Routing in 2018

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There are very few ways to assemble a single view of the entire Internet

The lens of routing is one of the ways in which information relating to the entire reachable Internet is bought together

Even so, its not a perfect lens, but it can provide some useful insights about the entire scope of the Internet
25 Years of Routing the Internet

This is a view pulled together from each of the routing peers of Route-Views.

- **1994**: Introduction of CIDR
- **2001**: The Great Internet Boom and Bust
- **2005**: Consumer Market
- **2011**: Address Exhaustion
2016–2018 in detail
2016–2018 in detail

Route Views Peers

RiS Peers

average growth trend
Routing Indicators for IPv4

Routing prefixes - growing by some 52,000 prefixes per year

AS Numbers - growing by some 3,400 prefixes per year
Routing Indicators for IPv4

But the average size of a routing advertisement continues to shrink.

More specifics are still taking up slightly more than one half of the routing table.
Routing Indicators for IPv4

The "shape" of inter-AS interconnection appears to be relatively steady.

Address Exhaustion is now visible in the extent of advertised address space.
AS Adjacencies (AS131072)

51,613 out of 63,080 ASNs have 1 or 2 AS Adjacencies (82%)
1,803 ASNs have 10 or more adjacencies
9 ASNs have >1,000 adjacencies

4,144 AS6939 HURRICANE - Hurricane Electric, Inc., US
4,032 AS3356 LEVEL3 - Level 3 Communications, Inc., US
3,702 AS174 COGENT-174 - Cogent Communications, US
1,724 AS6461 ZAYO Bandwidth, US
1,646 AS7018 ATT-INTERNET4 - AT&T Services, Inc., US
1,618 AS3549 LVLT – Level 3 Parent, US
1,428 AS3257 GTT-Backbone, DE
1,377 AS2914 NTT America, US
1,208 AS209 CENTURYLINK, US
957 AS701 Verizon Business, US

Most networks are stub AS’s
A small number of major connectors
What happened in 2018 in V4?

Routing Business as usual – despite IPv4 address exhaustion!

- From the look of the growth plots, its business as usual, despite the increasing pressures on IPv4 address availability
- The number of entries in the IPv4 default-free zone reached 750,000 by the end of 2018
- The pace of growth of the routing table is still relatively constant at ~52,000 new entries and 3,400 new AS’s per year
  - IPv4 address exhaustion is not changing this!
  - Instead, we appear to be advertising shorter prefixes into the routing system
What about IPv4 Address Exhaustion?

RIR Address Pool runout projections (as of April 2019):

- ARIN – no free pool left
- AFRINIC – May 2020
- LACNIC – November 2019
- APNIC – November 2020
- RIPE NCC – January 2020
Post-Exhaustion Routing Growth

• What’s driving this post-exhaustion growth?
  – Transfers?
  – Last /8 policies in RIPE and APNIC?
  – Leasing and address recovery?
Advertised Address "Age"

2010

80% of all new addresses announced in 2010 were allocated or assigned within the past 12 months.

2% of all new addresses announced in 2010 were &ge; 20 years ‘old’ (legacy)
Advertised Address "Age"

48% of all new addresses announced in 2018 were >= 20 years ‘old’ (legacy)

20% of all new addresses announced in 2018 were allocated or assigned within the past 12 months
2000 – 2018: IPv4 Advertised vs Unadvertised
2000 - 2018: Unadvertised Addresses

Total volume of "reclaimed" addresses
2018: Assigned vs Recovered

Change in the Unadvertised Address Pool

RIR Allocations

Change in Advertised Addresses

"draw down"
V4 in 2018

• The equivalent of 1.4 /8s were removed from the routing table across 2018
• Approximately 0.86 /8s were assigned by RIRs in 2015
  – 0.37 /8’s assigned by Afrinic
  – 0.28 /8s assigned by the RIPE NCC (last /8 allocations)
  – 0.10 /8s were assigned by APNIC (last /8 allocations)

• And a net of 2.1 /8’s were added to the pool of unadvertised addresses

In 2018 we saw legacy blocks transferring away from ISPs / end user sites and heading towards cloud SPs.
The Route-Views View of IPv6

IANA IPv4 Exhaustion
2017–2018 in Detail
Routing Indicators for IPv6

Routing prefixes - growing by some 15,000 prefixes per year

AS Numbers - growing by some 2,000 ASNs per year (which is 60% the V4 growth)
Routing Indicators for IPv6

The average size of a routing advertisement is getting smaller.
Routing Indicators for IPv6

Advertised Address span is growing at an exponential rate.

The “shape” of inter-AS interconnection in IPv6 is rising slightly. Local connections appear to be replacing overlay trunk transits.
AS Adjacencies (AS131072)

13,095 out of 16,465 ASNs have 1 or 2 AS Adjacencies (79%)
573 ASNs have 10 or more adjacencies
2 ASNs have >1,000 adjacencies

4,295 AS6939 HURRICANE - Hurricane Electric, Inc., US
1,049 AS3356 LEVEL3 - Level 3 Communications, Inc., US
749 AS174 COGENT-174 - Cogent Communications, US
719 AS2915 NTT America, US
632 AS1299 Telia Carrier, SE
V6 in 2018

• Overall IPv6 Internet growth in terms of BGP is still increasing, and is currently at some 15,000 route entries p.a.
What to expect
BGP Size Projections

How quickly is the routing space growing?

What are the projections of future BGP FIB size?
Growth in the V4 network appears to be constant at a long term average of 140 additional routes per day, or some 52,000 additional routes per year.
V4 BGP Table Size Predictions

Jan 2017  646,000
2018  699,000
2019  755,000
2020  807,000
2021  859,000
2022  911,000
2023  963,000
2024  1,015,000
V6 - Daily Growth Rates
V6 BGP Table Size Predictions

<table>
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<th>Year</th>
<th>Linear</th>
<th>Exponential</th>
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<td>Jan 2017</td>
<td>35,000</td>
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<tr>
<td>2018</td>
<td>49,000</td>
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<td><strong>2019</strong></td>
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<tr>
<td>2020</td>
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<tr>
<td>2024</td>
<td>130,000</td>
<td>255,000</td>
</tr>
</tbody>
</table>

Graph showing linear and exponential projections for V6 BGP table size over the years 2016 to 2024.
BGP Table Growth

The absolute size of the IPv6 routing table is growing much faster than the IPv4 table.

IPv6 will require the same memory size in around 5 years time, given that each IPv6 entry is 4 times the memory size of an IPv4 entry.

As long as we are prepared to live within the technical constraints of the current routing paradigm, the Internet’s use of BGP will continue to be viable for some time yet.
BGP Updates

• What about the level of updates in BGP?
IPv4 BGP Updates

Daily BGP v4 Update Activity for AS131072

Count

Date

Withdrawals
Announcements
Total
BGP FIB Size

IPv4 BGP Convergence Performance

Average Convergence Update Count per day (AS 131072)

Average Convergence Time per day (AS 131072)
Updates in IPv4 BGP

Still no great level of concern …

- The number of updates per instability event and the time to converge has been relatively constant
- Likely contributors to this outcome are the damping effect of widespread use of the MRAI interval by eBGP speakers, and the compressed topology factor, as seen in the relatively constant AS Path Length
V6 BGP Updates

Daily BGP v6 Update Activity for AS131072
V6 Convergence Performance
There is little in the way of scaling pressure from BGP as a routing protocol – the relatively compressed topology and stability of the infrastructure links tend to ensure that BGP remains effective in routing the internet

The issues of FIB size, line speeds and equipment cost of line cards represent a more significant issue for hardware suppliers – we can expect cheaper line cards to use far smaller LRU cache local FIBs in the high speed switches and push less used routes to a slower / cheaper lookup path. This approach may also become common in very high speed line cards
Some Practical Suggestions

- Understand your hardware’s high speed FIB capacity in the default-free parts of your network

- Review your IPv4 / IPv6 portioning - a dual-stack eBGP router will need 900,000 IPv4 slots and 110,000 IPv6 slots for a full eBGP routing table in line cards over the coming 24 months if they are using a full FIB load

- Judicious use of default routes in your internal network may allow you drop this requirement significantly
That's it!

Questions?