Another year of BGP!

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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, it’s not a perfect lens, but it can provide some useful insights about the entire scope of 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
2017-2020 in detail
2017-2020 in detail

Route Views Peers

RiS Peers

average growth trend
Routing Indicators for IPv4

Routing prefixes — growing by some 55,000 prefixes per year

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

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

But the average size of a routing advertisement continues to shrink.
Routing Indicators for IPv4

Address Exhaustion is now visible in the extent of advertised address space.

The “shape” of inter-AS interconnection appears to be relatively steady.
AS Adjacencies (AS131072)

54,697 out of 66,928 ASNs have 1 or 2 AS Adjacencies (82%)
2,195 ASNs have 10 or more adjacencies
10 ASNs have >1,000 adjacencies

4,788  AS6939  HURRICANE, US
4,378  AS3356  LEVEL3, US
3,870  AS174  COGENT-174, US
1,877  AS6461  ZAYO-6461, US
1,735  AS7018  ATT-INTERNET4, US
1,675  AS3257  GTT-BACKBONE GTT, DE
1,413  AS2914  NTT-COMMUNICATIONS-2914, US
1,306  AS1299  TELIANET Telia Carrier, EU
1,304  AS3549  LVLT-3549, US
1,161  AS209  CENTURYLINK-US-LEGACY-QWEST, US

Most networks are stub AS’s
A small number of major connectors
What's happening 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 has now reached 840,000

• The pace of growth of the routing table is still relatively constant at ~51,000 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:

- ARIN – no free pool left
- AFRINIC – December 2020
- LACNIC – no free pool left
- APNIC – January 2021
- RIPE NCC – no free pool left
Post-Exhaustion Routing Growth

• What’s driving this post-exhaustion growth?
  • Transfers?
  • Last /8 policies in RIPE and APNIC?
  • Leasing and address recovery?
20% of all new addresses announced in 2010 were allocated or assigned within the past 12 months.

80% of all new addresses announced in 2010 were >= 20 years "old" (legacy).
Advertised Address "Age"

Re-use of legacy addresses

Transfers
2000 - 2020: IPv4 Advertised vs Unadvertised
2013 - 2020: Post Free Pool Exhaustion IPv4 Advertised vs Unadvertised
2019 - 2020: Assigned vs Unadvertised

Change in Advertised Addresses
Change in the Unadvertised Address Pool
RIR Allocations

Unadvertised growth
Advertised growth
V4 for the last 16 months

• The equivalent of 0.1 /8s were added to the routing table
  • It would’ve been 1.1 /8s but on April 25 57.0.0.0/8 (SITA) was withdrawn from the routing table
• Approximately 0.8 /8s were assigned by RIRs
  • 0.35 /8s assigned by the RIPE NCC (last /8 allocations)
  • 0.24 /8’s assigned by Afrinic
  • 0.10 /8s were assigned by LACNIC
  • 0.07 /8s were assigned by APNIC (last /8 allocations)
• And a net of 0.7 /8’s were added to the pool of unadvertised addresses

Over this period we saw legacy blocks transferring away from ISPs / end user sites and heading towards cloud SPs.
The Route-Views View of IPv6
2018-2020 in Detail
Routing Indicators for IPv6

Routing prefixes – growing by some 20,000 prefixes per year

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

More Specifics now take up one half of the routing table

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

The "shape" of inter-AS interconnection in IPv6 is rising slightly. Local connections appear to be replacing overlay trunk transits.

Advertised Address span is growing at an exponential rate.
AS Adjacencies (AS131072)

15,720 out of 19,633 ASNAs have 1 or 2 AS Adjacencies (80%)
698 ASNs have 10 or more adjacencies
3 ASNs have >1,000 adjacencies

<table>
<thead>
<tr>
<th>ASN</th>
<th>Company</th>
<th>Country</th>
</tr>
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<tbody>
<tr>
<td>4,900</td>
<td>AS6939 HURRICANE, US</td>
<td>US</td>
</tr>
<tr>
<td>1,093</td>
<td>AS3356 LEVEL3, US</td>
<td>US</td>
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<tr>
<td>1,013</td>
<td>AS1299 TELIANET Telia Carrier, EU</td>
<td>EU</td>
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<tr>
<td>870</td>
<td>AS174 COGENT-174, US</td>
<td>US</td>
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<tr>
<td>830</td>
<td>AS2914 NTT-COMMUNICATIONS-2914, US</td>
<td>US</td>
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<td>622</td>
<td>AS5539 SPACENET SpaceNET AG, DE</td>
<td>DE</td>
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<td>517</td>
<td>AS3257 GTT-BACKBONE GTT, DE</td>
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<tr>
<td>327</td>
<td>AS20473 AS-CHOOPA, US</td>
<td>US</td>
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V6 in 2020

• Overall IPv6 Internet growth in terms of BGP is still increasing, and is currently at some 20,000 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 consistent to a long-term average of 150 additional routes per day, or some 55,000 additional routes per year.
V4 BGP Table Size Predictions

Jan 2017  646,000
2018      699,000
2019      760,000
2020      814,000
2021      864,000
2022      918,000
2023      972,000
2024      1,026,000
2025      1,081,000
2026      1,135,000
V6 - Daily Growth Rates
## V6 BGP Table Size Predictions

<table>
<thead>
<tr>
<th>Year</th>
<th>Linear</th>
<th>Exponential</th>
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<tbody>
<tr>
<td>2017</td>
<td>35,000</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>45,000</td>
<td>105,000</td>
</tr>
<tr>
<td>2019</td>
<td>62,000</td>
<td>137,000</td>
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<tr>
<td>2020</td>
<td>80,000</td>
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<td>2021</td>
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<td>2022</td>
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<td>2023</td>
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<tr>
<td>2024</td>
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<td></td>
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<tr>
<td>2025</td>
<td>165,000</td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>182,000</td>
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</tr>
</tbody>
</table>

![Graph showing linear and exponential predictions for V6 BGP Table Size](image-url)
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 4 years time, given that each IPv6 entry is 4 times the memory size of an IPv4 entry.

But this is not that big a growth rate, and BGP can handle this scale of managed route objects with ease.

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 vs. Date

Withdrawals
Announcements
Total
BGP FIB Size
IPv4 BGP Convergence Performance
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

- Withdrawals
- Announcements
- Total
- BGP FIB Size

Date Range: 2011 to 2020

Count:
- Withdrawals: +
- Announcements: ×
- Total: (Blue Line)
- BGP FIB Size: (Orange Line)
V6 Convergence Performance

Average Convergence Time per day (AS 131072)
V6 Convergence Performance

Average Convergence Time per day (AS 131072)
Routing Futures

- 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-capacity 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 memory partitioning - a dual-stack eBGP router will need 920,000 IPv4 slots and 140,000 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

• Using a hot cache for line card FIB cache would reduce the memory requirement significantly without visible performance cost
That's it!