RSAConference2015
San Francisco | April 20-24 | Moscone Center

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The Internet of TR-069 Things: One Exploit to Rule Them All

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/usr/bin/whoarewe

WE SECURE THE FUTURE

Agenda

- TR-069 quick tour / DEF CON recap
- Motivation
- The TR-069 Census 2014
- Research Highlights
- Mass Pwnage
- Disclosure
- Aftermath

TR-069

- a.k.a. **C**PE **W**AN **M**anagement **P**rotocol (CWMP)
  - 2004: v1.0
  - 2013: v1.4 (amendment 5)
  - 2015: amendment 6?

- This is what ISPs use to provision, monitor and configure your home routers (and more)

TR-069 Provisioning Session

SOAP RPC

(XML over HTTP)

Inform(reason)

<empty>

GetParameterValues(<key>*)

SetParameterValues(<key,value>*)

<empty>

Always initiates session

ACS can issue “Connection Request”

Dual authentication mechanism

Findings So Far

- **Presented at DEF CON 22**
- **Our research uncovered implementation and configuration flaws in many ISP's ACS deployments**
  - ACSs are a single point of pwnage in modern ISP infrastructure
  - Many TR-069 implementations just aren't serious enough
  - Leads to ISP fleet takeover

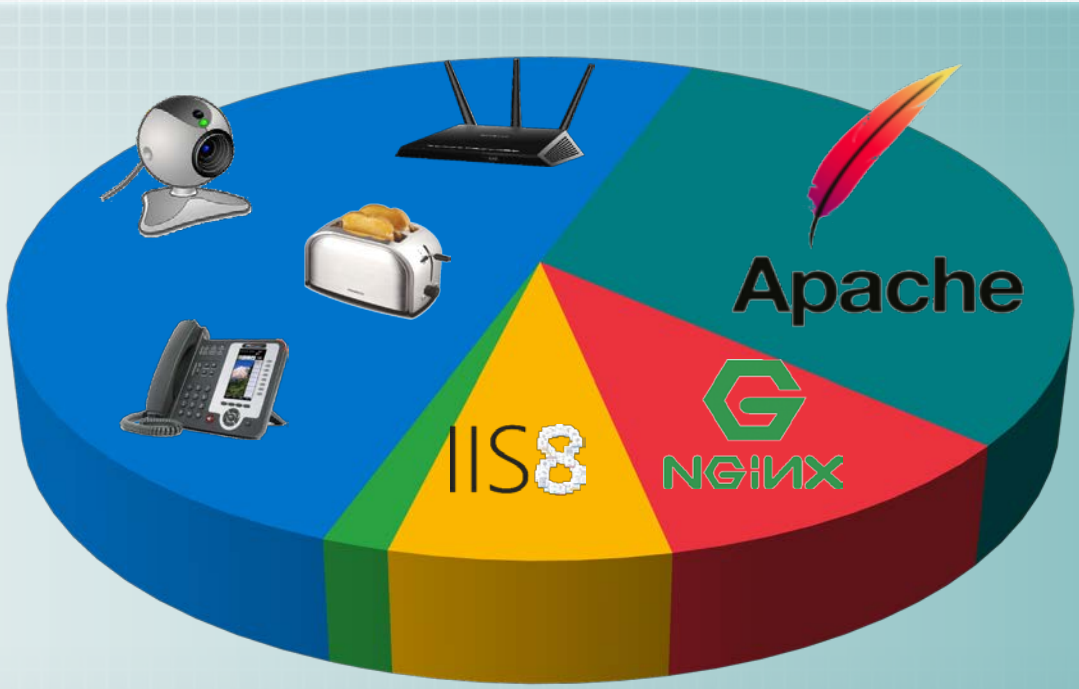
Connection Request

"The ACS can at any time request that the CPE initiate a connection to the ACS using the Connection Request notification mechanism. Support for this mechanism is REQUIRED in a CPE." (from TR-069)

Port	Service	Hit Rate (%)
80	HTTP	1.77
7547	CWMP	1.12
443	HTTPS	0.93
21	FTP	0.77
23	Telnet	0.71

Port 80 Analysis”

- Port 80 - ~70m
  - 50% Web Servers
  - 50% IoT things
    - Routers
    - Webcams
    - VoIP Phones
    - Toasters



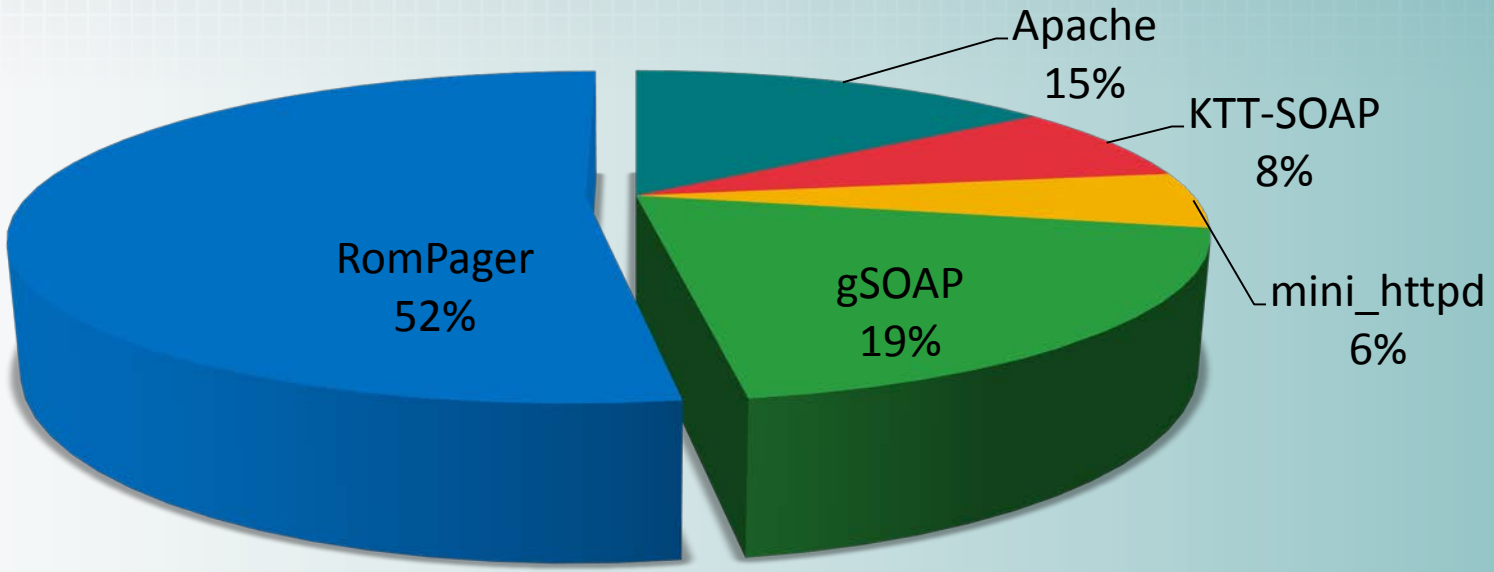
Port 7547 Analysis

- TR-069 - ~45m
  - 100% IoT

The TR-069 Census 2014

- We scanned 7547 (Nov 2014)
  - A few times
  - Help from friends (Rapid7, UMich)
- 1.18% respond
  - 46,093,733 IoT devices
  - All over the world
  - 0.06% = 2.2m

TR-069 CR Server Distribution

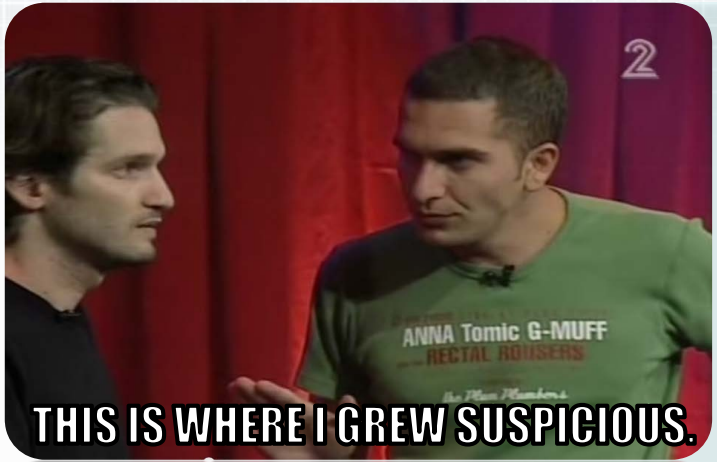


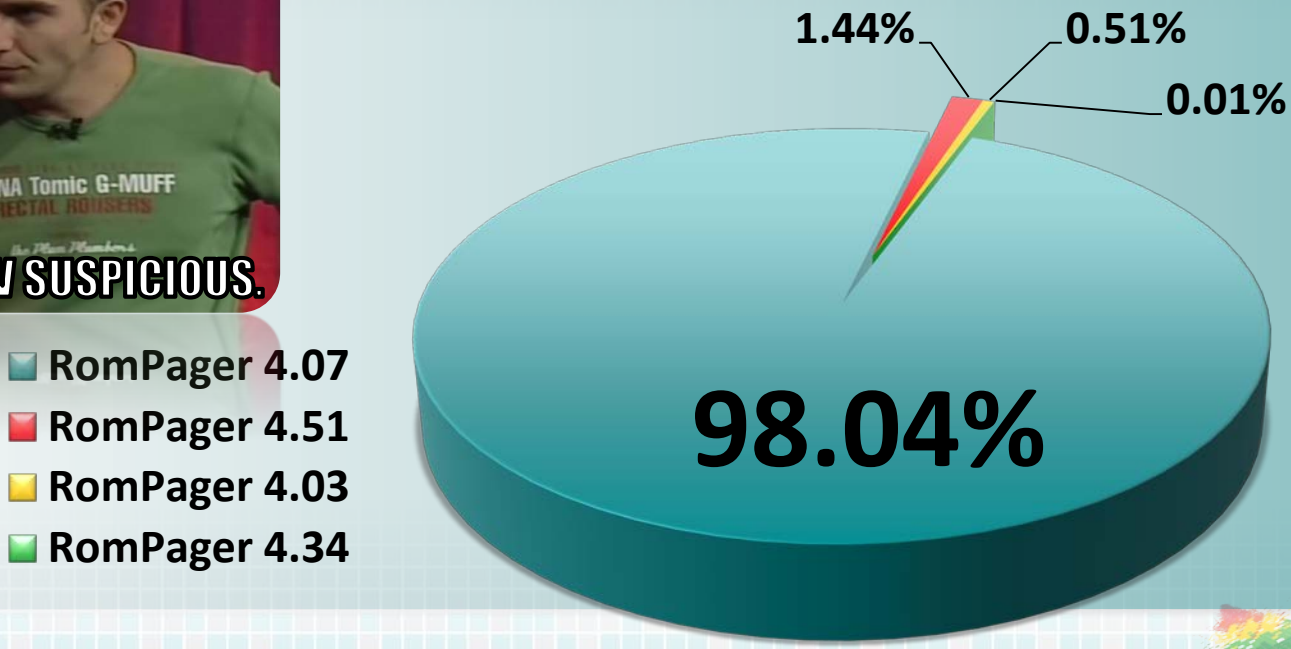
What is RomPager?

Internet Software for Embedded Devices

- Embedded HTTP server by Allegro Software
  - Massachusetts based company
- Optimized for minimal environments
  - small binary, small memory requirements
- First introduced in 1996
- Many versions since
  - Current version in 5.4

RomPager Versions Distribution





Response Headers
view source
Content-Type: text/html
EXT:
Server: RomPager/4.07 UPnP/1.0
Transfer-Encoding: chunked
WWW-Authenticate: Basic realm="TD-W8961ND"

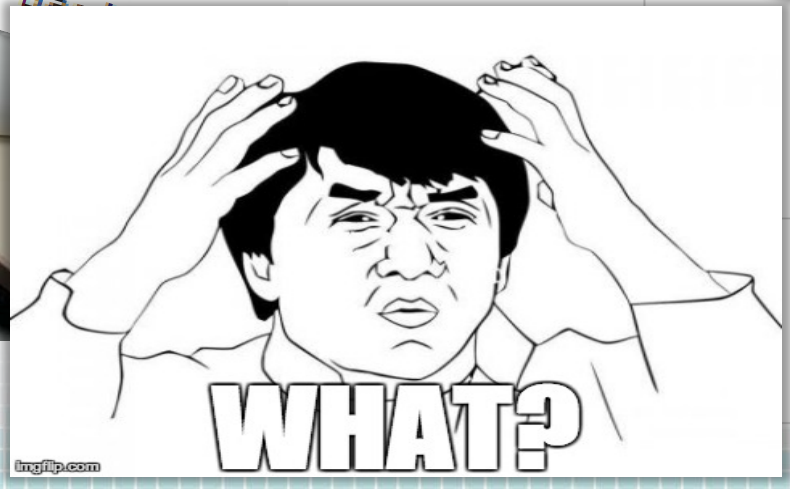
Published Date	3/5/2014
Language	English
File Size	1.38 MB
	Win2000/XP/2003/Vista/7/8/Mac/Linux

TD-W8961ND_V3_140305

Bug

6. … after we se…
7. Forbidden access to th… or http://wan/lan ip/xxx.htm.
8. Fixed other bugs and problems.

1.As we have updated the security mechanism on … of firmware, once you have upgraded to this firmw… not be able to downgrade to the old one.
2.You have to restore the device to factory default … new functions take effect; Click Maintenance->Sys… choose Factory Default Settings, Click RESTART



RomPager 4.07

- Dated to 2002
- Appears in many new firmwares
- 2,249,187 devices on port 80
- 11,328,029 devices on port 7457
- 200 different identified models
- 50 different brands

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Firmware Analysis

#RSAC

Dig Deeper

- Explore the firmware
  - Firmware update is one file called “ras”
  - Binwalk

TP-LINK®

```
DECIMAL       HEX             DESCRIPTION
--------------------------------------------------------------------------------
84992         0x14C00         ZynOS header, header size: 48 bytes, rom image type: ROMBIN, uncompressed
ags: 0xE0, uncompressed checksum is valid, the binary is compressed, compressed checksum is valid, memory
85043         0x14C33         LZMA compressed data, properties: 0x5D, dictionary size: 8388608 bytes, u
128002        0x1F402         GIF image data, version 8"9a", 200 x 50
136194        0x21402         GIF image data, version 8"9a", 560 x 50
350208        0x55800         ZynOS header, header size: 48 bytes, rom image type: ROMBIN, uncompressed
, flags: 0xE0, uncompressed checksum is valid, the binary is compressed, compressed checksum is valid, me
350259        0x55833         LZMA compressed data, properties: 0x5D, dictionary size: 8388608 bytes, u
```

Bootloader

Vendor logo

Main binary

Dig Deeper

- Downloaded all the RomPager 4.07 firmwares I could find
- All of them had ZynOS header! (mipsb32)

ZynOS

- Basic RTOS
- One binary
- No file system

Notoriously known for the “rom-0” vulnerability (CVE-2014-4019)
- 1,219,985 vulnerable world-wide (May 2014)

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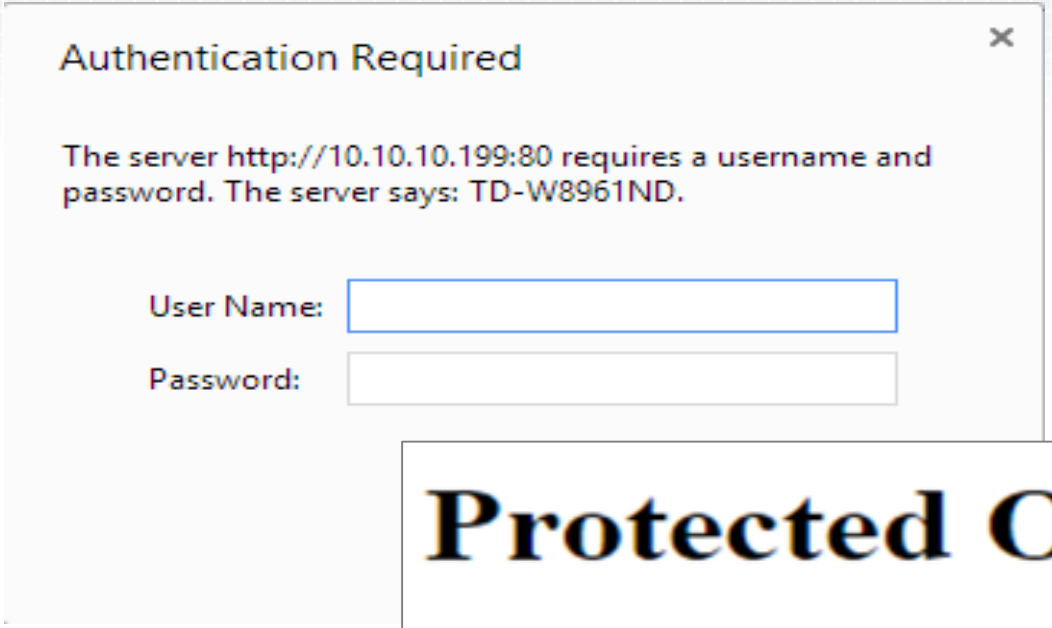
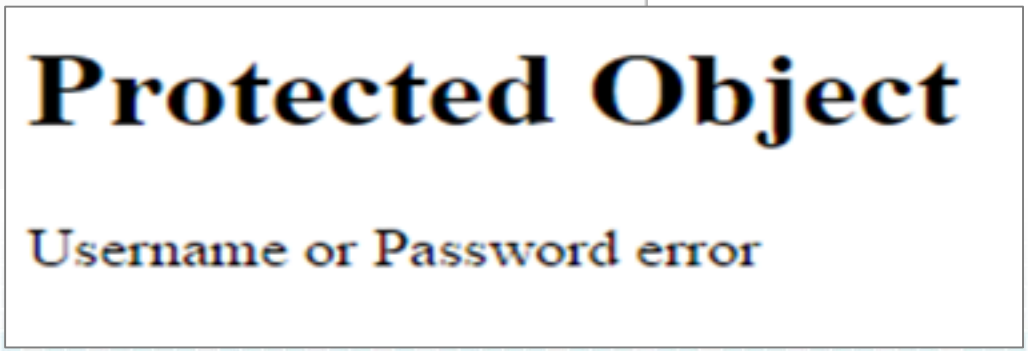
Attack Surface Analysis

http://192.168.1.1





http://192.168.1.1:7547

Manual Testing

Fuzzing over http headers

Crashed on username sub-header of digest authentication

{Authorization: Digest username=‘a’*600}

Handling HTTP requests

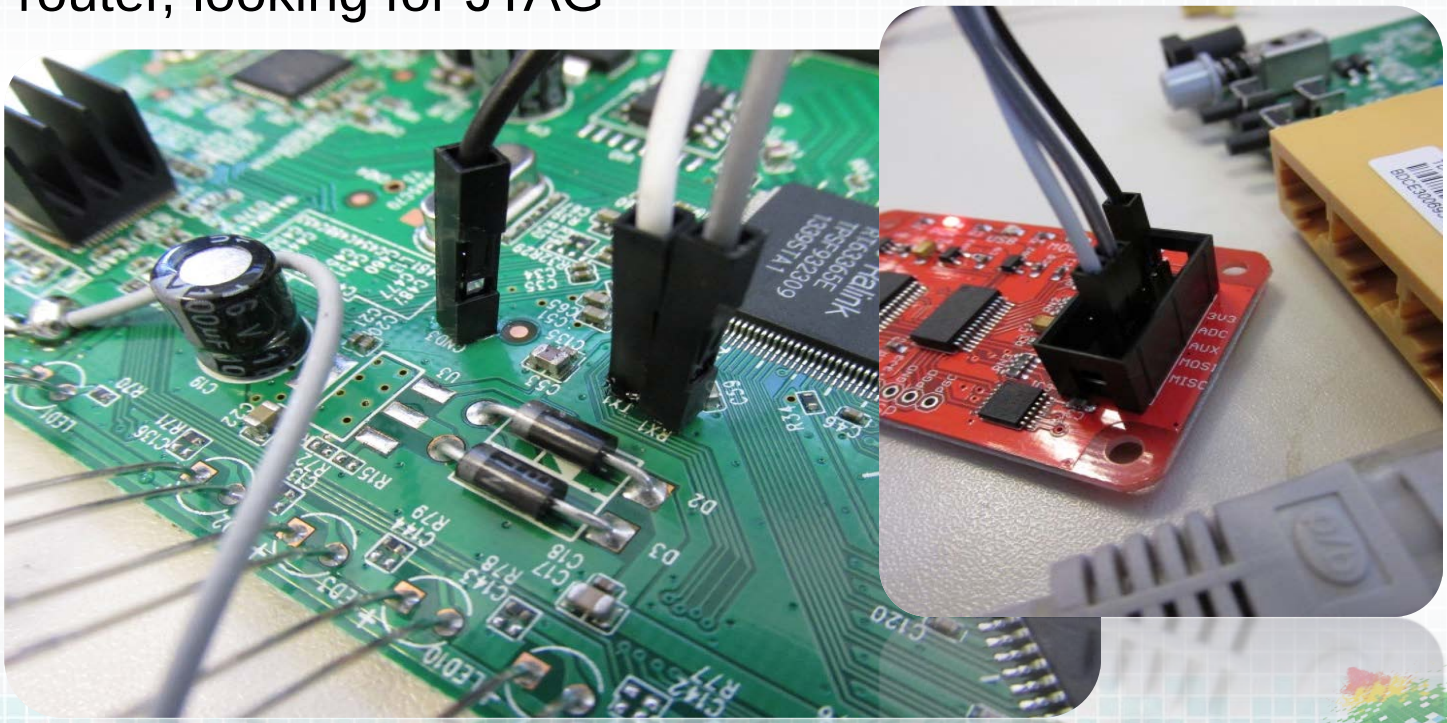
```
sw      $v0, 0x24($a0)
la      $t7, aContentLengt_0  # "content-length"
sw      $t7, 0x34($a0)
li      $t5, 0xE
sh      $t5, 0x38($a0)
la      $t2, HttpContentLengthHandler
sw      $t2, 0x30($a0)
la      $t0, aReferer     # "referer"
sw      $t0, 0x40($a0)
li      $a2, 7
sh      $a2, 0x44($a0)
la      $v1, HttpRefererHandler
sw      $v1, 0x3C($a0)
la      $t8, aHost        # "host"
sw      $t8, 0x4C($a0)
li      $t6, 4
sh      $t6, 0x50($a0)
la      $t3, HttpHostHandler
sw      $t3, 0x48($a0)
la      $t1, aAuthorization  # "authorization"
sw      $t1, 0x58($a0)
li      $a3, 0xD
sh      $a3, 0x5C($a0)
```

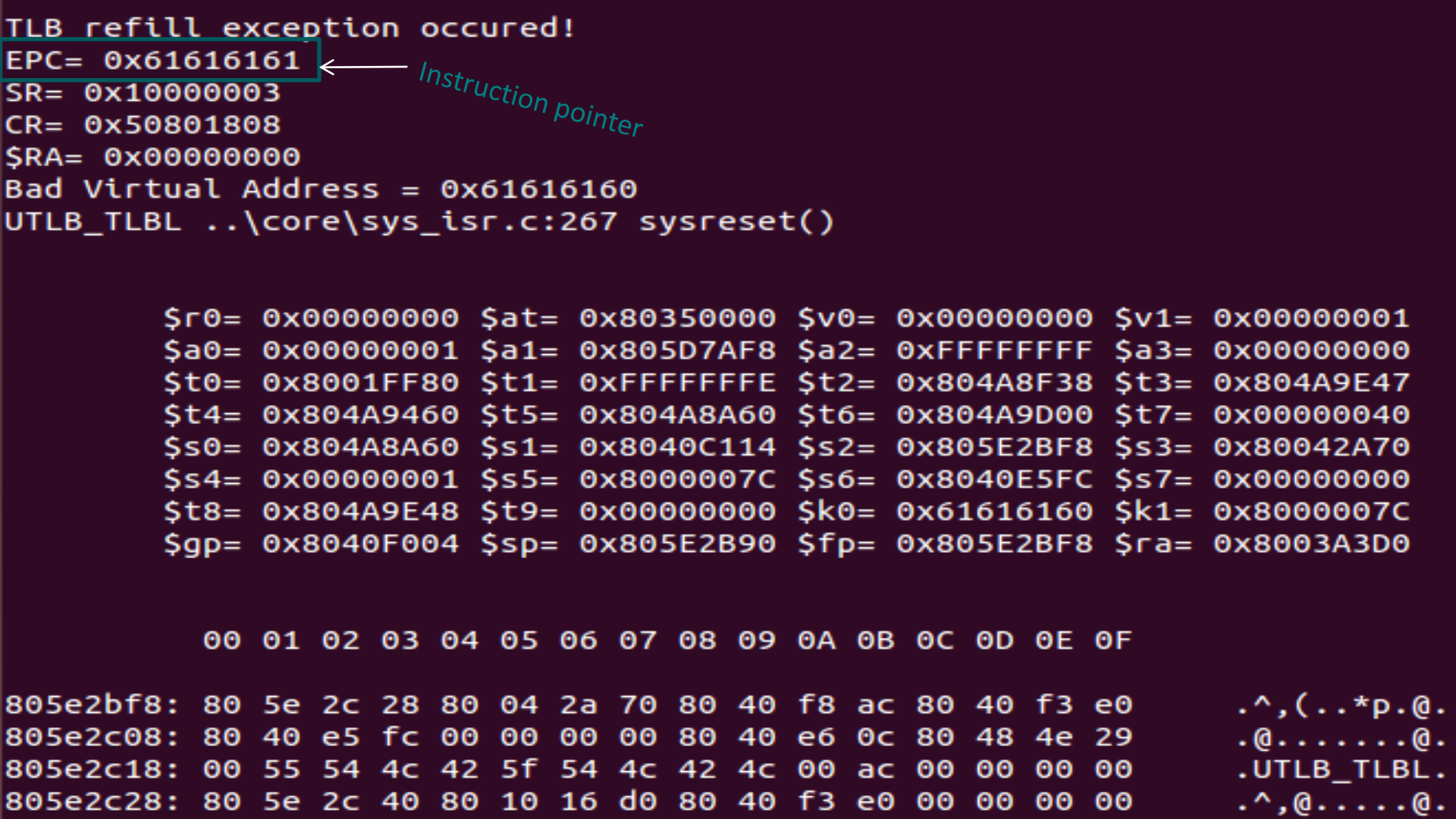
Vulnerability #1

```
Start 0x8010e234



.ent DigestUsernameHandler

var_8= -8
var_4= -4

addiu    $sp, -8
addiu    $a0, 0x3D60
sw       $ra, 8+var_4($sp)
addu     $at, $a1, $a2
sw       $fp, 8+var_8($sp)
sb       $zero, 0($at)
jal      strcpy
move     $fp, $sp
lw       $ra, 8+var_4($sp)
lw       $fp, 8+var_8($sp)
jr       $ra

addiu    $sp, 8
.end DigestUsernameHandler

End 0x8010e264
```

Debugging Level-Up

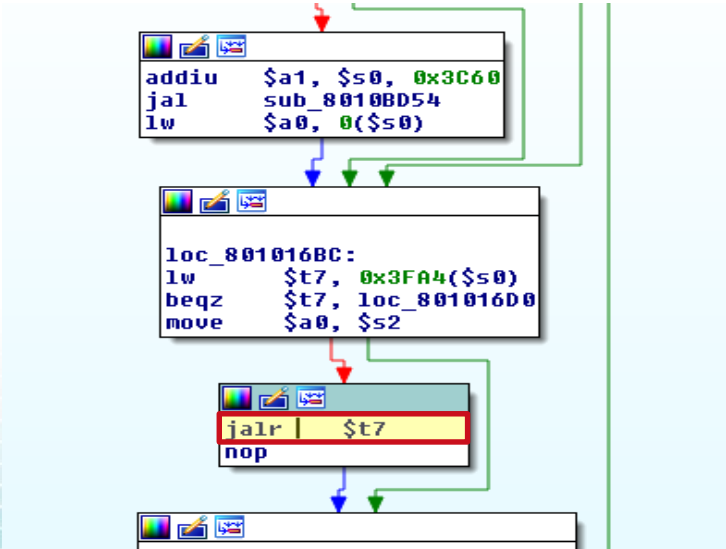
- Open up the router, looking for JTAG
- No JTAG
- U-ART?




TLB refill exception occured!
EPC= 0x61616161
Instruction pointer
SR= 0x10000003
CR= 0x50801808
$RA= 0x00000000
Bad Virtual Address = 0x61616160
UTLB_TLBL ..\core\sys_isr.c:267 sysreset()
$r0= 0x00000000 $at= 0x80350000 $v0= 0x00000000 $v1= 0x00000001
$a0= 0x00000001 $a1= 0x805D7AF8 $a2= 0xFFFFFFFF $a3= 0x00000000
$t0= 0x8001FF80 $t1= 0xFFFFFFFE $t2= 0x804A8F38 $t3= 0x804A9E47
$t4= 0x804A9460 $t5= 0x804A8A60 $t6= 0x804A9D00 $t7= 0x00000040
$s0= 0x804A8A60 $s1= 0x8040C114 $s2= 0x805E2BF8 $s3= 0x80042A70
$s4= 0x00000001 $s5= 0x8000007C $s6= 0x8040E5FC $s7= 0x00000000
$t8= 0x804A9E48 $t9= 0x00000000 $k0= 0x61616160 $k1= 0x8000007C
$gp= 0x8040F004 $sp= 0x805E2B90 $fp= 0x805E2BF8 $ra= 0x8003A3D0
00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
805e2bf8: 80 5e 2c 28 80 04 2a 70 80 40 f8 ac 80 40 f3 e0 .^,(..*p.@.
805e2c08: 80 40 e5 fc 00 00 00 00 80 40 e6 0c 80 48 4e 29 .@.....@.
805e2c18: 00 55 54 4c 42 5f 54 4c 42 4c 00 ac 00 00 00 00 .UTLB_TLBL.
805e2c28: 80 5e 2c 40 80 10 16 d0 80 40 f3 e0 00 00 00 00 .^,@.....@.

Exploit #1

- Unprotected strcpy
- 1. send large username
- 2 overwrite function pointer with ptr to shellcode
- 3 profit!
- Too easy?



Variance in the Wild

- Each device/firmware version has a different address space layout (“Nature’s ASLR”)
- If you know your target firmware and the exact memory layout, you can run code without too much hassle
- Attacker gets one chance per router because of dynamic IP allocation
- A potential generic solution would include finding an anchor for the shellcode using another infoleak vuln.
- That could work, but let’s keep looking!

Poor Man's GDB

ZynOS has unknown memory access debug primitives in serial

- Pre-boot

- Dynamic reversing is very slow
  - Patch, crash, repeat

- ZORDON - ZynOs Remote Debugger (Over the Network)
  - Breakpoints
  - View/Edit Memory and registers

Vulnerability #2

- Each incoming HTTP request populates a pre-allocated “request structure”.
  - No dynamic memory allocation, remember?
- RomPager 4.07 handles processing of up to 3 concurrent requests (3 pre-allocated structures)
- By sending 3 consecutive requests, one can overwrite the HTTP handlers structures

```
sh      $t5, 0x38($a0)
la      $t2, HttpContentLengthHandler
sw      $t2, 0x30($a0)
la      $t0, aReferer     # "referer"
sw      $t0, 0x40($a0)
li      $a2, 7
sh      $a2, 0x44($a0)
la      $v1, HttpRefererHandler
sw      $v1, 0x3C($a0)
```

```
TLB refill exception occured!
EPC= 0x61616161
SR= 0x10000003
CR= 0x50801808
$RA= 0x00000000
Bad Virtual Address = 0x61616160
UTLB_TLBL ..\core\sys_isr.c:267 sysreset()


        $r0= 0x00000000 $at= 0x80350000 $v0= 0x00000000 $v1= 0x00000001
        $a0= 0x00000001 $a1= 0x805D7AF8 $a2= 0xFFFFFFFF $a3= 0x00000000
        $t0= 0x8001FF80 $t1= 0xFFFFFFFE $t2= 0x804A8F38 $t3= 0x804A9E47
        $t4= 0x804A9460 $t5= 0x804A8A60 $t6= 0x804A9D00 $t7= 0x00000040
        $s0= 0x804A8A60 $s1= 0x8040C114 $s2= 0x805E2BF8 $s3= 0x80042A70
        $s4= 0x00000001 $s5= 0x8000007C $s6= 0x8040E5FC $s7= 0x00000000
        $t8= 0x804A9E48 $t9= 0x00000000 $k0= 0x61616160 $k1= 0x8000007C
        $gp= 0x8040F004 $sp= 0x805E2B90 $fp= 0x805E2BF8 $ra= 0x8003A3D0


          00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

805e2bf8: 80 5e 2c 28 80 04 2a 70 80 40 f8 ac 80 40 f3 e0      .^,(..*p.@...@..
805e2c08: 80 40 e5 fc 00 00 00 00 80 40 e6 0c 80 48 4e 29      .@.......@...HN)
805e2c18: 00 55 54 4c 42 5f 54 4c 42 4c 00 ac 00 00 00 00      .UTLB_TLBL......
805e2c28: 80 5e 2c 40 80 10 16 d0 80 40 f3 e0 00 00 00 00      .^,@.....@......
```

Exploit #2

- How can you exploit this?
  - Blind memory read (by replacing the HTTP header string ptr)

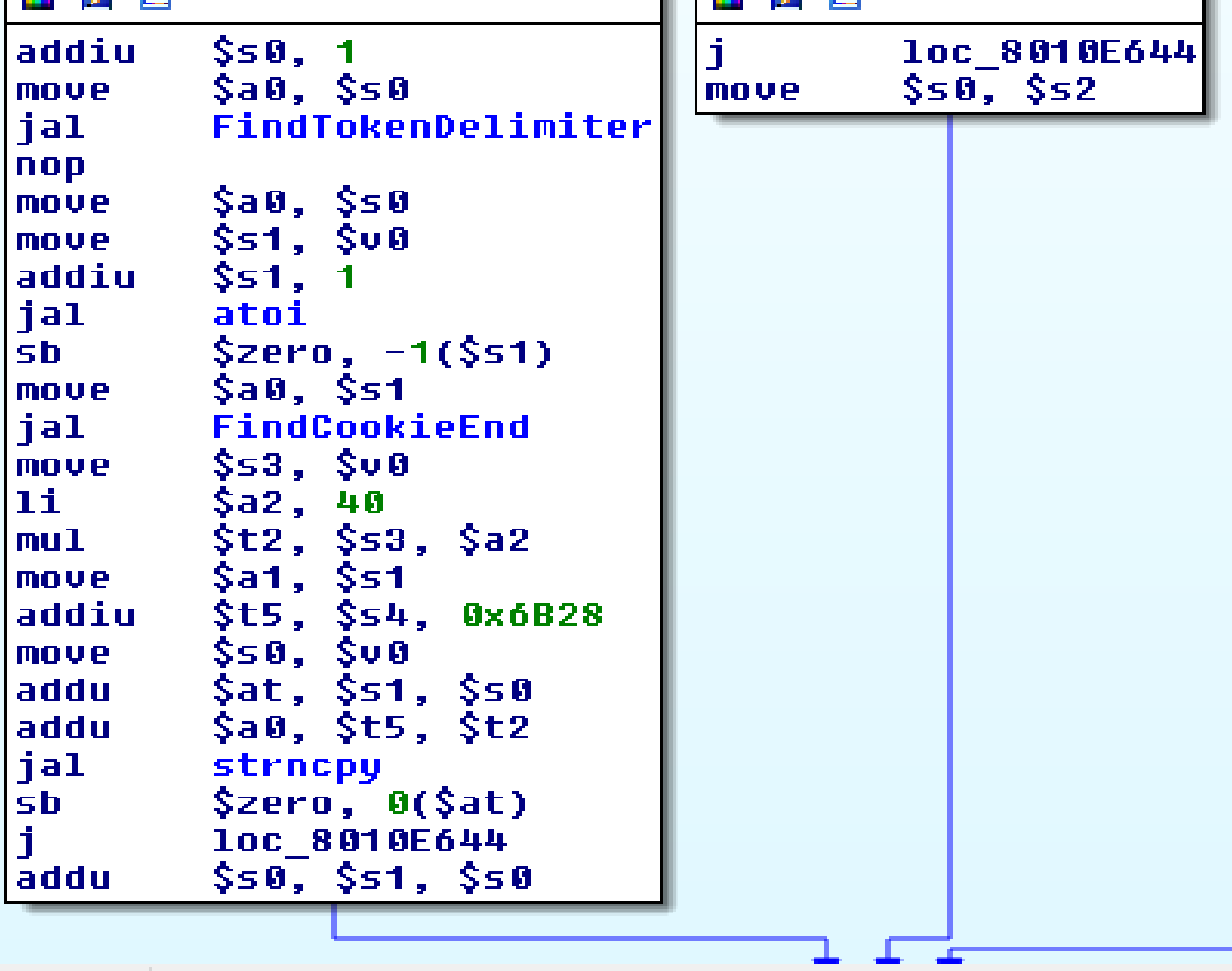
- Problem: only works on port 80.
  - already have “rom-0” for that

Vulnerability #3

Vulnerability #3

- Rom pager supports cookies
  - No dynamic memory allocation, remember?
- Pre-allocated cookies array
  - 10 cookies, 40 bytes long each
  - C0,C1,C2,…,C9

```
Accept-Encoding: gzip, deflate, sdch
Accept-Language: en-US,en;q=0.8,he;q=0.6
Cookie: C0=21232f297a57a5a743894a0e4a801fc3;

HTTP/1.1 200 OK
Content-Type: text/html
Date: Sat, 01 Jan 2000 00:05:13 GMT
```


addiu $s0, 1
move $a0, $s0
jal FindTokenDelimiter
nop
move $a0, $s0
move $s1, $v0
addiu $s1, 1
jal atoi
sb $zero, -1($s1)
move $a0, $s1
jal FindCookieEnd
move $s3, $v0
li $a2, 40
mul $t2, $s3, $a2
move $a1, $s1
addiu $t5, $s4, 0x6B28
move $s0, $v0
addu $at, $s1, $s0
addu $a0, $t5, $t2
jal strncpy
sb $zero, 0($at)
j loc_8010E644
addu $s0, $s1, $s0
j loc_8010E644
move $s0, $s2

Exploit #3 – Misfortune Cookie

- Arbitrary memory write relative to a fixed anchor in the RomPager internal management struct
  - Pretty much controls everything RomPager does
  - Overflow 32-bit for negative offsets ☺
- Non-harmful example as a POC:

```
Cookie: C107373883=/omg1337hax
```

Object Not Found

The requested URL '/omg1337hax' was not found on the RomPager server.

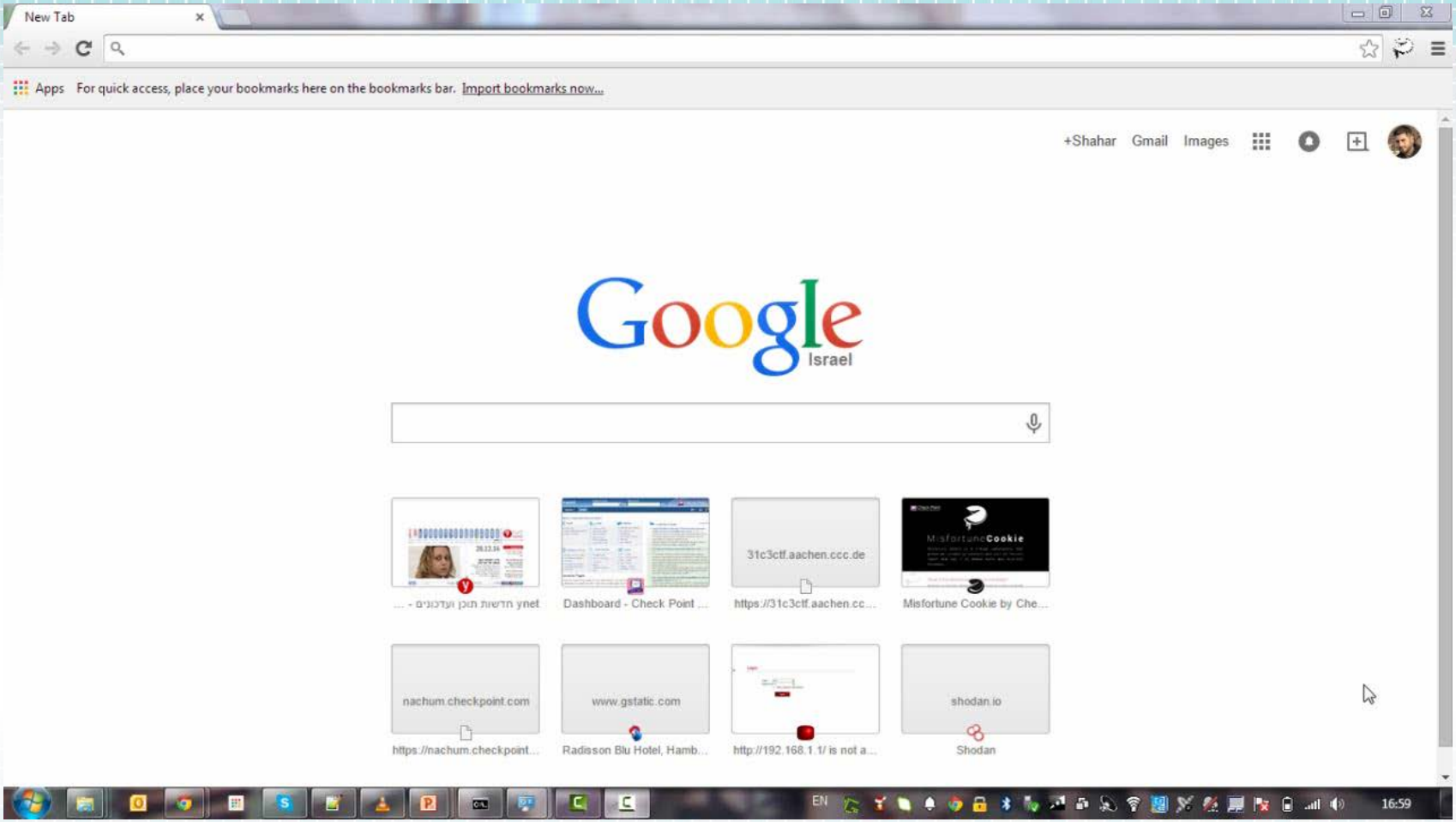
Return to last page

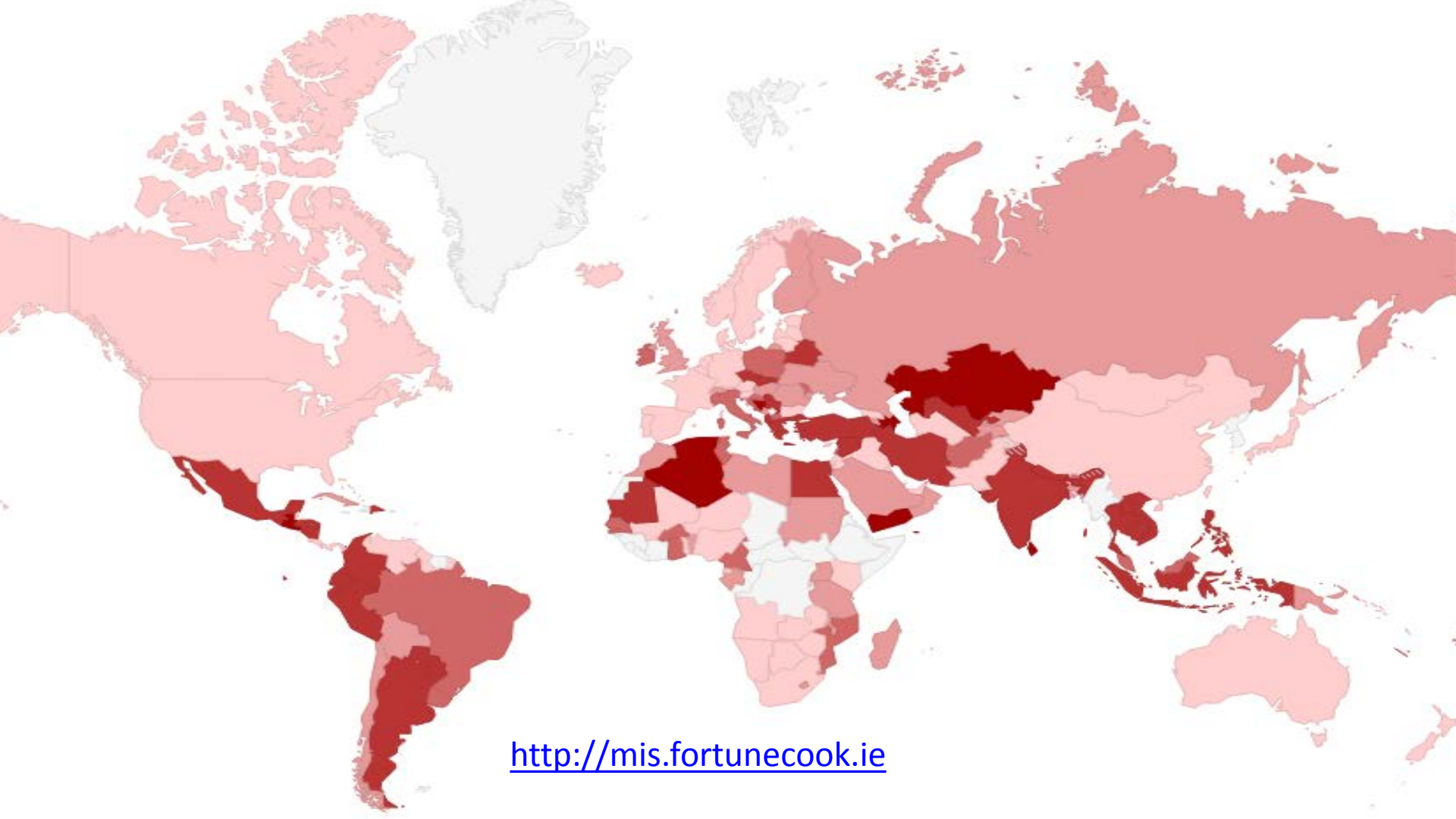
- **The technique works on any model of any brand that we had access to**

Exploit #3 – Misfortune Cookie

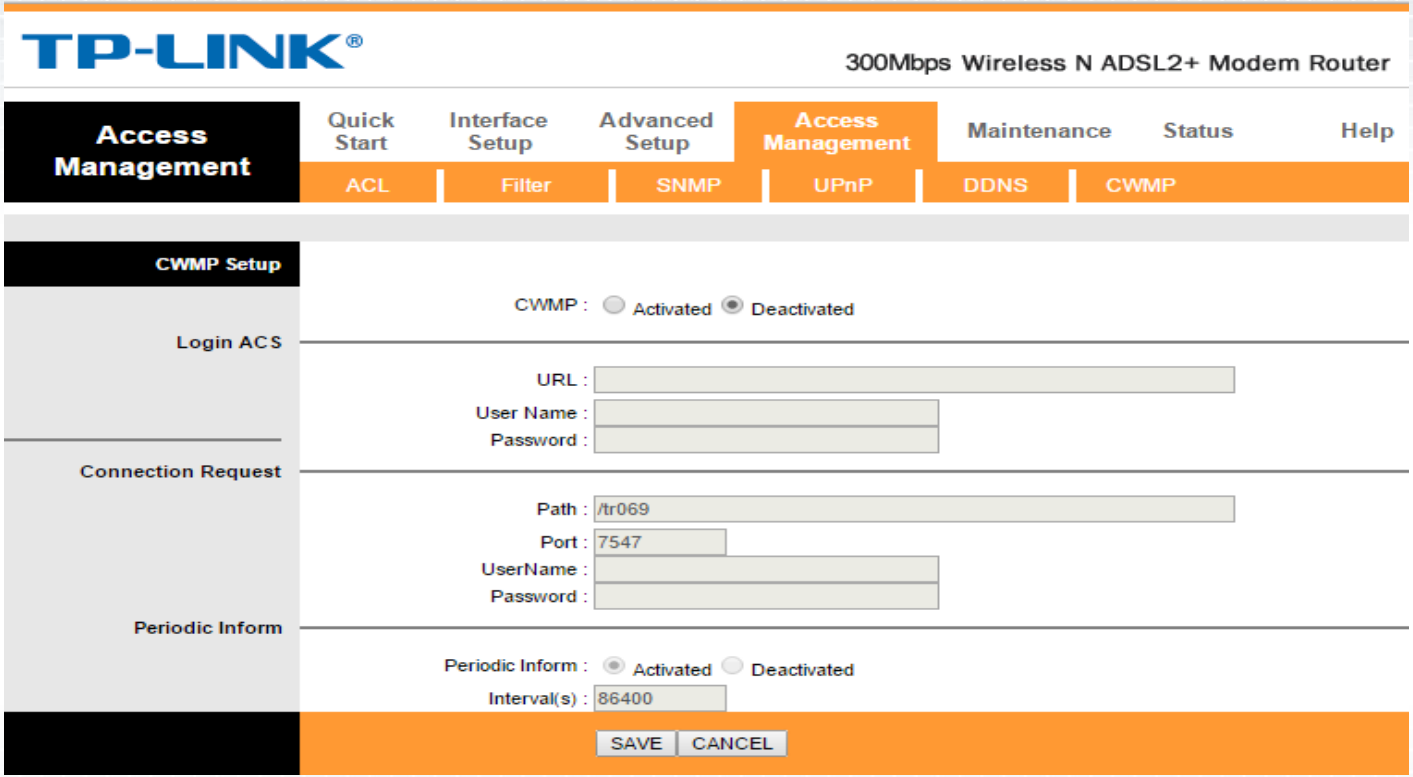
With a few magic cookies added to your request
you **bypass any authentication** and browse the configuration interface **as admin**, from **any open port**.

CVE-2014-9222/9223
http://mis.fortunecook.ie

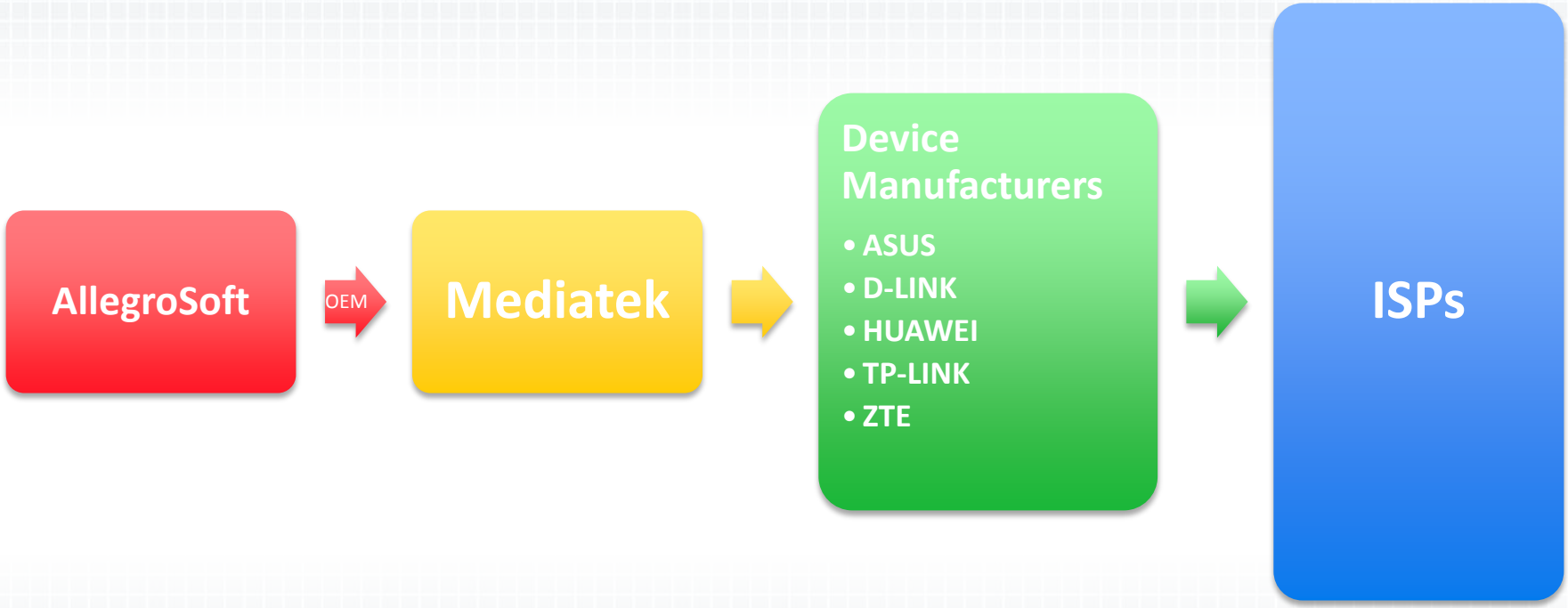

New Tab
Apps
For quick access, place your bookmarks here on the bookmarks bar.
Import bookmarks now...
+Shahar
Gmail
Images
Google
Israel
31c3ctf.aachen.ccc.de
Misfortune Cookie
Dashboard - Check Point ...
https://31c3ctf.aachen.cc...
Misfortune Cookie by Che...
nachum.checkpoint.com
www.gstatic.com
shodan.io
https://nachum.checkpoint...
Radisson Blu Hotel, Hamb...
http://192.168.1.1/ is not a...
Shodan
EN
16:59



http://mis.fortunecook.ie


TP-LINK®
300Mbps Wireless N ADSL2+ Modem Router
Access Management
Quick Start
Interface Setup
Advanced Setup
Access Management
Maintenance
Status
Help
ACL
Filter
SNMP
UPnP
DDNS
CWMP
CWMP Setup
CWMP : Activated Deactivated
Login ACS
URL :
User Name :
Password :
Connection Request
Path : /tr069
Port : 7547
UserName :
Password :
Periodic Inform
Periodic Inform : Activated Deactivated
Interval(s) : 86400
SAVE
CANCEL

FW Manufacturing Process



Vendor Communication

- We contacted AllegroSoft and the major affected vendors
  - Provided full description of the vulnerability and a non-harmful POC that triggers it
- Despite some broken English, the message got through
  - Most of the time
- AllegroSoft
  - “Can’t force any vendor to upgrade to latest version” **(they actually provided a patched version in 2005)**

Exploits in Public

- Analysis & exploit released February 16 by cawan (*Chui Yew Leong from Malaysia)*
  - http://cawanblog.blogspot.com/2015/02/misfortune-cookie-cve-2014-9222.html
  - Good job!
- CANVAS by Immunity released exploit for TP-W8961ND
  - https://vimeo.com/121925542
  - Seems to be similar to the one released by cawan

Recap

- We found a critical vulnerability in the **most popular service exposed in the public Internet.**
  - As far as we know
- Reported to all vendors.
- We made it public-friendly, with a catchy name, fancy logo and explanatory web site.
- A public exploit was released two months ago.

Is the Internet on fire?

- Do people care?
- Do vendors care?

- Also, check out https://istheinternetonfire.com

Can TP-Link clarify which, if any, models are vulnerable to the serio
for those products?

This report claims many WiFi routers, including TP-Link products, c
http://mis.fortunecook.ie/

12-29-2014 06:28

tplink

Administrator

Join Date: Mar 2012

Posts: 6

We have learned about the issue published by checkpoint a few days before, but we confirm it cannot actually attack our modem router (latest hardware & firmware versions for all models).
Let's have a further explanation, attackers make up cookies which includes our modem router's internal actions, and send it to LAN IP of the modem router, then the router will respond to the cookie. For example, attacker makes up a cookie which includes "rom-0", and send it to our modem with LAN IP address 192.168.1.1, then the router receives it and respond "rom-0 not found".
It in fact equals to access the router via http://192.168.1.1/rom-0 (or other URL), but all our modem routers with security mechanism firmware has already banned th

we confirm it cannot actually attack our modem route

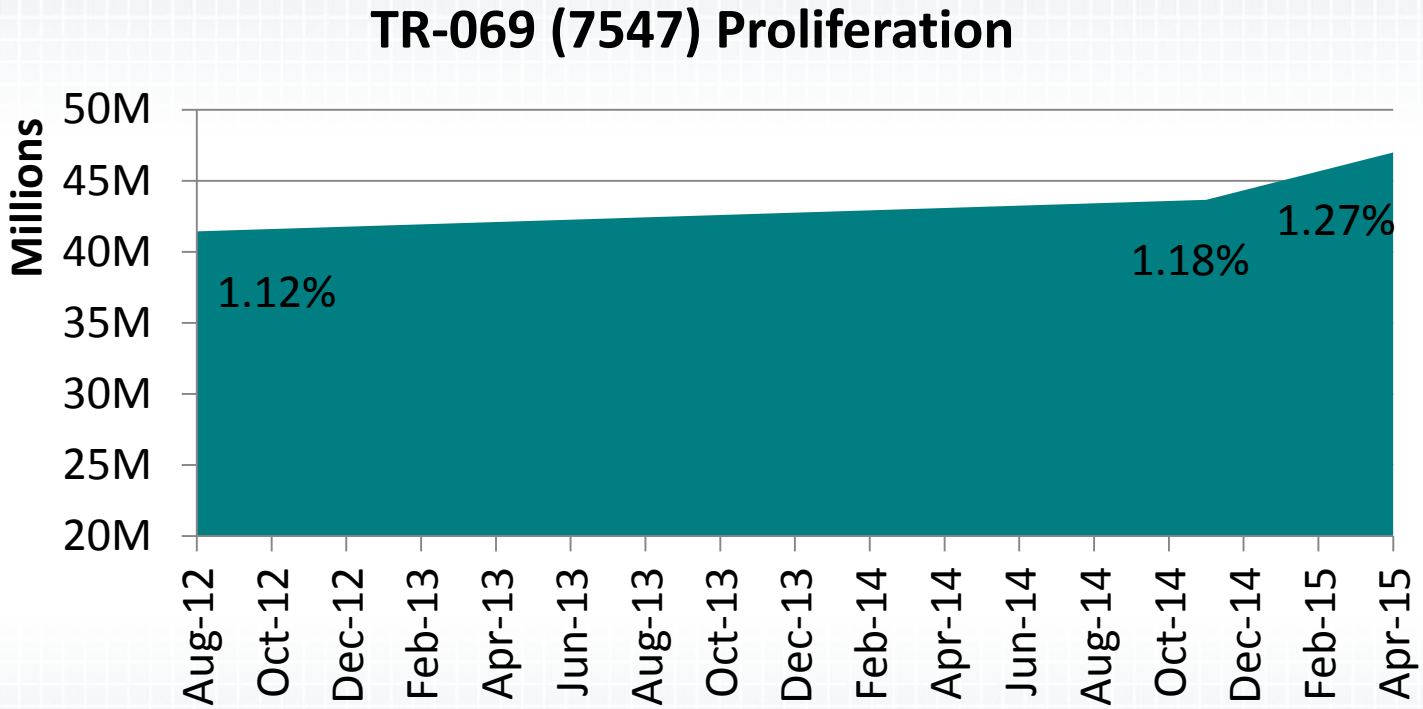
from the root.
If your modem router is not using latest hardware, however, please refer to this FAQ to do some settings, it will also make your modem router more safe.
http://www.tp-link.com/en/article/?faqid=573

Vendor Responses - Patch Wall of Shame

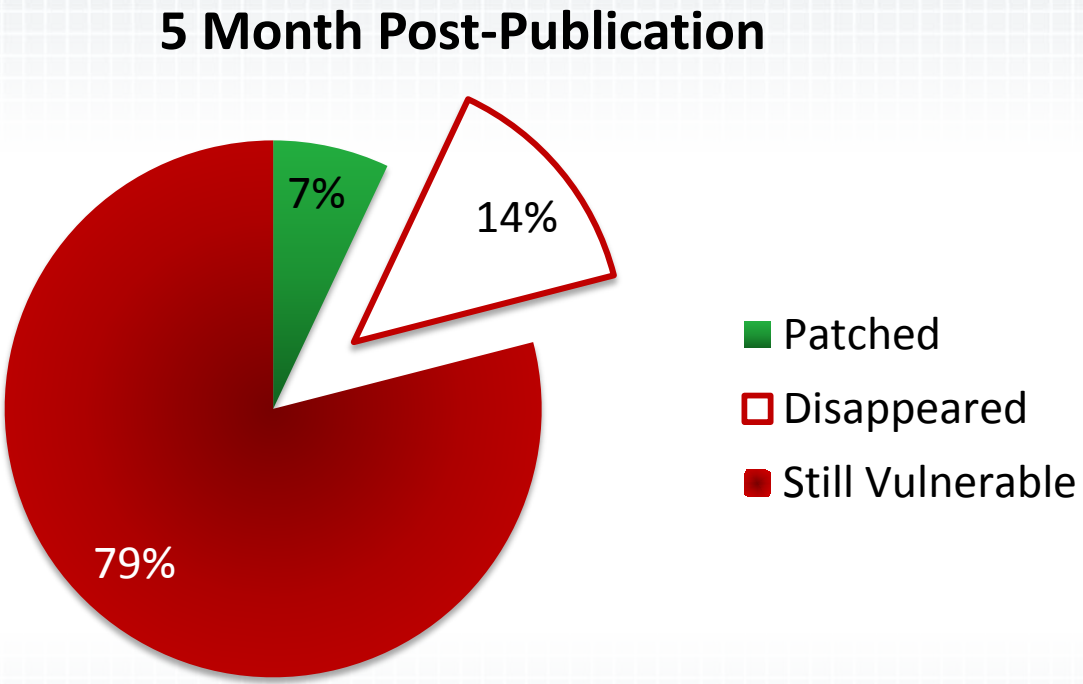
Vendor	Affected Models	Fixed	Will Fix	Won't Fix	
HUAWEI	2	2	-	-	http://www.huawei.com/en/security/psirt/security-bulletins/security-advisories/hw-407666.htm (December 2014)
ZTE	12	?	?	2	http://support.zte.com.cn/support/news/LoopholeInfoDetail.aspx?newsId=1006342 (January 2015)
ZyXEL	60	4	7 (Mar 15)	49	http://www.zyxel.com/support/announcement_misfortune_cookie_vulnerability.shtml (February 2015)
TP-Link	23	0	10 (Jun 15)	13	Private thread (April 2015)
D-Link	15	0	?	?	No response yet

(These vendors make up 92% of the vulnerable population)

The TR-069 Census 2015



The TR-069 Census 2015



In the Wild

- We deployed 10 honeypots with allocated IPs across the globe
  - Listening on 7547
  - Pretending to be “RomPager 4.07”
  - Recording all traffic
- We activated silent signatures deployed to ThreatCloud-enabled Check Point gateways around the world.
  - A lot of traffic.
  - Later enabled as ‘loud’ signatures.

Caught in the Wild

- 7547 Scanners
  - Shodan (indexed 40M devices)
  - University of Michigan
  - Meta-Intelligence
  - 7 Unidentified Scanners
    - Identify Yourself ☺

Potential Offenders List
123.30.128.71
12.174.243.4
67.61.75.2
46.183.216.200
199.217.118.79
192.64.41.88
207.10.134.42

Caught in the Wild

- Active Attacks
  - Check Point IPS blocked active attack attempts on a few customer networks
  - We hope to share more details at a future time

F.A.Q.

- Is RomPager bad?
  - No, they were actually very responsive and security aware. We just happened to research an old version of their software.
- Is this an intentionally placed backdoor?
  - Doesn't look like it.
- Can you tell me which IPs are affected in my country?
  - Scan 80 + 7547 + custom ISP TR-069 connection request ports

Apply

- Immediate actions:
  - Close all open ports to the WAN , accept those which are required and monitored.
  - Read Misfortune Cookie FAQ at: http://mis.fortunecook.ie
- In the upcoming months:
  - Detect any Misfortune Cookie vulnerable devices in your organization and update their firmware accordingly. You could also flash alternative firmware.
- Long term goals:
  - Reevaluate security of your network devices and their administrative access.
  - Replace low-end network devices with more security aware devices.

A Pessimistic Outlook

- We made a difference, but…
- Vendors are not paying the price for bad security.
- Customers (individuals and enterprises) should be the first to care.
  - That will only happen after a major compromise is revealed
  - Chances are it already happened
  - Chances are it won't be traced to the network gateway
- Vulnerable "Won't Fix"/EOS devices will stay online and unpatched for years

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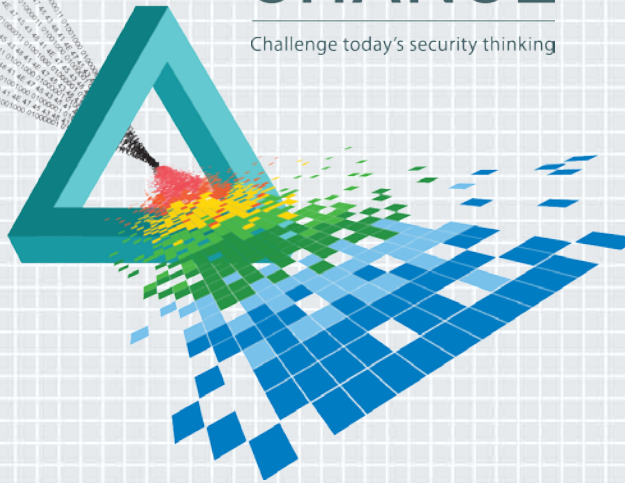

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Thank You!

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