We will charge you. How to [b]reach vendor's internal network using electric vehicle charging station

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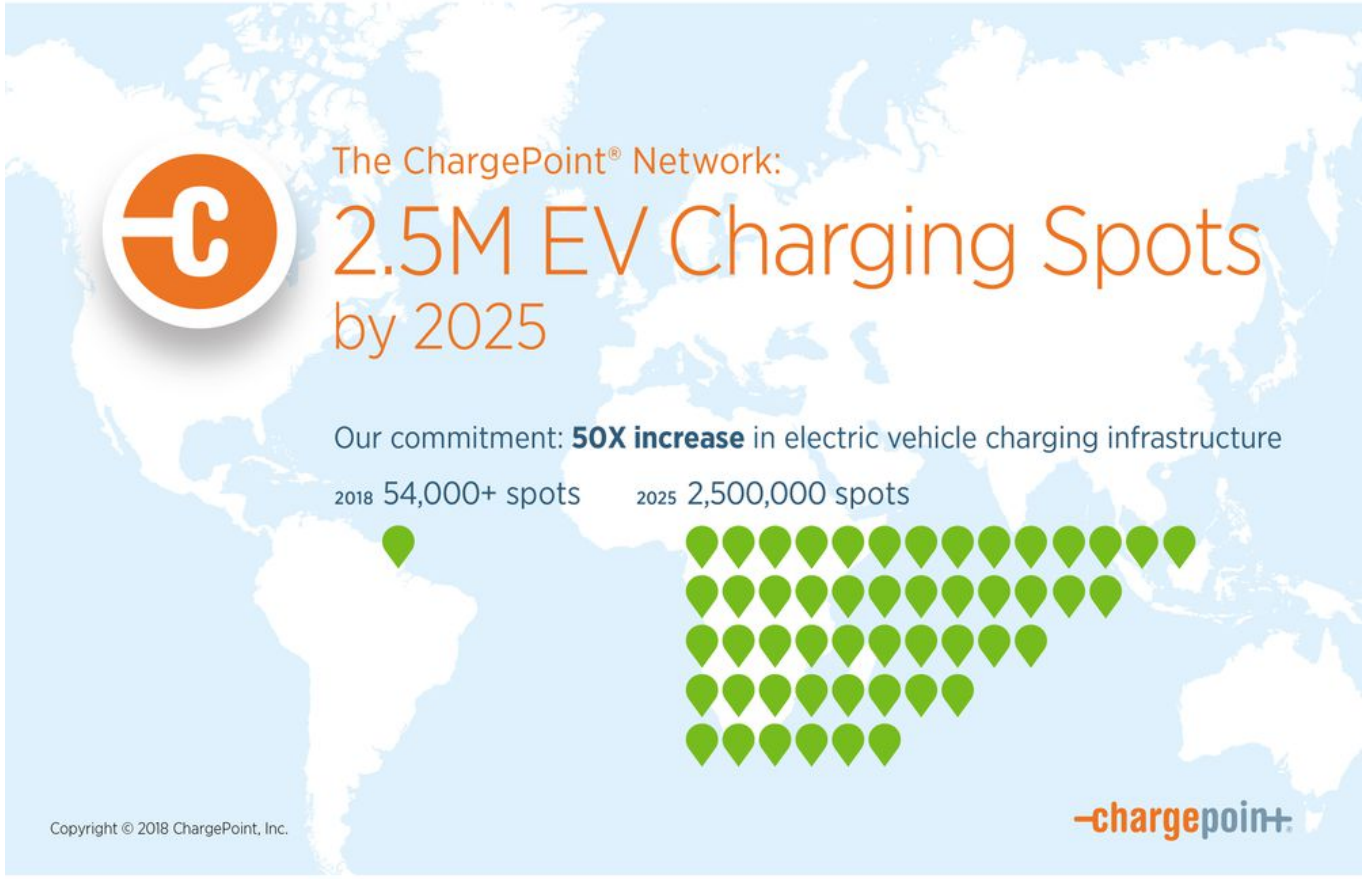
Whoami

KASPERSKY lab

- Application security specialist, Security Assessment
  @kl_secservices
- Hardware research
- Reverse engineering
- IoT and ICS protocols

ChargePoint Home

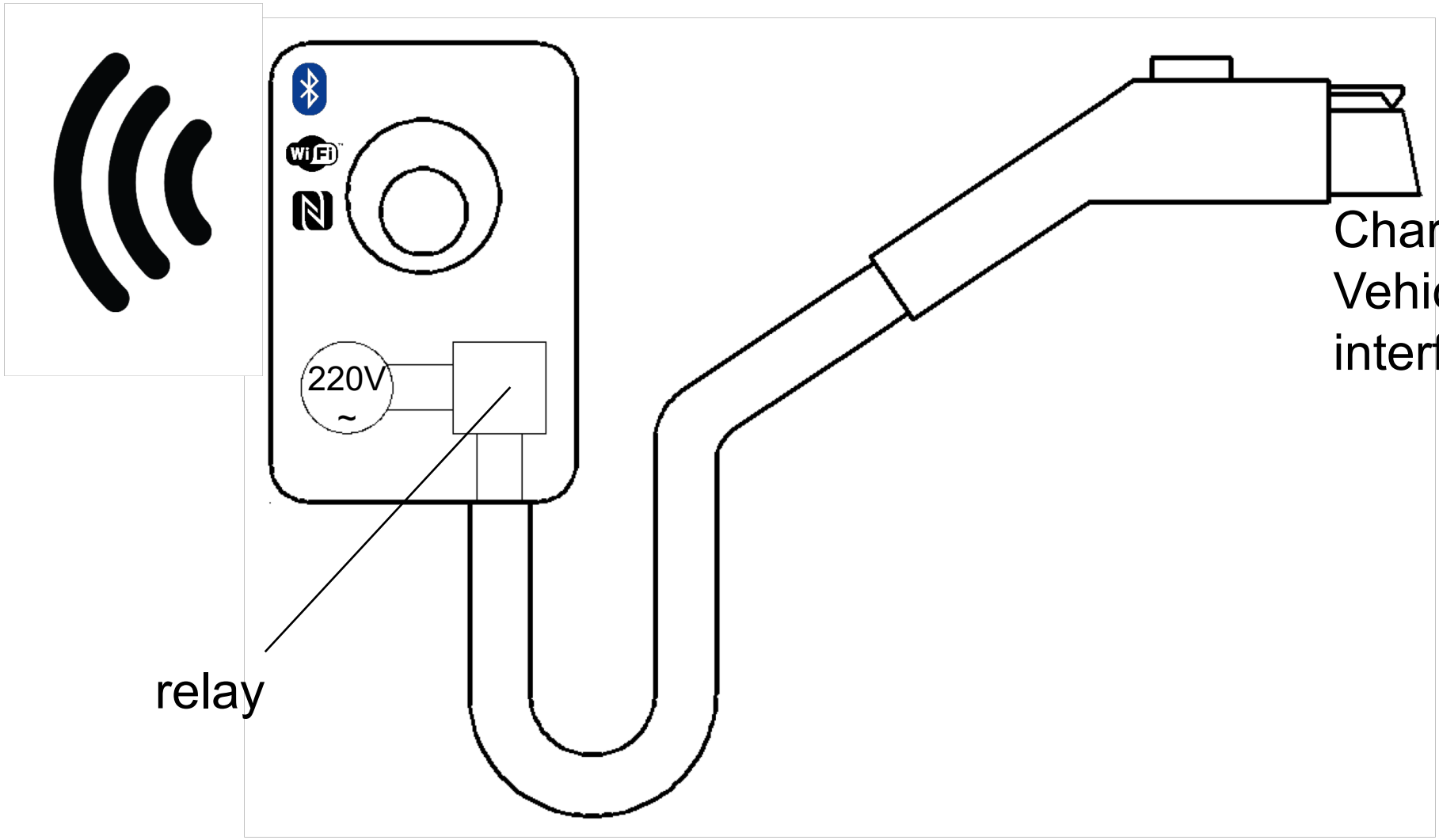


Marketing style

little monsters

chargepoint.

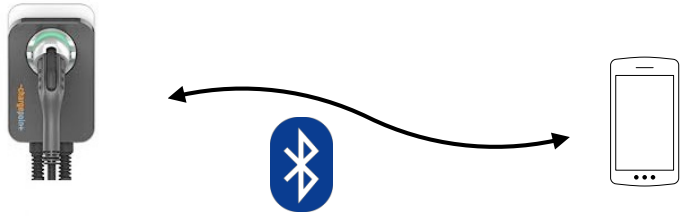
Communication scheme



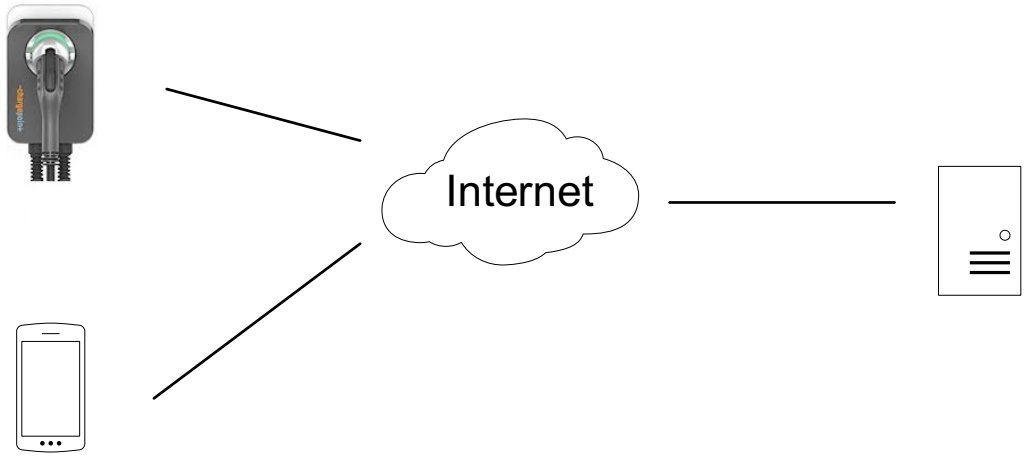
Android application

Communications with app

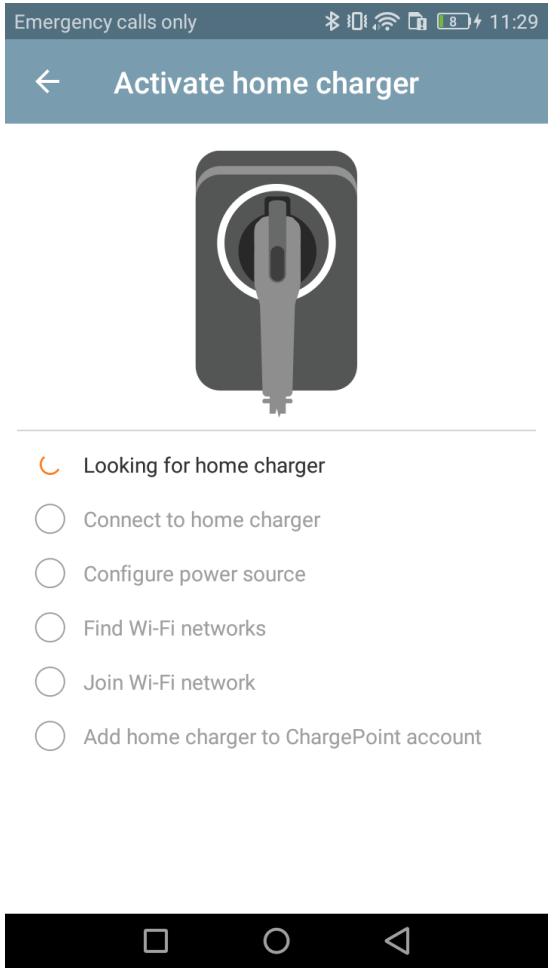
Inactivated state



Activated state

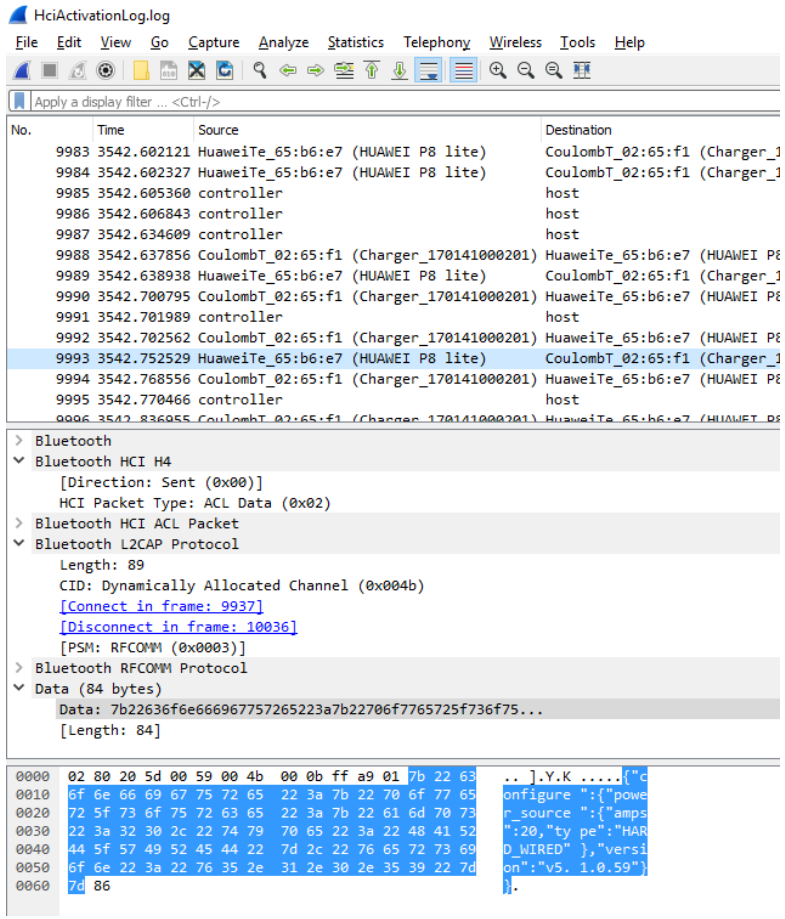


Android application analysis



- Uses Bluetooth to communicate with charger
- “Just works” pairing method implemented – no PIN code, passwords, etc.
- HCI logs
  - Can be easily collected on Android
  - Can be viewed with Wireshark
- Simple RFCOMM protocol

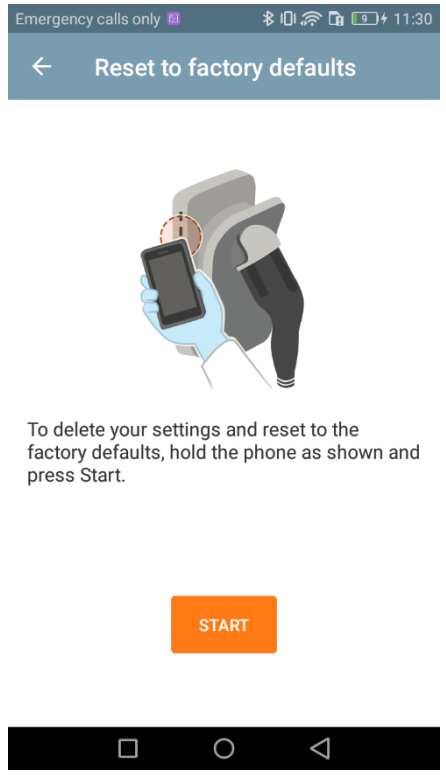
Commands from HCI log



1. **Get_version** – returns charger's firmware version
2. **Configure** – sets maximum allowed current consumption and charger's power supply type (plug-in or hardwired)
3. **Get_wifi_networks**
4. **Connect_to_wifi**
5. **Register_with_nos** – commands charger to send the information about smartphone's coordinates and mobile application account id to the backend server
6. **Shutdown_Bluetooth –** disables the Bluetooth service

ResetToFactoryDefaultsActivity

```
private void a() {
    this.a = new FlashSequence();
    if (PermissionUtil.requestCameraPermission(this, true)) {
    return;
}
try {
var1_1 = this.a.a();
...
```



Charger

Opened TCP Ports

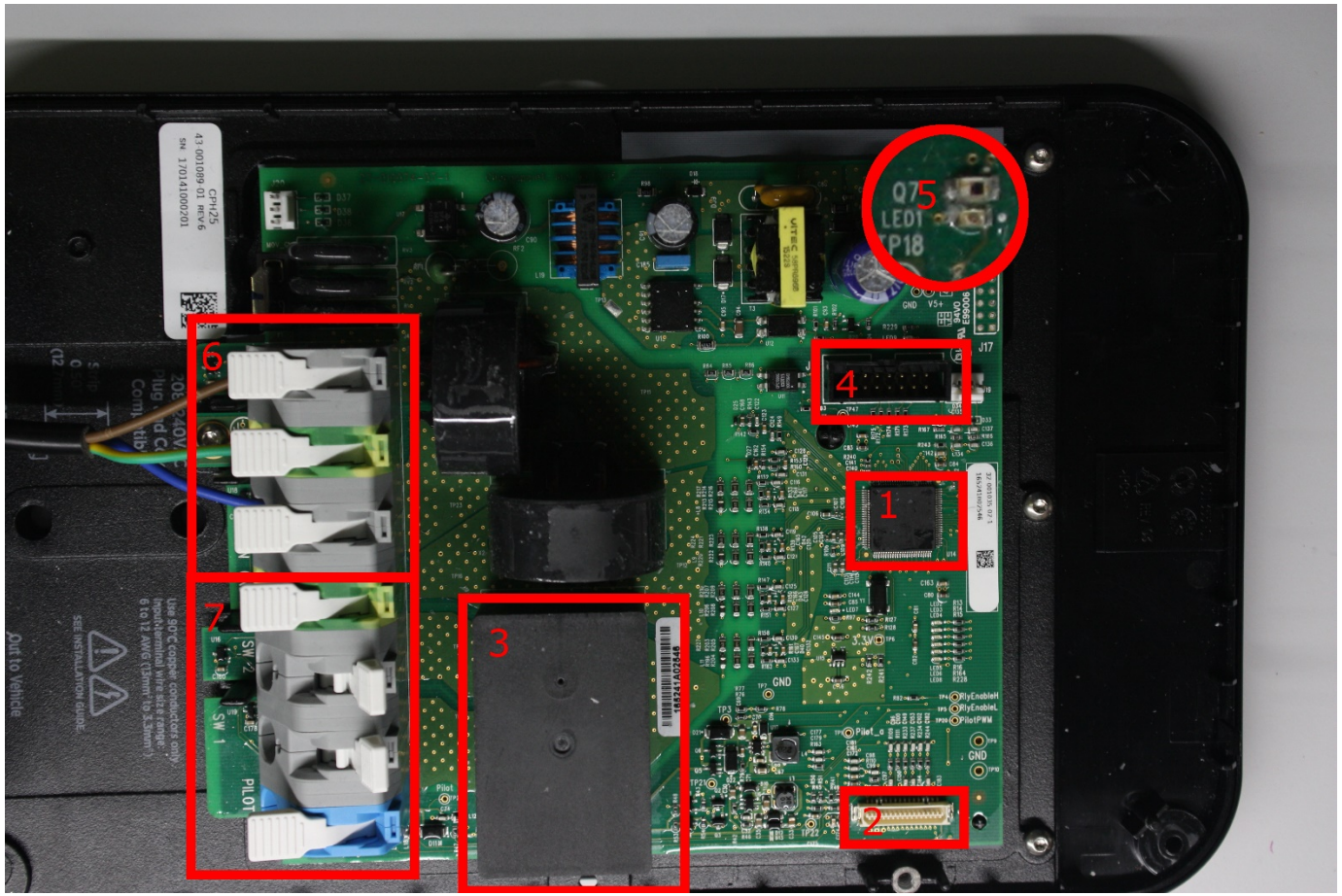
23	BusyBox telnetd
443	SSL with mutual authentication
55557	SSL with mutual authentication

HW Revision

2 boards with separate CU's

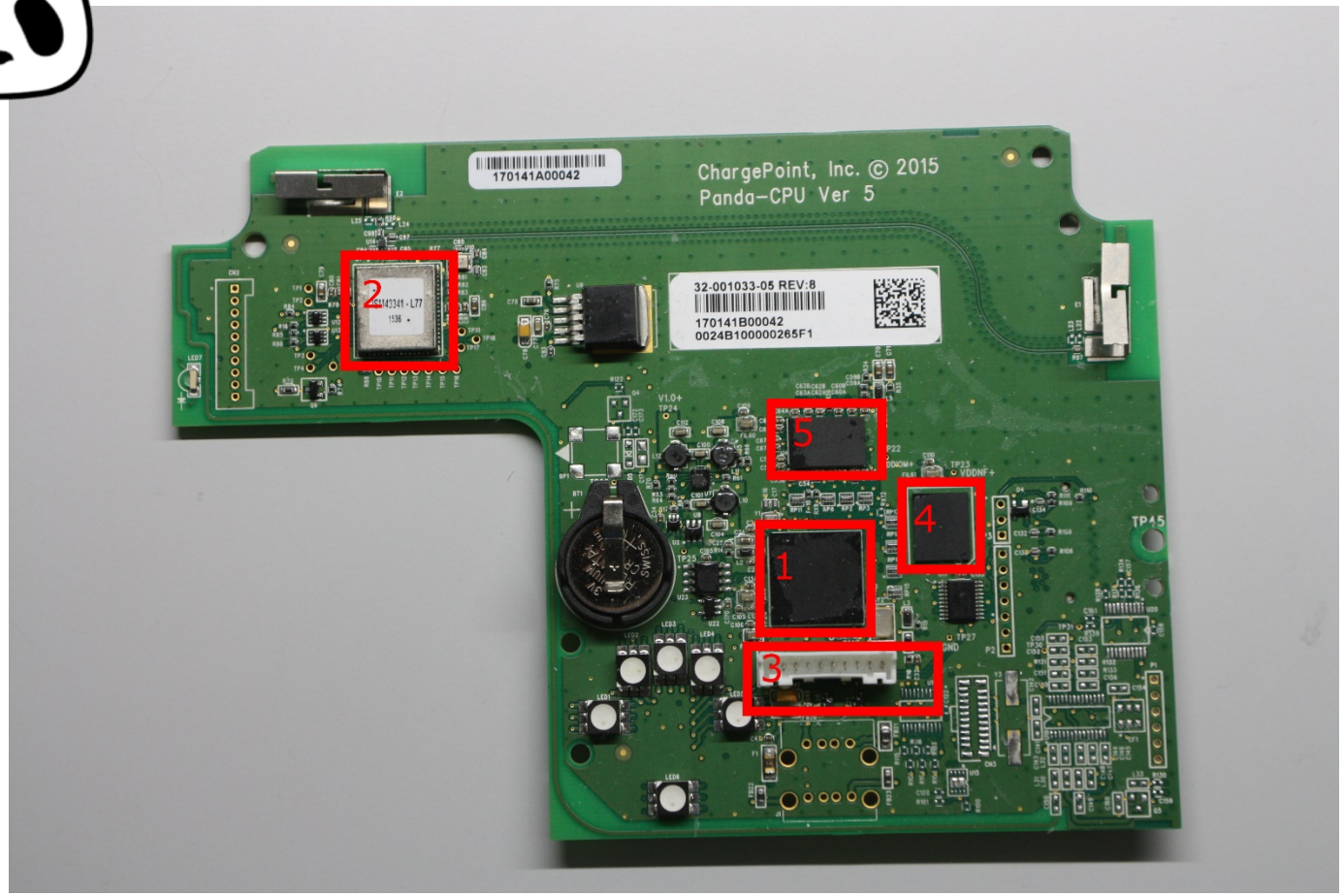
1. Power board –vehicle signaling interface control, current measurement
2. Panda board – wireless communications (mobile app, backend)

Power board



1. MCU, MSP430
   TI 6BATG4MSP430 F67691
2. Panda board socket
3. Mechanical relay
   TE T92S7D12-12
4. Debug socket
5. LED and photodiode
6. Power plug terminal strip
7. Vehicle outlet terminal strip

Panda board



1. MPU, ARM
   Atmel AT91SAM9N12
2. Wireless communication module
   ISM43341-L77
3. Debug socket (JTAG)
4. External DDR RAM 1 GB
   Micron 6WM17 D9RZT
5. NAND FLASH 512 MB
   Micron 4XD12 NW196

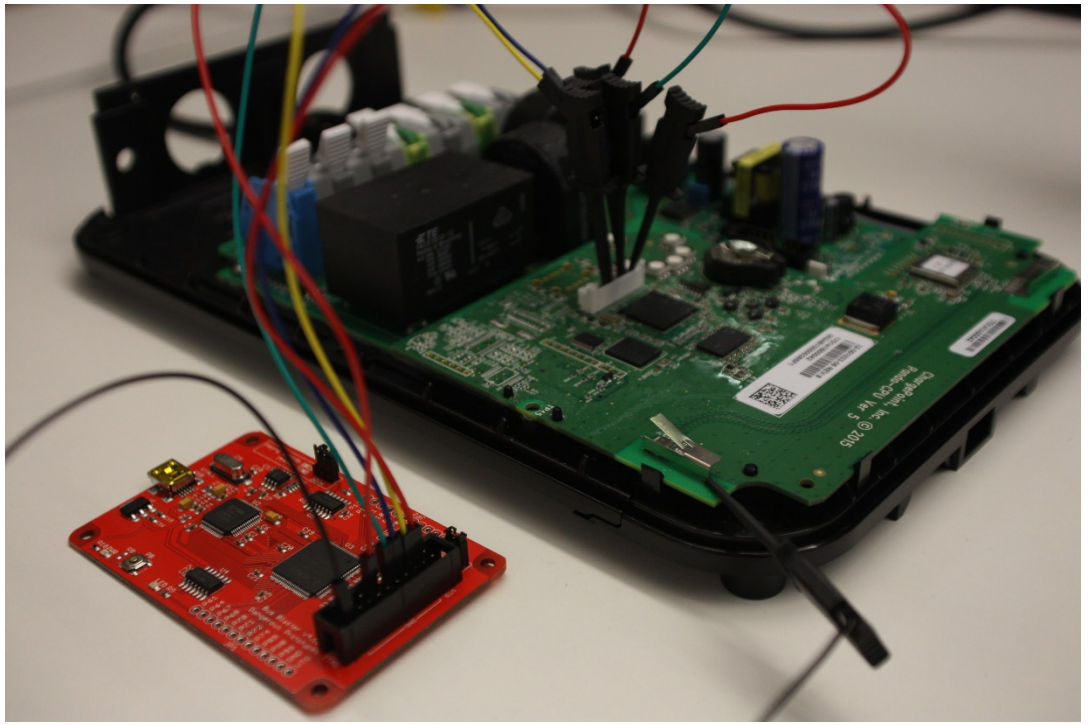
JTAG tool chest

NAME

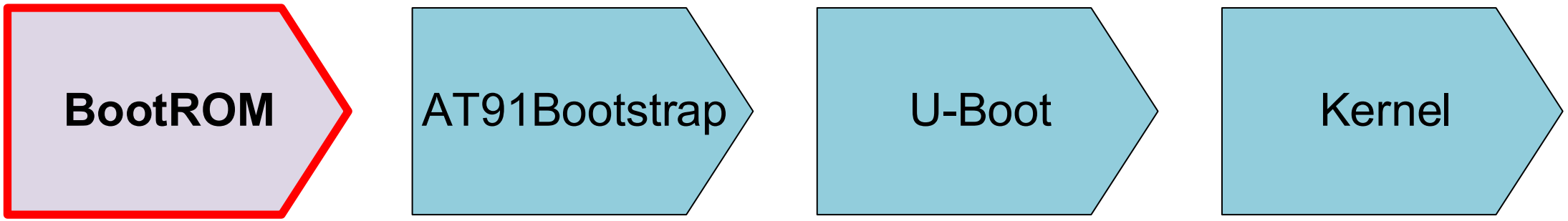
openocd - A free and open on-chip debugging, in-system programming and boundary-scan testing tool for ARM and MIPS systems

SYNOPSIS

openocd [**-fsdlcphv**] [**–file** <filename>] [**–search** <dirname>] [**–debug** <debuglevel>] [**–log_output** <filename>] [**–command** <cmd>] [**–pipe**] [**–help**] [**–version**]

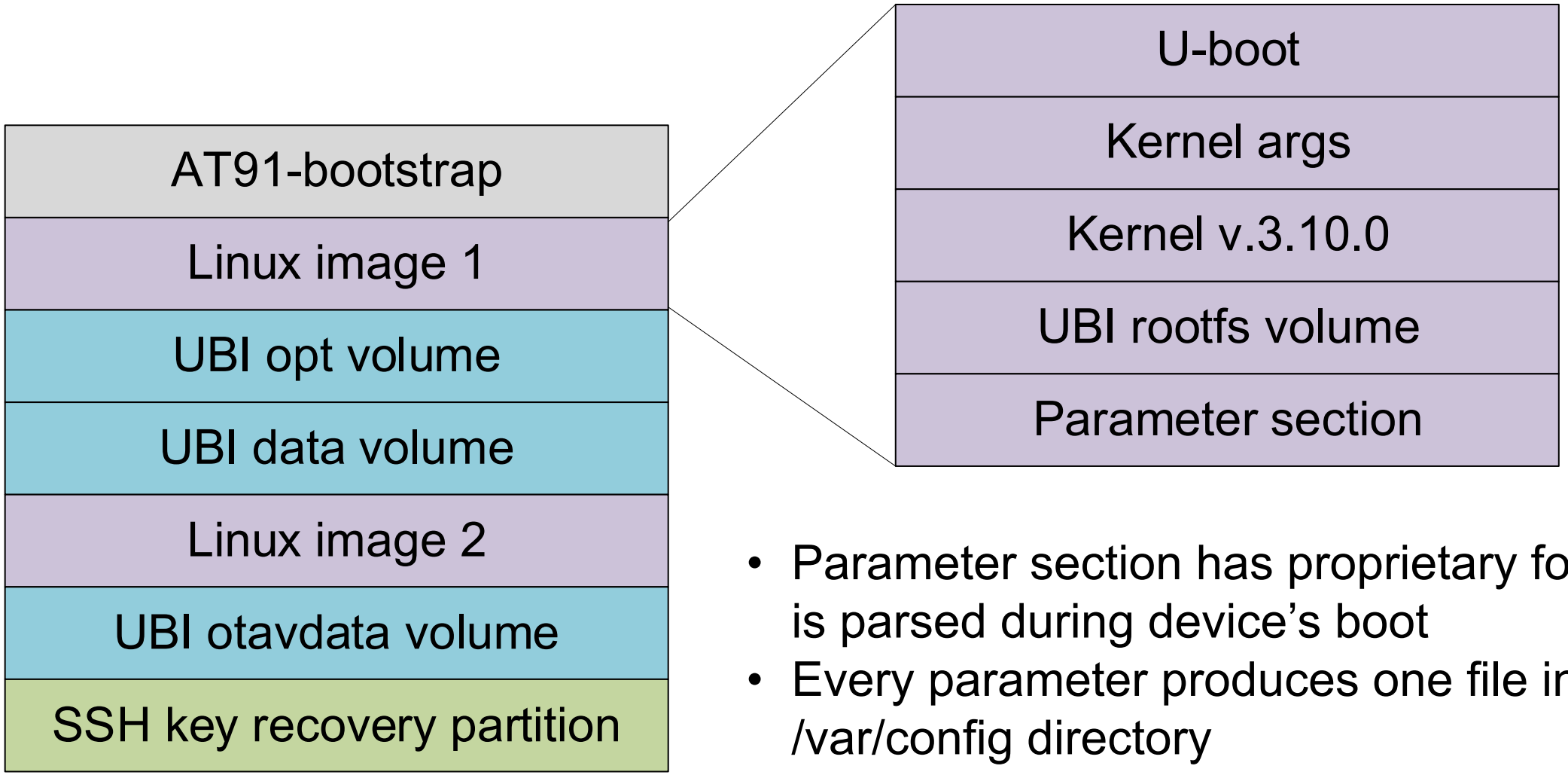


Playing with JTAG 1: Reading NAND



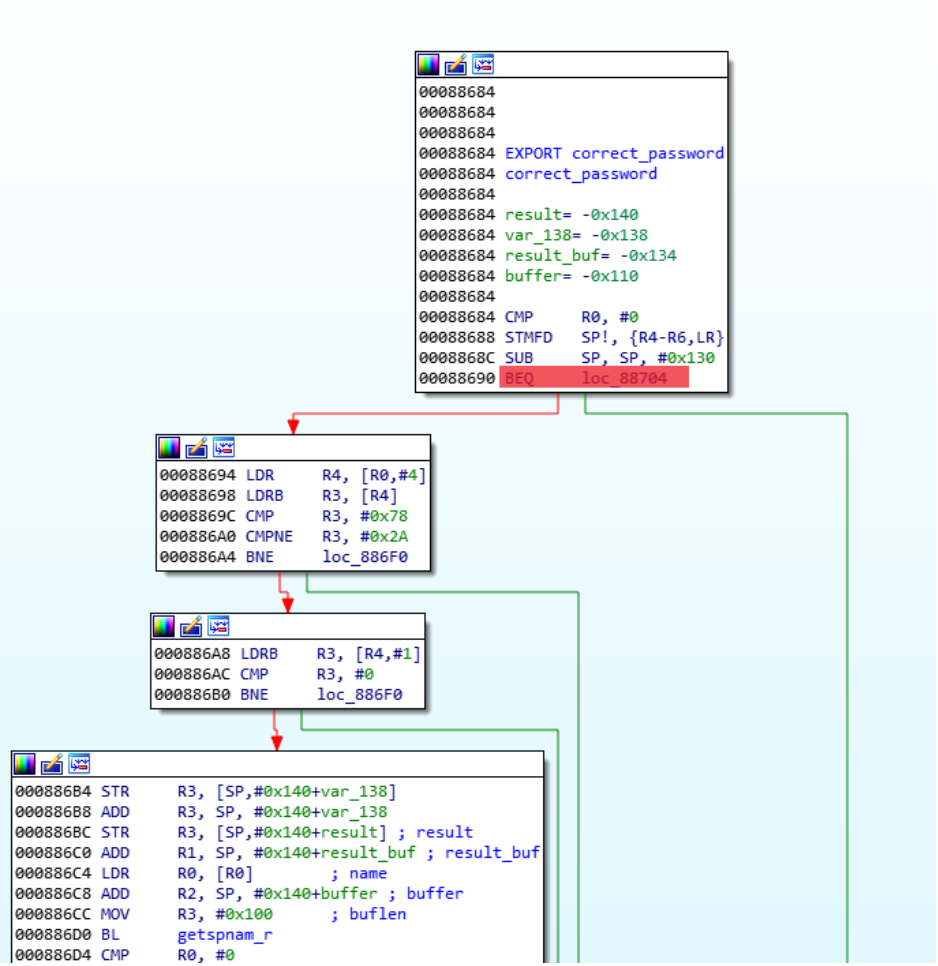
- Programmed in (every) Atmel MPU
- Contains procedure that reads NAND pages in fixed buffer in internal SRAM
- Procedure can be invocated in cycle with JTAG

NAND Layout



- Parameter section has proprietary format and is parsed during device's boot
- Every parameter produces one file in /var/config directory

Playing with JTAG 2: Root With Telnet



- Procedure that verifies the input password located in the Busybox
- We can invert result of the verification by changing the outlined instruction with JTAG

Wi-Fi

SSL (ports **443** and **55557**)

SSL services

SSL

- stunnel
- mutual authentication
- server's private key encrypted

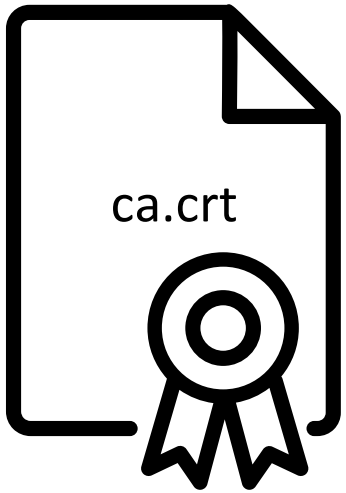
HTTP

- Thttpd
- No actual web content
- CGI interface

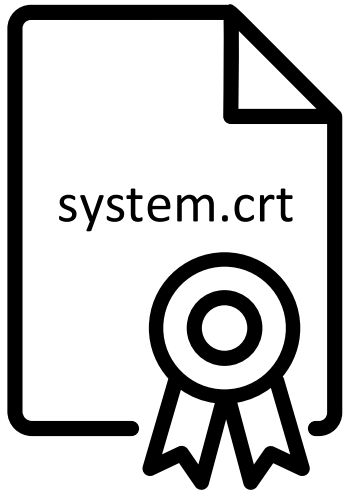
Telnet

- Busybox

Certificates

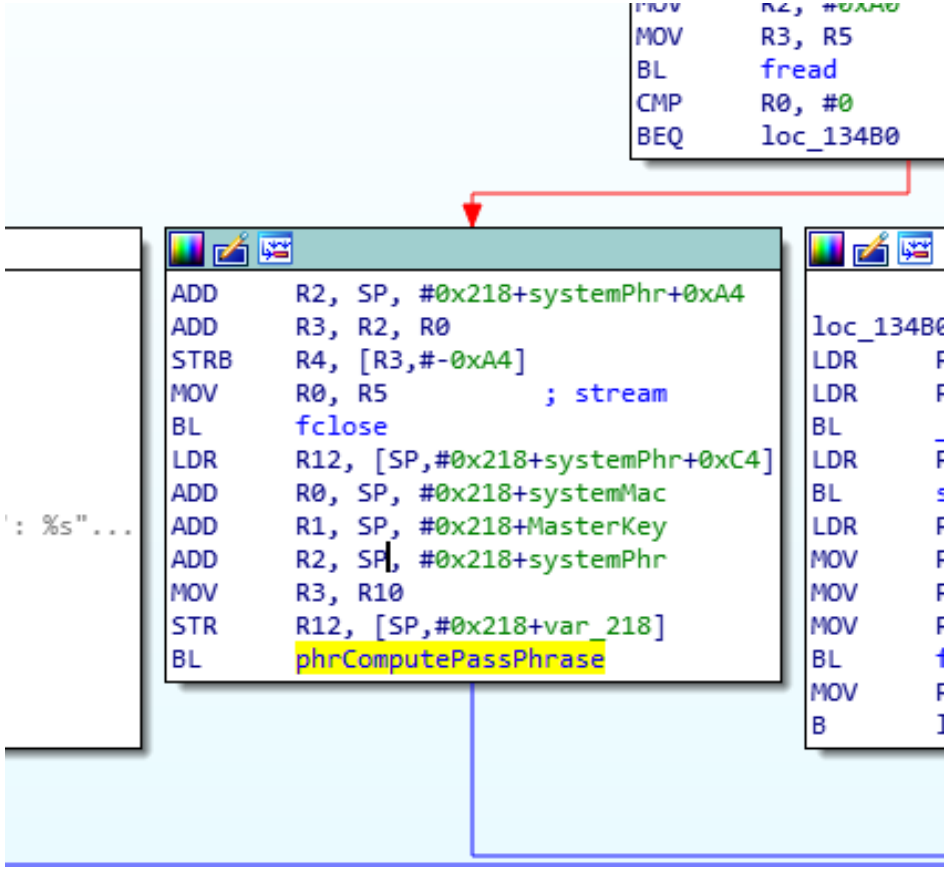


- Certificate authority



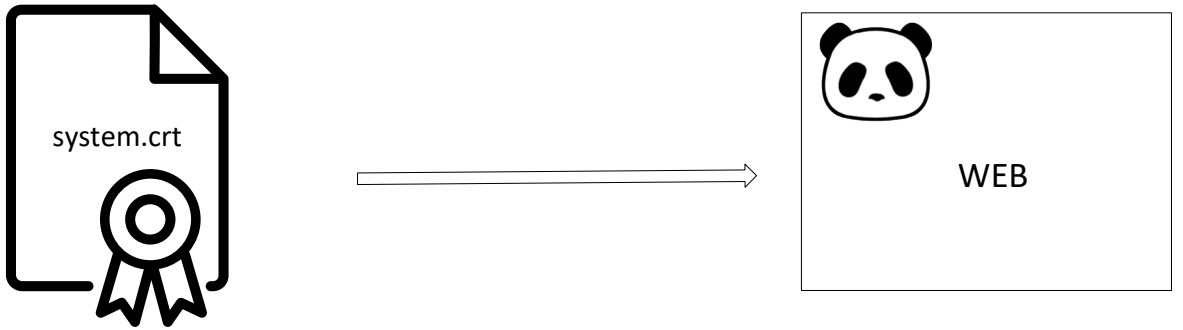
- SSL server certificate
- Stored with private key
- Private key is encrypted, but everything for the decryption is available

Certificate decryption key



- Decryption is done by stunnel
- Here is the code, that generates the decryption key
- We can download the key from the memory after the function execution (JTAG)

SSL Bypass

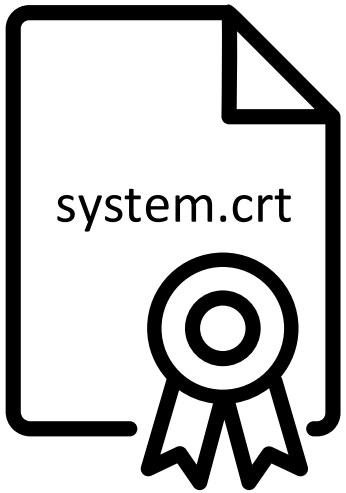


403 Forbidden

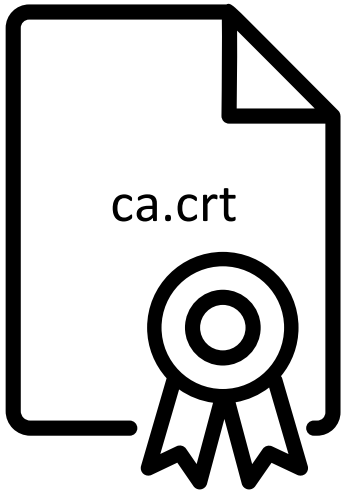
The requested URL '/' is a directory, and directory indexing is disabled on this server.

thttpd/2.25b 29dec2003

Certificates



Subject:
C = US, ST = CA, O = "Coulomb Technologies, Inc.", OU = Engineering,
CN = 0024b100000265f1.chargepoint.net,
emailAddress = ca@chargepoint.net
X509v3 Authority Key Serial:
B4:9F:86:A8:76:18:8A:33

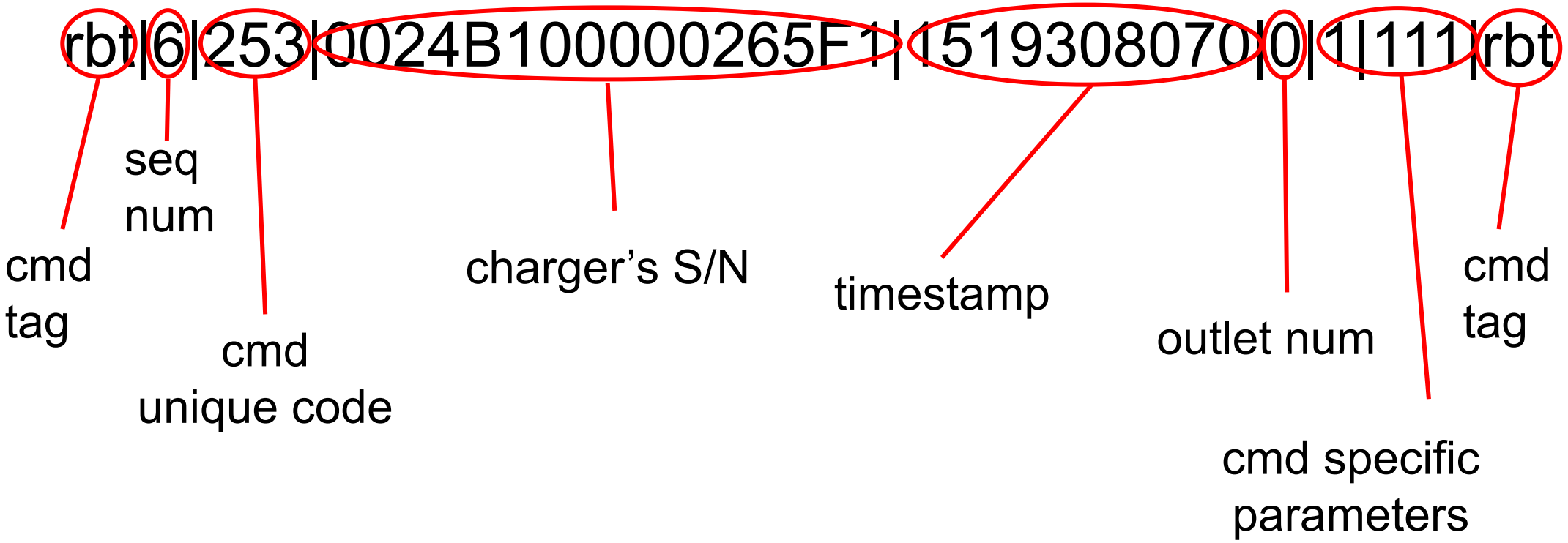


Serial Number:
B4:9F:86:A8:76:18:8A:33
Subject:
C = US, ST = CA, O = "Coulomb Technologies, Inc.",
OU = Engineering,
CN = ca.chargepoint.net, emailAddress = ca@chargepoint.net

CGI

uploadsm	dwnldlogsm	getsrvr
• uploading configuration	• downloading logs	• misc. commands

Command format



Vulnerabilities 1

Arbitrary file write in uploadsm

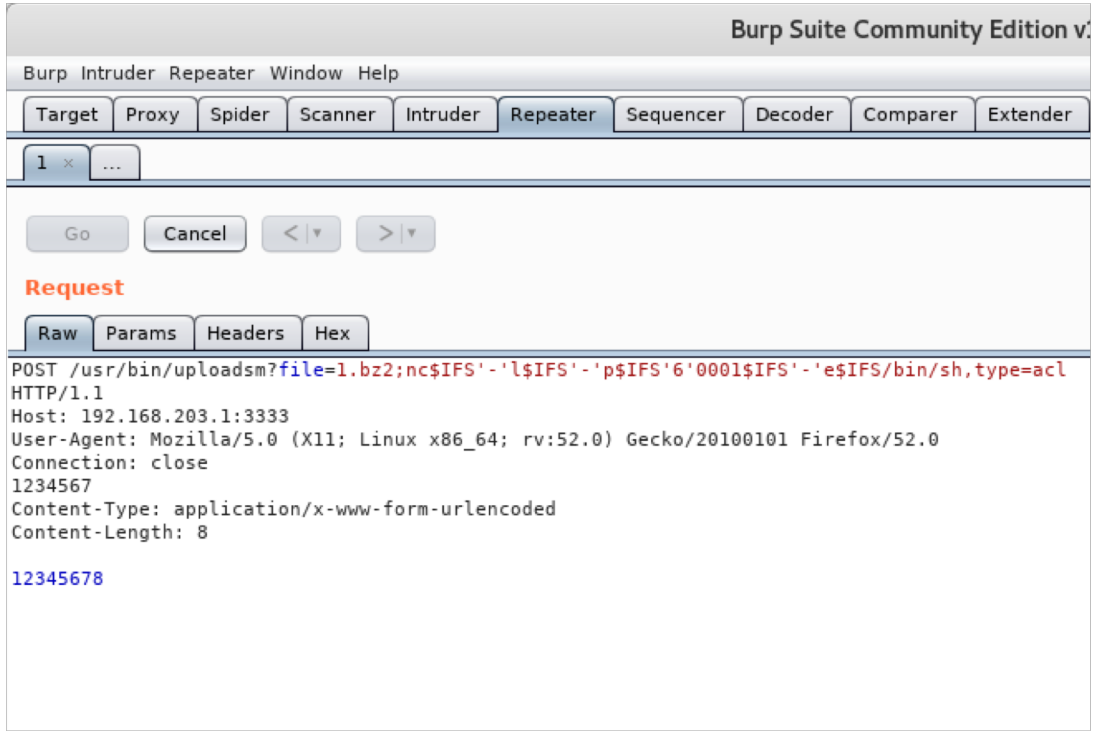
Substring from the input

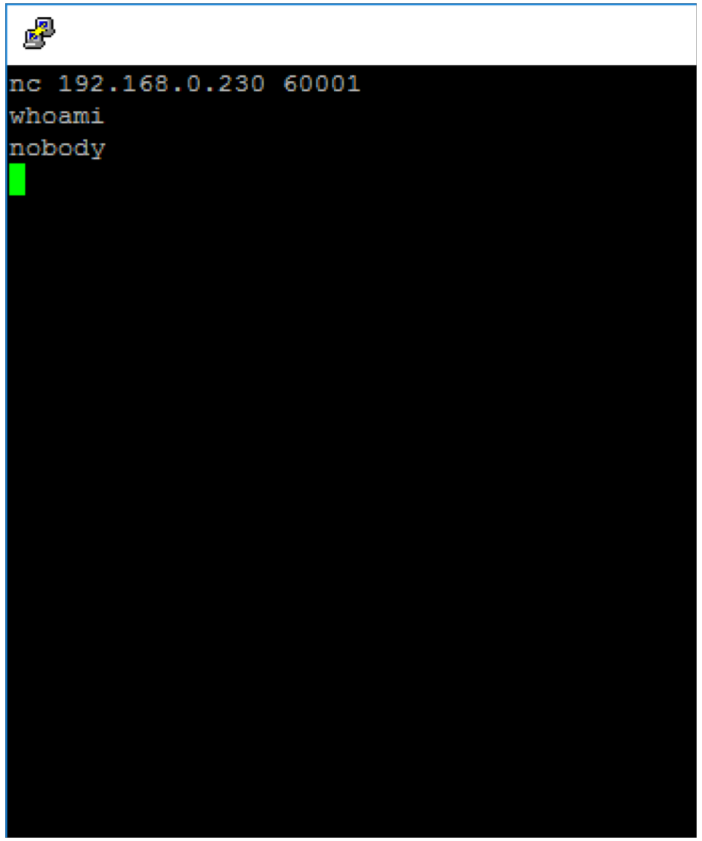
```
sprintf(path, "%s%s", "/otavdata/", newFilePath);
fopen (path,”wb”);
```

No verification against “../ sequence in file path

Vulnerabilities 2

OS command injection in uploadsm





Vulnerabilities 3

Stack buffer overflow in getsrvr and uploadsm

```
sscanf(&input,"%[^|]|%d|%d|%16s|%ld|%d|%d|%d|%[^|]|%[^|]|
%s",&v1,%v2,…,&v11)
```

Input commands are parsed without length checking

ASLR Bypass Details

- Stack is executable, but its position is randomized
- ~512 possible positions
- ~350 tries to guess position with 50% prob.
- 2 seconds per try
- 15 minutes in average for successful payload launch

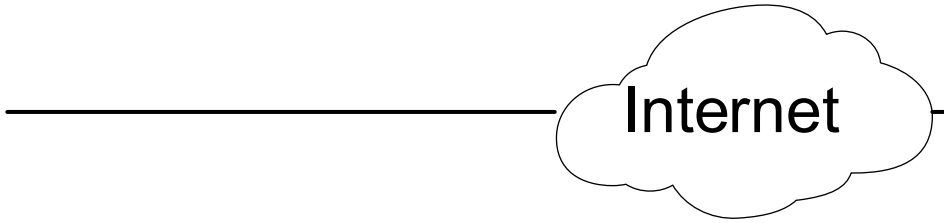
Wi-Fi

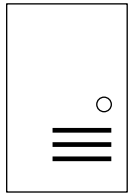
SSL (ports **443** and **55557**)

Communications with backend

Control server communications

GET /ws-prod/panda/v1 HTTP/1.1
…
Host: homecharger.chargepoint.com
…
Sec-WebSocket-Protocol: **ocpp2.0**
Sec-WebSocket-Extensions:
Sec-WebSocket-Version: 13





Backend

OCPP2.0(ChargePoint edition)

- Based on OCPP1.6
- Messages are encapsulated into standard OCPP packets
- Uses encrypted connection (TLS)
- Device’s TLS certificate is the same, that is used as webserver’s certificate (system.crt)

Stack buffer overflow

```
sscanf(input,"%[^|]|%d|%d|%16s|%ld|%d|%d|%16s|%s",&v1,&v2,&v
3,&v4,&v5,&v6,&v7,&v8,&v9);
```

Commands have the same format as in the CGI, that leads to the same vulnerability

ASLR Bypass Details

- ~512 possible positions
- ~350 tries to guess position with 50% prob.
- Reboot is occurring every 4 process crashes
- ~1 minute per try
- About 6 hours in average for successful payload launch
- A lot of special effects due to reboots

Wi-Fi

SSL (ports **443** and **55557**)

Communications with backend

Way to the vendor’s network

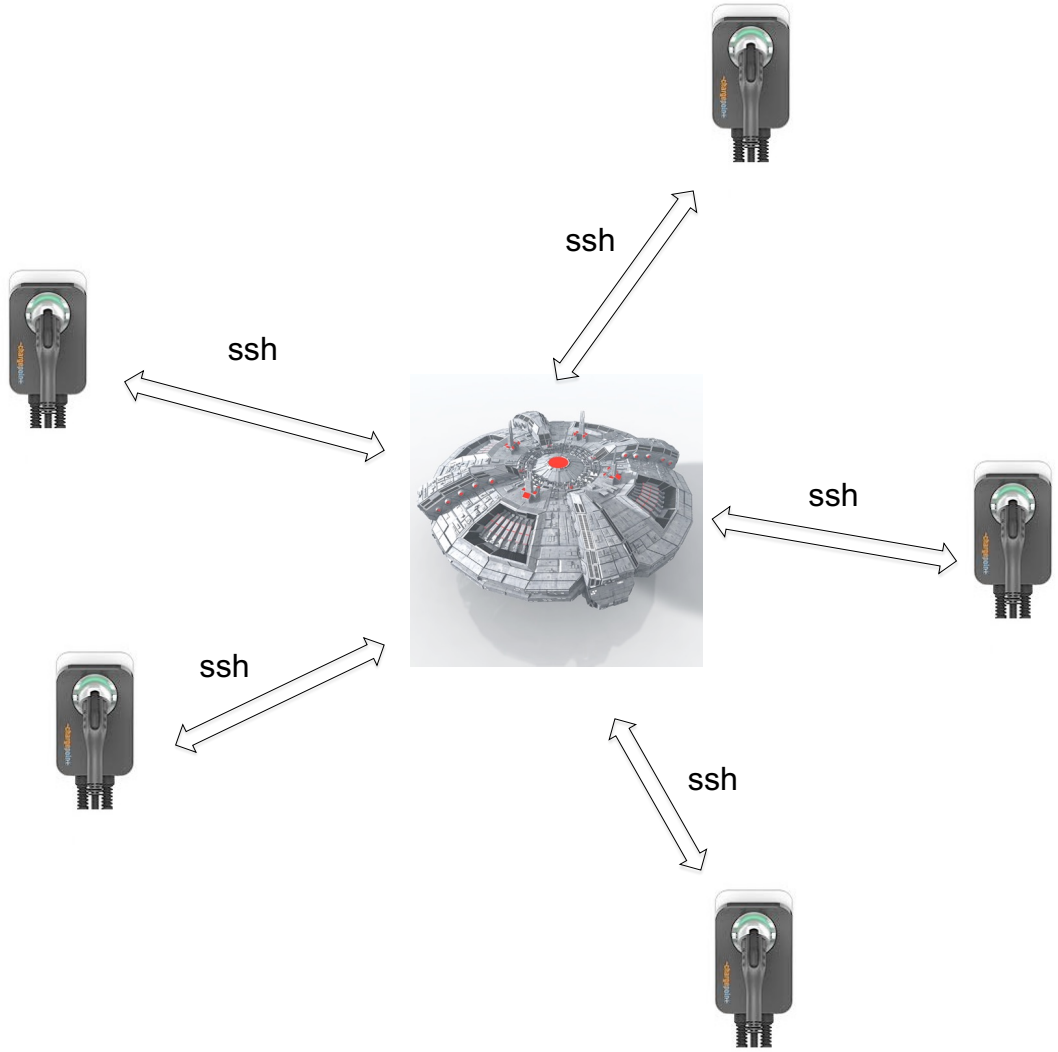
sshrevtunnel.sh

```
#!/bin/sh
# Bring up pinned up reverse tunnel to mothership.

while true; do
      ssh -o "StrictHostKeyChecking no" -o "ExitOnForwardFailure yes"
      $REVSYSTEMPORT -N -T -R $REVPORT:localhost:23 $REVHOST &
done

$REVPORT is calculated based on chargers S/N
$REVHOST is hardcoded for each year of production
```

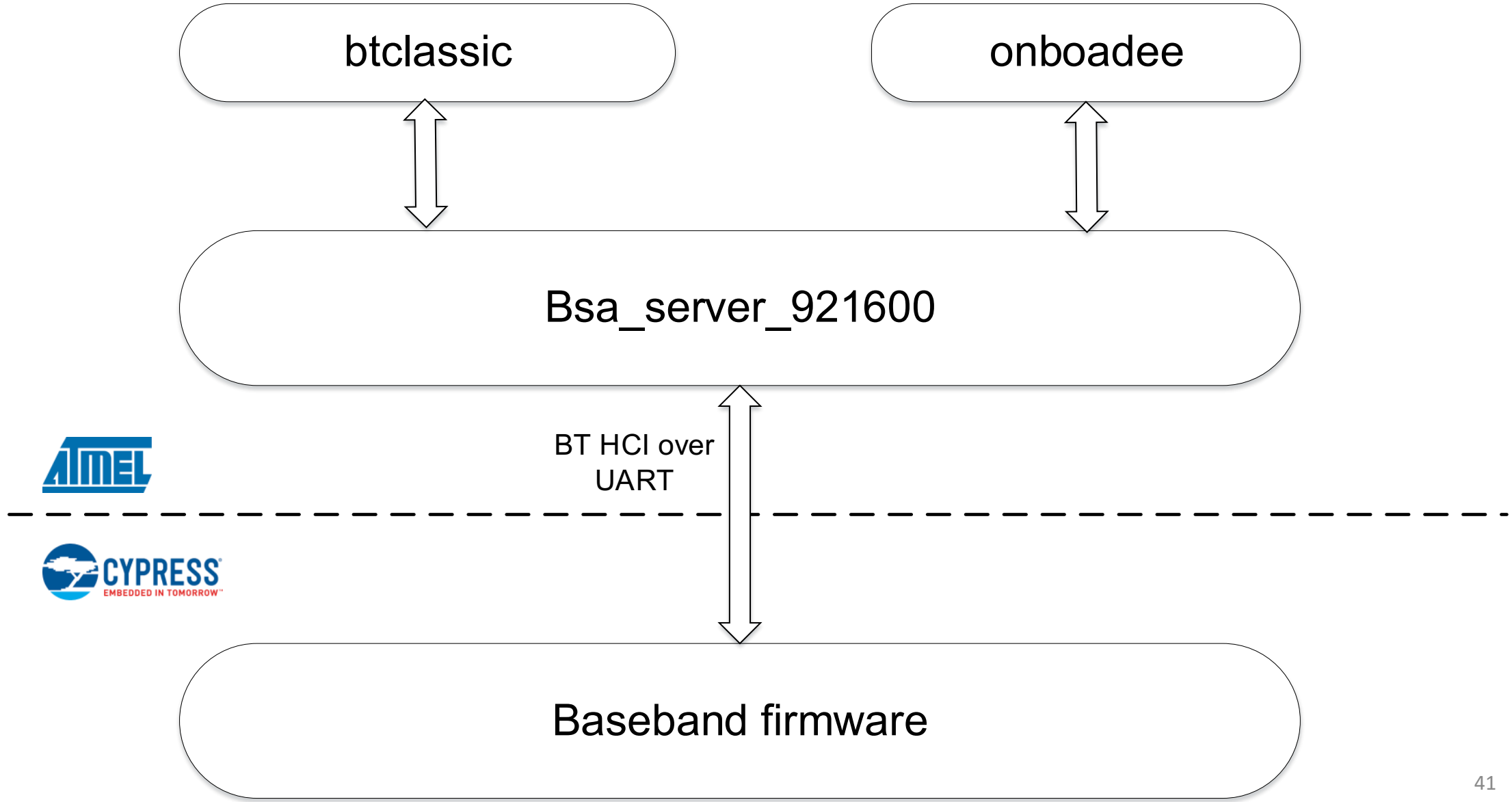
sshrevtunnel.sh



- Key-based authentication is used, and the key is stored in NAND in the unencrypted form
- Potentially it's possible to rule the mothership and the whole swarm (out of scope)

Bluetooth

Bluetooth stack



Vehicle interface

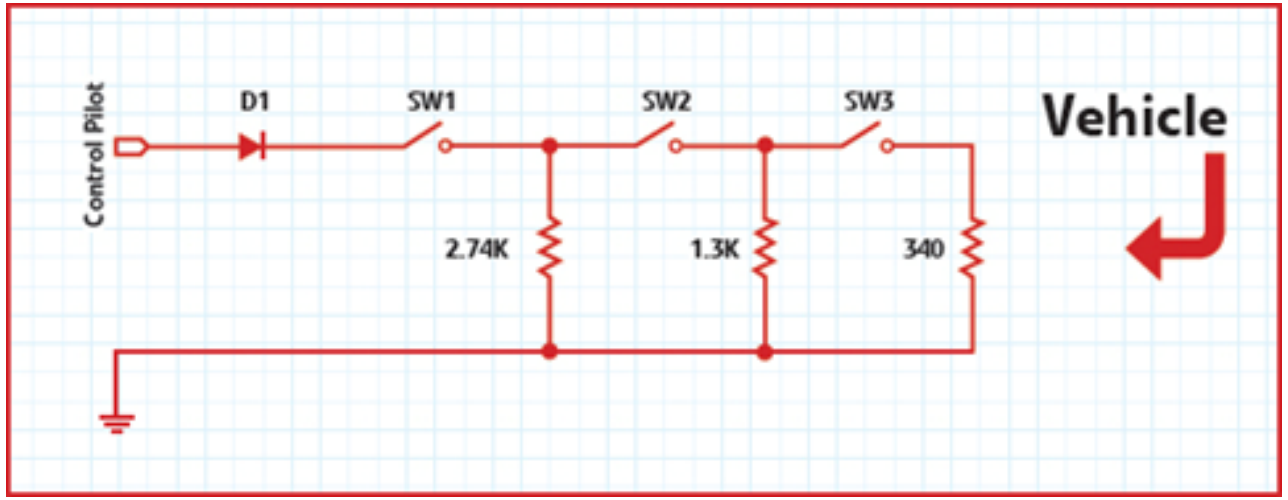
J1772 vehicle interface

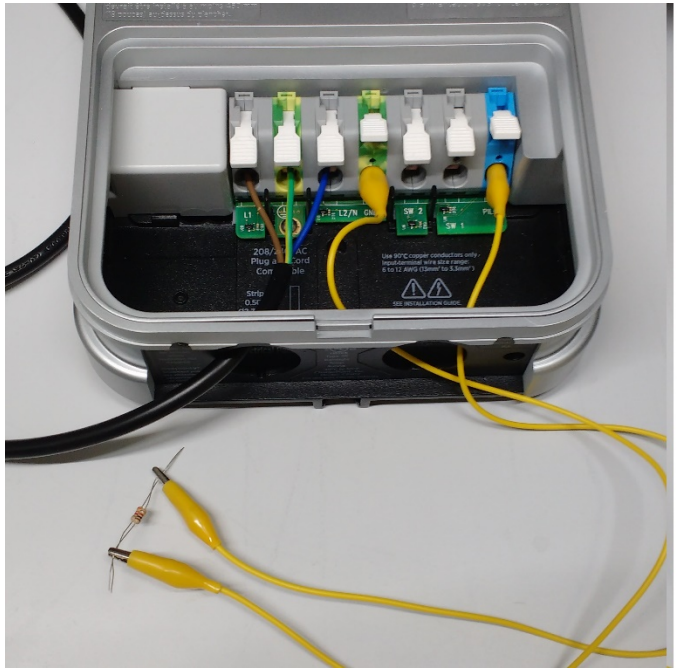
Vehicle signalize it’s status by closing switches:

SW1: vehicle charged

SW1&SW2: vehicle ready for charging

SW1&SW2&SW3: vehicle ready for charging with ventilation





Disclosure timeline & vendor response

- 07-08-2018: We sent all our findings to the vendor
- 21-08-2018: A detailed action plan was developed and discussed to mitigate the vulnerabilities
- 14-09-2018: New firmware with all bugs fixed was released

Information Security at ChargePoint

- ChargePoint takes the security of our products and services seriously. We dedicate significant resources to this area including:
  - Following best practices for secure design and testing of our products
  - Regular 3rd party penetration testing against our products and systems that store sensitive data
- Thank you Kaspersky for helping us enhance the security of our products!
  - Your patience and persistence were helpful as these were the first externally-detected vulnerabilities reported to us
  - All the vulnerabilities identified have been patched
- If you feel you have discovered a possible privacy or security vulnerability, please contact us at security@chargepoint.com with a description of the issue.

Summary

- Several vulnerabilities in Wi-Fi and Bluetooth stacks were found
- Coordinated disclosure: all vulnerabilities were promptly fixed
- EV industry opens wide area for research:
  - Transactions protocols
  - EV-EVSE communication protocols
  - …

Questions?

@kl_secservices
@d_sklyar