Compression Oracle Attacks on VPN Networks

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Defcon 26

About

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Interested in AppSec and writing software

Maker @ assetwatch.io, Attacker Surface Discovery as a Service

Overview

Compression Side Channel and Encryption

History of attacks

VPNs and how they use compression

Demo - Voracle Tool

How to find if your "VPN" is vulnerable

Way forward

Data Compression

LZ77

Replace redundant patterns

102 Characters

Everything looked dark and bleak, **everything looked** gloomy, and **everything** was under a blanket of mist

89 Characters

Everything looked dark and bleak, **(-34,18)**gloomy, and **(-54,11)**was under a blanket of mist

Data Compression

Huffman Coding

Replace frequent bytes with shorter codes

Char	Freq	Code
space	7	111
a	4	010
e	4	000
f	3	1101
h	2	1010
i	2	1000
m	2	0111
n	2	0010

https://en.wikipedia.org/wiki/Huffman_coding

Data Compression

DEFLATE - LZ77 + Huffman Coding

ZLIB, GZIP are well known DEFLATE libraries

Compression Side Channel

First known research in 2002

Compression and Information Leakage of Plaintext

John Kelsey, Certicom

The Side Channel

Length of encrypted payloads

Destination	Protocol	Length	Info
162.243.9.106	UDP	118	54452 → 443 Len=76
162.243.9.106	UDP	123	54452 → 443 Len=81
162.243.9.106	ISAKMP	158	IKE_AUTH MID=02 Initiator
162.243.9.106	UDP	119	54452 → 443 Len=77

Compression Oracle

Chosen Plain Text Attack

Brute force the secret byte by byte

Force a compression between the chosen byte and the existing bytes in the secret

Compression Oracle

Cookie: secret=637193 -some-data- Cookie: secret=1

Cookie: secret=637193 -some-data- (-34,15)1

Encrypted Payload Length = 43

Compression Oracle

Cookie: secret=637193 -some-data- Cookie: secret=2

Cookie: secret=637193 -some-data- (-34,15)2

Encrypted Payload Length = 43

Compression Oracle

Cookie: secret=637193 -some-data- Cookie: secret=3

Cookie: secret=637193 -some-data- (-34,15)3

Encrypted Payload Length = 43

Compression Oracle

Cookie: secret=637193 -some-data- Cookie: secret=4

Cookie: secret=637193 -some-data- (-34,15)4

Encrypted Payload Length = 43

Compression Oracle

Cookie: secret=637193 -some-data- Cookie: secret=5

Cookie: secret=637193 -some-data- (-34,15)5

Encrypted Payload Length = 43

Compression Oracle

Cookie: secret=637193 -some-data- Cookie: secret=6

Cookie: secret=637193 -some-data- (-34,16)

Encrypted Payload Length = 42

How can we convert this into an attack using browsers?

Back in 2012

The CRIME attack

Ingredients

Attacker on the data path can sniff packet length

Browser attaches cookies as part of any cross-domain request

Attacker controls HTTP request body

You get!

Chosen Plain Text attack using browsers

TIME Attack 2013

Tal Be'ery, Amichai Shulman

Timing side channel purely via browsers

Extending CRIME to HTTP Responses

Breachattack.com

BREACH Attack 2013

Angelo Prado, Neal Harris, Yoel Gluck

BreachAttack.com

So far

CRIME style attacks have been mostly targeted on HTTPS

Researchers have possibly explored all possible side channels to efficiently leak sensitive data

Lets talk VPNs

TLS VPNS

IPSEC

L2TP/ PPTP

TLS VPNs are pretty common these days

NordVPN

Hotspot Shield

PUREVPN

TunnelBear

ExpressVPN

privateinternetaccess

What do most of these SaaS VPNs have in common?

OPENVPN™

Compression

Almost all VPNs support compression by default

OpenVPN Client Configuration (*.OVPN)

```
remote-cert-tls server

#mute 10000
auth-user-pass

comp-lzo
verb 3
pull
fast-io
cipher AES-256-CBC
auth SHA512

<ca>
-----BEGIN CERTIFICATE-----
MIIExDCCA6ygAwIBAgIJAPyaiSxcR5IvMA0GCSqGSI
```

OpenVPN Compression Algorithms

LZO

LZ4

-LZ77 Family-

High level overview

Authentication & Key Negotiation (Control Channel)

Data Channel Encryption

High level overview

Authentication & Key Negotiation (Control Channel)

Data Channel Compression

Data Channel Encryption

Compress everything

UDP

TCP

Bi-Directional

We have a compress then encrypt on all of data channel

CRIME + BREACH on VPN Networks

Existing TLS channel are safe

Things are safe, if the underlying app layer already uses HTTPS / TLS.

Secure | https://www.google.com

```
ssh user@website.com
```

Things might go bad, if the VPN is helping you to encrypt already encrypted data

Not Secure www.bbc.com

```
DNS                74 Standard query 0x4ddc
DNS                74 Standard query 0xc3a7
```

Not Secure | corporate-network.internal.net

Lets see how this attack works on an HTTP website using an encrypted VPN

Given a HTTP Website through VPN, Can we leak Sensitive Cookie Data from a Cross-Domain Website?

Ingredients

- VPN Server and Client has **compression** turned on by default
- VPN User using a **vulnerable browser**
- Visits **attacker controlled website**

Vulnerable Browser?

Yes, the browser plays a huge role in how it sends plain HTTP requests.

Browser needs to send HTTP requests in single TCP Data Packet

Google Chrome splits HTTP packets into Header and Body

So we can't get the compression window in the same request

Mozilla Firefox sends them all in a single TCP data packet

Now we get the compression window in the same request

Attack Setup

VPN User

Attack Setup

VPN User

Vulnerable Browser

Attack Setup

HTTP WebApp

VPN User

Vulnerable Browser

Attack Setup

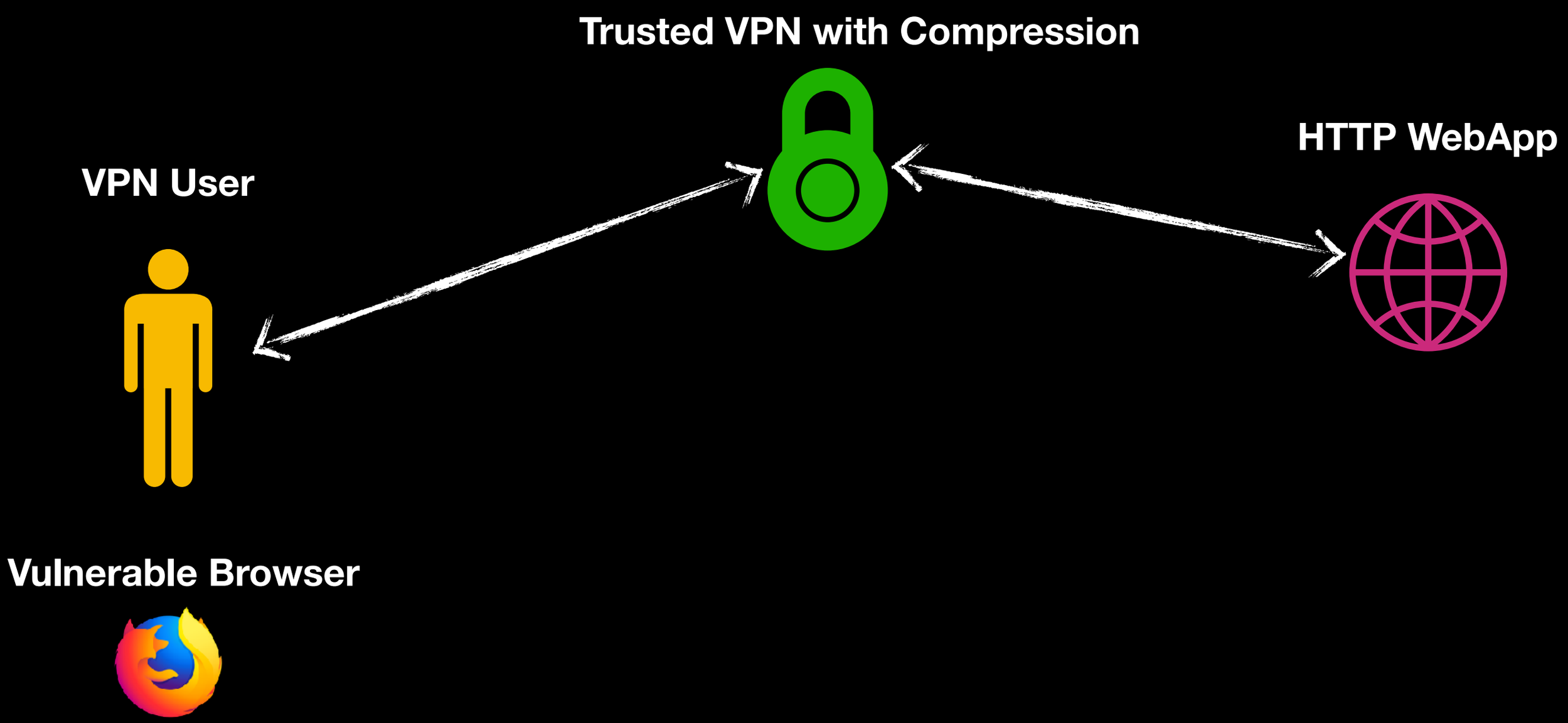
Trusted VPN with Compression

HTTP WebApp

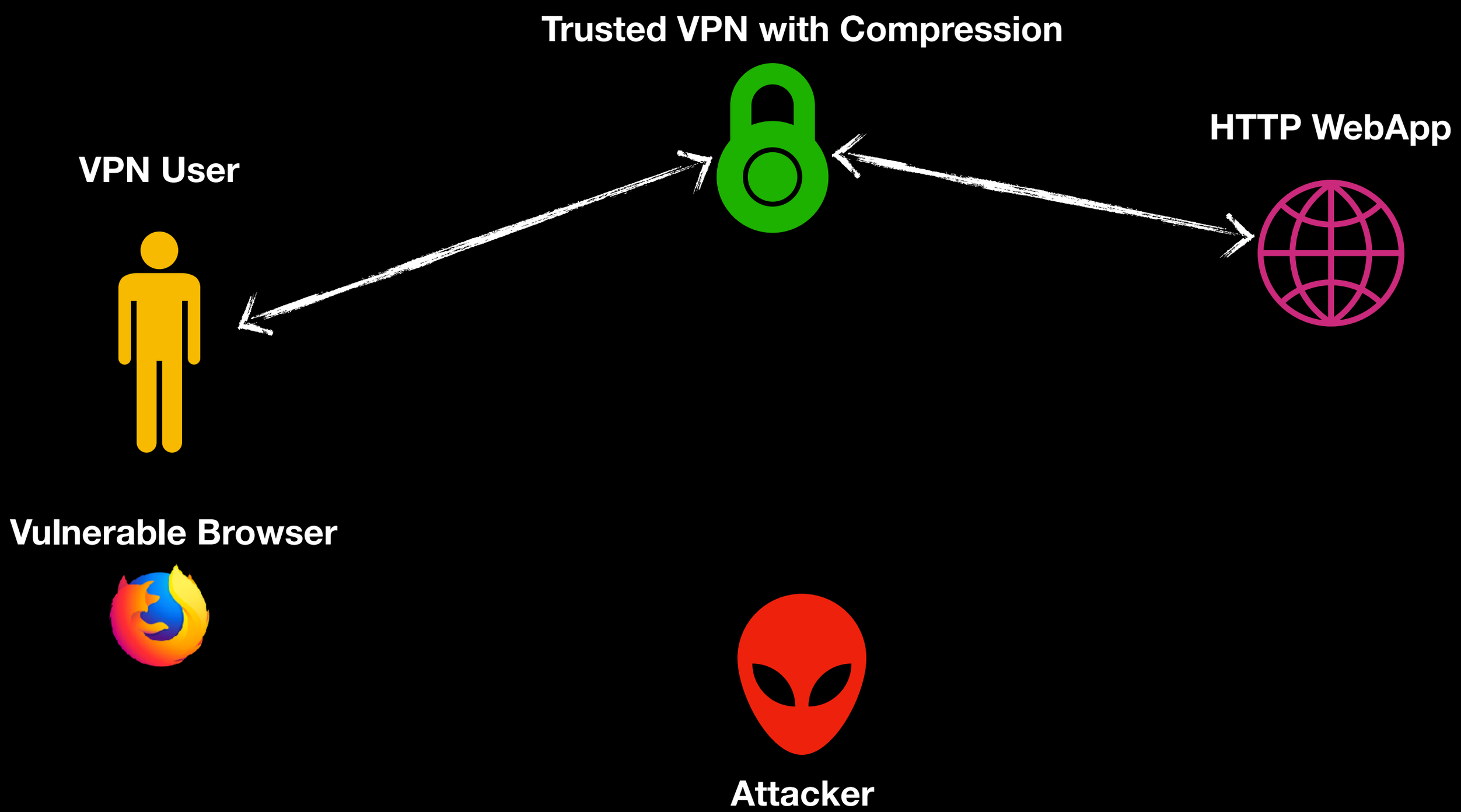
VPN User

Vulnerable Browser

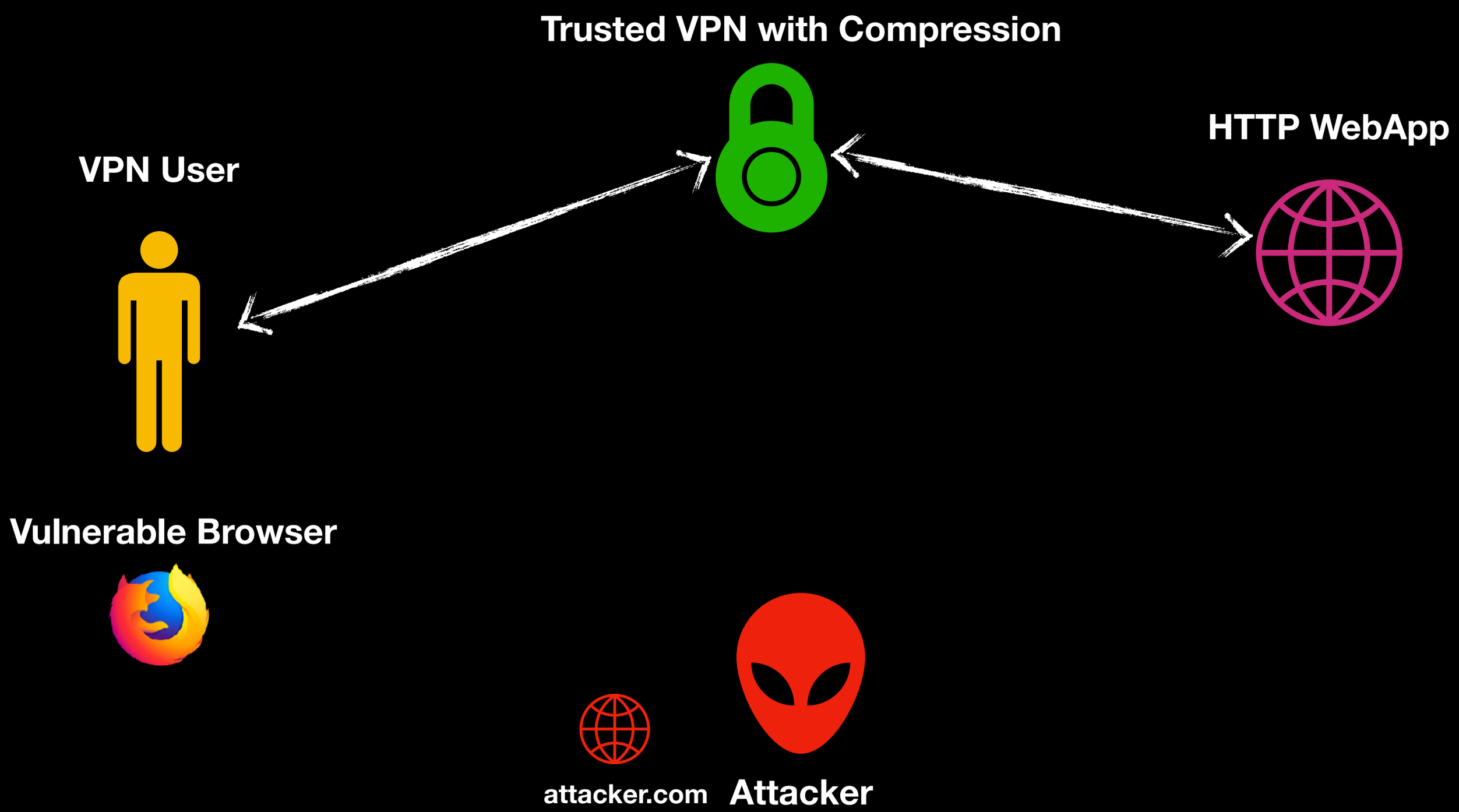
Attack Setup



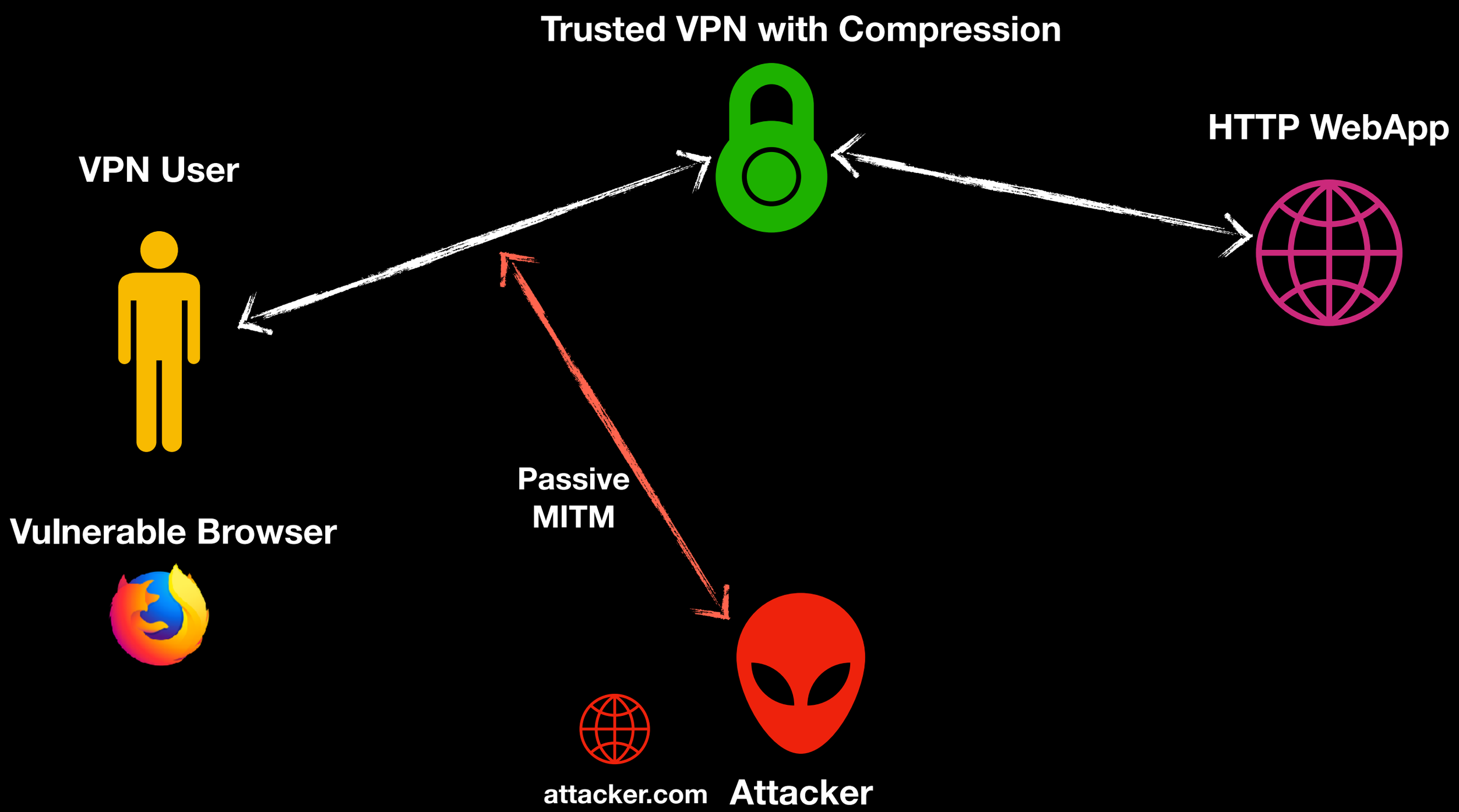
Attack Setup



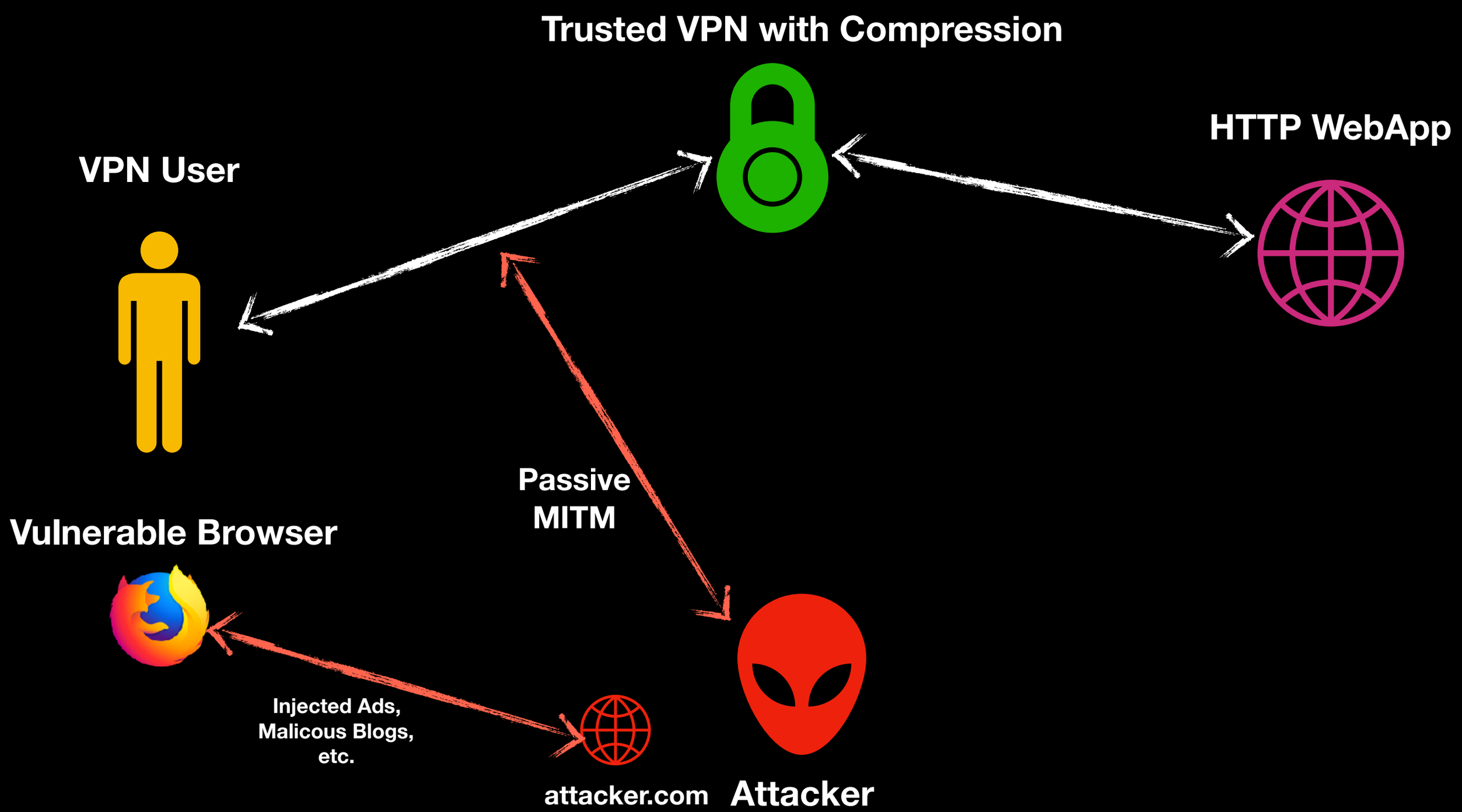
Attack Setup



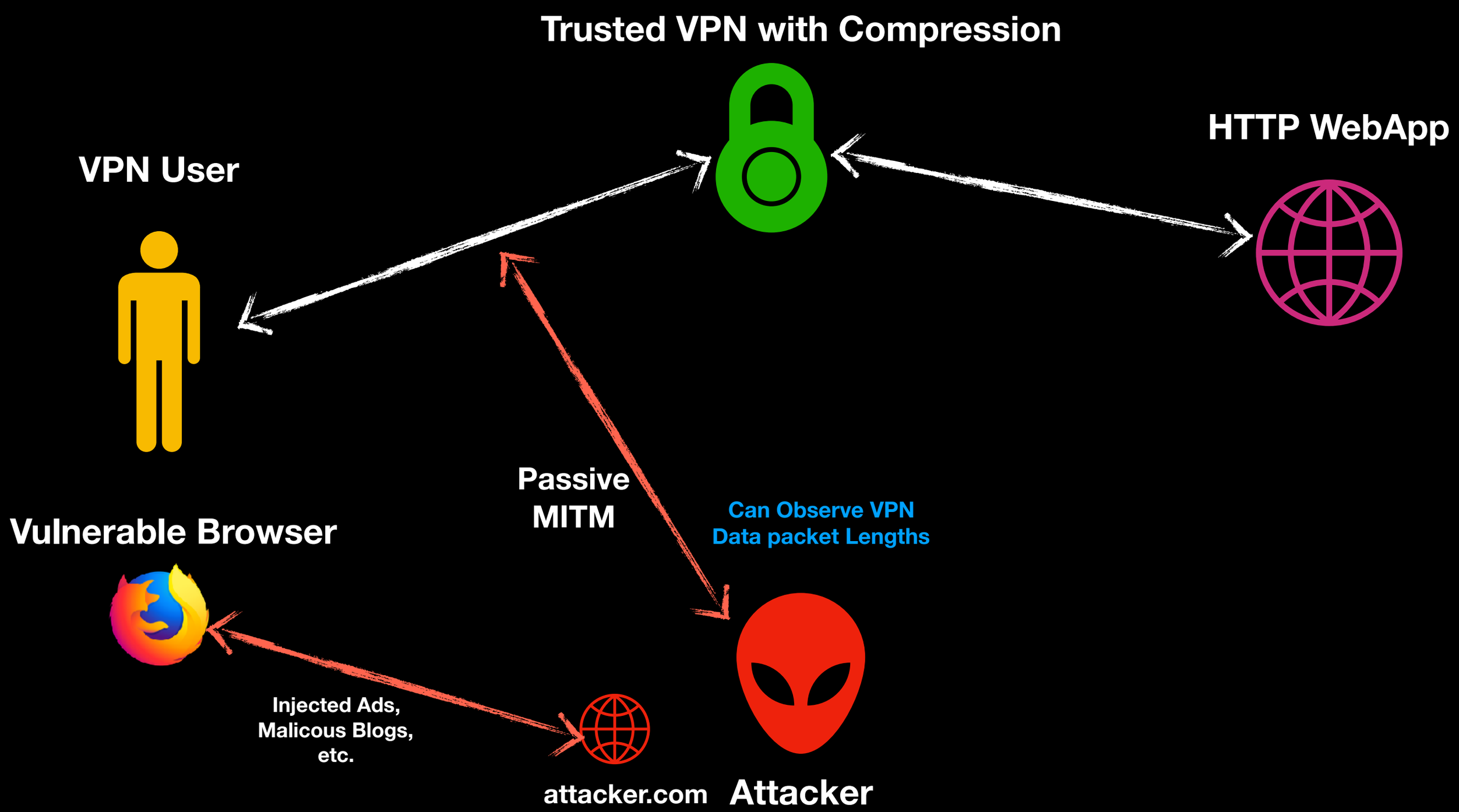
Attack Setup



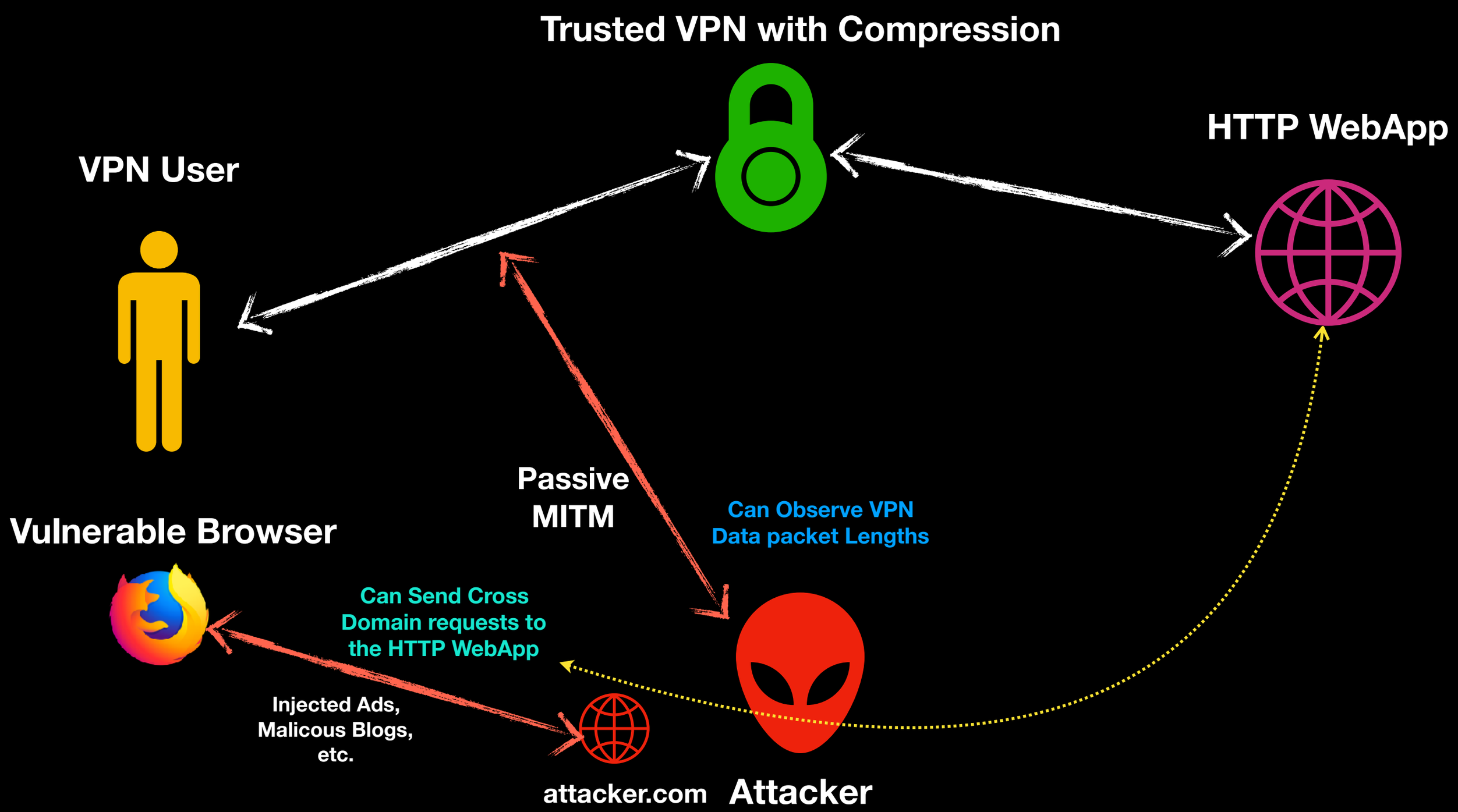
Attack Setup



Attack Setup



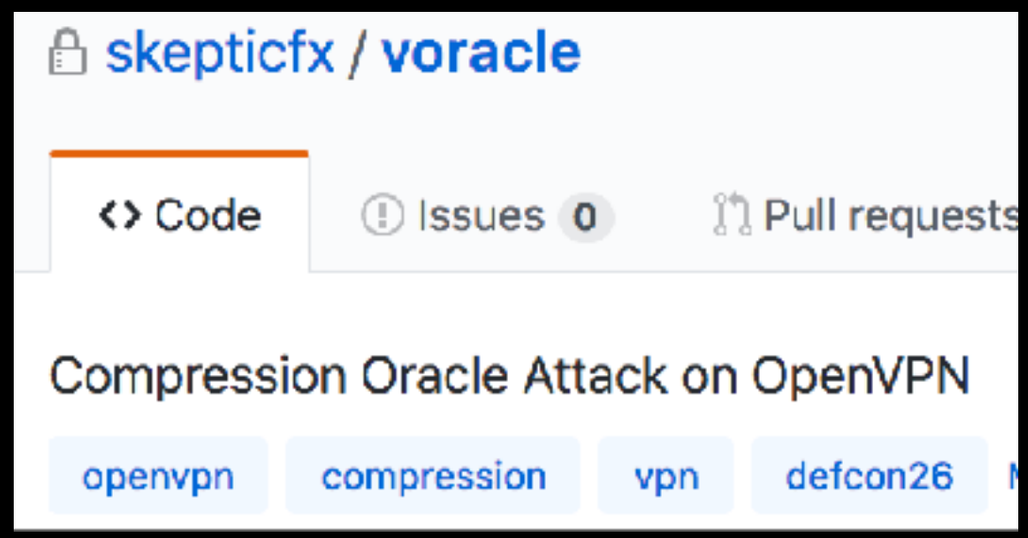
Attack Setup



Attacker can now conduct CRIME Style attacks on HTTP requests and responses

Demo

Voracle



https://github.com/skepticfx/voracle

How to tell if your VPN is vulnerable?

Ingredients

Wireshark

Terminal with Curl

Connected to your VPN under test

Observe VPN Payload Length

Curl and Observe Length

```
curl -s -o /dev/null -X POST http://website.com
-d "--some-data-- Secret=37346282;
--blah-- Secret=1 Secret=1"
```

Length = x

Curl and Observe Length

```
curl -s -o /dev/null -X POST http://website.com
-d "--some-data-- Secret=37346282;
--blah-- Secret=2 Secret=2"
```

Length = x

Curl and Observe Length

```
curl -s -o /dev/null -X POST http://website.com
-d "--some-data-- Secret=37346282;
--blah-- Secret=3 Secret=3"
```

Length = x-1

Curl and Observe Length

```
curl -s -o /dev/null -X POST http://website.com
-d "--some-data-- Secret=37346282;
--blah-- Secret=1 Secret=1"
```

Length = x

Fix?

Fixing Compression is an interesting problem

Selectively disable Compression - HPACK in HTTP2

Remember when SPDY was vulnerable to CRIME?

HPACK selectively disabled header compression for sensitive fields

HPACK: Header Compression for HTTP/2

draft-ietf-httpbis-header-compression-latest

7.1.3 Never-Indexed Literals

Implementations can also choose to protect sensitive header fields by not compressing them and instead encoding their value as literals.

https://http2.github.io/http2-spec/compression.html

For VPNs, Disable compression completely for any plain text transactions

Turning compression off by default is opinionated.

OpenVPN chose to warn the implementors more explicitly to turn off data Compression.

https://github.com/OpenVPN/openvpn/commit/a59fd147

OpenVPN / **openvpn**

Code | Pull requests 32 | Projects 0 | Insights

man: add security considerations to --compress section

```
As Ahamed Nafeez reported to the OpenVPN security team, we did not
sufficiently inform our users about the risks of combining encryption
and compression.  This patch adds a "Security Considerations" paragraph
to the --compress section of the manpage to point the risks out to our
users.

Signed-off-by: Steffan Karger <steffan@karger.me>
Acked-by: Gert Doering <gert@greenie.muc.de>
Message-Id: <1528020718-12721-1-git-send-email-steffan@karger.me>
URL: https://www.mail-archive.com/openvpn-devel@lists.sourceforge.net/msg16919.html
Signed-off-by: Gert Doering <gert@greenie.muc.de>
```

master

syzzer authored and **cron2** committed on Jun 3

TunnelBear turned off compression entirely

TunnelBear

Hi,

Thanks for the report.

As discussed via email, we have now removed compression support on our OpenVPN servers. Would you be able to verify that your attack is no longer possible with the TunnelBear client?

Thanks

Its time, everything moves to HTTPS

Takeaway

If you are using VPNs to access plain text websites over the internet, its time to move them to HTTPs.

Most corporates using VPN still allow plain text HTTP websites, because they think VPN protects them.

Thank you!

@skeptic_fx