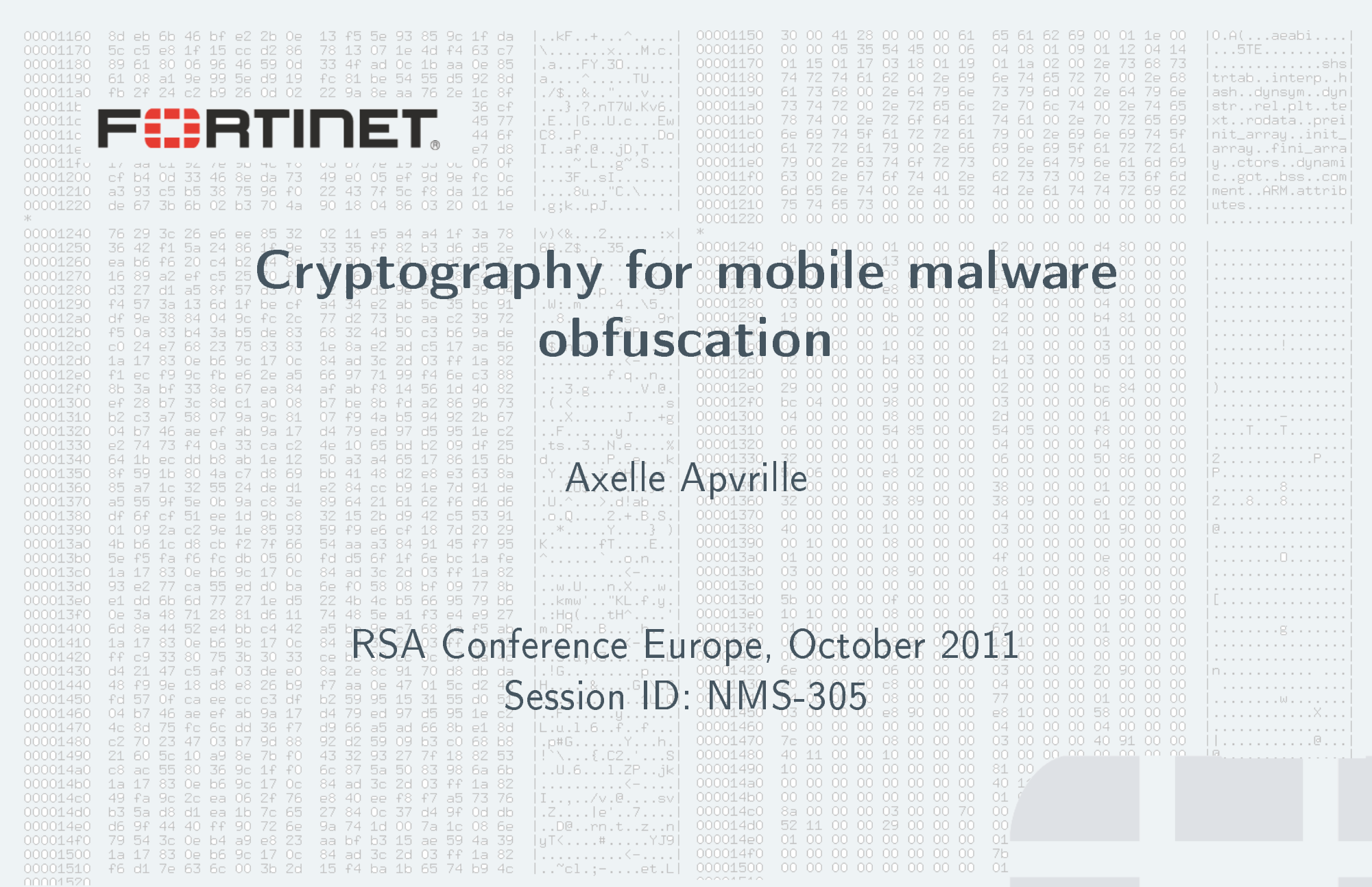


Cryptography for mobile malware obfuscation

Axelle Apvrille

RSA Conference Europe, October 2011

Session ID: NMS-305

Summary

Session objectives

Get familiar with real life mobile malware

Discuss (very) recent malware
Wrong ideas:

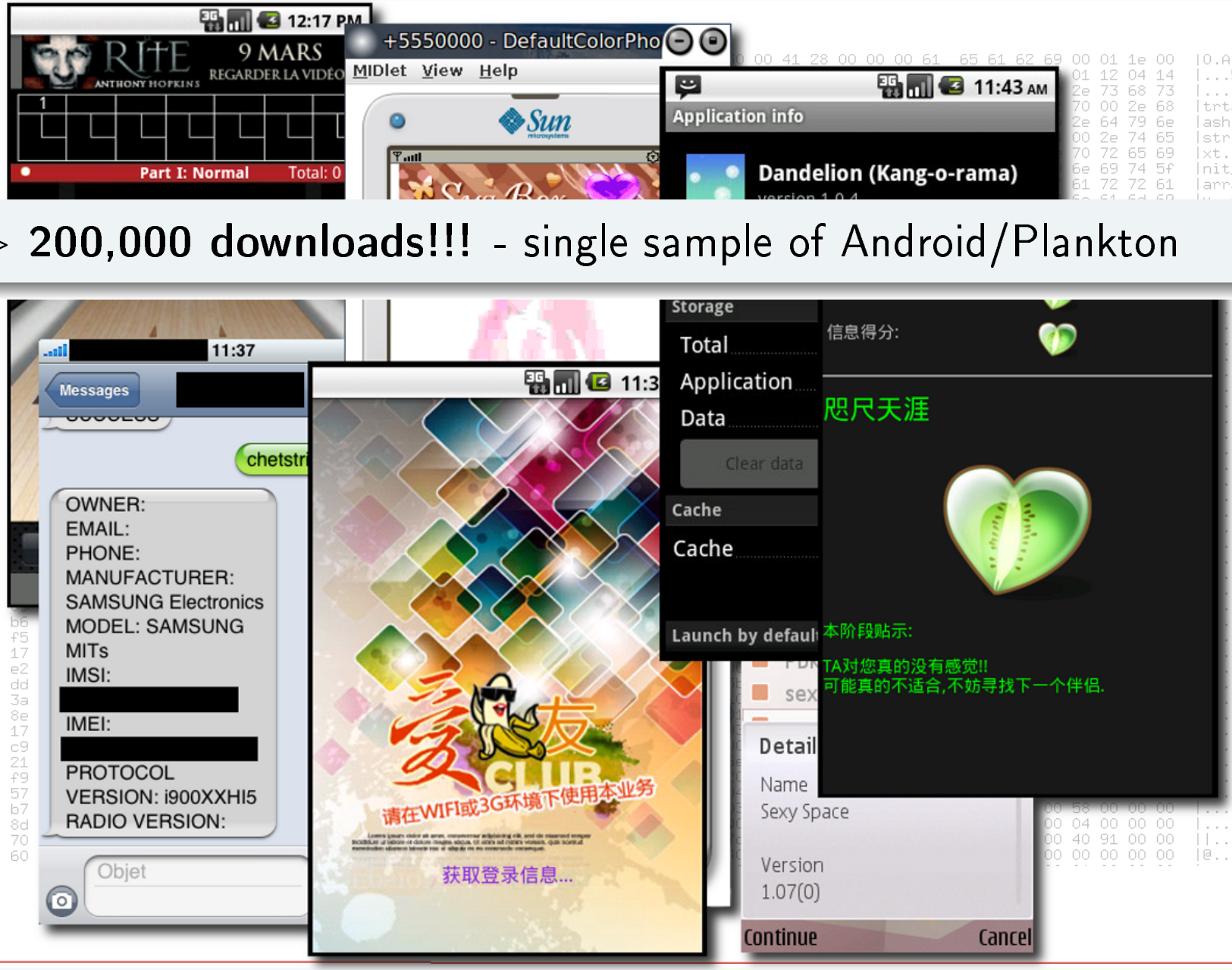
- "This never happens, I need not be concerned"
- "They do not use exploits, no interesting stuff in there"

How To See What's Hidden!

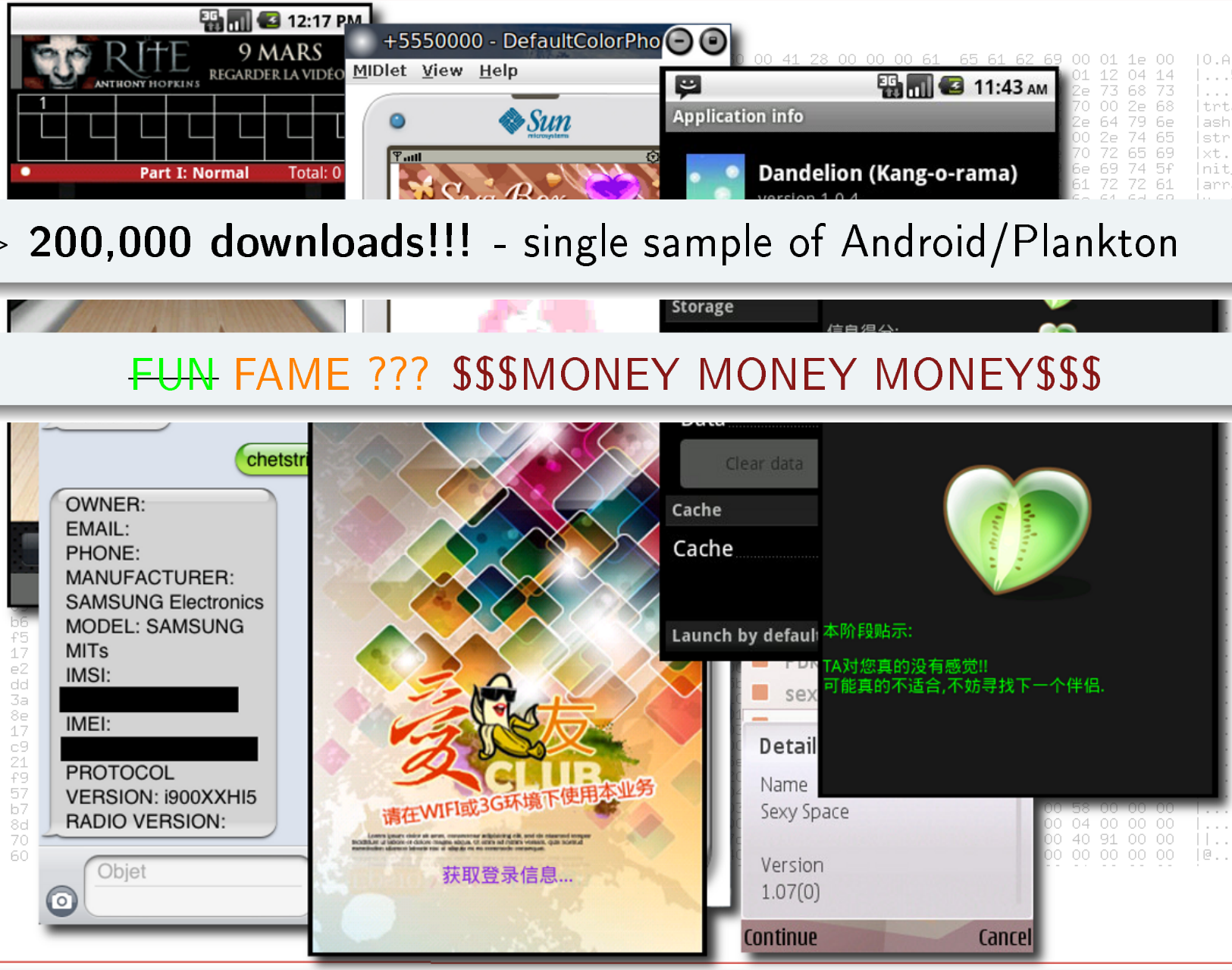
- Spot encryption routines in assembly listings
- Spot the key
- Decrypt!

Step by step examples with real malicious samples!

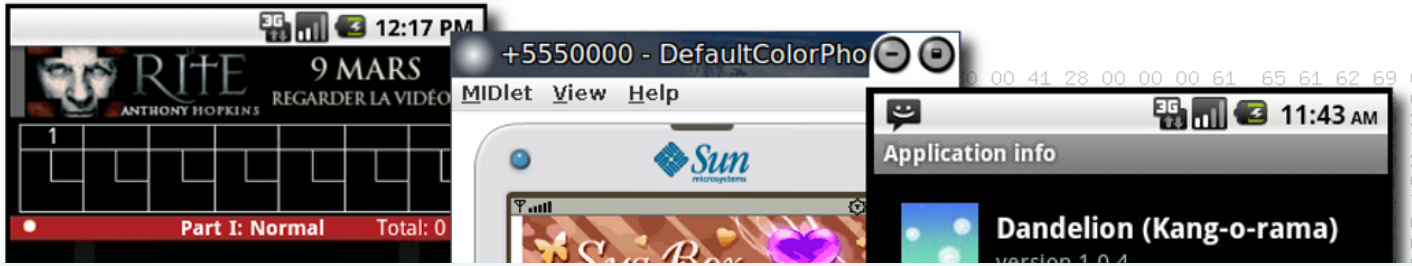
Mobile malware



Mobile malware



Mobile malware



> **200,000 downloads!!!** - single sample of Android/Plankton

~~FUN~~ FAME ??? $$$MONEY MONEY MONEY$$$

Basic malware: very successful

Advanced: exploits, polymorphic code (=code mutates), botnets, crypto...

Crypto in mobile malware

Motivations

- Obfuscation
- Hide maliciousness
- Harden reverse engineering
- Harden detection
- Keep control of their own malicious network

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Algorithms

Encryption algorithms only: Base64 $\rightarrow$ **AES**
Hash functions, signatures: not used (yet)

What's encrypted?

Encrypted payload	Motivation
SMS short codes and bodies	Analysis difficulty?

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Communication with remote servers	Keep control + Harden reversing
Variable names, keywords, filename	Harden reversing
Exploits or nested executables	Hide maliciousness + Harden reversing & detection
Binaries: polymorphic exec.	Harden reversing & detection

Summary

Simple obfuscation in Java/SmsBoxer.N!tr 1/2

Decompiled source code

```
this.jdField_b_String = a(b("L1RodW1icy5kYg=="));
```

b() does Base64 decoding, and a() reads a resource.

Simple obfuscation in Java/SmsBoxer.N!tr 1/2

Decompiled source code

```
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```

b() does Base64 decoding, and a() reads a resource.

Decode the string

```
$ echo "L1RodW1icy5kYg==" | openssl base64 -d
/Thumbs.db
```

Simple obfuscation in Java/SmsBoxer.N!tr 1/2

Decompiled source code

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Decode the string

```
$ echo "L1RodW1icy5kYg==" | openssl base64 -d
/Thumbs.db
```

Read Thumbs.db

The file contains base64-encoded data:

```
UO1TTn ...  HJlZmYuLi4NCg==
```

Simple obfuscation in mobile malware 2/2

Decode Thumbs.db

```
SMSNum-1: 3353
SMSText-1: xesss 3689
SMSNum-2: 3353
SMSText-2: xesss 3689
SMSNum-3: 7132
SMSText-3: xesss 3689
end of preff...
```

Simple obfuscation in mobile malware 2/2

Decode Thumbs.db

```
SMSNum-1: 3353
SMSText-1: xesss 3689
SMSNum-2: 3353
SMSText-2: xesss 3689
SMSNum-3: 7132
SMSText-3: xesss 3689
end of preff...
```

Base64 obfuscates:

1. the filename
2. the payload (SMS numbers and text)

Summary

Crypto apprentice no. 1: Android/PJapps

- Discovered in 2011, affects Android phones
- Remotely controls the phone: send SMS, add bookmark, visit URL, install app

Code builds this URL:

```
StringBuilder localStringBuilder1 =
    new StringBuilder("http://");
String str1 = Base64.encode(
    "alfo3gsa3nfdsrfo3isd21d8a8fccosm", 1);
...
```

This is **not** base64 + it's **decoding**:

alfo3gsa3nfdsrfo3isd21d8a8fccosm

l o g a n d r o i d 1 8 8 c o m

http://log.android188.com

Crypto apprentice no. 2: Java/Konov.S!tr

Using a hand-made and obscure algorithm

```
public String encryptSFrom = "R$...THE KEY";
String str = "";
char [] paramString = param.toCharArray();
int i = (encryptSFrom.toCharArray()).length - 1;
char [] enc = encryptSFrom.toCharArray();
int j = paramString.length - 1;
for (int l = 0; l <= j; ++l)  {
  int k = -1;
  for (int i1 = 0; i1 <= i; ++i1)
    if (enc[i1] == paramString[l])  {
      k = i1; break;
    }
  if (k != -1)  {
    if (k == 0) k = i;  else k -= 1;
    paramString[l] = enc[k];
  }
  str = str + paramString[l];
}
return str;
```

Java/Konov.S!tr: Decrypting the ciphertext

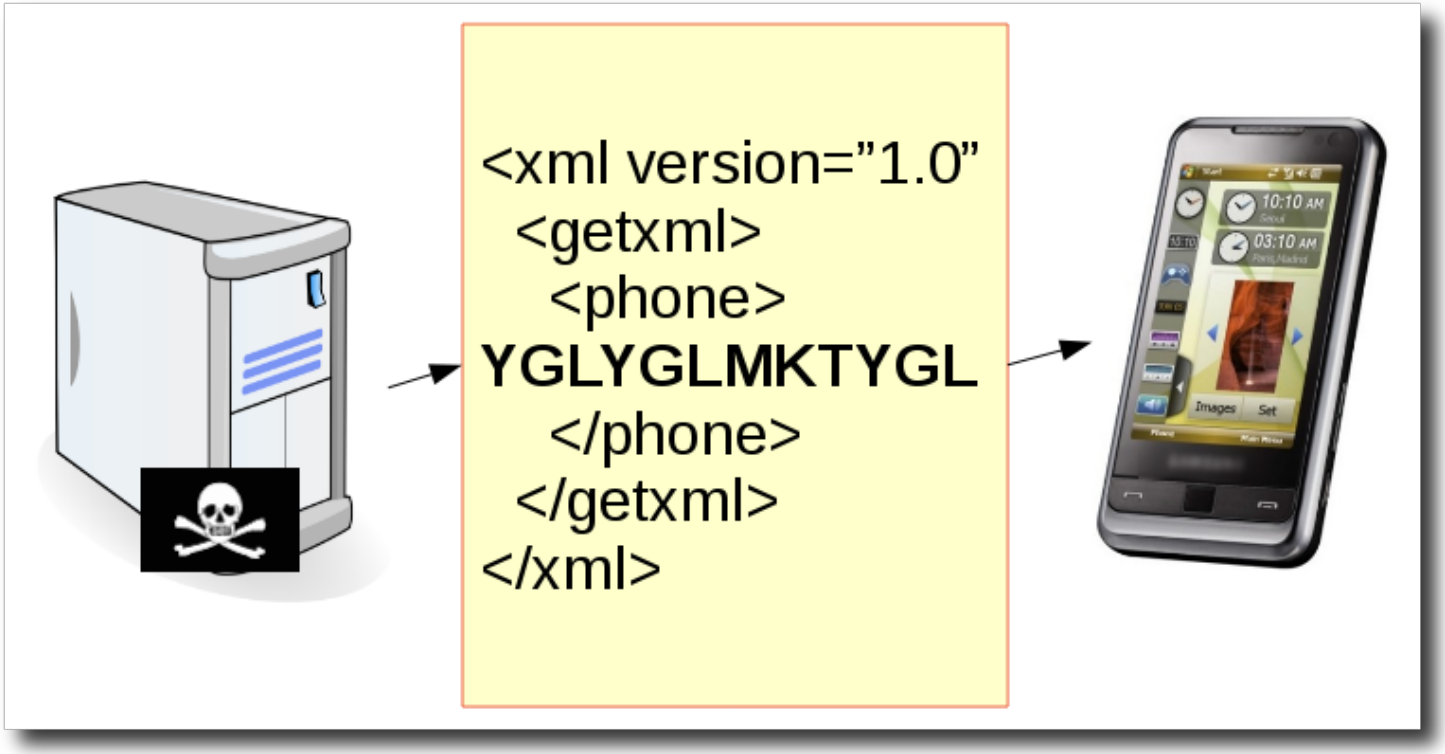
- Encrypts a file named /numbers.cfg (=ciphertext)
- No need to *understand* the algorithm, just to decrypt the ciphertext!
- Write a basic Java class, copy / paste the algorithm, call it on the ciphertext:

```
String str = decodeCes(getText("/numbers.cfg"));
System.out.println("Decoding string: "+ str);
```

Result: SMS numbers, body and corresponding price

```
7122::suksa1837::241.55py6.
7132::suksa1837::141.66py6.
8355::suksa1837::86.00py6.
```

Crypto apprentice no. 3: WinCE/Sejweek - 2009



Simple cryptographic substitution

```
Parameters::codeTable->AddShifrRow(S"YGL", S"1");
Parameters::codeTable->AddShifrRow(S"HKR", S"2");
Parameters::codeTable->AddShifrRow(S"DPO", S"3");
Parameters::codeTable->AddShifrRow(S"WHR", S"4");
Parameters::codeTable->AddShifrRow(S"MKT", S"5");
...
```

Crypto apprentice no. 4: SymbOS/ShadowSrv - 2010

Looks like a video downloading application, but sends SMS messages...

```
LDR R1, Y0RIoij[cR?dijWbbRH[]_ijhoR?dij...
```

Simple cryptographic translation (0x0A)

```
c:\System\Install\Registry\Install.reg
```

`Install.reg` is encrypted too (XOR).

Summary

XOR encryption in mobile malware

XOR encryption is basic, is it really used?

Yes.

- Java/Espaw.D!tr, Java/Swapi.AF, Java/Konov.K...
- WinCE/Pmcryptic (2008)
- SymbOS/Yxes (2009)
- SymbOS/Shurufa (2009)
- SymbOS/ShadowSrv (2010)
- SymbOS/Zhaomiao (2010)
- Android/DrdDream (2011)
- ...

Also found on **Pushdo** (PC malware)
Historical: red phone USA / Russia.

Why XOR ?!

Reasons

1. Perfect algo in theory if key truly random + as long as cipher
2. Efficient: 1 instruction
3. Easy to code

Malicious implementations

- Often 1-byte key
- Simple to break: frequency analysis

Spotting an XOR-encryption routine in Symbian

- a function with a buffer and a key as parameter

```
LDR R1, R4 ; R4 is a counter
LDR R0, R6 ; R6 is the buffer
```

- load one byte of the buffer: LDRB

```
BL _ZNK6TDesC83AtCEi ; TDesC8::AtC(int)
```

- apply the XOR key: EOR

```
EOR R3, R8, R3 ; R3 = R3 XOR R8 (key)
```

- increment a counter ADD

```
ADD R4, R4, #1 ; increment counter
```

- loop until all buffer has been processed: CMP, BL

```
CMP R4, R7 ; R7 is the maximum value
BLT loop   ; loop if not finished
```

Finding the value of the XOR key

Method 1. Close to the calling function

```
04 00 A0 E1 MOV     R0, R4              ; string
6E 10 A0 E3 MOV     R1, #0x6E ; 'n'     ; key
3F FA FF EB BL      analyst_xorencrypt  ; arg1 = string
                                        ; arg2 = key
```

Method 2. Break it!

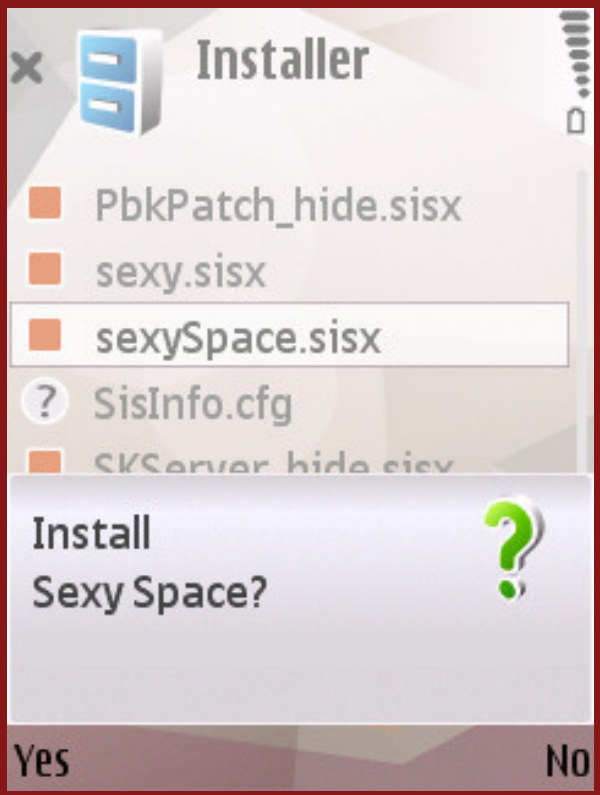
Use XORSearch tool (Didier Stevens)

```
$ wine XORSearch.exe -s Srv.cfg http
Found XOR 57 position 0000: http://[CENSORED]banw.com/api/
```

Taken from SymbOS/Shurufa.A!tr

Hands On Symbian Yxes Worm

Hands On Symbian Yxes Worm



What is it?

SymbOS/Yxes!worm is a **worm** for mobile phones. It sends SMS and connects to Internet. Discovered in 2009.

Why is it important?

1. High bills for victims
2. Said to have affected *"hundreds of thousands"* devices in China [source: Daniel Hoffman, CTO of Smobile]
3. First malware for Symbian OS 9
4. Advanced: hidden connections to Internet and SMS sending...

Hands On Yxes: spot the decryption routine

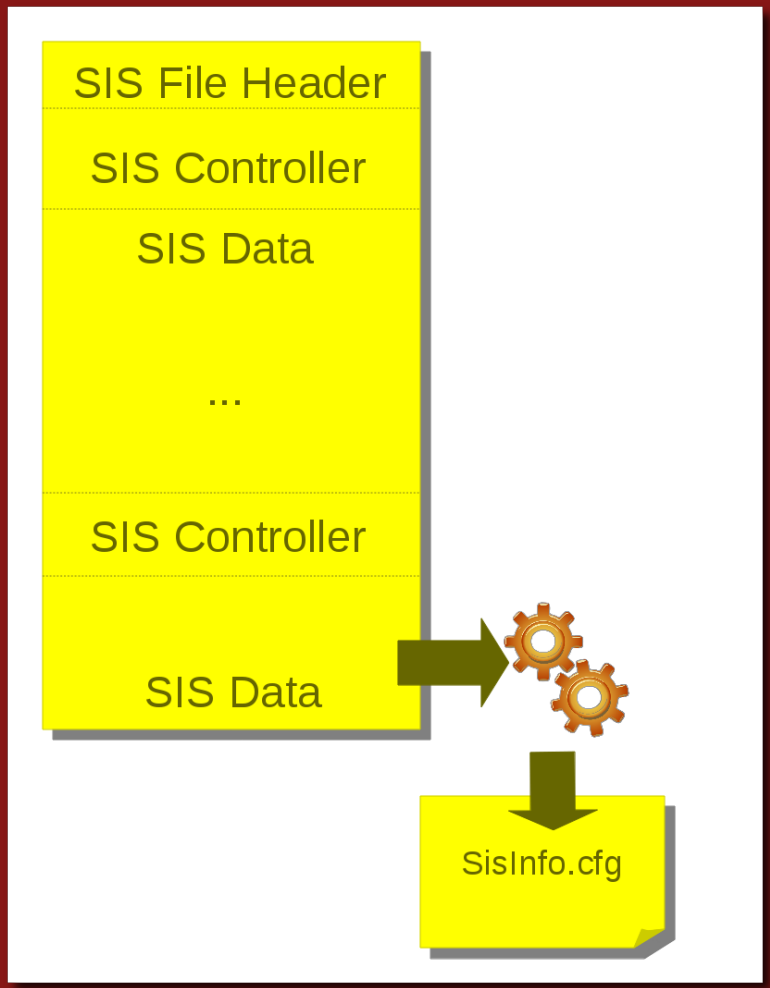
Where is the config file SisInfo.cfg?

Contents of Symbian package:

- Resource file [20026CA5].rsc: No
- Main malicious executable: AcsServer.exe No
- Installer: 0x20026CA6.exe Try here

Downloaded from a URL? which URL?

Hands On Yxes: Identify the encryption key



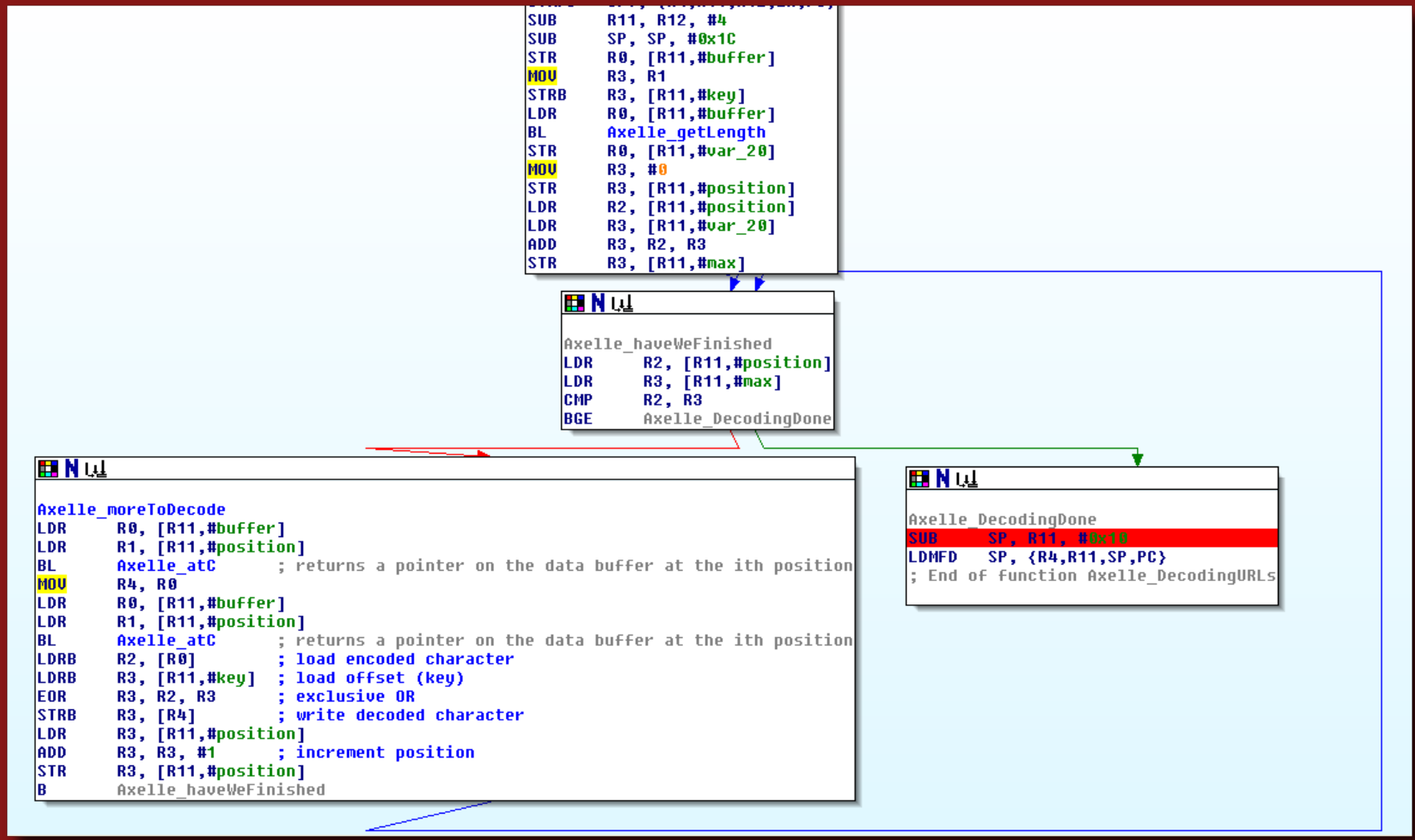
Reversing of the installer

Read section in Symbian package:
huh? why?

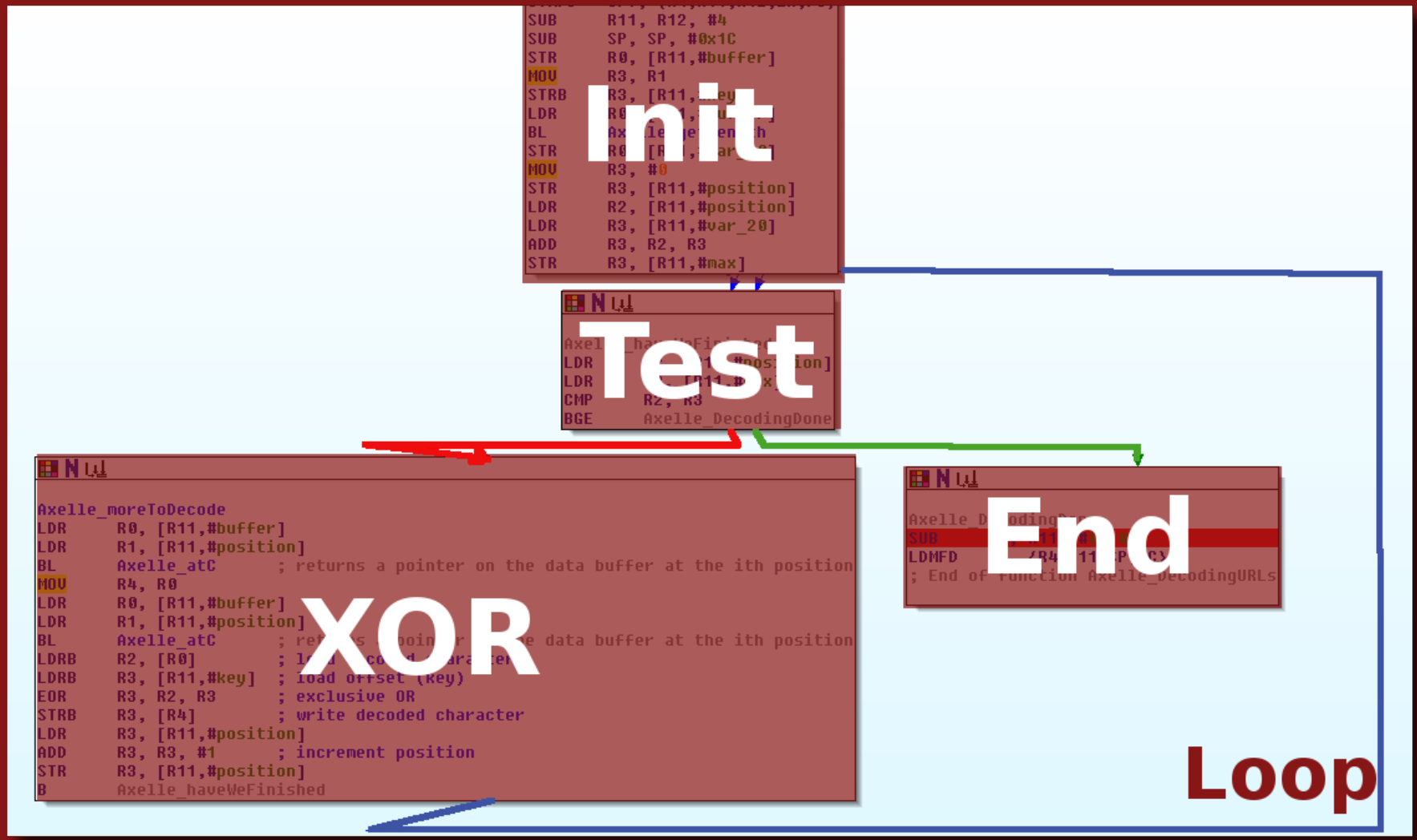
```
SUB R0, R11, #0xBC
MOV R1, #0xBF
BL Yxes_func
```

Key = 0xBF
Decryption routine = Yxes_func

Hands On Yxes: decryption routine



Hands On Yxes: decryption routine



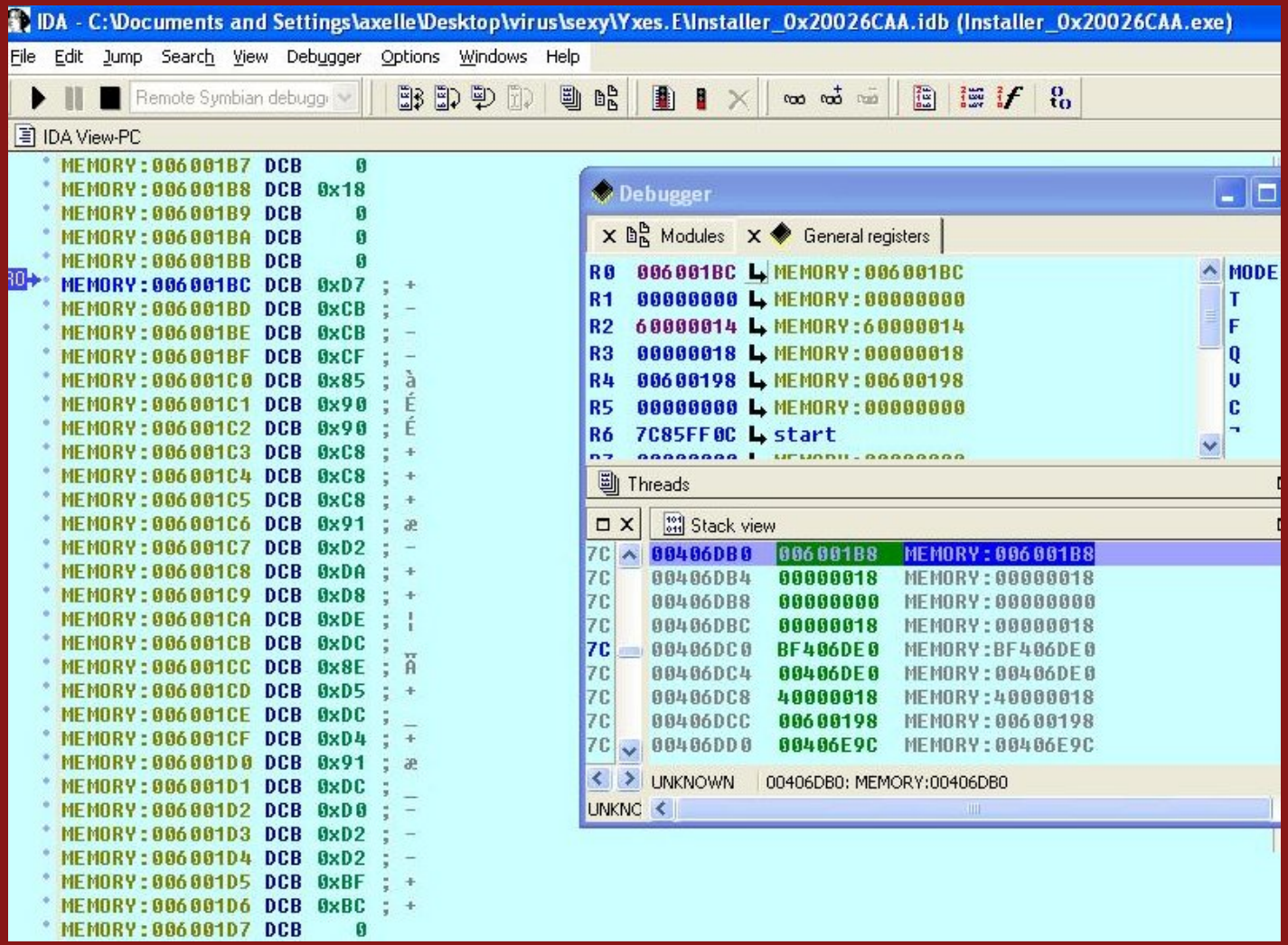
Decrypt it! Method 1

Read the configuration file on the phone

Easy but beware: ensure you do not propagate the virus

```
$ hexdump -C SisInfo.cfg
2f 2f 77  |........http://w|
63 6f 6d  |ww.megac1jck.com|
77 2e 6d  |....http://www.m|
00 00 68  |akt000b.com....h|
69 61 66  |ttp://www.mediaf|
74 70 3a  |ir8.com....http:|
30 61 64  |//www.megaup10ad|
2f 2f 77  |.com....http://w|
6d        |ww.mozi11a.com|
```

Decrypt URLs from a debug session - Method 2



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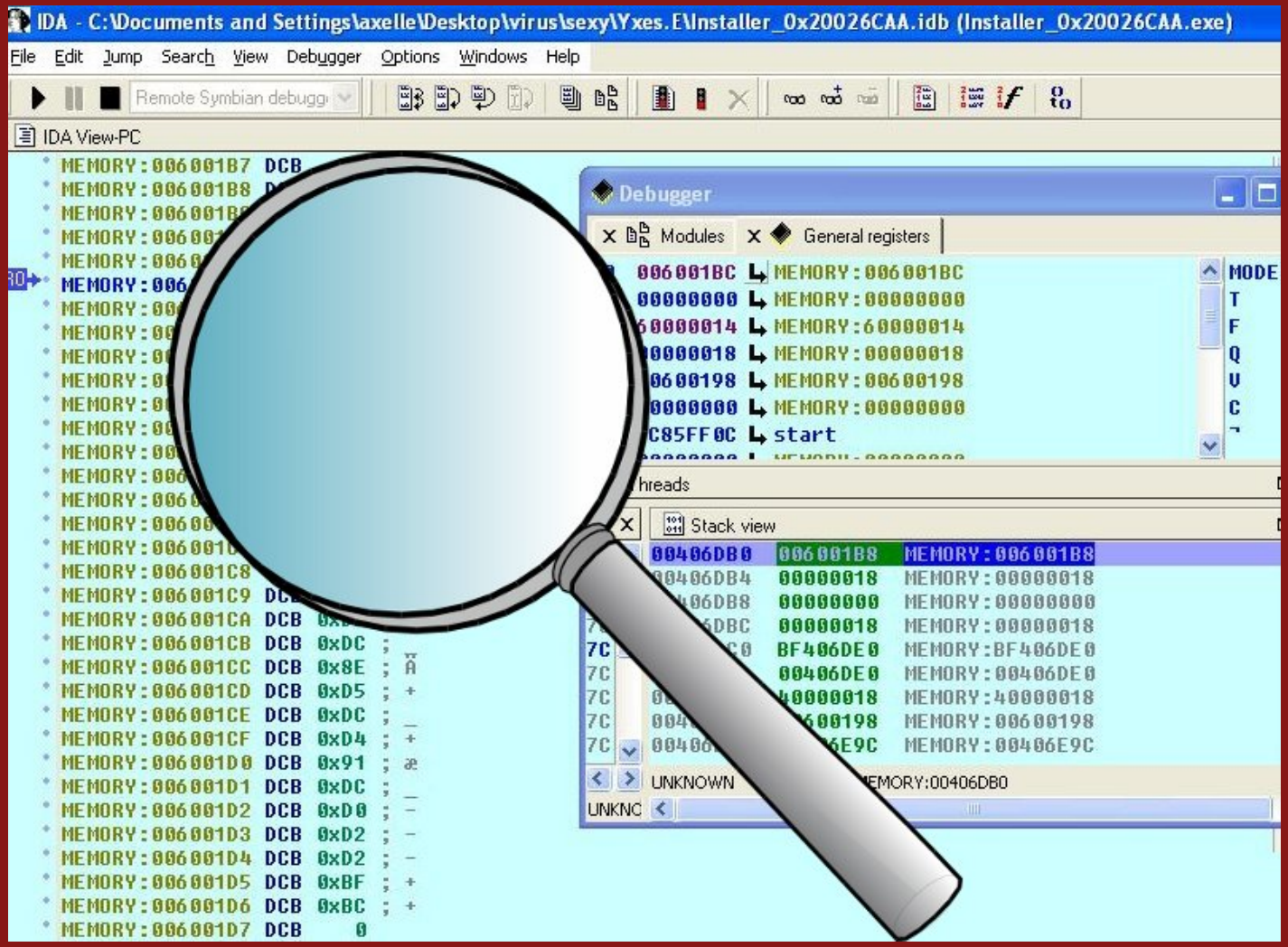


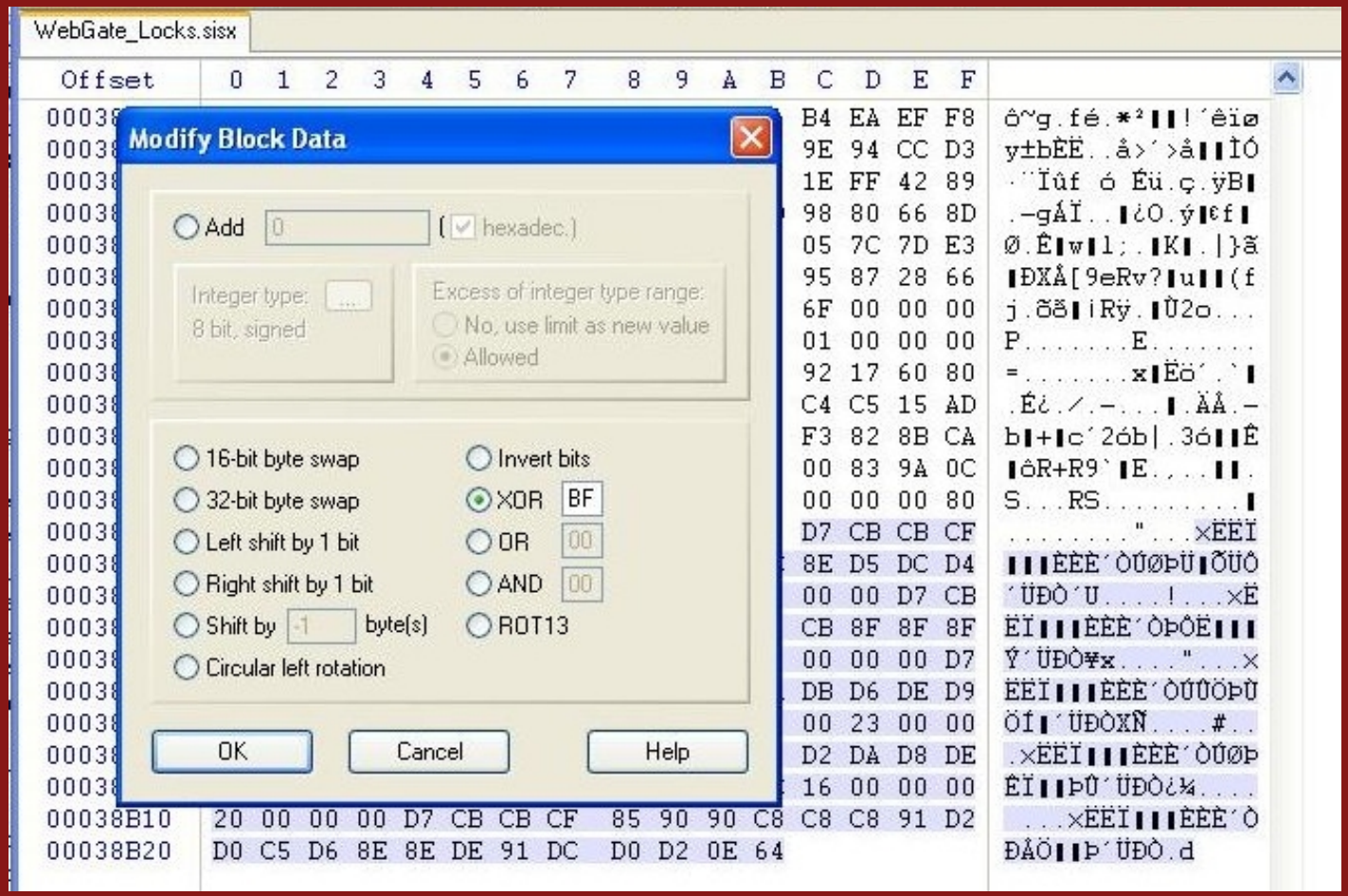
Decrypt URLs from a debug session - Method 2

```
MEMORY:006001BC DCB 0xD7 ; +
MEMORY:006001BD DCB 0xCB ; -
MEMORY:006001BE DCB 0xCB ; -
MEMORY:006001BF DCB 0xCF ; -
MEMORY:006001C0 DCB 0x85 ; à
MEMORY:006001C1 DCB 0x90 ; É
MEMORY:006001C2 DCB 0x90 ; É
MEMORY:006001C3 DCB 0xC8 ; +
MEMORY:006001C4 DCB 0xC8 ; +
```

Decrypt URLs from a debug session - Method 2

```
MEMORY:006001BC DCB 0x68 ; h
MEMORY:006001BD DCB 0x74 ; t
MEMORY:006001BE DCB 0x74 ; t
MEMORY:006001BF DCB 0x70 ; p
MEMORY:006001C0 DCB 0x3A ; :
MEMORY:006001C1 DCB 0x2F ; /
MEMORY:006001C2 DCB 0x2F ; /
MEMORY:006001C3 DCB 0x77 ; w
MEMORY:006001C4 DCB 0x77 ; w
```

Apply the XOR key to the ciphertext - Method 3



Apply the XOR key to the ciphertext - Method 3

XOR encryption in Java code

Java/SmsBoxer.F!tr

- the package contains an encrypted file a.zip and Java classes
- we decompile the classes
- one of the classes shows it loads the a.zip resource and then:

```
new a(...).field ^ 0x78 ^ 0x78;
```

where the constructor of **a** does:

```
this.a = (paramInt ^ 0x78);
```

XOR key

value xor 0x78 xor 0x78 xor 0x78 = value xor 0x78

Decrypting the resource of Java/SmsBoxer.F!tr

Quick Perl script to decrypt a.zip

```
$ cat a.zip |
 perl -ne 'print pack "C*", map {$_^0x78} unpack "C*", $_'
06159395 smswap 473151350 vsxwap 473159395
  smswap 473147122 gywap 473159395 smswap
  473159395 smswap 473
```

XOR encryption in Android/DrdDream.A!tr - 2011

- In the Android Market (removed)
- Root the phone (Rage against the cage)
- Leak private info, install without consent

Ciphertext and key are hard-coded

```
arrayOfByte[0] = 94;
arrayOfByte[1] = 42;
arrayOfByte[2] = 93;
...
KEYVALUE = "6^)(9-p35...";
```

XOR encryption

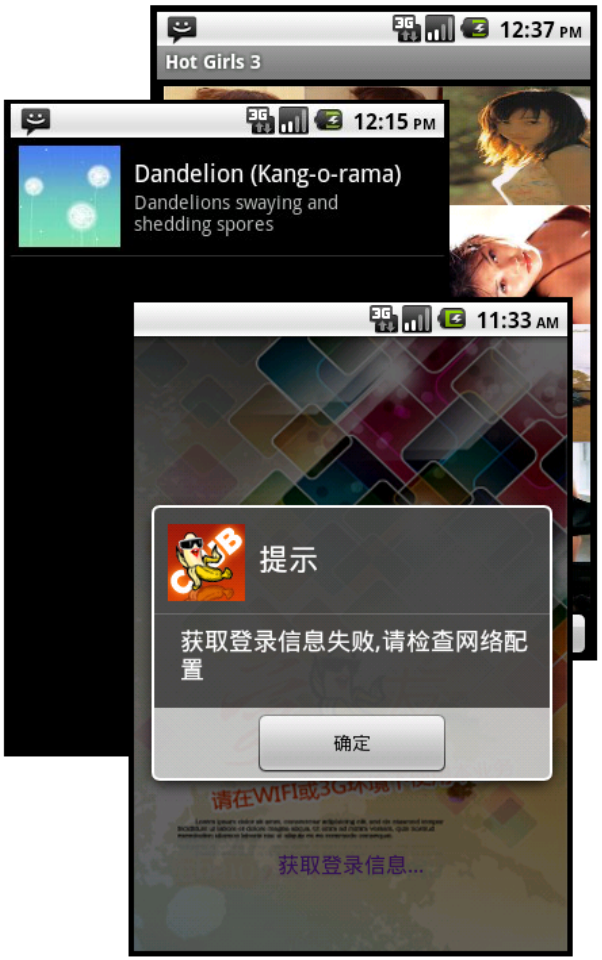
```
int l = arrayOfByte[j];
int i1 = KEYVALUE[i];
int i2 = (byte)(l ^ i1);
```

Decrypted value

http://[CENSORED]45.17:8080/GMServer/GMServlet

Summary

Modern algorithms in malware



- Android/Geinimi (Jan 2011): DES
- Android/Hongtoutou (Feb 2011) : DES
- Android/DrdLight (June 2011): DES
- Android/DroidKungFu (June 2011): AES
- ...

Locating the encryption code: search for KeySpec

In Android/DroidKungFu.A!tr

```
SecretKeySpec localSecretKeySpec =
    new SecretKeySpec(arrayOfByte, "AES");
```

In Android/DrdLight.A!tr (smali code)

```
new-instance v1, Ljavax/crypto/spec/DESKeySpec;
const-string v2, "DDH#X%LT"
invoke-virtual {v2}, Ljava/lang/String;->getBytes()[B
move-result-object v2
invoke-direct {v1, v2}, Ljavax/crypto/spec/DESKeySpec;
    -><init>([B)V
```

Beware

Several advertisement kits use encryption!

Identify the key

- Search for hard-coded constants

In Android/Geinimi.A!tr

```
b = new byte[] { 1, 2, 3, 4, 5, 6, 7, 8 };
```

In Android/Hongtoutou.A!tr

```
const-string v0, "48734154"
```

- Search for the code that creates the KeySpec

In Android/DroidKungFu.A!tr

```
private static byte[] defPassword = { 70, 117, 99, 107,
    95, 115, 69, 120, 121, 45, 97, 76, 108, 33, 80, 119 };
..
byte[] arrayOfByte = defPassword;
SecretKeySpec localSecretKeySpec =
   new SecretKeySpec(arrayOfByte, "AES");
```

- Search in assets or resources for unusual data

Decrypt it!

It's not difficult!

Write a standalone program, and copy/paste the malware's encryption code!

MyDecrypt.java for Android/Hongtoutou.A!tr

```
public class MyDecrypt {
    private byte [] desKey;
    public String kk;
    public static String CIPHER = "39...";
    public MyDecrypt() { this.kk = "48734154";   }
    public static String decrypt(String paramString1,
       String paramString2) throws Exception {
byte[] arrayOfByte1 = convertHexString(paramString1);
Cipher localCipher = Cipher.getInstance(
        "DES/CBC/PKCS5Padding");
byte[] arrayOfByte2 = paramString2.getBytes("UTF-8");
     ...
}
```

Android/Hongtoutou.A!tr decrypted

The result

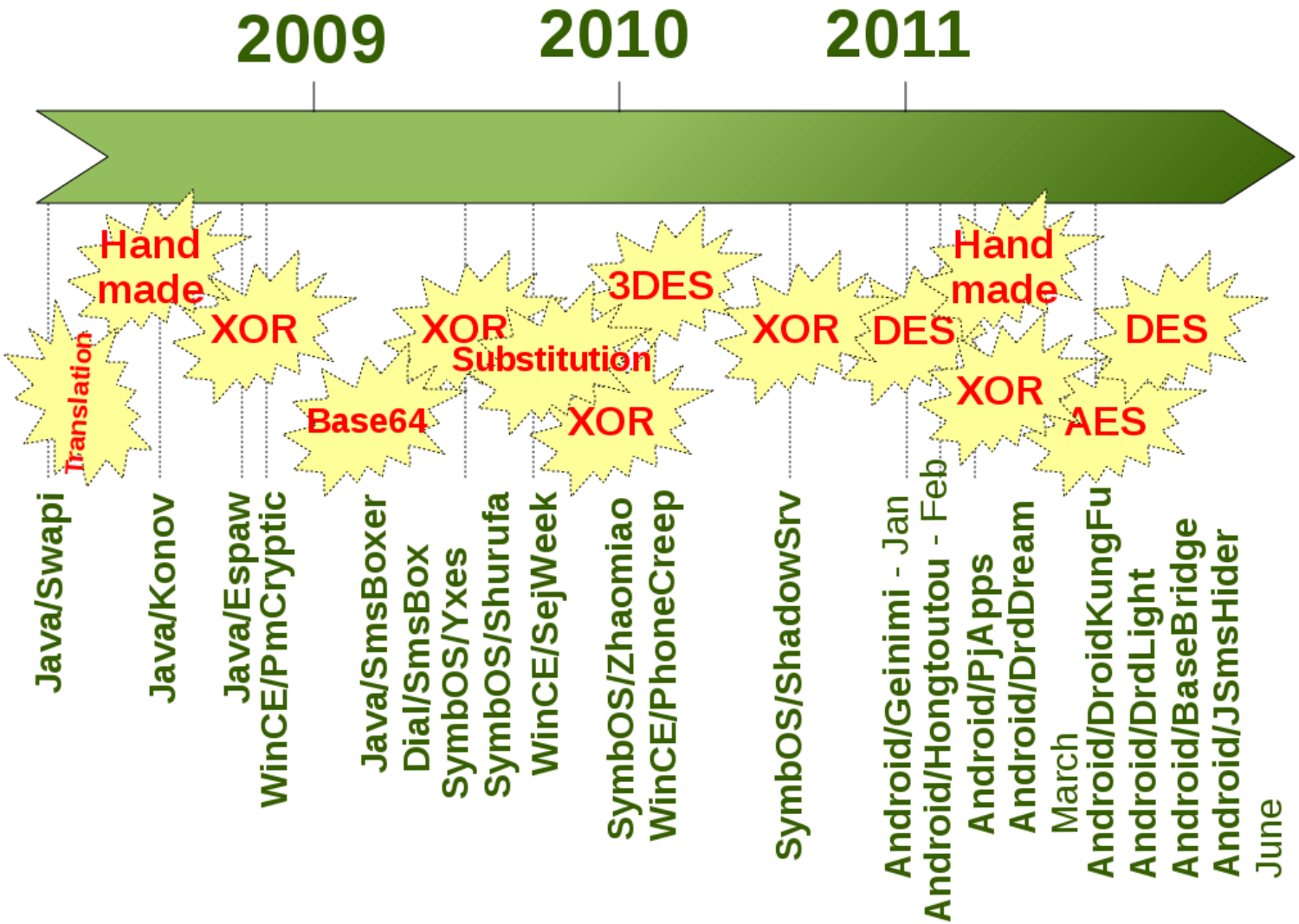
```
Result=B#1#963a_w1|http://[CENSORED]2.105/g/g.ashx?w=963a_w1
|1|http://[CENSORED]2.105/add/pk.aspx$B#1#961a_w1|
http://[CENSORED]2.105/g/g.ashx?w=961a_w1|1|
http://[CENSORED]2.105/add/pk.aspx$B#1#964a_w1|
http://[CENSORED]2.105/g/g.ashx?w=964a_w1|1|
http://[CENSORED]2.105/add/pk.aspx$B#1#978a_w1|
http://[CENSORED]2.105/g/g.ashx?w=978a_w1|1
```

What is this?

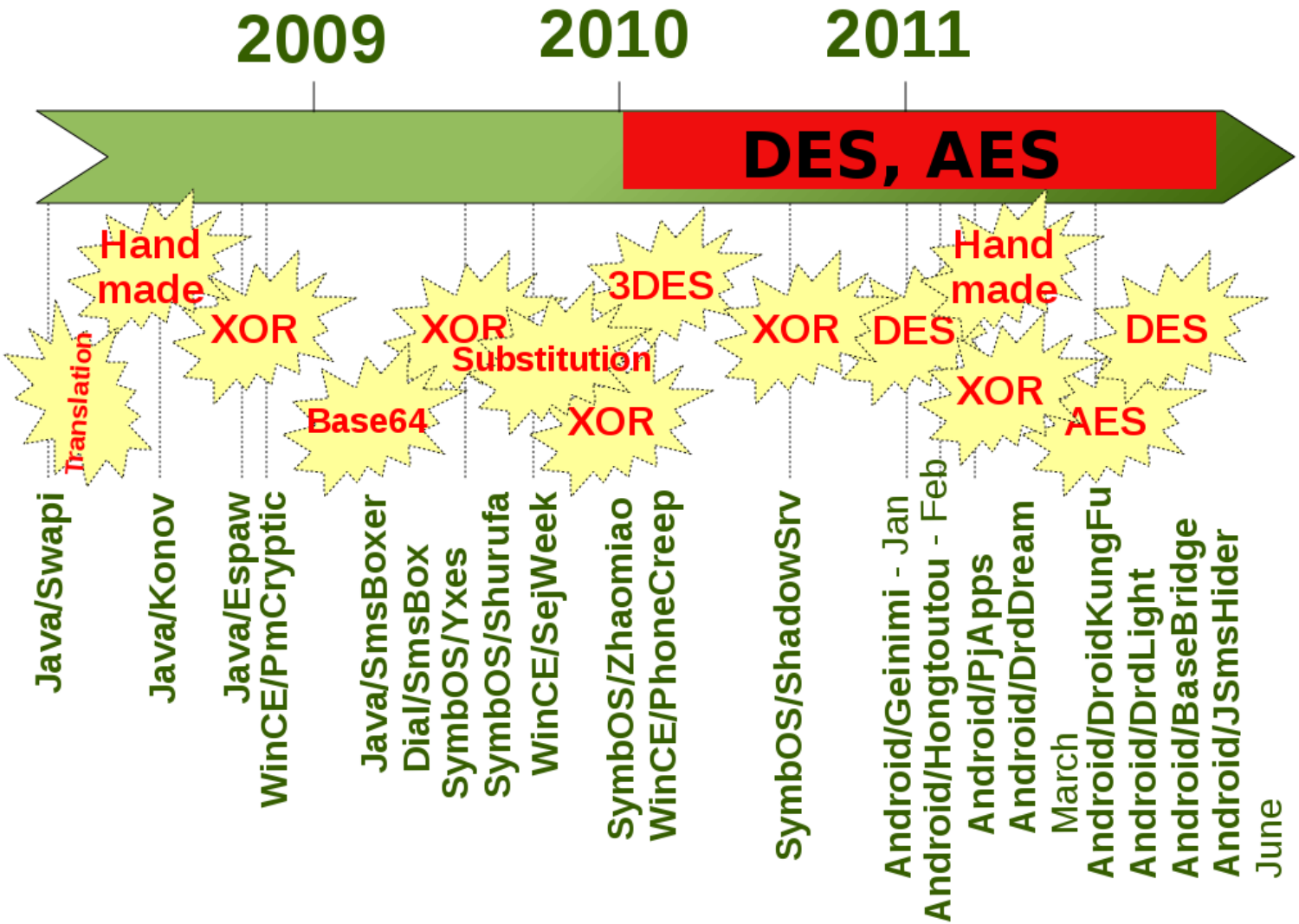
Result=Parameters | URL | Params ...

Summary

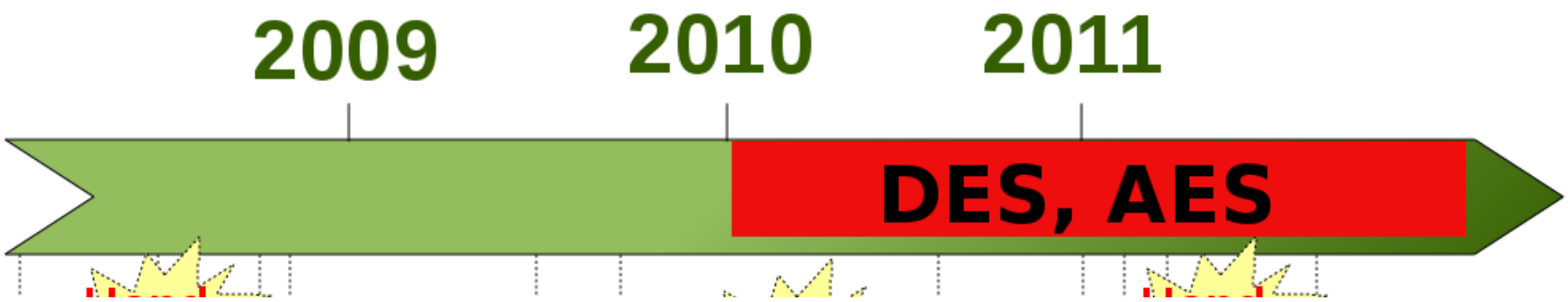
Noticeable Trends in Crypto



Noticeable Trends in Crypto



Noticeable Trends in Crypto



Explanations

- DES, AES in Android API
- Botnets

How efficient is it?

Efficiency against detection

Poor: AV signatures usually not based on encrypted data.
Only efficient against *basic* hash/checksum-based signatures.

Efficiency against analysis

Algorithm	Time to reverse
base64	☺
XOR	☹
AES, DES	☹
Custom	☹

- Hard-coded keys and ciphertext quite easy to spot
- Assembly more difficult to reverse

Apply

You are a ... mobile phone user

Do not trust your mobile phone (yet)

You are a Security Researcher, Architect, Cryptographer

- Mobile malware **IS** an issue.
- Mobile malware use crypto, exploits etc. Spread the word.

You are a (nice) developer

- Secret? Don't put it in the code ;)
- Have a look at Key Agreement schemes

You study malware

- Get your hands on a few mobile malware samples
- Spot the algo, the key, write your own decrypt code

References

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- Description of Java/Konov.S!tr
- Description of Java/SmsBoxer.F!tr
- Description of Java/SmsBoxer.N!tr
- Description of SymbOS/ShadowSrv.A!tr
- Description of SymbOS/Shurufa.A!tr.dldr
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Thank You !

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