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Implementing an USB Host Driver Fuzzer

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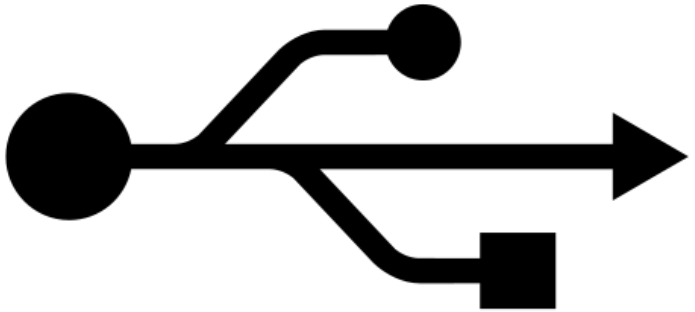

Disclaimer

- This is an implementation talk.
- We (still) haven't finished testing.
- No exploits were given that day.

Agenda

- USB Basics
- Facedancer Hardware
- dizzy Fuzzing Toolkit
- dizzy USB Additions
- Practical USB Fuzzing
- Results

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USB BASICS

USB History

- Development of the first specification started in 1994.

- USB version 1.0 released in 1996
- USB version 1.1 released in 1998
- USB version 2.0 released in 2001
- USB version 3.0 released in 2008

USB History

- Developed by a group of companies:

  Compaq, DEC, IBM, Intel, Microsoft, NEC, and Nortel

- Standardized by the USB Implementers Forum (USBIF)

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USB Versions

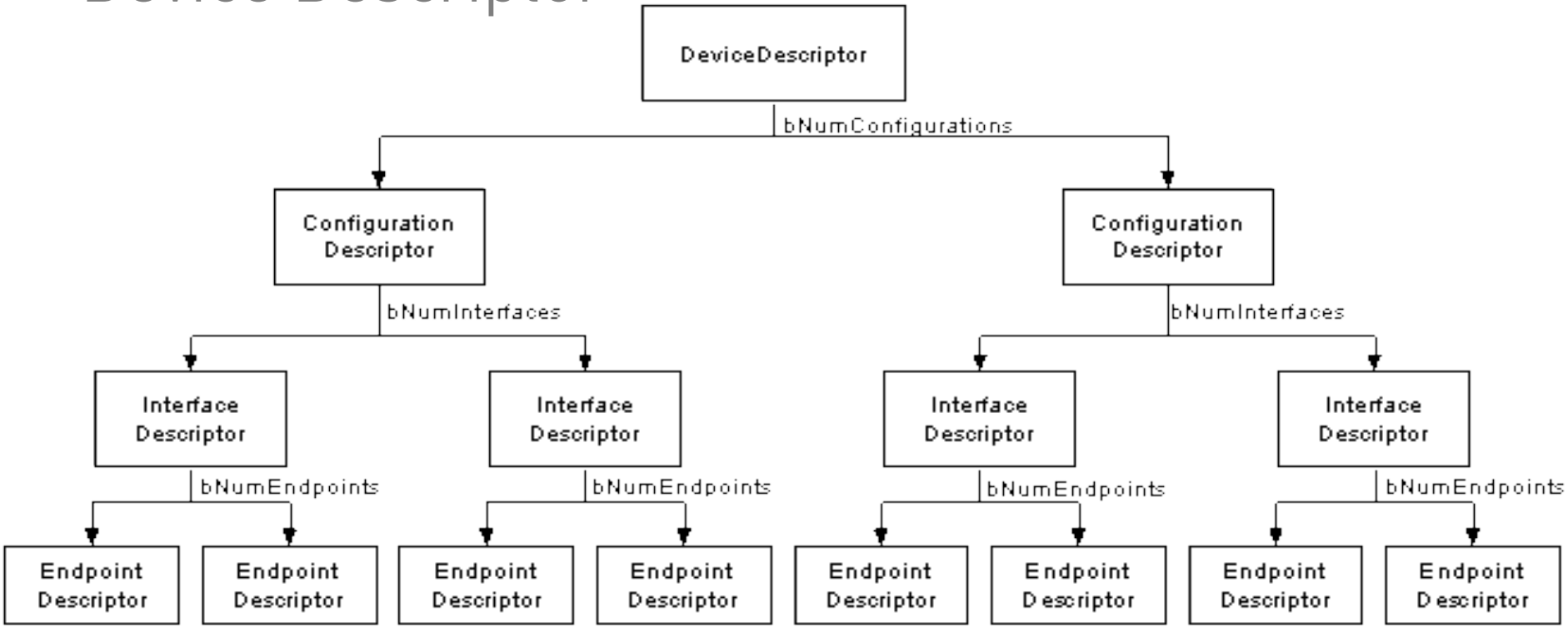
- Three different versions defined:
  - USB 1.1 with 1.5Mb/s
  - USB 2.0 with 480Mb/s
  - USB 3.0 with 4Gb/s

- Only USB 1.1 and USB 2.0 are addressed with this talk.

USB Descriptor

- Device descriptor identifies the USB device.
- Followed by more descriptors:
  - Configuration Descriptor
  - Interface Descriptor
  - Endpoint Descriptor
  - String Descriptor
- Signals the Host which driver to use.

Device Descriptor



USB Enumeration

- Device descriptor is requested.
- Selected configuration descriptor is requested.
- String descriptors referenced in device and configuration descriptor are requested (Manufacturer, Product, eg.).

USB Enumeration

1	0.00000	host	1.0	USB	36	GET DESCRIPTOR Request DEVICE
2	0.00000	1.0	host	USB	46	GET DESCRIPTOR Response DEVICE
3	0.00000	host	1.0	USB	36	GET DESCRIPTOR Request CONFIGURATION
4	0.00000	1.0	host	USB	37	GET DESCRIPTOR Response CONFIGURATION
5	0.00000	host	1.0	USB	36	GET DESCRIPTOR Request CONFIGURATION
6	0.00000	1.0	host	USB	163	GET DESCRIPTOR Response CONFIGURATION
7	0.00000	host	1.0	USB	36	GET DESCRIPTOR Request STRING
8	0.00000	1.0	host	USB	66	GET DESCRIPTOR Response STRING
9	0.01560	host	1.0	USB	36	GET DESCRIPTOR Request STRING
10	0.01560	1.0	host	USB	50	GET DESCRIPTOR Response STRING
11	15.6624	host	1.0	USB	36	GET DESCRIPTOR Request STRING
12	15.6624	1.0	host	USB	66	GET DESCRIPTOR Response STRING

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Well, how do matters stand with security?

USB Vulnerabilities

- Windows USB Descriptor Vulnerability
  - CVE-2013-1285
  - CVE-2013-1286
  - CVE-2013-1287
- Linux Kernel caiaq USB Drivers Buffer Overflow
  - CVE-2011-0712

USB Vulnerabilities (cont.)

- Solaris USB configuration descriptor kernel stack overflow
  - CVE-2011-2295
- usbmuxd 1.0.7 Buffer Overflow Vulnerability
  - CVE-2012-0065

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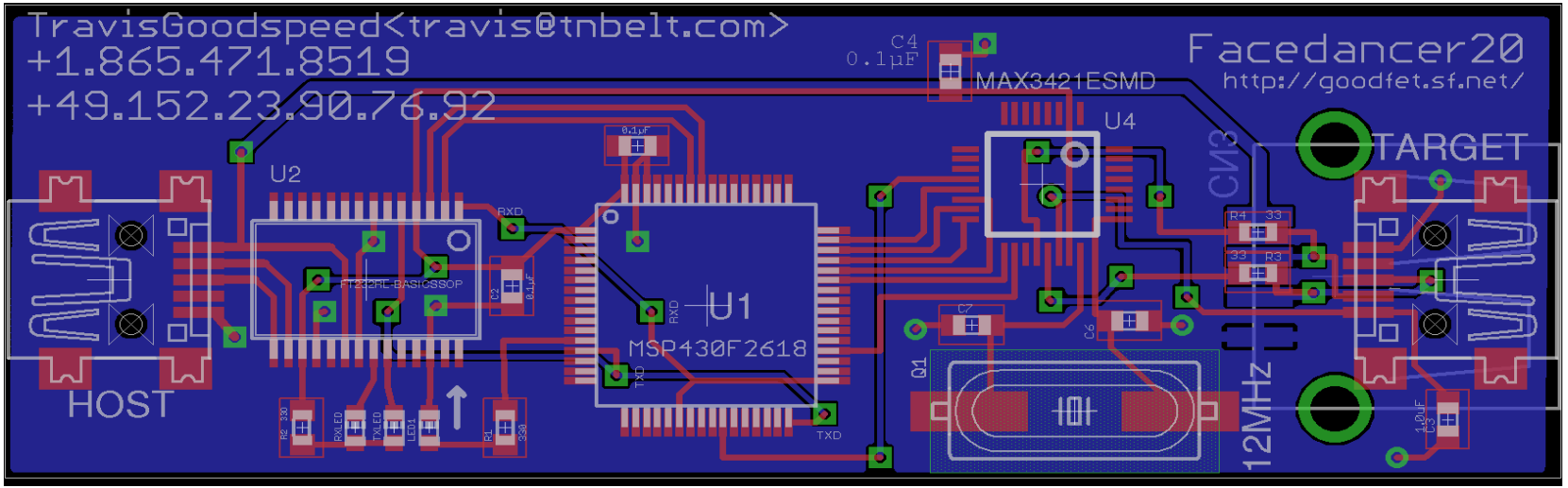
FACEDANCER HARDWARE

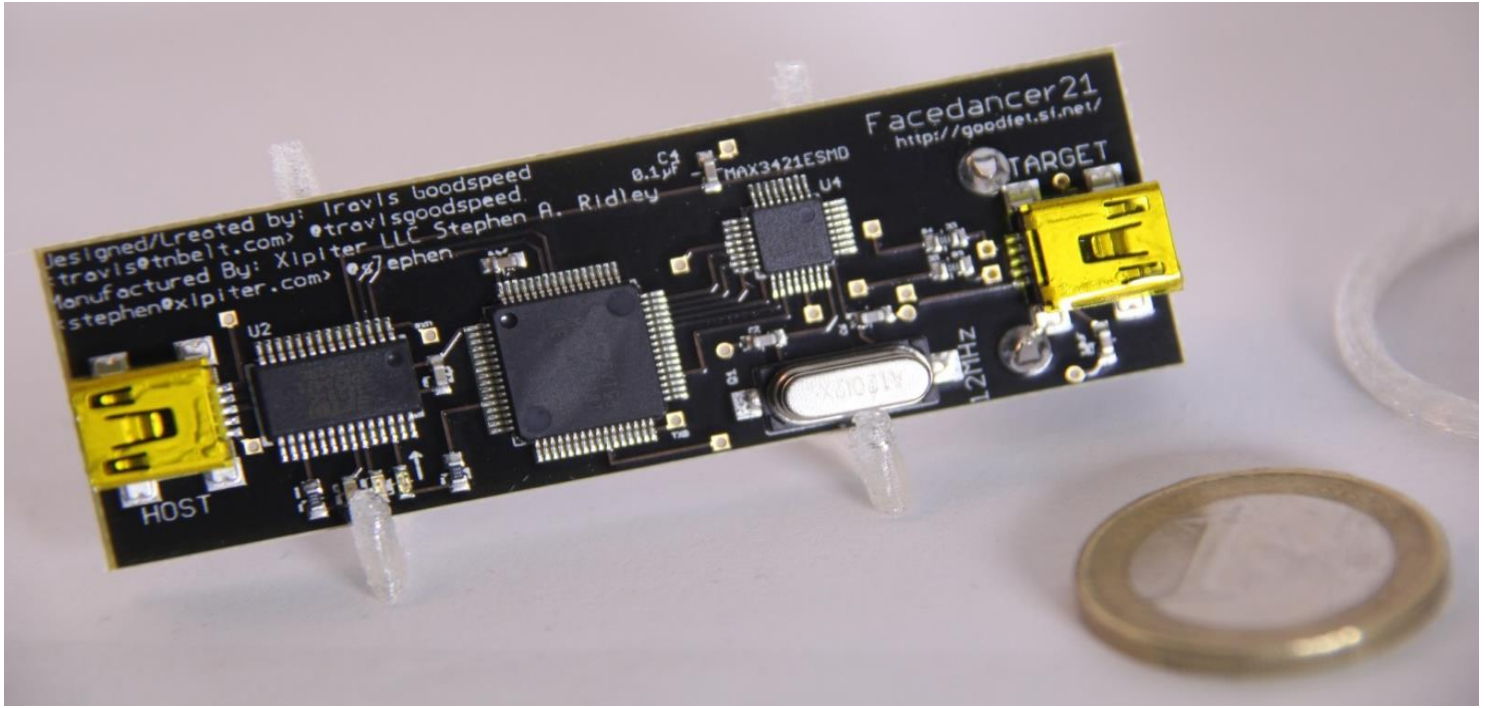
Facedancer

- External USB testing hardware.
- Allows to send raw USB PDUs.
- Consists of:
  - FT232R USB to serial UART (Host connect)
  - MSP430F2618 16bit µc
  - MAX3421E USB controller (Target connect)

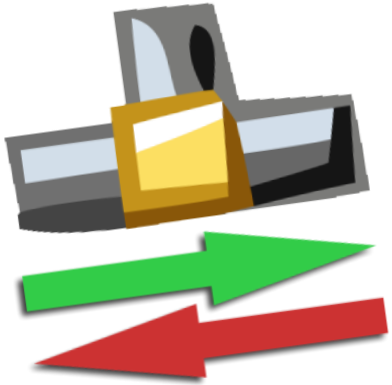
Facedancer


TravisGoodspeed<travis@tnbelt.com>
+1.865.471.8519
+49.152.23.90.76.92
C4
0.1µF
MAX3421ESMD
Facedancer20
http://goodfet.sf.net/
U4
TARGET
U2
HOST
FT232RL-BASICSSOP
RXD
U1
MSP430F2618
TXD
Q1
12MHz
R4 33
R3 33
C7
C6
C3 4.0UF

Facedancer

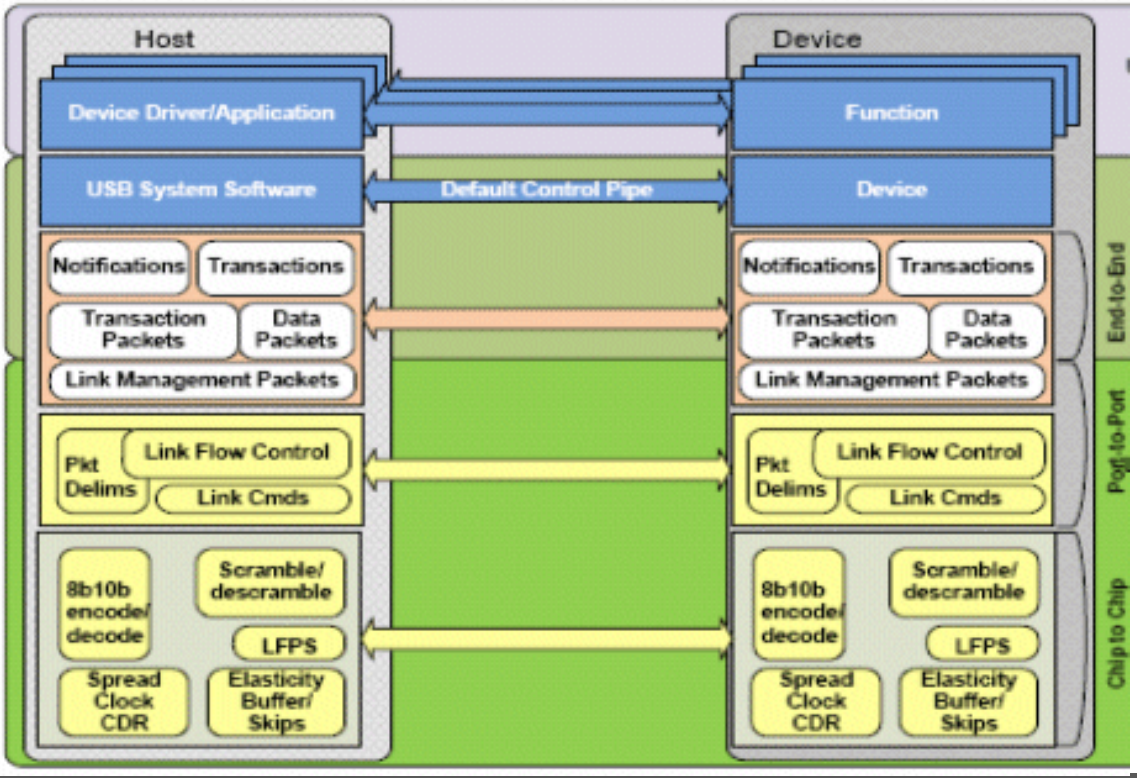

Designed/Created by: Travis Goodspeed
<travis@tnbelt.com> @travisgoodspeed
Manufactured By: Xipiter LLC Stephen A. Ridley
<stephen@xipiter.com> @sjephen
0.1µF
MAX3421ESMD
U4
U2
Facedancer21
http://goodfet.sf.net/
TARGET
HOST
12MHz

Facedancer



- Controlled from the host PC, using a python library.
- Implements basic USB protocol layer as well.

http://goodfet.sourceforge.net/hardware/facedancer21/


Host
Device
Device Driver/Application
Function
USB System Software
Default Control Pipe
Device
Notifications
Transactions
Transaction Packets
Data Packets
Link Management Packets
Pkt Delims
Link Flow Control
Link Cmds
8b10b encode/ decode
Scramble/ descramble
LFPS
Spread Clock CDR
Elasticity Buffer/ Skips
End-to-End
Port-to-Port
Chip to Chip

DIZZY FUZZING TOOLKIT

Fuzzing

Definition

“ Fuzzing or Fuzz Testing is a software negative testing technique. It uses the fault injection approach, which basically injects wrong data into the tested program. Fuzzing can be used to test parser of any kind like protocol parser, file format parser, language parser, etc. “

B. Miller, L. Fredriksen, and B. So.
An empirical study of the reliability of unix utilities.

Dizzy

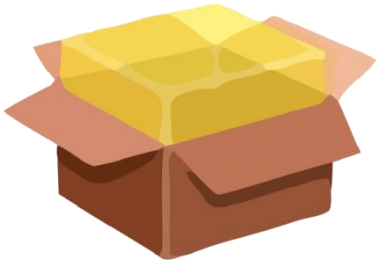
- Python based fuzzing toolkit.
- First release in 2011.

- Simple packet description syntax.
- Does state less and state full fuzzing.

http://c0decafe.de/tools/dizzy-0.8.2.tar.bz2

Dizzy packet description

- Defined in Python syntax.



```
name = "empty"

objects = []
functions = []
```

Dizzy packet description

- The *object* array contains the fields of the packet.
- The *functions* array contains operations performed on the packet before its sent to the target.

Dizzy packet description

- Available objects are:
  - field, list, rand, link, fill and padding.
- Available functions are:
  - time, time_no_fracs, length, lambda_length, csum, lambda_csum
- See dizzy README for details.

.dizz file example

```
name = "example"

objects = [
    field("type", 8, "\x00", "full"),
    field("length", 8, "\x06", "full"),
    field("value", None, "fuzz", "std"),
]
functions = [
    length("length", "type", "value"),
]
```

arp.dizz

```
name = "arp"

objects = [
    field("hw_type", 16, "\x00\x01", "full"),
    field("proto_type", 16, "\x08\x00", "full"),
    field("hw_size", 8, "\x06", "full"),
    field("proto_size", 8, "\x04", "full"),
    field("opcode", 16, "\x00\x01", "full"),
    field("mac_src", 48, "\x01\x02\x03\x04\x05\x06", "none"),
    field("ip_src", 32, "\xc0\xa8\x5f\xb5", "none"),
    field("mac_dst", 48, "\x00\x00\x00\x00\x00\x00", "none"),
    field("ip_dst", 32, "\xc0\xa8\x5f\xb6", "none"),
]
functions = []
```

more objects

```
objects = [
    rand("nonce", 8*16),
    list("list1", "default", "~/list1.txt"),
    field("val1", None, "fuzz", "std"),
    link("nonce_again", "nonce"),
]
```

padding example

```
field("val", 8, "\x01", "none"),
field("val2", None, "\x02", "std"),
padding("pad", "val", "val2", 8*8, "\x00"),
```

Interaction concept

- State full fuzzing is represented as a series of packets (.dizz files).
- Packets are sent out in order and an answer is read between.
- Parts of an answer can be extracted and used in further transmissions.

Dizzy interaction description

```
name = "testact"

objects = [
    dizz("first", "dizzes/first.dizz"),
    dizz("second", "dizzes/second.dizz"),
]

functions = []
```

Dizzy interaction description

```
name = "act1"

objects = [
    dizz("first", "dizzes/first.dizz"),
    dizz("auth", "dizzes/auth.dizz"),
    dizz("command", "dizzes/command.dizz"),
]

functions = [
    copy(2, "auth", 0x10, 0x20),
]
```

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DIZZY USB ADDITIONS

Dizzy Output Type

dizzy.py

- Two new output types:
  - usb-desc for USB descriptor fuzzing.
  - usb-endp for USB endpoint fuzzing.
- Added in *dizz_session* class.

Dizzy – Facedancer glue

usb.py

- Implements the USBDevice and USBInterface classes required by the Facedancer USB lib.
- *dizzUSB* class is used to start/stop/control the USB thread and descriptor payload.

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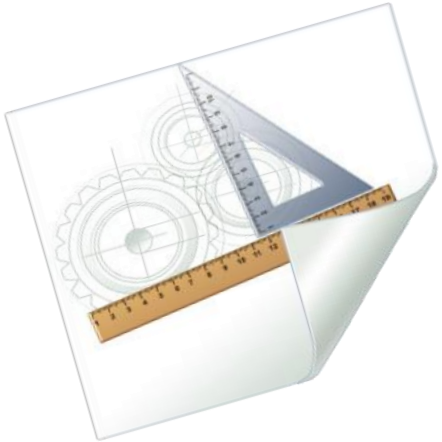
PRACTICAL USB FUZZING

USB fuzzing



- There are different targets on USB:
  - Device Descriptor
  - Configuration Descriptor
  - Endpoints

USB fuzzing

- Descriptor fuzzing targets the host OS USB stack.
- Endpoint fuzzing targets the USB device driver (either from the OS vendor or third party).

Were to get the descriptors

- We are setting up an USB device/configuration descriptor collection at **usbdescriptors.com**.
- You can contribute to the collection by submitting:
  - The output of lsusb –v
  - The raw descriptors

What you need

- Hardware:
  - Host PC
  - Facedancer Board
  - Two USB cables
  - Target PC

What you need

- Software:
  - Python and dizzy on the host.
  - USB device file.
  - Dizzy packet description file.

Step I

- Create the USB descriptor file from the device you want to emulate:

```
lsusb -s 1:1 -v | perl parse_lsusb.pl > DEVICENAME.usb
```

Step II

- Create / Modify your *.dizz* file:

```
vim dizzes/usb/configuration_descriptor.dizz
```

Step III

- Attach the Facedancer board to the host PC and to the target PC.

Step IV

- Start dizzy:

```
dizzy.py -o usb-desc -d DEVICENAME.usb -e CD
configuration_descriptor.dizz
```

Step V

- Monitor USB traffic via wireshark.
  - On Windows USBPcap is needed: http://desowin.org/usbpcap/

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RESULTS

Results

- We didn't perform wide scale fuzzing.
- Still, some unexpected behavior appeared during functional testing of the code (;

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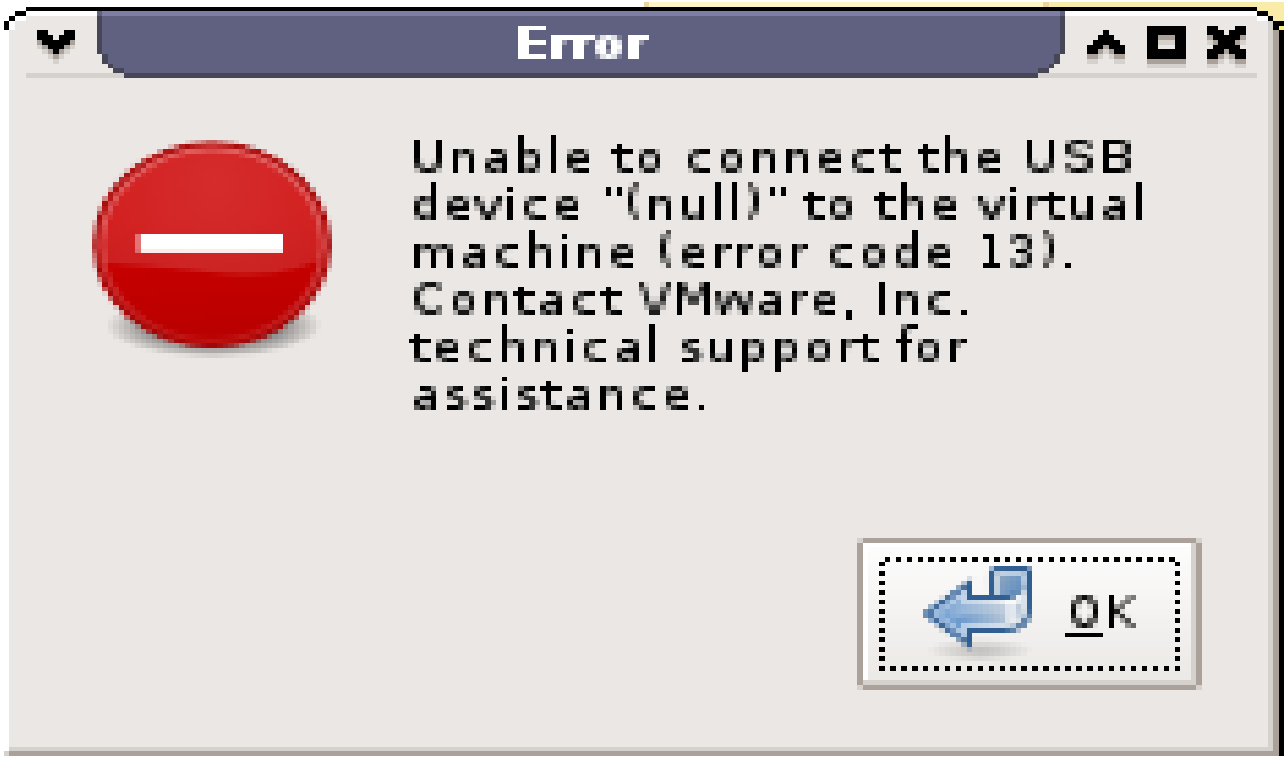
Results

- Host (USB Stack) crash
  - Win7 (x64), Linux 3.10 (x64)
- Software crashes on target:
  - Skype, VMware, etc...

Results


Error
Unable to connect the USB device "(null)" to the virtual machine (error code 13). Contact VMware, Inc. technical support for assistance.
OK

Results

- We didn't investigate those crashes, as getting the implementation done was the main prio.
- We will investigate them in the future, no worries (;

Conclusions

- In the past expensive hardware was needed to perform USB testing.
- With low cost hardware available more people can test USB implementations.
- Expect a bunch of new USB vulnerabilities to show up.

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There's never enough time...

THANK YOU...

...for yours!


Q&A
You have
Questions
We have
Answers