IP Address Parsing for Humans

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Agenda

Agenda ***you are here*** (1 min)
About Me & Intro (2 min)
What’s in a Network? (10 min)
Parsing Networks (5 min)
Compare & Contrast (20 min)
Bringing it Home (5 min)

About Me

This is my 2nd time* talking at SCaLE!

I love Python & networks

*https://youtu.be/7zZ9980X_bs

Core Dev for:
Trigger, NSoT, Nautobot

20+ years in InfraSec

#NetSecDevOps

In other words…

I love IPAM

(IP Address Management for those in the back)

Intro

IPAM is Hard

IPv4 is exhausted (except not really)

IPv6 is scary (but not really)

Spreadsheets make this infinitely worse

Manual allocation is the devil

Automation is the stairway to heaven

Before we jump in

All code is Python

`>>>` means we’re in a Python interactive shell

`pip install` is used to install libraries

This is dry content but we’ll have fun!

One Last Thing™

Lecture style talk so please ask questions

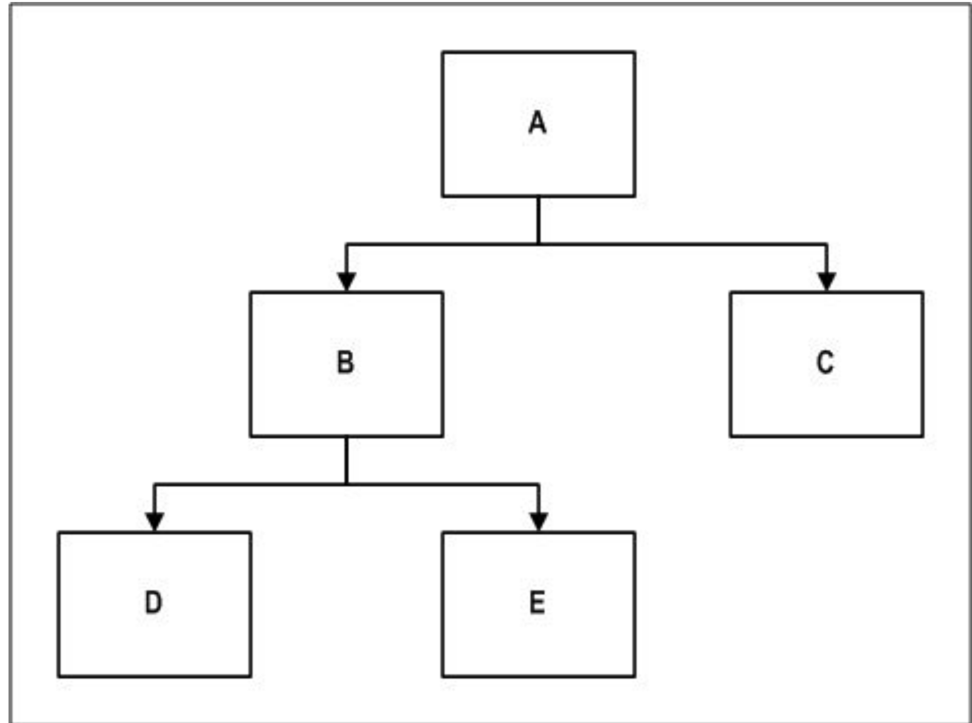
Leaving time at the end for demos and Q&A

Okay that was 2 things 3 if you count this one

What’s in a Network?

IP networks are trees

```
A 192.168.0.0
   ├── B 192.168.1.0
   │   ├── D 192.168.1.1
   │   └── E 192.168.1.2
   └── C 192.168.2.0
```



Tree Terminology

Ancestors are the parents of the parent

Parent is the direct parent network

Child is a direct child of a parent

Descendents are the children of children

Terminology

Subnets are descendent networks

Supernets are ancestor networks

Prefixes are networks (aka aggregates)

IP addresses are point locations on a network

Terminology (cont.)

Prefix length is the size of a prefix (in bits)

Host addresses are assigned to interfaces

Gateway is the entry point to a network

Broadcast is the end point of a network

Prefixes all the way down

Everything is a prefix

A host address is just the smallest prefix

A network contains other network prefixes

Subnet masks aren’t really used anymore

CIDR is the way

Classless **I**nter-**D**omain **R**outing

Prefix length is how you allocate & route

Larger number means smaller prefix (bits)

Zeros can be omitted or “compressed”

IPv4 anatomy

IPv4 address in dotted-decimal notation

172 . 16 . 254 . 1

10101100.00010000.11111110.00000001

8 bits

32 bits (4 bytes)

IPv4 networks

32-bit period-delimited; (4) 8-bit *octets*

All `0.0.0.0/0` (aka “quad zero”); or `0/0`

Localhost `127.0.0.1/32`

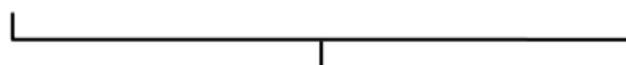
Link local `169.154/16`

Private `10/8, 192.168/16, 172.16/12`

IPv6 anatomy

An IPv6 address (in hexadecimal)

2001:0DB8:AC10:FE01:0000:0000:0000:0000



2001:0DB8:AC10:FE01::

Zeroes can be omitted

10000000000001:0000110110111000:1010110000010000:1111111000000001:

0000000000000000:0000000000000000:0000000000000000:0000000000000000

IPv6 networks

128-bit colon-delimited; (8) 16-bit *hextets*

All `::/0` (aka “double colon zero”); or `::`

Localhost `::1/128`

Link local `fe80::/10`

Private `fdaf:3c0f:118c:61ad::/64`

IPv6 Networks (cont.)

IPv6 networks are *stupendously* large

/64 is the smallest prefix length you should use

/48 is the minimum size for BGP routing

Compressed form collapses zeros into `::`

Compression

IPv4 trailing zeros can be omitted

```
192.168.0.0/24 -> 192.168/24
0.0.0.0/0 -> 0/0
```

IPv6 leading or consecutive zeros

```
21da:00d3:0000:0000:0000:0000:00ff:9c5a
    -> 21da:d3::ff:9c5a
fe80:0000:0000:0000:0000:0000:0000:0000/10
    -> fe80::/10
0000:0000:0000:0000:0000:0000:0000:0000/0
    -> ::/0
```

Parsing Networks

Pro Tips

DO use IP libraries to parse

DO NOT use spreadsheets; use IPAM

DO NOT cast IPv6 networks as lists (huge)

DO NOT use regex

DO NOT USE REGEX

Regex aka “regular expressions”

`\d+.\d+.\d+.\d+` is “fine” for IPv4, but just no

There is nothing regular about IPv6

But if you insist…

J/K DO NOT DO THIS

```
"^\s((([0-9A-Fa-f]{1,4}:){7}([0-9A-Fa-f]{1,4}|:))|(([0-9A-Fa-f]{1,4}:){6}(:[0-
9A-Fa-f]{1,4}|((25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])(.(25[0-5]|2[0-4][
0-9]|1[0-9][0-9]|[1-9]?[0-9])){3})|:))|(([0-9A-Fa-f]{1,4}:){5}(((:[0-9A-Fa-f]{
1,4}){1,2})|:((25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])(.(25[0-5]|2[0-4][0
-9]|1[0-9][0-9]|[1-9]?[0-9])){3})|:))|(([0-9A-Fa-f]{1,4}:){4}(((:[0-9A-Fa-f]{1
,4}){1,3})|((:[0-9A-Fa-f]{1,4})?:((25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9]
)(.(25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])){3}))|:))|(([0-9A-Fa-f]{1,4}:
){3}(((:[0-9A-Fa-f]{1,4}){1,4})|((:[0-9A-Fa-f]{1,4}){0,2}:((25[0-5]|2[0-4][0-9
]|1[0-9][0-9]|[1-9]?[0-9])(.(25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])){3})
)|:))|(([0-9A-Fa-f]{1,4}:){2}(((:[0-9A-Fa-f]{1,4}){1,5})|((:[0-9A-Fa-f]{1,4}){
0,3}:((25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])(.(25[0-5]|2[0-4][0-9]|1[0-
9][0-9]|[1-9]?[0-9])){3}))|:))|(([0-9A-Fa-f]{1,4}:){1}(((:[0-9A-Fa-f]{1,4}){1,
6})|((:[0-9A-Fa-f]{1,4}){0,4}:((25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])(.
(25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])){3}))|:))|(:(((:[0-9A-Fa-f]{1,4}
){1,7})|((:[0-9A-Fa-f]{1,4}){0,5}:((25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9
])(.(25[0-5]|2[0-4][0-9]|1[0-9][0-9]|[1-9]?[0-9])){3}))|:)))(%.+)?\s$"
```

Credit: http://stackoverflow.com/a/5567938/194311

Do this instead

```python
import ipaddress


def parse_network(prefix):
    """Returns an IP network object or None if the prefix is invalid."""
    try:
        return ipaddress.ip_network(prefix)
    except ValueError:
        return None
```

Isn’t this nice?

```
>>> parse_network("bogus")

>>> parse_network("192.168.0.0/24")
IPv4Network('192.168.0.0/24')

>>> parse_network("::/0")
IPv6Network('::/0')

>>> parse_network("fe80::/10")
IPv6Network('fe80::/10')

>>> parse_network("fe80::/10").version == 6
True
```

IPs are integers

```
>>> netaddr.IPAddress(0)
IPAddress('0.0.0.0')

>>> netaddr.IPAddress(0, version=6)
IPAddress('::')

>>> v4 = netaddr.IPNetwork("192.168.0.0/16")

>>> int(v4.ip)
3232235520

>>> int(netaddr.IPNetwork("fe80::1cbe:4216:28a4:ea7d"))
338288524927261089656090062382923311741
```

IPs are integers (cont.)

Binary integers represent each address

Bitwise math is used to calculate networks

This is out of scope for this talk!

See `inet_pton`, `inet_ntop`, et al. man(3) pages

One big IP family!

If IP >= your gateway address

And IP <= your broadcast address

Then IP is a member of the network

192.168.0.1 is a member of 192.168.0.0/24

Compare & Contrast

Library Overview

netaddr comprehensive IP manipulation

ipaddress bare bones IP manipulation

cidrize parses commonly used human inputs

ipparser simplifies parsing & DNS resolution

The Big Dogs

netaddr is the most advanced; but 3rd party

ipaddress is in the standard library

They share most features

Low level and missing user-friendly features

Common features

Membership (netaddr)

```
>>> net = IPNetwork("192.168.0.0/24")

>>> "192.168.0.1" in net
True

>>> "192.168.1.1" in net
False

>>> IPAddress("192.168.0.1") > IPAddress("192.168.0.0")
True

>>> IPAddress("192.168.0.1") > IPAddress("192.168.0.255")
False
```

Sub/supernets (both)

```
>>> list(net.subnet(25))
[IPNetwork('192.168.0.0/25'),
IPNetwork('192.168.0.128/25')]

>>> net.supernet(23)
[IPNetwork('192.168.0.0/23')]

>>> net in IPNetwork("192.168.0.0/23")
True
```

```
>>> list(net2.subnets())
[IPv4Network('192.168.0.0/25'),
IPv4Network('192.168.0.128/25')]

>>> net2.supernet()
IPv4Network('192.168.0.0/23')

>>> net2 in ip_network("192.168.0.0/23")
False

>>> net2.subnet_of(
  ip_network("192.168.0.0/23"))
True
```

Operations (both)

```
>>> net[0]
IPAddress('192.168.0.0')

>>> next(net.iter_hosts())
IPAddress('192.168.0.1')

>>> net.broadcast
IPAddress('192.168.0.255')

>>> net.prefixlen
24

>>> net.size
256
```

```
>>> net2[0]
IPv4Address('192.168.0.0')

>>> next(net2.hosts())
IPv4Address('192.168.0.1')

>>> net2.broadcast_address
IPv4Address('192.168.0.255')

>>> net2.prefixlen
24

>>> net2.num_addresses
256
```

Other stuff (both)

```
>>> net.is_
net.is_ipv4_compat()
net.is_loopback()
net.is_reserved()
net.is_ipv4_mapped()
net.is_multicast()
net.is_unicast()
net.is_link_local()
net.is_private()

>>> net.hostmask
IPAddress('0.0.0.255')

>>> net.version
4
```

```
>>> net2.is_
net2.is_global
net2.is_loopback
net2.is_private
net2.is_unspecified
net2.is_link_local
net2.is_multicast
net2.is_reserved

>>> net2.hostmask
IPv4Address('0.0.0.255')

>>> net2.version
4
```

netaddr

netaddr PROs

Tons of extra utilities

MAC (EUI) address support

IPSet object for doing advanced subnet math

IPRange object for calculating address ranges

netaddr CONs

Slow compared to *ipaddress*

3rd party so it must be installed using `pip`

IPNetwork objects

```
>>> net = netaddr.IPNetwork("192.168.0.0/24")

>>> net.info
{'IPv4': [{'date': '1993-05',
 'designation': 'Administered by ARIN',
 'prefix': '192/8',
 'status': 'Legacy',
 'whois': 'whois.arin.net'}]}

>>> netaddr.IPNetwork("0/0")
IPNetwork('0.0.0.0/0')
```

IPAddress objects

```
>>> netaddr.IPAddress(0)
IPAddress('0.0.0.0')

>>> netaddr.IPAddress(0, version=6)
IPAddress('::')

>>> ip = netaddr.IPAddress("1.2.3.4")

>>> ip.info
{'IPv4': [{'date': '2010-01',
 'designation': 'APNIC',
 'prefix': '1/8',
 'status': 'Allocated',
 'whois': 'whois.apnic.net'}]}
```

IPSet objects

```
>>> net_set = netaddr.IPSet(["192.168.0.0/24"])

>>> slash26 = netaddr.IPSet(["192.168.0.128/26"])

>>> net_diff = net_set - slash26

>>> net_diff
IPSet(['192.168.0.0/25', '192.168.0.192/26'])

>>> net_diff ^ slash26
IPSet(['192.168.0.0/24'])
```

IPRange objects

```
>>> v4_range = netaddr.IPRange('192.168.0.1', '192.168.0.2')

>>> v4_range
IPRange('192.168.0.1', '192.168.0.2')

>>> list(v4_range)
[IPAddress('192.168.0.1'), IPAddress('192.168.0.2')]

>>> v6_range = netaddr.IPRange('fe80::1', 'fe80::2')

>>> list(v6_range)
[IPAddress('fe80::1'), IPAddress('fe80::2')]
```

EUI (MAC) objects

```
>>> mac = EUI('00-1B-77-49-54-FD')

>>> oui = mac.oui

>>> oui
OUI('00-1B-77')

>>> oui.registration().address
['Lot 8, Jalan Hi-Tech 2/3', 'Kulim  Kedah  09000', 'MY']

>>> oui.registration().org
'Intel Corporate'
```

ipaddress

ipaddress PROs

In Python standard library since Python 3.3

Fast especially under large workloads

~3x faster than *netaddr* in my testing

Great for rapid prototyping and basic parsing

ipaddress CONs

Basic AF (but that is also a strength)

Distinct classes require you to be explicit

`IPv4Address`, `IPv4Network`, `IPv6Address`, `IPv6Network`

Constructors are limiting; can’t specify version

`ip_address()`, `ip_network()`

ip_network()

```
>>> ipaddress.ip_network("0/0")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File
"/Users/jathan/.pyenv/versions/3.11.6/lib/python3.11/ipaddress.py",
line 83, in ip_network
    raise ValueError(f'{address!r} does not appear to be an IPv4 or
IPv6 network')
ValueError: '0/0' does not appear to be an IPv4 or IPv6 network

>>> ipaddress.ip_network("192.168.0.0/24")
IPv4Network('192.168.0.0/24')

>>> ipaddress.ip_network("fe80::/10")
IPv6Network('fe80::/10')
```

ip_address()

```
>>> ipaddress.ip_address(0)
IPv4Address('0.0.0.0')

>>> ipaddress.ip_address(0, version=6)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: ip_address() got an unexpected keyword argument 'version'

>>> ipaddress.ip_address("1.2.3.4")
IPv4Address('1.2.3.4')

>>> ipaddress.ip_address("fe80::1")
IPv6Address('fe80::1')
```

Class objects

```
>>> ipaddress.IPv4Address("192.168.0.1")
IPv4Address('192.168.0.1')

>>> ipaddress.IPv4Network("192.168.0.0/24")
IPv4Network('192.168.0.0/24')

>>> ipaddress.IPv6Address("fe80::1")
IPv6Address('fe80::1')

>>> ipaddress.IPv6Network("fe80::/10")
IPv6Network('fe80::/10')
```

Helpers

```
>>> from ipaddress import collapse_addresses, summarize_network_range,
IPv4Address, IPv4Network

>>> range = summarize_address_range(
  IPv4Address('192.0.2.0'), IPv4Address('192.0.2.128'))

>>> list(range)
[IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/32')]

>>> collapsed = collapse_addresses(
  [IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/25')])

>>> list(collapsed)
[IPv4Network('192.0.2.0/24')]
```

The Small Dogs

cidrize built on top of *netaddr*

ipparser built on top of *ipaddress*

They share many features

High level adding user-friendly features

cidrize

cidrize PROs

Strict & loose parsing modes

Wildcards and **bracket** ranges

CLI utility included that is very handy

Returns IPNetwork objects (might be a con)

cidrize CONs

Slower than *ipparser* because *netaddr*

Weird name from a weird guy

No URL or DNS support

Ranges limited to v4 addresses

Wildcards and more

```
>>> cidrize.cidrize("192.168.1.*")
[IPNetwork('192.168.1.0/24')]

>>> cidrize.cidrize("192.168.1.0-15")
[IPNetwork('192.168.1.0/28')]

>>> cidrize.cidrize("192.168.1.1[56]")
[IPNetwork('192.168.1.0/27')]

>>> cidrize.cidrize("any")
[IPNetwork('0.0.0.0/0')]

>>> cidrize.cidrize("::")
[IPNetwork('::/0')]
```

Strict vs. loose

```
>>> cidrize.cidrize("192.168.1.*", strict=True)
[IPNetwork('192.168.1.0/24')]

>>> cidrize.cidrize("192.168.1.0-15", strict=True)
[IPNetwork('192.168.1.0/28')]

>>> cidrize.cidrize("192.168.1.1[56]", strict=True)
[IPNetwork('192.168.1.15/32'), IPNetwork('192.168.1.16/32')]

>>> cidrize.cidrize("192.168.0.254-192.168.1.3")
[IPNetwork('192.168.0.0/23')]

>>> cidrize.cidrize("192.168.0.254-192.168.1.3", strict=True)
[IPNetwork('192.168.0.254/31'), IPNetwork('192.168.1.0/30')]
```

cidr CLI

```
$ cidr -v 192.160.0.0/24

Information for 192.160.0.0/24

IP Version:             4
Spanning CIDR:          192.160.0.0/24
Block Start/Network:    192.160.0.0
1st host:               192.160.0.1
Gateway:                192.160.0.254
Block End/Broadcast:    192.160.0.255
DQ Mask:                255.255.255.0
Cisco ACL Mask:         0.0.0.255
# of hosts:             254
Explicit CIDR blocks:   192.160.0.0/24
```

ipparser

ipparser PROs

Very fast because *ipaddress*

Returns strings but this might be a con, too?

DNS, URL, port support with `resolve=True`

Nmap XML report parser

ipparser CONs

Only returns IPs and not networks

Advanced ranges are passed through

Ranges also limited to v4 addresses

Invalid inputs don’t raise errors :(

DNS and ranges

```
>>> ipparser.ipparser("socallinuxexpo.org", resolve=True)
['23.21.71.118']

>>> ipparser.ipparser("socallinuxexpo.org,google.com", resolve=True)
['23.21.71.118', '142.250.176.14']

>>> ipparser.ipparser("192.168.1.0-15")
['192.168.1.0', '192.168.1.1', '192.168.1.2', '192.168.1.3',
'192.168.1.4', '192.168.1.5', '192.168.1.6', '192.168.1.7',
'192.168.1.8', '192.168.1.9', '192.168.1.10', '192.168.1.11',
'192.168.1.12', '192.168.1.13', '192.168.1.14', '192.168.1.15']

>>> ipparser.ipparser("192.168.0.254-192.168.1.3")
['192.168.0.254-192.168.1.3']
```

Bringing it Home

When to use netaddr

For advanced applications

Calculating subnet allocations with IPSets

Managing MAC addresses

Leveraging metadata such as designation

When to use ipaddress

When performance matters

For common use-cases

Quick & dirty solutions

If you can’t use 3rd party libraries

When to use cidrize

Parsing user inputs in apps and utilities

When you need max flexibility in user inputs

If you need a CLI utility out of the box

When to use ipparser

When performance matters

Parsing user input AND performance required

DNS resolution is required

Nmap support is required

Thank You!

Pick your poison

netaddr

https://netaddr.readthedocs.io/

ipaddress

https://docs.python.org/3/library/ipaddress.html

cidrize

https://cidrize.readthedocs.io/

ipparser

https://github.com/m8sec/ipparser

Stay in Touch

@jathanism

on *ALL THE THINGS*