A Tour through the Realms of Reverse Engineering

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Universidad Zaragoza
1542

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Legacy Systems
Room A.12

Outline

Agenda

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Introduction to Reverse Engineering (I)

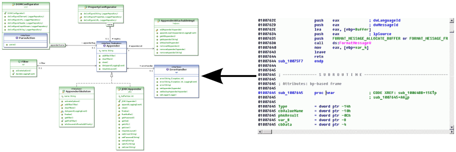
Reverse Engineering

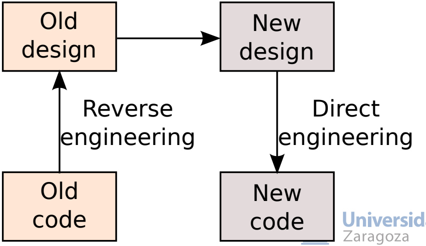
- Figure out how something works from an exhaustive analysis
- Improvement of legacy products/systems
- Different application domains
  - Hardware (legacy hardware)
  - Software (e.g. Samba)

Introduction to Reverse Engineering (I)

Reverse Engineering

- Figure out how something works from an exhaustive analysis
- Improvement of legacy products/systems
- Different application domains
  - Hardware (legacy hardware)
  - Software (e.g. Samba)
- Going backward in the development cycle





Introduction to Reverse Engineering (II): Motivation (1)

Motivation

- Interoperability
- Non-existent documentation
- Final product analysis
- Security audit
- Industrial (or military) espionage (e.g. II WW)
- Removal of anti-copy or limited use protections
- Creation of duplicates without license
- Academic
- Innate curiosity
- Learn about the errors of other people

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Introduction to Reverse Engineering (II): Motivation (2)

Find bugs in software

- Incorrect checking of buffer limits (buffer overflow)
- Use of data without previous validation
- Cyclic routines for input data
- Byte-level copy operations
- Pointer arithmetic based in user-input data
- “Trust" in security systems with dynamic inputs

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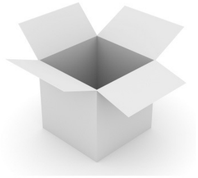
Introduction to Reverse Engineering (III): Approaches

- White-box
  - *Full* knowledge (e.g., source code)
  - E.g.: *WhiteBox SecureAssistant*, *IDAPro*, *SourceScope*...



Introduction to Reverse Engineering (III): Approaches

- White-box
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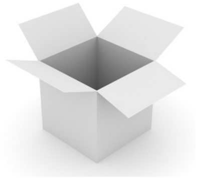
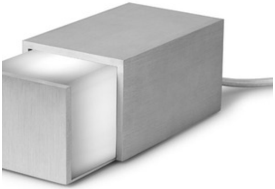
- Gray-box
  - *Partial* knowledge
  - E.g.: Rational's Purify (use/consumption of memory), Valgrind





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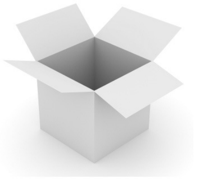
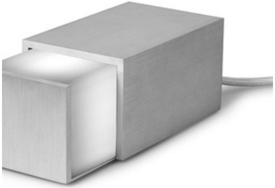
Introduction to Reverse Engineering (III): Approaches

- White-box
  - *Full* knowledge (e.g., source code)
  - E.g.: *WhiteBox SecureAssistant*, *IDAPro*, *SourceScope*. . .
- Gray-box
  - *Partial* knowledge
  - E.g.: Rational's Purify (use/consumption of memory), Valgrind
- Black-box
  - *Null* knowledge
  - Analyse outputs of the system depending on different inputs





Reverse Engineering

Choose your side!

On hardware

- Reverse engineering of integrated circuits/smart cards
  - Low-level details
  - Physics and electronic knowledge (plus special hardware)
- Reverse engineering of devices
  - How system works?
  - How are the inputs and outputs?

On software

- Reverse engineering of protocols
  - How network layer works
- Reverse engineering of software
  - Low-level code analysis: assembly, calling conventions
  - Use of debugging/disassembler/decompiler tools
  - Programming

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Reverse Engineering of Protocols

- Message format
  - **Normally done by manual analysis**
  - Recent research on automatic analysis
    - Message clustering
    - Emulate protocol implementation tracing message processing
- Protocol inference
  - **Get the state-machine of the protocol**
  - Two techniques
    - Off-line learning: observes communication and build a state-machine that matches observed message sequences → NP-complete problem
    - On-line learning: the predictor is updated at each step with the given data. Polynomial time

Check out papers of J. Caballero et al. (2007, 2009) and Cho et al. (2010)

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Reverse Engineering of Software

Reverse code engineering

- Also known as *cracking* (also as Software Reverse Engineering)
- Remove code protections (copyrights)
- NOT always bad: bugs detection, potential exploits, . . . in your programs

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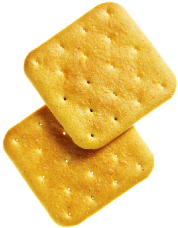
Reverse Engineering of Software

Reverse code engineering

- Also known as *cracking* (also as Software Reverse Engineering)
- Remove code protections (copyrights)
- NOT always bad: bugs detection, potential exploits, . . . in your programs
- Crackers: something else than a (salt) cookies. . .
  - NOT MISTAKE with *CRiminal hACKERS*



Reverse Engineering of Software

- Involves knowledge of assembler
- Involves knowledge of file formats
- Involves knowledge of Operating System
- Involves knowledge of networks

Reverse Engineering of Software

- Involves knowledge of assembler
- Involves knowledge of file formats
- Involves knowledge of Operating System
- Involves knowledge of networks
- Involves knowledge of laws
  - Jail is cold

Methods

- Analyze information exchange (on computer bus and network)
- Disassembler: read `PUSH EAX` instead of `0x50`
- Decompilation: recreate the high-level representation of the bytes

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Reverse Engineering of Software

Well-known RCE examples

- Samba
  - They reverse-engineer unpublished information about how Windows file sharing worked
- Wine
  - They reverse-engineer unpublished information about Windows API
- OpenOffice
  - They reverse-engineer unpublished information about Microsoft Office file formats
- Mac OS System 4.1
  - Reversed in 1987 by Bell Laboratories to enable this OS to execute on RISC machines of their own

Reverse Engineering of Software

Static Analysis

- Code is not executed (cold analysis)
- Steps:
  1. Analyse the PE header
  2. Read the code (disassembler)
  3. Search for strings
  4. THINK!

Reverse Engineering of Software

Static Analysis

- Code is not executed (cold analysis)
- Steps:
  1. Analyse the PE header
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Can you figure out what is doing? → Not enough in all binaries

Reverse Engineering of Software

Dynamic Analysis

- Code is executed (hot analysis)
- Steps:
  1. Analyse the PE header
  2. Read the code (debugger)
  3. Search for strings
  4. Observe the execution
  5. THINK!

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Reverse Engineering of Software

Dynamic Analysis

- Code is executed (hot analysis)
- Steps:
  1. Analyse the PE header
  2. Read the code (debugger)
  3. Search for strings
  4. Observe the execution
  5. THINK!

Can you find out *now* what is doing?

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Reverse Engineering of Software

Understanding Assembler from Code – a MUST!

```c
int main(int argc, char* argv[])
{
  printf("Hello, world! My name is %s and
    I've %d years old.", "Restituto", 23);
  return 0;
}
```

```asm
  .section .rdata,"dr"
LC0:
  .ascii "Restituto\0"
  .align 4
LC1:
  .ascii "Hello, world! My name is %s and
                I've %d years old.\0"
  .text

_main:
LFB6:
  push  ebp
  mov   ebp, esp
  and   esp, -16
  sub   esp, 16
  call  ___main
  mov   DWORD PTR [esp+8], 23
  mov   DWORD PTR [esp+4], OFFSET FLAT:LC0
  mov   DWORD PTR [esp], OFFSET FLAT:LC1
  call  _printf
  mov   eax, 0
  leave
  ret
```

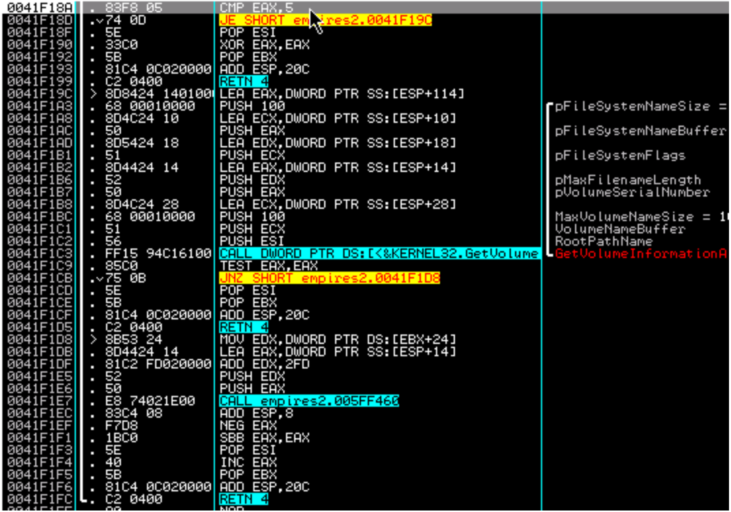
Reverse Engineering of Software

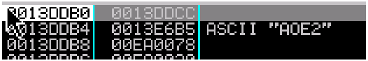
Basic techniques

- CD-Check
  - Check presence of a specific drive (e.g., AoE II, AvP Gold Editon)
- Event-fishing
  - Windows follows event-driven paradigm
  - Detect where a certain message is handled. That is, reveal the function that handles an input
- Serial-fishing
  - Find the correct serial for registering a software
- Keygenning. Two types:
  - Self-keygenning: patch the binary to show the correct key by itself
  - Keygen: replicate the key code generation

Reverse Engineering of Software

Example of CD Check (1)





Reverse Engineering of Software

Example of CD Check (2)

```
* Reference To: KERNEL32.GetDriveTypeA, Ord:0104h
                                  |
:10001898 FF1568110110            Call dword ptr [10011168]
:1000189E 83F805                  cmp eax, 00000005
:100018A1 7569                    jne 1000190C
:100018A3 33ED                    xor ebp, ebp
:100018A5 BF01000000              mov edi, 00000001

* Referenced by a (U)nconditional or (C)onditional Jump at Address:
|:100018FD(C)
|
:100018AA 8D4C2414                lea ecx, dword ptr [esp+14]
:100018AE 57                      push edi
:100018AF 51                      push ecx
:100018B0 8D542454                lea edx, dword ptr [esp+54]

* Possible StringData Ref from Data Obj ->"%strack%02d.cda"
                                  |
:100018B4 68C4600110              push 100160C4
:100018B9 52                      push edx
:100018BA 895C2458                mov dword ptr [esp+58], ebx
:100018BE E89A0F0000              call 1000285D
:100018C3 8D44245C                lea eax, dword ptr [esp+5C]
```

```
* Possible StringData Ref from Data Obj ->"rb"
                                  |
:100018C7 68C0600110              push 100160C0
:100018CC 50                      push eax
:100018CD E8780F0000              call 1000284A
:100018D2 8BF0                    mov esi, eax
:100018D4 83C418                  add esp, 00000018
:100018D7 3BF3                    cmp esi, ebx
:100018D9 7424                    je 100018FF
:100018DB 56                      push esi
:100018DC 6A0B                    push 0000000B
:100018DE 8D4C2428                lea ecx, dword ptr [esp+28]
:100018E2 6A04                    push 00000004
:100018E4 51                      push ecx
:100018E5 E8180E0000              call 10002702
:100018EA 8B4C2458                mov ecx, dword ptr [esp+58]
:100018EE 56                      push esi
:100018EF 03E9                    add ebp, ecx
:100018F1 E88F0D0000              call 10002685
:100018F6 83C414                  add esp, 00000014
:100018F9 47                      inc edi
:100018FA 83FF10                  cmp edi, 00000010
:100018FD 7EAB                    jle 100018AA

* Referenced by a (U)nconditional or (C)onditional Jump at Address:
|:100018D9(C)
|
:100018FF 83FF10                  cmp edi, 00000010
:10001902 7508                    jne 1000190C
:10001904 81FDC09A4200            cmp ebp, 00429AC0
:1000190A 741F                    je 1000192B

* Referenced by a (U)nconditional or (C)onditional Jump at Address:
|:10001902(C)
|
:1000190C 8A442413                mov al, byte ptr [esp+13]
:10001910 FEC0                    inc al
:10001912 3C7A                    cmp al, 7A
:10001914 88442413                mov byte ptr [esp+13], al
:10001918 0F8E6DFFFFFF            jle 1000188B
:1000191E 5F                      pop edi
:1000191F 5E                      pop esi
:10001920 5D                      pop ebp
:10001921 33C0                    xor eax, eax
:10001923 5B                      pop ebx
:10001924 81C4A0000000            add esp, 000000A0
:1000192A C3                      ret
```

Reverse Engineering of Software

Example of serial-fishing (1)

Serial hardcoded in the code

Serial hardcoded in the code

```
00424FEC PUSH registro.00422798                      UNICODE "\english.dll"
0042505D MOV DWORD PTR SS:[EBP-90],registro.0042     UNICODE "Trial version expired"
00425080 MOV DWORD PTR SS:[EBP-80],registro.0042     UNICODE "This trial version has exp
004250FB MOV DWORD PTR SS:[EBP-90],registro.0042     UNICODE "Este producto ha caducado"
0042511E MOV DWORD PTR SS:[EBP-80],registro.0042     UNICODE "Este producto ha caducado.
00425187 PUSH registro.00422734                      UNICODE "alt"
004251D0 MOV DWORD PTR SS:[EBP-80],registro.0042     UNICODE "ERROR!"
0042542B PUSH registro.00422E48                      UNICODE "utilities 77 backdoor"
00425454 PUSH registro.00422E14                      UNICODE "RC10-FFGH-PPBA-9999"
004255C0 PUSH registro.00422798                      UNICODE "\english.dll"
00425625 MOV DWORD PTR SS:[EBP-80],registro.0042     UNICODE "Registration"
0042563C PUSH registro.00422E78                      UNICODE "There is a problem when tr
004256?1 PUSH registro.00422E6C                      UNICODE "..."
```

Serial hardcoded in the code

```
00424FEC PUSH registro.00422798                      UNICODE "\english.dll"
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0042563C PUSH registro.00422E78                      UNICODE "There is a problem when tr
```
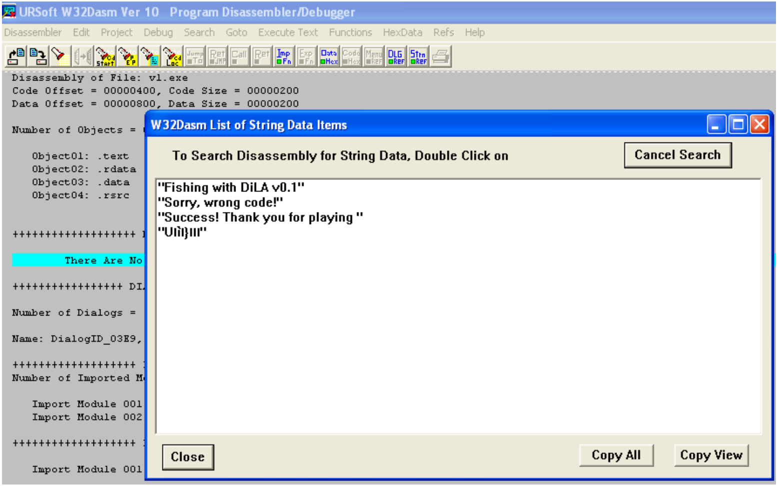

(Un)fortunately, not so common nowadays. . . ⌣̈

Reverse Engineering of Software

Example of serial-fishing (2) – file `fwdv1.zip`



Reverse Engineering of Software

Example of serial-fishing (2) – file `fwdv1.zip`

```
* Reference To: user32.DialogBoxParamA, Ord:008Ah
                                    |
:00401016 E87B000000                Call 00401096
:0040101B 6A00                      push 00000000

* Reference To: kernel32.ExitProcess, Ord:0080h
                                    |
:0040101D E886000000                Call 004010A8
:00401022 55                        push ebp
:00401023 8BEC                      mov ebp, esp
:00401025 817D0C11010000            cmp dword ptr [ebp+0C], 00000111
:0040102C 754D                      jne 0040107B
:0040102E 817D10EB030000            cmp dword ptr [ebp+10], 000003EB
:00401035 7542                      jne 00401079
:00401037 6A00                      push 00000000
:00401039 6A00                      push 00000000
:0040103B 68EA030000                push 000003EA
:00401040 FF7508                    push [ebp+08]

* Reference To: user32.GetDlgItemInt, Ord:00F3h
                                    |
:00401043 E854000000                Call 0040109C
:00401048 3D9A020000                cmp eax, 0000029A
:0040104D 7416                      je 00401065
:0040104F 6A10                      push 00000010

* Possible StringData Ref from Data Obj ->"Fishing with DiLA v0.1"
                                    |
:00401051 6800304000                push 00403000

* Possible StringData Ref from Data Obj ->"Sorry, wrong code!"
                                    |
:00401056 6817304000                push 00403017
:0040105B FF7508                    push [ebp+08]

* Reference To: user32.MessageBoxA, Ord:019Dh
```

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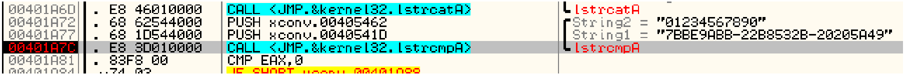
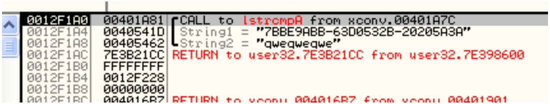
Reverse Engineering of Software

Example of serial-fishing (2) – file `fwdv1.zip`

Reverse Engineering of Software

Example of self-keygenning (1) – file `X-Converter.zip`





- Recall last example: `lstrcmpA`
  - Offset `0040541D`: valid key

Let's make the binary speak by itself. . .

Reverse Engineering of Software

Example of self-keygenning (2) – file `X-Converter.zip`

MessageBox function

Displays a modal dialog box that contains a system icon, a set of buttons, and a brief application-specific message, such as status or error information. The message box returns an integer value that indicates which button the user clicked.

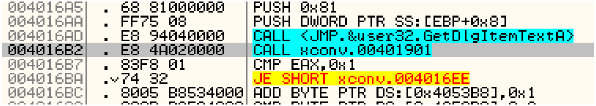
Syntax

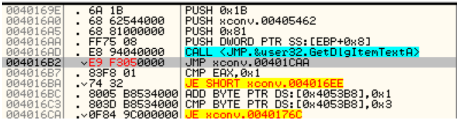
C++

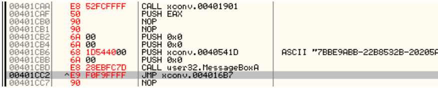
```cpp
int WINAPI MessageBox(
  _In_opt_  HWND hWnd,
  _In_opt_  LPCTSTR lpText,
  _In_opt_  LPCTSTR lpCaption,
  _In_      UINT uType
);
```

Reverse Engineering of Software

Example of self-keygenning (3) – file `X-Converter.zip`







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Reverse Engineering of Software

Example of self-keygenning (3) – file `X-Converter.zip`

Reverse Engineering of Software

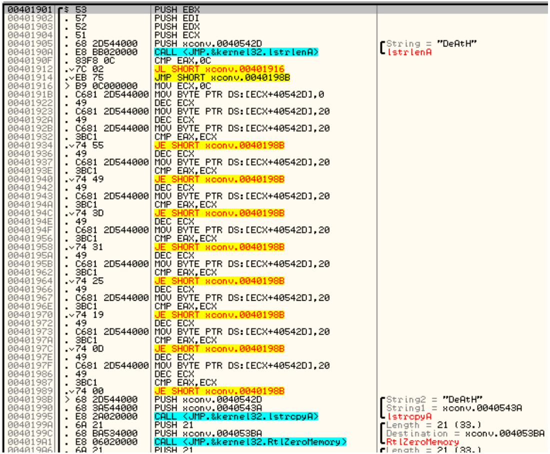
Example of keygenning (1) – file `X-Converter.zip`

```
0040166B  .v0F85 24010000  JNZ xconv.00401795
00401671  . 6A 0E          PUSH 0E                                   [Count = E (14.)
00401673  . 68 2D544000    PUSH xconv.0040542D                       |Buffer = xconv.0040542D
00401678  . 68 80000000    PUSH 80                                   |ControlID = 80 (128.)
0040167D  . FF75 08        PUSH DWORD PTR SS:[EBP+8]                 |hWnd
00401680  . E8 C1040000    CALL <JMP.&user32.GetDlgItemTextA>        [GetDlgItemTextA
00401685  . 83F8 0C        CMP EAX,0C
00401688  .v7F 4B          JG SHORT xconv.004016D5
0040168A  . 83F8 04        CMP EAX,4
0040168D  .v7C 46          JL SHORT xconv.004016D5
0040168F  . 68 2D544000    PUSH xconv.0040542D                       [String2 = "DeAtH"
00401694  . 68 06334000    PUSH xconv.00403306                       |String1 = xconv.00403306
00401699  . E8 26050000    CALL <JMP.&kernel32.lstrcpyA>             [lstrcpyA
0040169E  . 6A 1B          PUSH 1B                                   [Count = 1B (27.)
004016A0  . 68 62544000    PUSH xconv.00405462                       |Buffer = xconv.00405462
004016A5  . 68 81000000    PUSH 81                                   |ControlID = 81 (129.)
004016AA  . FF75 08        PUSH DWORD PTR SS:[EBP+8]                 |hWnd
004016AD  . E8 94040000    CALL <JMP.&user32.GetDlgItemTextA>        [GetDlgItemTextA
004016B2  . E8 4A020000    CALL xconv.00401901
004016B7  . 83F8 01        CMP EAX,1
004016BA  .v74 32          JE SHORT xconv.004016EE
004016BC  . 8005 B8534000  ADD BYTE PTR DS:[4053B8],1
004016C3  . 803D B8534000  CMP BYTE PTR DS:[4053B8],3
004016CA  .v0F84 9C000000  JE xconv.0040176C
004016D0  .vE9 81000000    JMP xconv.00401756
004016D5  > 6A 10          PUSH 10                                   [Style = MB_OK|MB_ICONHAND|MB_APPLMODAL
004016D7  . 68 79304000    PUSH xconv.00403079                       |Title = "Sorry"
004016DC  . 68 53324000    PUSH xconv.00403253                       |Text = "Sorry username must be at least 4 characters♪◘long and not mo
004016E1  . FF75 08        PUSH DWORD PTR SS:[EBP+8]                 |hOwner
004016E4  . E8 69040000    CALL <JMP.&user32.MessageBoxA>            [MessageBoxA
004016E9  .vE9 D7000000    JMP xconv.004017C5
004016EE  > E8 A8030000    CALL xconv.00401A9B
004016F3  . C605 72434000  MOV BYTE PTR DS:[404372],1
004016FA  . 6A 40          PUSH 40                                   [Style = MB_OK|MB_ICONASTERISK|MB_APPLMODAL
004016FC  . 68 33304000    PUSH xconv.00403033                       |Title = "Thank you!"
00401701  . 68 3E304000    PUSH xconv.0040303E                       |Text = "Registration done. Thank you for registering this program!"
00401706  . FF75 08        PUSH DWORD PTR SS:[EBP+8]                 |hOwner
00401709  . E8 44040000    CALL <JMP.&user32.MessageBoxA>            [MessageBoxA
0040170E  . 6A 00          PUSH 0                                    [Result = 0
```

- 4 $\leq$ length name $\leq$ 12
- Length serial: 27 (read)
- Checking procedure: `00401901`
- Name buffer: `buf_42D`

Reverse Engineering of Software

Example of keygenning (2) – file `X-Converter.zip`



```
00401901  $ 53              PUSH EBX
00401902  . 57              PUSH EDI
00401903  . 52              PUSH EDX
00401904  . 51              PUSH ECX
00401905  . 68 2D544000     PUSH xconv.0040542D                        String = "DeAtH"
0040190A  . E8 BB020000     CALL <JMP.&kernel32.lstrlenA>              lstrlenA
0040190F  . 83F8 0C         CMP EAX,0C
00401912  .v7C 02           JL SHORT xconv.00401916
00401914  .vEB 75           JMP SHORT xconv.0040198B
00401916  > B9 0C000000     MOV ECX,0C
0040191B  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],0
00401922  . 49              DEC ECX
00401923  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
0040192A  . 49              DEC ECX
0040192B  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
00401932  . 3BC1            CMP EAX,ECX
00401934  .v74 55           JE SHORT xconv.0040198B
00401936  . 49              DEC ECX
00401937  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
0040193E  . 3BC1            CMP EAX,ECX
00401940  .v74 49           JE SHORT xconv.0040198B
00401942  . 49              DEC ECX
00401943  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
0040194A  . 3BC1            CMP EAX,ECX
0040194C  .v74 3D           JE SHORT xconv.0040198B
0040194E  . 49              DEC ECX
0040194F  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
00401956  . 3BC1            CMP EAX,ECX
00401958  .v74 31           JE SHORT xconv.0040198B
0040195A  . 49              DEC ECX
0040195B  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
00401962  . 3BC1            CMP EAX,ECX
00401964  .v74 25           JE SHORT xconv.0040198B
00401966  . 49              DEC ECX
00401967  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
0040196E  . 3BC1            CMP EAX,ECX
00401970  .v74 19           JE SHORT xconv.0040198B
00401972  . 49              DEC ECX
00401973  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
0040197A  . 3BC1            CMP EAX,ECX
0040197C  .v74 0D           JE SHORT xconv.0040198B
0040197E  . 49              DEC ECX
0040197F  . C681 2D544000   MOV BYTE PTR DS:[ECX+40542D],20
00401986  . 49              DEC ECX
00401987  . 3BC1            CMP EAX,ECX
00401989  .v74 00           JE SHORT xconv.0040198B
0040198B  > 68 2D544000     PUSH xconv.0040542D                        String2 = "DeAtH"
00401990  . 68 3A544000     PUSH xconv.0040543A                        String1 = xconv.0040543A
00401995  . E8 2A020000     CALL <JMP.&kernel32.lstrcpyA>              lstrcpyA
0040199A  . 6A 21           PUSH 21                                    Length = 21 (33.)
0040199C  . 68 BA534000     PUSH xconv.004053BA                        Destination = xconv.004053BA
004019A1  . E8 06020000     CALL <JMP.&kernel32.RtlZeroMemory>         RtlZeroMemory
004019A6  . 6A 21           PUSH 21                                    Length = 21 (33.)
```

Reverse Engineering of Software

Example of keygenning (3) – file `X-Converter.zip`


```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;
```

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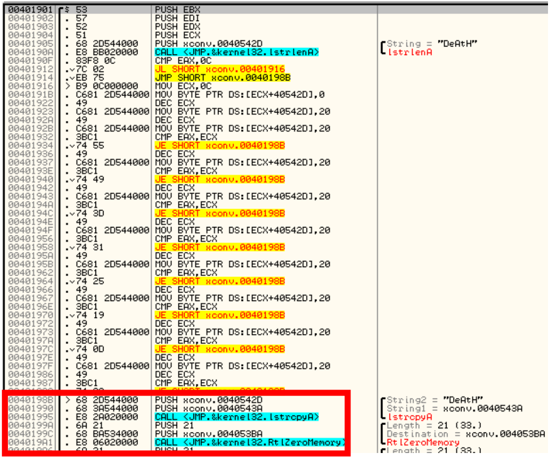
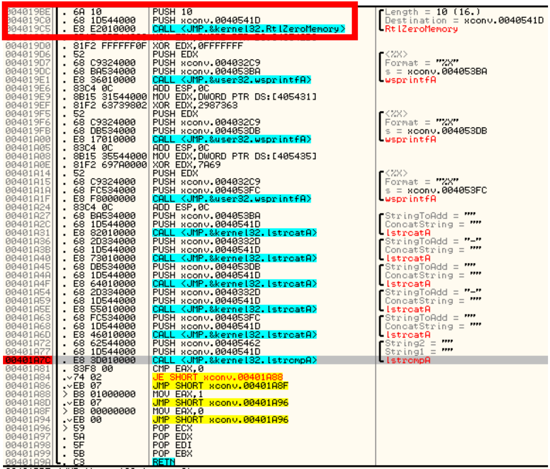
Example of keygenning (4) – file `X-Converter.zip`




```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;

buf_43A = buf_42D;
buf_3BA = zeros(33);
```

Reverse Engineering of Software

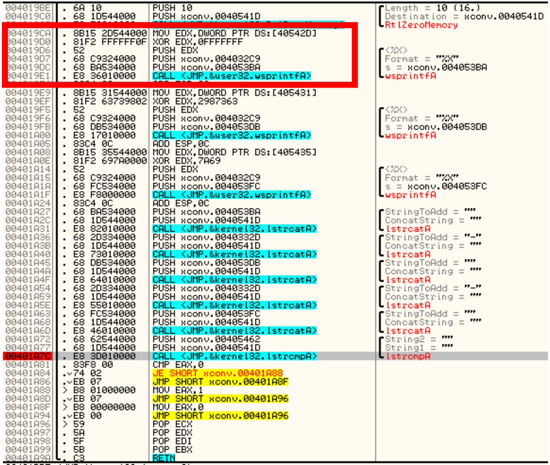
Example of keygenning (5) – file `X-Converter.zip`




```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;

buf_43A = buf_42D;
buf_3BA = zeros(33);
buf_3DB = zeros(33);
buf_3FC = zeros(33);
buf_41D = zeros(16);
```

Reverse Engineering of Software

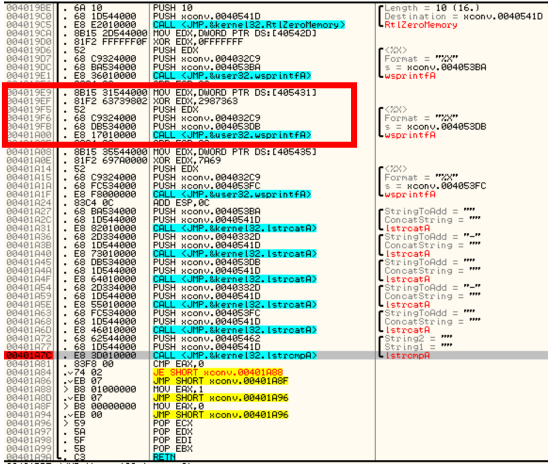
Example of keygenning (6) – file `X-Converter.zip`




```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;

buf_43A = buf_42D;
buf_3BA = zeros(33);
buf_3DB = zeros(33);
buf_3FC = zeros(33);
buf_41D = zeros(16);

edx = buf_42D; // 4 bytes
edx ^= 0xFFFFFFF;
buf_3BA = <edx in string>
// Recall endianness!!
```

Reverse Engineering of Software

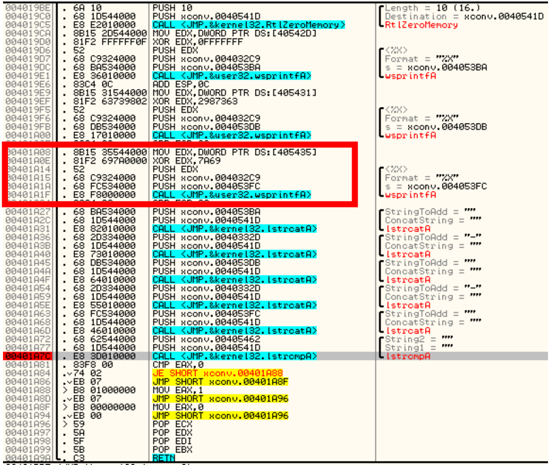
Example of keygenning (7) – file `X-Converter.zip`




```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;

buf_43A = buf_42D;
buf_3BA = zeros(33);
buf_3DB = zeros(33);
buf_3FC = zeros(33);
buf_41D = zeros(16);

edx = buf_42D; // 4 bytes
edx ^= 0xFFFFFFF;
buf_3BA = <edx in string>
// Recall endianness!!

edx = (buf_42D + 4); // 4 bytes
edx ^= 0x2987363;
buf_3DB = <edx in string>
// Recall endianness!!
```

Reverse Engineering of Software

Example of keygenning (8) – file `X-Converter.zip`




```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;

buf_43A = buf_42D;
buf_3BA = zeros(33);
buf_3DB = zeros(33);
buf_3FC = zeros(33);
buf_41D = zeros(16);

edx = buf_42D; // 4 bytes
edx ^= 0xFFFFFFF;
buf_3BA = <edx in string>
// Recall endianness!!

edx = (buf_42D + 4); // 4 bytes
edx ^= 0x2987363;
buf_3DB = <edx in string>
// Recall endianness!!

edx = (buf_42D + 8); // 4 bytes
edx ^= 0x7A69;
buf_3FC = <edx in string>
// Recall endianness!!
```

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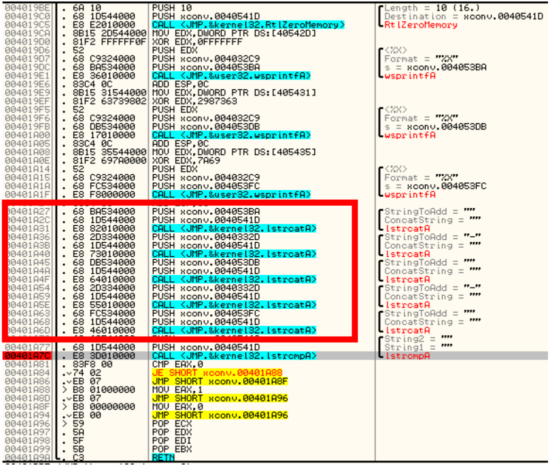
Reverse Engineering of Software

Example of keygenning (9) – file `X-Converter.zip`




```
eax = strlen(buf_42D);
ecx = 12;
buf_42D[ecx] = 00;
for(; eax != ecx; ecx--)
  buf_42D[ecx] = 20;

buf_43A = buf_42D;
buf_3BA = zeros(33);
buf_3DB = zeros(33);
buf_3FC = zeros(33);
buf_41D = zeros(16);

edx = buf_42D; // 4 bytes
edx ^= 0xFFFFFFF;
buf_3BA = <edx in string>
// Recall endianness!!

edx = (buf_42D + 4); // 4 bytes
edx ^= 0x2987363;
buf_3DB = <edx in string>
// Recall endianness!!

edx = (buf_42D + 8); // 4 bytes
edx ^= 0x7A69;
buf_3FC = <edx in string>
// Recall endianness!!

buf_41D = buf_3BA & '-'
   & buf_3DB & '-' & buf_3FC;
```

Reverse Engineering of Software

Example of keygenning (10) – file `X-Converter.zip`

```
void generate_key(char *name, int len)
{
        int bufLen = 32;
        char    buf_3BA[bufLen], buf_3DB[bufLen],
                buf_3FC[bufLen], buf_41D[15],
                nameFilled[12];
        // Init
        memset(nameFilled, ' ', 12);
        for(int i = 0; i < len; i++)
                nameFilled[i] = name[i];

        memset(buf_3BA, 0, bufLen);
        memset(buf_3DB, 0, bufLen);
        memset(buf_3FC, 0, bufLen);
        memset(buf_41D, 0, 15);

        // Compute 1st num
        sprintf(buf_3BA, "%X",
                compute_number(nameFilled, 0, 0xFFFFFFF));
        // Compute 2nd num
        sprintf(buf_3DB, "%X",
                compute_number(nameFilled, 4, 0x2987363));
        // Compute 3rd num
        sprintf(buf_3FC, "%X",
                compute_number(nameFilled, 8, 0x7A69));

        // Build key
        sprintf(buf_41D, "%s-%s-%s",
                buf_3BA, buf_3DB, buf_3FC);
        printf("Dear %s, your key is %s.\n", name, buf_41D);
}
```

```
int compute_number(char *name,
                   int init, int xor_val)
{
        int edx = name[init];

        for(int i = 1; i < 4; i++)
          edx ^= name[init + i] << 8*i;

        return edx^xor_val;
}

/* Example of first num computation
edx  = nameFilled[0];
edx ^= nameFilled[1] << 8;
edx ^= nameFilled[2] << 16;
edx ^= nameFilled[3] << 24;
// XOR it
edx ^= 0xFFFFFFF; */
```

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Agenda

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Reverse Engineering of Integrated Circuits/Smart Cards

Near Field Communication ¿?

Near Field Communication: What is it? (I)

- Bidirectional short-range contactless communication technology
  - Up to 10 cm
- Based on RFID standards, works in the 13.56 MHz spectrum
- Data transfer rates vary: 106, 216, and 424 kbps

Near Field Communication: What is it? (I)

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Security based on proximity concern: physical constraints

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- Based on RFID standards, works in the 13.56 MHz spectrum
- Data transfer rates vary: 106, 216, and 424 kbps

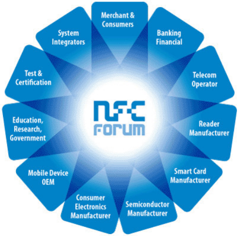
Security based on proximity concern: physical constraints

Main elements & operation modes

- Two main elements:
  - Proximity Coupling Device (PCD, also NFC-capable device)
  - Proximity Integrated Circuit Cards (PICC, also NFC tags)
- Three operation modes:
  - Peer to peer: direct communication between parties
  - Read/write: communication with a NFC tag
  - Card-emulation: an NFC device behaves as a tag

Near Field Communication: What is it? (II)

"Big" actors

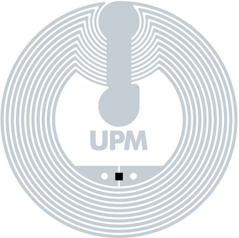


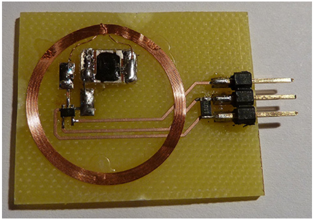
NFC Forum

- Non-profit industry association
- Formed on March 18, 2004
- Founders: NXP Semiconductors (formerly Philips Semiconductors), Sony and Nokia
- Promotes implementation and standardisation of NFC
- 190 member companies (June 2013). Some located at Spain:
  - Applus
  - AT4 Wireless

Near Field Communication: What is it? (III)

Real actors (1)



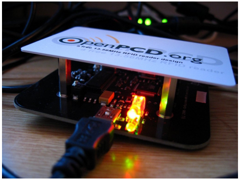


PICC

- Proximity Integrated Circuit Card
- Commonly named as *tag*
- Passive or active (depends on power supply)
  - Widely used (cheaper): passive ones
- It contains:
  - Internal capacitor
    - Stores the energy coming from the reader
  - Resistor

Near Field Communication: What is it? (III)

Real actors (2)



PCD

- Proximity Coupling Device
- Commonly named as *reader/writer*
- Active (forced)
- Contains the antenna
  - Communication at the 13.56MHz (±7kHz) frequency
  - Electronic field

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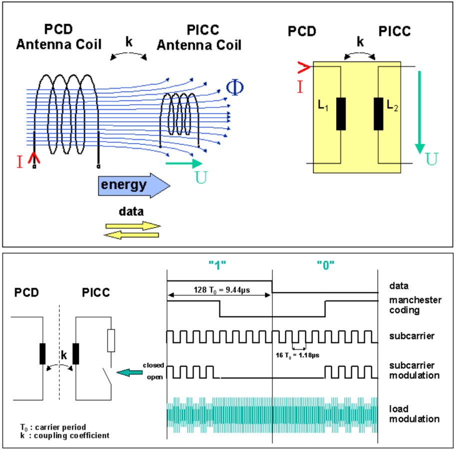
Near Field Communication: What is it? (IV)

An interesting reading on this topic. . .

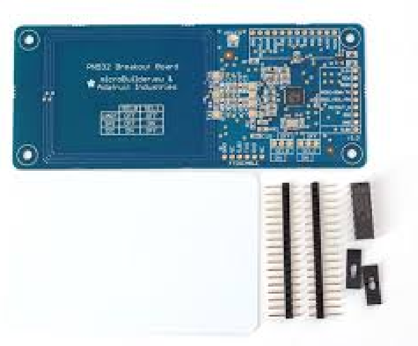


[Taken from 13.56 MHz RFID Proximity Antennas (`http://www.nxp.com/documents/application_note/AN78010.pdf`)]

Near Field Communication: Where is it used? (V)

Near Field Communication

Lab Environment



Hardware

- AdaFruit PN532
- A computer

Software

- C compiler
- NFC Library (`libnfc`)
- NFC tools (`nfc-tools`)

MIFARE classic ¿?

MIFARE Classic (I): What is it?

MIFARE product family

- Introduced in 1995 by NXP
- “Advanced technology for RFID identification”
- Based on ISO/IEC 14443 Type A/B 13.56 MHz standard
- Several products:
  - Ultralight
  - Classic
  - DESFire
  - SmartMX

MIFARE Classic (I): What is it?

MIFARE product family

- Introduced in 1995 by NXP
- "Advanced technology for RFID identification"
- Based on ISO/IEC 14443 Type A/B 13.56 MHz standard
- Several products:
  - Ultralight
  - Classic
  - DESFire
  - SmartMX
- 50M reader and 5B card components sold
- $\sim$ 80% contactless ticketing credentials (according to ABI Research)

MIFARE Classic (II): Some of its common uses

Some systems using MIFARE Classic

- Access Controls
  - University of Zaragoza
  - Personal entrance Schiphol Airport (AMS)
  - Dutch military bases
  - Hotel room keys
  - Many office and official buildings
- Ticketing events
- Public transport systems
  - OV-Chipkaart (NL)
  - Oyster card (London, UK)
  - Smartrider (AU)
  - EMT (Málaga, Spain)
  - Wikipedia: `http://en.wikipedia.org/wiki/MIFARE`

MIFARE Classic (III): Internal Structure (1)

Logical Structure

- EEPROM memory
- Basic unit: 16B block
- A sector is a set of blocks
- Two size variants:
    - 1KB (16 sectors, 4 blocks each)
    - 4KB (40 sectors, first 32 sectors are 4-block, the rest 16-block)

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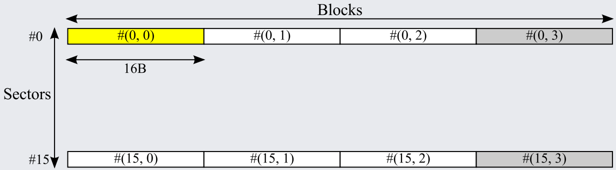
MIFARE Classic (III): Internal Structure (1)

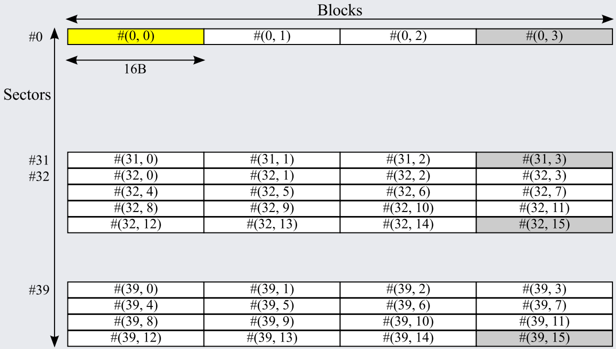
Logical Structure

- EEPROM memory
- Basic unit: 16B block
- A sector is a set of blocks
- Two size variants:
  - 1KB (16 sectors, 4 blocks each)
  - 4KB (40 sectors, first 32 sectors are 4-block, the rest 16-block)

Let me show you this graphically...

MIFARE Classic (III): Internal Structure(2)





MIFARE Classic (III): Internal Structure (3)

Manufacturer block

- Sector 0, block 0 (yellow one in previous slide)
- Contains:
  - UID (4B)
  - BCC (bit count check, 1B): XOR-ing of UID bytes
  - Manufacturer data (11B)
- Set and locked by manufacturer → read only!

MIFARE Classic (III): Internal Structure (3)

Manufacturer block

- Sector 0, block 0 (yellow one in previous slide)
- Contains:
  - UID (4B)
  - BCC (bit count check, 1B): XOR-ing of UID bytes
  - Manufacturer data (11B)
- Set and locked by manufacturer → read only!
  - Not the case for some Chinese cards ☺

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MIFARE Classic (III): Internal Structure (4)

Storing data. . .

Storing data into blocks

- Read/write block
  - You can store data as you want, no matter how
- Data block
  - Predefined format (look below!)
  - Don't worry: APIs will help you!
    - Only need a *value*, it puts all the values properly on its own. . .)
  - Contains:
    - Value (twice)
    - Value negated (once)
    - 1-byte address (twice)
    - 1-byte address negated (twice)

Value	$\overline{\text{Value}}$	Value	@	$\overline{@}$	@	$\overline{@}$
0	4	8	12	13	14	15

MIFARE Classic (III): Internal Structure (5)

Key A	Access bits	Key B
0	6	10 — 15

Sector trailer

- Last one in each sector (grey ones in previous slide)
- Contains:
  - Key A
  - Access Bits
  - Key B
- Authentication per sector before any operation is allowed
- Access bits define how is the auth. required and what operations are allowed
- **Having fun with access bits may provoke a useless tag!**
- Keys are set to `FFFFFFFFFFFFh` at delivery

MIFARE Classic (III): Internal Structure (6)

Operations

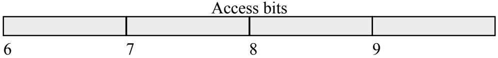
Operation	Description	Valid for...		
		R/W block	Value block	Sector trailer
Read	Reads a memory block	√	√	√
Write	Writes a memory block	√	√	√
Increment	Reads the value, increments it and stores		√	
Decrement	Reads the value, decrements it and stores		√	
Transfer	Transfers contents of internal register to a block		√	
Restore	Loads contents of a block to internal register		√	

MIFARE Classic (III): Internal Structure (7)

Access Conditions

Access Bits	Valid Commands	Block
$C1_0 C2_0 C3_0$	(all operations)	0
$C1_1 C2_1 C3_1$	(all operations)	1
$C1_2 C2_2 C3_2$	(all operations)	2
$C1_3 C2_3 C3_3$	Read, Write	3

- 3 bits define access conditions for every data block and sector trailer
- Stored non-negated and negated
- Commands are executed only after a successful authentication



	Bit 7							Bit 0
Byte 6	$\overline{C2_3}$	$\overline{C2_2}$	$\overline{C2_1}$	$\overline{C2_0}$	$\overline{C1_3}$	$\overline{C1_2}$	$\overline{C1_1}$	$\overline{C1_0}$
Byte 7	$C1_3$	$C1_2$	$C1_1$	$C1_0$	$\overline{C3_3}$	$\overline{C3_2}$	$\overline{C3_1}$	$\overline{C3_0}$
Byte 8	$C3_3$	$C3_2$	$C3_1$	$C3_0$	$C2_3$	$C2_2$	$C2_1$	$C2_0$
Byte 9	user data (free)							

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MIFARE Classic (III): Internal Structure (8)

Access Conditions for sector trailer

Access Bits			Access condition for...					
			Key A		Access bits		Key B	
*C*1	*C*2	*C*3	read	write	read	write	read	write
0	0	0	-	key A	key A	-	key A	key A
0	0	1	-	key A	key A	key A	key A	key A
0	1	0	-	-	key A	-	key A	-
0	1	1	-	key B	key A (or B)	key B	-	key B
1	0	0	-	key B	key A (or B)	-	-	key B
1	0	1	-	-	key A (or B)	key B	-	-
1	1	0	-	-	key A (or B)	-	-	-
1	1	1	-	-	key A (or B)	-	-	-

(- means never)

Recall: show `mfcab` tool (`https://bitbucket.org/rjrodriguez/mfcab`)

MIFARE Classic (III): Internal Structure (9)

Access Conditions for data blocks

Access Bits			Access condition for...				Application
*C*1	*C*2	*C*3	Read	Write	Increment	Decrement, Transfer, Restore	
0	0	0	key A (or B)†	key A (or B)	key A (or B)	key A (or B)	Transport configuration
0	0	1	key A (or B)†	-	-	key A (or B)	Value block
0	1	0	key A (or B)†	-	-	-	R/W block
0	1	1	key B	key B	-	-	R/W block
1	0	0	key A (or B)	Key B	-	-	R/W block
1	0	1	key B	-	-	-	R/W block
1	1	0	key A (or B)	key B	key B	key A (or B)	Value block
1	1	1	-	-	-	-	R/W block

(- means never)

† if key B can be read in the sector trailer, then it cannot be used for authentication

MIFARE Classic: Communication Protocol (I)

Protocol steps

1. Get the tags in the reader's range
2. Select only one tag (anticollision loop)
3. Access a block, with key A or key B (starts authentication step)

Authentication step

- Challenge-response mutual authentication using nonces
  - Nonce: randomly generated information
  - Nonces generated from a LFSR (next slides)

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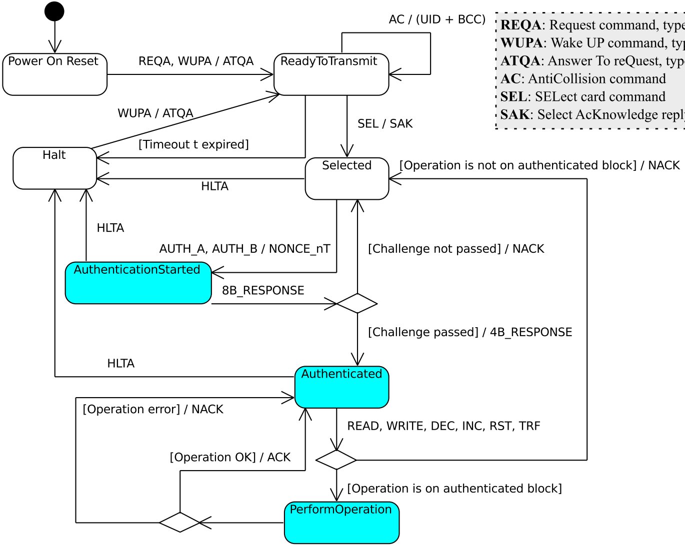
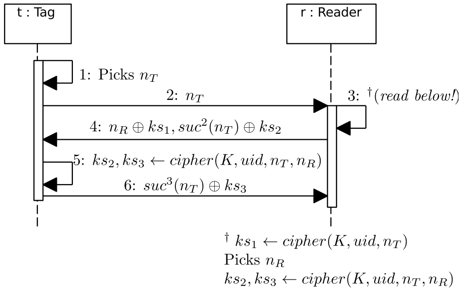
MIFARE Classic: Communication Protocol (II)

UML-SM of a NFC tag



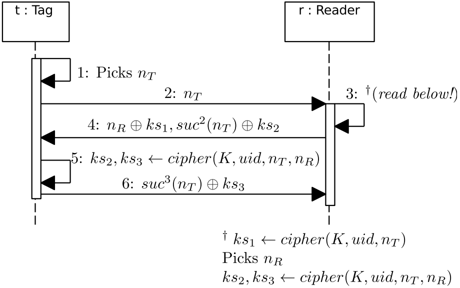
REQA: Request command, type A
WUPA: Wake UP command, type A
ATQA: Answer To reQuest, type A
AC: AntiCollision command
SEL: SELect card command
SAK: Select AcKnowledge reply

MIFARE Classic: Communication Protocol (III)



- Three-pass authentication
  1. Send nonce (n_T) as challenge
     - Generated by a 16-bit LFSR ($g(x) = x^{16} + x^{14} + x^{13} + x^{11} + 1$)
  2. Send response and other nonce n_R as challenge
  3. Send response
- Note: from n_T, communication is ciphered

MIFARE Classic: Communication Protocol (IV)



Known plaintext [GKMRVSJ-ESORICS-08]

- Recall: n_T is in plaintext

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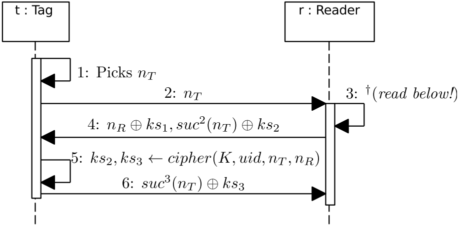

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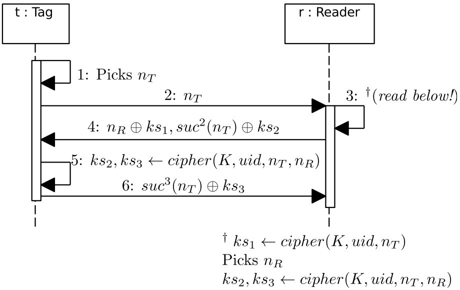

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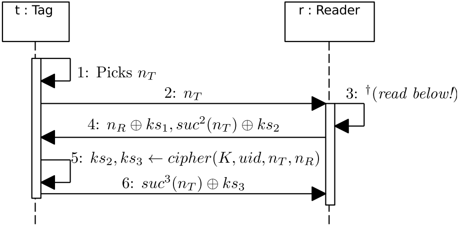

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  - `HLT` command is known, then we recover ks_3
- Eavesdropping a successful authentication session
  - ks_2, ks_3 recovered from $suc^2(n_T) \oplus n_T, suc^3(n_T) \oplus n_T$

MIFARE Classic: CRYPTO1 (I)

- Proprietary stream cipher. Key length of 48 bits
- “Security by obscurity” principle
- Hardware on-chip: faster cryptographic operations!
- Reversed some years ago. . . :
  - K. Nohl and H. Plötz: “Mifare: Little Security, Despite Obscurity”, in *Chaos Communication Congress*, 2007. Reverse engineering on silicon implementation
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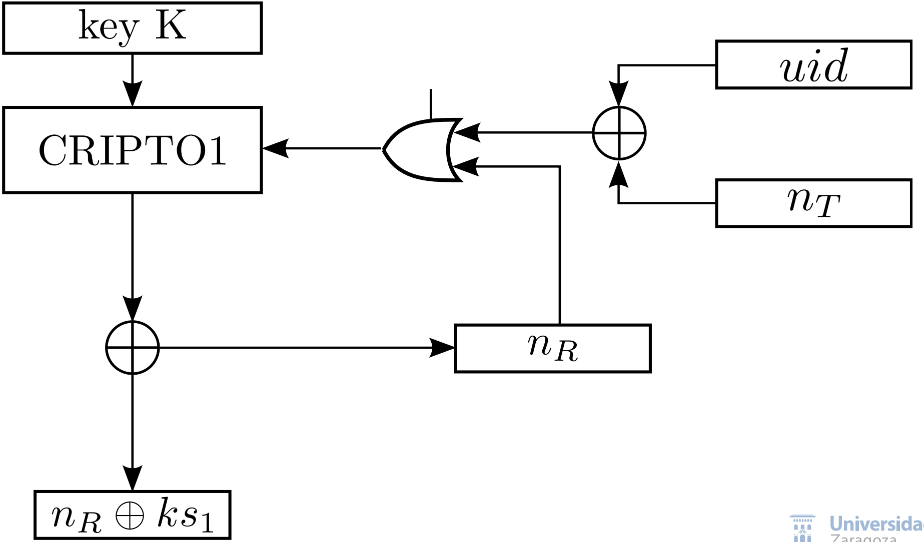
- Linear Feedback Shift Register (LFSR) + two-layer non-linear filter generator
  - At every clock tick, register is shifted one bit to the left
  - Leftmost bit: discarded
  - Feedback bit: computed with $g(x)$

$$g(x) = x^{48} + x^{43} + x^{39} + x^{38} + x^{36} + x^{34} + x^{33} + x^{31} + x^{29} + x^{24} + x^{23} + x^{21} + x^{19} + x^{13} + x^{9} + x^{7} + x^{6} + x^{5} + 1$$

MIFARE Classic: CRYPTO1 (II)

Initialisation diagram



MIFARE Classic: Known Weaknesses (I)

On Pseudo-Random Number Generator

MOST CRITICAL weakness

Low entropy

- LFSR generating nonces: 16-bit length
- 0.6 seconds to generate ALL possible nonces [NESP-USENIX-08]
- Generator resets to a known state every time the tag starts operating
  - Just a wait a fixed number of clock cycles. . .
  - Experimentally possible to get the same nonce every 30ms using Proxmark 3 reader

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MIFARE Classic: Known Weaknesses (II)

On Cryptographic Cipher

$$x_9, x_{11}, x_{13}, \ldots, x_{47}$$

Keystream generation

- Odd bits as inputs to the filter functions
- Divide-and-Conquer technique
  - Split even, odd bits in groups
  - Firstly focus on odd group:
    - After 2 shifts, new input is $x_{11}, x_{13}, \ldots, x_{47}$ and x_{49}
    - Used for generating two keystreams
    - Explore what bits generate the right keystreams
- Attack: Recover all sector keys without the needed of a genuine reader

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MIFARE Classic: Known Weaknesses (III)

On Cryptographic Cipher

$$x_9, x_{11}, x_{13}, \ldots, x_{47}$$

Leftmost bit not used in filter generator

- First 9 bits unused
- Attack: Rollback LFSR state bit a bit
  - Recover the initial state of LFSR

Statistical Bias [C-SECRYPT-09]

- With a $\pi = 0.75$, ks_1 is independent of the last three bits of n_R
- Attack: card-only attack
  - Recover one key, then apply nested authentication attack [GKMRVSJ-ESORICS-08]
  - Does not require any pre-computation
  - Extremely fast, and requires a few hundred queries
  - Further information: `http://eprint.iacr.org/2009/137.pdf`

MIFARE Classic: Known Weaknesses (IV)

On Communication Protocol

One-Time Padding (OTP)

- ISO-14443-A: every byte sent is followed by a parity bit
- MIFARE Classic computes parity bit over plaintext instead of ciphertext
- LFSR is not shifted after parity bit encryption

MIFARE Classic: Known Weaknesses (IV)

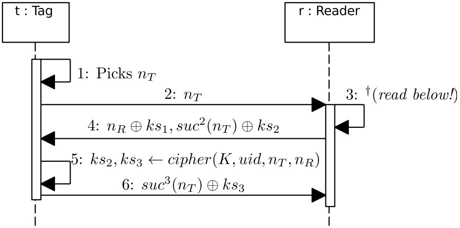
On Communication Protocol

One-Time Padding (OTP)

- ISO-14443-A: every byte sent is followed by a parity bit
- MIFARE Classic computes parity bit over plaintext instead of ciphertext
- LFSR is not shifted after parity bit encryption
- Next plaintext and parity bit use the same keystream → OTP seems not to be OTP. . .
- More examples of violating OTP property:
  - Venona Project (U.S. counter-intelligence program during Cold War)
  - Point-to-Point Tunneling Protocol (PPTP)
  - IEEE 802.11 WEP

MIFARE Classic: Known Weaknesses (V)

On Communication Protocol



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Picks n_R
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Information Leak from Parity

- Second step in authentication, reader sends $n_R, suc^2(n_T)$
- PICC checks parity bits in n_R before checking $suc^2(n_T)$
  - When parity is incorrect, PICC does not answer
  - When $suc^2(n_T)$ is incorrect, it answers `NACK` (transmission error)
- `NACK` sent encrypted → ks_3 can be recovered

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MIFARE Classic: Known Weaknesses (VI)

On Deployment

Default Keys

- Some chip manufacturers leave default keys on chips
- This is obvious, as companies must make the effort to do system integration for clients. . . (sic!)
- RTFM: Chip manufacturer warns about CHANGING default keys
- Default keys are well-known and documented

FFFFFFFFFFFFh	000000000000h	1A982C7E459Ah
A0A1A2A3A4A5h	B0B1B2B3B4B5h	AABBCCDDEEFFh
D3F7D3F7D3F7h	4D3A99C351DDh	

Related Work (I)

On MIFARE Classic weaknesses analysis (1)

NP-CCC-07 K. Nohl and H. Plötz, "Mifare: Little Security, Despite Obscurity", in *Chaos Communication Congress*, 2007.

GKMRVSJ-ESORICS-08 García et al., "Dismantling MIFARE Classic", in *Procs. of the European Symposium on Research in Computer Security* (ESORICS), 2008.

KHG-CARDIS-08 G.d Koning Gans et al., "A Practical Attack on the MIFARE Classic", in *Procs. of the Smart Card Research and Advanced Applications Conference* (CARDIS), 2008.

NESP-USENIX-08 K. Nohl et al., "Reverse-Engineering a Cryptographic RFID Tag". In *USENIX Security Symposium*, 2008.

GRBS-SP-09 F.D. García et al., "Wirelessly Pickpocketing a Mifare Classic Card", in *Procs. of the 30th IEEE Symposium on Security and Privacy* (S&P), 2009.

Related Work (II)

On MIFARE Classic weaknesses analysis (2)

C-SECRYPT-09 N.T. Courtois, "The Dark Side of Security by Obscurity and Cloning MiFare Classic Rail and Building Passes Anywhere, Anytime". In *Procs. of the Int. Conf. on Security and Cryptography* (SECRYPT), 2009

GRBS-SP-09 F.D. García et al., "Wirelessly Pickpocketing a Mifare Classic Card", in *Procs. of the 30th IEEE Symposium on Security and Privacy* (S&P), 2009

Tan-MScThesis-09 W.H. Tan, "Practical Attacks on the MIFARE Classic", Imperial College London, 2009

On NFC Attacks

VK-NFC-11 R. Verdult and F. Kooman, "Practical Attacks on NFC Enabled Cell Phones". In *Procs. of the 3rd Int. Workshop on Near Field Communication*, 2011

Related Work (III)

On MIFARE Attacks

- Sogeti ESEC Pentest: "Playing with NFC for fun and coffee"
- BackTrack Linux: "RFID Cooking with Mifare Classic" (2012)
- C. Miller, "Exploring the NFC Attack Surface", in *BlackHat US*, 2012.
- ComputerWorld article: "Android NFC hack enables travelers to ride subways for free, researchers say" (2012)
- HackPlayers: "Cómo colarse en el metro de forma elegante" (2012)
- Security ArtWork: "Hacking RFID, rompiendo (...) Mifare" (2010)

On NFC-related issues

- R. Lifchitz, Hacking the NFC credit cards for fun and debit (Hackito Ergo Sum 2012)
- J.M. Esparza, Give me your credit card, the NFC way (NcN'12)
- J. Vila, R.J. Rodríguez, Practical Experiences on NFC Relay Attacks with Android: Virtual Pickpocketing Revisited. In *RFIDSec 2015*

Reverse Engineering of Integrated Circuits/Smart Cards

Extending the lab environment

- NFC brings “cards” to mobile devices
- Payment sector is quite interested in this new way for making payments
  - 500M NFC payment users expected by 2019
- Almost 300 smart phones available at the moment with NFC capabilities
  - Check `http://www.nfcworld.com/nfc-phones-list/`
  - Most of them runs Android OS

Time to buy a NFC-capable device!

Android and NFC: A Tale of L♥ve (I)

Recap on evolution of Android NFC support

NFC operation modes supported

Software
- Reader/Writer
- Peer-to-peer

Hardware
- Card-emulation

Software
- Reader/Writer
- Peer-to-peer
- Card-emulation

Hardware
- Card-emulation

Android 2.3.3 Gingerbread (API level 10)

- **NfcA** (ISO/IEC 14443-3A)
- **NfcB** (ISO/IEC 14443-3B)
- **Ndef**
- **IsoDep** (ISO/IEC 14443-4)
- **NfcV** (ISO/IEC 15693)
- **NfcF** (JIS 6319-4)
- **NdefFormatable**
- **MifareClassic**
- **MifareUltralight**

Android 4.2 Jelly Bean (API level 17)

- **NfcBarcode**

Android CyanogenMod OS 9.1

- **IsoPcdA** (ISO/IEC 14443-4A)
- **IsoPcdB** (ISO/IEC 14443-4B)

thanks to Doug Year

Android 4.4 KitKat (API level 19)

NfcAdapter.ReaderCallback added

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Android and NFC: A Tale of L♥ve (II)

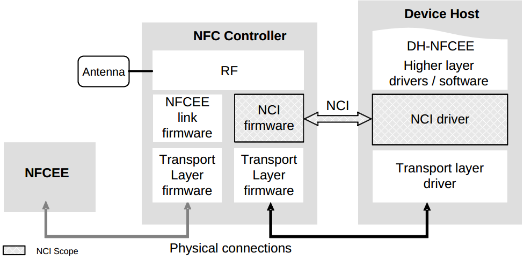
Digging into Android NFC stack

- Event-driven framework, nice API support
- Two native implementations (depending on built-in NFC chip)
  - `libnfc-nxp`
  - `libnfc-nci`

Android and NFC: A Tale of L♥ve (II)

Digging into Android NFC stack

- Event-driven framework, nice API support
- Two native implementations (depending on built-in NFC chip)
  - `libnfc-nxp`
  - `libnfc-nci`
- NXP dropped in favour of NCI:
  - Open architecture, not focused on a single family chip
  - Open interface between the NFC Controller and the DH
  - Standard proposed by NFC Forum



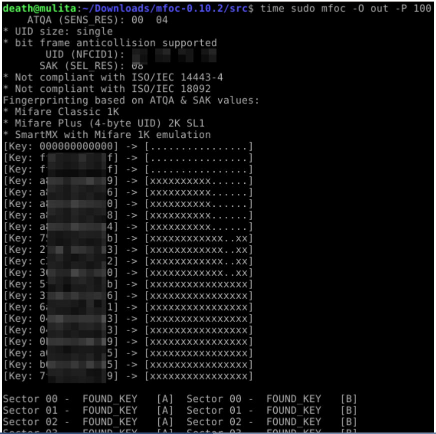
Specific goals

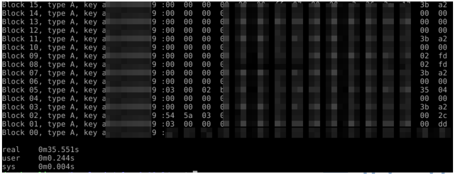
- Figure out the pair of keys (A, B)
- Make a dump of a real card
- Study the card content
- Check any integrity about unauthorised content alteration
- Make a clone card
- Do a mobile app for card-hacking

Reverse Engineering of Integrated Circuits/Smart Cards

Using mfoc

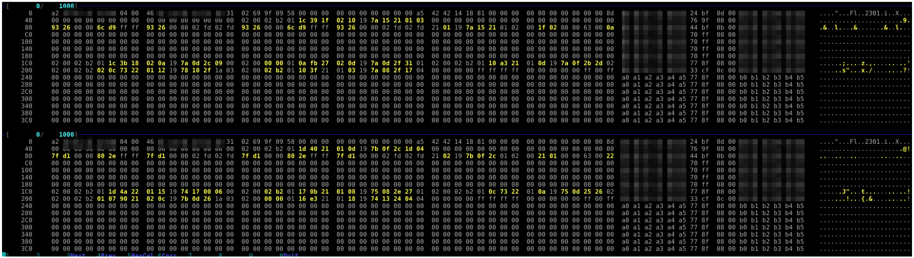
- Two different Classic version
  - MIFARE Classic 1K (T1)
  - MIFARE Classic 4K (T2)





Reverse Engineering of Integrated Circuits/Smart Cards

Understanding the card content. . .

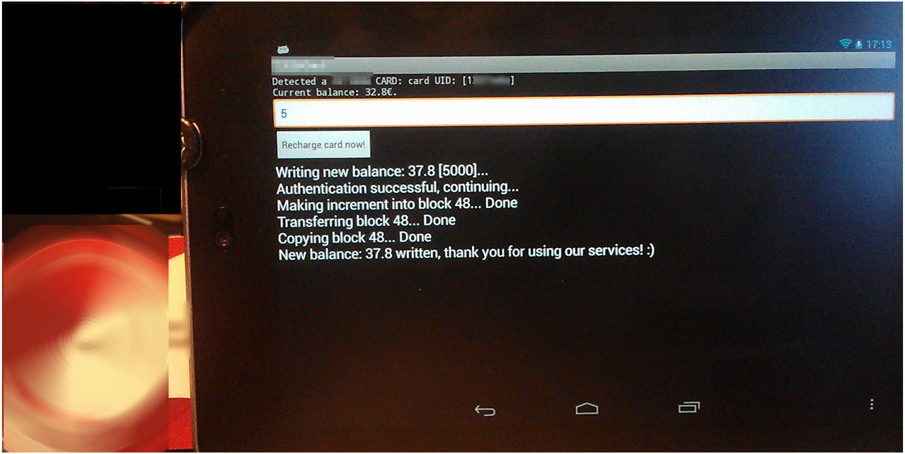


Summary of data

	T1	T2
Card ID	(0, 3)	(10, 3)
Last bus used	(1, 2)	(1, 2)
Current balance	(2, [1, 2])	(12, [1, 2])
Historic	(7, [1, 2, 3]), (8, [1, 2])	(7, [1, 2, 3]), (8, [1, 2])

Reverse Engineering of Integrated Circuits/Smart Cards

Building a PoC in Android O.S. (1)



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Reverse Engineering of Integrated Circuits/Smart Cards

Building a PoC in Android O.S. (2) – DEMO

Reverse Engineering of Integrated Circuits/Smart Cards

Recalling the initial goals

Goal	Achieved?	Some remarks
Figure out the pair of keys (A, B)	√	Some keys are the default ones
Make a dump of a real card	√	Fast, and simple
Study the card content	√	Not a single bit encrypted
Check any integrity about unauthorized content alteration	√	no integrity
Make a cloned card	√*	A perfect clone (Chine cards rulez!)
Do a mobile app for card-hacking	√	Android fu$#ing rocks!

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Reverse Engineering of Integrated Circuits/Smart Cards

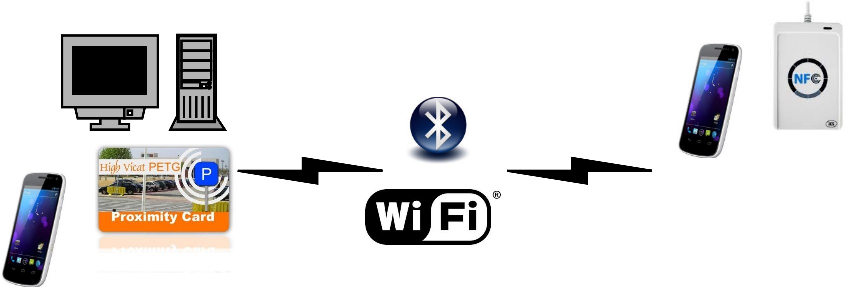
Thinking (and acting?) badly. . . (1)

What else could be done. . .

- Identity spoofing
  - Possible penalties for spoofed people
  - Consume the real balance of someone else
- Use of all public services for free
- Black market?
  - Fake recharge point
  - Whether I sold a card illegitimately charged. . .
- Just put the app in Google Play, and have fun ⌣̈

Reverse Engineering of Integrated Circuits/Smart Cards

Thinking (and acting?) badly. . . (2): Relay attacks



Reverse Engineering of Integrated Circuits/Smart Cards

Event timeline

Nov 2012 Nice chat with J.M. Esparza ☺

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Reverse Engineering of Integrated Circuits/Smart Cards

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- **(today)** As they don't care, me neither

Reverse Engineering of Integrated Circuits/Smart Cards

Lessons Learned

- It's good to collaborate with police... but you need to be patient
  - You'll have a good sleep at night and not in jail...

Reverse Engineering of Integrated Circuits/Smart Cards

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Reverse Engineering of Integrated Circuits/Smart Cards

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  - Not even when someone spots out the problem
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- This is not U.S., unfortunately (in this case)

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Remember, not economic gain but free beer instead!

Some conclusions. . .

- MIFARE Classic is like a memory card
- Vulnerable from 2009
- Weaknesses and attacks very well-known and widely documented

Some conclusions...

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  - Unauthorized content alteration
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  - Clone attacks

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Thinking to deploy MIFARE Classic as an access control system?

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Don't.

Agenda

Conclusions

Take-home messages

- **Reverse engineering is an ART that involves a lot of domains**
  - Network protocols
  - Software
  - Integrated circuits/smart cards
  - File formats (forensics)
- Black-box analysis: once we found something, keep digging!

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Never ending learning game!

A Tour through the Realms of Reverse Engineering

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November 23, 2016

Legacy Systems
Room A.12