Reverse engineering smart cards

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Overview

objective
: understand smart card communication based on sniffable communication

hardware
: standard card reader

software
: something that can talk to the smart card (typically in emulator), `cat /dev/usbmon0`, some own tools

Smart card basics

Practical examples

Smart card basics

Practical examples

Common cards and readers

Low level

- shape and contacts defined in ISO 7816-1 and -2
- contacts for ground, power, reset, clock, and I/O
- serial communication
- ATR: answer to reset (up to 33 byte)
- protocol T=1 for sending and receiving byte string messages

High level

```
> 00 a4 00 00 02 01 02
< 90 00
> 00 b0 00 00 00
< 00 00 02 14 90 00
```

- command/response dialogue
- command = APDU, consisting of
  - CLA (usually `00`, other values indicate proprietary commands or RFU)
  - INS (instruction, eg. `a4` = "Select File")
  - P1, P2 (arguments, eg `04 00` = "Select by DF")
  - length and data, depending on INS
- response, consisting of
  - data, depending on INS
  - SW1, SW2 (return code, eg `90 00` = "OK")

Interfaces and drivers

CCID standard for USB card readers

PC/SC Windows API for smart cards

PCSC-Lite the same interface on Linux and OS X

OpenSC library focused on crypto (PKCS#x), brings some own drivers

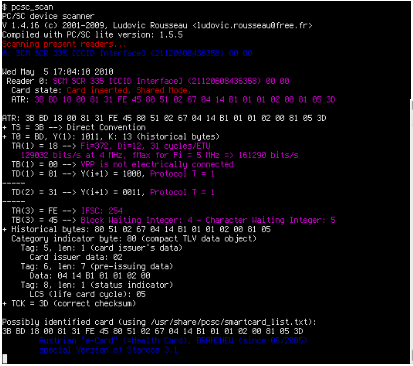
libchipcard library focused on not blocking unused devices

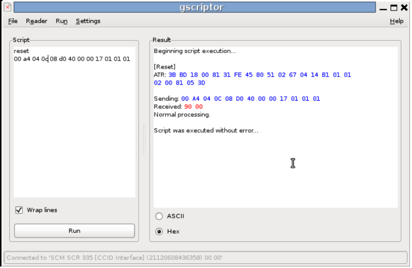
carddecoders my tools and example programs for smart card reverse engineering, based on Python PCSC bindings (`http://christian.amsuess.com/tools/carddecoders/`)

Smart card basics

Practical examples

Trying it out: pcsc-tools





- pcsc_scan
- (g)scriptor

Sniffing on Linux

- Software that talks to the card can run in a VM (eg. ActiveX applet)
- Linux lets you sniff USB communication using `/dev/usbmon0`; output is CCID inside usbmon's binary logging format
- Workflow:
  - `sudo cat /dev/usbmon0 > sniffing_run_1.out`
  - Do something with the card
  - Stop `cat` with `^C`
  - `logdecoder -r sniffing_run_1.out` (from carddecoders)

```
> 00 a4 00 00 02 01 02
< 90 00
> 00 b0 00 00 00
< 00 00 02 14 90 00
```

Interpreting returned data: Encodings

- Look for numbers known to be read
- Big Endian: 02 00 = 512

```
> 00 a4 00 00 02 01 02
< 90 00
> 00 b0 00 00 00
< 00 00 02 14 90 00
```

€ 5.32

Interpreting returned data: Encodings

- Look for numbers known to be read
- Big Endian: 02 00 = 512
- Binary Coded Decimal: 12 34 = 1 234

```
> 00 a4 00 00 02 3f 00
< 90 00
> 00 a4 00 00 02 00 02
< 90 00
> 00 b0 00 00 08
< 09 6f 06 70 00 21 20 00 90 00
```

BLZ 12000

Interpreting returned data: Encodings

- Look for numbers known to be read
- Big Endian: `02 00` $= 512$
- Binary Coded Decimal: `12 34` $= 1\,234$
- ASCII: `31 32 33 34` $= 1234$

Interpreting returned data: Encodings

- Look for numbers known to be read
- Big Endian: 02 00 = 512
- Binary Coded Decimal: 12 34 = 1 234
- ASCII: 31 32 33 34 = 1234
- Other creative encodings for dates etc.

```
> 00 b2 01 04 00
< [...] 90 00 01 00 05 10 46 01 00 [...]
> 00 b2 02 04 00
< [...] 90 00 00 93 44 13 31 00 00 [...]
> 00 b2 03 04 00
< [...] 90 00 00 93 44 13 31 00 00 [...]
```

2010-01-05, 10:46 local time (day 5 of the year '010)
2009-12-10, 13:31 local time (day 344 of the year '009)

Exploring commands

- Some commands can be bent.

```
> 00 b0 00 00 08
< 09 6f 06 70 00 21 20 00 90 00
```

According to ISO 7816, the last byte gives the number of bytes to read. Let's assume it works like POSIX's `read`:

```
> 00 b0 00 00 00
< 09 6f [...] 95 01 23 66 02 00 [...] 01 90 00
```

Exploring commands

- Some commands can be bent.
- Others can be bruteforced.

```
> 00 a4 00 00 02 df 01
< 90 00
```

This was known to work. . . Let's try this:

```
> 00 a4 00 00 02 df 08
< 6a 00
```

No . . . One more?

```
> 00 a4 00 00 02 df 09
< 6f 14 84 07 a0 00 [. . .] 54 52 4f 90 00
```

This works, and even sends data immediately.

Card state

- Smart card directory structure:

```
/ 3f 00 ........................ master file (MF)
├── 00 02 .............. single file: "Read Binary"
├── df 01 ...................... dedicated file (DF)
│   ├── 01 01
│   └── 01 03 .... fixed records: "Read Record(n)"
└── df 09
    └── 00 01 . variable records: "Read Record(n)"
```

- File selection seems rather safe for experimenting
- More card state: authentication, challenge/response (limited tries!)

Tools provided by carddecoders

- `logdecoder`

Decodes usbmon output to

```
> 00 a4 00 00 02 00 02
< 90 00
> 00 b0 00 00 08
< 09 6f 06 70 00 21 20 00 90 00
```

...And generates Python code from it:

```python
card.transmit(SelectFile([0x00, 0x02]))
# OK
card.transmit(ReadBinary(length=8))
# 09 6f 06 70 00 21 20 00, OK
```

Tools provided by carddecoders

- `logdecoder`
- `carddecoders.reverse_helpers`

Find numbers in various encodings:

```
>>> contains_number(ByteString(
    "09 6f 06 70 00 21 20 00"), 12000)
number found in BCD at offset 5.5 bytes
>>> contains_number(ByteString(
    "09 6f 06 70 00 21 20 00"), 1648)
number found in big endian encoding ending
at 4.0 bytes
```

Find length indicators:

```
>>> backward_length(ByteString(
    "70 3c 5f [...] 5f 28 02 00 40"))
index 1: 60 remaining
index 59: 2 remaining
```

Further reading

- Introduction to Smart Cards

  http://www.smartcard.co.uk/tutorials/sct-itsc.pdf
- Overview over ISO 7816

  http://www.cardwerk.com/smartcards/smartcard_standard_ISO7816.aspx
- Smartcard protocol sniffing (hardware side)

  http://events.ccc.de/congress/2007/Fahrplan/events/2364.en.html