DEEPSEC 2009

USB Device Drivers

A Stepping Stone into your Kernel

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Agenda

- USB intro
- Motivation
- Attack surface
- Vulnerability identification
  - Hardware-aided approach
  - Emulated environment
- Crash analysis
- Some findings
- Conclusion

Who am I?

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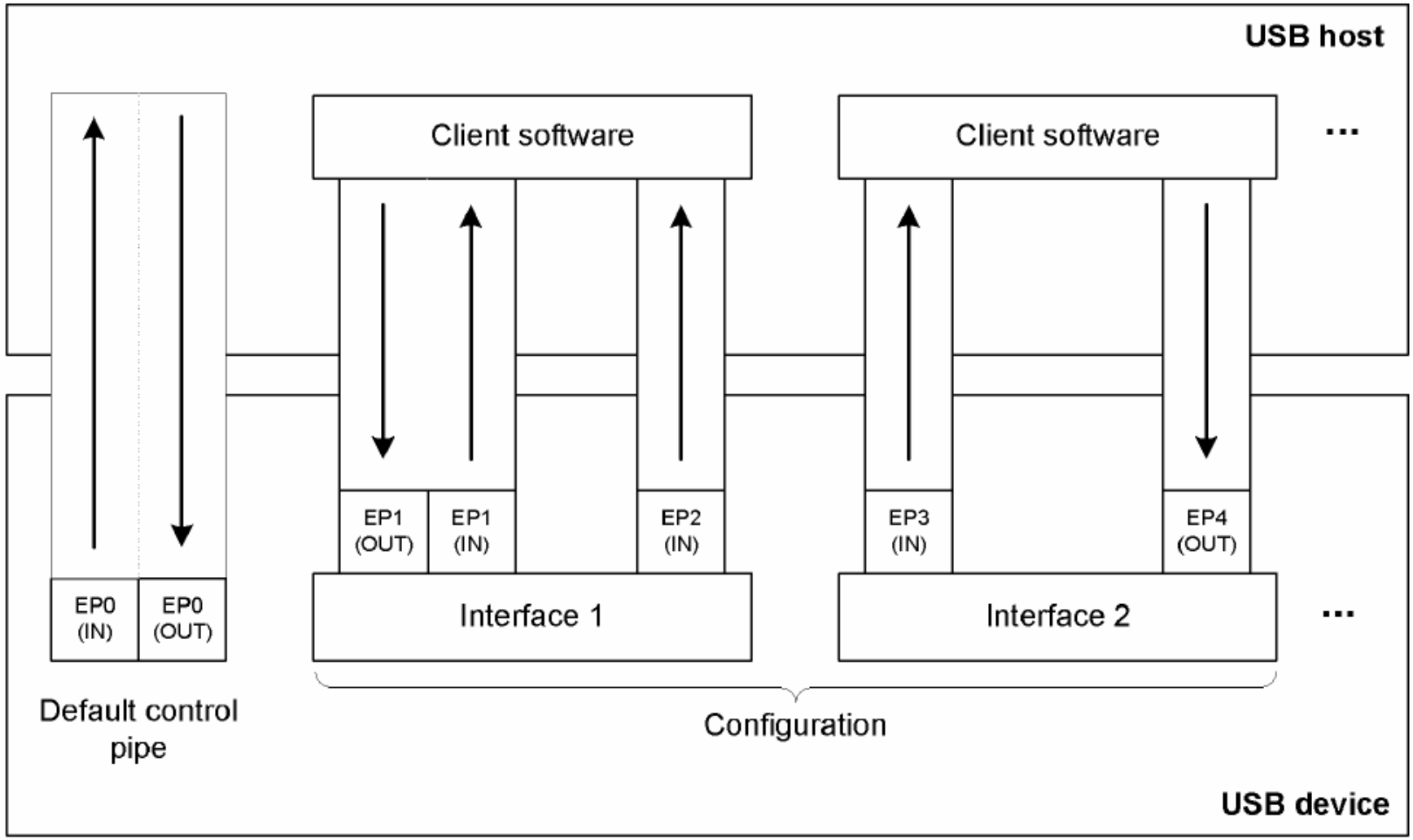
  - Bug hunter / security researcher
  - Penetration tester at n.runs AG
  - Living in Hamburg, Germany

USB intro

USB concepts

- Host / device
- Enumeration
- Descriptors
- USB lingo
  - Endpoints
  - Pipes
  - Interfaces
  - Configurations

USB overview



Motivation

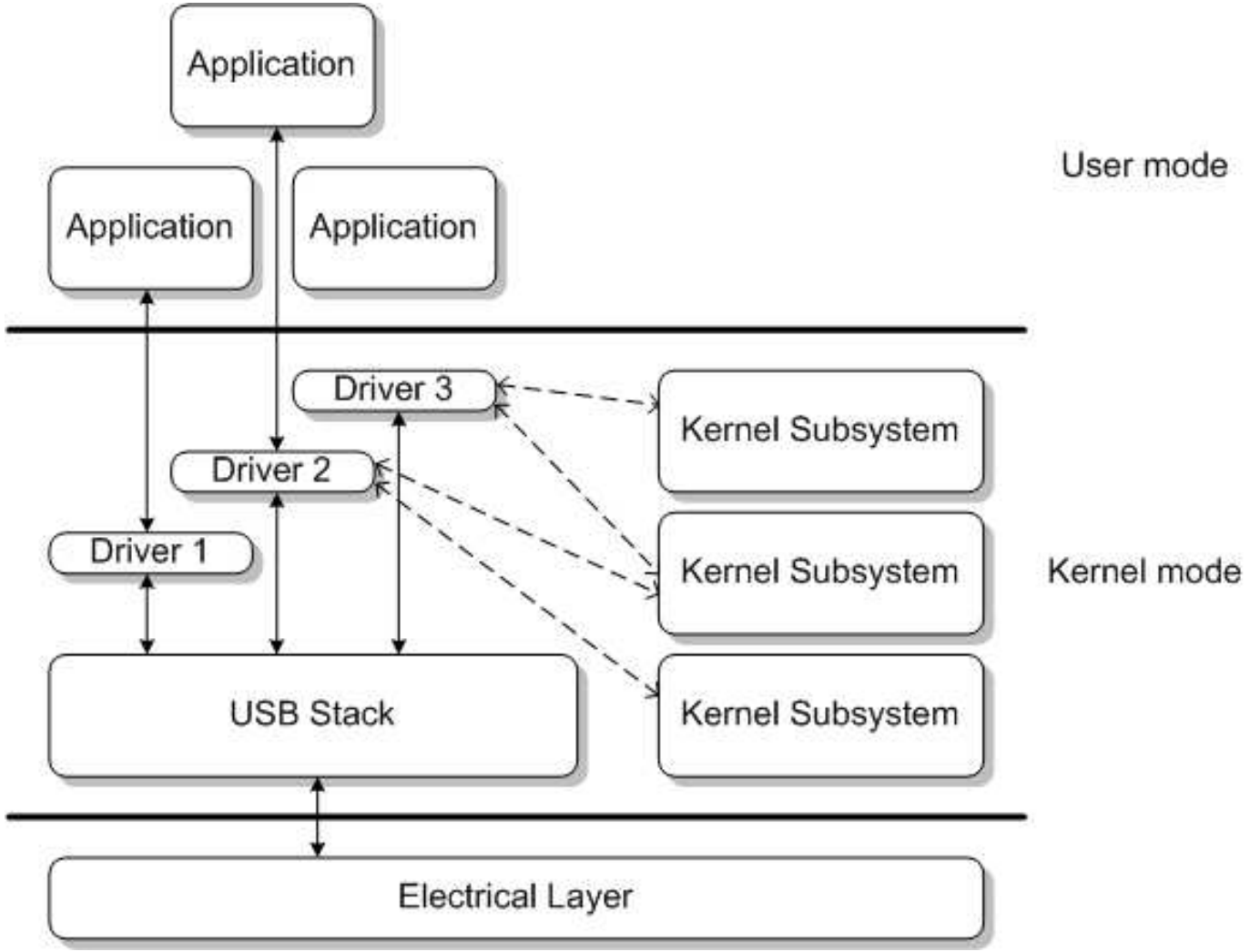
- Social engineering attacks
- Gain access to locked workstations
  - USB device enumeration starts even while workstation is locked!
- Digital voting pen
- Wireless USB (CWUSB)
- Unprotected USB ports…

Motivation

Attacks

- Data leakage
- AutoRun malware
  - U3 flash drives
- Malicious USB mouse/keyboard
- Bugs in USB stacks and device drivers

Attack surface



Vulnerability identification

- Hardware fuzzer
- Hardware-aided software fuzzer
- Emulated environments
- USB over IP

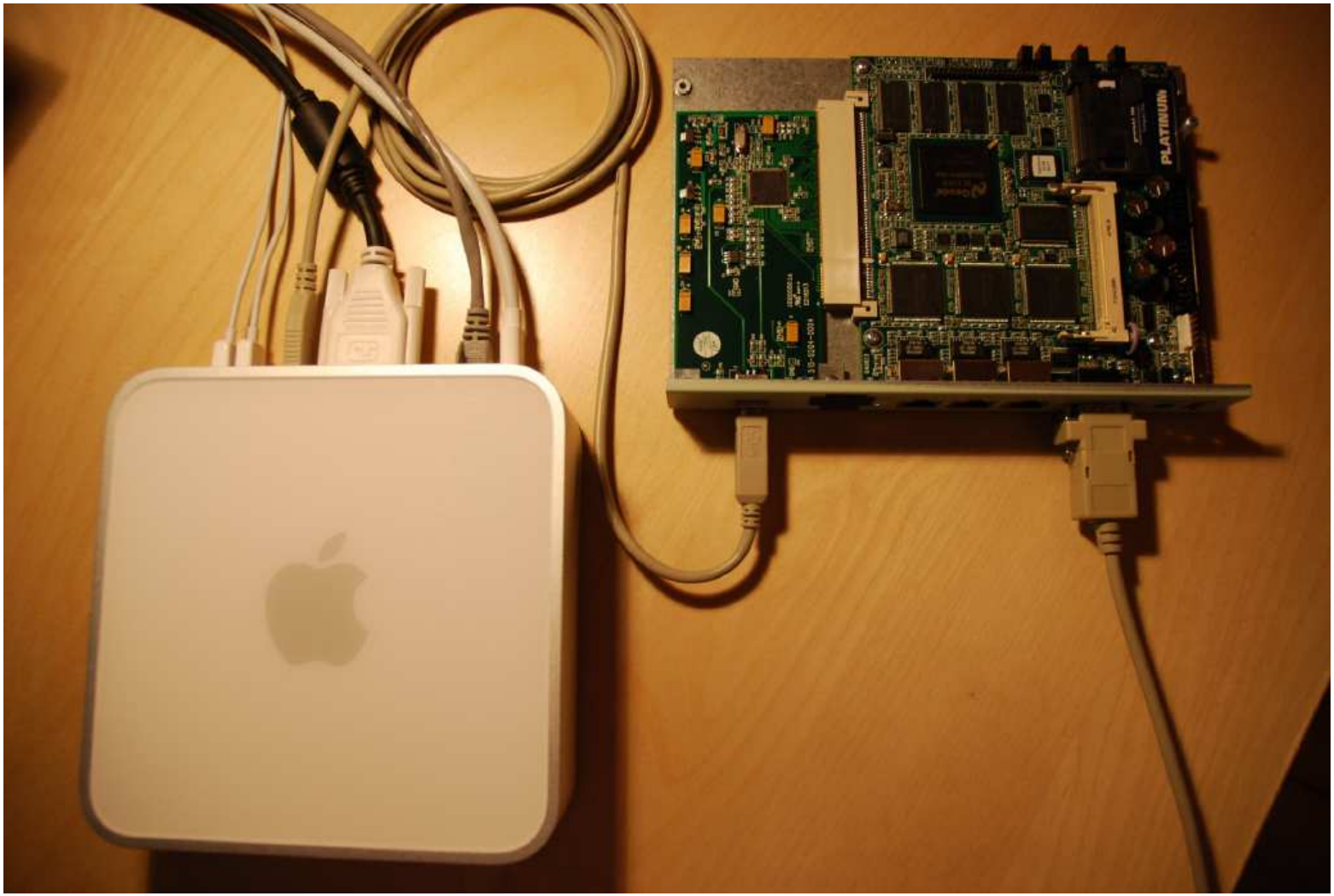
Hardware fuzzer

- Direct connection to target
  - No middle layer which could influence results
  - Embedded devices can be fuzzed
- Disadvantages
  - Fuzzing target might stop responding
    - Fuzzing EP0 on Windows XP (SP2)
  - Inflexible during development

Hardware-aided software solution

- Linux-USB Gadget API Framework
  - Peripheral controller drivers
  - Gadget drivers
    - Ethernet
    - Mass storage
    - Serial
    - MIDI
    - GadgetFS
- Peripheral controller
  - Netchip NET2280
  - PCI evaluation board

Hardware-aided software solution



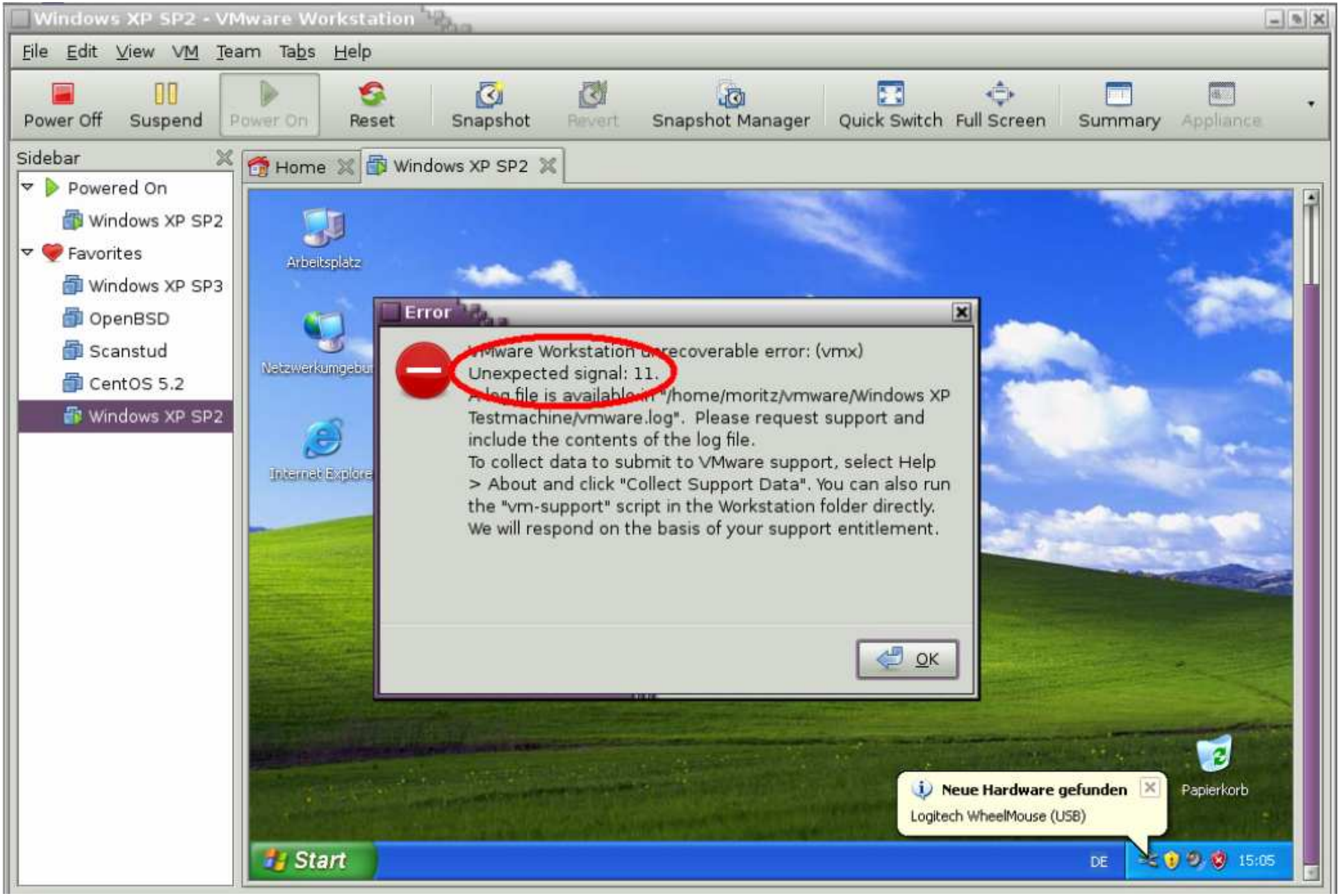
Hardware-aided software solution

- Linux-USB Gadget API Framework
  - Disadvantages
    - Encountered various dead locks on fuzzing host
    - Main focus doesn‘t seem to be fuzzing ;-)
    - Still bad target control
  - Can be used to build the final exploit
    - No firmware writing required

Emulated environments

- Good target monitoring capabilities
- Virtual machine snapshots
  - Quickly recover non-responding target
  - Easy way to reproduce crashes
- Use of high level languages
- (Interesting) side effects…

…bugs in virtualisation software



USB over IP

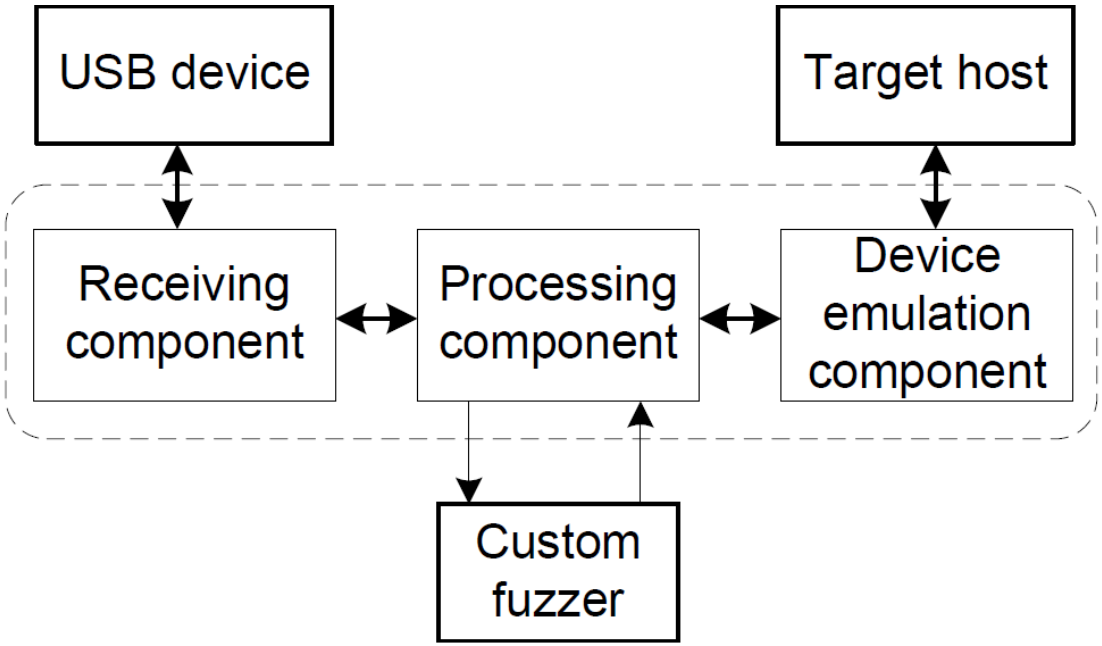
- Use of USB over IP bridge
- Easy access to raw USB packets
  - Existing fuzzers / fuzzing frameworks can be used
  - USB hardware sniffer
- All bridges we know of require software on the host :(
- Currently planing our own USB-IP-USB bridge
  - Work in progress

Fuzzing

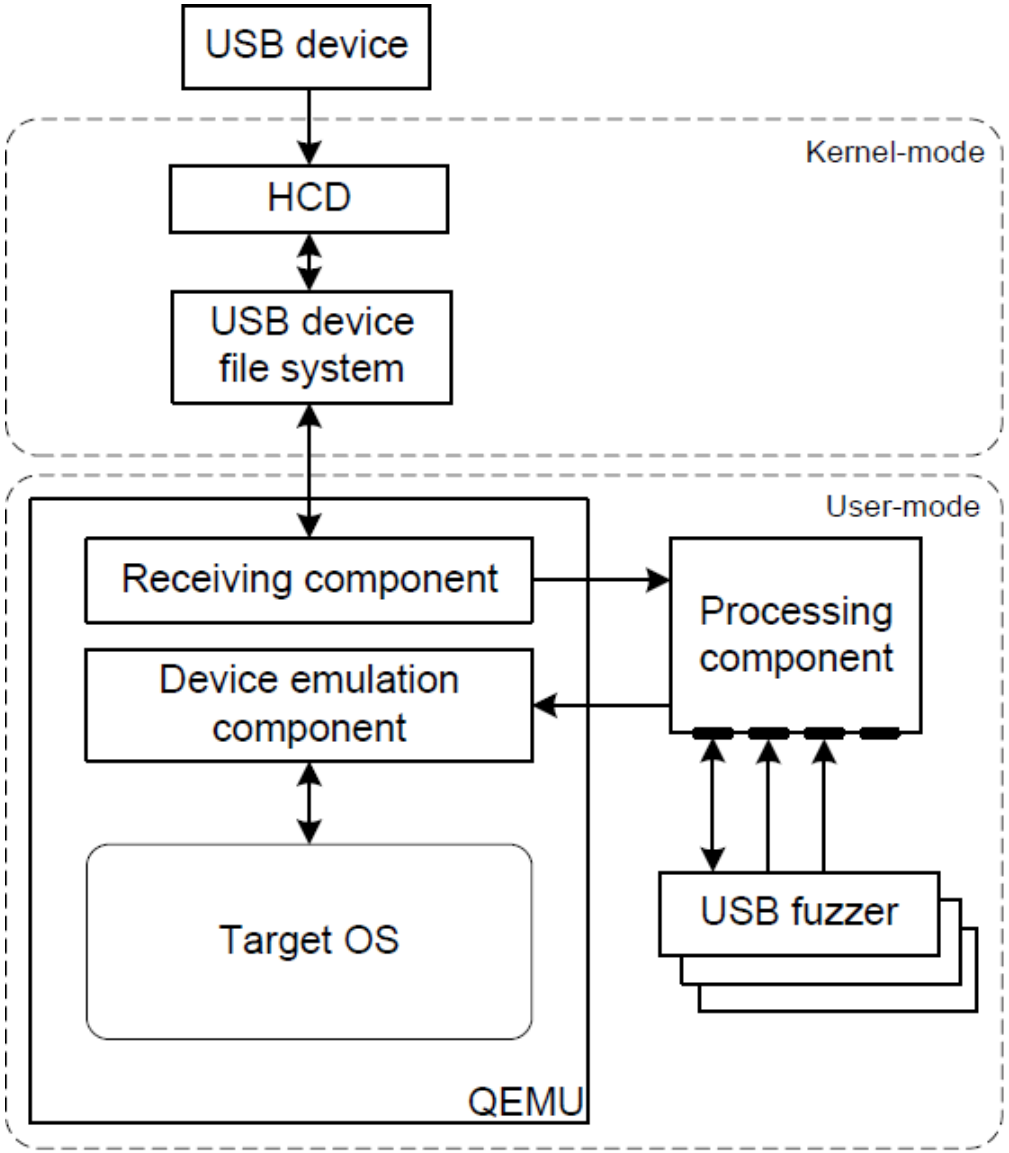
- Generation-based fuzzing
  - Time consuming
    - New device firmware
    - New Linux gadget driver
  - Good code coverage
- Mutation-based fuzzing
  - Good for first quick results
  - USB man-in-the-middle fuzzing

Fuzzing in emulated environments

- First approach
  - Implemented as a patch to Qemu
  - Complete fuzzing logic implemented in python
  - Easy development of custom fuzzers



Fuzzing in emulated environments



Fuzzing in emulated environments

- Disadvantages of first approach
  - Restricted to Qemu
  - Maintaining patches is no fun
- We can do better…

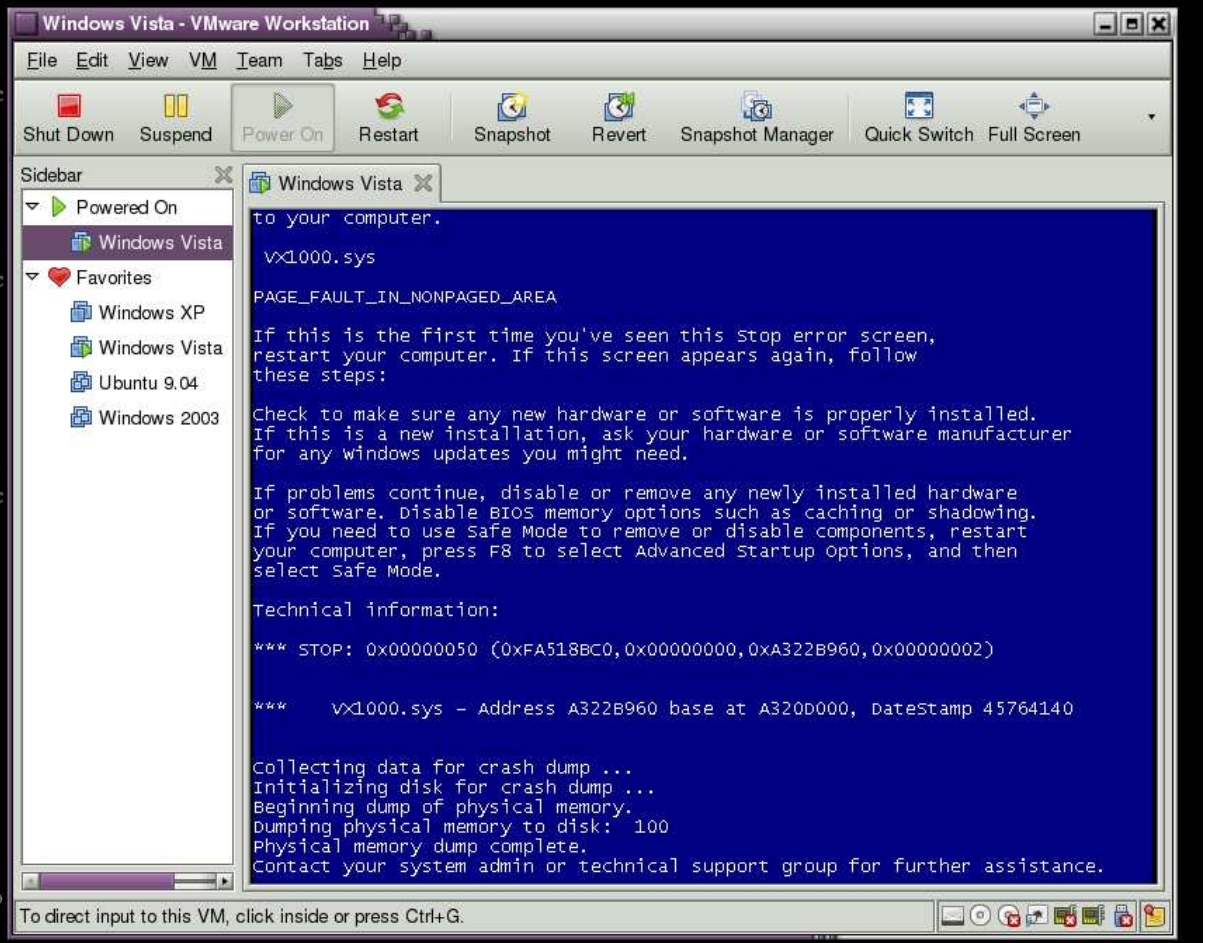
Universal man-in-the-middle fuzzer

- Based on USB device file system
- All USB communication passes through usbfs (/proc/bus/usb)
- Syscall interception (ptrace)
  - Fuzz data before it is passed to the virtualisation software
- Universal solution (Qemu, Vmware, …)
  - No modifications needed

Universal man-in-the-middle fuzzer

- Automic device attachment/detachment
  - Qemu
    - usb_add host:0123:4567
    - usb_del host:0123:4567
  - Vmware
    - No VIX API available (AFAIK)
    - Re-attachment can be triggered by starting/stopping the VM

```
      => IOCTL_USB_REAPURBNDELAY (urb.actual_length=9,urb.buffer_length=17)
[*] Fuzzing URB data in packet 8
    80 06 00 02 00 00 09 00 09 9d 7e cc 03 d2 00 80    ..........~.....
    97                                                .
      => IOCTL_USB_RESET
      => IOCTL_USB_REAPURBNDELAY
      => IOCTL_USB_SUBMITURB urb[type=2,
      => IOCTL_USB_REAPURBNDELAY (urb.ac
[*] Fuzzing URB data in packet 9
    c2 06 00 02 0c 00 09 dd 09 85 7e 01
    fa
      => IOCTL_USB_REAPURBNDELAY
      => IOCTL_USB_SUBMITURB urb[type=2,
      => IOCTL_USB_REAPURBNDELAY (urb.ac
[*] Received URB packet 10
      => IOCTL_USB_RESET
      => IOCTL_USB_REAPURBNDELAY
      => IOCTL_USB_SETCONFIG 1
      => IOCTL_USB_GETDRIVER
      => IOCTL_USB_SUBMITURB urb[type=2,
      => IOCTL_USB_REAPURBNDELAY (urb.ac
[*] Fuzzing URB data in packet 11
    80 06 01 03 09 ec 04 00 16 c2 c3 00
      => IOCTL_USB_REAPURBNDELAY
      => IOCTL_USB_REAPURBNDELAY
      => IOCTL_USB_RELEASEINTF 0
      => IOCTL_USB_IOCTL
      => IOCTL_USB_RELEASEINTF 1
      => IOCTL_USB_IOCTL
      => IOCTL_USB_RELEASEINTF 2
      => IOCTL_USB_IOCTL
[*] Closing usbfs descriptor 345
[*] Opening /proc/bus/usb/002/003 (345)
[*] Reading 9 bytes from usbfs descripto
    09 00 00 00 09 ec 04 00 16
      => IOCTL_USB_CLAIMINTF 0
      => IOCTL_USB_CLAIMINTF 1
      => IOCTL_USB_CLAIMINTF 2
[*] Process 4449 detached
[*] Check if guest is still alive
[*] Guest does not respond... We crashed it :)
moritz@kindergarten ~/share/projects/usbfsmitm/utils $
```



Crash analysis

- Reproducing a triggered crash
  - Re-apply the same modifications
    - Based on packet number received from host
    - Works best for crashes in enum phase
    - Doesn‘t really work for crashes after hundreds of packets beeing exchanged…
  - Replaying the whole communication
    - Works with easy protocols (e.g. HID)
    - Breaks with mass storage devices

Evaluation

Apple iPod Shuffle

- Connected to Windows XP (SP2)
- Double-free of kernel pool memory in usbstor.sys

```
Probably caused by : USBSTOR.SYS ( USBSTOR+dfb )

Followup: MachineOwner
---------

0: kd> !analyze -v
*******************************************************************************
*                                                                             *
*                        Bugcheck Analysis                                    *
*                                                                             *
*******************************************************************************

BAD_POOL_CALLER (c2)
The current thread is making a bad pool request.  Typically this is at a bad IRQL
Arguments:
Arg1: 00000007, Attempt to free pool which was already freed
Arg2: 00000cd4, (reserved)
Arg3: 940082a5, Memory contents of the pool block
Arg4: 86e70008, Address of the block of pool being deallocated
```

- Kernel pool memory corruption in disk.sys
  - While reading the partition table
- Crash in iTunes iPodService.exe
  - NULL pointer deref

Microsoft LifeCam VX-1000

- Kernel oops on Ubuntu 9.04
  - NULL pointer deref in SN9C102 driver
- NULL pointer deref on Windows Vista (SP2)
  - Inside vx1000.sys driver

Various mass storage devices

- NULL pointer deref on Windows Vista (SP2)
  - Inside the usbhub.sys driver
- Function pointer set to NULL
  - call 0x00000000
  - Not reproduceable using current approach :(

Conclusion

- Fuzzing in emulated environment seems like the right approach
- Reproduction of crashes can be hard sometimes
- Potential for more vulns to be discovered
  - More intelligent fuzzing
  - 3rd party drivers?

Questions?

- Fuzzer will be published when ready…
  - Drop me a line, if you want to be notified (moritz@jodeit.org)