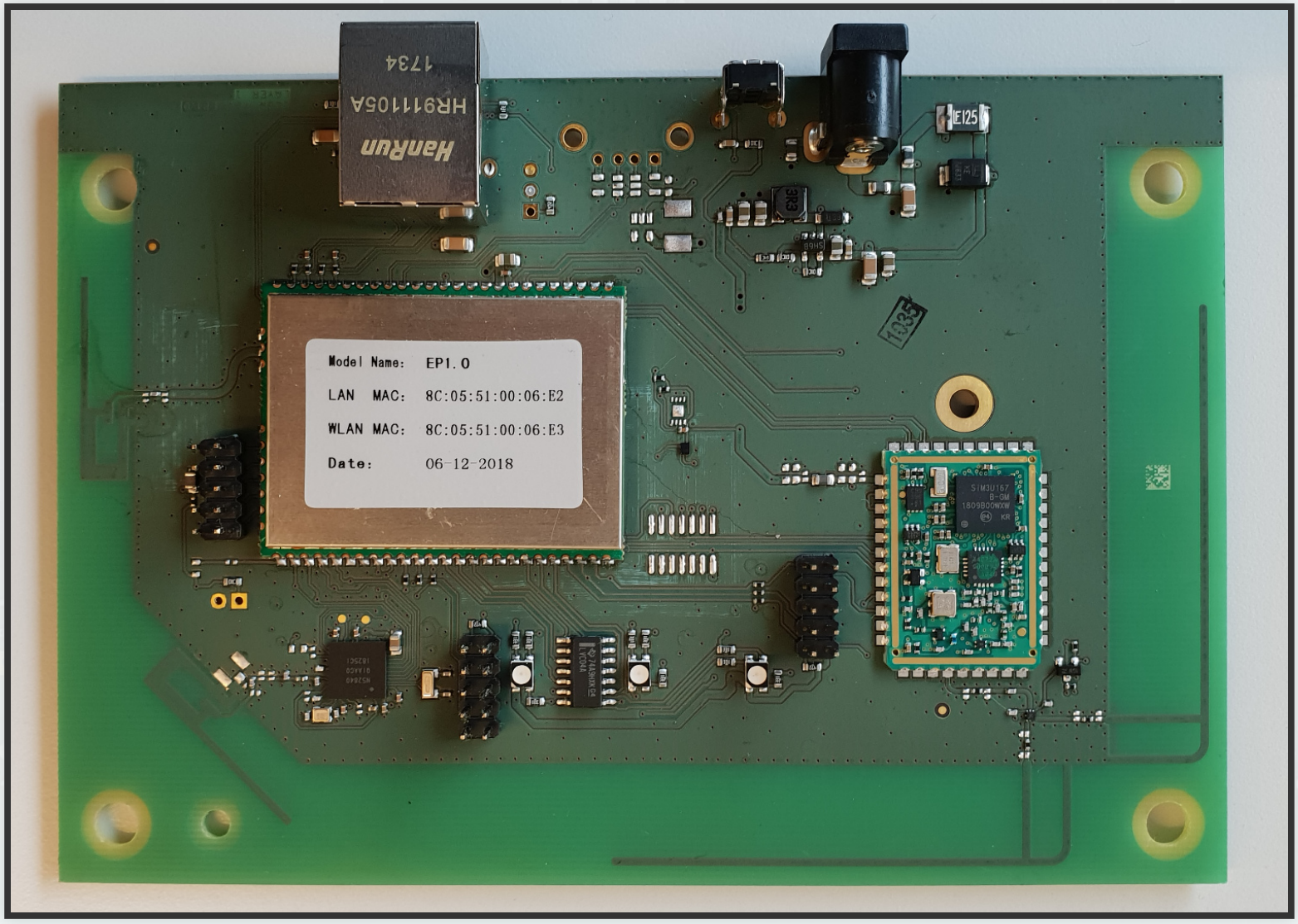
- MediaTek MT7688 SoC
  - 580MHz MIPS 24KEc CPU
  - integrated Wi-Fi
- 128MB DDR2 RAM
- 8MB SPI NOR flash
- 128MB SPI NAND flash

Radio module for communication with devices

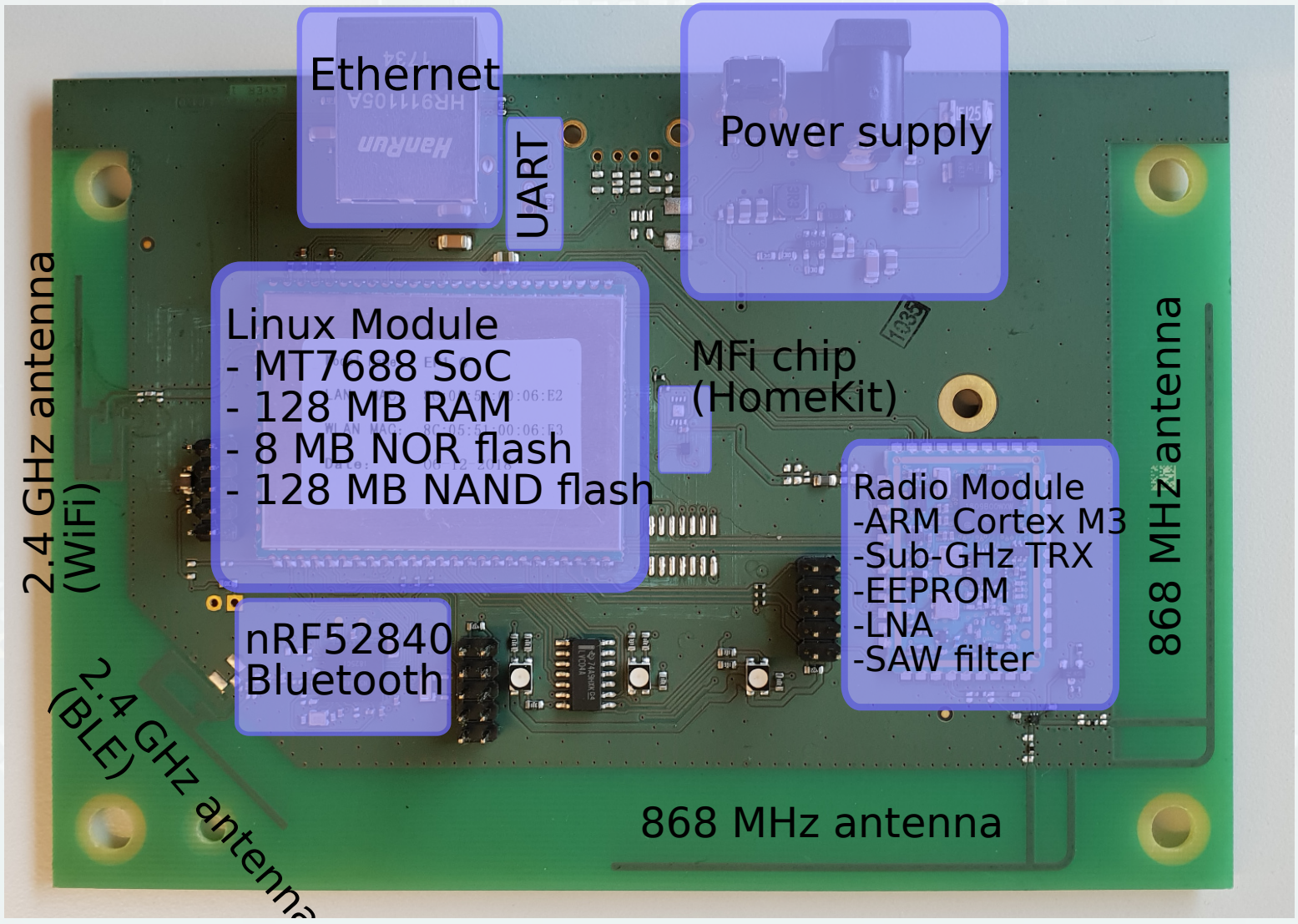


- SiM3U167 ARM Cortex-M3 MCU
- Si4476 Sub-GHz transceiver

Hardware – PCBA



Hardware – Details



Software – Flash Layouts

8 MB NOR:

- uboot: U-Boot code (640 kB)
- uboot_env0: U-Boot environment #1 (64 kB)
- uboot_env1: U-Boot environment #2 (64 kB)
- factory: calibration and configuration for MT7688 (64 kB)
- unused: free space (7360 kB)

128 MB NAND (UBI device with multiple volumes):

- rootfs0: squashfs (40 MB)
- rootfs1: squashfs (40 MB)
- kernel0: fitImage (4 MB)
- kernel1: fitImage (4 MB)
- overlay: UBIFS (30 MB)

Software – Build System

Mostly off the shelf plus own layers for...

- distribution
- custom packages
- 3rd-party software
- MediaTek MT7688 BSP
- device firmwares


Open-Source from Scratch

Golem.de Calling Us Out

Bezeichnend ist auch der Umgang von Gardena mit der genutzten Open-Source-Software. Auf mehrfache Nachfrage zur Herausgabe des Quellcodes hieß es stets: Der Open-Source-Code wie der Linux-Kernel sei unverändert übernommen worden und müsse daher nicht herausgegeben werden - ein klarer Verstoß gegen die Lizenzbedingungen. Es fehlt auch die Angabe eines *"Written Offer"*, also einer Adresse, über die der Quellcode bezogen werden kann.

https://www.golem.de/1605/120646

Attempt #1

Smart Garden Issues / SGISSUE-632

Legal issues with gateway

Edit | Comment | Assign | More | Start Test | Won't Fix Issue | Reject Issue

Details

Type:	Bug	Status:	IN PROGRESS (View Workflow)
Priority:	Highest	Resolution:	Unresolved
Affects Version/s:	None		
Component/s:	Gateway		
Labels:	None		
PI Priority:	PI Arena		
Sub-Group:	9031		

Progress?

[redacted] added a comment - 2017-05-12 15:33

I priorized this issue down to "MEDIUM", since it is no release blocker.

Reto Schneider added a comment - 2017-07-24 09:24

How much progress here?

Reto Schneider added a comment - 2017-07-28 12:35

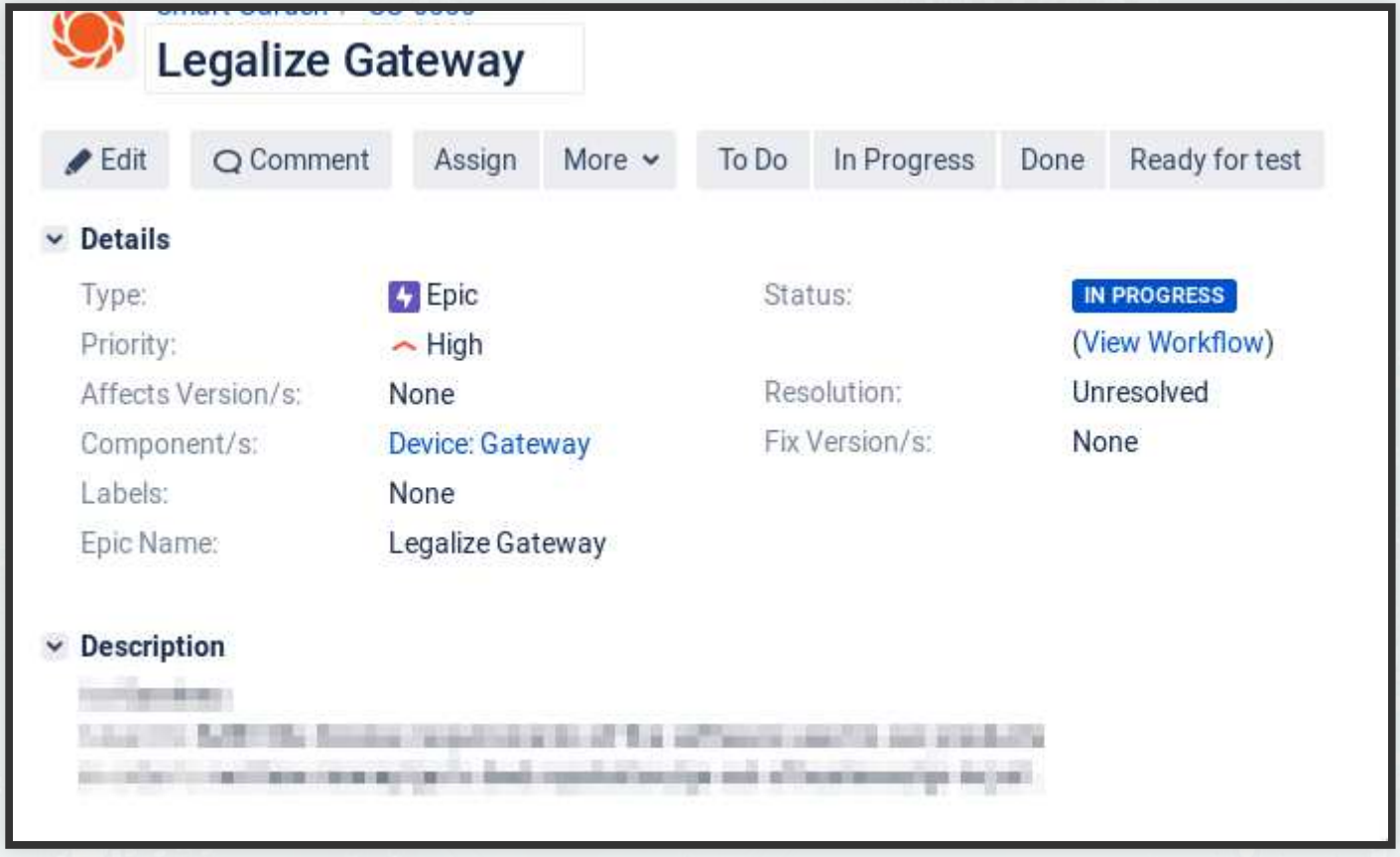
Back to highest as this issue has a chance of hampering or even killing our business and/or reputation.

Money, Money, Money...

Die angedrohte Strafe ist happig: 250.000 Euro Ordnungsgeld oder ersatzweise bis zu sechs Monate Haft drohen Mike Decker, Geschäftsführer der Firma Geniatech Europe aus Herzogenrath bei Aachen, sollte er noch einmal das freie Betriebssystem Linux verbreiten und dabei gegen die komplizierten Lizenzbedingungen verstoßen. Erstritten hat das Urteil des Landgerichtes Köln der in der Szene umstrittene Entwickler Patrick McHardy. Am kommenden Mittwoch wird sich das Oberlandesgericht Köln mit dem Fall beschäftigen.

https://heise.de/-3986181

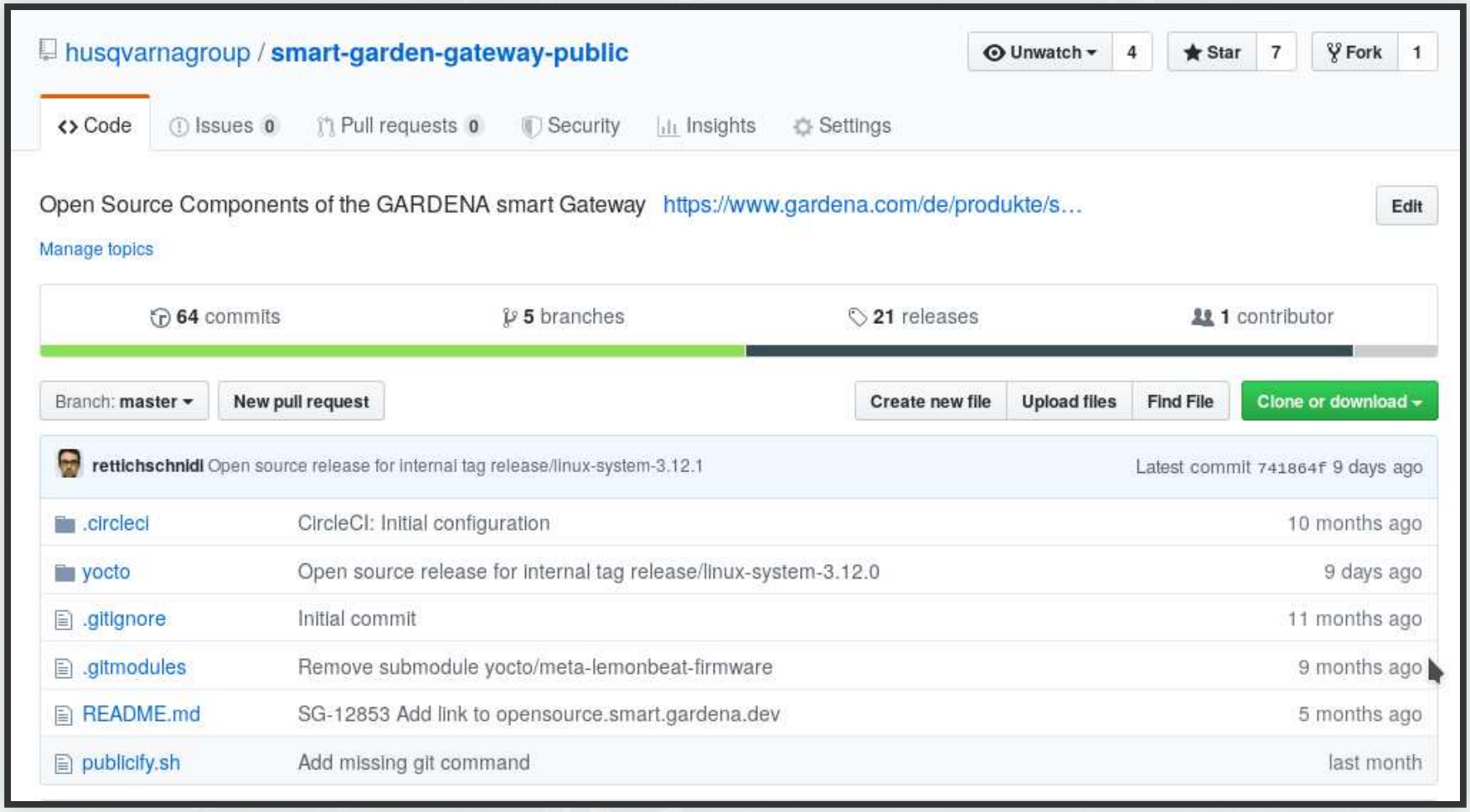
Attempt #2


Legalize Gateway
Edit
Comment
Assign
More
To Do
In Progress
Done
Ready for test
Details
Type:
Epic
Status:
IN PROGRESS
Priority:
High
(View Workflow)
Affects Version/s:
None
Resolution:
Unresolved
Component/s:
Device: Gateway
Fix Version/s:
None
Labels:
None
Epic Name:
Legalize Gateway
Description

Progress

Problem (legally) resolved, but some internal improvements still outstanding.

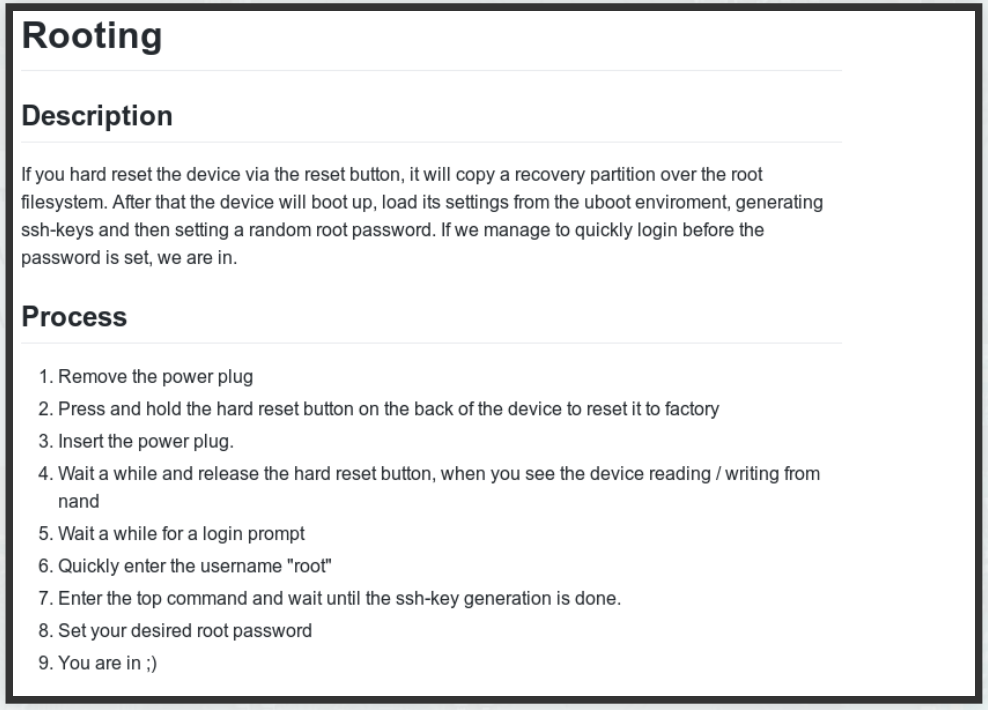
Results: Code on GitHub



https://github.com/husqvarnagroup/smart-garden-gateway-public


Keeping the Products Open

First Gateway: Reverse Engineering by Customers



Rooting

Description

If you hard reset the device via the reset button, it will copy a recovery partition over the root filesystem. After that the device will boot up, load its settings from the uboot enviroment, generating ssh-keys and then setting a random root password. If we manage to quickly login before the password is set, we are in.

Process

1. Remove the power plug
2. Press and hold the hard reset button on the back of the device to reset it to factory
3. Insert the power plug.
4. Wait a while and release the hard reset button, when you see the device reading / writing from nand
5. Wait a while for a login prompt
6. Quickly enter the username "root"
7. Enter the top command and wait until the ssh-key generation is done.
8. Set your desired root password
9. You are in ;)

https://github.com/gardena-smart-reverse-engineering/

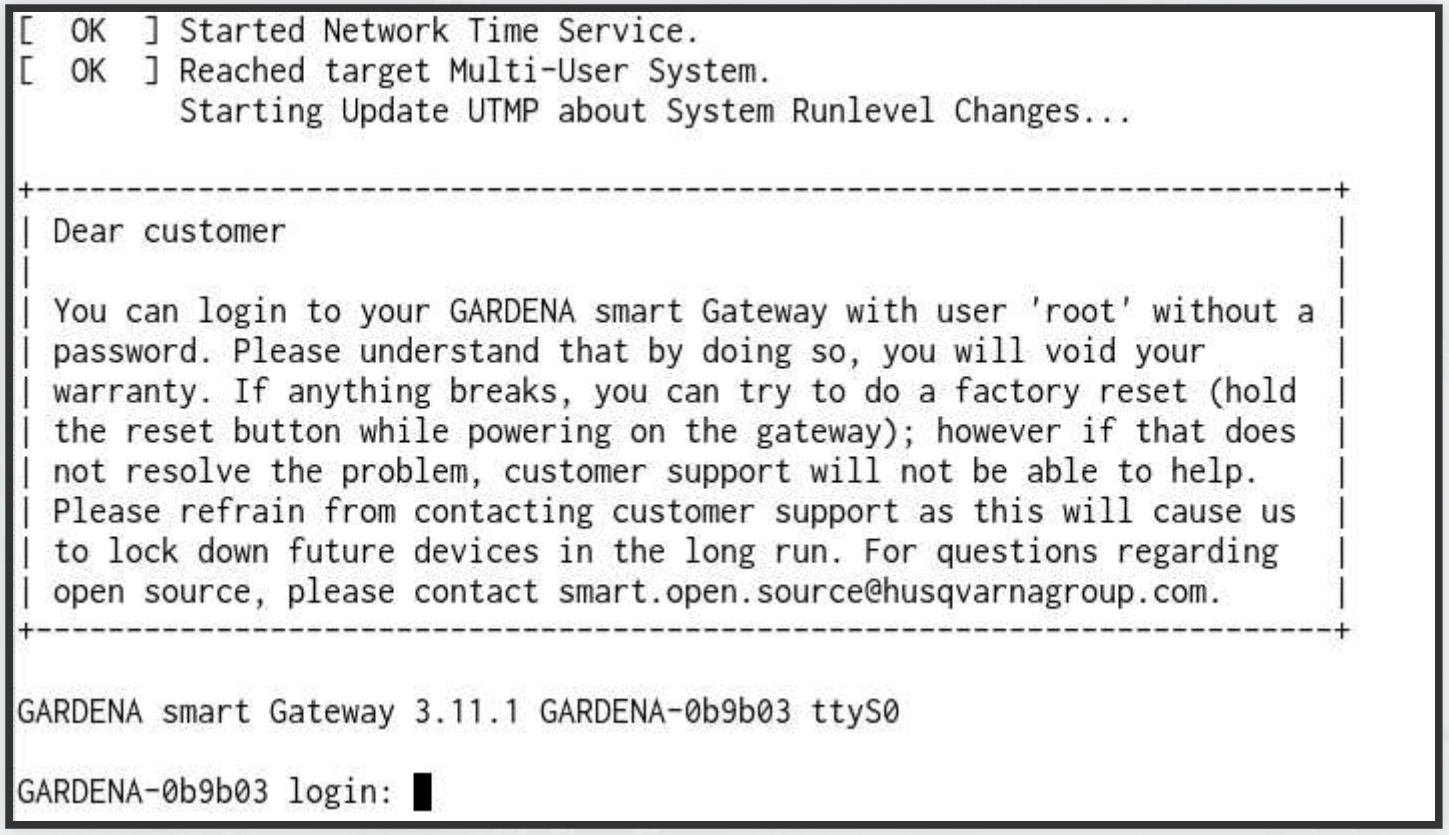
Developers Perspective

- reliable lockdown is difficult and expensive
- local security is not important here
  - much easier for an attacker to just turn off the water in the garden, than to access the gateway inside the house
- you buy it, you own it
- conclusion: we would prefer to just leave local root access via UART open

Quality Department: Convincing & Explaining

(note: SSH password was never empty)

Result


[OK] Started Network Time Service.
[OK] Reached target Multi-User System.
Starting Update UTMP about System Runlevel Changes...
Dear customer
You can login to your GARDENA smart Gateway with user 'root' without a password. Please understand that by doing so, you will void your warranty. If anything breaks, you can try to do a factory reset (hold the reset button while powering on the gateway); however if that does not resolve the problem, customer support will not be able to help. Please refrain from contacting customer support as this will cause us to lock down future devices in the long run. For questions regarding open source, please contact smart.open.source@husqvarnagroup.com.
GARDENA smart Gateway 3.11.1 GARDENA-0b9b03 ttyS0
GARDENA-0b9b03 login:


Mainline FTW

MT7688 Support in April 2018

MediaTek:

- U-Boot: based on 1.1.3 from 2005
- Linux: 2.6.x
- OpenWrt: 3.10 from 2014

Upstream:

- U-Boot: No support at all
- Linux: Not supported
- OpenWrt: Supported, Linux 4.14 (LTS)

MT7688 Support: Way Out (Plan)

U-Boot

- hired U-Boot initiator (DENX) to implement support for our hardware

Linux

- ported patches over from OpenWrt

Management Rationale

- lower project risk
- cost savings with smaller NOR flash

November 2018

- U-Boot support worked very well
- keeping DENX to work on updating to Linux 4.19 (LTS)
- impending manufacturing start and sale for gardening season 2019

Mainlining Win #1: Wi-Fi Alliance Certification

Solution: Hire (very motivated) mt76 maintainer, solved 45 man hours later

Mainlining Win #2: BitFlips

January 2019: 30 out of 250 devices failed selftest

```
[16401.605487] ubi0: scrubbed PEB 340 (LEB 0:76), data moved to PEB 354
[16401.616238] ubi0: fixable bit-flip detected at PEB 354
[16401.616254] ubi0: schedule PEB 354 for scrubbing
[16401.661569] ubi0: fixable bit-flip detected at PEB 354
[16401.730866] ubi0: scrubbed PEB 354 (LEB 0:76), data moved to PEB 340
[16401.736318] ubi0: fixable bit-flip detected at PEB 340
[16401.736335] ubi0: schedule PEB 340 for scrubbing
```

Solution: Kernel 4.19 with new, mainline SPI-NAND framework

October 2019

Results so far:

- project successful
- MT7688 well supported in upstream Linux and U-Boot
- mt76 WLAN driver passed certification for at least two other companies

Follow up project:

- porting old gateway to new code base
- upstream support to Linux and U-Boot

Mainlining Conclusion

Probably best risk reduction we had

- mainlining cost less than 10% of the project budget
- project likely would have failed without it

Upstreaming as much as possible is in our own best interest

- small embedded team
- maintenance done by 2 embedded devs (us; part-time)
- upstreaming keeps our future workload low
- synergies with other MT7688 users

Outsourcing helped with speed and quality

- DENX and embeDD are much better with low-level work

Questions & Contact Info

Thank you for your attention

Questions?

Feedback? Ideas? Let us know!

- pull requests are also welcome :-)

Contact

- smart.open.source@husqvarnagroup.com
- reto.schneider@husqvarnagroup.com
- andreas.mueller@husqvarnagroup.com

Fun & Adventures (Backup)

Certificates

- during manufacturing, the bootstrapping server generates a key/certificate pair
- the certificate is signed by a service on an external server (bad idea!)
- at one point, this server started simply returning an empty body, rather than the certificate (but still HTTP status 200 OK)
- we were lucky to have a test

```
def test_013_openvpn_client_certificate(self):
  """Check the plausibility of the stored OpenVPN certificate"""
  conf_openvpn_crt = fw_getenv("conf_openvpn_crt")
  self.assertTrue(conf_openvpn_crt)
  self.assertTrue('%-----BEGIN CERTIFICATE-----%' in conf_openvpn_crt)
  self.assertTrue('%-----END CERTIFICATE-----' in conf_openvpn_crt)
```

Python Cache Problems (I)

Symptoms:

```
root@GARDENA-0b8a80:/usr/lib/python3.5/site-packages# /usr/bin/ipr-setup
Traceback (most recent call last):
  File "/usr/bin/ipr-tool", line 186, in <module>
    main()
  File "/usr/bin/ipr-tool", line 178, in main
    initialize_gateway_id()
  File "/usr/bin/ipr-tool", line 56, in initialize_gateway_id
    batch_id = get_batch_id()
  File "/usr/bin/ipr-tool", line 32, in get_batch_id
    body = bootstrap_get_batch()
  File "/usr/lib/python3.5/site-packages/bootstrap.py", line 64, in bootstrap_
    return bootstrap_server_get(BOOTSTRAP_SERVER_BATCH_CONFIG_PATH)
  File "/usr/lib/python3.5/site-packages/bootstrap.py", line 30, in bootstrap_
    connection.request("GET", path)
  File "/usr/lib/python3.5/http/client.py", line 1107, in request
    self._send_request(method, url, body, headers)
  File "/usr/lib/python3.5/http/client.py", line 1152, in _send_request
```

Python Cache Problems (II)

Problem analysis:

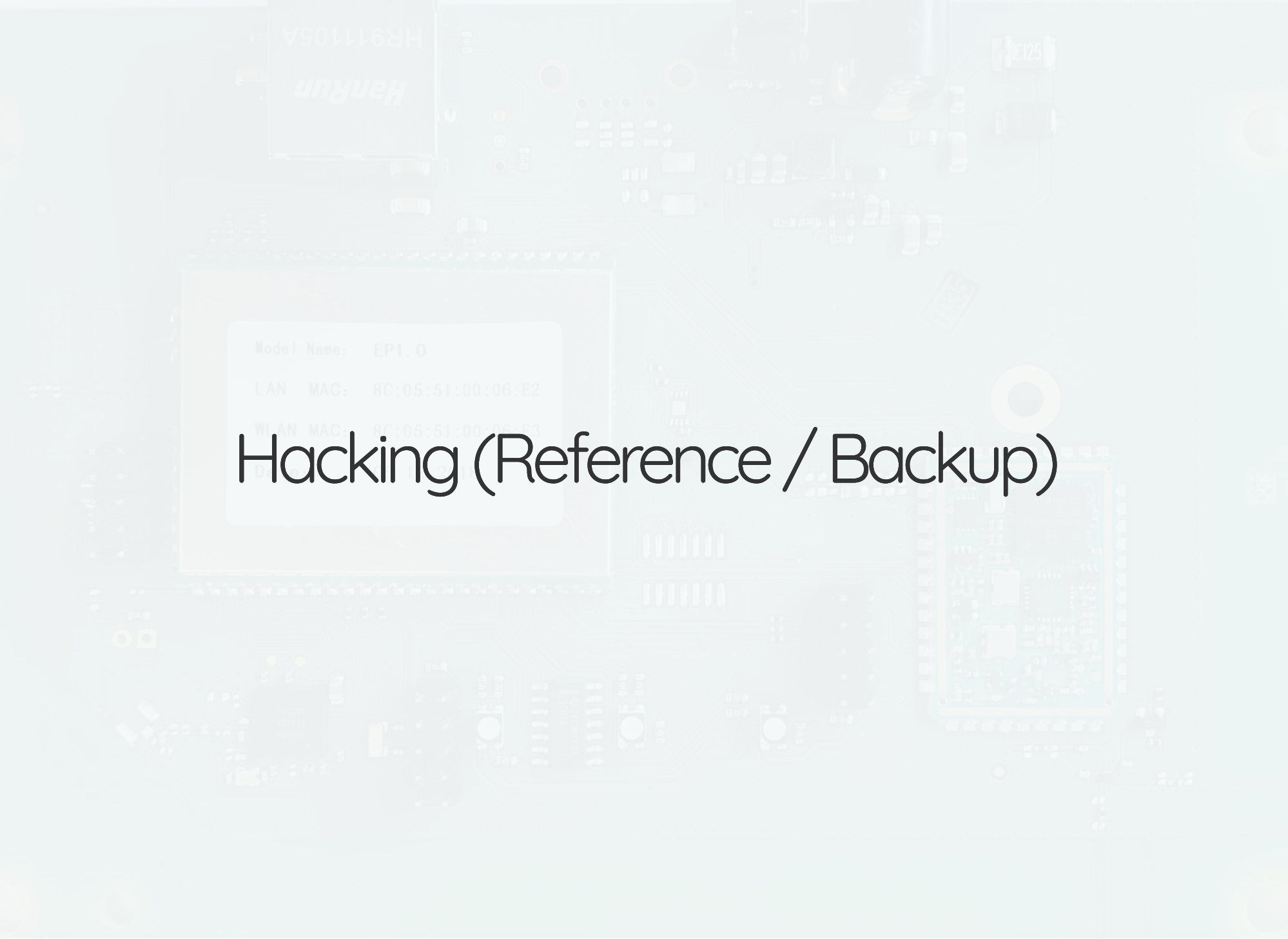
- during manufacturing, we ran a python script, which turned an LED green when done
- manufacturer immediately removed power when LED green
- python cache was generated but not fully written to disk

Lessons learned:

- always sync before turning LED green
- barrier when copying files (cp; sync; mv)
- generate python cache during build time

Manual fixing:

```
fw_printenv | grep "^[a-z_]\+\(done\|finalized\|passed\)="
find /usr/lib/python3.5/ -type d -name __pycache__ -exec rm -r {} \;
/sbin/fw_setenv fct_finalized && rm -f /etc/fct_finalized
fw_printenv fct_finalized || ([ "$(fw_printenv -n self_test_passed)" == "1" ]
/sbin/fw_printenv -n self_test_passed && fct-tool --set-leds green && echo OK
```



Hacking (Reference / Backup)

Building the Software

```
REPO="https://github.com/husqvarnagroup/smart-garden-gateway-public"
git clone --recurse-submodules $REPO
cd smart-garden-gateway-public
export TEMPLATECONF=${PWD}/yocto/meta-distribution/conf
source yocto/openembedded-core/oe-init-build-env build-gardena
bitbake gardena-image-opensource-prod
```

Flashing Custom Software

- assemble UART connector and connect via terminal (settings: 115200n8)
- set up TFTP
- place kernel & rootfs image in TFTP directory
    - Rename gardena-image-opensource-prod-gardena-sg-mt7688.squashfs-xz to gardena-image-prod-gardena-sg-mt7688.squashfs-xz
- reboot
- send any character to enter U-Boot
- run "ubi part nand" and "do_flash" for programming
- run "env set update_url invalid && saveenv" to prevent fetching of updates
    - run "env set update_url && saveenv" to re-enable them

```
U-Boot 2019.01-rc2-mt7688-2018-12-18-gardena-rc2-yocto (Sep 12 2019 - 11:19:51

CPU:   MT7628 Rev 1.2 - Boot from XTAL (3-Byte SPI Addr)
Model: Gardena smart-Gateway-MT7688
DRAM:  128 MiB
Loading Environment from SPI Flash... SF: Detected xm25qh64a with page size 25
OK
Watchdog: Started
F-Data:factory-data version 1 detected
Net:   eth0: eth@10110000
Hit any key to stop autoboot:  0
=> run do_flash
BOOTP broadcast 1
DHCP client bound to address 10.42.0.2 (10 ms)
Using eth@10110000 device
TFTP from server 10.42.0.1; our IP address is 10.42.0.2
Filename 'fitImage-mt7688.bin'.
```

Installing Additional Packages via OPKG

```
root@GARDENA-0b9b03:~# opkg update
Downloading http://sg-low-cost-gateway-dev.s3.amazonaws.com/feeds/opkg-head/al
Updated source 'uri-all-0'.
Downloading http://sg-low-cost-gateway-dev.s3.amazonaws.com/feeds/opkg-head/mi
Updated source 'uri-mips32r2el-24kc-nf-0'.
Downloading http://sg-low-cost-gateway-dev.s3.amazonaws.com/feeds/opkg-head/mt
Updated source 'uri-mt7688-0'.
root@GARDENA-0b9b03:~# opkg install tcpdump
Installing tcpdump (4.9.2) on root.
Downloading http://sg-low-cost-gateway-dev.s3.amazonaws.com/feeds/opkg-head/mi
Configuring tcpdump.
root@GARDENA-0b9b03:~#
```