redhat.

IPSEC FOR LARGE SCALE DEPLOYMENTS

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THE LIBRESWAN PROJECT

An Internet Key Exchange (“IKE”) daemon for IPsec

- Continuation of openswan, which itself was a fork of freeswan
- Uses the NSS library for all its crypto
- Certified (FIPS, Common Criteria, USGv6, etc.)
- Supports X.509 and DNSSEC as PKI
- Supports raw public keys and PSK
- Supports IKEv1 and IKEv2

IPsec PRIMER

IKE + IPsec = VPN

IKE (USERLAND)

ISAKMP, IKE SA, PHASE 1
UDP PORT 500 AND 4500

- Command Channel
- Peer authentication
- Connection parameter negotiation
- IPsec symmetric key generation
- Communicates to kernel

- IKE itself is encrypted
- IKE does not encrypt the IP traffic

IPsec (KERNEL)

IPsec SA, CHILD SA, PHASE 2
PROTOCOL 50 (ESP) AND 51 (AH)

- Data Channel
  - Encapsulated Security Payload (ESP) IP packet encryption
  - Authenticated Header (AH)
  - ESPinUDP (for NAT)

- Tunnel Mode (IP in IP)
- Transport Mode

LINUX IPsec IMPLEMENTATION (XFRM)

1. IPsec in the kernel has policies (SPD) and states (SAD)
   - Visible via: ip xfrm policy, ip xfrm state
   - Communication between userland and kernel visible via: ip xfrm monitor
   - Packets matching policies with a linked state causes encryption/decryption
   - Unencrypted packets matching an encryption policy without state are dropped
   - First outgoing plaintext packet matching IPsec policy without IPsec state triggers an ACQUIRE
2. Userland inserts “trap” policies for on-demand tunnels
3. Userland requests to receive ACQUIREs and processes these when received
   - Perform IKE negotiation with remote peer
   - Send IPsec policy and encryption/authentication keys to the kernel
4. Kernel processes netlink messages
   - Install received crypto keys in state, link crypto state to policy
   - If TCP was stored, send out cached TCP packet

LINUX IPsec IMPLEMENTATION (XFRM)

Mobile IKE: Support for mobile clients that change IP address

1. Libreswan receives an IKE message from a new IP address
2. Matches the encrypted IKE packet via SPI’s to an existing peer
3. Decrypts and confirms this IKE packet is a new packet (via sequence number)
4. Send XFRM_MIGRATE message to kernel
5. Kernel updates endpoint IP of the XFRM state
6. Libreswan confirms via a reply IKE message using the new destination IP address

LINUX XFRM / NETKEY KERNEL STATE

```
src 10.3.230.191/32 dst 0.0.0.0/0
        dir out priority 666 ptype main
        tmpl src 76.10.157.68 dst 209.132.183.55
                proto esp reqid 16413 mode tunnel
src 0.0.0.0/0 dst 10.3.230.191/32
        dir fwd priority 666 ptype main
        tmpl src 209.132.183.55 dst 76.10.157.68
                proto esp reqid 16413 mode tunnel
src 0.0.0.0/0 dst 10.3.230.191/32
        dir in priority 666 ptype main
        tmpl src 209.132.183.55 dst 76.10.157.68
                proto esp reqid 16413 mode tunnel

src 209.132.183.55 dst 76.10.157.68
        proto esp spi 0x605ad2be reqid 16413 mode tunnel
        auth-trunc hmac(sha1) 0x4b7e46cdee9c27588a1a75f6846073cea 96
        enc cbc(aes) 0x11ddc9080945111087e81f9ebda5aacb7612c78af1895
src 76.10.157.68 dst 209.132.183.55
        proto esp spi 0x8ca00de3 reqid 16413 mode tunnel
        auth-trunc hmac(sha1) 0x1119585d334a88e023134a100eca6b09f 96
        enc cbc(aes) 0x310b852b9cbaf2cace7979c1aeb5df4b32eb418c5c300
```

2019: Libreswan

- RFC 8229 “TCP Encapsulation of IKE and IPsec packets” support [*]
- Proof of concept for per-cpu IPsec SA support (pCPU XFRM)
- XFRMi virtual interface support to replace VTI virtual interfaces
- libvirt/KVM based testing complimented with namespace based testing
  - Much faster, takes less resources, can run tests in parallel
- NSS: Use the new “IPsec profile” X.509 validation (RFC 4945)
- Dramatically improve IKE performance by offloading more code to threads
- NSS: Cache decrypted private keys (Bob’s performance trick)
- RFC 5685 IKEv2 REDIRECT support for dynamic load balancing
- CVE-2019-12312 (crasher) and CVE-2019-10155 (sig validation failure)
- Improvements for Enterprise-wise (mesh) encryption

XFRMi virtual interface

- Specify: ipsec-device=<num>   will create device ipsecN
- tcpdump on ethX shows encrypted packets, on ipsecN shows plaintext
- Can be managed by the system (eg NetworkManager) or by libreswan
- Allow for routing based VPNs – if packet enters device, encrypt it
- Uses XFRM IF_ID (new IPsec policy parameter) and does not require MARKing
- Can be placed in a network namespace to enforce VPN-only access
- Some support in NetworkManager and systemd

- Older VTI (ip_vti0) implementation had limitations:
  - Each IPsec SA needed its own VTI interface and could only be ipv4 or ipv6
  - There could only be one wildcard interface (max 1 dynamic IP remote client)
  - VTI Only supported Tunnel Mode, not Transport Mode
  - Used GRE keys and MARKs

TCP support for Remote Access VPN

- IPsec (ESP) is usually encapsulated in UDP to traverse NATs
- IKE protocol uses UDP
- Some networks block IPsec (or all UDP except DNS)

- RFC 8229: TCP encapsulation of IKE and ESP
  - Port number not defined (evasive actions)
  - “IKETCP” prefix to support demultiplexing (aka IPsec-in-TLS support)

- New per connection options:
  - tcp-listen=<port>
  - tcp-remoteport=<port>
  - tcponly=yes|no

Per-CPU support for high speed IPsec SAs

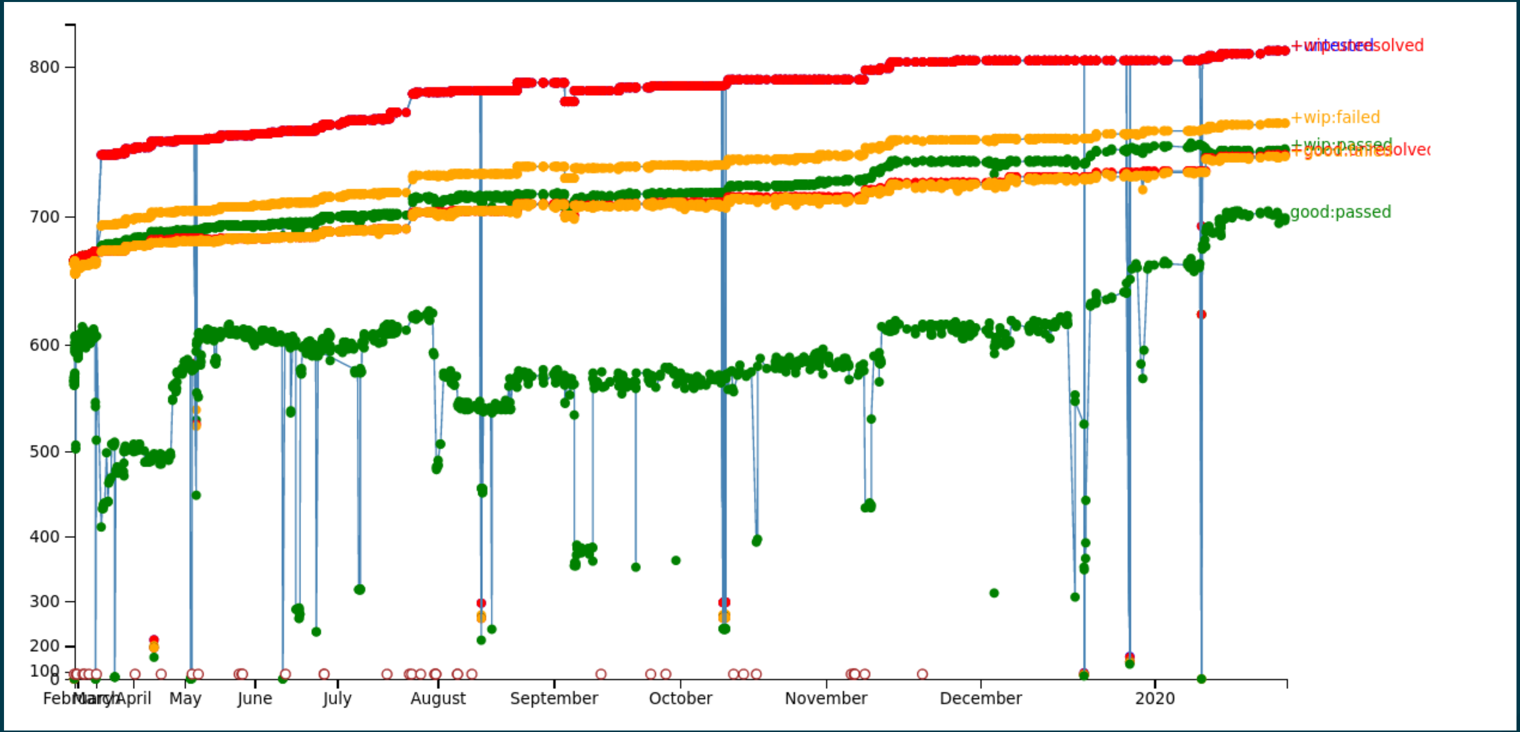
- Proof of Concept for per-cpu IPsec SA support (pCPU XFRM)
- Currently, 1 IPsec SA can only use 1 CPU (about 1-5 gbps)
- With pCPU, create <num> cpu times identical IPsec SA's
  - One IPsec SA is the main (catch all) IPsec SA
  - Further identical IPsec SA's are installed for a specific CPU
- Processes generating traffic on one CPU, use the one IPsec SA
  - Reduces out-of-order packets if multiple processes are sending data
- lab result show CPU combined speed (eg 3 CPU * 1gbps/cpu results in 3gbps)
- TODO: per-cpu "fake" ACQUIRE messages for per-CPU on-demand support
- TODO: support for on-demand QoS IPsec SA's
- See libreswan.org/wiki/XFRM_pCPU for kernel and libreswan code and docs
  - clones=<num>

Libreswan testing

- KVM/libvirt testing - 700+ tests
- libreswan.org/wiki/Test_Suite_-_KVM
- Took between 4 and 8 hours to run – reduced to 2-3 hours
- Would regularly hang KVM instances
- Tests cannot run in parallel

- Introduced namespaces based testing
- libreswan.org/wiki/Test_Suite_-_Namespace
- Re-uses KVM/libvirt tests, so most of the 700+ tests are functional
- Tests can be started in parallel (but sadly not too many still)

TESTING.LIBRESWAN.ORG



IPsec deployment types

- Host to host VPN
- Site to site VPN
- Remote Access VPN
- Enterprise wide encryption (mesh encryption)
- Internet wide Opportunistic Encryption (try IPsec, fallback to clear)

Host to host example configuration

Using self-signed or CA based certificates:

```
    # install localcertificate: ipsec import MyName.example.com.p12
    # Convention used: left means local, right means remote
    # /etc/ipsec.d/host-to-host.conf
    # bring up manually using: ipsec auto –up host-to-host

    conn host-to-host
            left=192.1.2.23
            leftid=@MyName.example.com
            # our certificate
            leftcert=MyName.example.com
            right=192.1.2.45
            rightid=@Peer.example.com  # ID must be SubjectAltName on cert
            # their certificate transmitted via IKE
            auto=ondemand
```

Net to Net example configuration

Using self-signed or CA based certificates:

```
# install localcertificate: ipsec import MyName.example.com.p12
# Convention used: left means local, right means remote
# /etc/ipsec.d/net-to-net.conf
# bring up manually using: ipsec auto –up net-to-net

conn net-to-net
        left=192.1.2.23
        leftsubnet=192.0.1.0/24
        leftid=@MyName.example.com
        # our certificate
        leftcert=MyName.example.com
        right=192.1.2.45
        rightsubnets={192.0.2.0/24, 192.168.0.0/16}
        rightid=@Peer.example.com  # ID must be SubjectAltName on cert
        # their certificate transmitted via IKE
        auto=ondemand
```

Remote Access Server configuration

Using CA based certificates:

```
# /etc/ipsec.d/vpnserver.conf

conn vpnserver
        left=193.110.157.148
        leftcert=vpn.nohats.ca
        leftid=@vpn.nohats.ca
        # for split-VPN, specify your server’s subnet instead of 0/0
        leftsubnet=0.0.0.0/0
        rightaddresspool=100.64.13.2-100.64.13.254
        right=%any
        rightid=%fromcert
        # server options
        auto=add
        rekey=no
        modecfgdns=8.8.8.8
        modecfgpull=yes
        dpddelay=9m
        dpdtimeout=30m
        dpdaction=clear
        mobike=yes
        ipsec-interface=yes
```

Remote Access Client configuration

Using CA based certificates:

```
# Import my PKCS#12 cert: ipsec import letoams.nohats.ca.p12
# /etc/ipsec.d/corporate.conf

conn corporate-vpn
     left=%defaultroute
     leftcert=letoams.nohats.ca
     leftsubnet=0.0.0.0/0
     leftmodecfgclient=yes
     right=vpn.nohats.ca
     rightsubnet=0.0.0.0/0
     rightid=@vpn.nohats.ca
     narrowing=yes
     rekey=yes
     mobike=yes
```

Remote Access Client configuration

Using CA based certificates:

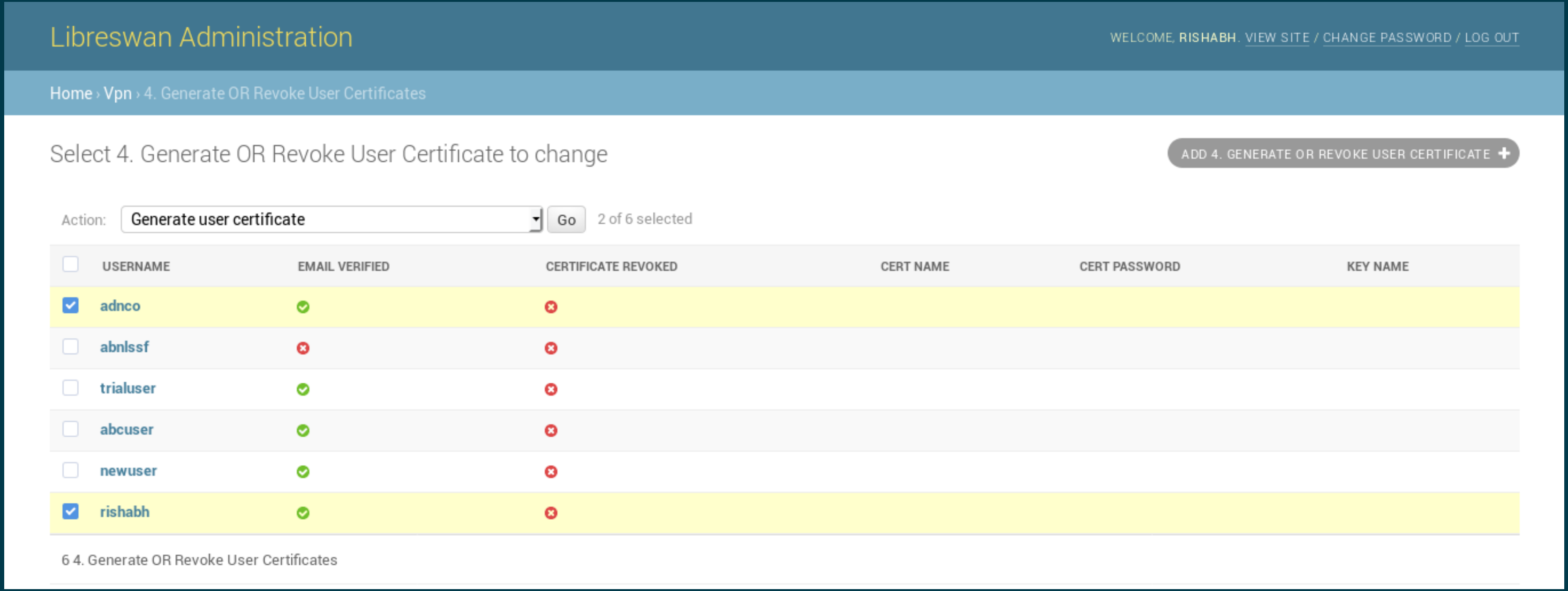
```
$ sudo ipsec auto --up vpn.nohats.ca
181 "vpn.nohats.ca"[1] 193.110.157.148 #1: initiating IKEv2 IKE SA
181 "vpn.nohats.ca"[1] 193.110.157.148 #1: STATE_PARENT_I1: sent v2I1, expected v2R1
182 "vpn.nohats.ca"[1] 193.110.157.148 #2: STATE_PARENT_I2: sent v2I2, expected v2R2 {auth=IKEv2
    cipher=AES_GCM_16_256 integ=n/a prf=HMAC_SHA2_512 group=MODP2048}
002 "vpn.nohats.ca"[1] 193.110.157.148 #2: certificate verified OK
    E=info@nohats.ca,CN=vpn.nohats.ca,OU=Clients,O=No Hats
    Corporation,L=Ottawa,ST=Ontario,C=CA
002 "vpn.nohats.ca"[1] 193.110.157.148 #2: IKEv2 mode peer ID is ID_FQDN: '@vpn.nohats.ca'
003 "vpn.nohats.ca"[1] 193.110.157.148 #2: Authenticated using RSA with IKEv2_AUTH_HASH_SHA2_512
002 "vpn.nohats.ca"[1] 193.110.157.148 #2: received INTERNAL_IP4_ADDRESS 100.64.13.3
002 "vpn.nohats.ca"[1] 193.110.157.148 #2: received INTERNAL_IP4_DNS 193.110.157.148
005 "vpn.nohats.ca"[1] 193.110.157.148 #2: Received INTERNAL_DNS_DOMAIN: nohats.ca
002 "vpn.nohats.ca"[1] 193.110.157.148 #2: up-client output: updating resolvconf
002 "vpn.nohats.ca"[1] 193.110.157.148 #2: negotiated connection [100.64.13.3-100.64.13.3:0-65535 0] ->
[0.0.0.0-255.255.255.255:0-65535 0]
004 "vpn.nohats.ca"[1] 193.110.157.148 #2: STATE_V2_IPSEC_I: IPsec SA established tunnel mode
{ESP/NAT=>0x0bb71fd2 <0x899a9f05 xfrm=AES_GCM_16_256-NONE NATOA=none NATD=193.110.157.148:4500
DPD=passive}
```

Remote Access Client NetworkManager plugin

networkmanager-libreswan

Remote Access Server Web interface

Preview: github.com/Rishabh04-02/Libreswan-managing-interface



Libreswan Administration

WELCOME, RISHABH. VIEW SITE / CHANGE PASSWORD / LOG OUT

Home › Vpn › 4. Generate OR Revoke User Certificates

Select 4. Generate OR Revoke User Certificate to change

ADD 4. GENERATE OR REVOKE USER CERTIFICATE +

Action: Generate user certificate | Go | 2 of 6 selected

	USERNAME	EMAIL VERIFIED	CERTIFICATE REVOKED	CERT NAME	CERT PASSWORD	KEY NAME
☑	adnco	✓	✗			
☐	abnlssf	✗	✗			
☐	trialuser	✓	✗			
☐	abcuser	✓	✗			
☐	newuser	✓	✗			
☑	rishabh	✓	✗			

6 4. Generate OR Revoke User Certificates

Remote Access Server interface

- Setup a Certificate Agency CA)
- Setup the VPN server (TLS and IPsec)
- Generate client certificates (PKCS#12) for download
- Generate iOS/OSX VPN profiles (1 click install)
- Traffic Accounting of clients
- Temporarily and permanently Revoke client certificates

Enterprise wide (mesh) encryption

- Each node attempts on-demand (opportunistic) IPsec to each other node
- A node policy can be REQUIRE, OPTIONAL, or NO encryption using IPsec
- Nodes should be able to list policies based on IP ranges and/or ports
- Exceptions should be allowed for specific nodes
- Added a new node should not require any reconfiguration on existing nodes
- Idle IPsec connections should be removed over time
- Currently support X.509 and DNSSEC as PKI for authenticating nodes

- WARNING: Your network based firewalls and IDS are bypassed!

Enterprise wide (mesh) encryption

Group policy files in /etc/ipsec.d/policies/* list network CIDRs andports

```
/etc/ipsec.d/policies/clear                   - Only allow cleartext
/etc/ipsec.d/policies/clear-or-private        - Default clear, allow IPsec
/etc/ipsec.d/policies/private                 - Require IPsec
/etc/ipsec.d/policies/private-or-clear        - IPsec, fallback to clear

# /etc/ipsec.d/policies/private-or-clear
193.110.157.0/24
193.111.228.0/24

# /etc/ipsec.d/policies/private
10.0.0.0/8
192.168.0.0/16

# /etc/ipsec.d/policies/clear
193.110.157.0/24:22  # ssh
193.110.157.0/24:443 # https
```

Enterprise wide (mesh) encryption

Policy files are implemented using “regular” connection definitions

```
# install localcertificate: ipsec import node1.example.com.p12
# /etc/ipsec.d/private.conf

conn private
        left=%defaultroute
        leftid=%fromcert
        # our certificate
        leftcert=node1.example.com
        right=%opportunisticgroup
        rightid=%fromcert
        failureshunt=drop
        negotiationshunt=hold
        auto=ondemand
```

Enterprise wide (mesh) encryption

Configuration for IPsec with fallback to cleartext

```
# install localcertificate: ipsec import node1.example.com.p12
# /etc/ipsec.d/private-or-clear.conf

conn private-or-clear
        left=%defaultroute
        leftid=%fromcert
        # our certificate
        leftcert=node1.example.com
        right=%opportunisticgroup
        rightid=%fromcert
        failureshunt=passthrough
        negotiationshunt=passthrough
        # to not leak cleartext during IKE negotiation:
        # negotiationshunt=hold
        auto=ondemand
```

Enterprise wide (mesh) encryption

Configuration for preferring plaintext but accepting IPsec if requested

```
# install localcertificate: ipsec import node1.example.com.p12
# /etc/ipsec.d/clear-or-private.conf

conn clear-or-private
        left=%defaultroute
        leftid=%fromcert
        # our certificate
        leftcert=node1.example.com
        right=%opportunisticgroup
        rightid=%fromcert
        failureshunt=passthrough
        negotiationshunt=passthrough
        # to not leak cleartext during IKE negotiation:
        # negotiationshunt=hold
        # don’t initiate, but allow responding
        auto=add
```

Recap: Enterprise wide (mesh) encryption

- Create policy connections in /etc/ipsec.d/*.conf for IPsec policy groups
- Place IP address/port ranges in /etc/ipsec.d/policues/*
- Import host PKCS#12 certificate into libreswan
- Start the IPsec service
- Profit!

- Check encryption
  - ipsec trafficstatus
  - ipsec status
  - ipsec shuntstatus (for remote peers we tried and failed IPsec to)

Internet wide mesh encryption using LetsEncrypt

(Requires libreswan 3.30, uses NAT-within-IPsec)

```
# setup on laptop
# (host initiated as anonymous, authenticates remote server)
$ sudo ipsec letsencrypt --client
# echo “193.110.157.131/32” >> /etc/ipsec.d/policies/private-or-clear
# echo “0.0.0.0/0” >> /etc/ipsec.d/policies/private-or-clear

# Setup on server:
# (host authenticates itself via FQDN (eg letsencrypt.nohats.ca)
$ sudo ipsec letsencrypt --server
# (create a letsencrypt certificate for IPsec)
$ sudo ipsec letsencrypt --generate-certificate my.example.com
```

LETSENCRYPT CLIENT FOR IPSEC

Anonymous client to authenticated server

```
$ ping letsencrypt.libreswan.org
PING letsencrypt.libreswan.org (193.110.157.131) 56(84) bytes of data.
64 bytes from letsencrypt.libreswan.org (193.110.157.131): icmp_seq=2
ttl=64 time=96.2 ms
64 bytes from letsencrypt.libreswan.org (193.110.157.131): icmp_seq=3
ttl=64 time=96.7 ms

ipsec whack --trafficstatus
006 #2: "private-or-clear#193.110.157.131/32"[1]
100.64.0.2/32=== ...193.110.157.131, type=ESP, add_time=1471926595,
inBytes=252, outBytes=252, id='CN=letsencrypt.libreswan.org',
lease=100.64.0.2/32
```

DRAFT-ANTONY-IPSECME-OPPO-NAT

Eliminating the IP address conflicts caused by NAT

```
193.110.15.131  Remote Opportunistic IPsec server
192.168.2.45      Opportunistic Client pre-NAT IP address
100.64.0.2      IP address from IPsec server address pool
# ip xfrm pol
src 100.64.0.2/32 dst 193.110.157.131/32
     dir out priority 2080 ptype main
     tmpl src 192.1.2.45 dst 193.110.157.131
          proto esp reqid 16389 mode tunnel
src 193.110.157.131/32 dst 100.64.0.2/32
     dir fwd priority 2080 ptype main
     tmpl src 193.110.157.131 dst 192.1.2.45
          proto esp reqid 16389 mode tunnel
src 193.110.157.131/32 dst 100.64.0.2/32
     dir in priority 2080 ptype main
     tmpl src 193.110.157.131 dst 192.1.2.45
          proto esp reqid 16389 mode tunnel
src 192.168.2.45/32 dst 193.110.157.131/32
     dir out priority 2080 ptype main
     tmpl src 192.1.2.45 dst 193.110.157.131
          proto esp reqid 16389 mode tunnel
```

DRAFT-ANTONY-IPSECME-OPPO-NAT

Eliminating the IP address conflicts caused by NAT

```
193.110.15.131  Remote Opportunistic IPsec server
192.168.2.45    Opportunistic Client pre-NAT IP address
100.64.0.1      Client IP address assigned y Opportunistic Ipsec server

# iptables -t nat -L -n

Chain PREROUTING (policy ACCEPT)
target     prot opt source               destination
DNAT       all  --  193.110.157.131      100.64.0.1 \
          policy match dir in pol ipsec to:192.168.2.45

Chain POSTROUTING (policy ACCEPT)
target     prot opt source               destination
SNAT       all  --  0.0.0.0/0            193.110.157.131 \
          policy match dir out pol ipsec to:100.64.0.1


Basically: NAT within the IPsec subsystem
```

QUESTIONS & ANSWERS