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

```
1 > 00 a4 00 00 02 01 02
2 < 90 00
3 > 00 b0 00 00 00
4 < 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

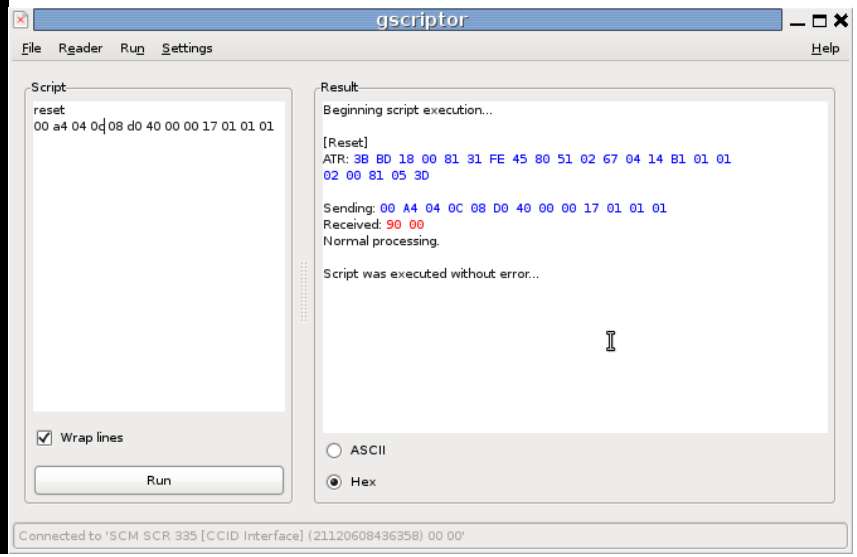
Trying it out: pcsc-tools

```
$ pcsc_scan
PC/SC device scanner
V 1.4.16 (c) 2001-2009, Ludovic Rousseau <ludovic.rousseau@free.fr>
Compiled with PC/SC lite version: 1.5.5
Scanning present readers...
0: SCM SCR 335 [CCID Interface] (21120608436358) 00 00

Wed May  5 17:04:10 2010
 Reader 0: SCM SCR 335 [CCID Interface] (21120608436358) 00 00
  Card state: Card inserted, Shared Mode,
  ATR: 3B BD 18 00 81 31 FE 45 80 51 02 67 04 14 B1 01 01 02 00 81 05 3D

ATR: 3B BD 18 00 81 31 FE 45 80 51 02 67 04 14 B1 01 01 02 00 81 05 3D
+ TS = 3B --> Direct Convention
+ T0 = BD, Y(1): 1011, K: 13 (historical bytes)
  TA(1) = 18 --> Fi=372, Di=12, 31 cycles/ETU
    129032 bits/s at 4 MHz, fMax for Fi = 5 MHz => 161290 bits/s
  TB(1) = 00 --> VPP is not electrically connected
  TD(1) = 81 --> Y(i+1) = 1000, Protocol T = 1
-----
  TD(2) = 31 --> Y(i+1) = 0011, Protocol T = 1
-----
  TA(3) = FE --> IFSC: 254
  TB(3) = 45 --> Block Waiting Integer: 4 - Character Waiting Integer: 5
+ Historical bytes: 80 51 02 67 04 14 B1 01 01 02 00 81 05
  Category indicator byte: 80 (compact TLV data object)
    Tag: 5, len: 1 (card issuer's data)
      Card issuer data: 02
    Tag: 6, len: 7 (pre-issuing data)
      Data: 04 14 B1 01 01 02 00
    Tag: 8, len: 1 (status indicator)
      LCS (life card cycle): 05
+ TCK = 3D (correct checksum)

Possibly identified card (using /usr/share/pcsc/smartcard_list.txt):
3B BD 18 00 81 31 FE 45 80 51 02 67 04 14 B1 01 01 02 00 81 05 3D
       Austrian "e-Card" (=Health Card), BRANDNEW (since 06/2005)
       special Version of Starcos 3.1
```



- `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)

```
1 > 00 a4 00 00 02 01 02
2 < 90 00
3 > 00 b0 00 00 00
4 < 00 00 02 14 90 00
```

Interpreting returned data: Encodings

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

```
1 > 00 a4 00 00 02 01 02
2 < 90 00
3 > 00 b0 00 00 00
4 < 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

```
1 > 00 a4 00 00 02 3f 00
2 < 90 00
3 > 00 a4 00 00 02 00 02
4 < 90 00
5 > 00 b0 00 00 08
6 < 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.

```
1 > 00 b2 01 04 00
2 < [...] 90 00 01 00 05 10 46 01 00 [...]
3 > 00 b2 02 04 00
4 < [...] 90 00 00 93 44 13 31 00 00 [...]
5 > 00 b2 03 04 00
6 < [...] 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.

```
1 > 00 b0 00 00 08
2 < 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`:

```
1 > 00 b0 00 00 00
2 < 09 6f [...] 95 01 23 66 02 00 [...] 01 90 00
```

Exploring commands

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

```
1 > 00 a4 00 00 02 df 01
2 < 90 00
```

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

```
1 > 00 a4 00 00 02 df 08
2 < 6a 00
```

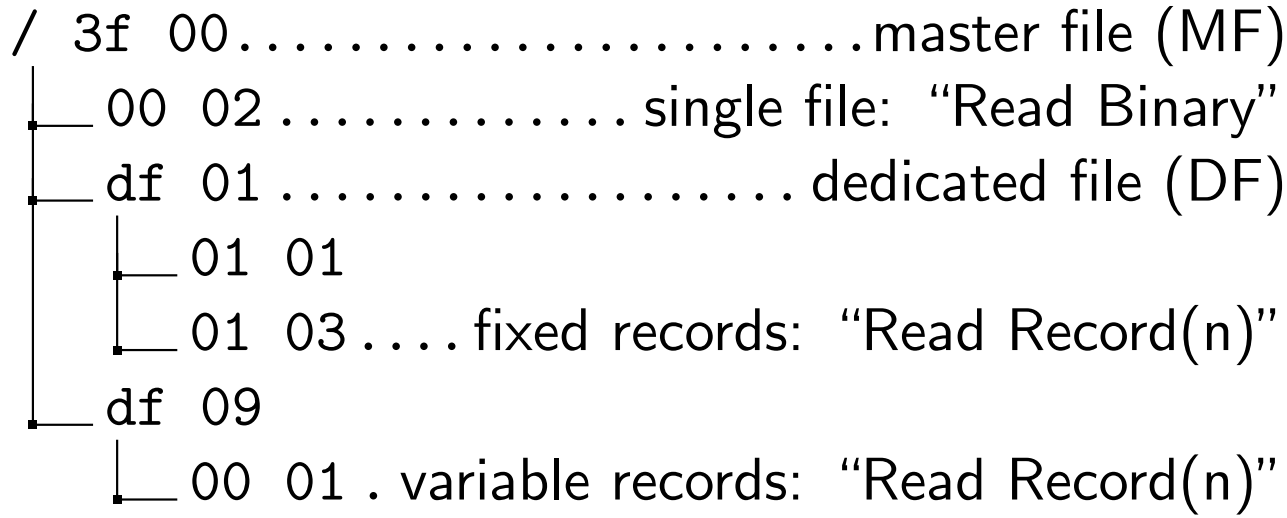
No . . . One more?

```
1 > 00 a4 00 00 02 df 09
2 < 6f 14 84 07 a0 00 [...] 54 52 4f 90 00
```

This works, and even sends data immediately.

Card state

- Smart card directory structure:



- 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:

```
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`