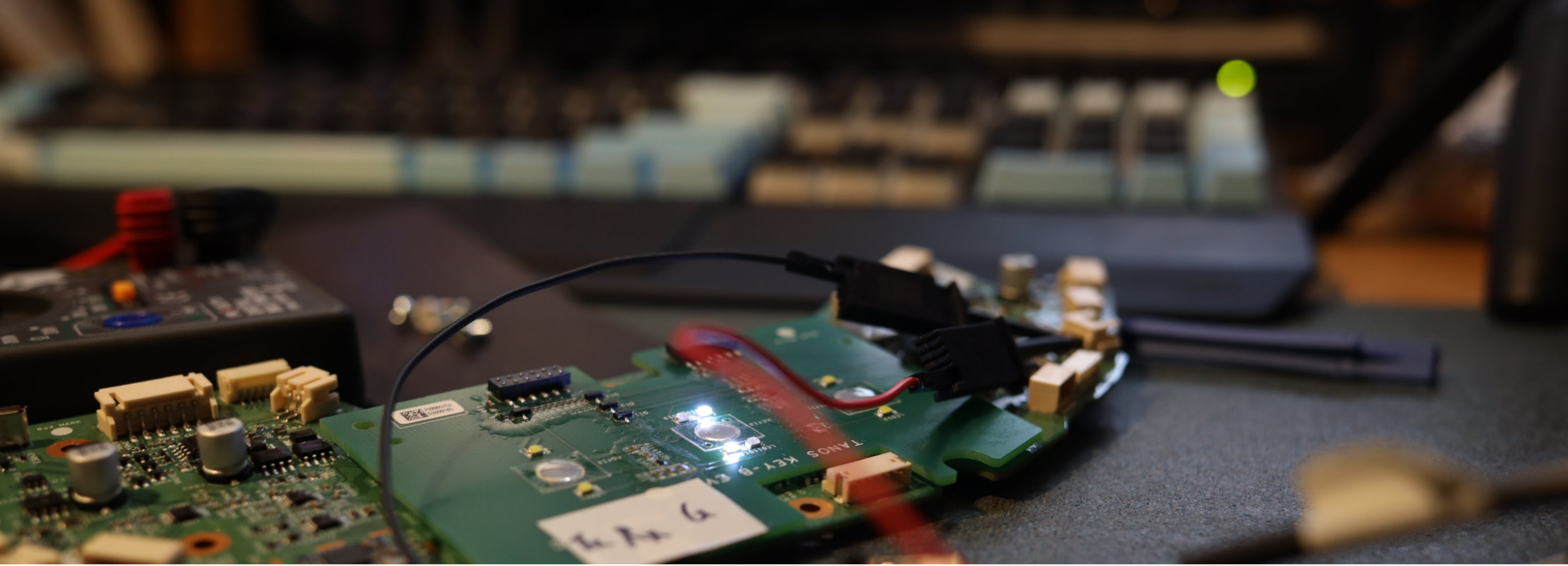


“Smart” Vacuum Cleaners

An Audit Into The Security and Integrity of IoT Systems

Andrew Wong | UNSW Sydney

Today’s Agenda

- Thesis B plan
- Thesis B review
- Thesis B retrospective
- Thesis C revised plan

Statement

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

- Digital Privacy - Investigate the nature of network data (i.e. content, frequency, destination) and how the data is used.
- Product Security - Investigate potential security vulnerabilities and assess the effectiveness of current security fortifications.

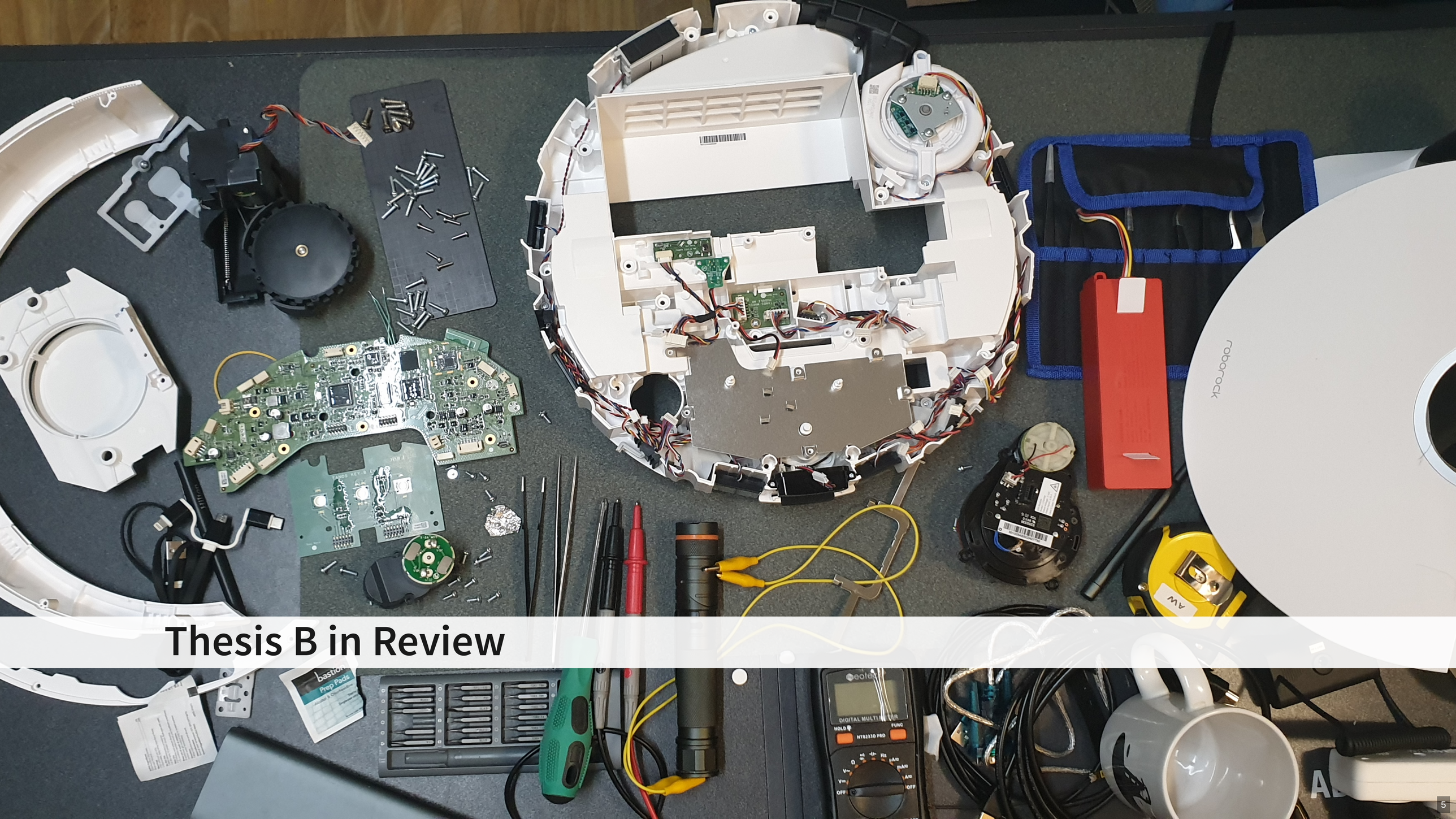
Original Project Timeline

Thesis B - Binary Assessment

- Disassembly and analysis of firmware binaries to identify vulnerabilities
  - inc. ADB binary functionality
- Search for unsecured secrets, logs, configurations

Thesis C - Connectivity Assessment

- Inspection of outbound internet traffic - security, PII, etc
- Inspection of local network traffic
- Inspection of interaction with nearby devices
- Protocol analysis



Thesis B in Review

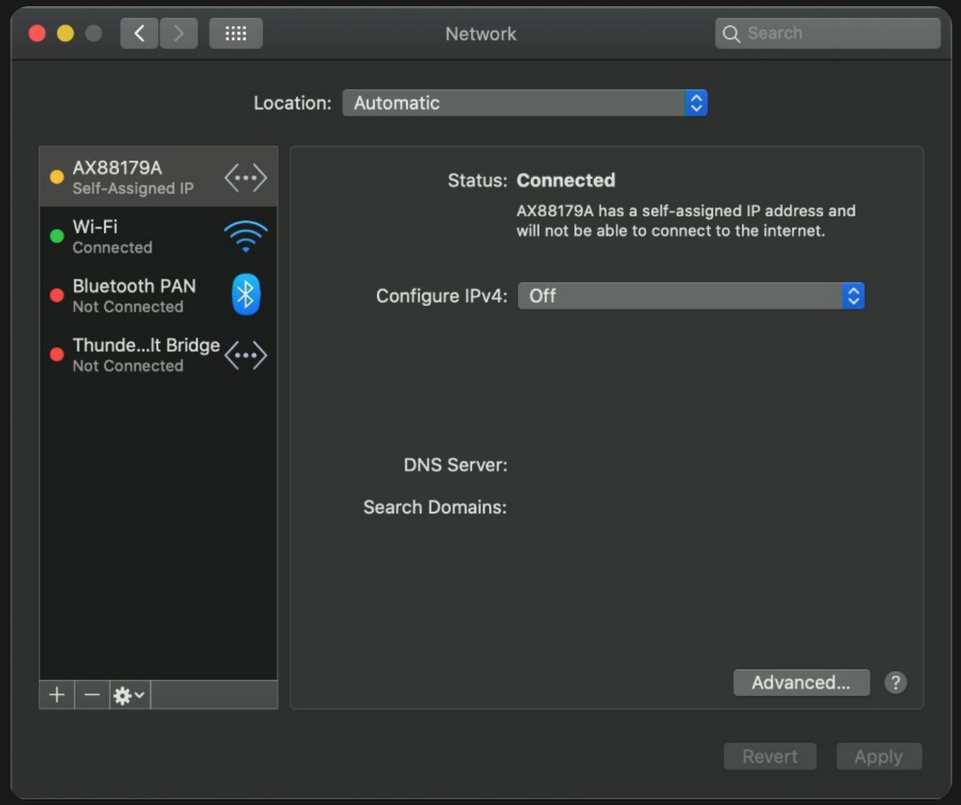
More logging

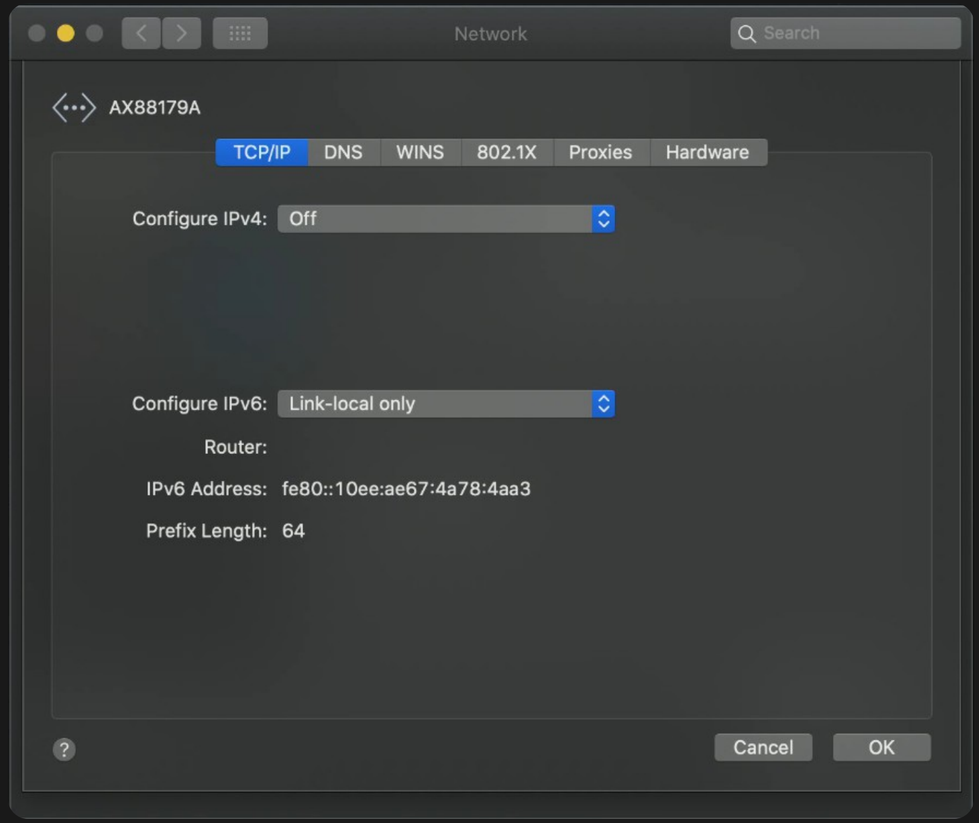
Previously packet captures only logged WAN traffic…

- Now port mirroring from a switch (TP-Link TL-SG105E)
- Now getting all LAN data too! (port mirrored from AP)

More logging

Previously packet captures only logged WAN traffic…



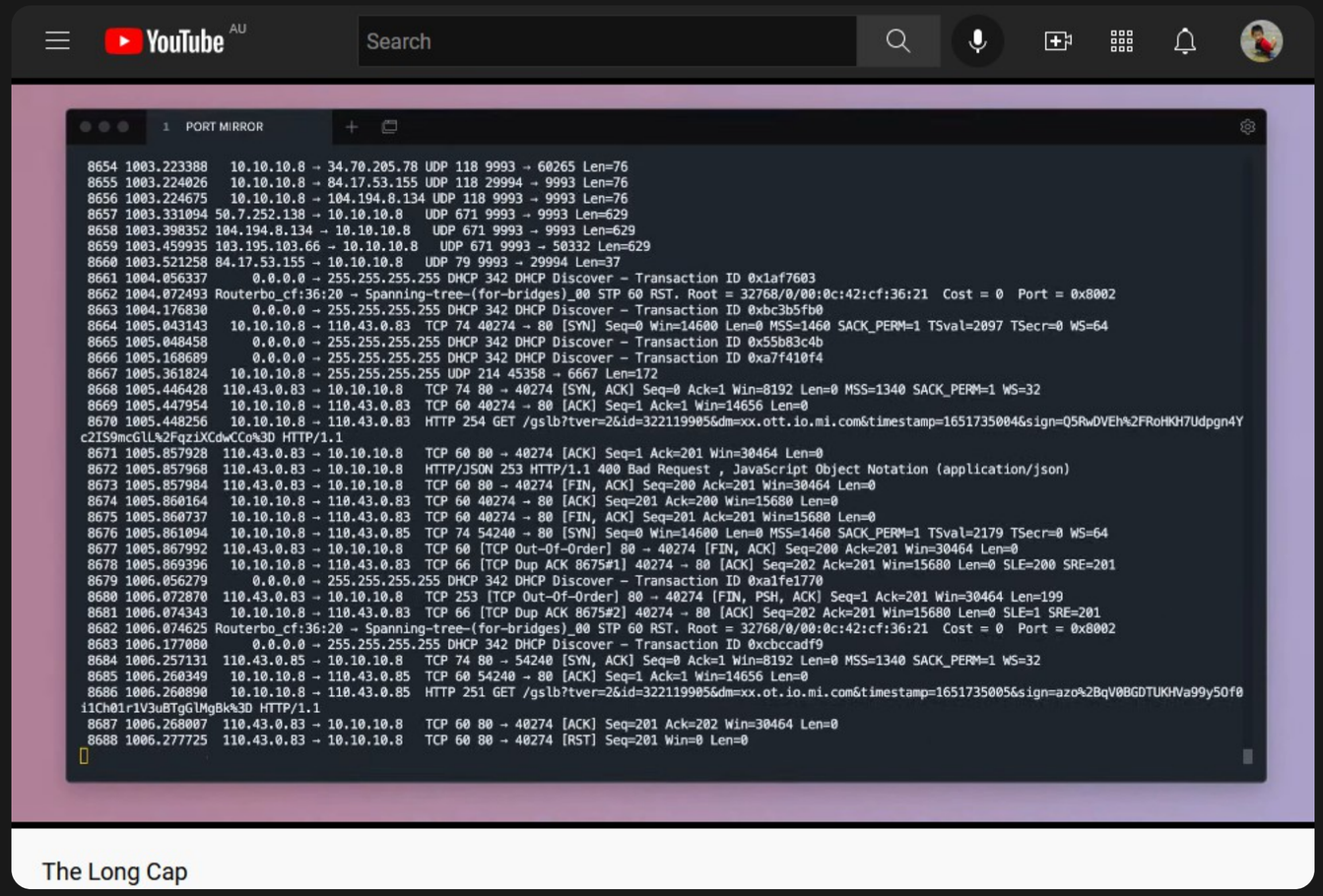


- The switch doesn’t have true port mirroring - also seeing sink traffic
- Disabled IPv4 and (attempt to disable) IPv6 on the network adapter
- Can filter out irrelevant packets later

More logging

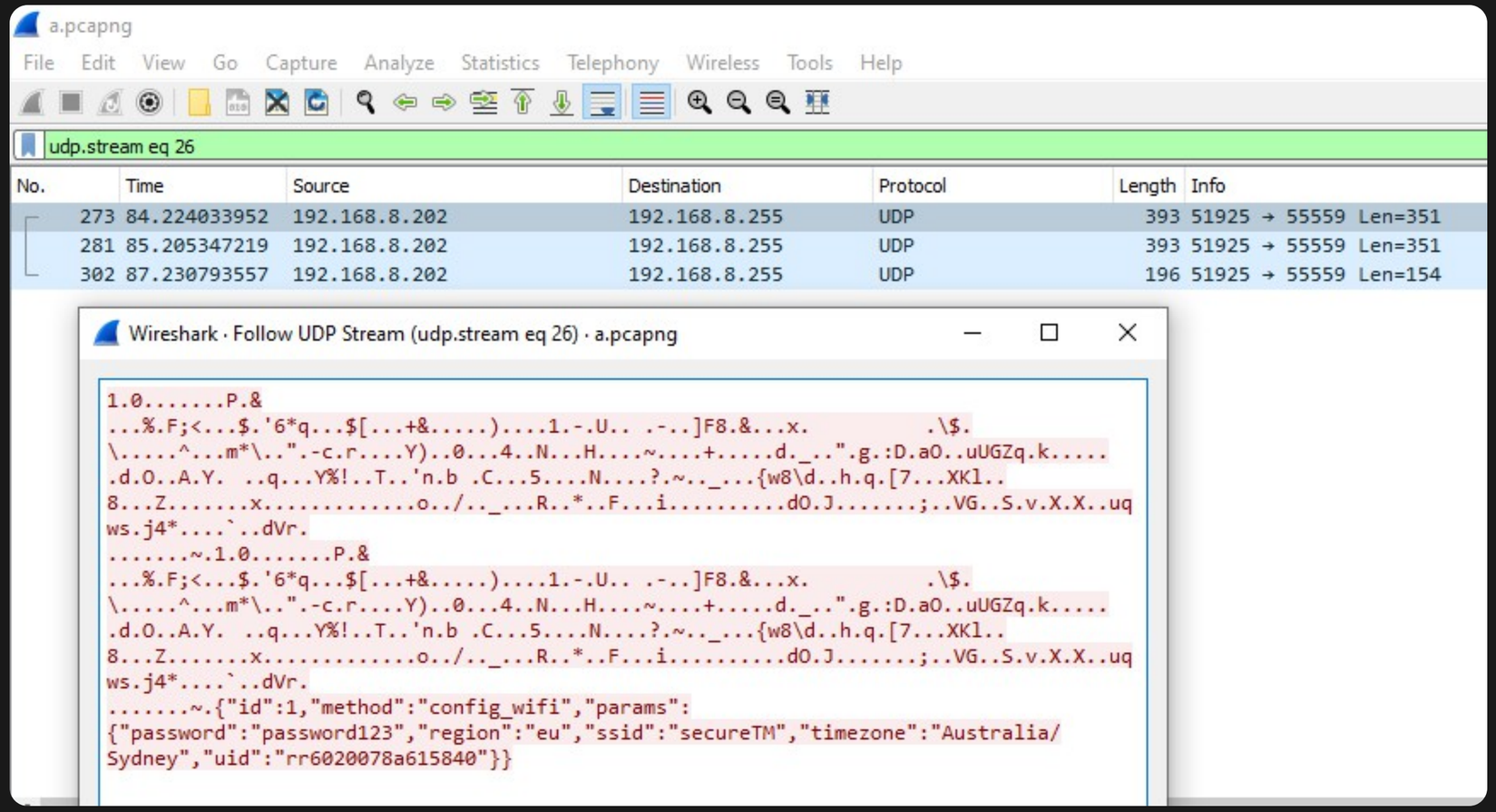
Previously packet captures only logged WAN traffic…

Will later use dumps to check frequency and access



Speaking of packets…

WiFi credentials in plain text during setup



- Minor issue, only exploitable during time of setup

Fingerprinting

System

```
[ 0.340]U-Boot 2011.09-rc1-dirty (Mar 25 2020 - 20:45:43) Allwinner Technology
[ 0.000000] Linux version 3.4.39 (rockrobo@apimg) (gcc version 4.8.4 (Ubuntu/Linaro 4.8
[ 0.000000] CPU: ARMv7 Processor [410fc075] revision 5 (ARMv7), cr=10c5387d
[ 0.000000] Machine: sun8i
...
```

CPU: Allwinner R16 (ARM Cortex-A7) - ARMv7l / armhf

ACU: STM32F103VCT6 (ARM Cortex-M3)

Roborock Firmware version: 3.5.4_1558

Operating system: Ubuntu 14.04.3 LTS

Fingerprinting

Users

root@192.168.8.1:22

```
root@rockrobo:~# ~/z5206677/bat /etc/passwd
```

File: **/etc/passwd**
Size: **1.1 KB**

```
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin
lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin
mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin
uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin
www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin
list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/var/run/ircd:/usr/sbin/nologin
gnats:x:41:41:Gnats Bug-Reporting System (admin):/var/lib/gnats:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin
libuuid:x:100:101::/var/lib/libuuid:
syslog:x:101:104::/home/syslog:/bin/false
sshd:x:102:65534::/var/run/sshd:/usr/sbin/nologin
dnsmasq:x:103:65534:dnsmasq,,,:/var/lib/misc:/bin/false
```

root@192.168.8.1:22

```
root@rockrobo:~# ~/z5206677/bat /etc/shadow
```

File: **/etc/shadow**
Size: **679 B**

```
root:$6$mptOwWOW$DpR0O/CdKUfpapA3rEGl/4m6WZOkRYC5LSaCJSYKj9iHuZp2PUzfolgrGVeHW5tMtRSYlBWSlonusy67027JF/::0:99999:7:::
daemon:*:16652:0:99999:7:::
bin:*:16652:0:99999:7:::
sys:*:16652:0:99999:7:::
sync:*:16652:0:99999:7:::
games:*:16652:0:99999:7:::
man:*:16652:0:99999:7:::
lp:*:16652:0:99999:7:::
mail:*:16652:0:99999:7:::
news:*:16652:0:99999:7:::
uucp:*:16652:0:99999:7:::
proxy:*:16652:0:99999:7:::
www-data:*:16652:0:99999:7:::
backup:*:16652:0:99999:7:::
list:*:16652:0:99999:7:::
irc:*:16652:0:99999:7:::
gnats:*:16652:0:99999:7:::
nobody:*:16652:0:99999:7:::
libuuid:!:16652:0:99999:7:::
syslog:*:16652:0:99999:7:::
sshd:*:16799:0:99999:7:::
dnsmasq:*:16799:0:99999:7:::
```

No additional users

```
root@rockrobo:~# ls /home
ruby
```

`/home/ruby` exists but no user `ruby`, though exists in `/etc/passwd`~

Fingerprinting

Processes

- Everything is running as root

Fingerprinting

Ports

```
root@rockrobo:~# netstat -nltp
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Progra
tcp        0      0 127.0.0.1:54322         0.0.0.0:*               LISTEN      991/miio_c
tcp        0      0 127.0.0.1:54323         0.0.0.0:*               LISTEN      991/miio_c
tcp        0      0 0.0.0.0:22              0.0.0.0:*               LISTEN      1644/sshd
tcp        0      0 127.0.0.1:55551         0.0.0.0:*               LISTEN      998/rriot_
tcp        0      0 0.0.0.0:6668            0.0.0.0:*               LISTEN      998/rriot_
tcp6       0      0 :::22                   :::*                    LISTEN      1644/sshd
```

`tcp/22` and `tcp/6668` are exposed

Fingerprinting

Firewall

At least port 22 is blocked by `iptables`

```
root@rockrobo:~# iptables -L
Chain INPUT (policy ACCEPT)
target     prot opt source               destination
DROP       udp  --  anywhere             anywhere             udp dpt:6665
DROP       tcp  --  anywhere             anywhere             tcp dpt:6665
DROP       tcp  --  anywhere             anywhere             tcp dpt:ssh

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
```

- What runs on port `6665`
  - `player`
  - What about file-based IPC?

Fingerprinting

```
root@rockrobo:~# ip6tables -L
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
```

… except IPv6 isn’t..

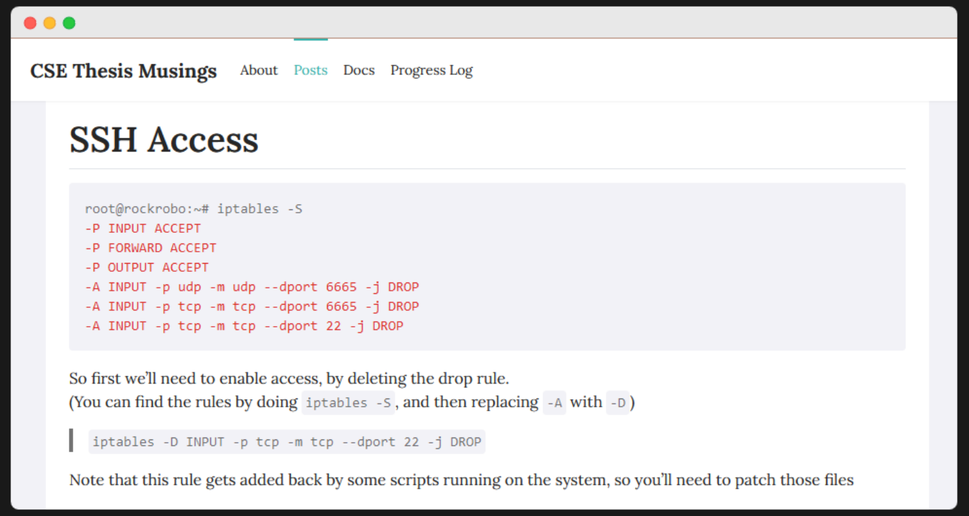
Future work: Test IPv6 lease

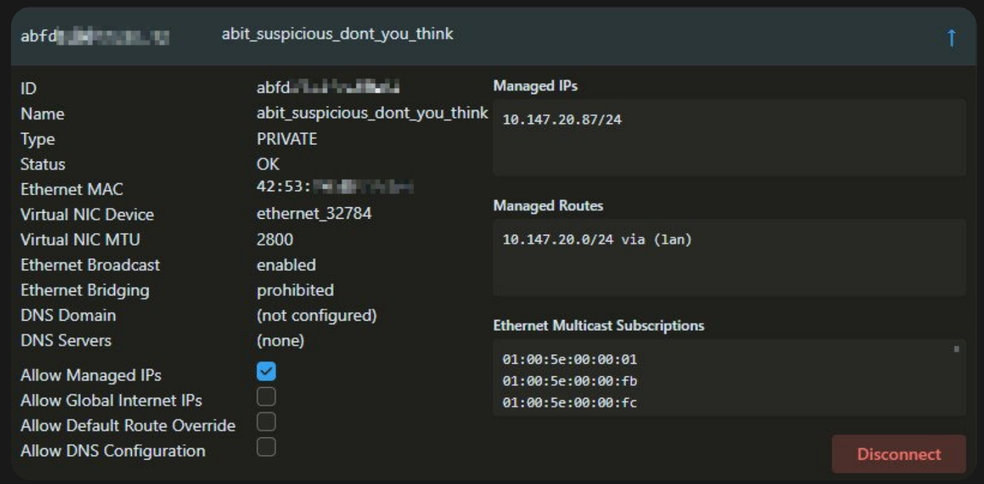
Fingerprinting

Other small tests

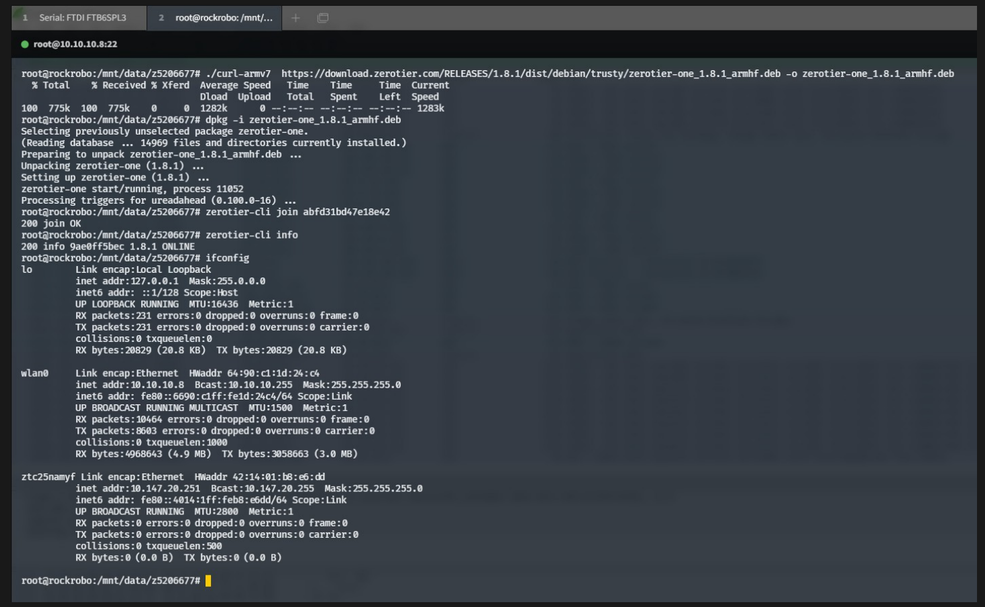
- Can I ping the internet / make outbound connections?
  - Yes
- Can I run my own software
  - Yes (`armhf` architecture)

Going wireless - establishing SSH



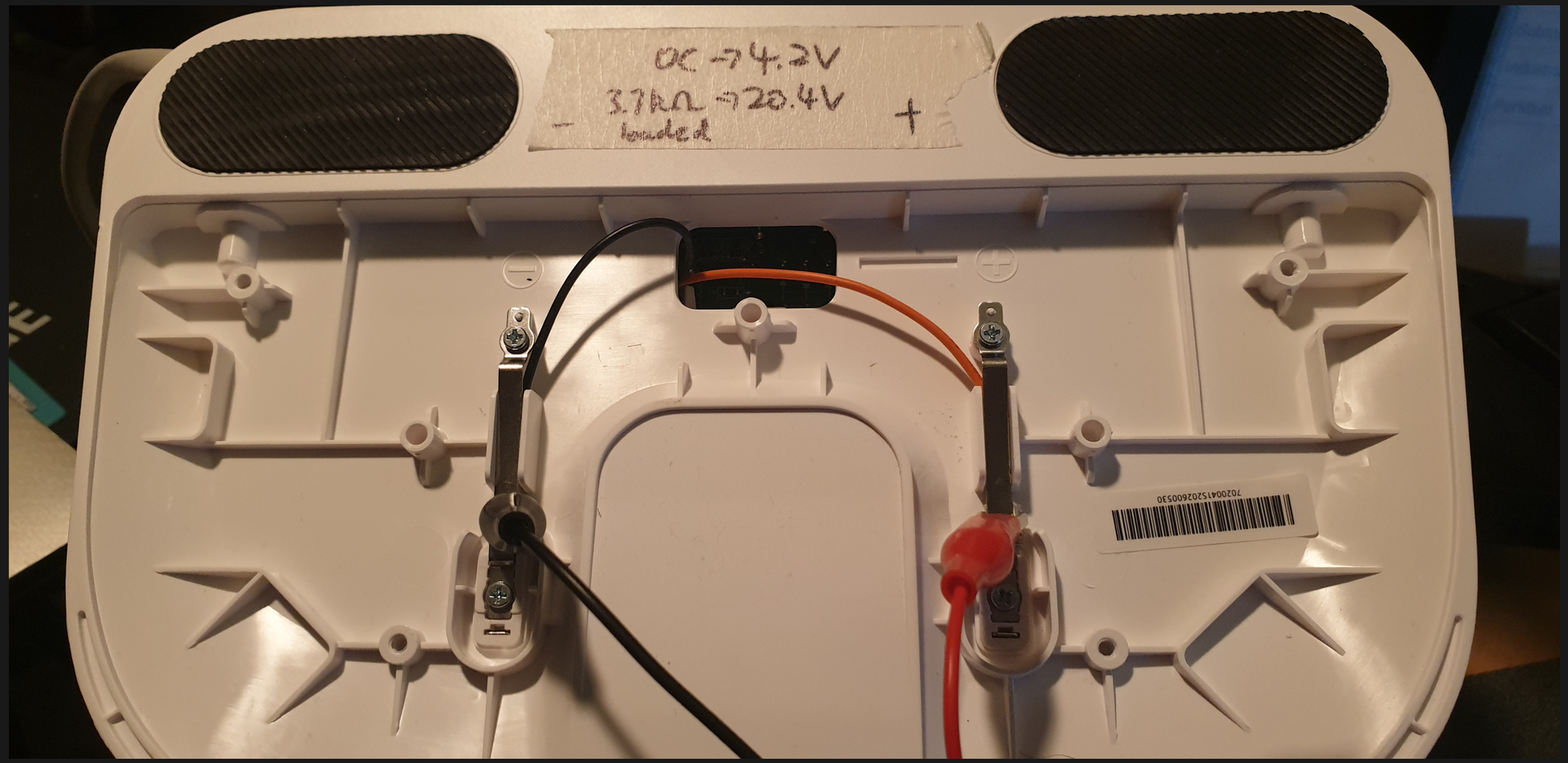


- Remove iptables rule to gain access
  - (and so could an attacker)
- Can I add persistent access?
  - Yes, modify `rrwatchdoge.conf`
- Can also add remote access
  - e.g. ZeroTier



Trivial Power Analysis

Batteries don't last forever!



Test: What if I unplug the battery?

- No change in output during boot
- But device will turn off after around 20 seconds

```
Ubuntu 14.04.3 LTS rockrobo ttyS0

rockrobo login:                                          #### Usual login prompt
wait-for-state stop/waiting
haveged: haveged Stopping due to signal 15               #### Shutdown SIGTERM

 * Stopping rsync daemon rsync                                        [ OK ]
 * (not running)
 * Asking all remaining processes to terminate...                     [ OK ]
 * All processes ended within 1 seconds...                            [ OK ]
umount: /tmp: device is busy.
        (In some cases useful info about processes that use
         the device is found by lsof(8) or fuser(1))
 * Unmounting temporary filesystems...                                [fail]
 * Deactivating swap...                                               [ OK ]
 * Unmounting local filesystems...                                    [ OK ]
 * Will now halt
[   26.948171] [MCU_UART] sent ap poweroff event to mcu  #### Device turns off
```

See 2-wire log, 4-wire log

File System Imaging

The eMMC only has 4GB of storage, so we can’t (also shouldn’t) image the flash onto itself… but we can image it remotely!

```
IP=10.10.10.8
for partition in `ssh root@$IP "ls /dev/mmcblk0?* -1"`
do
    ssh root@$IP "sudo dd if=$partition bs=1M" | dd of=$(basename $partition).img
done
```

File System Structure

partition	label	size	description
mmcblk0p1	UDISK	1.5 GB	user data
mmcblk0p2	boot-res	8 MB	bootloader stuff
mmcblk0p5	env	16 MB	
mmcblk0p6	app (RO)	64 MB	device data
mmcblk0p7	recovery	512 MB	stock firmware
mmcblk0p8	system_a	512 MB	Main OS (boot)
mmcblk0p9	system_b	512 MB	Backup OS
mmcblk0p10	Download	528 MB	Update temp
mmcblk0p11	reserve	16 MB	blackbox???

Recovery Reset

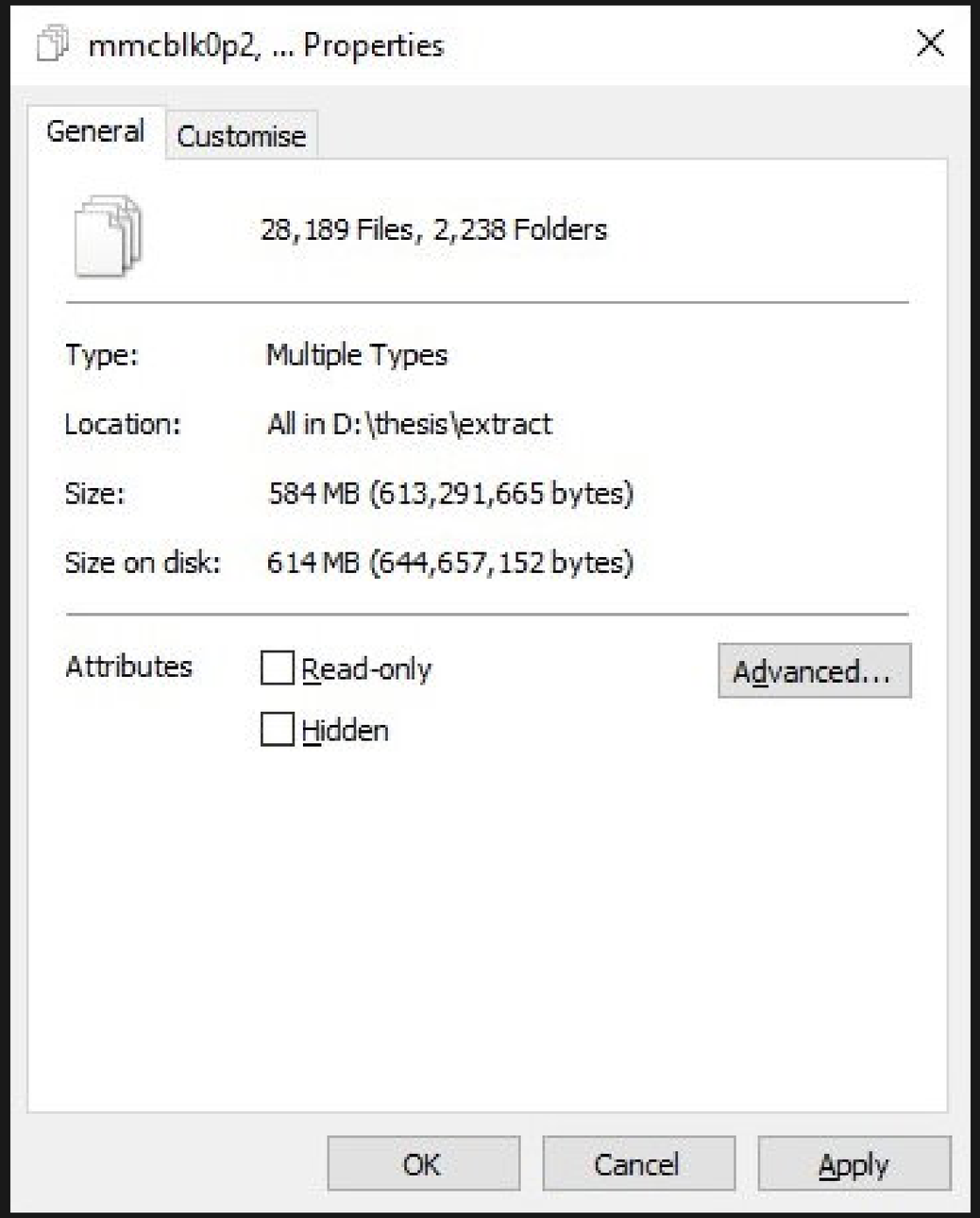
Recovery supposedly resets `system_a`, `system_b`, `UDISK` and `Download`

```
flag a=2,flag b=4,will be recover system
play opt/rockrobo/resources/sounds/en/bl_recovery_bootfailed.wav
Loading file "opt/rockrobo/resources/sounds/en/bl_recovery_bootfailed.wav" from mmc device 2:7
195238 bytes read
sunxi codec request dma 0x5ebb47b4
rr_recovery_pre_check:716:found recovery num 3
Loading file "/boot/zImage" from mmc device 2:7
3882616 bytes read
part recovery valid
recovery from "recovery" to "system_a"
cover init begin
found recovery
set src start=0,src_size=0
found system_a
set dest start=645922816,dest_size=536870912
real_cover:141:total size=536870912,block=1048576

MMC read: dev # 2, block # 253952, count 8192 ... 8192 blocks read: OK

MMC write: dev # 2, block # 1302528, count 8192 ... 8192 blocks write: OK
```

- What about the other partitions?
- Can we install software in the `recovery` partition? A: Yes



28,189 files…

Well there's for sure a lot of files to look at…

I did a thing - Commentree

Plain-text annotation / commentary tool

(some) Interesting Files

The Search

- Looked for any passwords, secrets, keys, IDs, function calls, logs, …
- Find changed files (*)
- See where they are used
- See how they are used
- Anything of general interested

(some) Interesting Files

- mmcblk0p1
  - miio/device.token
  - miio/device.uid
  - rockrobo/
  - rockrobo/rrlog/ (logs are encrypted!)
- mmcblk0p8/opt/rockrobo
  - Binaries
  - scripts/pipes.sh
  - rrlog/misc.sh
- mmcblk0p11/endpoint.bin - AWS address + key?

(some) Interesting Files

mmcblk0p8/opt/rockrobo/rrlog/misc.sh

```
...

#echo "=======device.conf==========" >> /dev/shm/misc.log
#cat /mnt/default/device.conf >> /dev/shm/misc.log

...
```

mmcblk0p6/device.conf

```
did=DDDDDDDDD                    # (9 digits)
key=XXXXXXXXXXXXXXXX             # (16 alpha-num, case-sensitive)
mac=64:90:C1:1D:24:C4
vendor=roborock
model=roborock.vacuum.s6
```

(some) Interesting Files

Calls for `system`

(some) Interesting Files

/var/log/apt/history.log

Installed packages that are not part of the base system

```
Start-Date: 2016-01-25  11:18:05
Commandline: /usr/bin/apt-get install rsync
Install: rsync:armhf (3.1.0-2ubuntu0.2)
End-Date: 2016-01-25  11:18:11

Start-Date: 2016-04-05  12:30:59
Commandline: /usr/bin/apt-get install ccrypt
Install: ccrypt:armhf (1.10-4)
End-Date: 2016-04-05  12:31:01

Start-Date: 2016-04-25  09:58:29
Commandline: /usr/bin/apt-get install tcpdump
Install: tcpdump:armhf (4.5.1-2ubuntu1.2), libpcap0.8:armhf (1.5.3-2, automatic)
End-Date: 2016-04-25  09:58:33
```

- Why does a vacuum cleaner need `rsync` or `tcpdump`?
- No usage calls found yet

(some) Interesting Files

`mmcblk0p7/usr/sbin/tcpdump`

- External but unmodified binary
- Only hub traffic visible (wireless)
- (not really that interesting)

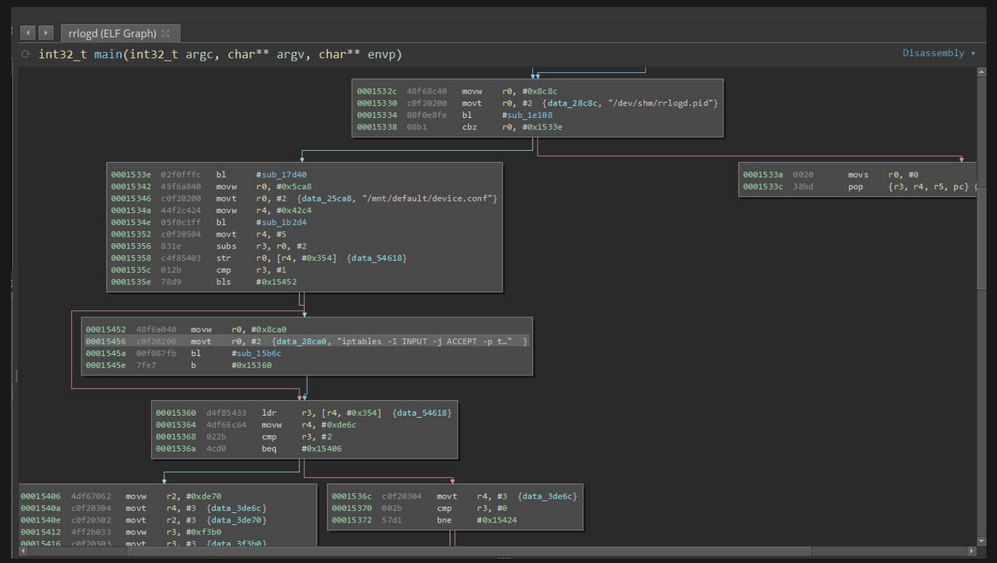
(some) Interesting Files

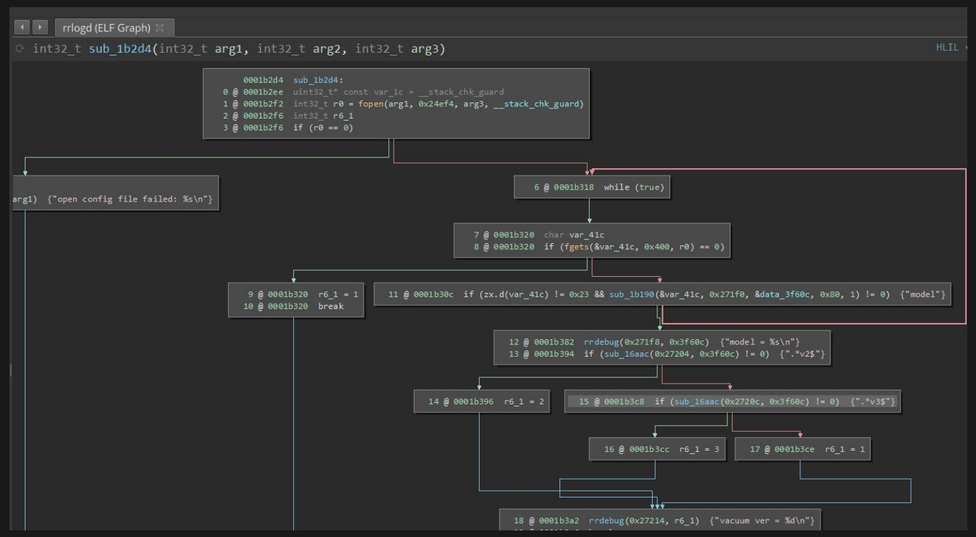
mmcblk0p8/opt/rockrobo/rrlog/rrlogd

Logs are encrypted at rest (after being packed)

Originally used to be a symmetric key, now using a public key

😕 Logging program has the functionality to unblock port 22?





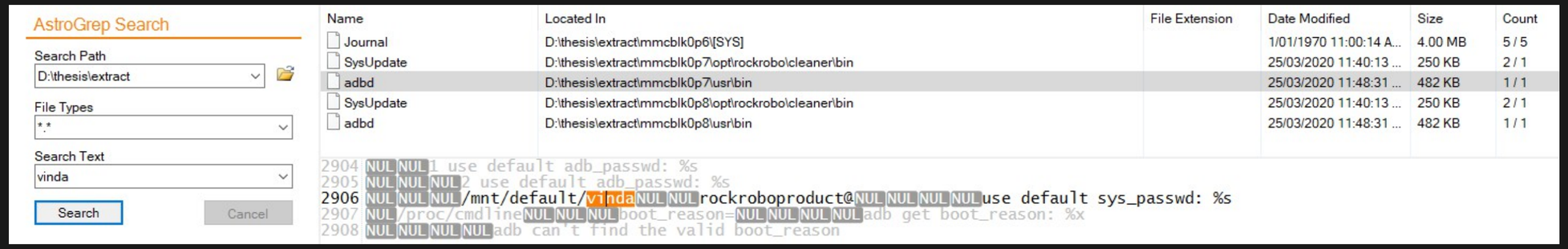

```
iptables -I INPUT -j ACCEPT -p tcp --dport 22
```

(some) Interesting Files

mmcblk0p6/vinda

Previously… XOR this file to get the `root` password

File References



(some) Interesting Files

mmcblk0p7/usr/bin/adbd

- Custom ADB binary
- Had a brief look (more)

```
locksec_init_key: can not find the prefix str from adb conf file, use default
locksec_init_key: can not find the suffix str from adb conf file, use default
locksec_init_serial: adb read 465 bytes from /proc/cpuinfo
locksec_init_key: locksec_init_key, rockrobo%()+-[]_8a80ab8936d76c118000:;<=>?@{}rubyde
locksec_apply_key: locksec_apply_key, erI09cyW%()+-[]_8a80ab8936d76c118000:;<=>?@{}CzD2
locksec_apply_passwd: adb source str: erI09cyW%()+-[]_8a80ab8936d76c118000:;<=>?@{}CzD2
locksec_apply_passwd: locksec_apply_passwd, passwd: 0y[ad8@w
```

Related files

- mmcblk0p6/vinda
- mmcblk0p6/adb.conf
- mmcblk0p8/var/log/upstart/adbd.log

(some) Interesting Files

Future: the other programs

- cleaner
- miio
- rockrobo
- rrlog
- rriot

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

Wireless credentials are stored in plain text

- Anyone with physical access to the machine can gain wireless credentials
- However, takes a lot of effort to open up the device
- Why? `wpa_supplicant` is part of the underlying Linux framework

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

⚠ SSH server exposed on `tcp/22`

- Why does this server exist?
- When / where is it used?
  - Allow rule inside the `rrlogd` binary
- Roborock has made an attempt to protect their product with `iptables`
- But did not fully product their product against access via IPv6

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

Processes are running as `root`

- Any vulnerability in any of the programs can result in elevated access
  - Dropping of iptables restrictions
  - Persistence planting
  - System takeover
- Should run as a de-privileged user
- Why? Compatibility, perhaps ease of development
  - i.e. `udev` rules

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

Recovery partition is modifiable

- Can be modified to contain malicious software that persists a factory reset
- Mountable - `mount /dev/mmcblk0p7 ...`
- Why? Allows easy updates of the ‘factory image’
- But the partition could somehow be encrypted

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

A note on hardware and software

> *access to the hardware = game over?*

- Are there tamper-proof / tamper-evident design possibilities?
- What about some sort of “Secure Element”
- Or read protection?
- Choice of OS
- Choice of auth implementation (e.g. `vinda`)
- Limitation on what programs are allowed to execute?

Issues, thoughts & discussions

How have manufacturers of IoT / smart home devices addressed the increasing concerns of digital privacy and product security?

The Good Things

- An effort to restrict SSH access via `iptables`
- AuthN / AuthZ is present within interfaces to the device
- UART shell requires a password
- Logs are encrypted locally

Current Challenges

Intercepting encrypted data / TLS traffic

- Ubuntu 14.04 has some issues (?)
  - `PolarProxy` is too new (libc requirements)
  - apt update doesn't work with socks5:// or http proxies properly???
- Routing?
- Hook into the encryption/decryption process somehow?
  - Use `Frida`?
  - Or look at the data communicated by the smartphone app?
    - `Objection` tool didn't work with the RoboRock app

Current Challenges

> *Electricity is funny.*

Using my main personal computer is not a good idea for a test-bench…

Thank you Gigabyte for having ESD-protected USB ports

Current Challenges

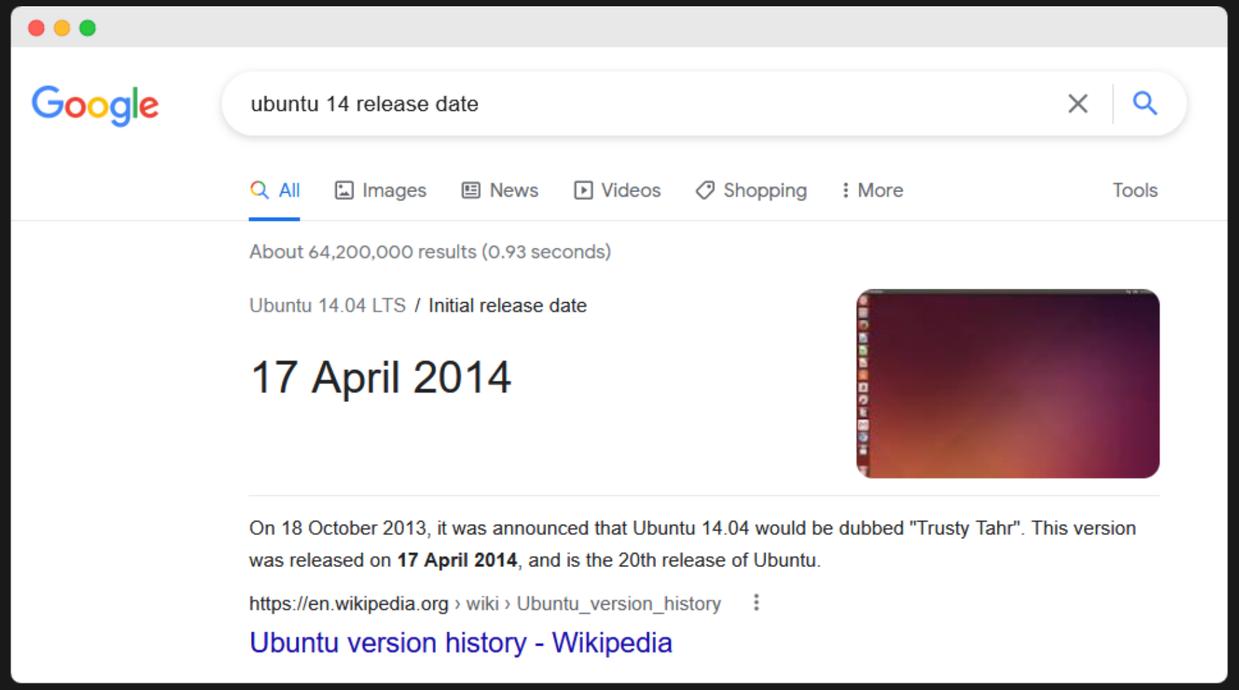
Still a lot of files to look at

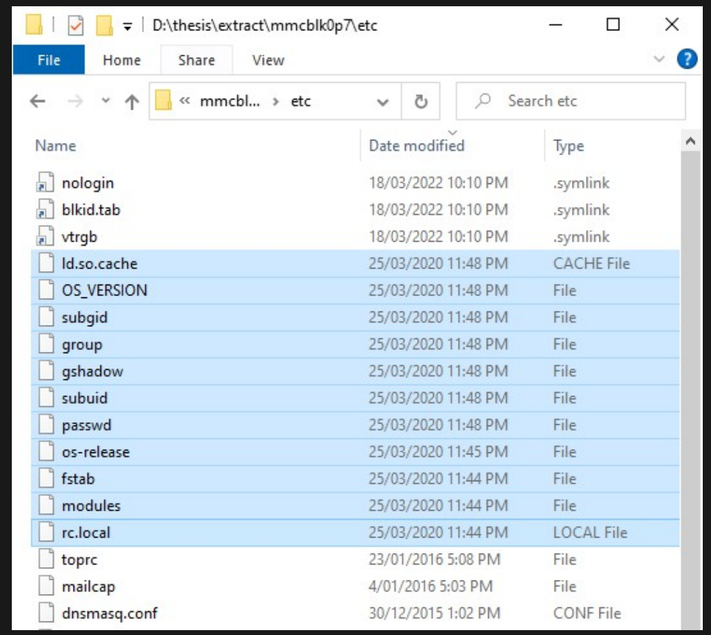
Need to figure out which files are worthwhile to inspect..

Current Challenges

File Inspection Approach 1 - Filter by date modified

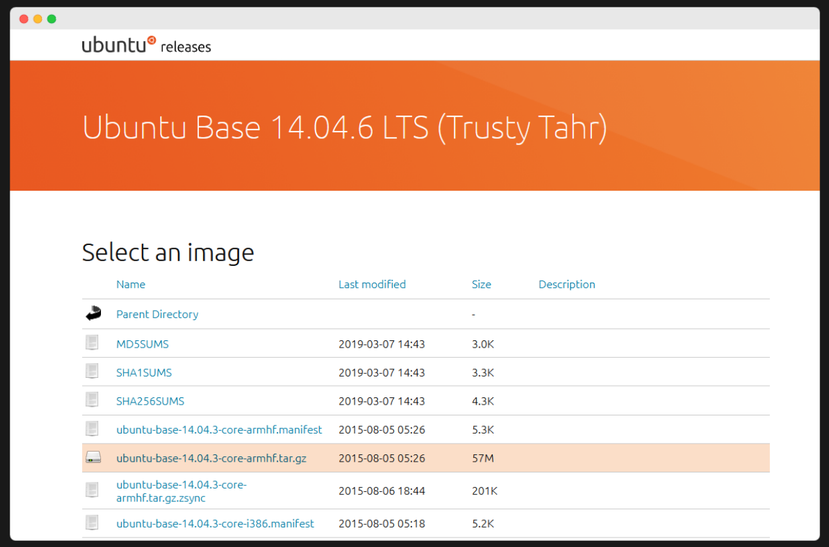
Ubuntu 14.04.3 LTS was released back in 2014, any changes would have a later timestamp (hopefully)





Current Challenges

File Inspection Approach 2 - Binary Comparisons



Compare executable files and find differences in binary function

bindiff, binwalk, ssdeep, sdhash

As seen in A Large-Scale Analysis of the Security of Embedded Firmwares - Andrei C, Jonas Z, Aur'elien F, Davide B

Thesis B Retrospective

- Time management - could have done more work
  - Busy / other commitments
  - Hardware work restricts me to only working at home
- Project breadth / depth / scope
  - Binary analysis takes a lot of time

Response

- Schedule more focus times
- Hardware work pretty much completed - likely able to work remotely now
- Restrict binary analysis to the most likely binaries
  - May consequently miss something

Thesis B Completion

- Analysis of firmware binaries to identify vulnerabilities
  - Still in progress
- Search for unsecured secrets, logs, configurations
  - Completed (excluding encrypted `rrlog` files)

Revised Thesis C Plan

- (priority) Inspection of outbound WAN traffic - security, PII, etc
- ~~Inspection of LAN traffic~~ rather, see if it is stored
- ~~Inspection of interaction with nearby devices~~
- ~~Protocol analysis~~
- Update to a newer firmware version and look at changes
- Check what files gets cleared during a format
- Binary assessment
- Verify IPv6 SSH access

Incoming Timeline

- 22T2 W1 - IPv6 SSH verification, continue binary assessment
- 22T2 W2 - WAN traffic analysis
  - Look at network behaviour
  - Try view WAN data pre-encryption / post-decryption
- 22T2 W4 - Update to latest version (and hope we don’t get locked out)
  - Do another vacuum clean, reimage, compare binaries
- 22T2 W5 - Factory reset device, check for remnant files
- 22T2 W8 - Demo submission
- 22T2 W11 - Report submission

Thank You

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