USB for All!!1

You should be looking at USB.

Yes, you.

Introduction

- Who We Are
  - Jesse Michael
  - Mickey Shkatov
- What We Do
  - Break things
  - Cry about the current level of security research focused on USB

DISCLAIMER: The views and opinions expressed in this presentation are those of the authors and not their employer.

Purpose of this talk

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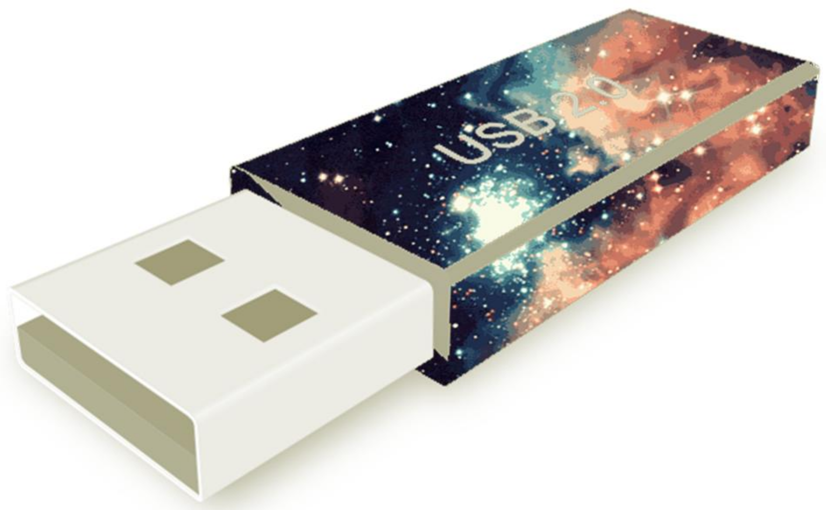
- We want to demonstrate to attendees how easy it is to get started at performing their own USB security research and help them understand why they should undertake this challenge.

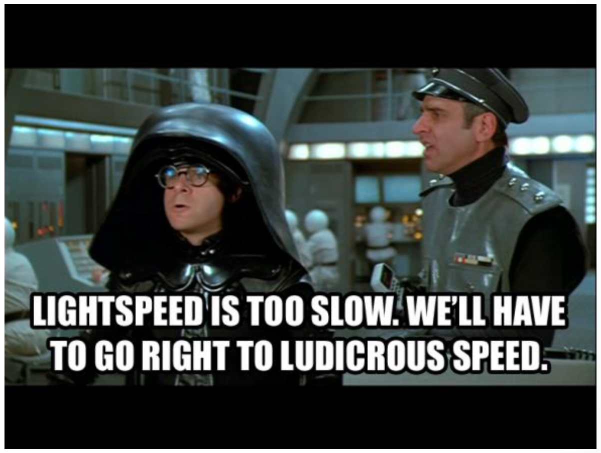


Why care about USB?

- We believe that even though USB is a pervasive technology in modern computing platforms, current security research has still only scratched its surface.
- USB has some interesting capabilities and is currently being used in a wide array of lesser-known usage models that can result in security problems.

USB Basics

- USB versions
  - 1.0, 1.1, 2.0, 3.0, 3.1
- Speeds
  - Low Speed, Full Speed, High Speed, Super Speed Gen1 and Gen2
- Device classes
  - HID, Mass Storage, Image, Video, Audio, Communications, Vendor Defined
- Physical connections
  - 1.x/2.0 standard
    - Vcc (5V), Data+, Data-, Ground
  - 1.x/2.0 mini/micro
    - Added USB OTG ID Pin
  - 3.0+
    - Added SSTx+, SSTx-, SSRx+, SSRx-


LIGHTSPEED IS TOO SLOW. WE'LL HAVE TO GO RIGHT TO LUDICROUS SPEED.

Getting started

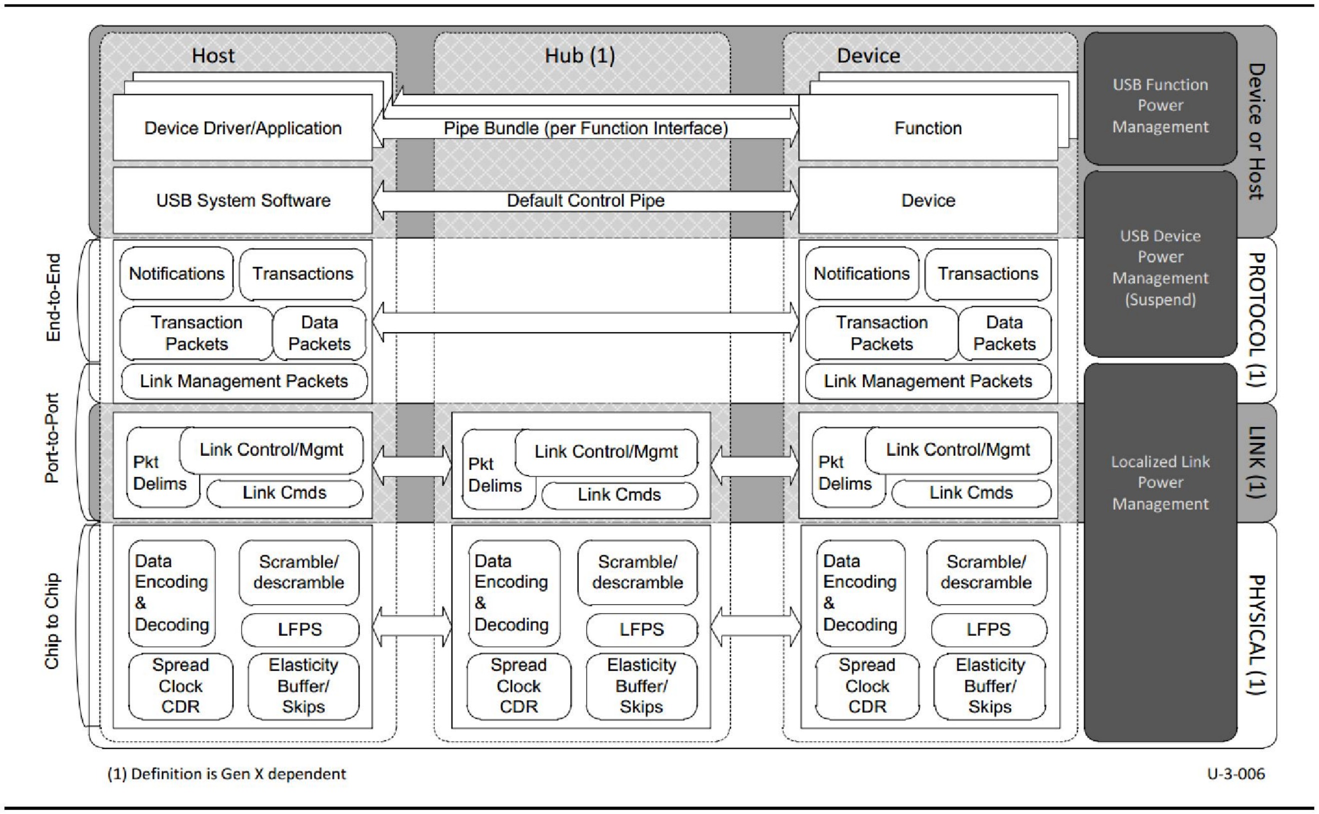


Figure 3-4. Enhanced SuperSpeed Bus Communications Layers and Power Management Elements

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

At over 600 pages, the USB specification can be a little intimidating...

Getting started

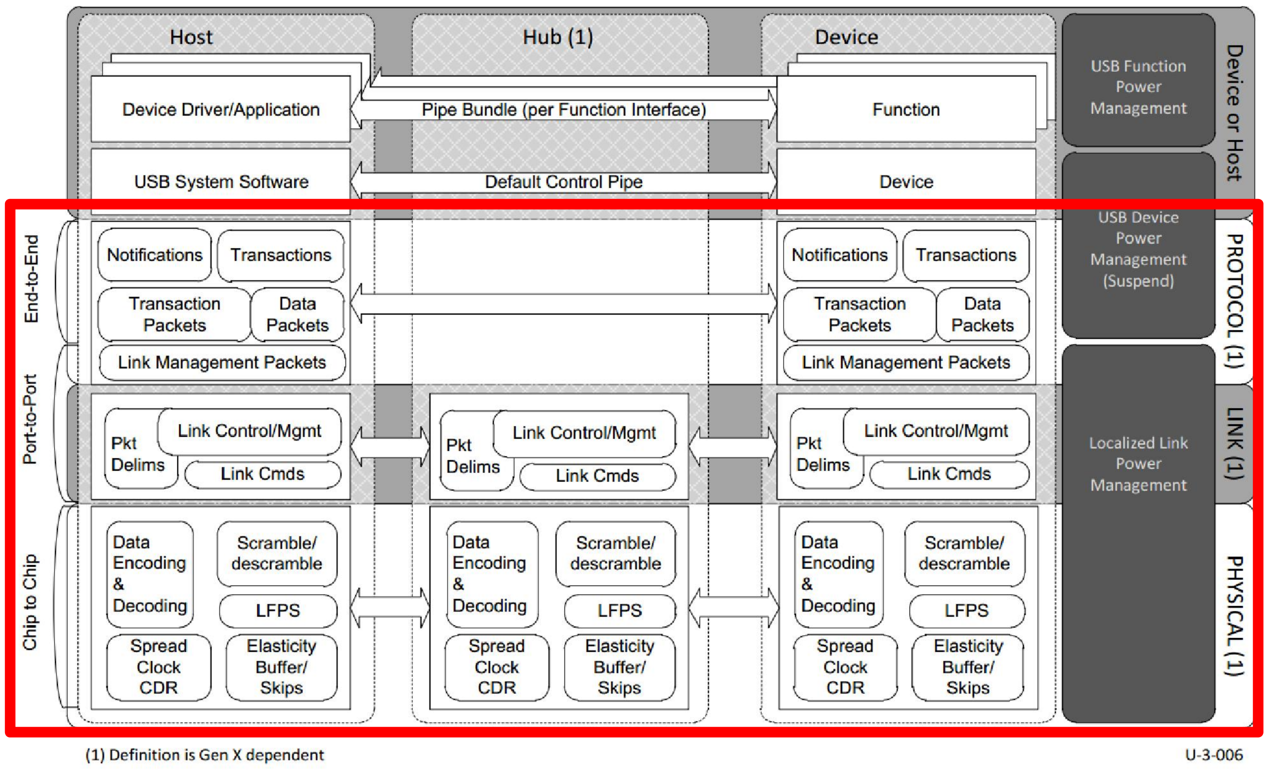


Figure 3-4. Enhanced SuperSpeed Bus Communications Layers and Power Management Elements

In most USB devices, the physical, link, and protocol layers are handled in hardware...

Getting started

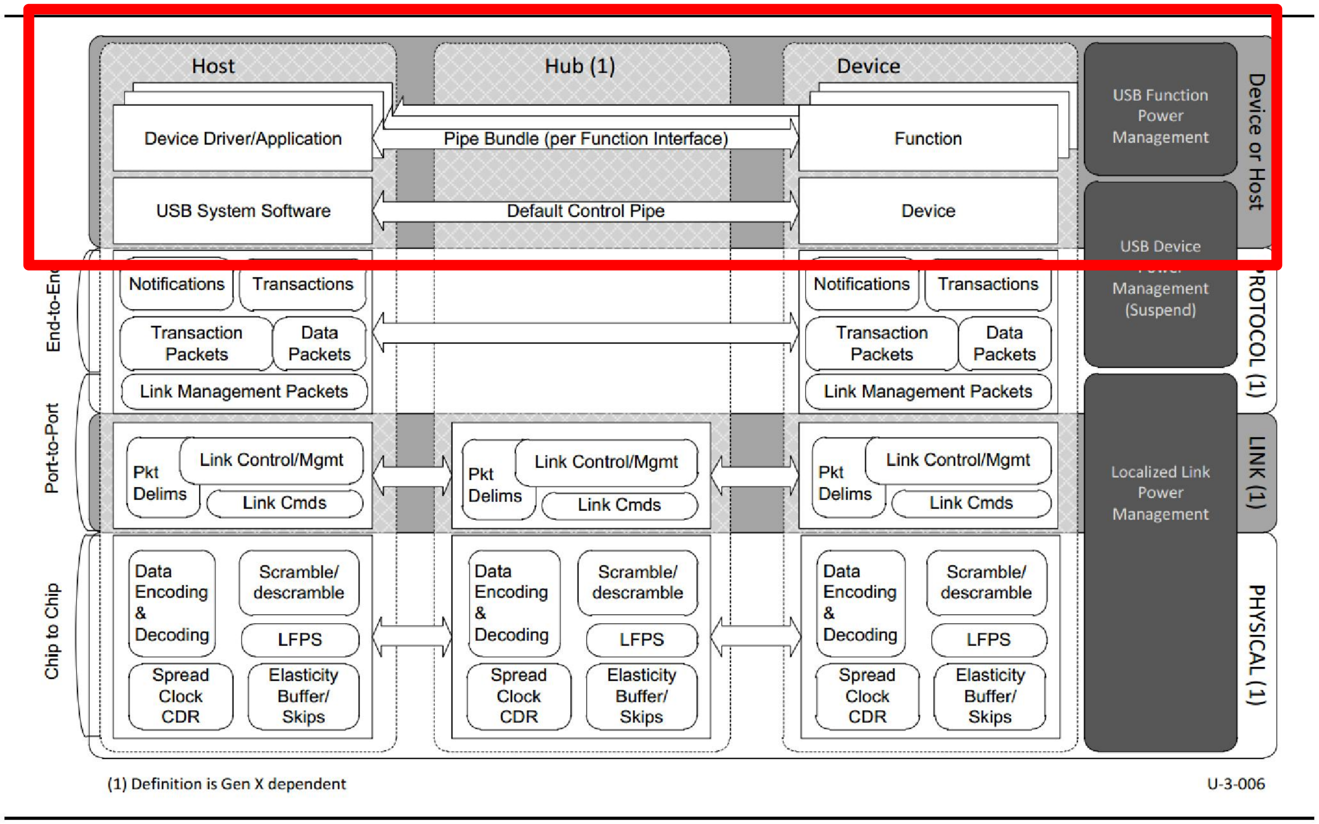


Figure 3-4. Enhanced SuperSpeed Bus Communications Layers and Power Management Elements

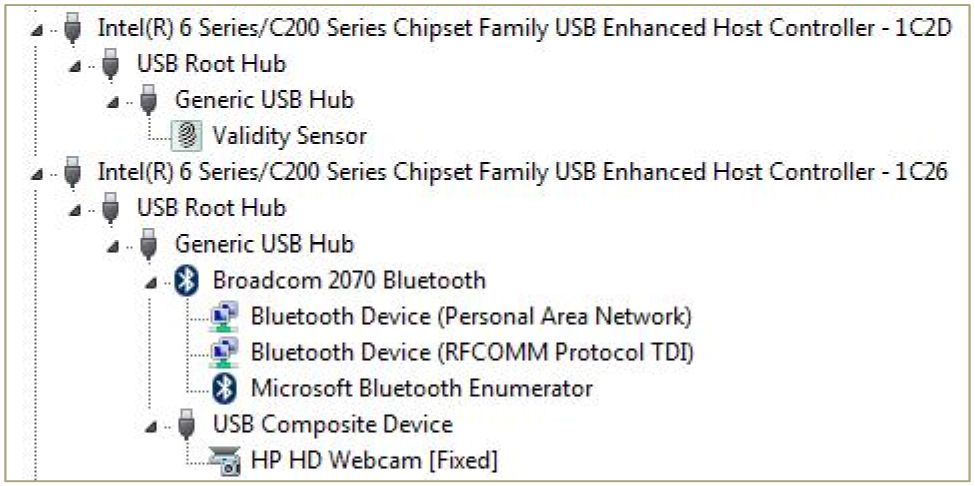
These areas are the easiest place to get started and find vulnerabilities so we'll focus here and on some bigger picture views of how USB devices are used in modern platforms.

Do I need to touch it?

Most people think about USB like this...

Do I need to touch it?

...but almost all modern laptops have internal USB devices.



```
Intel(R) 6 Series/C200 Series Chipset Family USB Enhanced Host Controller - 1C2D
    USB Root Hub
        Generic USB Hub
            Validity Sensor
Intel(R) 6 Series/C200 Series Chipset Family USB Enhanced Host Controller - 1C26
    USB Root Hub
        Generic USB Hub
            Broadcom 2070 Bluetooth
                Bluetooth Device (Personal Area Network)
                Bluetooth Device (RFCOMM Protocol TDI)
                Microsoft Bluetooth Enumerator
            USB Composite Device
                HP HD Webcam [Fixed]
```

Which often contain their own processors with firmware and are separate from the host CPU and operating system.

What could go wrong?

There’s firmware in my USB?

Even “simple” USB devices can have interesting complexity

As an example, here’s a sync cable for an older phone...

There's firmware in my USB?

That contains a USB to UART bridge chip that looks like this internally...

- 8052 processor
- 10K Boot ROM
- 16K RAM
- 2K SRAM
- Loads firmware from I^{2}C

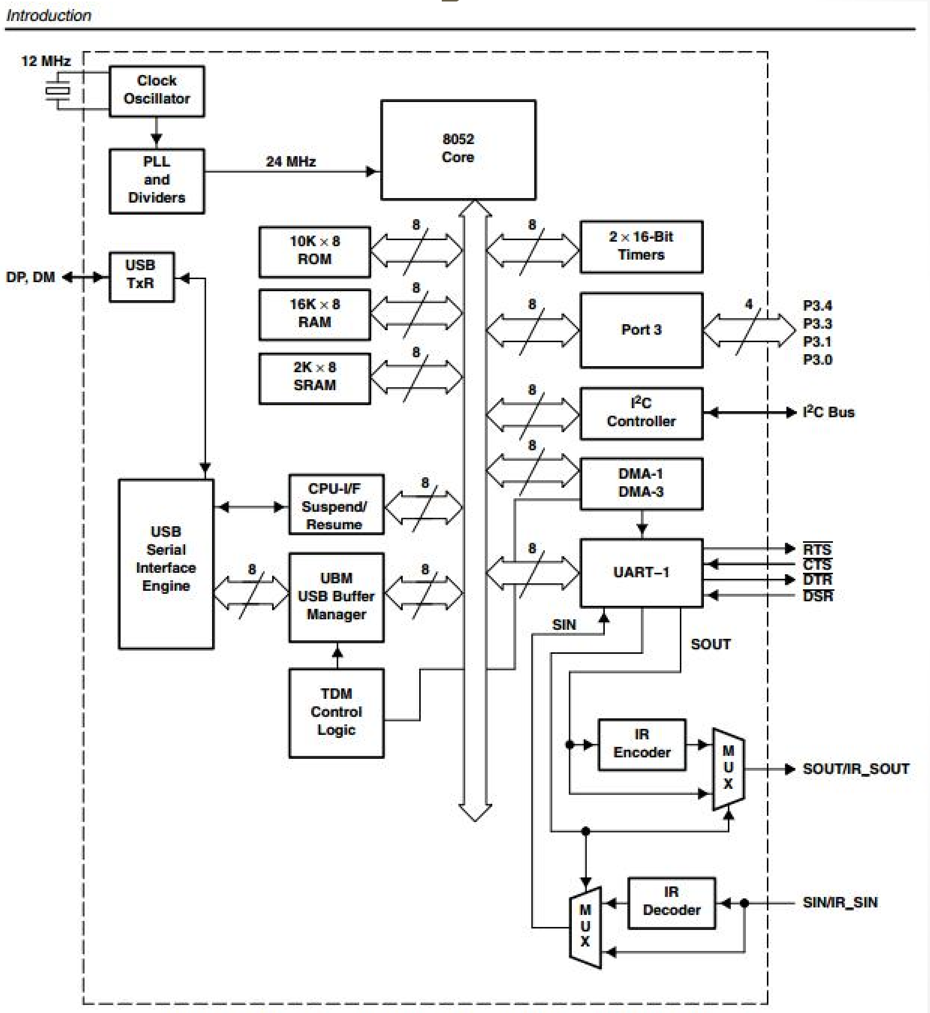
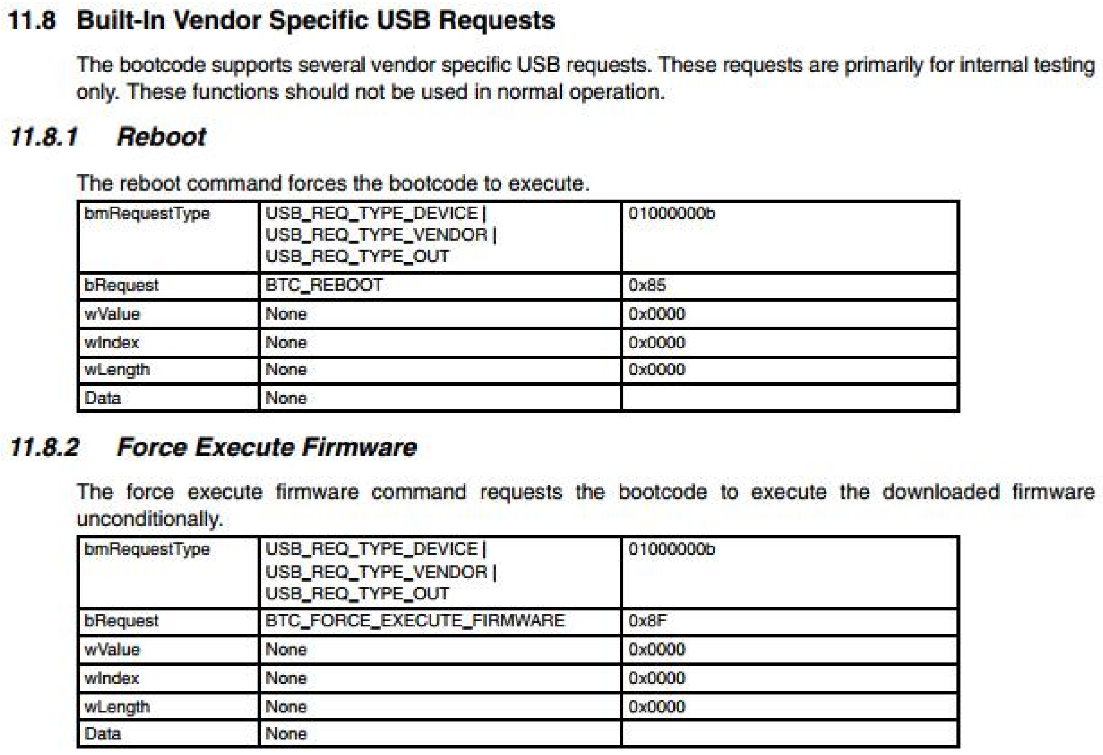


Figure 1–2. USB-to-Serial (Single Channel) Controller Block Diagram

There's firmware in my USB?

And the datasheet describes how to run your own code in it...



11.8 Built-In Vendor Specific USB Requests

The bootcode supports several vendor specific USB requests. These requests are primarily for internal testing only. These functions should not be used in normal operation.

11.8.1 Reboot

The reboot command forces the bootcode to execute.

bmRequestType	USB_REQ_TYPE_DEVICE | USB_REQ_TYPE_VENDOR | USB_REQ_TYPE_OUT	01000000b
bRequest	BTC_REBOOT	0x85
wValue	None	0x0000
wIndex	None	0x0000
wLength	None	0x0000
Data	None	

11.8.2 Force Execute Firmware

The force execute firmware command requests the bootcode to execute the downloaded firmware unconditionally.

bmRequestType	USB_REQ_TYPE_DEVICE | USB_REQ_TYPE_VENDOR | USB_REQ_TYPE_OUT	01000000b
bRequest	BTC_FORCE_EXECUTE_FIRMWARE	0x8F
wValue	None	0x0000
wIndex	None	0x0000
wLength	None	0x0000
Data	None	

Arbitrary code execution inside your phone sync cable? Really?

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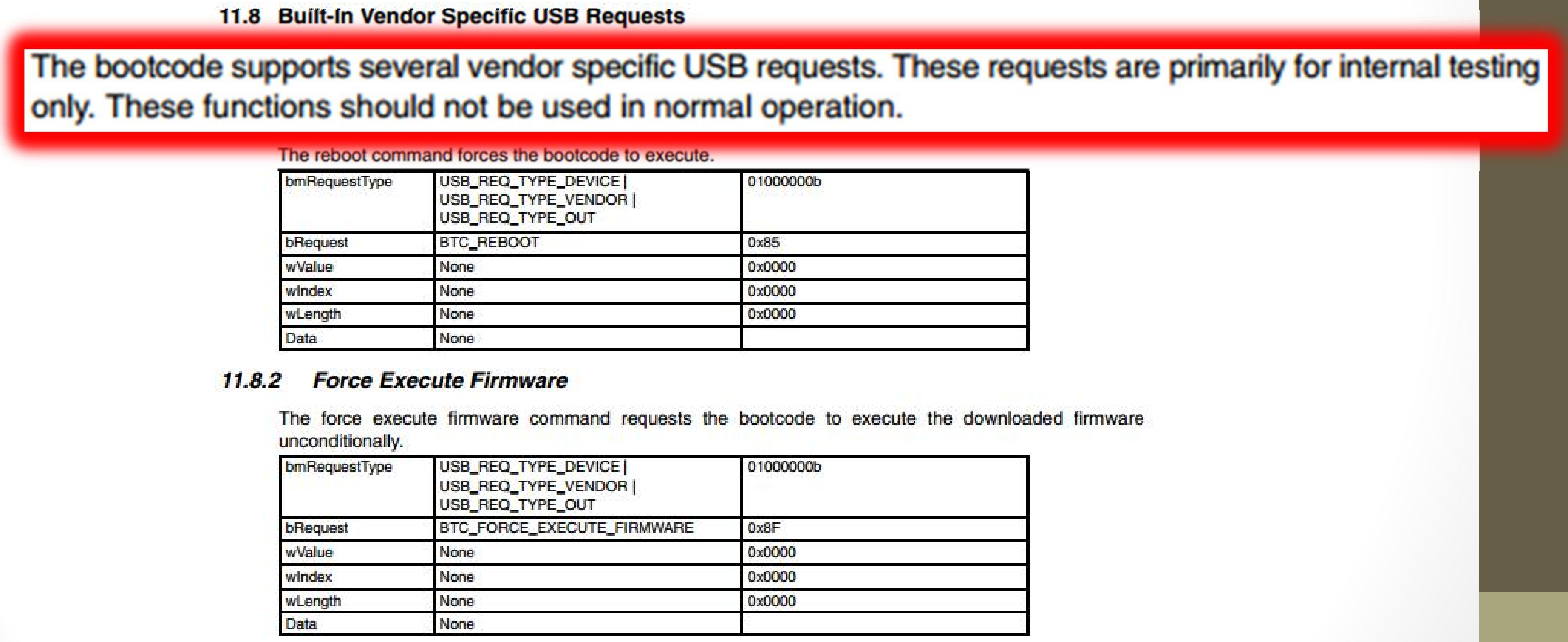

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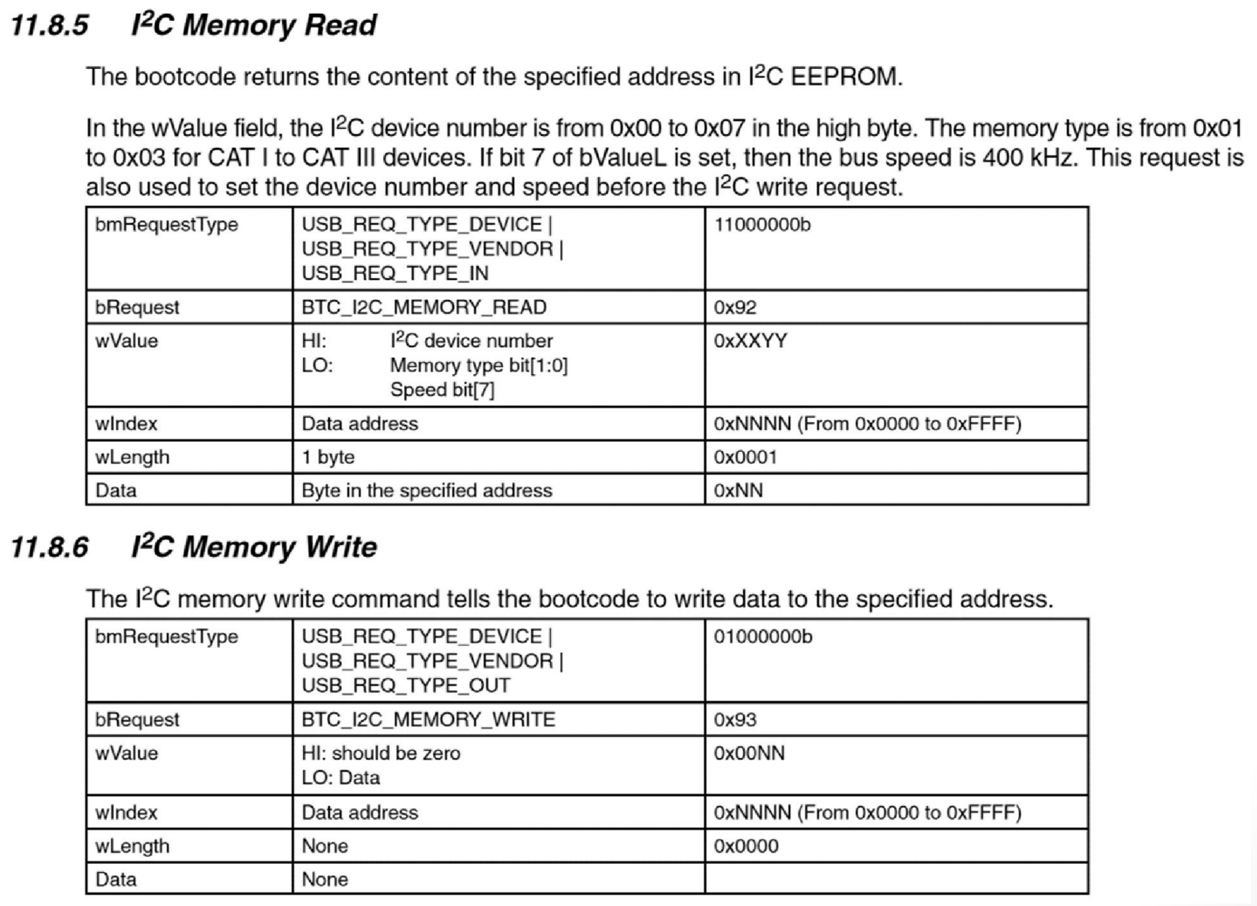
The datasheet also describes how to read and write to the I^{2}C EEPROM it executes code from…



11.8.5 *I^{2}C Memory Read*

The bootcode returns the content of the specified address in I^{2}C EEPROM.

In the wValue field, the I^{2}C device number is from 0x00 to 0x07 in the high byte. The memory type is from 0x01 to 0x03 for CAT I to CAT III devices. If bit 7 of bValueL is set, then the bus speed is 400 kHz. This request is also used to set the device number and speed before the I^{2}C write request.

bmRequestType	USB_REQ_TYPE_DEVICE | USB_REQ_TYPE_VENDOR | USB_REQ_TYPE_IN	11000000b
bRequest	BTC_I2C_MEMORY_READ	0x92
wValue	HI: I^{2}C device number LO: Memory type bit[1:0] Speed bit[7]	0xXXYY
wIndex	Data address	0xNNNN (From 0x0000 to 0xFFFF)
wLength	1 byte	0x0001
Data	Byte in the specified address	0xNN

11.8.6 *I^{2}C Memory Write*

The I^{2}C memory write command tells the bootcode to write data to the specified address.

bmRequestType	USB_REQ_TYPE_DEVICE | USB_REQ_TYPE_VENDOR | USB_REQ_TYPE_OUT	01000000b
bRequest	BTC_I2C_MEMORY_WRITE	0x93
wValue	HI: should be zero LO: Data	0x00NN
wIndex	Data address	0xNNNN (From 0x0000 to 0xFFFF)
wLength	None	0x0000
Data	None	

Device Firmware Upgrade

http://www.usb.org/developers/devclass_docs/DFU_1.1.pdf

There's actually a specification for how to create USB devices with upgradable firmware.

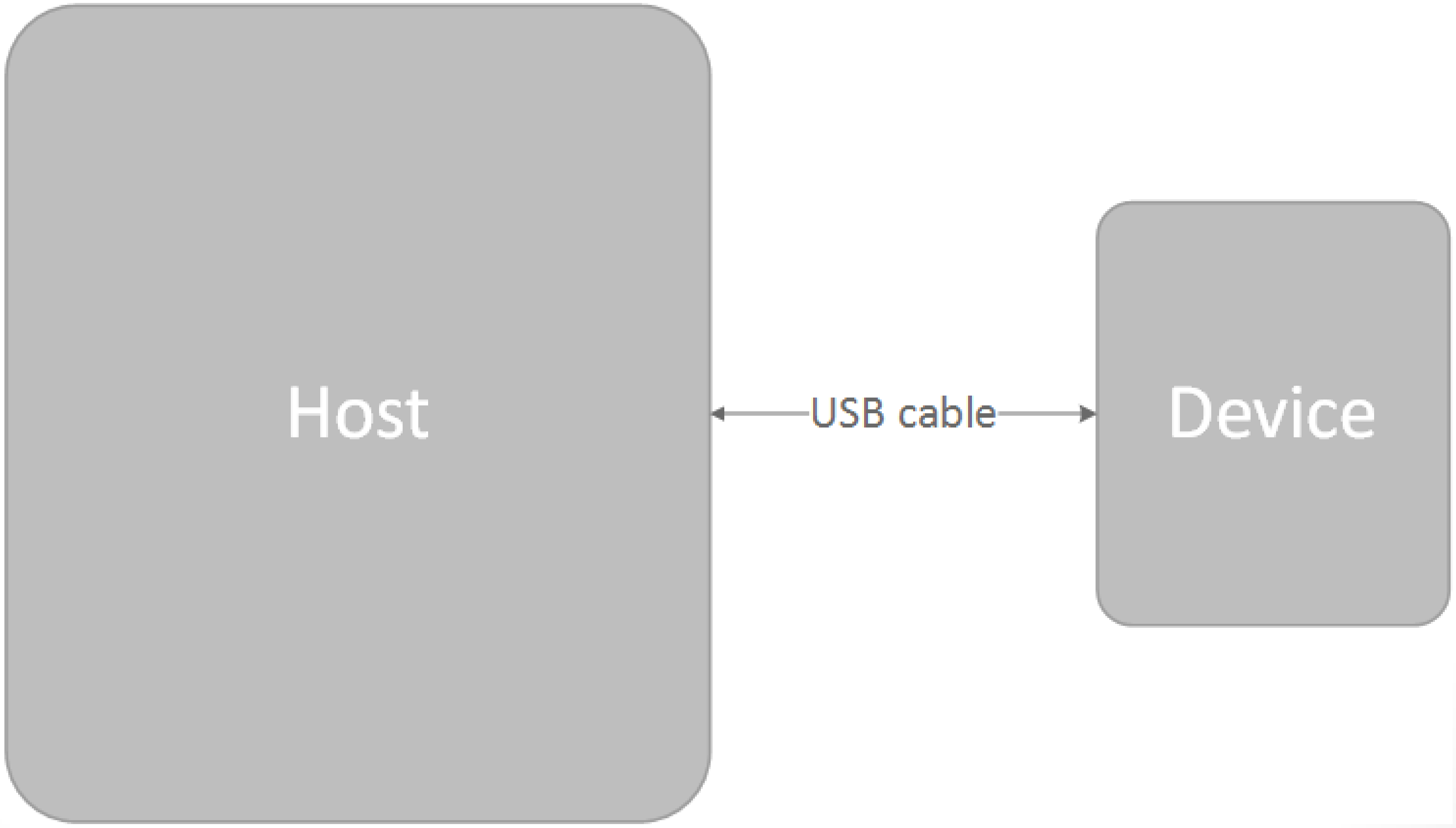
It doesn't mention security at all. And most devices that implement this capability don't bother to do any validation of the firmware image other than basic checksums which are easy to bypass.

DFU and similar custom device upgrade methods are a good way to easily get arbitrary code execution within a USB device.

What can we do with that?

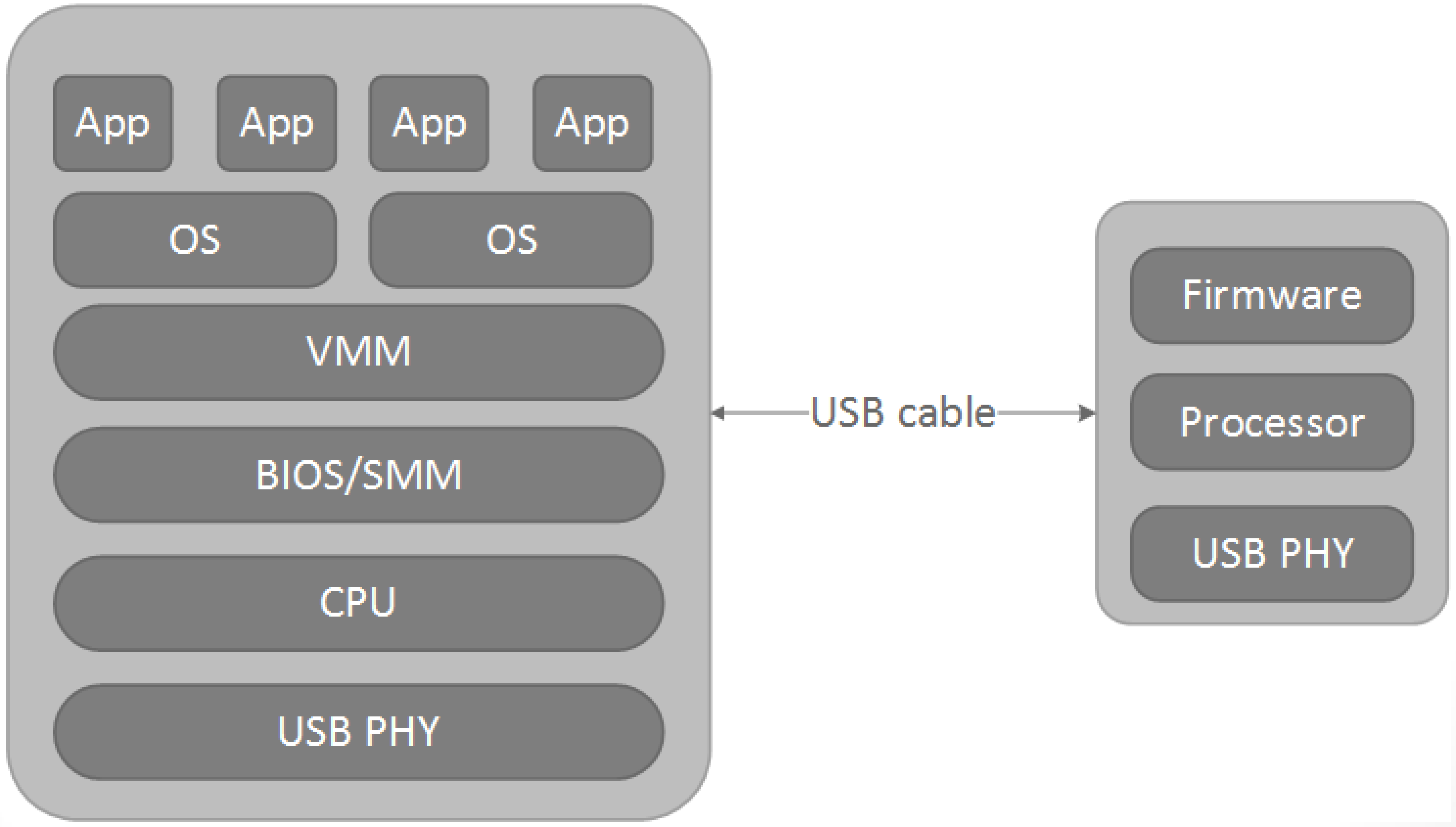
Attack Surfaces

So instead of looking at it like this...



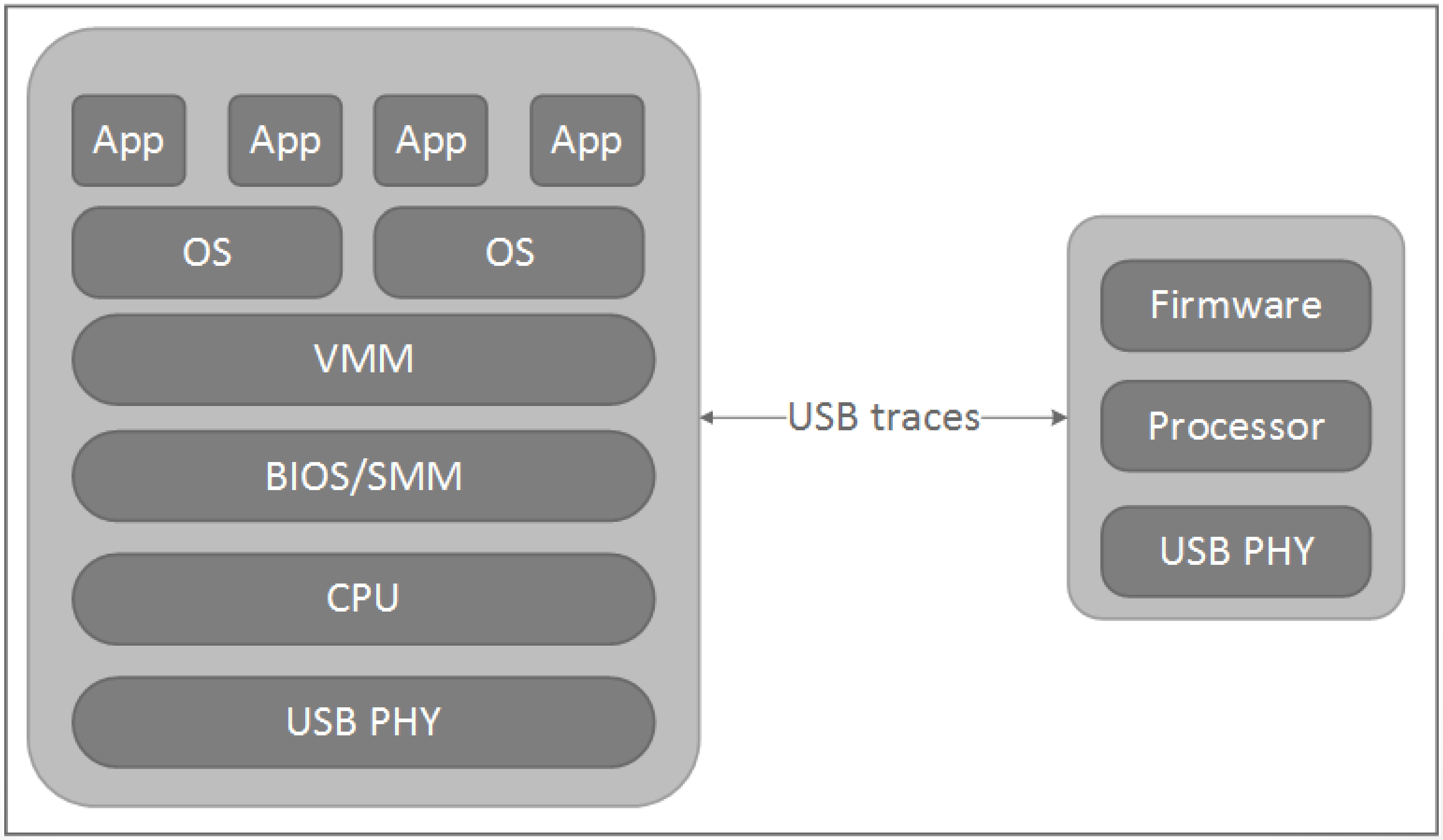
Attack Surfaces

There's actually a lot more going on...



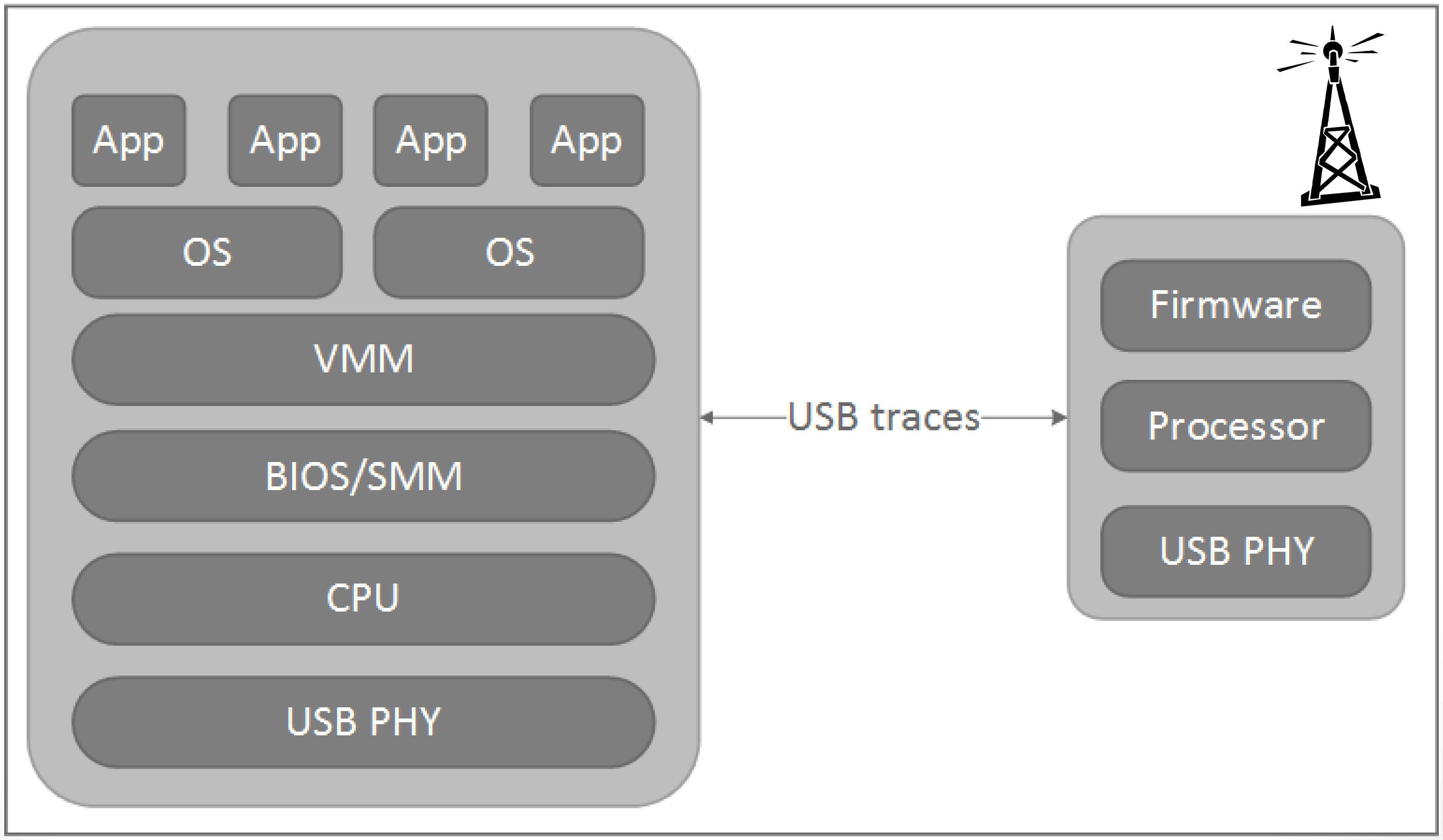
Attack Surfaces

All of this is probably happening inside your laptop right now.



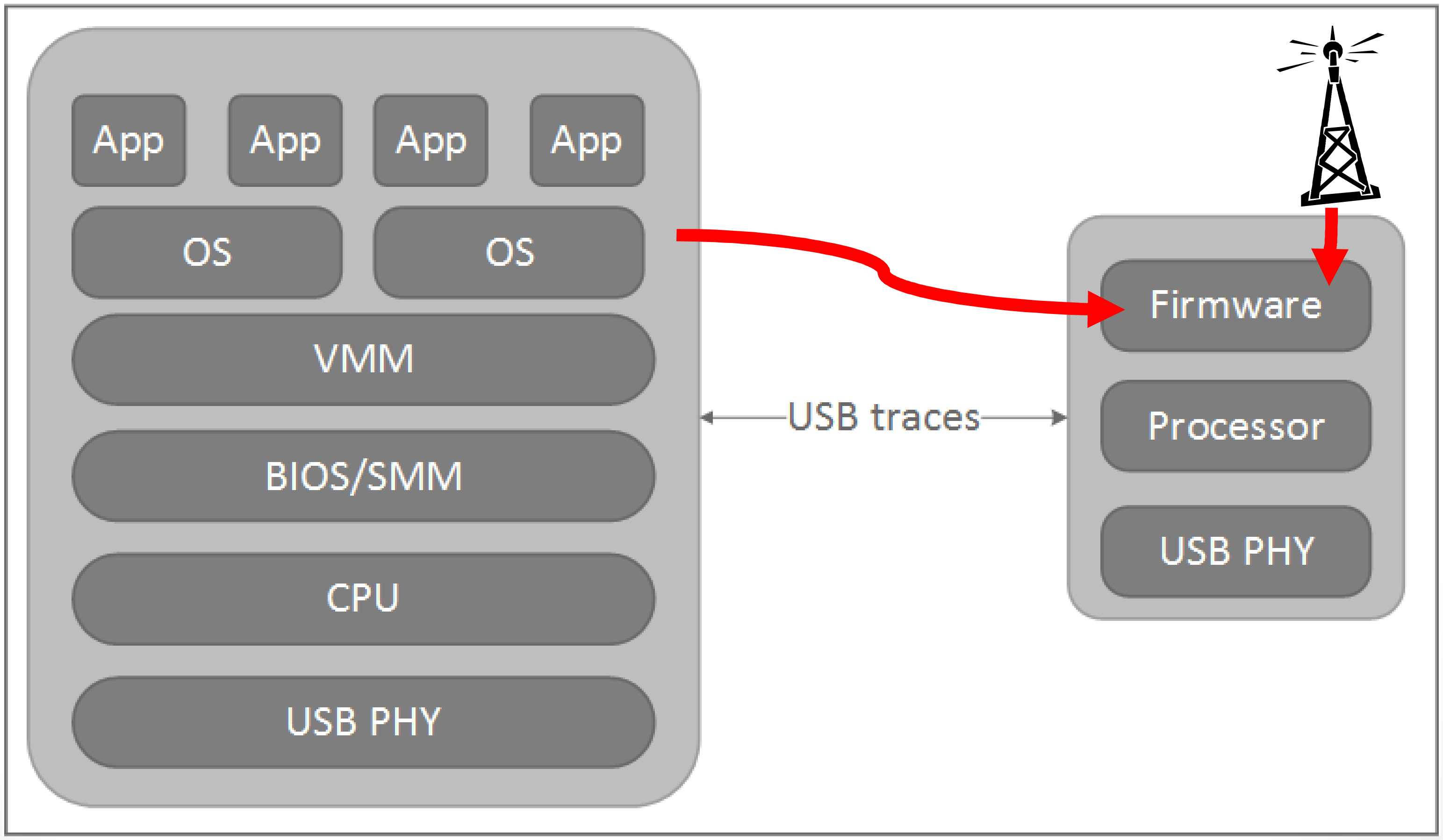
Attack Surfaces

Some USB devices even have radio interfaces...



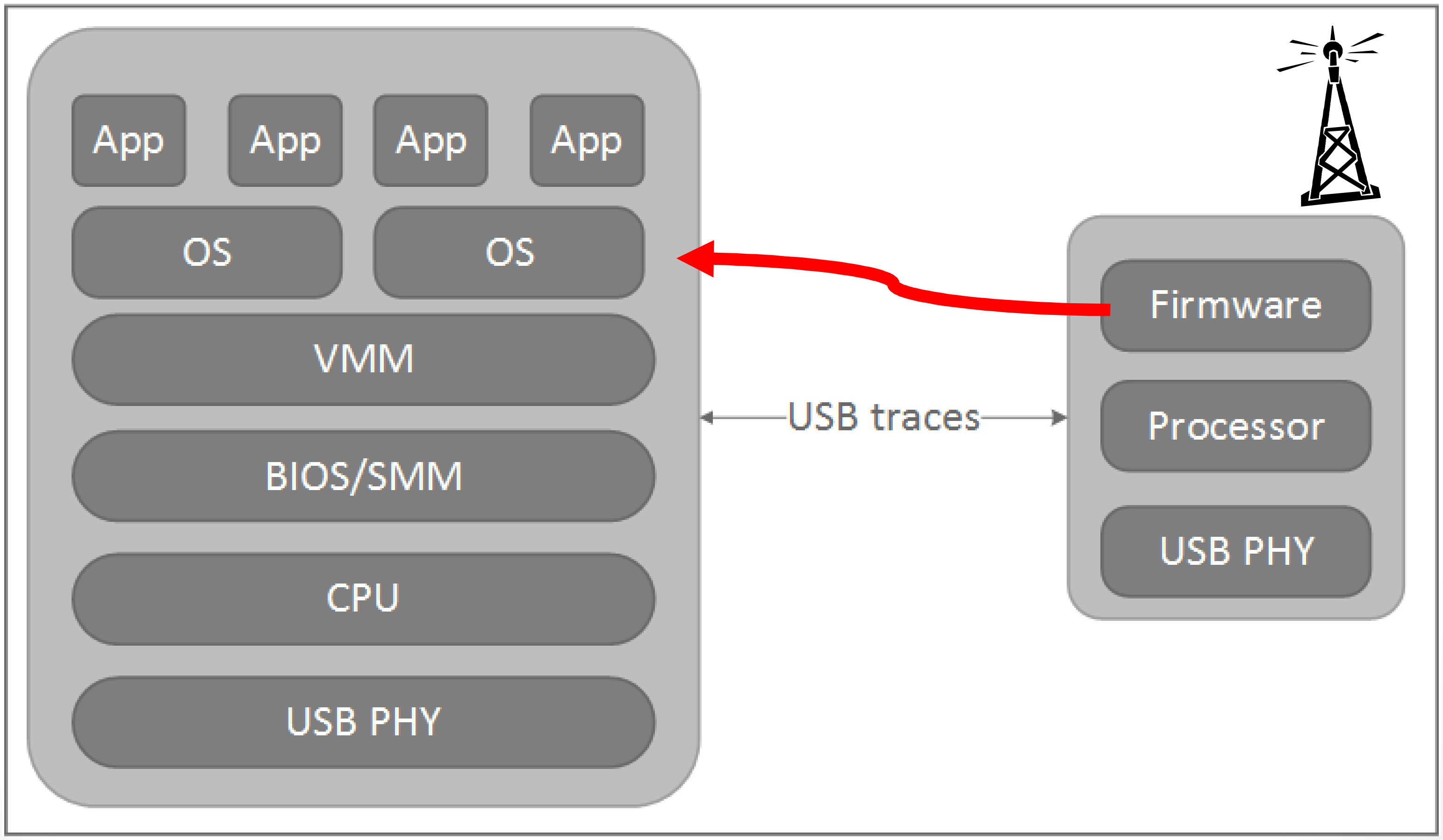
Attack Surfaces

If you can get arbitrary code execution within the USB device...



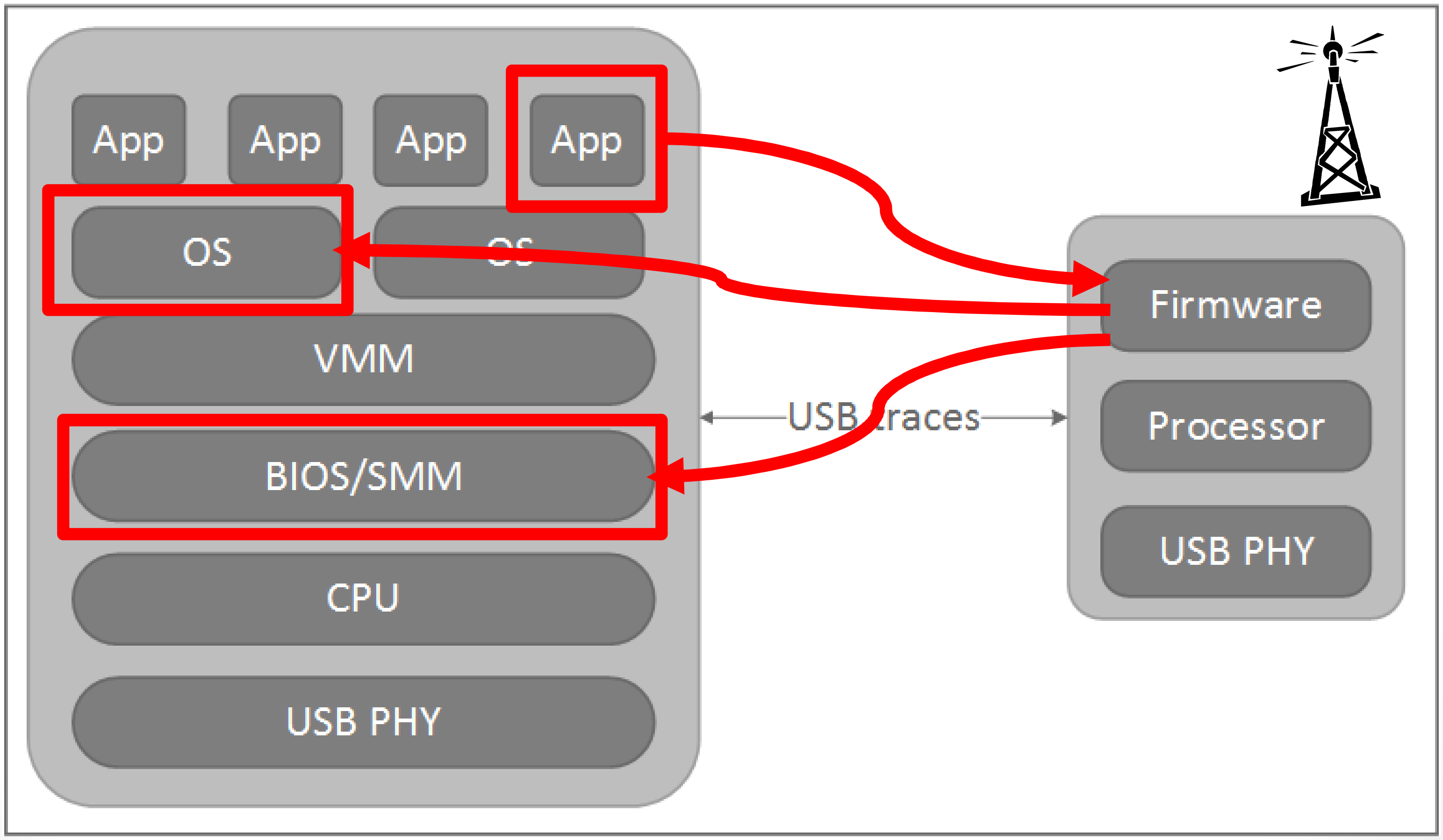
Attack Surfaces

It can be used to attack components within the host.



Attack Surfaces

Even with attacks originating from the host, these can cross privilege boundaries



Debug Capability

- Allows low-level debug over USB
- Now required to gain Windows Logo certification
  - “If the XHCI controller in the SUT has any user-accessible ports, the controller must have debug capability.”

Media Agnostic USB

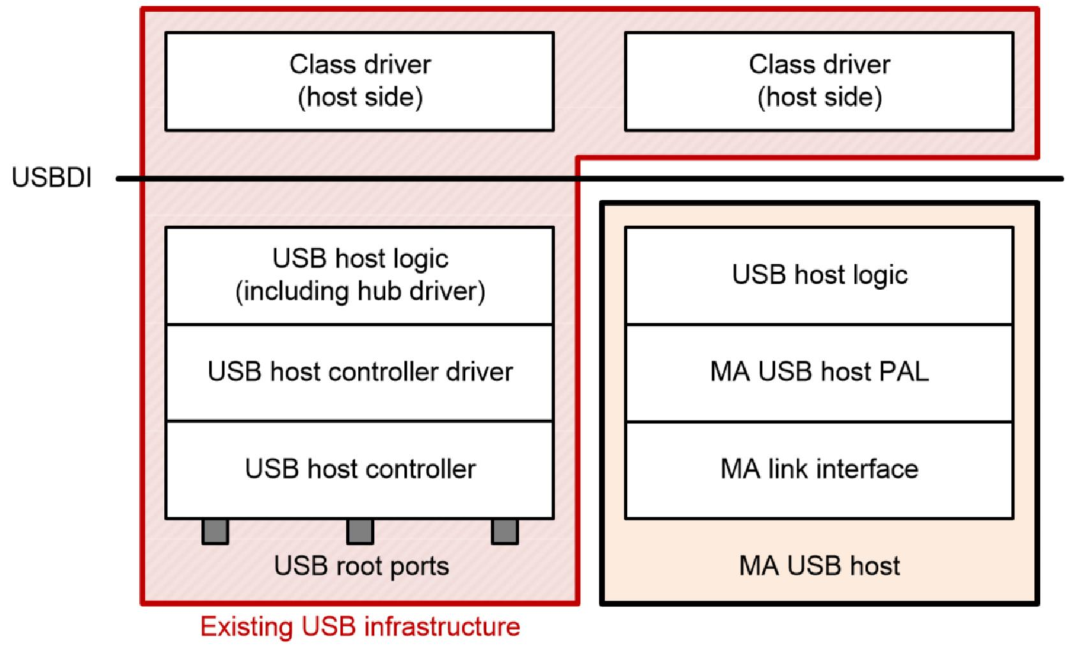


Figure 1—Building blocks of an MA USB host and relationship to existing USB infrastructure

http://www.usb.org/developers/devclass_docs/Media_Agnostic_USB_v1.0.zip

Media Agnostic USB

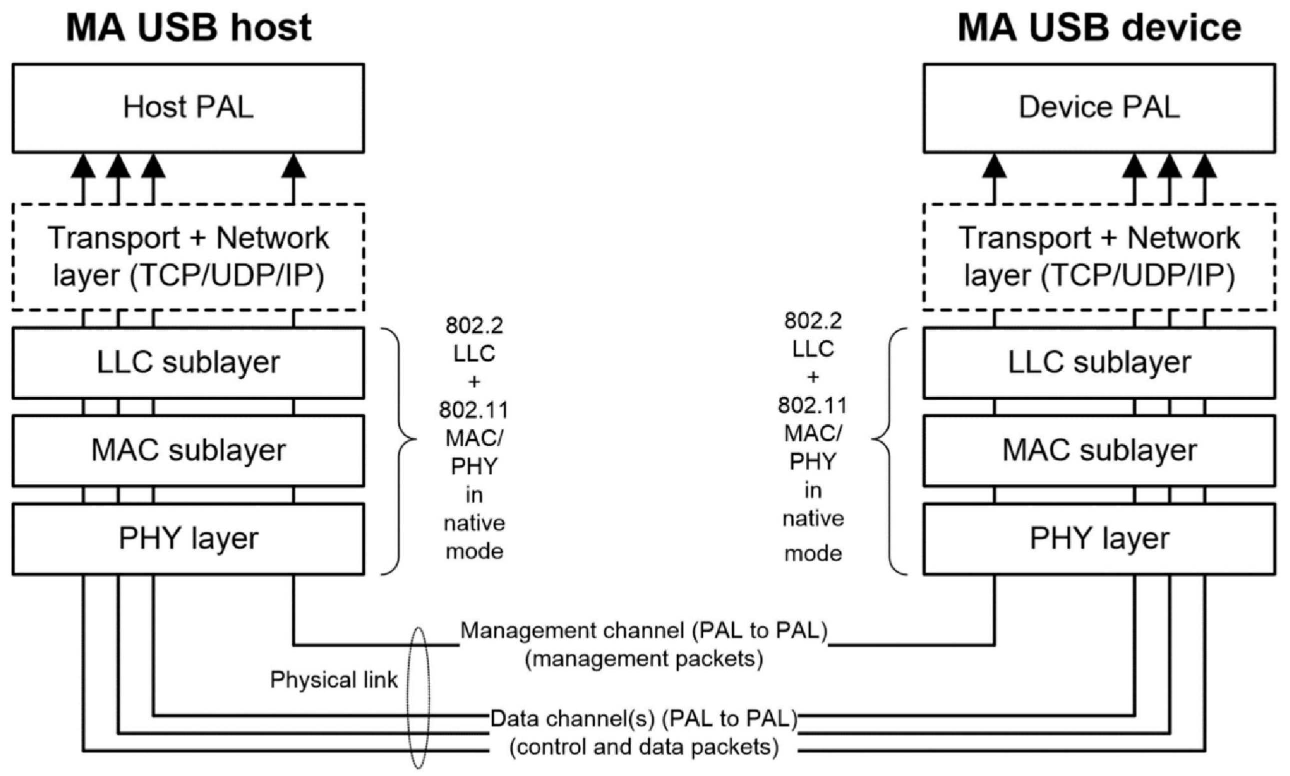

MA USB host
MA USB device
Host PAL
Device PAL
Transport + Network layer (TCP/UDP/IP)
Transport + Network layer (TCP/UDP/IP)
LLC sublayer
MAC sublayer
PHY layer
LLC sublayer
MAC sublayer
PHY layer
802.2 LLC + 802.11 MAC/ PHY in native mode
802.2 LLC + 802.11 MAC/ PHY in native mode
Management channel (PAL to PAL) (management packets)
Physical link
Data channel(s) (PAL to PAL) (control and data packets)

Figure 9—MA USB protocol hierarchy

Tools!

Total Phase Beagle 5000

http://www.totalphase.com/protocols/usb/

Supports USB 3.0 SuperSpeed, but very expensive. Can only be used for observation and not injection.

Total Phase Beagle 480

http://www.totalphase.com/protocols/usb/

Less expensive than Beagle 5000, but only supports USB 2.0. Can only be used for observation and not injection.

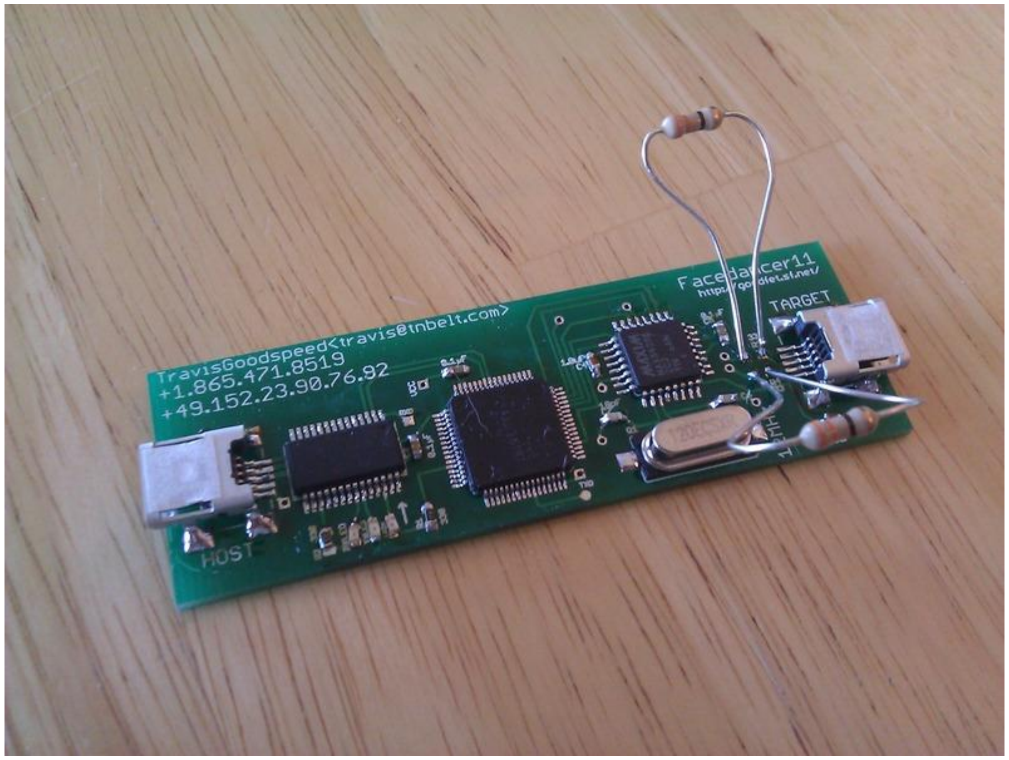
ITIC 1480A USB 2.0 Protocol Analyzer

USB 2.0 LS/FS/HS Protocol Analyzer Model 1480A
Host Power
Link Power
Link Activity
Link Under Test
(c) 2008 International Test Instruments Corporation

http://www.internationaltestinstruments.com/products/97-1480a-usb-20-protocol-analyzer.aspx

HW less expensive than Beagle 480, but some SW modules sold separately. Can only be used for observation and not injection.

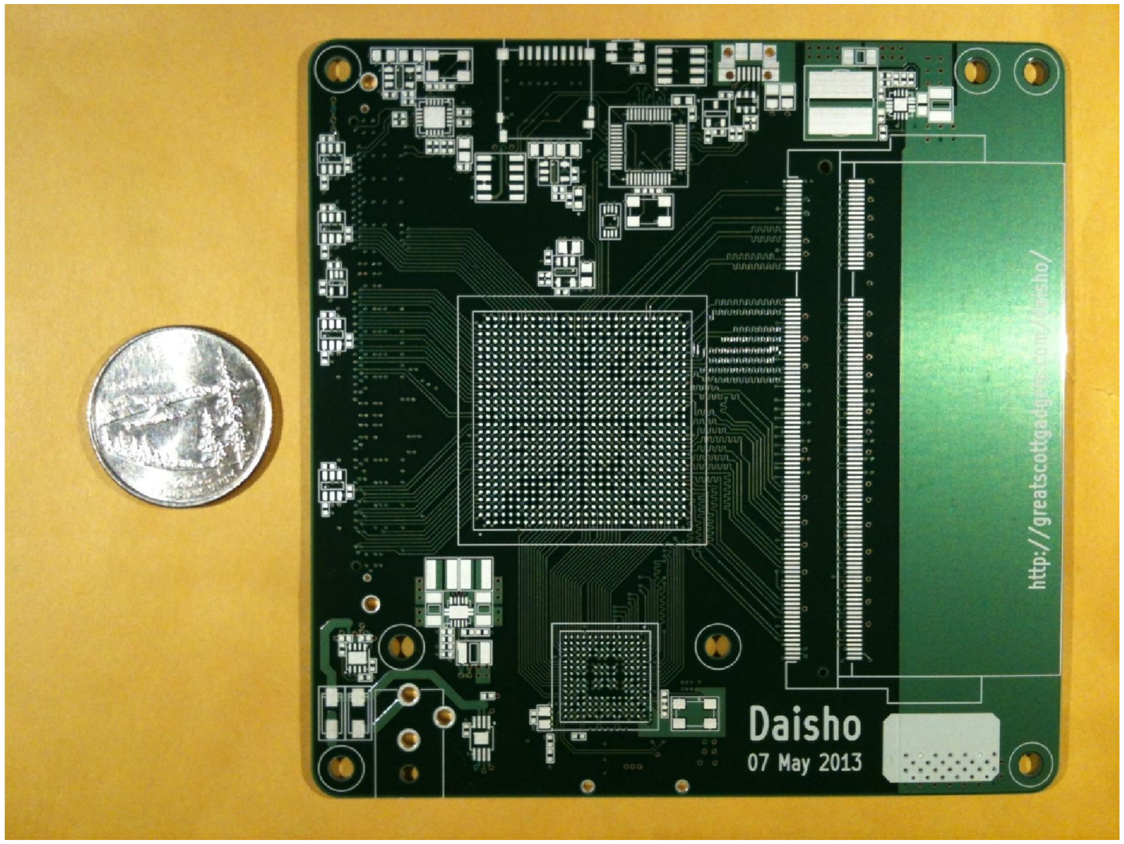
Facedancer



http://goodfet.sourceforge.net/

Open source, cheap and easy to build, allows arbitrary emulation of USB endpoints, but can be very slow

Daisho



https://github.com/mossmann/daisho

Open source, intended to support full USB 3.0 SuperSpeed monitoring and injection, but still in development

USBProxy

https://github.com/dominicgs/USBProxy

Open source project to create a USB 2.0 MitM device using the BeagleBone Black, still in early stages, but can already do some cool stuff

libusb

- http://www.libusb.org/
- Good way to get started with writing tools to access USB devices

Peach Publishers

- Data Publisher
- Configuration Publisher

- This uses libUsbDotNet which hasn’t been maintained in a while, so it has its bugs, but has been useful for finding issues.

- Available on the DEFCON CD.
- Submitted to Peach upstream

Phison PS2303 framework

- https://bitbucket.org/flowswitch/phison/

- Phison PS2303 is a USB 3.0 NAND controller used in many flash drives

- 8051-compatible core
- 256KiB ram
- USB, NAND, and DMA controllers
- Stores firmware in NAND

- Goal of the project is to use PS2303-based flash drives as a cheap USB3.0 development platform

Kautilya toolkit

- https://github.com/samratashok/Kautilya
- Collection of 40+ USB HID payloads for penetration testing
  - Dump Process Memory
  - Dump Windows Vault Credentials
  - Download and Execute
  - Connect to Hotspot and Execute code
  - Code Execution using Powershell
  - Code Execution using DNS TXT queries
  - Add an admin user
  - Add a user and Enable RDP
  - Add a user and Enable Powershell Remoting
  - … and more
- Designed to be used with Arduino devices like the Teensy, but easily adaptable to other devices like the Phison chipset

Demos!

Summary

- USB is a pervasive technology in modern computing devices.
- Not just external ports which require physical access to attack
- Devices connected over USB run upgradable firmware
- Debug capability required for Windows certification
- Interesting attack scenarios with internal devices

USB provides a rich set of capabilities and is being used in a variety of configurations that could result in security vulnerabilities and it’s easier than people think to get started looking at this stuff.

Questions?

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