# Fuzzing the USB in your devices

or “How to root your USB-stick”

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# whoami

- Technical IT-sec background


- Currently in Information Assurance
  - When you're sure it does what it's specified to ...

    … how sure are you “it doesn't do anything else”?

# Motivation

*“Security will not get better until tools for practical exploration of the attack surface are made available.”*

Joshua Wright – willhackforsushi.com

# Motivation

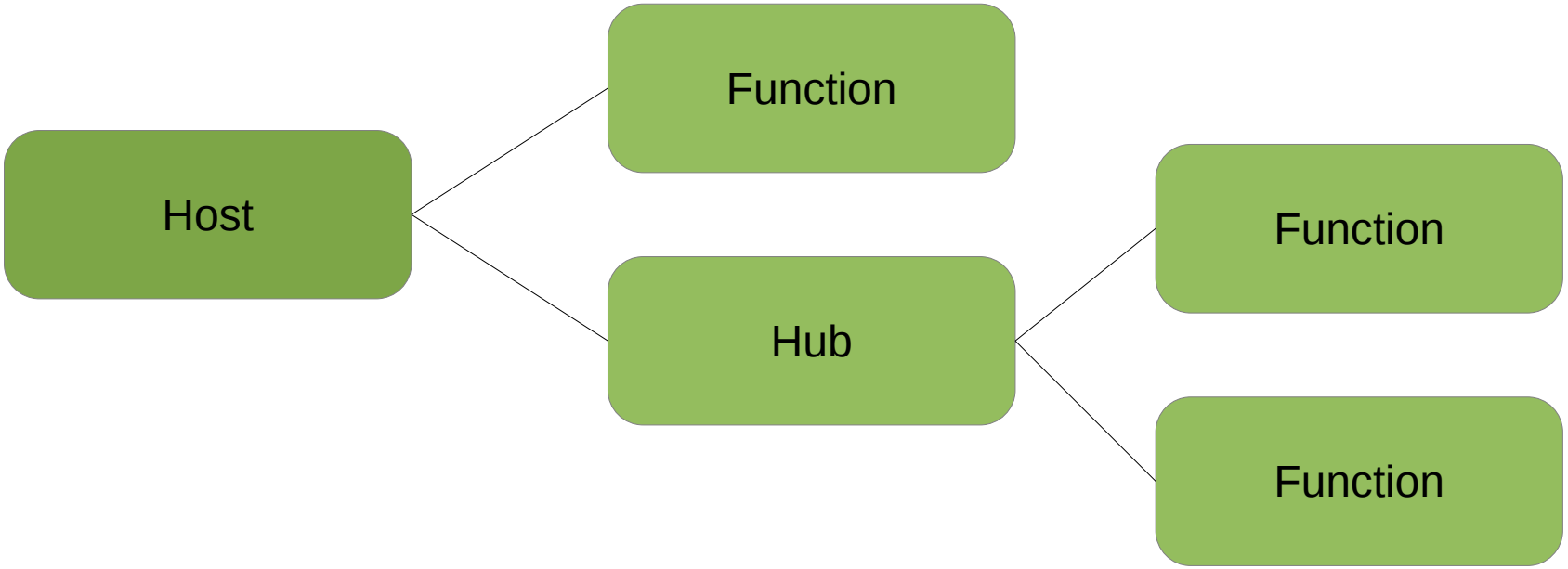

- Explore USB attack surface

  … of devices!

  - Mobile Devices
  - “Secure” USB Drives
  - “PinPad” Card Readers
  - and more...

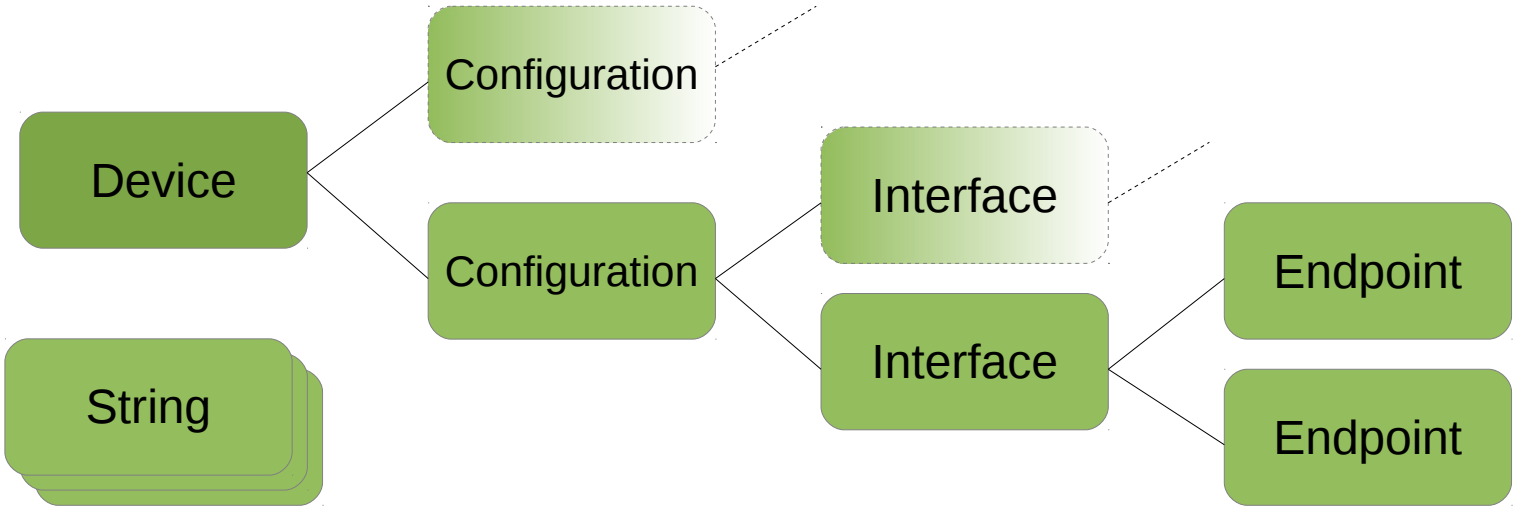

# Intro to USB

- Host-controlled “bus”
  - Initiator / Responder - “Host” / “Function”
  - IN / OUT



# Intro to USB

- Devices carry “descriptors”
  - Hosts “enumerate” them
  - Configurations, Interfaces, Endpoints



# Intro to USB

- Device Classes
  - Indicated in Device descriptor …

    … or in Interface descriptors

| Device Classes | |
|---|---|
| 01h | Audio |
| 02h | CDC |
| 03h | HID |
| 05h | Phyical |
| ... | ... |

| CDC Sub Classes | |
|---|---|
| 01h | Direct Line |
| 02h | Abstract |
| 03h | Telephone |
| 04h | Multi-Channel |
| ... | ... |

| CDC Interface Protocols | |
|---|---|
| 01h | ITU-T V.250 |
| 02h | PCCA-101 |
| 03h | PCCA-101 + Annex O |
| 04h | GSM 7.07 |
| ... | ... |

# Intro to USB

- Transfer types
  - Control
  - Bulk
  - “Interrupt”
  - Isochronous

# Intro to USB

- Transfer types
  - Control
    - Endpoint 0 (EP0), “default” endpoint

| Field | Size | Description |
|---|---|---|
| bmRequestType | 8 bits | Direction, Type, Recipient |
| bRequest | 8 bits | Specific request value |
| wValue | 16 bits | Request specific parameter |
| wIndex | 16 bits | Request specific parameter |
| wLength | 16 bits | Bytes to transfer (if any) |

| Standard Device Requests | |
|---|---|
| 00h | GET_STATUS |
| 01h | CLEAR_FEATURE |
| 03h | SET_FEATURE |
| 05h | SET_ADDRESS |
| 06h | GET_DESCRIPTOR |
| 07h | SET_DESCRIPTOR |
| ... | ... |

# Intro to USB

- Transfer types
  - Bulk
    - Asynchronous (“bursty”)
    - Use available bandwidh (“laggy”)
    - 2 endpoints (IN/OUT) make a “Pipe”

# Intro to USB

- Transfer types
  - Control
  - Bulk
  - “Interrupt”
  - Isochronous

# Fuzzing USB Hosts

- Darrin Barrall, David Dewey (2005)
- Moritz Jodeit, Martin Johns  (2009)
- Rafael Dominguez Vega (2009)
- Tobias Müller (2010)
- Travis Goodspeed's Facedancer

# Fuzzing USB Devices

- Prior work
  - Pod2g, posixninja in 2010
  - Andy Davis @ BHUSA 2011
- Facedancer20
- libusb!

# Fuzzing with libusb

- libusb
  - Library for developing userland drivers
  - Works on Linux, Windows, MacOS
  - Nice introduction by Peter Stuge @ 27C3
- Limitations
  - Not expecting some “invalid” input
    - Tends to crash instead of error out
  - Linux kernel performs sanity checks

# Building a simple fuzzer

- PyUSB – python interface to libusb
- Let's target Control Transfers
- Simple iterative loops around ctrl_transfer()

# Demo Time!

# Building a simple fuzzer

```python
#!/usr/bin/env python

import sys
import usb.core

def TestCtrlTransfer(device, rt, r, v, i):
    for size in (2, 10, 100, 1000, 4000):
        try:
            res = device.ctrl_transfer(rt&0x80, r, v, i, bytearray().fromhex(u'ff'*size))
        except usb.core.USBError as e:
            if (e.backend_error_code != -9): # ignore LIBUSB_ERROR_PIPE
                print('OUT %0.2x %0.2x %0.4x %0.4x err(%i) len(%u)' % (rt, r, v, i, e.backend_error_code, size))
        try:
            res = device.ctrl_transfer(rt|0x80, r, v, i, size)
        except usb.core.USBError as e:
            if (e.backend_error_code != -9): # ignore LIBUSB_ERROR_PIPE
                print('IN  %0.2x %0.2x %0.4x %0.4x err(%i) len(%u)' % (rt, r, v, i, e.backend_error_code, size))

arg = sys.argv[1].split(':')
device = usb.core.find(idVendor=int(arg[0],16), idProduct=int(arg[1],16))

for t in range(0, 0x04): # bmRequestType.Type
    for r in range(0, 0x04): # bmRequestType.Recipient
        for q in range(0, 0x100): # bRequest
           for v in range(0, 0x1000): # wValue
                for i in range(0, 0x1000): # wIndex
                    TestCtrlTransfer(device, r|(t<<4), q, v, i)
```

# Building a simple fuzzer

- Adding some target control
  - Monitoring
    - Simple: ctrl_transfer(GET_STATUS)
    - Better: use a class-specific request
  - Resuming
    - Simple: device.reset() to recover device
    - Better: use external hub for power control

# Building a simple fuzzer

```
def is_alive(device):

    res = ""
    try:
        res = device.ctrl_transfer(0x80, 0, 0, 0, 2)
    except usb.core.USBError as e:

        if e.backend_error_code == -4: # LIBUSB_ERROR_NO_DEVICE
            print "Device not found!"
            sys.exit()

        if e.backend_error_code == -3: # LIBUSB_ERROR_ACCESS
            print "Access denied to device!"
            sys.exit()

        print "GET_STATUS returned error %i" % e.backend_error_code
        return False

    if len(res) != 2:
        print "GET_STATUS returned %u bytes: %s" % (len(res), binascii.hexlify(res))
        return False

    return True
```

# Building a simple fuzzer

```
def is_alive(device):

    try:
        device.write(bytearray().fromhex(u'55534243E019EA8500020000800000A2800000000000000010000000000000'))
    except usb.core.USBError as e:
        if e.backend_error_code == -4: # LIBUSB_ERROR_NO_DEVICE
            raise Exception('Function check failed: device not present!')
        elif e.backend_error_code == -6: #LIBUSB_ERROR_BUSY
            raise Exception('Function check failed: function is busy!')
        else:
            print "Function check failed: usb error %i" % e.backend_error_code
            return False

    try:
        res = ep_in.read(readlen)
    except usb.core.USBError as e:
        print "Function check failed: usb error %i" % e.backend_error_code
        return False

    if len(res) != 0x206:
        print "Function check returned %u bytes: %s" % (len(res), binascii.hexlify(res))
        return False

    return True
```

# Extending our reach

- Reach more complex code!
- Device Classes
  - Audio, CDC, HID, Image, Printer, Mass Storage, Hub, Smart Card, Video, Wireless Controller, DFU, Vendor Specific

http://www.usb.org/developers/defined_class/

http://www.usb.org/developers/devclass_docs/

# First attempt: Peach

- Very easy to add pyUSB “Publisher”
- Data modelling and test cases in XML
  - Very cumbersome to work with state
- Target control framwork: “Agents”
  - Not built for controlling local devices

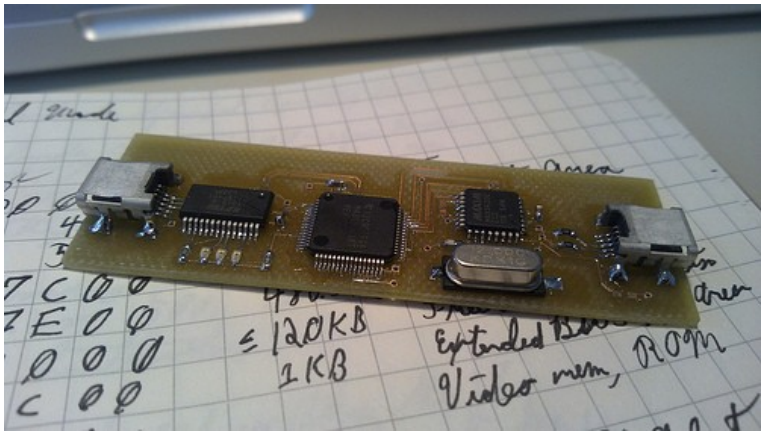
# Second attempt: Scapy

- Scapy for data modelling
  - Abstracts data as “Layers” of “Packets”
  - Keeps everything in python!
  - Easy use of python code for “fixups”
- Easy reuse of code with Facedancer!
  - Travis Goodspeed, Ryan Speers
  - http://rmspeers.com/archives/252

# Demo Time!

# Helpful tools

- Total Phase Beagle USB
  - http://www.totalphase.com/protocols/usb/
- Travis Goodspeed's Facedancer
  - http://goodfet.sourceforge.net/

# Get the code

https://github.com/ollseg/usb-device-fuzzing

Will gladly accept pull requests...

# Examples of bugs found

# First bug found

- Atmel AT91SAM7 example USB code
  - Prevalent in devices using Atmel MCUs
- Off-by-one on string descriptor index
  - ctrl_transfer(0x80, 6, 3<<8 | i+1, 0, len)

```
/* ----------------------------------------------------
 *         ATMEL Microcontroller Software Support
 * ----------------------------------------------------
 * Copyright (c) 2008, Atmel Corporation
<snip>
static void GetDescriptor(
    const USBDDriver *pDriver,
    unsigned char type,
    unsigned char index,
    unsigned int length)
{
<snip>
    // Check the descriptor type
    switch (type) {
<snip>
        case USBGenericDescriptor_STRING:
            TRACE_INFO_WP("Str%d ", index);

            // Check if descriptor exists
            if (index > numStrings) {

                USBD_Stall(0);
            }
            else {

                pString = pStrings[index];
```

# Bugs in Nokia phones

- Random crashes while fuzzing
- Seemed related to “large” Control Transfers
- Looks like a stack buffer overwrite
- Threw together a 5-line python PoC

DEMO TIME!

# Bugs in USB-Sticks

SLIDE REDACTED

# Exploiting a USB-stick

SLIDE REDACTED

# Future work

- Support more protocols
- Reaching deeper into targets
- https://wiki.mozilla.org/WebUSB/
- Travis Goodspeed's Facedancer!

# Thank You!

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https://github.com/ollseg/usb-device-fuzzing

Please remember to fill out the feedback forms!