IPv6 for the InfoSec Pro On the Go

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#include disclaimer.h

Before We Begin

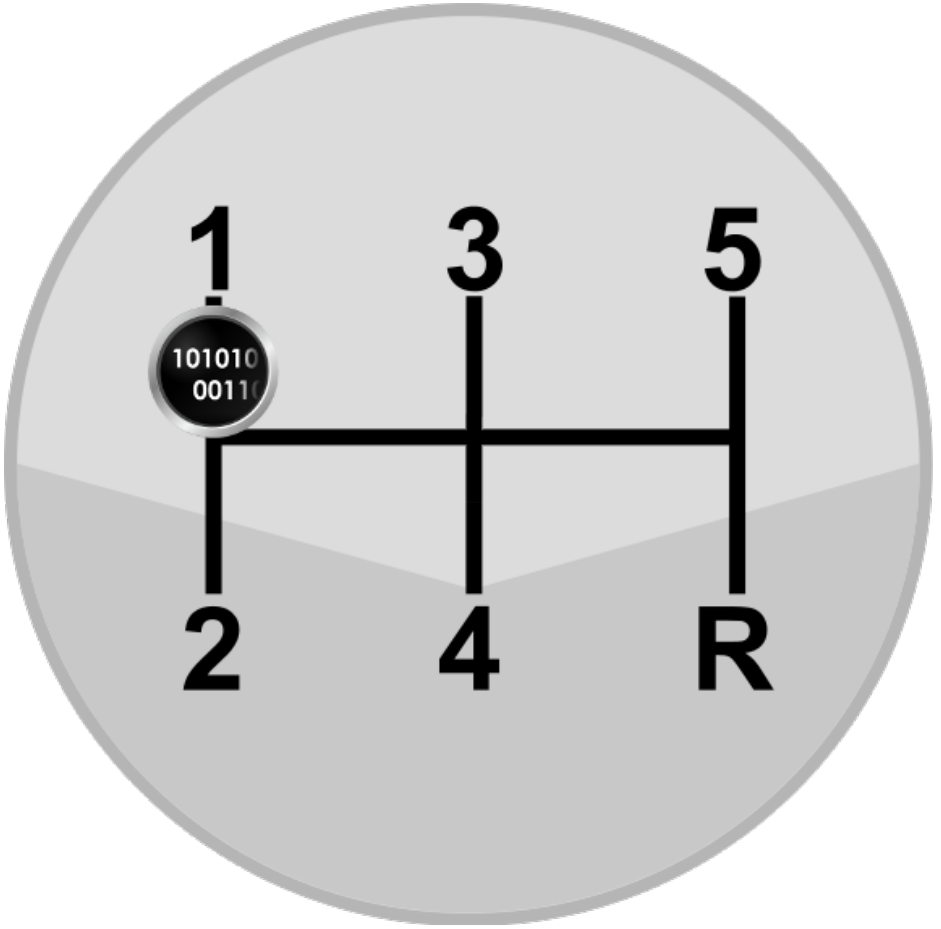
- First RFCs published December 1995
- 432 RFCs about or affecting IPv6
  - 234 Standards Track
  - 163 Informational
  - 27 Experimental
  - 8 Best Current Practice
  - 46 Obsolete
- Numbers are a little old (mid 2015?)

Nothing I tell you is false, but not all may prove to be true.

Agenda

- IPv6 Basics
- Default Behaviour
- Infrastructure notes
- Tools and Technology
- My Goal

Basics



IPv6 Basics

- Size
- Representation
- Interfaces
- Transitions

RFC2460

Internet Protocol Version 6 Specification

IPv6 Basics - Size

- IPv6 addresses are 128 bits long
- Each Regional Internet Registry gets multiple /23 blocks
  - Divided into 512 /32 blocks
- One /32 for each ISP
  - Divided into 65,536 /48 blocks
- One /48 for each ISP's Customer
  - Divided into 65,536 /64 networks internally

Still in Flux? Some talk of /56 assignments

IPv6 Basics – Size (2)

- *All IPv6:* 2^{128} =

  340,282,366,920,938,463,463,374,607,431,768,211,456

- *ISP:* 2^{96} =

  79,228,162,514,264,337,593,543,950,336

- *Customer:* 2^{80} =

  1,208,925,819,614,629,174,706,176

- *Smallest Subnet:* 2^{64} =

  18,446,744,073,709,551,616

* Wolfram Alpha

PRO TIP!

Describe the amount of space in terms of the number of Internets!

Let **cI** (classic Internet) = 2^{32}

Therefore

Smallest IPv6 Subnet of 2^{64} hosts = $\mathbf{cI^2}$

AKA

An Internet of Internets!

IPv6 Basics - Representation

- 8 groups of 16 bits each written as 4 hex characters
  - 2001:0034:0000:0000:0000:FF45:A6B3:0D3B
- From any group, leading zeros can be removed
  - 2001:34:0:0:0:FF45:A6B3:D3B
- Any consecutive set of zeros can be “collapsed” to “::”
  - 2001:34::FF45:A6B3:D3B

- Therefore Loopback:
  - 0000:0000:0000:0000:0000:0000:0000:0001
- Becomes:
  - ::1

IPv6 Basics – Representations (2)

- Networks are represented as CIDR Prefixes
  - 2001:2::/48 *or* 2001:4:112::/48
- Reserved spaces
  - 2000::/3 Global Unicast (~ $cI^{3.90}$)
  - FE80::/10 Link Scoped Unicast (~ $cI^{3.69}$)
    - i.e. FE80::1111%eth0 or FE80::1111%1
  - FF00::/8 Multicast
  - Others and subsets

PRO TIP!

- When writing your own code, remember to normalize your IPv6 addresses.
- Check that software you rely upon does as well.
- Hint: Try not to store them as strings
- But you already do this right?

IPv6 Basics – Representations (3)

- IPv4 Compatible addresses
  - Defined as ::/96 (::192.168.0.2 or ::C0A8:2)
  - Used to connect IPv6 over IPv4 networks
  - Deprecated
- IPv4 Mapped addresses
  - Defined as ::FFFF::/96
  - ::FFFF:192.168.0.2 or ::FFFF:C0A8:2
  - Used to connect IPv4 applications to IPv6 Sockets

Both of these are transition technologies

PRO TIP!

- By the way “::” is the IPv6 equivalent of “0.0.0.0”
- Also “::FFFF:” is the same as “::ffff:”
  - but capitals are easier to read

IPv6 Basics – Interfaces

- Each interface can have multiple IPv6 addresses
  - How many is OS dependent it seems
  - Linux configuration limit of 16
  - Sometime necessary to add %interface to the address
- “All modern devices run both IPv4 and IPv6”
  - Some VoIP phones do not
  - Android SLAAC only?
  - Desktop and server OS’s are OK
- All in addition to the usual IPv4 setup

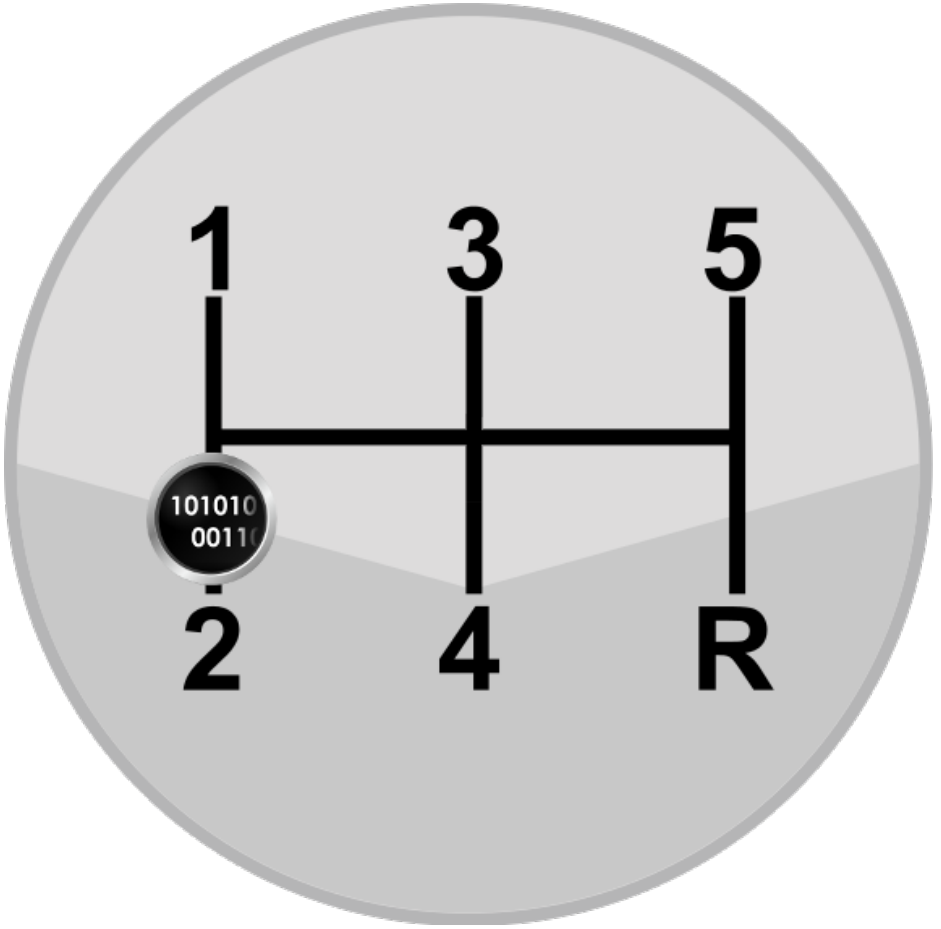
IPv6 Basics – Transitions

- NAT64/DNS64
- 6to4 (community wants this deprecated 2011)
- ISATAP (look for prefix fe80::0200:5efe:)
- IPv6 Automatic Routing
- 6over4 (uses IPv4 multicast)
- Teredo (Miredo software last changes 2013?)
- PortProxy (MS only, not just IPv6)

NAT64 and DNS64

- Meant for pure IPv6 networks
- NAT64 (RFC6146)
  - An interface in each space
  - A gateway translating IPv6 to IPv4
- DNS64
  - A DNS server that returns temp IPv6 addresses for IPv4 only services
  - Used to get IPv6-only endpoints to the NAT64

Default Behaviour



Default Behaviours

- Stateless Address Auto-configuration (RFC4862)
- Privacy extensions (RFC4941)
- Neighbor Discovery Protocol (RFC4861)
  - Neighbour Solicitation and Advertisement
  - Router Solicitation and Advertisement
  - Redirection

Default - SLAAC

- Derived from IEEE addresses (if available)
  - 00:01:02:AA:BB:CC
- Split it in half, and insert “FF:FE”
  - 00:01:02:FF:FE:AA:BB:CC
- Flip the second last bit in the first eight
  - 02:01:02:FF:FE:AA:BB:CC (64 bit address)
- Prepend the prefix and rewrite
  - FE80::0201:02FF:FEAA:BBCC (128 bit link address)

SLAAC: Stateless Auto Address Configuration

PRO TIP!

- This is why the smallest network is a /64 or always will be
- RFCs state that a interface identifier should be used to generate a unique address.
- Hardware address is a natural fit, but there needs to be other ways (non-ether protocols?)

Default – SLAAC (2)

- Treat newly generated address as “Tentative”
- Perform Duplicate Address Detection (DAD)
- If no duplicate address detected
  - Assign to the interface
  - Set expiry (always “forever” on link-local)
  - Set preference (always “preferred” on link-local)
- Else
  - Stop (choke; no retry; no other MAC?)

PRO TIP!

- If you monitor for DAD and respond, you can DoS networks.

DAD: Duplicate Address Detection

Default – Privacy Extensions

- Create additional global addresses for new outbound connections!
- Make them temporary
  - a few hours to a few days
- Make them random
  - next address always unpredictable
  - But re-creatable!

PRO TIP!

- Each address is also a “listening” address (naturally)
- Privacy extensions are not on by default in Mac OSX.

Default – Neighbor Discovery Protocol

- Protocol for node communication on the same link (RFC 4861)
- Sort of like:
  - IPv4's ARP
  - ICMP Router Discovery
  - ICMP Redirect
- Also has Neighbor Unreachability Detection
- Uses multi-cast addressing (not broadcast)
  - FF02::1 for all-nodes
  - FF02::2 for all-routers
  - And others...

All done via ICMPv6

PRO TIP!

- ICMPv6 provides much more functionality than ICMPv4. Be very careful what you choose to block at firewalls.

- But blocking unsolicited router advertisements is a good idea

Default – Neighbor Solicitation and Advertisement

- Solicitations
  - Multicast ICMP to resolve an address
    - Multicast address FF02::1
  - Unicast to confirm reachability
- Advertisements
  - In response to solicitation
  - Without solicitation, used to propagate changes

PRO TIP!

Multicast Address	Reason
FF02::1	All Nodes
FF02::2	All Routers
FF02::1:2	All DHCPv6 Agents

There are many more.

If you ping6 these addresses, you will get interesting results! Including multiple “Duplicate” responses similar to pinging broadcast addresses.

These 3 should be particularly interesting to pentesters.

PS: there is no broadcast address any more

Default – Router Solicitation and Advertisement

- Same as Neighbor Solicitation and Advertisement except also contains:
  - address space advertised (global address prefix)
  - Preference/priority (high, med, low)
  - Router lifetime / prefix lifetime
  - Flags including “Managed” and “OtherConfig”
- Does not contain anything that could be considered “authentication” or “proof-of-source”

PRO TIP!

- 33:33:00:00:00:00 – 33:33:FF:FF:FF:FF are reserved for IPv6 Multicast at the ethernet layer.

- It is possible to (re)play an “advertisement” packet directly to an end node by changing the dest ether address to that of the end node

- In the case of router advertisements, the end node could be tricked into assigning itself an address in a different prefix

Default – DHCPv6

- RFC3315
- If router advertisement has “Managed” or “OtherConfig” flag set, get info from DHCPv6
- Requires endpoint configuration
  - Linux NetworkManager is SLAAC by default can be set to use DHCPv6 (ignores flags?)
  - DHClient must run a second instance with “-6” switch

Default – DUID

- The host identifier is this DHCP Unique Identifier
- In RFC3315
  - Type 1: Link Layer Address plus Time (DUID-LLT)
  - Type 2: Enterprise Number (DUID-EN)
  - Type 3: Link Layer Address (DUID-LL)
- In RFC6355
  - Type 4: A created UUID (DUID-UUID)

- DHCPv6 does not define the use of MAC as an identifier
- A lot of alternative servers popping up that do

DUID: DHCP Unique IDentifier

PRO TIP!

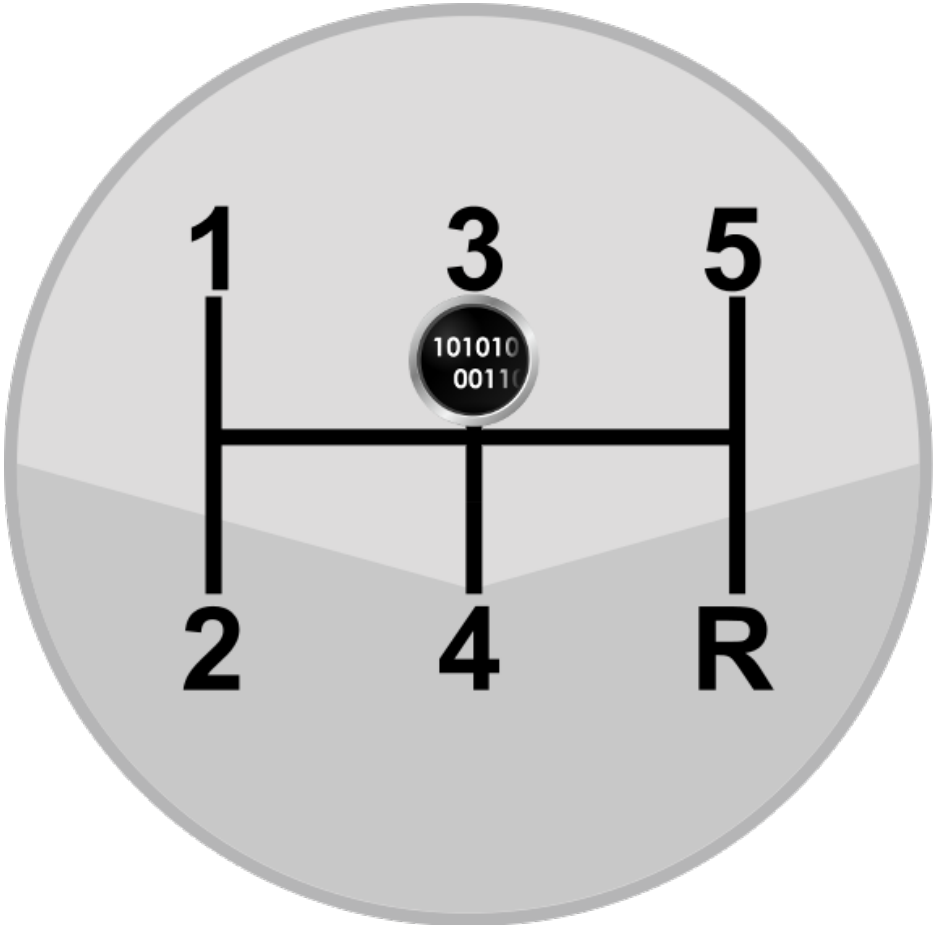
- In ISC DHCPv6 address reservations are set by DUID, not hardware address

- In some cases, hardware address is extractable from the DUID but not if DUID-EN or DUID-UUID is used.

- Ubuntu uses DUID-UUID
- Android doesn’t support DHCPv6

- But you can get hardware address from a DHCP proxy (same box?)

Infrastucture Notes



Infrastructures

- All-default (non-)configuration
  - AKA the “ignored”
- Minimal Configuration
  - AKA the “explored”
- Turned off and/or disabled
  - AKA the “removed”
- Complete Configuration
  - AKA the “matured”

PRO TIP!

- BTW, did I mention that there is no NAT?

Infrastructures - Ignored

- Devices have FE80:: addresses
- Devices are asking for router information
  - But not finding any
- Some internal communication
  - Service discovery
- No controls / detection mechanisms
  - And sometimes incapable controls (ie. Firewalls)
- Probably the majority for years to come

PRO TIP!

- Firewalls that cannot control IPv6 just let it though (Cisco FWSM)
- Blanket denies in IPv4 can be forgotten in IPv6
- iptables and ip6tables: two separate commands

Infrastructures - Explored

- Has a router advertising an IPv6 prefix
- Might have a DHCPv6 server
- Dual Stacks
  - Traffic defaults to IPv6 when available
- Set DNS server via prefix advert (RFC6106)
- Tunnelled?

PRO TIP!

- If you set your IPv6 router to the highest priority, it will be slightly harder to introduce a rogue router
- Forging redirects may still be an effective attack even if you do the above

Infrastructures - Removed

- “Don’t understand / can’t support. Therefore turning it off.”
- Easy to do with central configuration mgmt
  - Or via gold images?
- A little harder for IoT and “appliances”
  - There will always be something that remains
- Actively blocks / alerts on IPv6

PRO TIP!

- If you choose to disable IPv6 on your network(s), then setting up alerts when IPv6 is detected is an excellent way to detect a rogue device.

- Isolating devices that cannot have IPv6 turned off may be a good idea as well.

Infrastructures - Matured

- One or more routers advertising large prefixes
- DHCPv6 possibly with dynamic DNS
- DNS64 and NAT64
- SEcure Neighbor Discovery (RFC3971 RFC6494)
- Ready to run as a pure IPv6 network

only anecdotal; haven’t seen one

SEND: SEcure Neighbor Discovery

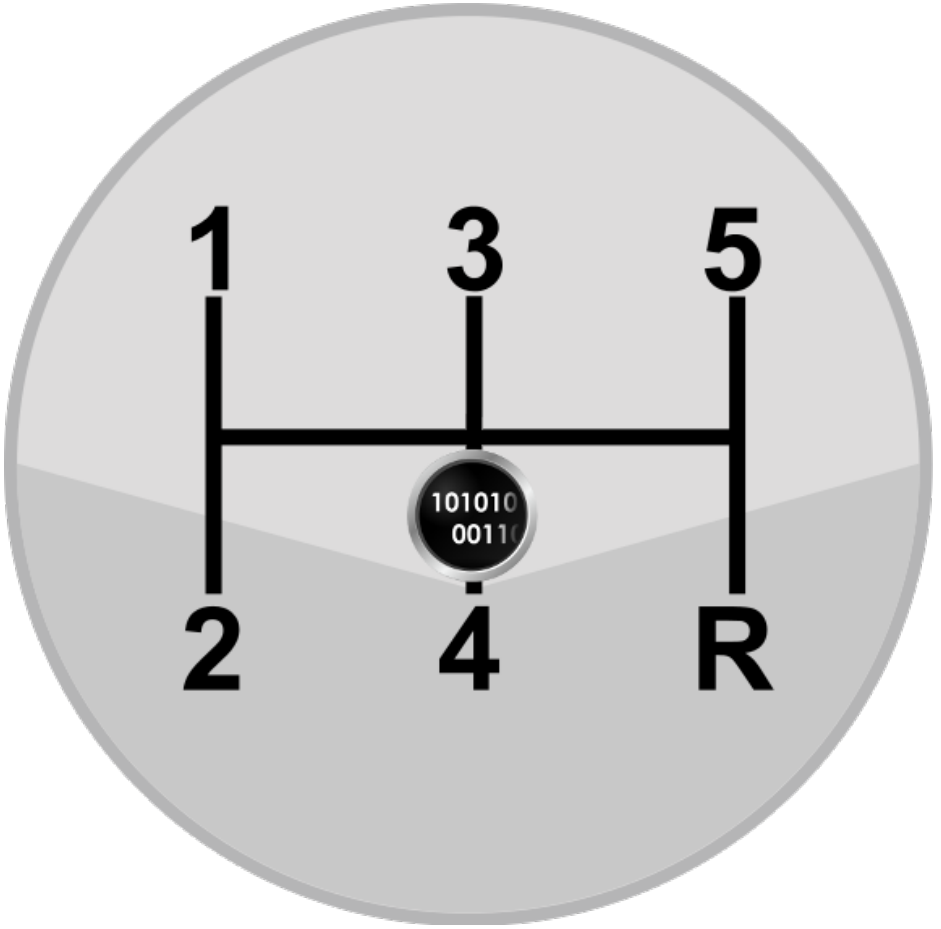
PRO TIP!

- “Naming” servers and subnets is strongly suggested.

- If you have 2001:501:1DD:0000::/56
  - Servers: 2001:501:1DD:AA::/64
  - Workstations: 2001:501:1DD:1:/64
  - ServerDev: 2001:501:1DD:BB::/64
  - Guest: 2001:501:1DD:FF::/64

- Notice not using :0000::/64 to avoid possible confusion
- Also, easier to see where traffic is from/to

Tools and Technology



Tools and Technology

- SEND (RFC3971 RFC6494)
- THC-IPv6
- Scanners
- Python and Scapy Library

Secure Neighbor Discovery (SEND)

- Extended Neighbor discovery options that provide:
  - An authorization delegation discovery process
  - an address ownership proof mechanism
  - and requirements for the use of these components in Neighbor Discovery Protocol
- Requires pretty extensive PKI
  - Cryptographically Generated Addresses
  - Certificates and “trust anchors”
  - Signing all ND packets (in RSA with max 2048 bit?)

Secure Neighbor Discovery (SEND)

- RFC says “SEND is applicable in environments where physical security on the link is not assured …”
  - What did physical security look like in 2005?
- Do we trust the physical security of ANY network?
- Wireless is called out specifically as not physically secure (surprise)

THC-IPv6 Attack Framework

- https://www.thc.org/thc-ipv6/
- An excellent set of tools and libraries
  - Now with public development on github
- In my env's some work and some do not
- Old, but kept up to date. v3.0 released this year.
- Strongly recommend running "alive6" as part of any recon.

Scanners

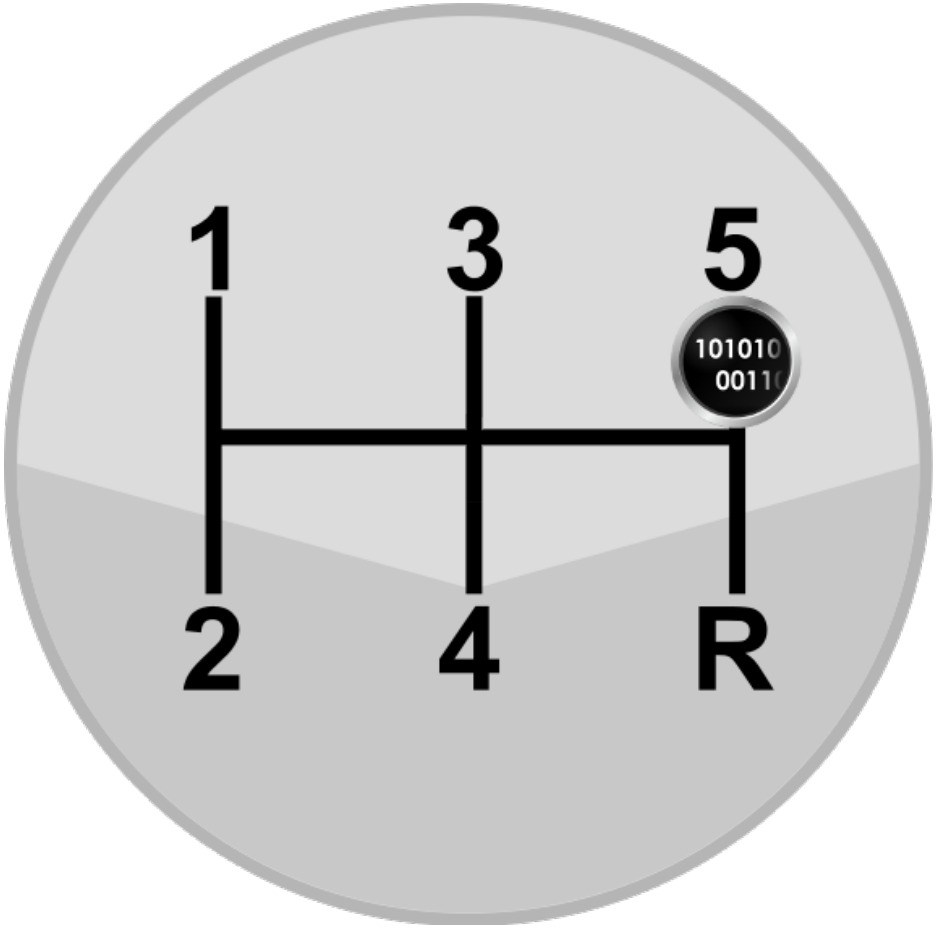
- Specifically calling out NMAP and MASSCAN
- NMAP
  - Scans known IPv6 targets as expected
  - Implements Neighbor Discovery scan as -6 -PR
  - Takes a long time to ND scan even a /64
  - Can address smaller than /64
- MASSCAN
  - Cannot do IPv6 today
  - But if it could, and it scaled linearly, a /64 would take 33 days with a single 10GBit interface

Python and Scapy library

- Scapy is a “packet rolling” library for python
- It has rich support for IPv6
- Very easy to use
- This is how to generate a Router Advertisement packet:

  Ether()/IPv6()/ICMPv6ND_RA()/ICMPv6NDOptPrefixInfo(prefix='aaaa:aaaa:aaaa:aaaa::',prefixlen=64)

My Goals



Automated MITM

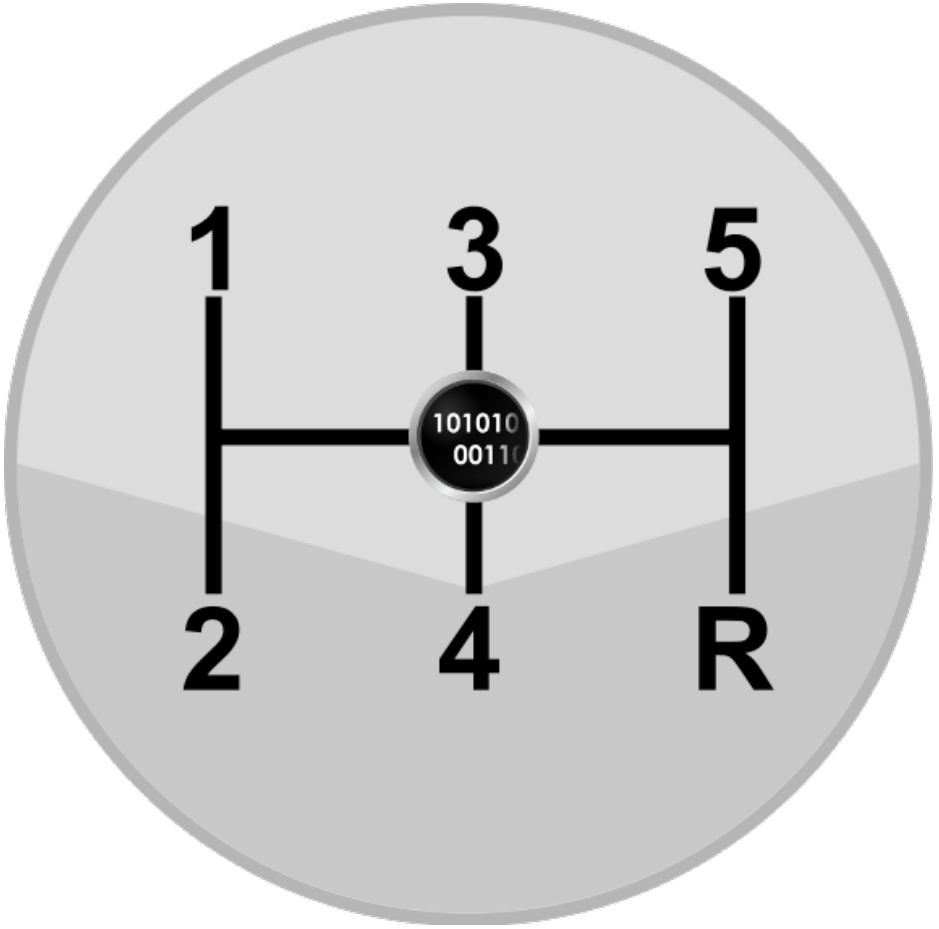
- Includes:
  - A rogue router
  - A dhcpv6 server
  - A NAT64/DNS64 install
- Interfaces
  - One IPv4 and One IPv6
  - Wifi connectivity

- Trying to see how far I can get with each of the infrastructure types

Automated MITM (2)

- Abilities:
  - Find and suppress installed routers (if necessary)
  - Find and suppress DHCPv6 servers (might not need to)
  - Target specific nodes or entire networks
  - Redirect traffic via local NAT64/DNS64 and do the usual tricks
- Today:
  - Advertise a specific prefix to any node chosen by MAC
  - Suppress targeted routers
    - but this breaks the network at the moment

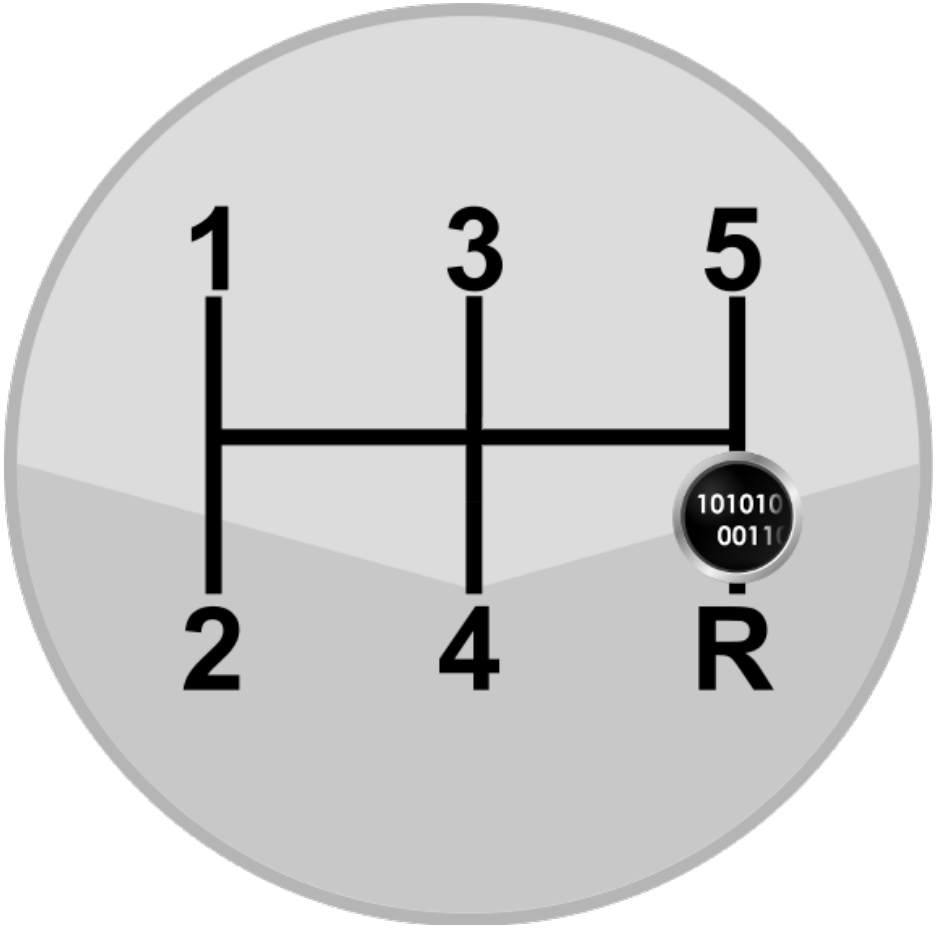
Help?



Help?

- Transition technologies
- IPv6 and Mobile
- SEND implementation (and TCO)
- IPv6 and IoT
- Automated MITM

Epilogue



RFC1924 Base85

- Base85 representation of IPv6 addresses
- Makes this:
  - 2606:aa00:400:402:3008:f8b:5c7c:f645
- Look like this:
  - b7gxONQAq42t8cj~PXPu

- Turns out it was an April Fool's RFC from 1996
  - I spent longer on this than I care to admit

Questions?

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BACKUPS!

IPv6 Basics – Multi-Routing

- Each stack can have multiple DEFAULT routes
  - Plus routers can tell you to go elsewhere
- Plus each DHCPv6 static route
- Plus tunnel / transition routes
- Plus all the classic IPv4 routing stuff

More on this later

Home routing Multiple ISPs?
Shortness of IPv6 /64?
IPv6 on mobile
Transitions and Translations
Point to point encryption
SEND

IPv6mcast_ff:3d:66:8d (33:33:ff:3d:66:8d)

Android Cyanogen never makes a dhcpv6 request

IOT inventory no-v6 or half-v6?

PRO TIP!

IPv6 Default – Autoconfig

- SLAC
- permanent
- Temporary
- http://www.iana.org/assignments/ipv6-address-space.