
Too Many Cooks
Exploiting the
Internet of TR-069 Things
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@oppenheim1
Check Point
SOFTWARE TECHNOLOGIES LTD.


MATTHEW KODY FOSTER
AS "COAT"


SMARF


SHAHAR TAL
as himself


LIOR OPPENHEIM
as himself


LARS VON TRIER
AS "PIE"
[adult

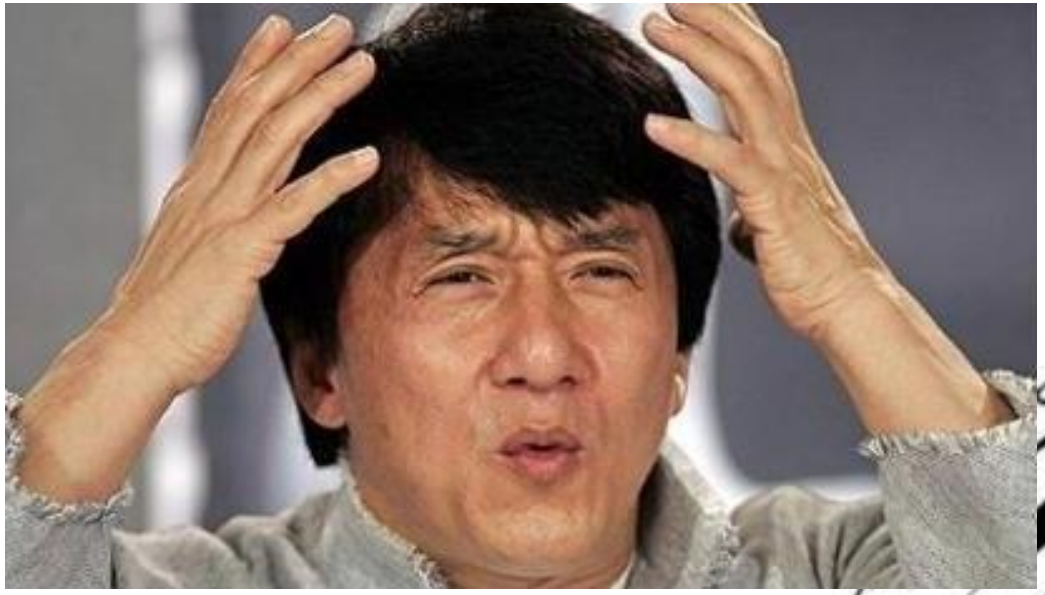
DANNY DEVITO

as "IPv4-enabled Toaster"


GIL SHWED
as "Big Boss"/ "Security Mastermind"

ARNOLD SCHWARZENEGGER

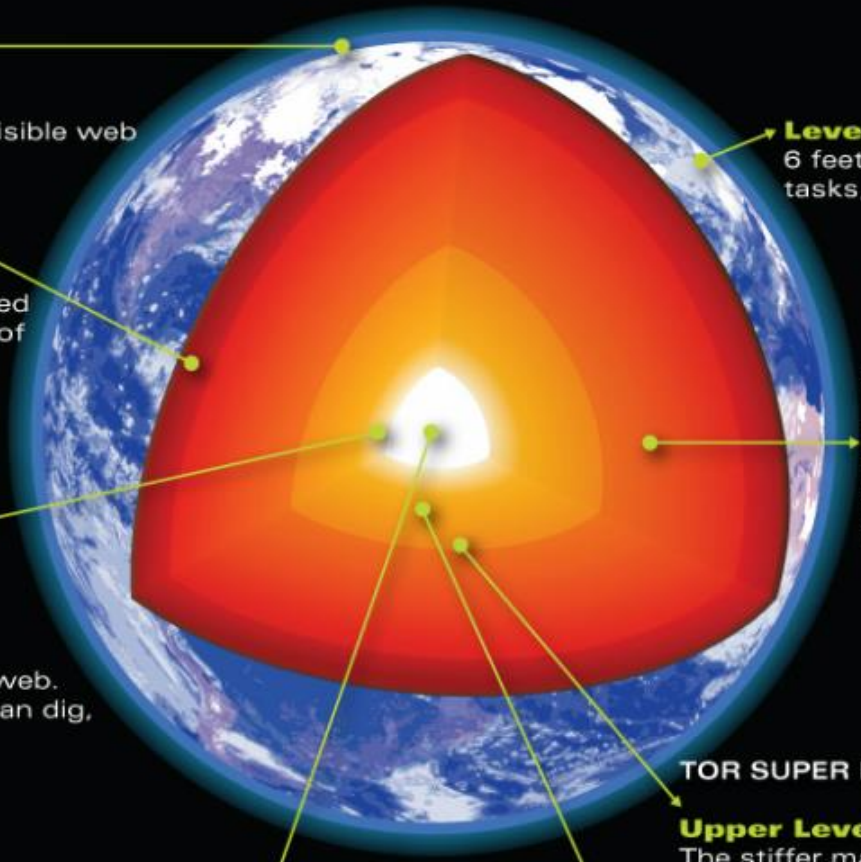
as "TP-Link TD-W8961ND"



JACKIE CHAN

as himself in "WHAT? meme"

Levels of the deep web



Level 0
Google and friends – the visible web

Level 1
6 feet under. Contains newgrounds, web freaks, Intel tasks, web hosting, colleges.

Level 2
We're getting warmer.
FTP servers, google's locked results, heavy porn, most of the info on the net.

FOR FURTHER DIGGING PROXI IS REQUIRED

Level 3
Deep web - heavy porn, hackers, pedophile, archives, math research, super-computing, visual processing, gore, suicides

Level 5
the inner core – Marianas web.
Where no one you know can dig,
in a solid state.
Quantum computing.

TOR SUPER DEEP BOREHOLE IS NOW IN SESSION

Upper Level 4
The stiffer mantle - Hardcandy, onion IB, hidden wiki, assassins line of blood, most of the black market, hard drugs trade, bount hunters, human trafficking, everybody's personal records

Level 6 - 8
The hottest place on the planet.
level 6 - Mainly super quantom programming defending from breaches
level 7 - The people that are trying
level 8 - The source. non respons s signals to all other levels and affects them directly.

CLOSED SHELL SYSTEM REQUIRED FOR FURTHER DRILLING

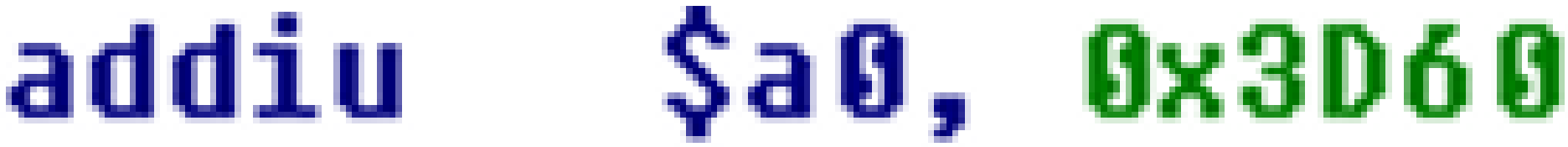
Lower Level 4
Tesla plans, scat CP, hardcore rape, ww2 experiments, location of Atlantis, assassination networks, gadolinium gallium garnet quantum electronic processors, crystalline power metrics, CAIMEO (AI Super-intelligence), The Law of 13's, Geometric Algorthymic Shortcuts, Nephilism Protocols

עג"ג

as "Cyber Expert"

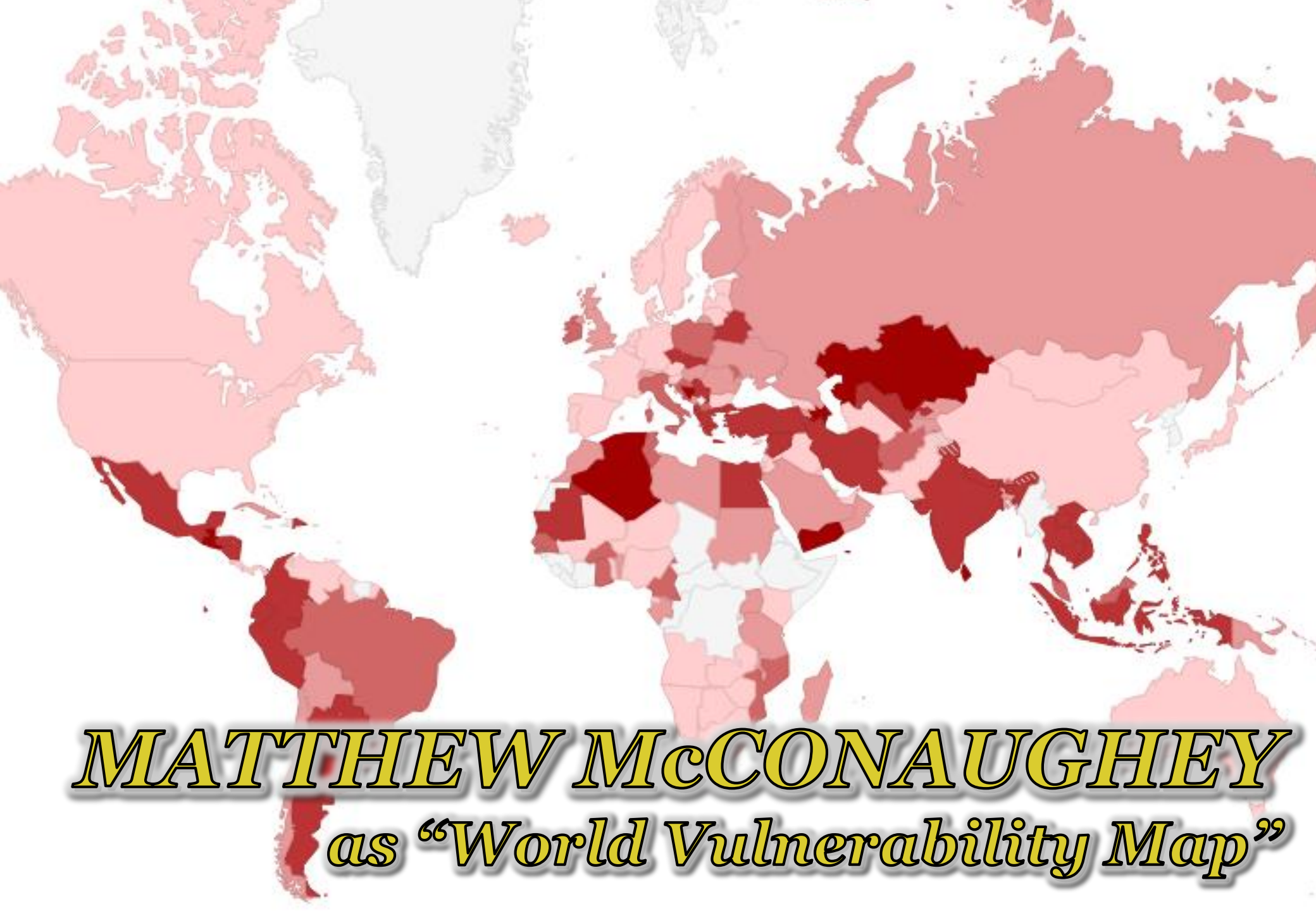
Prezi

(Homage for Wiki deep web http://deepweb.wikia.com/wiki/Levels_of_the_Deep_Web)



SETH ROGAN

as "Add Immediate (unsigned) MIPS Instruction"


MATTHEW McCONAUGHEY
as "World Vulnerability Map"


CHECK POINT
as "Hiring AWESOME PEOPLE in Tel Aviv"

Too Many Cooks

- Awesome viral video that we liked
- Written and directed by Casper Kelly
- Watch it

HOW THE BIZARRE ADULT SWIM 'INFOMERCIAL' T
MANY COOKS TOOK OVER THE INTERNET

How did this happen? Creator Caspar Kelly tries to explain.

By Ben Collins on November 7, 2014

Follow @oneunderscore_ 1,487 followers

Watch Adult Swim's Demented, Surreal Sitcom Parody 'Too Many Cooks'

he 12-minute video, created by Casper Kelly, first aired on the network duri
rning "Infomercials" slot

Share 493 Tweet 342 Pin it Comment 8 Email

/USR/BIN/WHOAREWE

- Malware and Vulnerability Research @ Check Point

1. Find Problems
2. Tell Vendors
3. Share with Community

Agenda

- TR-069 quick tour / DEF CON recap
- Motivation
- The TR-069 Census 2014
- Research Highlights
- Mass Pwnage ← BORDERLINE-LEGAL DEMO HERE
- A Pessimistic Outlook

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?

broadband forum

- 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

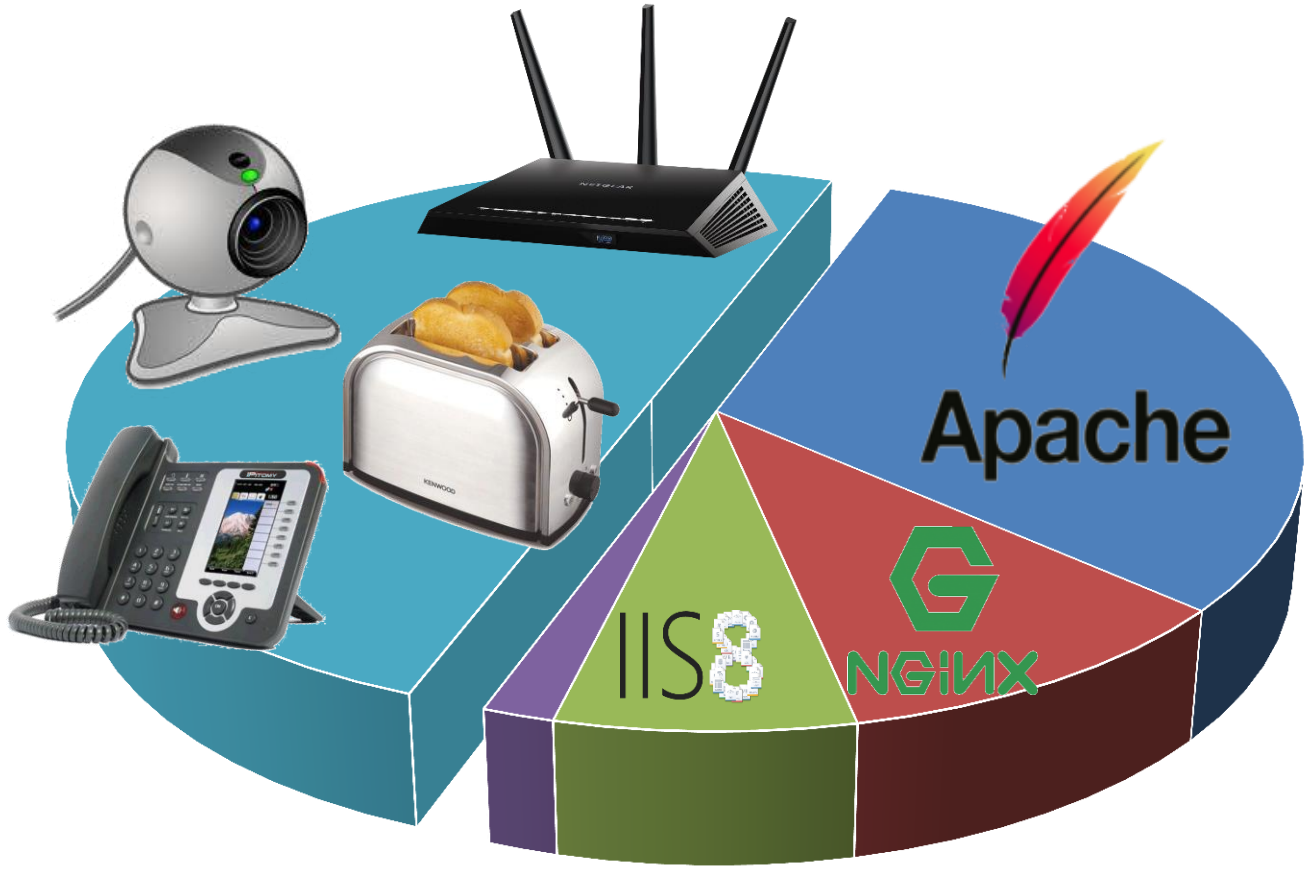
Connection Request

- "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."

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

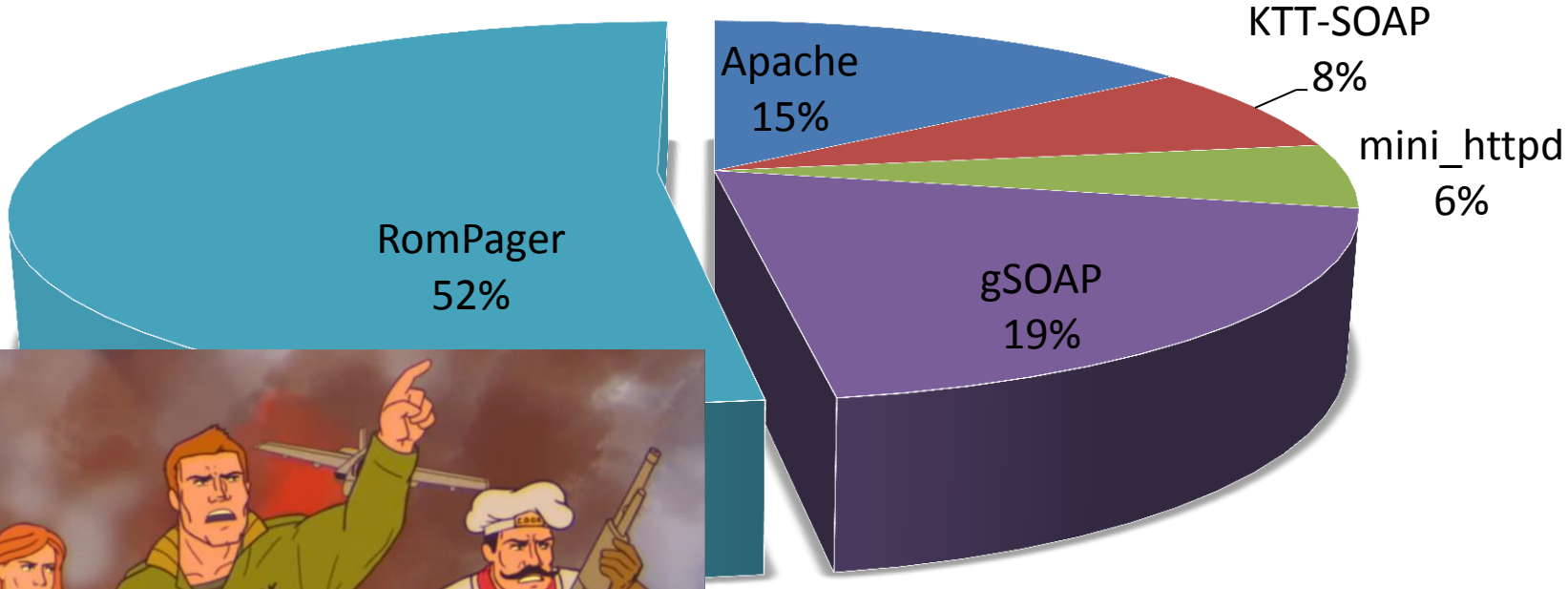
The TR-069 Census 2014

- 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

RAPID7

MICHIGAN

TR-069 CR Server Distribution

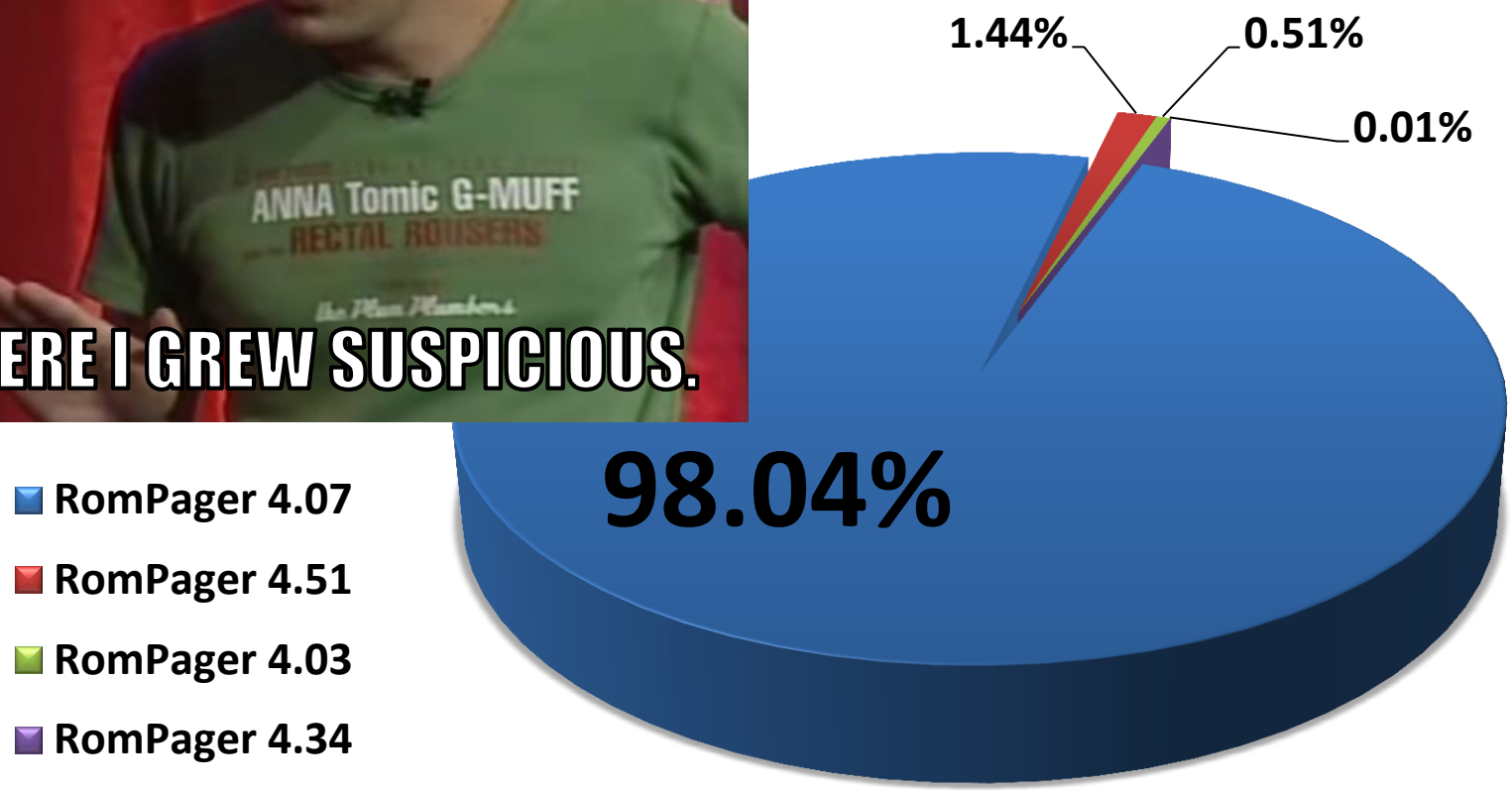


What is RomPager

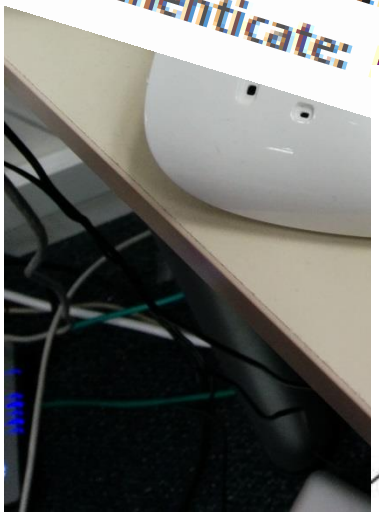
Internet Software for Embedded Devices

- 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"



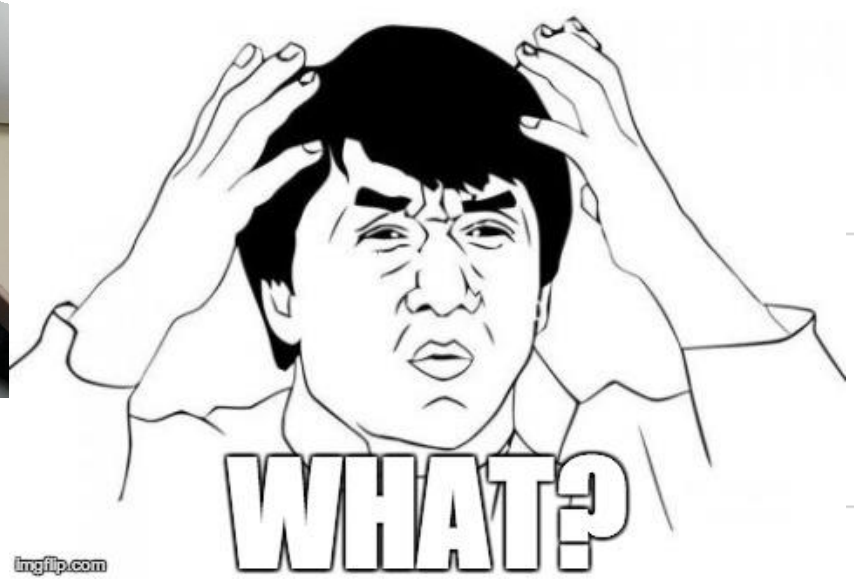
Published Date	3/5/2014
Language	English
File Size	1.38 MB
	Win2000/XP/2003/Vista/7/8/Mac/Linux

TD-W8961ND_V3_140305

security mechanism.
ter's time can't synchron

6. [illegible] after we set up
7. Forbidden access to the de[illegible] 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 7547

- 200 different identified models
- 50 different brands

FIRMWARE ANALYSIS

Dig deeper

- Explore the firmware
  - Firmware update is one t
  - 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)

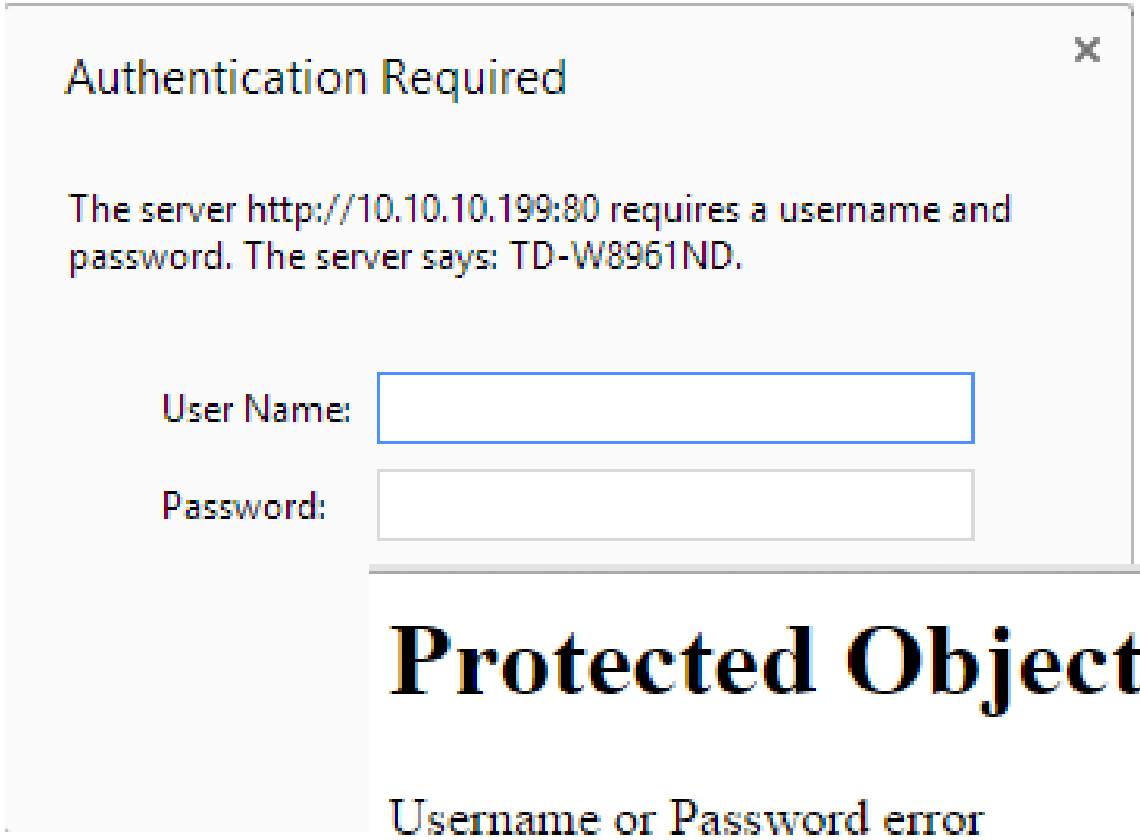
ZynOS

- 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)


The attack surface

http://192.168.1.1



http://192.168.1.1:7547

Object Not Found

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

Return to last page

Manual Testing

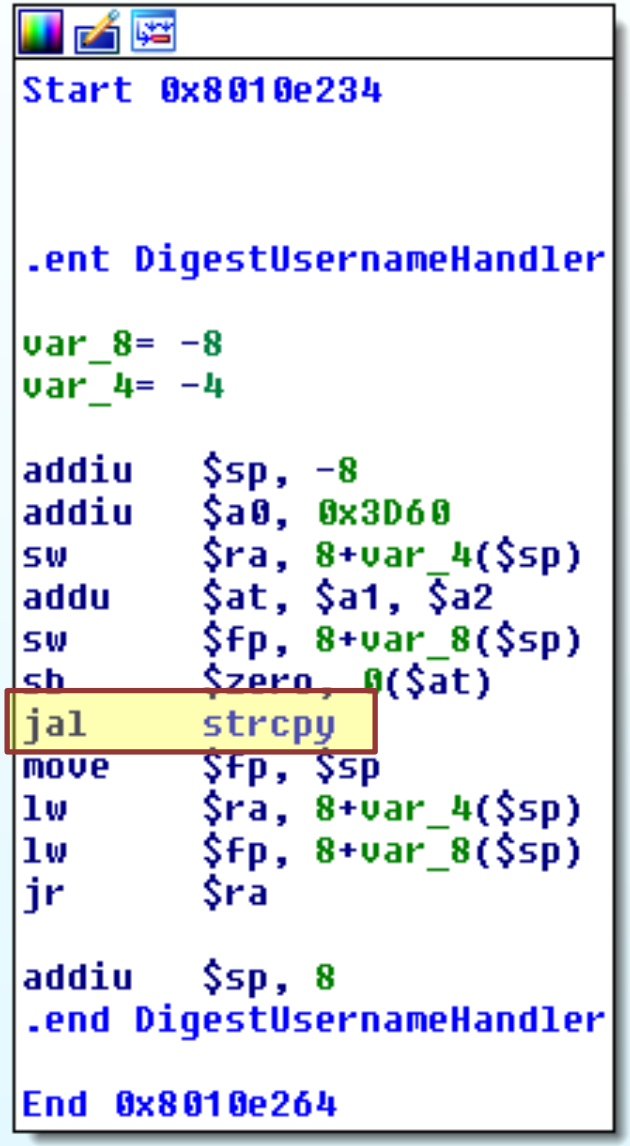
- Fuzzing over http headers
- Crashed on username sub-header of digest authentication

  {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)
```

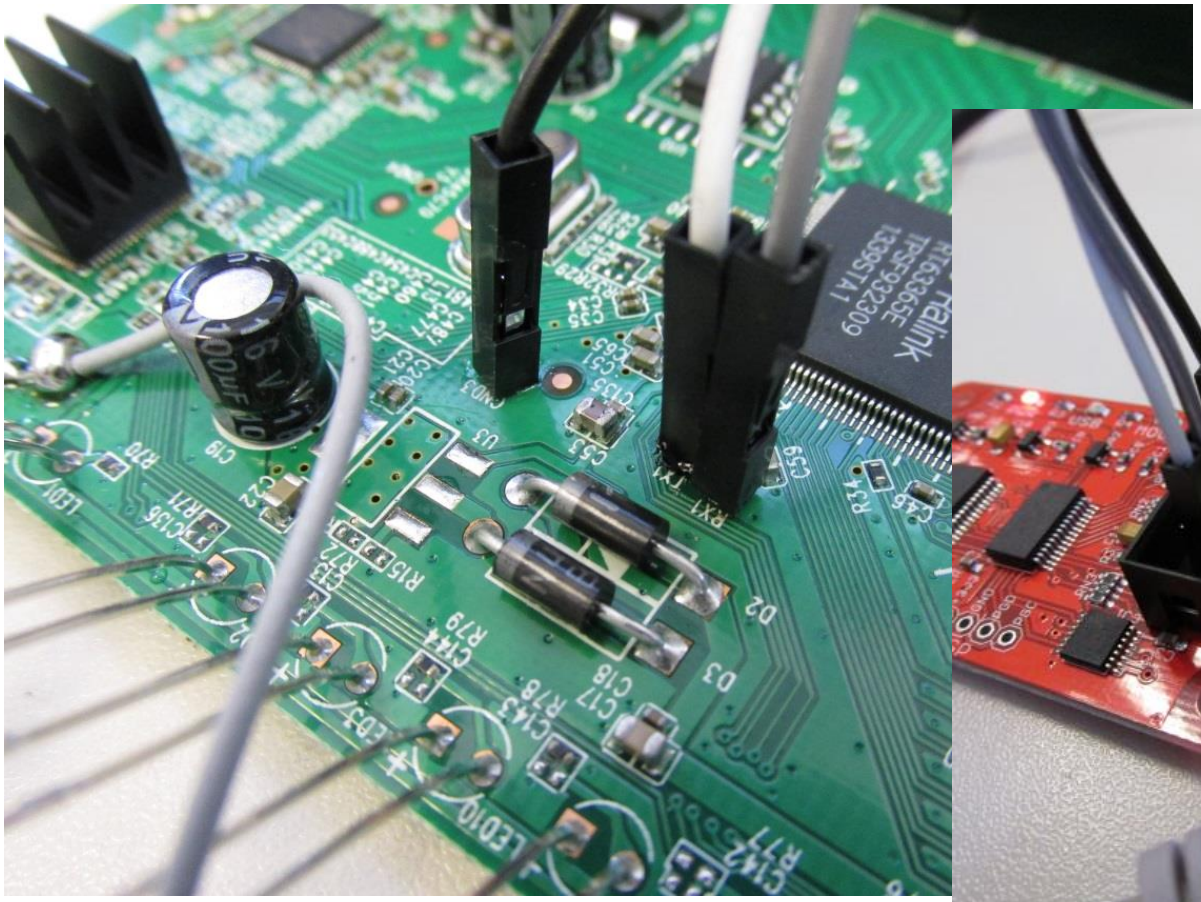
Vulnerability #1

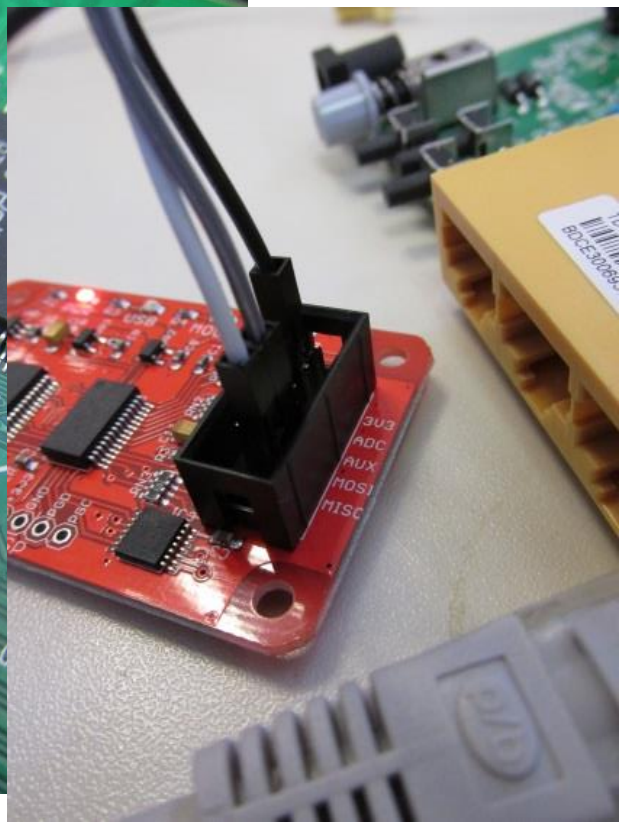


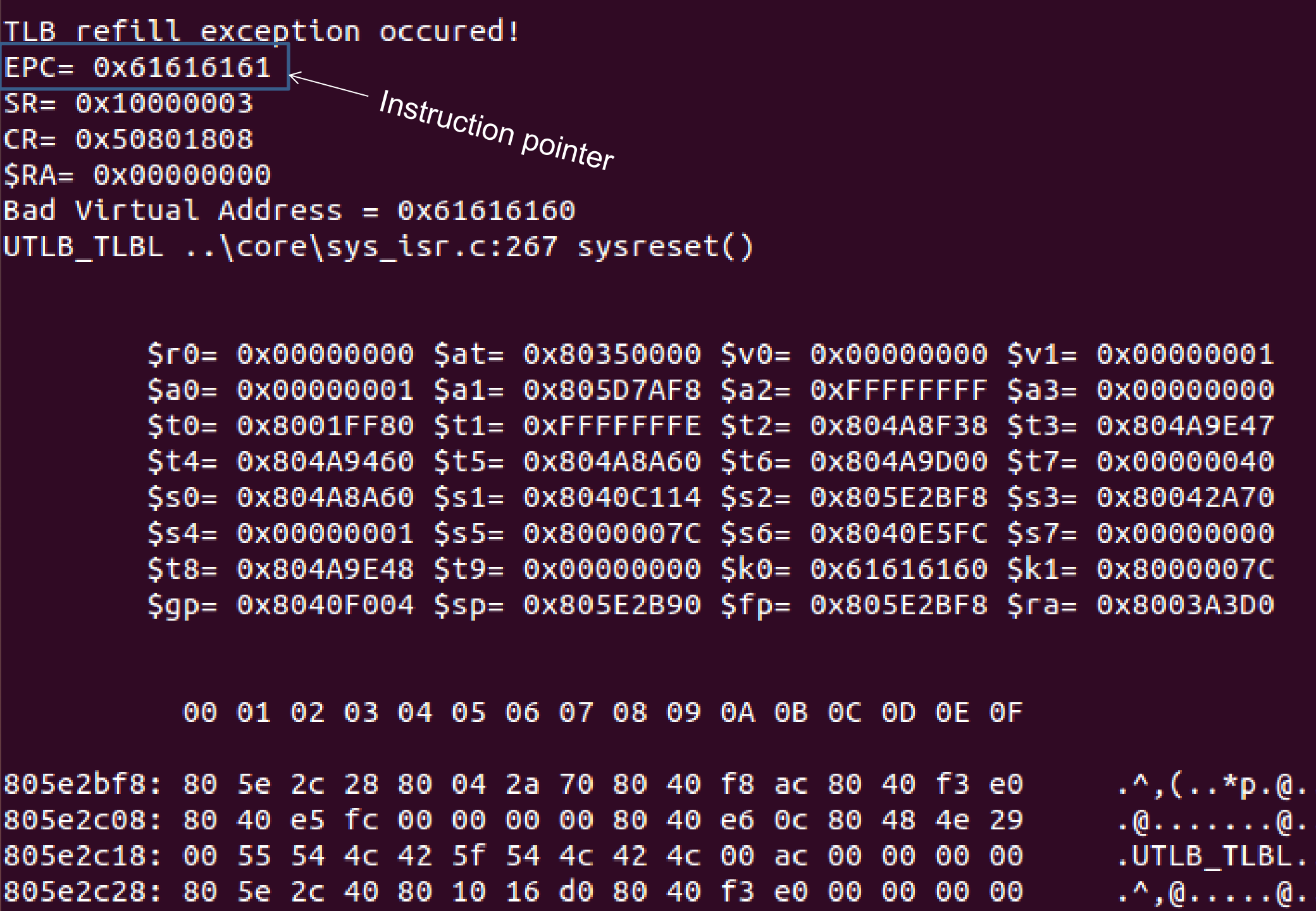
```
Start 0x8010e234



.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
```

Pimped up my router

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

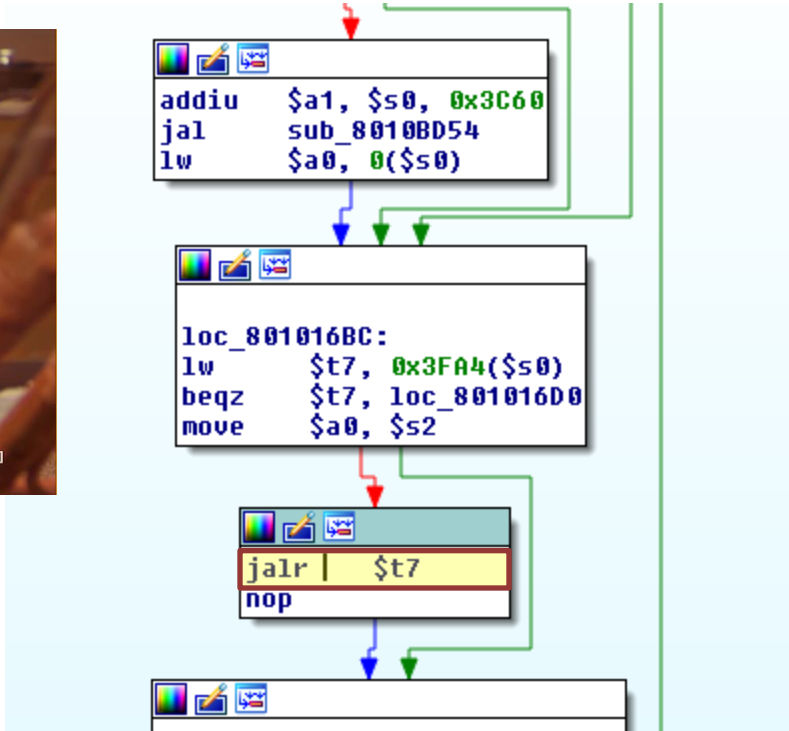





TLB refill exception occured!
EPC= 0x61616161
SR= 0x10000003
CR= 0x50801808
$RA= 0x00000000
Bad Virtual Address = 0x61616160
UTLB_TLBL ..\core\sys_isr.c:267 sysreset()
Instruction pointer
$r0= 0x00000000 $at= 0x80350000 $v0= 0x00000000 $v1= 0x00000001
$a0= 0x00000001 $a1= 0x805D7AF8 $a2= 0xFFFFFFFF $a3= 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 p
  - Pre-boot
- Dynamic reversing is very slow
  - Patch, crash, repeat
- No JTAG support
- 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)

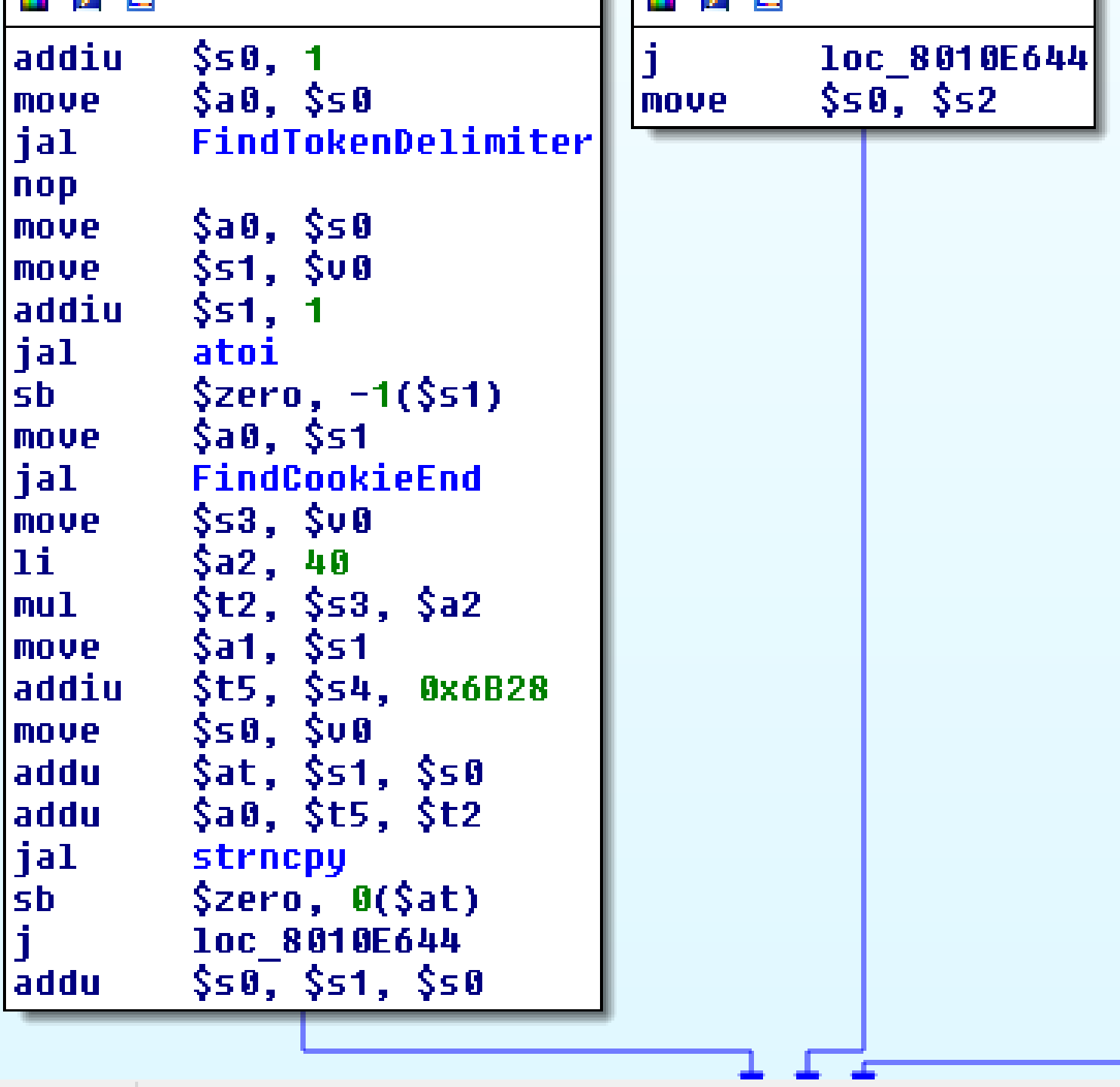
- Problem: only works on port 80.
  - already have "rom-0" for that

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**.

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

Port

UserName

Password

Periodic Inform

Periodic Inform

Interval(s

Countermeasures

- Cancel Internet subscription
- Alternative firmware
- Don't buy these models until they're fixed
  http://mis.fortunecook.ie/misfortune-cookie-suspected-vulnerable.pdf

Manufacturing process

Alleg oft

Device Manufacturers

- ZTE

Too Many Cooks DO SPOIL THE BROTH

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
  - Some patched firmware already out
- AllegroSoft
  - "Can't force any vendor to upgrade to latest version" (**they actually provided a patched version in 2005**)

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 share the exploit?
  - No.
- Can you tell me which IPs are affected in my country?
  - Scan 80 + 7547 + custom ISP TR-069 connection request ports

Recap

- We found a pretty serious vulnerability in the most popular service exposed in IPv4.
  - As far as we know

Hey industry, fix this.


Thank You
@jifa
@oppenheim1