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Finding Cryptography in Object Code

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Current Work

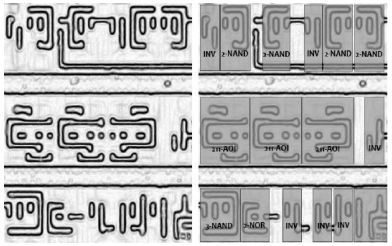
- Malware is using cryptography

- When reverse-engineering, crypto algorithm must be found and identified

- The Bad Guys use many obfuscation techniques, but they usually do not change the underlying crypto algorithm

Mifare: Little Security, Despite Obscurity

- Henryk Plötz/Karsten Nohl presented at 24C3 (Dec'07) and CanSecWest 2008 (also USENIX Security 08)
- Hardware hack of a smartcard crypto algorithm
- "*Focus on interesting-looking parts:*
  - *strings of flip-flops (registers)*
  - *XOR*
  - *Units around the edges that sparsely [connect] to the rest of the chip*"



- More:

http://events.ccc.de/congress/2007/Fahrplan/events/2378.en.html

http://www.cs.virginia.edu/~evans/pubs/usenix08/usenix08.pdf

FindCrypt: locating constants

- Many algorithms have constants that are unique (MD4, CAST-128, etc).
- Easy enough... just search for them:
  - data segment
  - text segment
- This is *findcrypt* from Datarescue:
  http://hexblog.com/2006/01/findcrypt.html
  http://hexblog.com/2006/02/findcrypt2.html
- Also KANAL (plug in for PeiD)
  http://peid.has.it/

Example:

```
void
MD5Init(MD5_CTX *ctx) {
  ctx->count = 0;
  ctx->state[0] = 0x67452301;
  ctx->state[1] = 0xefcdab89;
  ctx->state[2] = 0x98badcfe;
  ctx->state[3] = 0x10325476;
}
```

Becomes:

```
<MD5Init>:
  push   %ebp
  mov    %esp,%ebp
  mov 0x8(%ebp),%eax
  movl $0x0,0x10(%eax)
  movl $0x0,0x14(%eax)
  movl $0x67452301,(%eax)
  movl $0xefcdab89,0x4(%eax)
  movl $0x98badcfe,0x8(%eax)
  movl $0x10325476,0xc(%eax)
  leave
  ret
```

Most crypto algorithms have these magic constants

Example (cont):

```
void
MD5Init(MD5_CTX *ctx) {
  ctx->count = 0;
  ctx->state[0] = 0x67452301;
  ctx->state[1] = 0xefcdab89;
  ctx->state[2] = 0x98badcfe;
  ctx->state[3] = 0x10325476;
}
```

```
00000000 <MD5Init>:
 0: 55                    push %ebp
 1: 89 e5                 mov  %esp,%ebp
 3: 8b 45 08              mov  0x8(%ebp),%eax
 6: c7 40 10 00 00 00 00  movl $0x0,0x10(%eax)
 d: c7 40 14 00 00 00 00  movl $0x0,0x14(%eax)
14: c7 00 01 23 45 67     movl $0x67452301,(%eax)
1a: c7 40 04 89 ab cd ef  movl $0xefcdab89,0x4(%eax)
21: c7 40 08 fe dc ba 98  movl $0x98badcfe,0x8(%eax)
28: c7 40 0c 76 54 32 10  movl $0x10325476,0xc(%eax)
2f: c9                    leave
30: c3                    ret
```

IA32

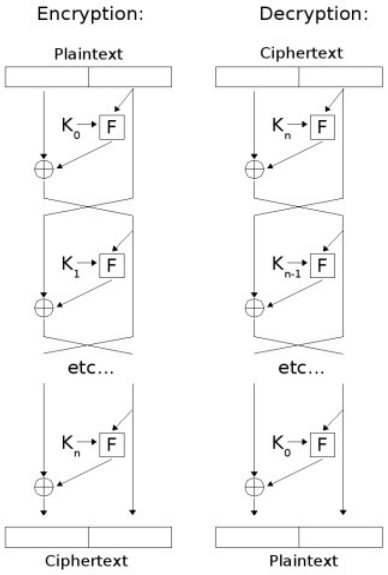
SPARC64

```
0000000000000000 <MD5Init>:
  0: 03 19 d1 48    sethi %hi(0x67452000), %g1
  4: 05 3b f3 6a    sethi %hi(0xefcda800), %g2
  8: c0 72 20 10    clrx  [ %o0 + 0x10 ]
  c: 82 10 63 01    or    %g1, 0x301, %g1
 10: 84 10 a3 89    or    %g2, 0x389, %g2
 14: c2 22 00 00    st    %g1, [ %o0 ]
 18: c4 22 20 04    st    %g2, [ %o0 + 4 ]
 1c: 03 26 2e b7    sethi %hi(0x98badc00), %g1
 20: 05 04 0c 95    sethi %hi(0x10325400), %g2
 24: 82 10 60 fe    or    %g1, 0xfe, %g1
 28: 84 10 a0 76    or    %g2, 0x76, %g2
 2c: c2 22 20 08    st    %g1, [ %o0 + 8 ]
 30: 81 c3 e0 08    retl
 34: c4 22 20 0c     st   %g2, [ %o0 + 0xc ]
```

A Better Way? Look for behavior...

- Don't search for concrete constants
- Look for properties unique to cryptographic functions
- We'll search for these properties

Look for...



Feistel Cipher

- Heavy use of integer operations:
  - AND/OR $a \wedge b$ $a \vee b$
  - ADD/SUB
  - XOR $a \oplus b$
- No floating point operations
- XOR is interesting by itself, it's a part of:
  - DES, SKIPJACK, RC4, BLOWFISH, AES
  - It has a C operator: `c = a ^ b;`
  - Other languages have it too (well, COBOL doesn't)

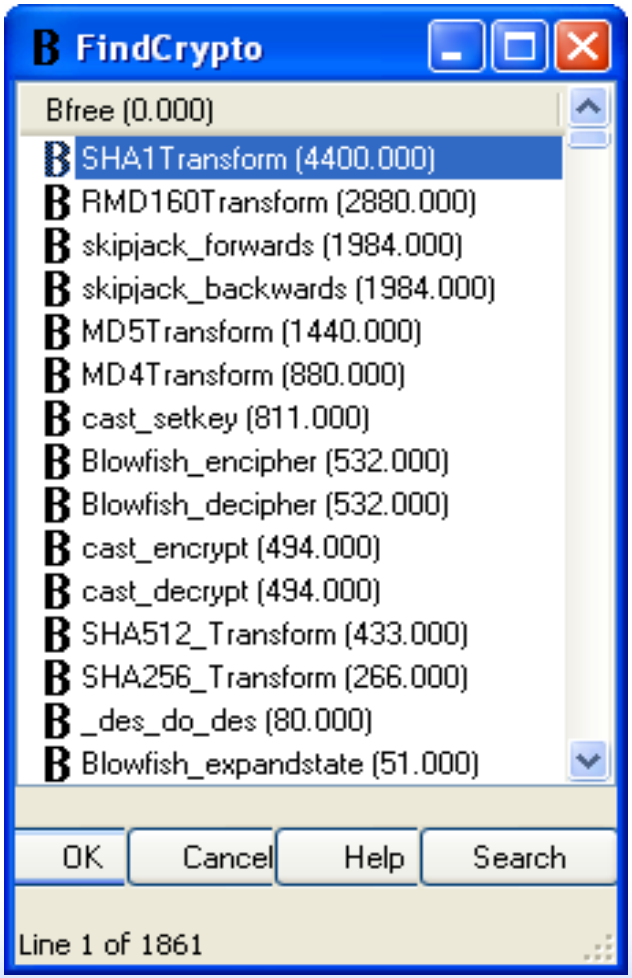
Looking for XOR...

- Not just any XOR will do, however...
  - `XOR %eax, %eax`
  - On many arch's, including IA32, this is very commonly used to “zero” a register (e.g. `eax`)
  - 93% of XOR usage is “zeroing” in Linux *glibc*
- Constant/immediate form: `xor $0x103, %eax`
  - Not usually interesting
- But memory references and registers are...

Rotation (ROR, ROL, not ROTFL)

- Commonly “diffusion” part of “confusion and diffusion” (Claude Shannon)
- No C operator, so...
  - Compiler optimization (libc)
  - Inline assembler (OpenSSL)

Example: OpenBSD libc



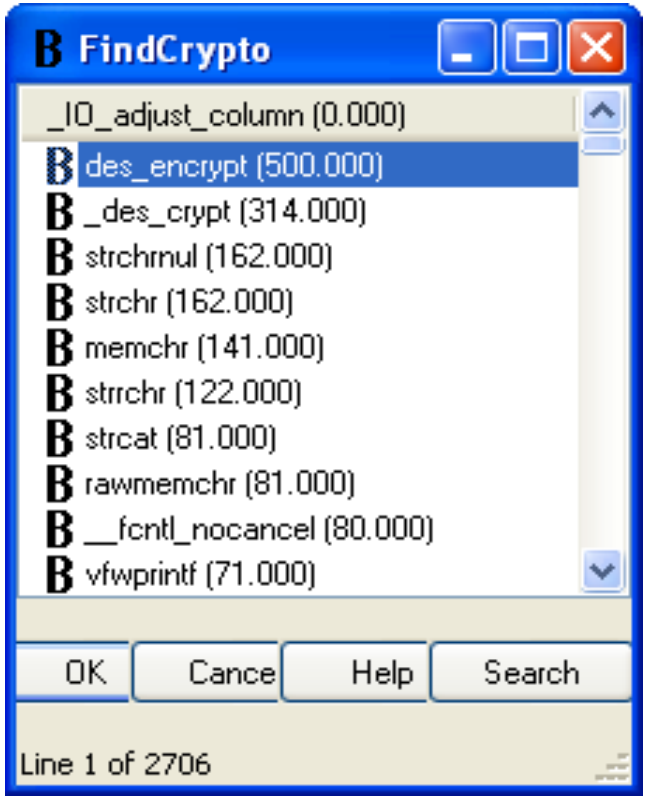
- Has quite a bit of crypto:
  SHA1, MD4/MD5, RMD160, CAST-128, SKIPJACK, DES/3DES, BLOWFISH
- 1379 functions total (4.3)

- Versions tested all the way back to 2.5 (May 1999!) (Remember a.out?)

- Compiler seems to have little effect (gcc 2.8.1, 2.95.2, 3.3.5)

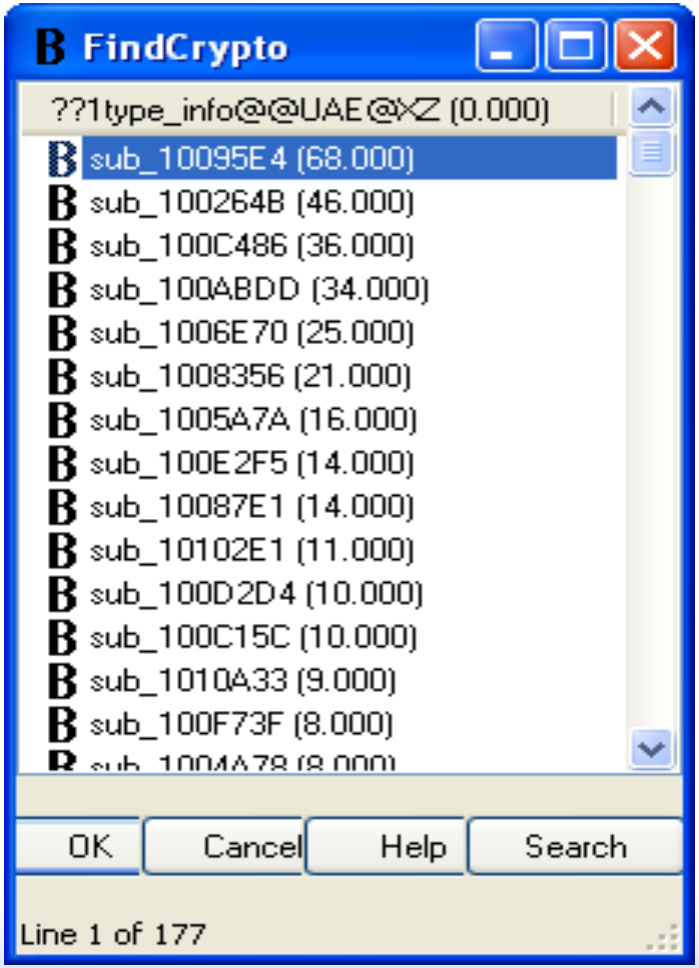
- Nor do compiler options (O0 to O3)

Example: Linux libc



- Not much crypto... just DES
  i.e. `crypt()`

Example: CALC.EXE



- Shouldn't have any crypto

… and doesn't appear to...

Scoring...

- Initially tried a density...

$$density = \frac{score}{num\ of\ instructions}$$

```
00000000 <abs>:
 0:   55              push %ebp
 1:   89 e5           mov  %esp,%ebp
 3:   8b 45 08        mov  0x8(%ebp),%eax
 6:   5d              pop  %ebp
 7:   99              cltd
 8:   31 d0           xor  %edx,%eax
 a:   29 d0           sub  %edx,%eax
 c:   c3              ret
```

```
public ntohl
ntohl proc near

arg_0= dword ptr  4

mov     eax, [esp+arg_0]
ror     ax, 8
rol     eax, 10h
ror     ax, 8
retn
ntohl endp
```

Hazards

- Changing/obscuring constants (*findcrypt* can't deal with this)
- FindCrypto not immune to dead/obscured code (combine with dead code analysis?)

Notably missing

- Asymmetric algorithms (DH, RSA, etc.)

  Macro operations on big numbers (>=512bit)

$$c = m^e \bmod n$$

$$m = c^d \bmod n$$

- RC4 (not Feistel cipher)

Questions/Comments?

```
00000000 <_exit>:
   0: 8b 5c 24 04           mov   0x4(%esp),%ebx
   4: b8 fc 00 00 00        mov   $0xfc,%eax
   9: ff 15 00 00 00 00     call  *0x0
   f: b8 01 00 00 00        mov   $0x1,%eax
  14: cd 80                 int   $0x80
  16: f4                    hlt
```