CSE508 Network Security

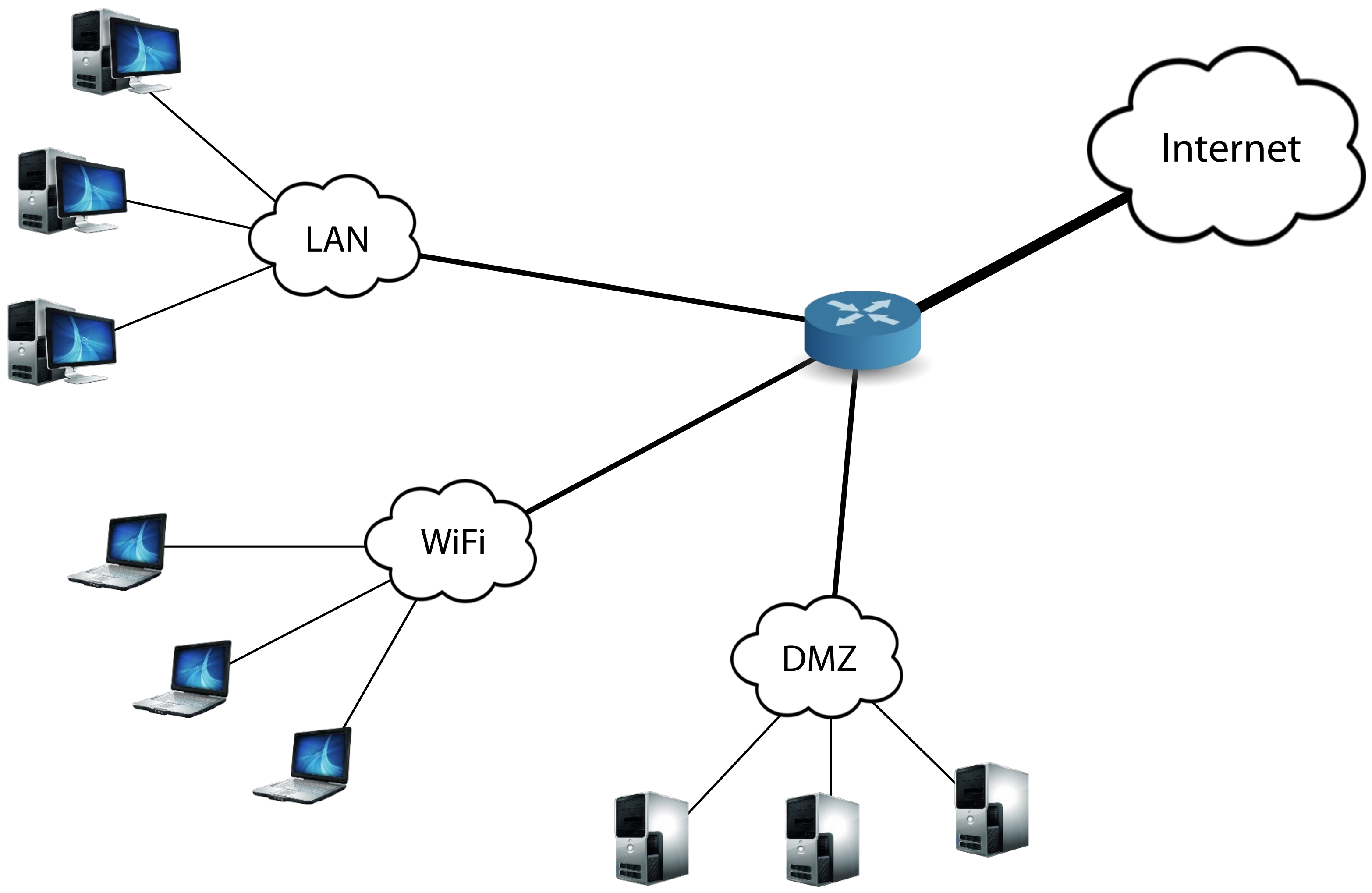
2021-03-04

Firewalls and Tunnels

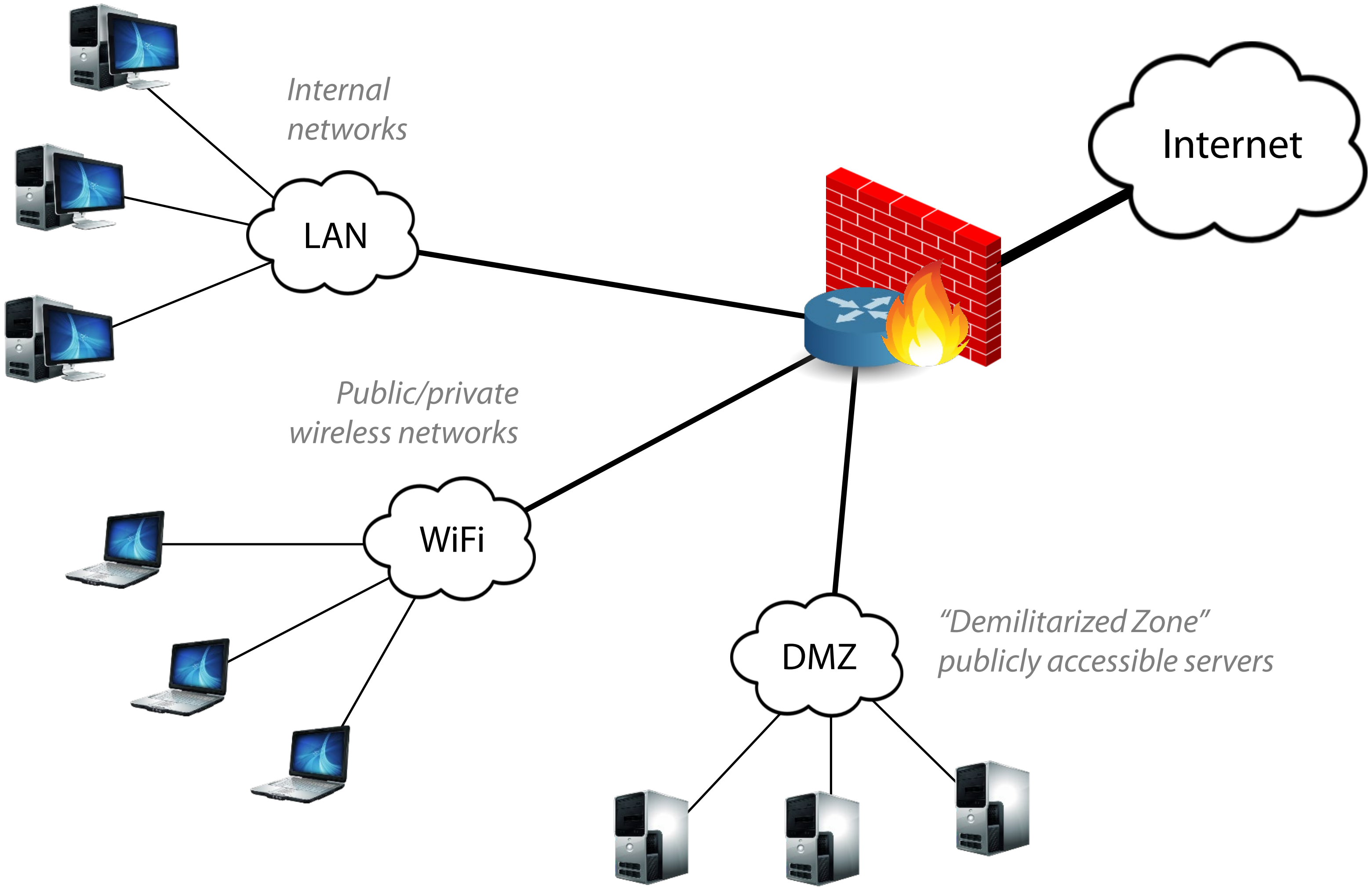
Michalis Polychronakis

Stony Brook University

Typical Network Topology

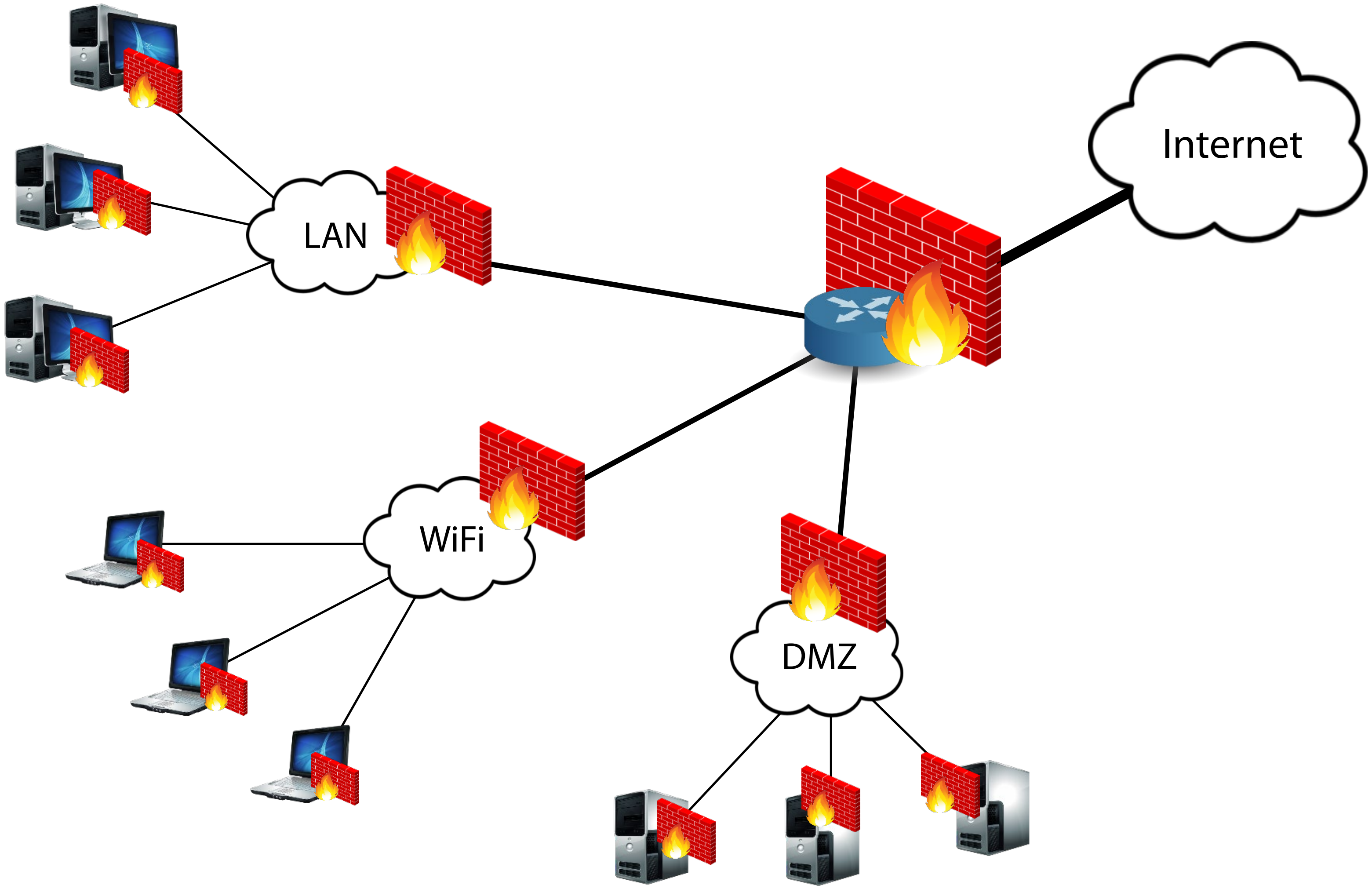


Firewalls: separate local networks from the Internet



Internal networks
Internet
LAN
Public/private wireless networks
WiFi
DMZ
"Demilitarized Zone" publicly accessible servers

Firewalls: Reality



Firewalls

Filter traffic according to a predefined *policy*

- Mostly statically defined, but dynamic updates are possible (block an ongoing DoS attack, protocols with dynamically negotiated port numbers, etc.)

Barrier between administrative domains

- Internal networks vs. the outside world
- Mission-specific subnets/VLANs (publicly accessible servers, machine clusters, user groups, printers, VoIP, IoT, …)
- Less trusted segments (guest WiFi network, contractors, …)

Main strategies

- Default-deny: drop everything unless explicitly allowed
- Default-allow: block specific protocols/hosts/ports/…

Firewalls: why are they needed?

Hosts may run vulnerable services: prevent outside access

- Limit the "attack surface" ➔ expose fewer services

Internal hosts may get compromised: damage control

- Prevent propagation, outgoing attacks, exfiltration, …

Hide the structure of private networks: hinder network reconnaissance

- Block port scanning, service fingerprinting, …

Network intelligence: log interesting events

- Troubleshooting, monitoring/tuning, auditing, forensics, …

Simply block unwanted traffic: policy enforcement

- Noise, backscatter, spoofed packets, DoS attacks, brute-force password guessing, Bittorrent, Facebook, Netflix, games, VPNs, …

A Theory of Firewalls (Bellovin)

Three properties must hold for a firewall to be effective

The firewall should be placed at a topological chokepoint

- Not always true in modern enterprises: links to suppliers/contractors, cellular connectivity, VPN/proxy software, …

“Inside” nodes share the same security policy

- Do they? BYOD, IoT, work from home, …

“Inside” nodes are trusted, “outside” hosts are untrusted

- BYOD: an already infected device may appear inside the network
- Internal hosts can be infected due to client-side attacks (e.g., drive-by download attacks, malware, phishing, supply chain attacks, …)
- Insider threats, disgruntled employees, …

Stateless Filtering

Decide by considering each packet in isolation

- Rules mostly based on network and transport layer fields
- Simple implementation: no need to keep state

Limitations

- Dynamically negotiated/non-standard port numbers (FTP, SIP, BitTorrent, …)
- Connectionless protocols (e.g., UDP): cannot distinguish between queries and replies
- IP fragmentation: port numbers are present only in the first fragment
- Rulesets can get complex and hard to understand

Still useful for simple scenarios

- Ingress/egress filtering, strict configurations, …

Stateless Firewalls and TCP

Common configuration: block incoming but allow outgoing connections

- Incoming (externally initiated) connections should be blocked
- Incoming packets of established connections should be allowed

Can be achieved without keeping state

- Block incoming SYN-only packets
- Allow incoming packets with the ACK bit set

Not an ideal solution: *ACK scanning*

ACK-scanning (`nmap -sA`)

Can determine whether a stateless firewall is used

- Not whether a specific port is open or not

When an ACK is sent to a closed port, or sent out-of-sync to an open port, the expected behavior is to respond with a RST

- Stateful firewalls discard out-of-sync ACK packets, leading to no response

Step 1: SYN → SYN/ACK or RST
Step 2: ACK → RST *The port is unfiltered by any firewall type*

Step 1: SYN → SYN/ACK
Step 2: ACK → no response *Stateful firewall*

Step 1: SYN → no response
Step 2: ACK → RST *Stateless firewall*

Stateful Filtering

Firewall keeps per-connection state

- Track TCP three-way handshake, UDP query/responses, …
- Decisions are made by considering each packet in the context of the connection/session it belongs to

Most common firewall type

More flexible policies

- Internally vs. externally initiated connections/sessions

Still cannot handle dynamically negotiated port numbers and higher-level protocol semantics

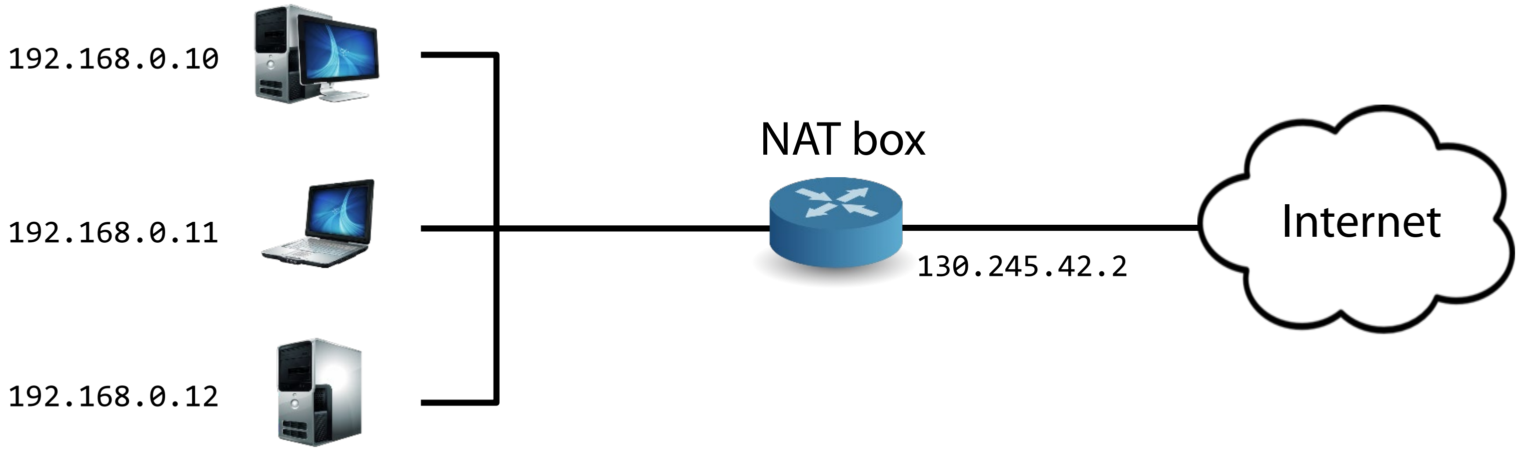
- Missing application-level context

Network Address Translation

Share a public IP address with many internal hosts

- In general: remap an IP address space into another
- Global shortage of IPv4 addresses
- Widely used (home networks, wireless networks, …)

Rewrite packet address and port information (per-connection state)



NAT vs. Stateful Firewall

Similar functionality and state

NAT in addition **modifies** packets: performs address/port translation

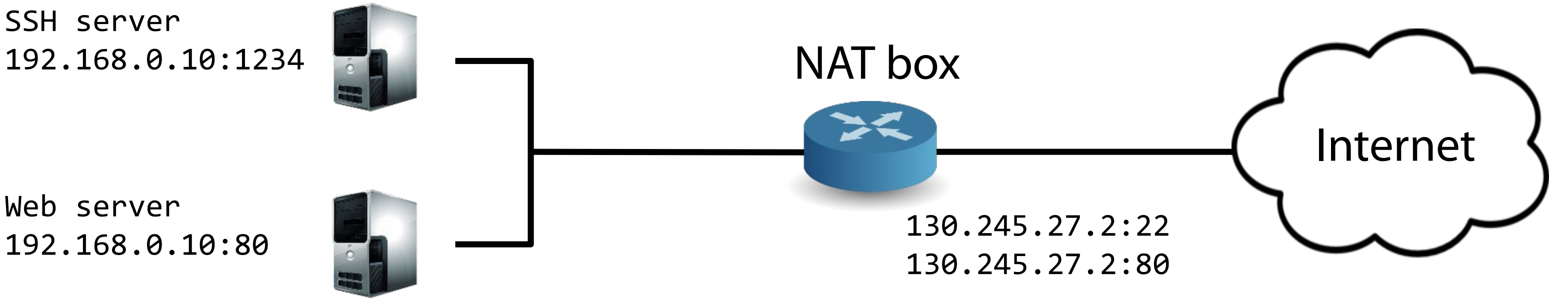
Are NATs firewalls?

Not in the strict sense, as they do not fully track the TCP 3-way handshake or any other higher-layer state

But they *do* provide some protection: allow only outgoing connections

Internal hosts can become accessible through *port forwarding*

Explicitly map a local IP:port to a public IP:port



UPnP

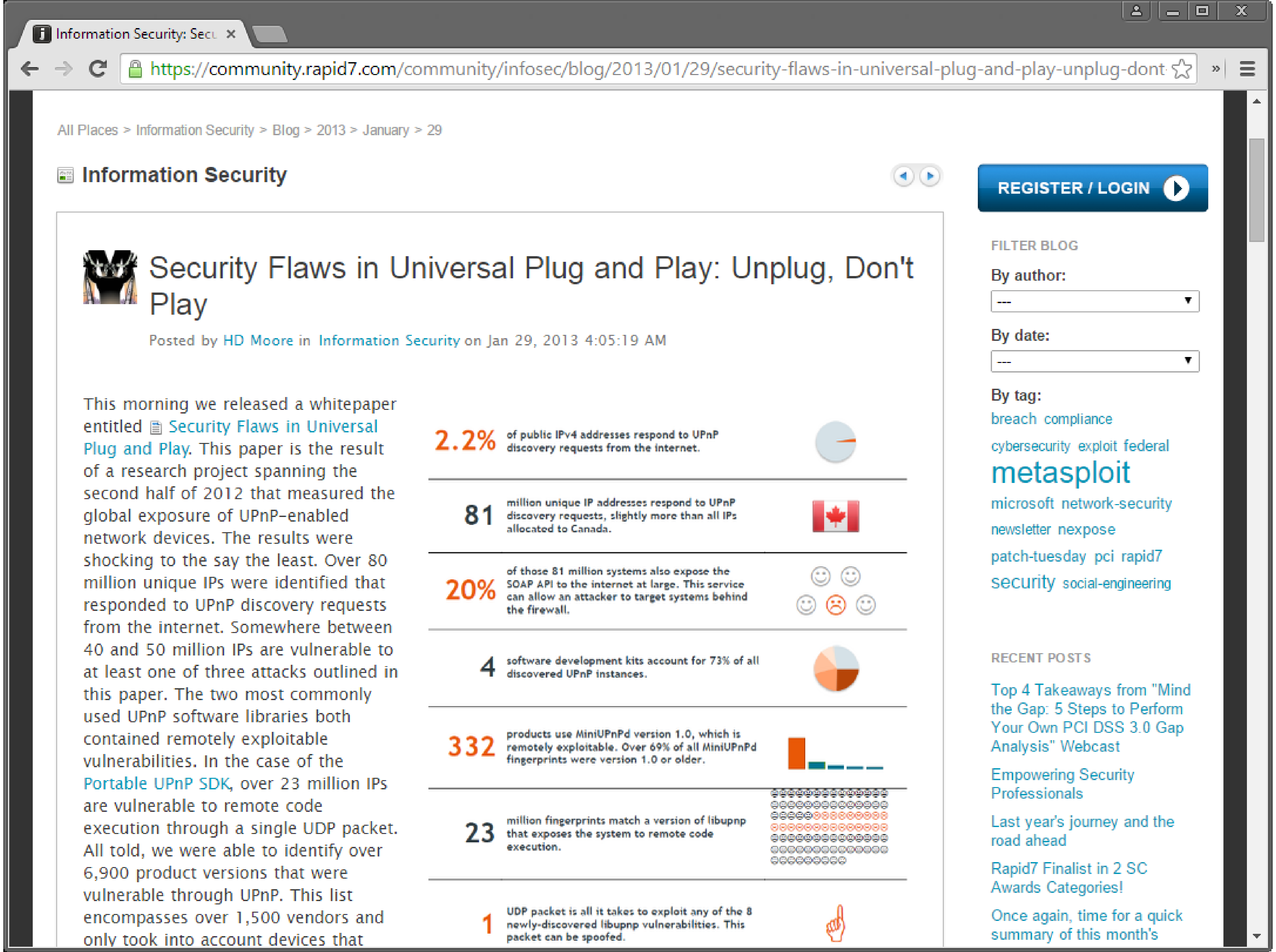
Universal Plug and Play

Widely supported protocol by home routers to enable device discovery and NAT traversal

- “Please allow external hosts to reach me on port 12345”
- Skype, Bittorrent, games, …

No authentication!

- Malware can easily punch holes
- Worse: ~~Flash~~, XSS, …
- Even worse: external requests (!)



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Empowering Security Professionals

Last year's journey and the road ahead

Rapid7 Finalist in 2 SC Awards Categories!

Once again, time for a quick summary of this month's

Information Security

Security Flaws in Universal Plug and Play: Unplug, Don't Play

Posted by HD Moore in Information Security on Jan 29, 2013 4:05:19 AM

This morning we released a whitepaper entitled Security Flaws in Universal Plug and Play. This paper is the result of a research project spanning the second half of 2012 that measured the global exposure of UPnP-enabled network devices. The results were shocking to the say the least. Over 80 million unique IPs were identified that responded to UPnP discovery requests from the internet. Somewhere between 40 and 50 million IPs are vulnerable to at least one of three attacks outlined in this paper. The two most commonly used UPnP software libraries both contained remotely exploitable vulnerabilities. In the case of the Portable UPnP SDK, over 23 million IPs are vulnerable to remote code execution through a single UDP packet. All told, we were able to identify over 6,900 product versions that were vulnerable through UPnP. This list encompasses over 1,500 vendors and only took into account devices that

2.2% of public IPv4 addresses respond to UPnP discovery requests from the internet.

81 million unique IP addresses respond to UPnP discovery requests, slightly more than all IPs allocated to Canada.

20% of those 81 million systems also expose the SOAP API to the internet at large. This service can allow an attacker to target systems behind the firewall.

4 software development kits account for 73% of all discovered UPnP instances.

332 products use MiniUPnPd version 1.0, which is remotely exploitable. Over 69% of all MiniUPnPd fingerprints were version 1.0 or older.

23 million fingerprints match a version of libupnp that exposes the system to remote code execution.

1 UDP packet is all it takes to exploit any of the 8 newly-discovered libupnp vulnerabilities. This packet can be spoofed.

Generic Port Forwarding

Bypass firewall policies!

Example: connect to a host that is blocked by a local firewall policy

Remote host: `nc -l -p 12345 -c ‘nc blocked.com 80’`

Local host: `wget remote.edu:12345`

Or using SSH local port forwarding

```
ssh -L 12345:blocked.com:80 remote.edu
```

Also the other way around: remote port forwarding

Example: allow public access to a server running in a private network

```
ssh -R 8080:localhost:80 remote.edu
```

Proxies

Intermediate “stepping stones”

- Operate at the application layer
- Act as both a client and a server

Application-level filtering

- Example: HTTP-level filtering (domains, URLs, ads, …)

Many non-security uses as well

- HTTP content caching (one of the first uses of web proxies)
- Reverse proxies (in front of application servers): quickly serve the same dynamically-generated content
- Transcoding (reduce the resolution of media content for mobile devices)

Explicit vs. transparent proxies

- The former require application configuration

SOCKS Proxies

Also known as circuit-level gateways

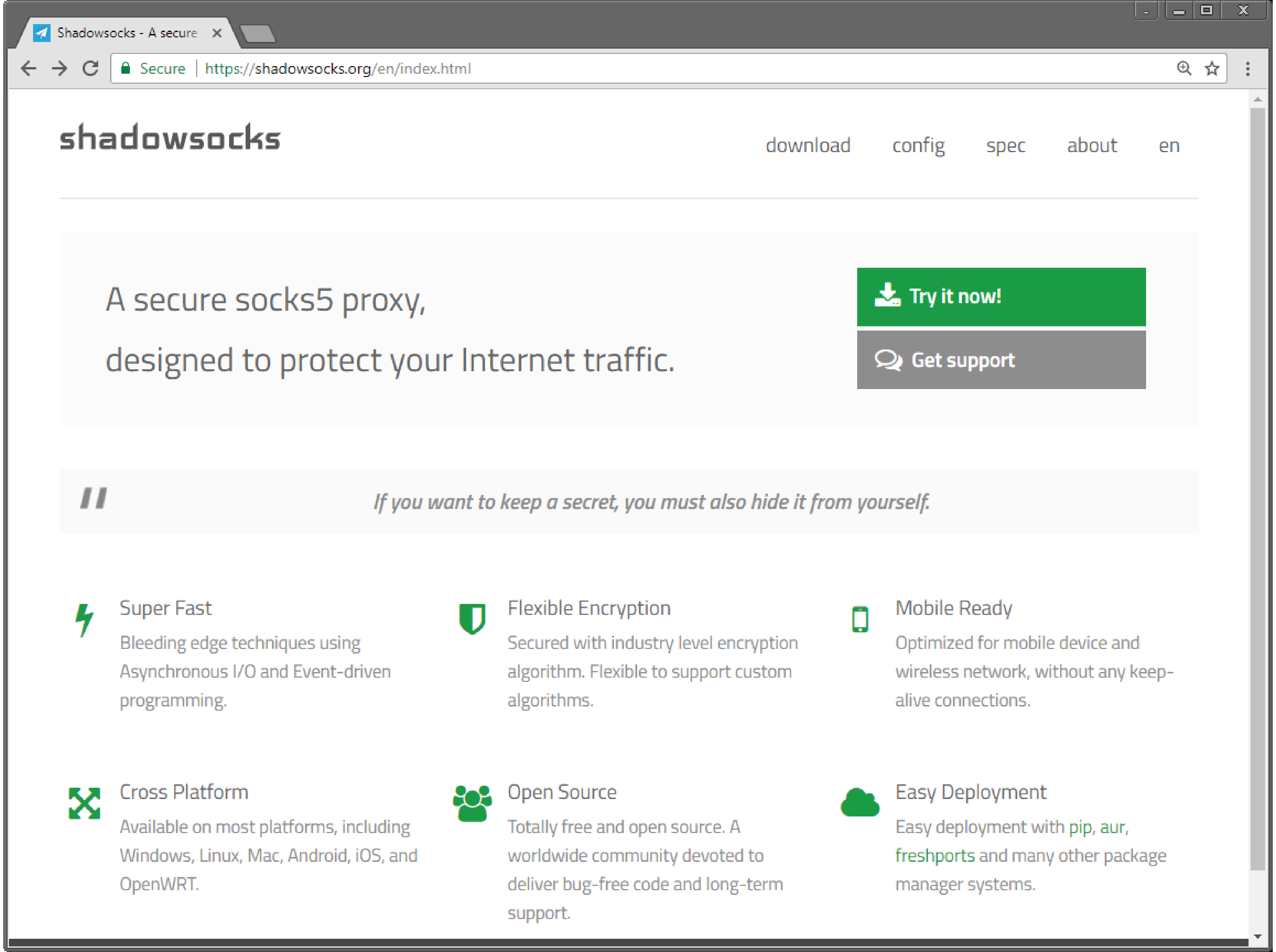
Socket Secure (SOCKS): protocol for generic forwarding of packets through a proxy

Supported by many applications and protocols

HTTP, FTP, SMTP, POP3, NNTP, …

Example: dynamic application-level port forwarding

```
ssh –D 12345 sshserver.com
chrome --proxy-server='socks://localhost:12345'
```



shadowsocks

A secure socks5 proxy,

designed to protect your Internet traffic.

> *If you want to keep a secret, you must also hide it from yourself.*

Super Fast

Bleeding edge techniques using Asynchronous I/O and Event-driven programming.

Flexible Encryption

Secured with industry level encryption algorithm. Flexible to support custom algorithms.

Mobile Ready

Optimized for mobile device and wireless network, without any keep-alive connections.

Cross Platform

Available on most platforms, including Windows, Linux, Mac, Android, iOS, and OpenWRT.

Open Source

Totally free and open source. A worldwide community devoted to deliver bug-free code and long-term support.

Easy Deployment

Easy deployment with pip, aur, freshports and many other package manager systems.

Application-level "Firewalls"

Similar to proxies, but less generic

- Application-specific filtering
- Often built into applications

Example: SMTP

- Spam filtering, phishing detection, attachment scanning, …

Overlap with more generic *intrusion detection systems* (future lecture)

Recent buzzword: web application firewalls (WAF)

- Server-side HTTP filtering for common attack patterns (XSS, SQL injection, …)
- A specific instance of application-level filtering/scanning

Host-based Firewalls

Firewalls running on end hosts

- Windows firewall
- IPtables

“Personal” firewalls: apply common-sense policies (deny incoming, allow outgoing)

- Particularly important for home users, laptops, etc.

On-by-default client firewall deployment contributed significantly in ending the era of internet worms

Simple IPtables Example

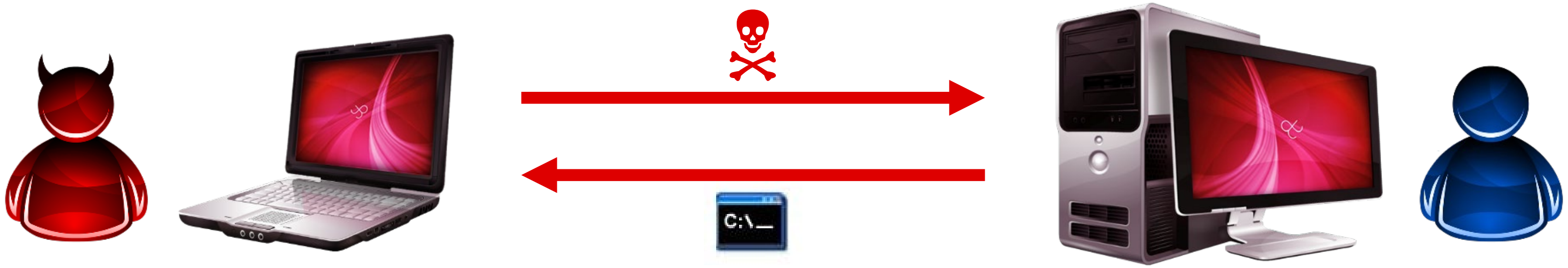
```
# flush all chains
iptables -F
iptables –X

# defaults for predefined chains
iptables -P INPUT DROP
iptables -P OUTPUT DROP
iptables -P FORWARD DROP

# allow anything on localhost interface
iptables -A INPUT -i lo -j ACCEPT
iptables -A OUTPUT -o lo -j ACCEPT

# allow all traffic from specific subnets
iptables -A INPUT -s 128.59.0.0/255.255.0.0 -j ACCEPT
iptables -A INPUT -s 160.39.0.0/255.255.0.0 -j ACCEPT
```

Simple IPtables Example

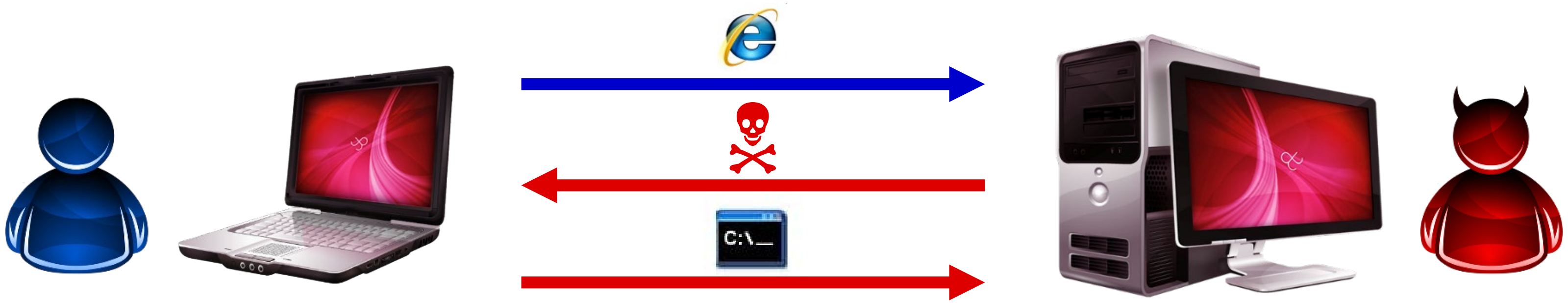
```
# allow all inbound traffic for specific services
iptables -A INPUT -p tcp -m tcp --syn --dport 22 -j ACCEPT
iptables -A INPUT -p tcp -m tcp --syn --dport 80 -j ACCEPT

# allow inbound established and related outside communication
iptables -A INPUT -m conntrack --ctstate ESTABLISHED,RELATED -j
ACCEPT

# allow ICMP
iptables -A INPUT -p icmp -j ACCEPT

# allow all outgoing traffic
iptables -A OUTPUT -j ACCEPT
```

Is this a good idea?

Before Host-based Firewalls:



After Host-based Firewalls:



Per-process Firewall

Most “personal” firewalls still allow all outgoing traffic by default

- Severe usability problems otherwise

Do all programs really need to communicate with the outside world?

Deny by default and whiltelist only what is needed

- No easy solution for this in most OSes – need to rely on hacks or third party solutions
- GlassWire, TinyWall, Windows Firewall Control, …

Virtual Private Networks

Users may not always be behind the firewall, but still need full access to internal network resources

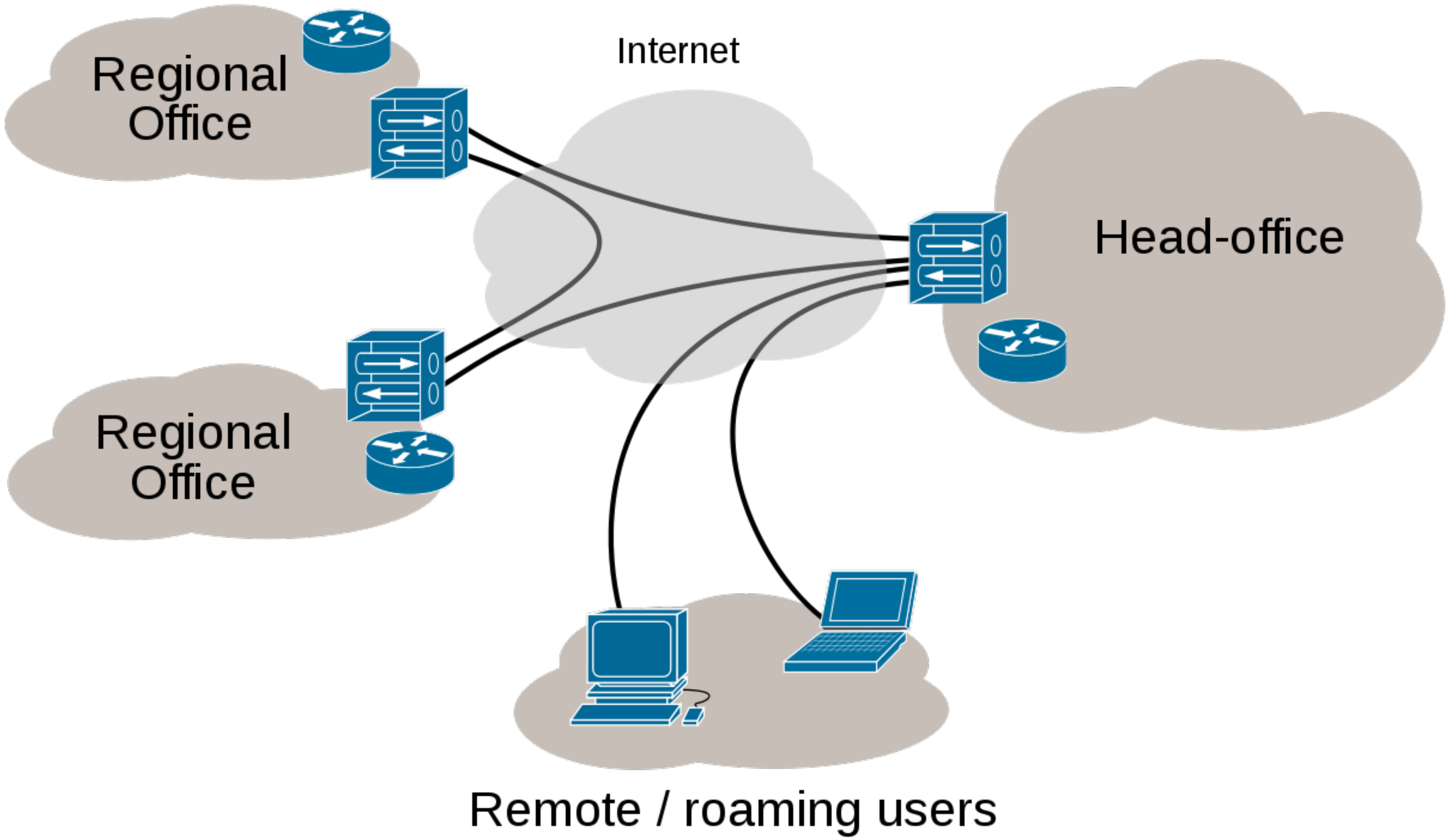
- Offices at different locations, employees on the move, access to home "cloud," …

VPNs bridge private networks across a public (untrusted) network

- Virtual point-to-point secure connections (encryption)
- Create a *trusted* shared network among them

Remote host/network virtually becomes part of the local network

VPN Examples



© Ludovic.ferre – https://commons.wikimedia.org/wiki/File:Virtual_Private_Network_overview.svg

VPN Implementations

Tunneling/encapsulation: packets are transferred as *data* over another protocol

L2 over L4 (PPTP), *L2 over L2* (PPPoE), *L2 over L3* (L2TP), *L3/L4 over L3* (IPsec), *L2/L3 over L4* (OpenVPN)

Three major families in wide use today:

PPTP: L2, introduced in 1995, commonly used in Windows ➔ *Broken*

IPsec: L3, widely supported by most operating systems

- Completely transparent to applications
- Tunnel is handled directly by the OS

SSL: Application layer – OpenVPN

- User-space implementation, multiplatform
- Typically requires the installation of a software client

VPN Implementations

~~Tunneling/encapsulation: packets are transferred as *data* over another protocol~~

~~*L2 over* [illegible]~~~~*P), L2 over L2 (*PPPoE*), L2 over L3 (*~~ [illegible] ~~*/L4 over L3 (*IPsec*), L2/L3 over L4 (*OpenVPN*)*~~

~~Three major~~ [illegible] ~~in wide use tod~~[illegible]

~~PPTP: L2, introdu~~[illegible] ~~1995, co~~[illegible] ~~used in Windows ➔ *Broken*~~

~~IPsec: L3, widely sup~~[illegible] ~~operating systems~~

~~Completely transparen~~[illegible]~~ations~~

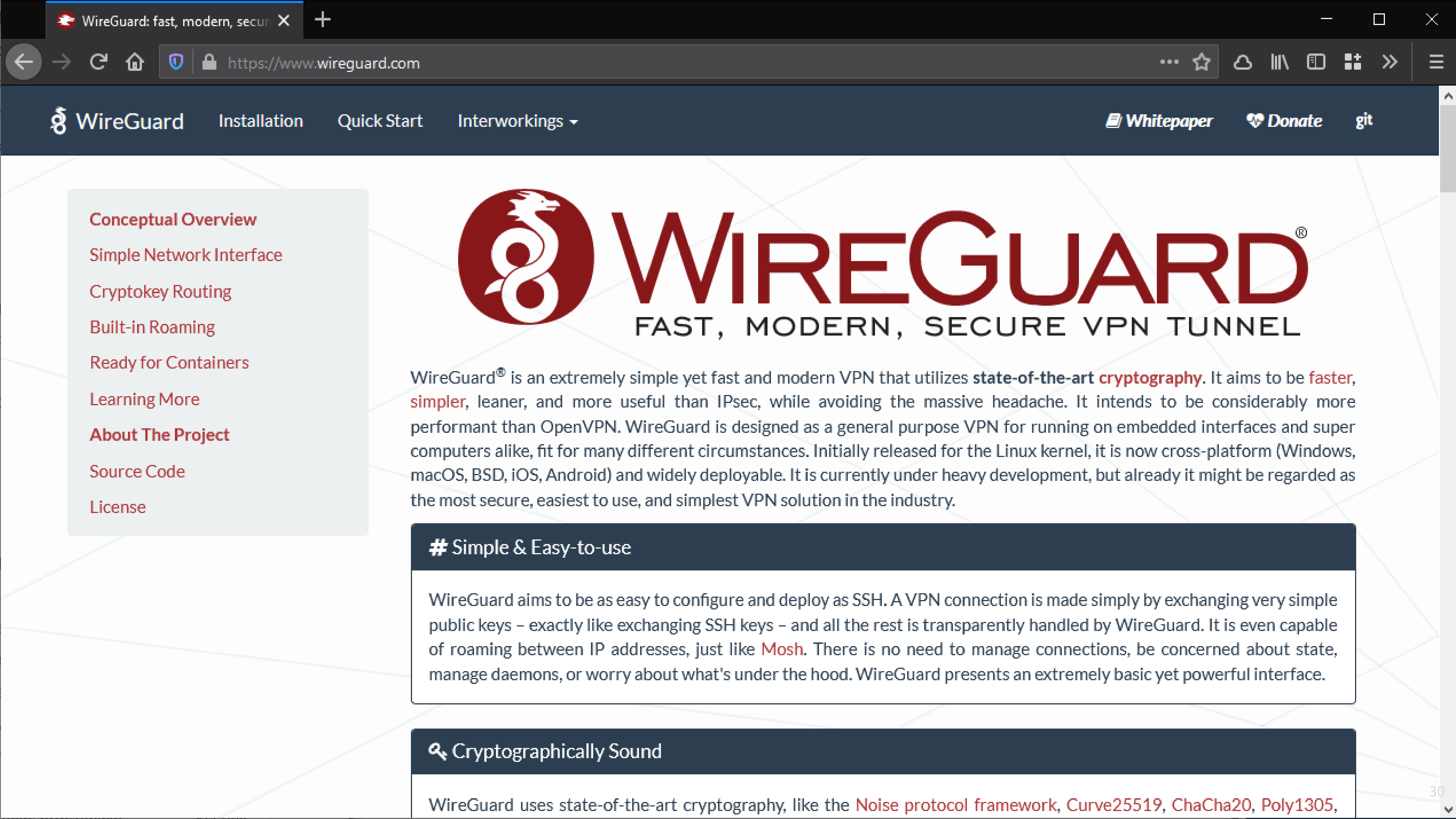
~~Tunnel is handled d~~[illegible]

~~SSL: Application~~ [illegible] ~~OpenV~~[illegible]

~~User-spac~~[illegible]~~ntation, multipl~~[illegible]

~~Typical~~[illegible]~~s the installation of a so~~[illegible]~~nt~~

Just use Wireguard



WireGuard® is an extremely simple yet fast and modern VPN that utilizes **state-of-the-art cryptography**. It aims to be faster, simpler, leaner, and more useful than IPsec, while avoiding the massive headache. It intends to be considerably more performant than OpenVPN. WireGuard is designed as a general purpose VPN for running on embedded interfaces and super computers alike, fit for many different circumstances. Initially released for the Linux kernel, it is now cross-platform (Windows, macOS, BSD, iOS, Android) and widely deployable. It is currently under heavy development, but already it might be regarded as the most secure, easiest to use, and simplest VPN solution in the industry.

Simple & Easy-to-use

WireGuard aims to be as easy to configure and deploy as SSH. A VPN connection is made simply by exchanging very simple public keys – exactly like exchanging SSH keys – and all the rest is transparently handled by WireGuard. It is even capable of roaming between IP addresses, just like Mosh. There is no need to manage connections, be concerned about state, manage daemons, or worry about what's under the hood. WireGuard presents an extremely basic yet powerful interface.

Cryptographically Sound

WireGuard uses state-of-the-art cryptography, like the Noise protocol framework, Curve25519, ChaCha20, Poly1305,

VPN Risks

Personal use of VPNs has become popular for bypassing restrictions

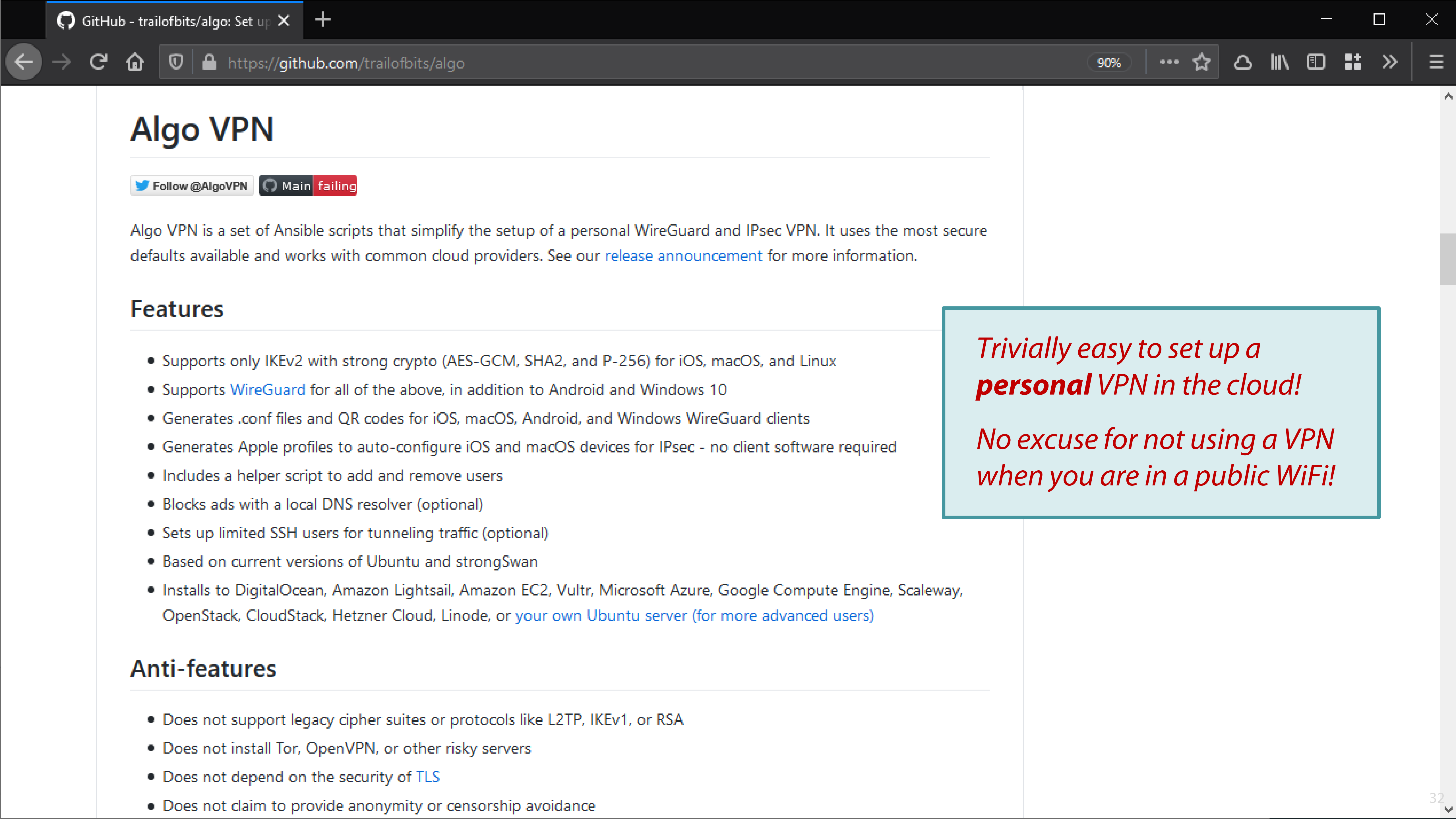
- Country-based content, censorship, corporate/school/parental controls, …

A third-party VPN server can observe all our traffic (!)

- Be wary of VPN services that claim “privacy” and “anonymity”
- VPN services are still subject to local laws
- Shady services may monetize our traffic

Client-side VPN software is too powerful

- Can monitor (spy on) system-wide activities besides the traffic itself
- Most operating systems have built-in VPN support!
- There shouldn’t be any need to install closed-source VPN software


GitHub - trailofbits/algo: Set up
https://github.com/trailofbits/algo
90%
Follow @AlgoVPN
Main failing

Algo VPN

Algo VPN is a set of Ansible scripts that simplify the setup of a personal WireGuard and IPsec VPN. It uses the most secure defaults available and works with common cloud providers. See our release announcement for more information.

Features

- Supports only IKEv2 with strong crypto (AES-GCM, SHA2, and P-256) for iOS, macOS, and Linux
- Supports WireGuard for all of the above, in addition to Android and Windows 10
- Generates .conf files and QR codes for iOS, macOS, Android, and Windows WireGuard clients
- Generates Apple profiles to auto-configure iOS and macOS devices for IPsec - no client software required
- Includes a helper script to add and remove users
- Blocks ads with a local DNS resolver (optional)
- Sets up limited SSH users for tunneling traffic (optional)
- Based on current versions of Ubuntu and strongSwan
- Installs to DigitalOcean, Amazon Lightsail, Amazon EC2, Vultr, Microsoft Azure, Google Compute Engine, Scaleway, OpenStack, CloudStack, Hetzner Cloud, Linode, or your own Ubuntu server (for more advanced users)

Anti-features

- Does not support legacy cipher suites or protocols like L2TP, IKEv1, or RSA
- Does not install Tor, OpenVPN, or other risky servers
- Does not depend on the security of TLS
- Does not claim to provide anonymity or censorship avoidance

*Trivially easy to set up a **personal** VPN in the cloud!*

No excuse for not using a VPN when you are in a public WiFi!

“Secure Gateways”

Nowadays it is common for most of the discussed technologies to be consolidated into a single box

- Routing, Firewall, NAT, VPN, Proxy, WiFi access point, …

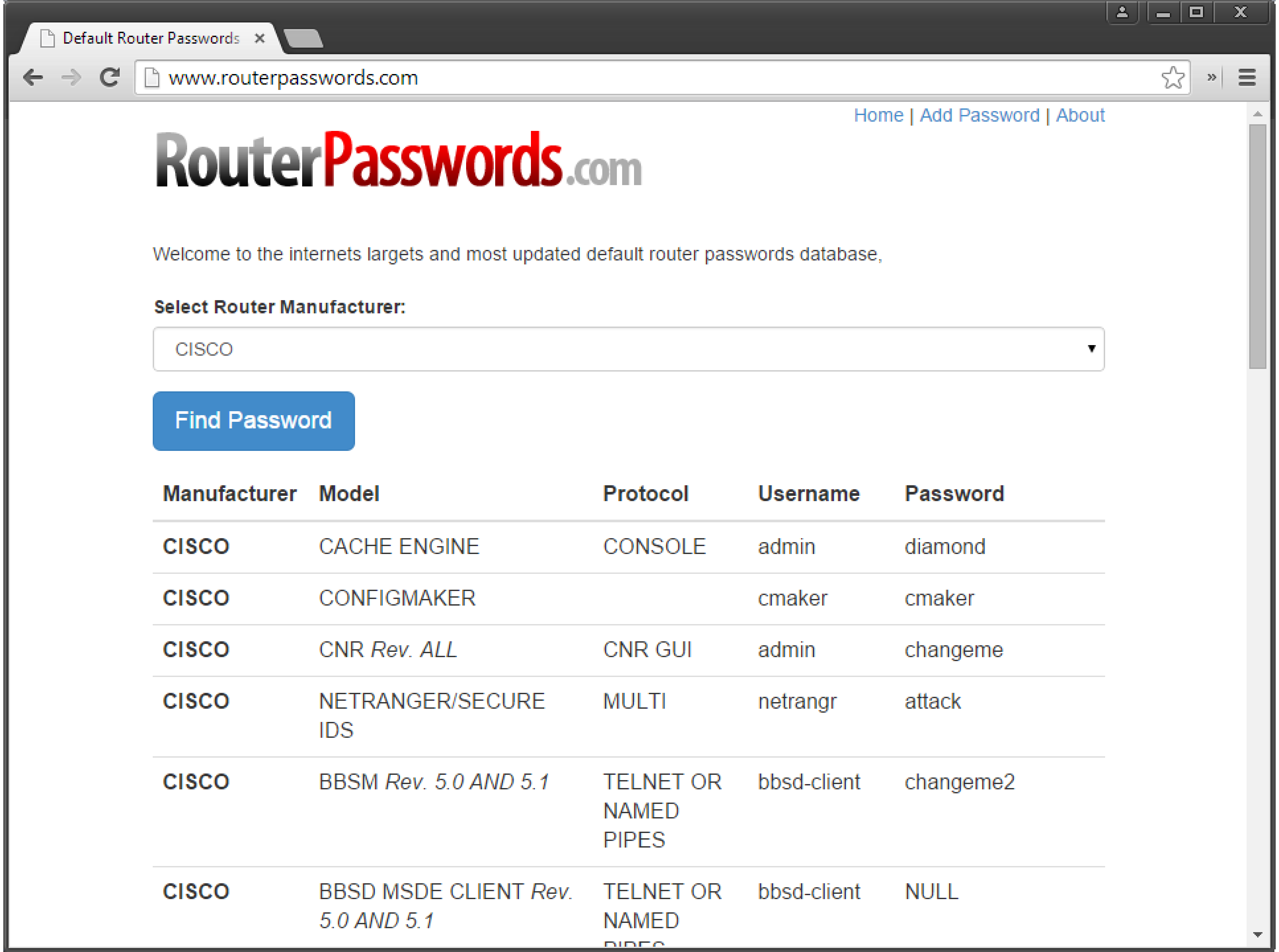
Common in home and enterprise settings

Routers and firewalls used to be “simple” devices – not anymore

- Features ➔ complexity ➔ security issues

Critical hosts in the network that need to be protected

- Administrative interface, OS patches/updates, service vulnerabilities, …

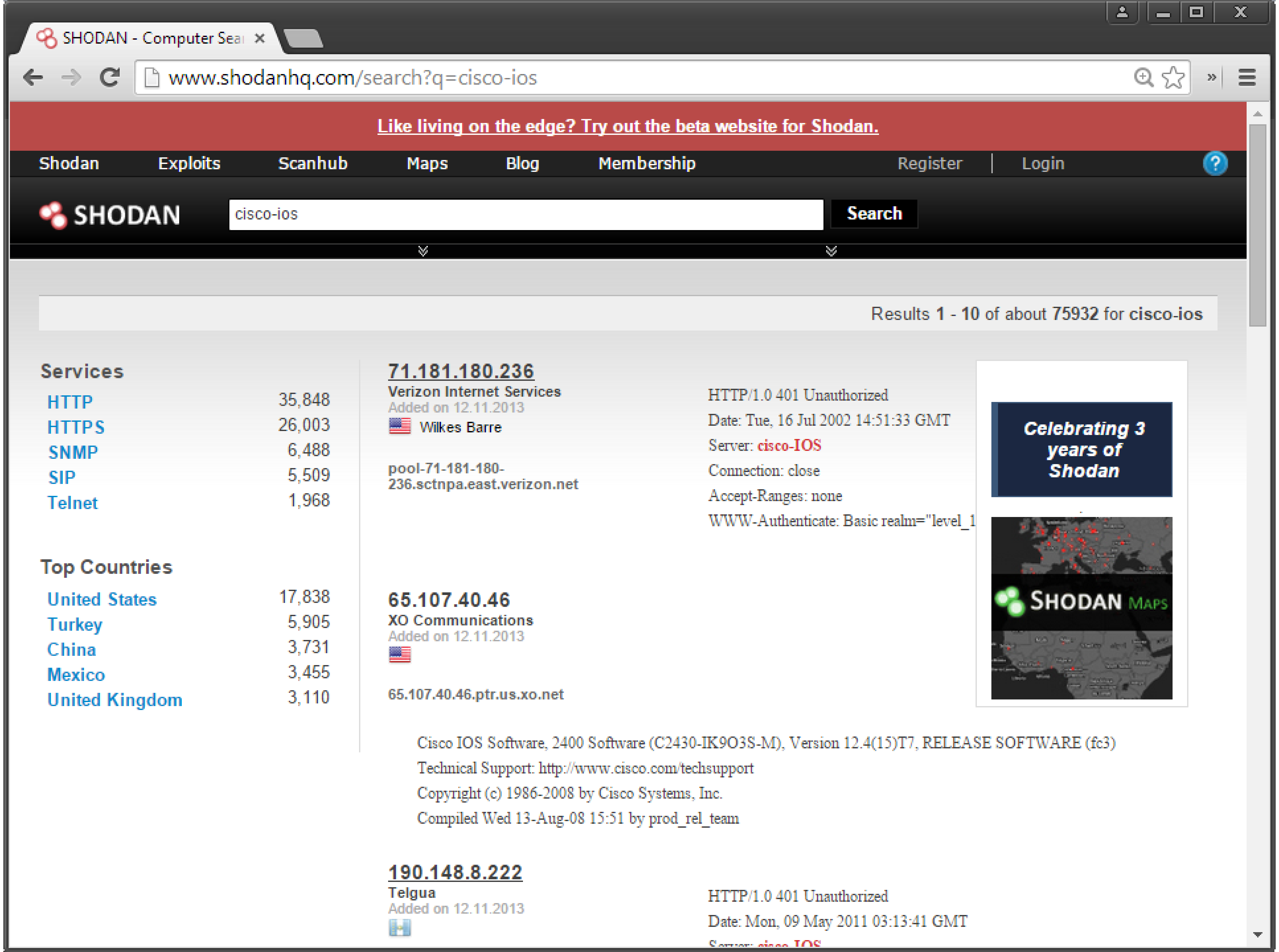


RouterPasswords.com

Welcome to the internets largets and most updated default router passwords database,

Select Router Manufacturer: CISCO

Manufacturer	Model	Protocol	Username	Password
CISCO	CACHE ENGINE	CONSOLE	admin	diamond
CISCO	CONFIGMAKER		cmaker	cmaker
CISCO	CNR *Rev. ALL*	CNR GUI	admin	changeme
CISCO	NETRANGER/SECURE IDS	MULTI	netrangr	attack
CISCO	BBSM *Rev. 5.0 AND 5.1*	TELNET OR NAMED PIPES	bbsd-client	changeme2
CISCO	BBSD MSDE CLIENT *Rev. 5.0 AND 5.1*	TELNET OR NAMED	bbsd-client	NULL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Services

HTTP	35,848
HTTPS	26,003
SNMP	6,488
SIP	5,509
Telnet	1,968

Top Countries

United States	17,838
Turkey	5,905
China	3,731
Mexico	3,455
United Kingdom	3,110

71.181.180.236
Verizon Internet Services
Added on 12.11.2013
Wilkes Barre

pool-71-181-180-236.sctnpa.east.verizon.net

```
HTTP/1.0 401 Unauthorized
Date: Tue, 16 Jul 2002 14:51:33 GMT
Server: cisco-IOS
Connection: close
Accept-Ranges: none
WWW-Authenticate: Basic realm="level_1
```

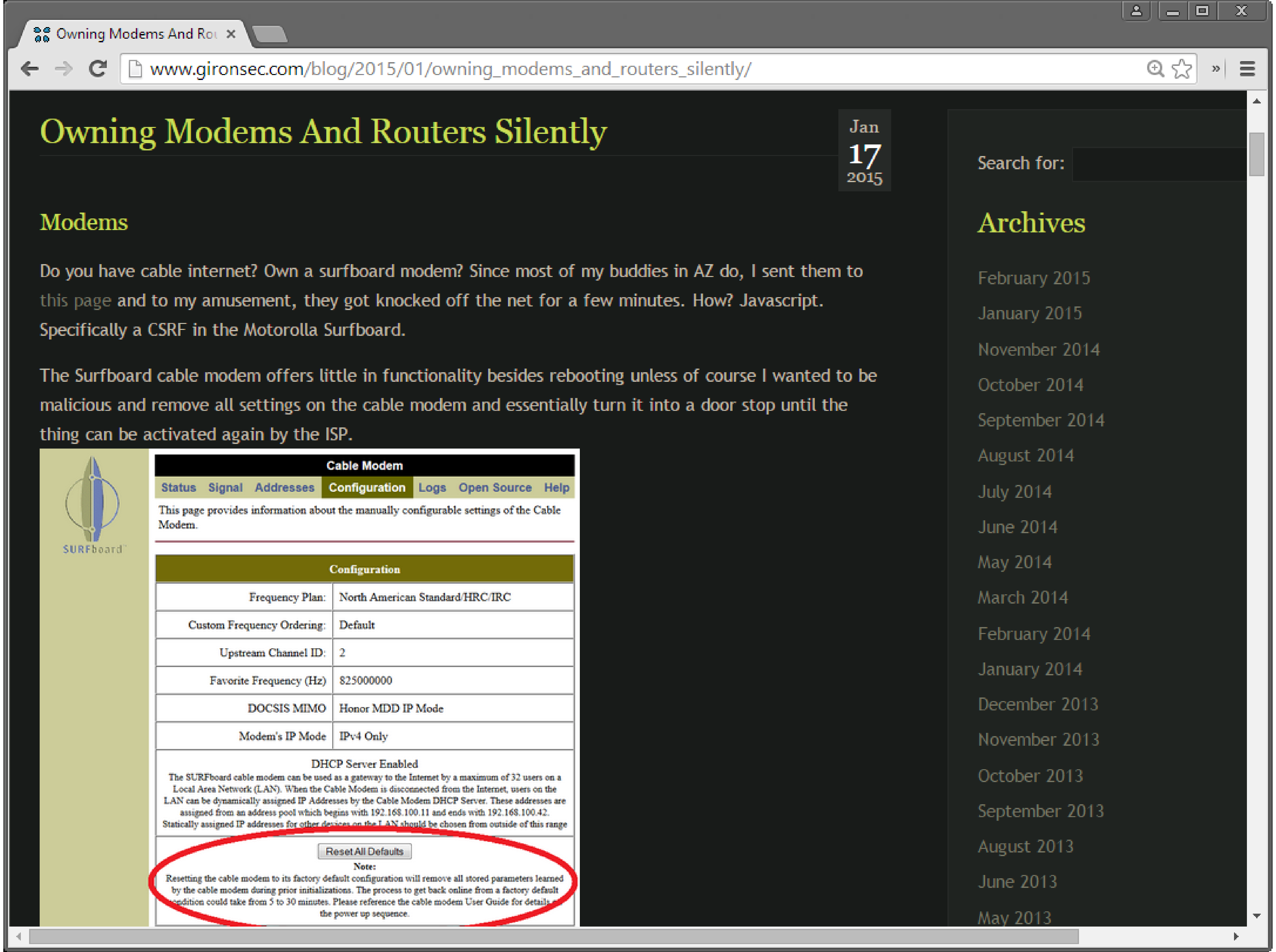
65.107.40.46
XO Communications
Added on 12.11.2013

65.107.40.46.ptr.us.xo.net

```
Cisco IOS Software, 2400 Software (C2430-IK9O3S-M), Version 12.4(15)T7, RELEASE SOFTWARE (fc3)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2008 by Cisco Systems, Inc.
Compiled Wed 13-Aug-08 15:51 by prod_rel_team
```

190.148.8.222
Telgua
Added on 12.11.2013

```
HTTP/1.0 401 Unauthorized
Date: Mon, 09 May 2011 03:13:41 GMT
Server: cisco-IOS
```



Owning Modems And Ro
www.gironsec.com/blog/2015/01/owning_modems_and_routers_silently/

Owning Modems And Routers Silently

Jan
17
2015

Modems

Do you have cable internet? Own a surfboard modem? Since most of my buddies in AZ do, I sent them to this page and to my amusement, they got knocked off the net for a few minutes. How? Javascript. Specifically a CSRF in the Motorolla Surfboard.

The Surfboard cable modem offers little in functionality besides rebooting unless of course I wanted to be malicious and remove all settings on the cable modem and essentially turn it into a door stop until the thing can be activated again by the ISP.

This page provides information about the manually configurable settings of the Cable Modem.

Configuration	
Frequency Plan:	North American Standard/HRC/IRC
Custom Frequency Ordering:	Default
Upstream Channel ID:	2
Favorite Frequency (Hz)	825000000
DOCSIS MIMO	Honor MDD IP Mode
Modem's IP Mode	IPv4 Only

DHCP Server Enabled

The SURFboard cable modem can be used as a gateway to the Internet by a maximum of 32 users on a Local Area Network (LAN). When the Cable Modem is disconnected from the Internet, users on the LAN can be dynamically assigned IP Addresses by the Cable Modem DHCP Server. These addresses are assigned from an address pool which begins with 192.168.100.11 and ends with 192.168.100.42. Statically assigned IP addresses for other devices on the LAN should be chosen from outside of this range

Note:

Resetting the cable modem to its factory default configuration will remove all stored parameters learned by the cable modem during prior initializations. The process to get back online from a factory default condition could take from 5 to 30 minutes. Please reference the cable modem User Guide for details on the power up sequence.

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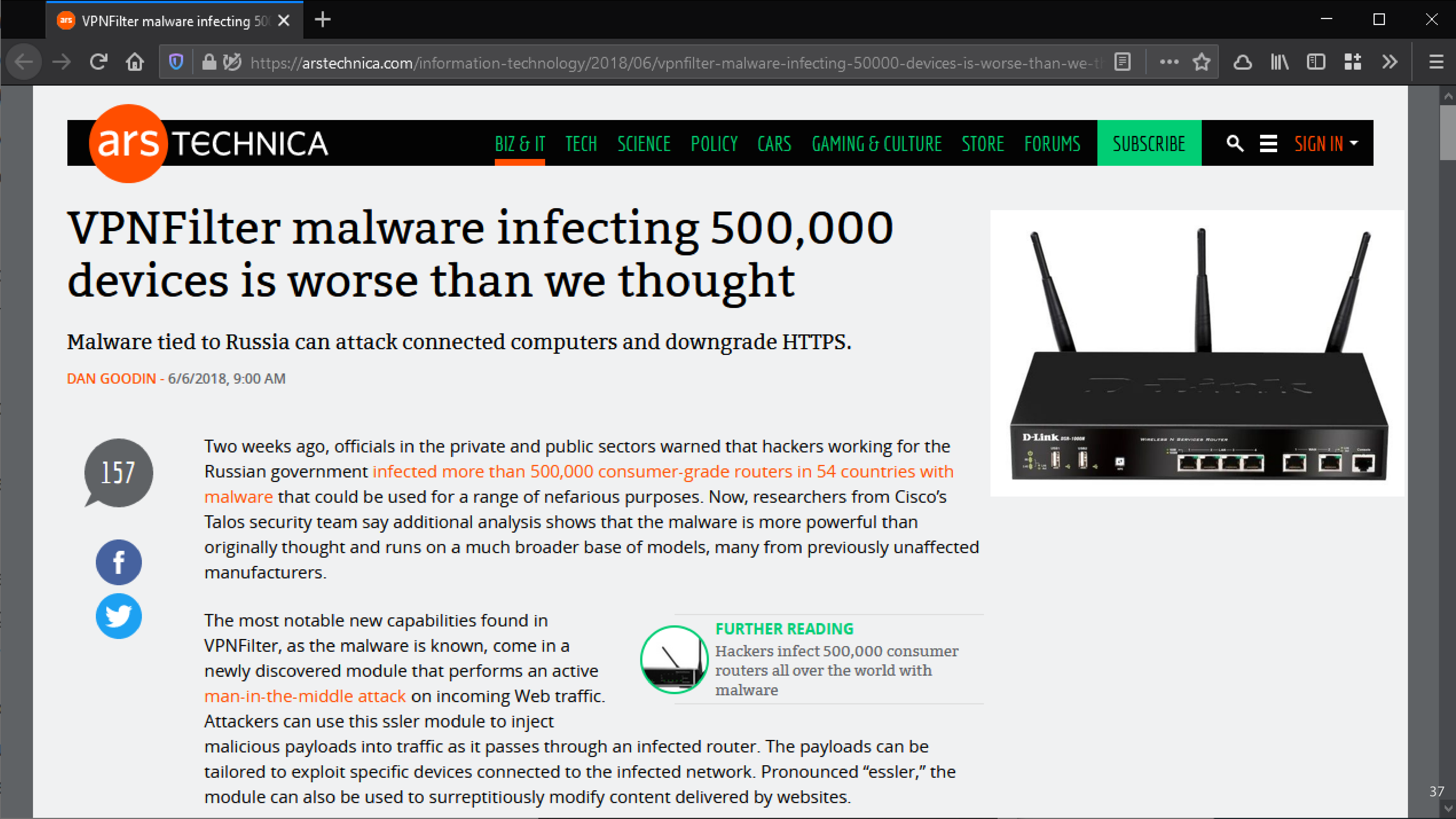
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D-Link DSR-1000N
WIRELESS N SERVICES ROUTER

VPNFilter malware infecting 500,000 devices is worse than we thought

Malware tied to Russia can attack connected computers and downgrade HTTPS.

DAN GOODIN - 6/6/2018, 9:00 AM

Two weeks ago, officials in the private and public sectors warned that hackers working for the Russian government infected more than 500,000 consumer-grade routers in 54 countries with malware that could be used for a range of nefarious purposes. Now, researchers from Cisco's Talos security team say additional analysis shows that the malware is more powerful than originally thought and runs on a much broader base of models, many from previously unaffected manufacturers.

The most notable new capabilities found in VPNFilter, as the malware is known, come in a newly discovered module that performs an active man-in-the-middle attack on incoming Web traffic. Attackers can use this ssler module to inject malicious payloads into traffic as it passes through an infected router. The payloads can be tailored to exploit specific devices connected to the infected network. Pronounced "essler," the module can also be used to surreptitiously modify content delivered by websites.

FURTHER READING
Hackers infect 500,000 consumer routers all over the world with malware

Discussion Topic: Port Knocking

Open otherwise firewalled ports on demand by "knocking" the right combination of ports

- Sometimes recommended for "securing" SSH and other servers
- Firewall opens the port only after observing connection attempts to the right combination of (closed) ports
- Variation: single packet authorization (packet containing a magic value)

Is it useful or pointless?

Discussion Topic: Running SSH on a non-default port

Is it useful or pointless?