Hardware Backdooring is practical

Jonathan Brossard (Toucan System)

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

Agenda

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

Who am I ?

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

  Likes : Unix, network, architecture, low level, finding 0days (mem corruptions).

  Dislikes : web apps, canned exploits.

- Super pure English accent (French, learned English in India, lives in Australia... ;))

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 introductory material

Former Pentagon analyst: Ch

www.zdnet.com/

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

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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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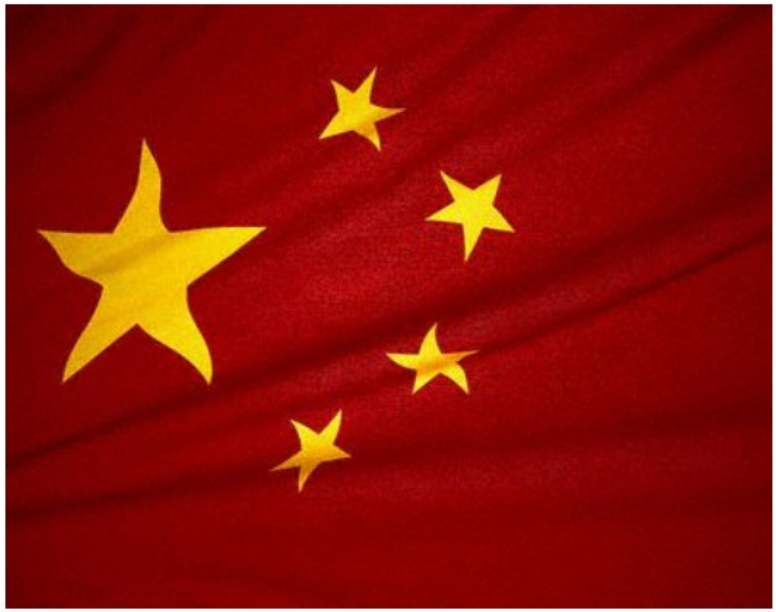
Chine, Réseau, Windows, ZTE, Huawei

22 commentaire(s)

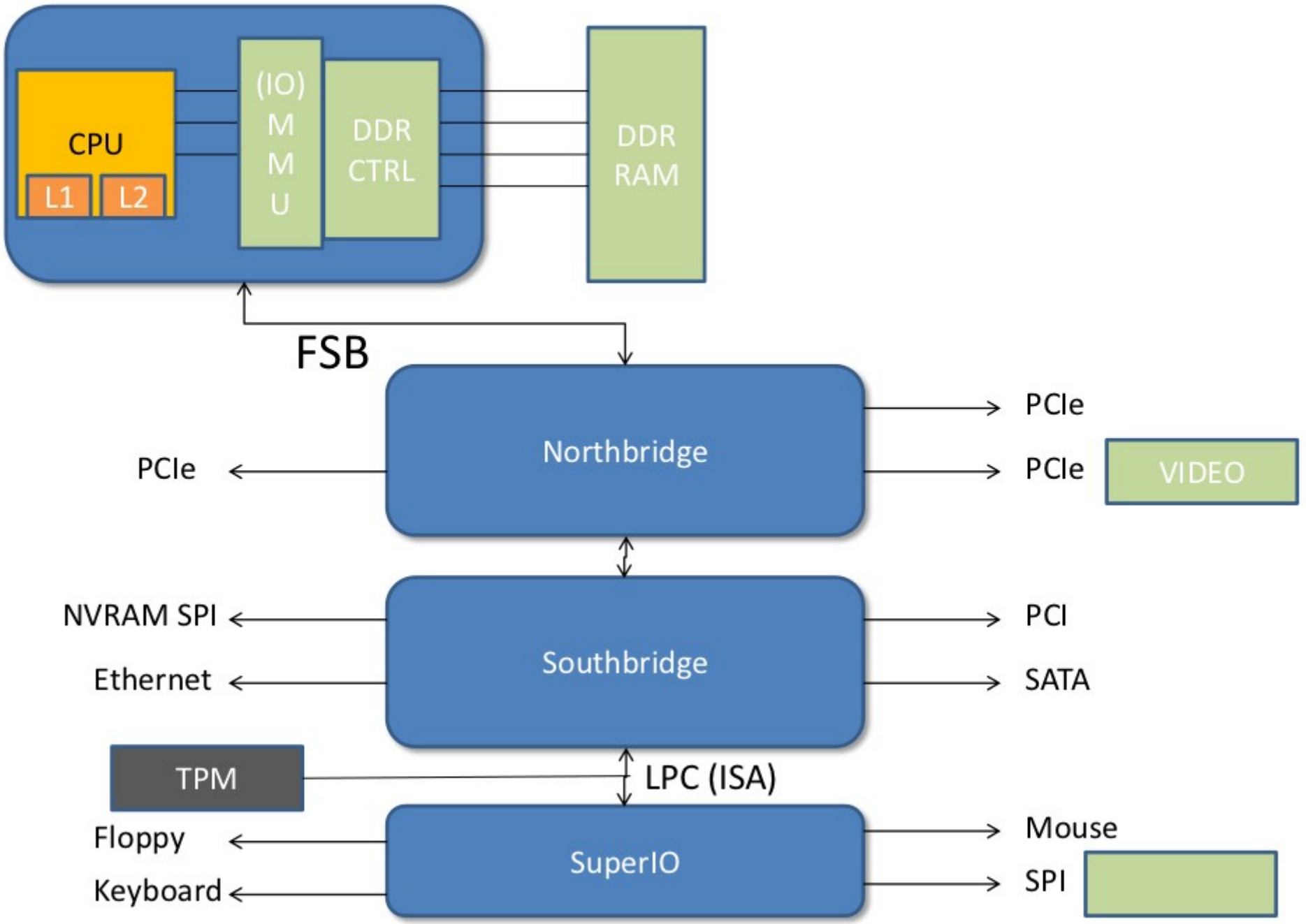
Faudra-t-il se passer des équipements chinois dans le secteur des télécommunications ? Un rapport sénatorial dédié à la cyberdéfense avance cette idée, pointant du doigt les liens entre les industriels ZTE et Huawei et le pouvoir central chinois. Mais en matière de cyberdéfense, les matériels en provenance 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)
- 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 : 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

        movl    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 in Coreboot shellcode  ;)
        nop
```

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

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

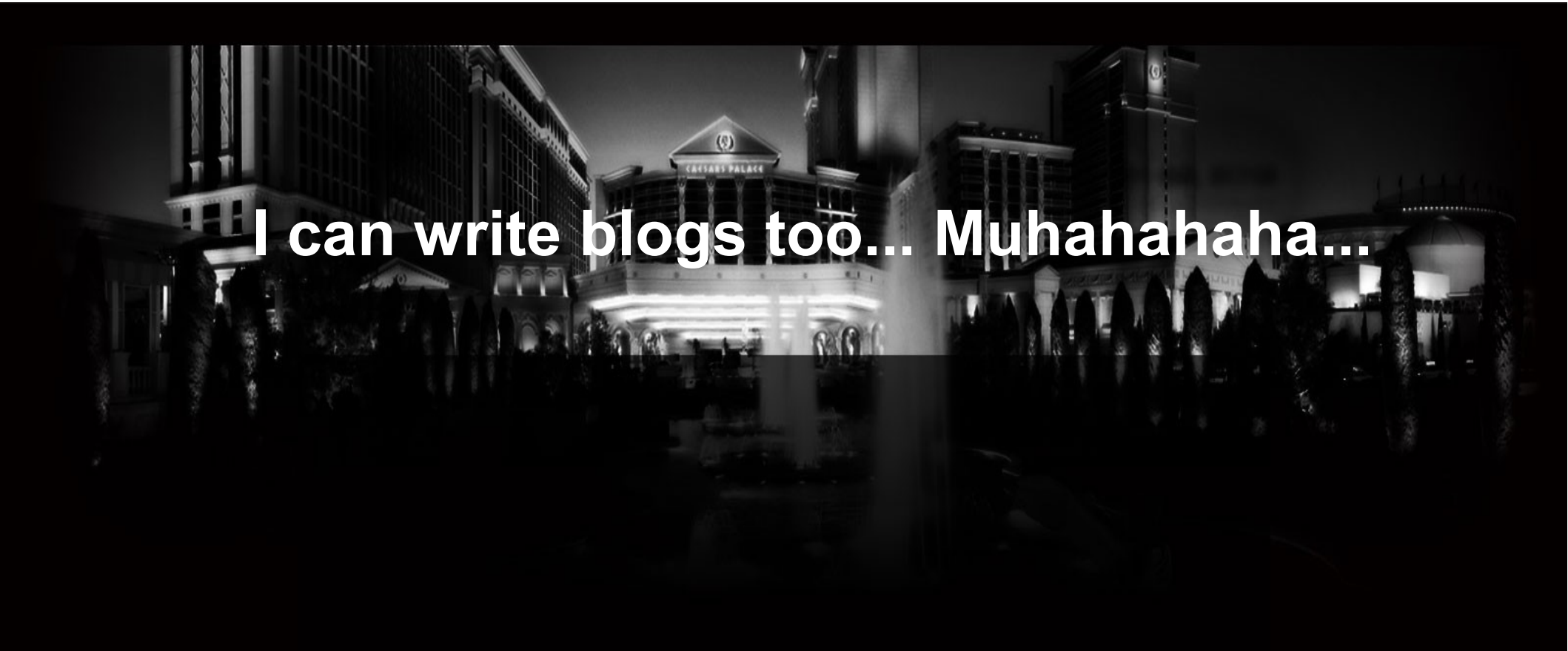
Rakshasa : stealthness

- 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 !

DEMO : Evil remote carnal pwnage (of death)



How to properly build a botnet ?

- HTTPS + assymetric cryptography (client side certificates, signed updates)
- Fastflux and/or precomputed IP addresses

  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.

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.

How about Avs ??

- Putting an AV on a server to protect against unknown threats is purely cosmetic.
- You may as well put lipstick on your servers...

Example : 3 years old bootkit

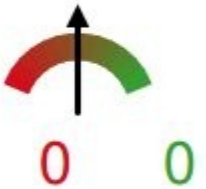
virustotal

SHA256: 214ce3ce21e38ea145ba2cd52cce7e94367a2701ea5f4efda4a1cc248fbec1d2

File name: konFLOPPY.img

Detection ratio: 2 / 43

Analysis date: 2012-03-07 07:14:43 UTC (3 weeks, 3 days ago)



Kaspersky	-	20120307
McAfee	-	20120307
McAfee-GW-Edition	Heuristic.BehavesLike.Exploit.CodeExec.EPMG	20120307
Microsoft	-	20120307
NOD32	-	20120307
Norman	nown virus, B.H	20120304
nProtect	-	20120306

Example : 3 years old bootkit (+ simple packer)

virus

SHA256: 8

File name: k

Detection ratio: 0

Analysis date: 2

Antivirus		
AhnLab-V3		
AntiVir		
Antiy-AVL		
Avast		
AVG		
BitDefender		
ByteHero		
CAT-QuickHeal	-	20120331
ClamAV	-	20120331
Commtouch	-	20120330
Comodo	-	20120331
DrWeb	-	20120331
Emsisoft	-	20120331

Realistic attack scenarii

Realistic attack scenarii

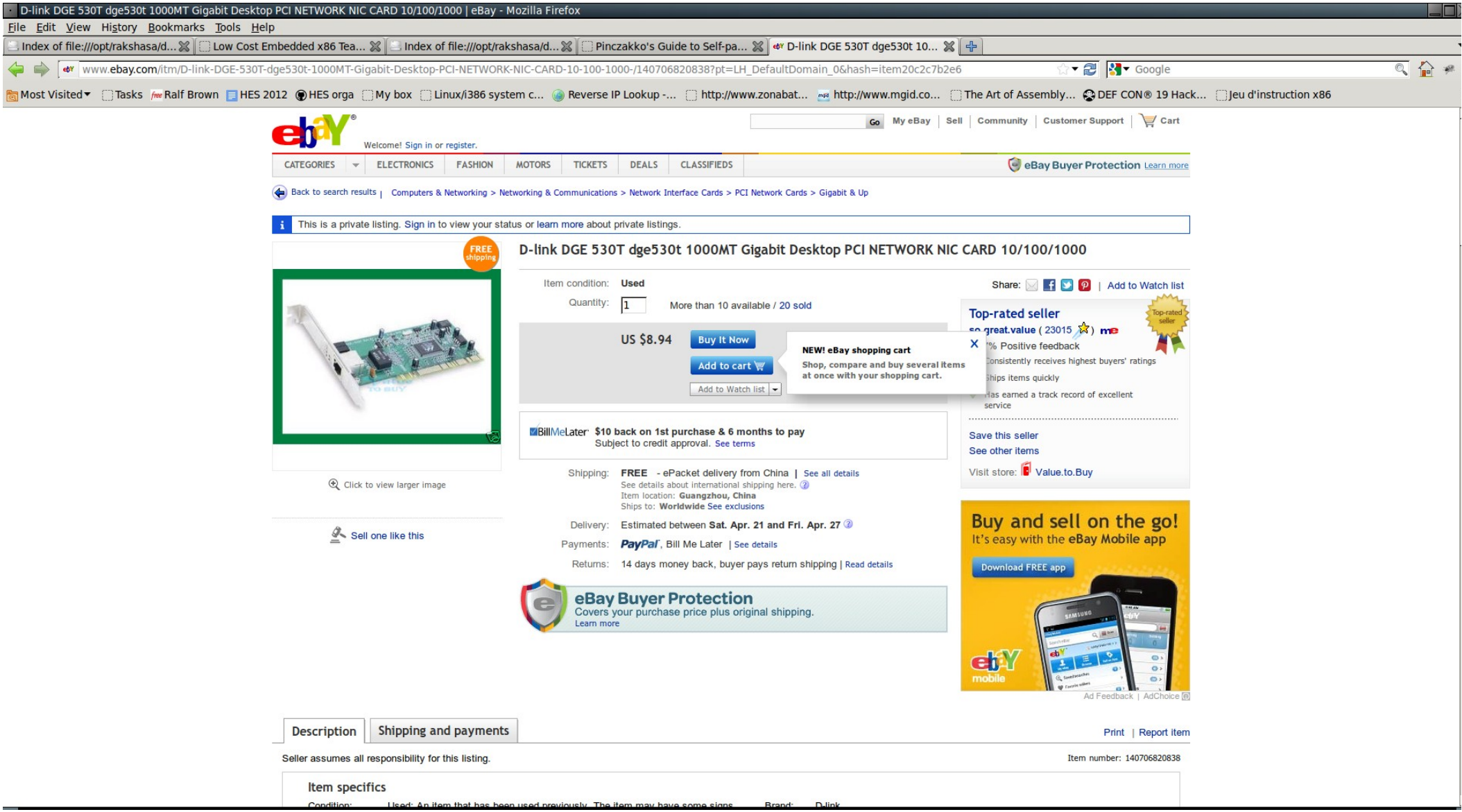
- Physical access :

Anybody in the supply chain can backdoor your hardware. Period.
Flash from a bootable USB stick (< 3mins).

- Remote root compromise :

```
If (OS == Linux) {
        flash_bios;
} else {
   Pivot_over_the_MBR ;
}
```

Realistic attack scenarii



BONUS : Backdooring the datacenter

iPXE - open source boot firmware [howto:vmware] - Mozilla Firefox

File Edit View History Bookmarks Tools Help

iPXE - open source boot firmwa...

ipxe.org/howto/vmware

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Using iPXE in VMware

You can replace the default VMware PXE ROM with an iPXE ROM, which will enable you to boot your virtual machine via HTTP, iSCSI, AoE, or any other protocol supported by iPXE.

Table of Contents

- Selecting the network adapter
- Building the ROM images
- Configuring the virtual machine
- Booting the virtual machine

Selecting the network adapter

VMware is capable of emulating several network adapters:

VMware name	iPXE driver name	PCI vendor:device IDs	iPXE ROM image
e1000	e1000	8086:100f	8086100f.mrom
e1000e	e1000e	8086:10d3	808610d3.mrom
vlance	pcnet32	1022:2000	10222000.rom
vmxnet	(not supported)	15ad:0720	
vmxnet3	vmxnet3	15ad:07b0	15ad07b0.rom

Select one of the supported network adapters, and ensure that your virtual machine is configured to use this adapter. You can do this by editing the .vmx file that defines your virtual machine, and changing the setting

```
ethernet0.virtualDev
```

For example, to select an e1000 network adapter:

```
ethernet0.virtualDev = "e1000"
```

Building the ROM images

Download iPXE and then build ROM images for all of the supported network adapters using:

```
make bin/8086100f.mrom bin/80861043.mrom bin/10222000.rom bin/15ad07b0.rom
```

Copy the iPXE ROM images 8086100f.mrom, 80861043.mrom, 10222000.rom and 15ad07b0.rom to a suitable location (e.g. to the directory /usr/lib/vmware/resources/).

Configuring the virtual machine

Edit the .vmx file that defines your virtual machine, and add the following lines:

```
ethernet0.romsize = 262144
e1000bios.filename = "/usr/lib/vmware/resources/8086100f.mrom"
e1000ebios.filename = "/usr/lib/vmware/resources/80861043.mrom"
vlance.filename = "/usr/lib/vmware/resources/10222000.rom"
vmxnet.filename = ""
vmxnet3.filename = "/usr/lib/vmware/resources/15ad07b0.rom"
```

(replacing /usr/lib/vmware/resources/ with the name of the directory to which you copied the iPXE ROM images).

Booting the virtual machine

Boot your virtual machine in the usual way. You should see VMware detect and use the iPXE ROM:

Remediation

Remediation (leads)

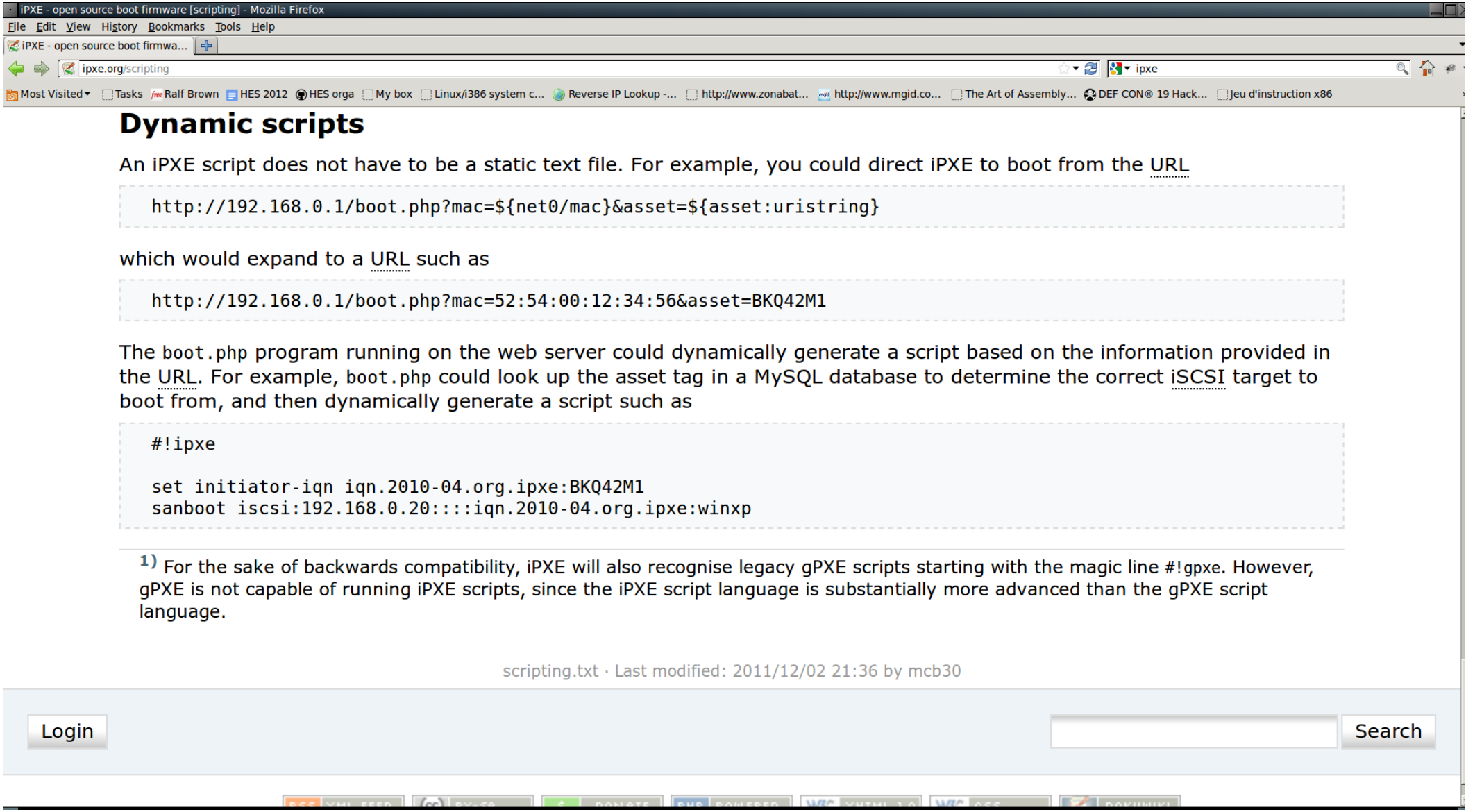
- Flash any firmware uppon reception of new hardware with open source software you can verify.
- Perform checksums of all firmwares by physically extracting them (FPGA..) : costly !
- Verify the integrity of all firmwares from time to time
- Update forensics best practices :
  1) Include firmwares in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

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

Side note on remote flashing

- BIOS flashing isn't a problem : the flasher (Linux based) is universal.
- PCI roms flashing is more of a problem : flasher is vendor dependant...

Detecting network card manufacturer from the remote C&C



Backdooring like ~~NSA~~ China

Backdooring like a 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.

More DEMOS

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).

Questions ?