BGP: 2008

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APNIC
Some BGP-related questions:

The Network Operator:

- How big a router should you buy today if you want it to cope with BGP in 3 years time?
- What FIB size?
- What processing capability?
- What about if you are looking for an operational lifespan of 5 years?
More BGP Questions

The Protocol Engineer:

– Is BGP scaling or failing?
– Do we need to develop a new IDR protocol?
– How much time do we have?
The Network Architecture Researcher:

– Are the Internet’s concepts of names and addresses adequate?

– Are alternate models of id / loc split more friendly to routing?

– Is routing scaling an intractable problem within the confines of the current architecture?
One Approach:

guess!
Or:

you could see what answers a more disciplined approach to these questions could provide!
An approach to generating some answers

• Use real data about today’s network
  – Understand the actual data about IDR and the operation of BGP
  – Use a long base line of consistent observations of BGP behaviour
  – Analyze the data carefully
BGP measurements

• There are a number of ways to “measure” BGP:
  – Assemble a large set of BGP peering sessions and record everything
    • RIPE NCC’s RIS service
    • Route Views
  – Perform carefully controlled injections of route information and observe the propagation of information
    • Beacons
    • AS Set manipulation
    • Bogon Detection and Triangulation
  – Take a single BGP perspective and perform continuous recording of a number of BGP metrics
AS131072 (or AS2.0) BGP measurement

• Successor to the AS1221 observation point
• Data collection since 1 July 2007 (since 2000 for AS1221)
• Passive data measurement technique (no advertisements or probes)
• Quagga platform, connected to AS4608 and AS4777 via eBGP
• IPv4 and IPv6 simultaneous
• Archive of all BGP updates and daily RIB dumps
• Data and reports are continuously updated and published: http://bgp.potaroo.net
Some Caveats

• This is a measurement at the EDGE, not in the MIDDLE
• It is a single stream measurement, not an aggregated measurement
• This is a measurement of the ‘production network’ used for forwarding traffic
• There is NO iBGP traffic being measured
• This is what an eBGP customer may see in terms of load for a single eBGP feed
BGP: 2008

- Analysis of BGP data collected at AS131072 from 1 January 2008 to 31 December 2008
IPv4 BGP Prefix Count

![Graph showing IPv4 BGP Prefix Count from January 2008 to January 2009. The graph displays a steady increase in the number of active BGP entries (FIB).](image)
IPv4 BGP Prefix Count

The graph shows the active BGP prefix count over time from January 2008 to January 2009. The y-axis represents the number of active BGP entries, while the x-axis represents the date ranging from January 2008 to January 2009. The data indicates a steady increase in the number of active BGP prefixes during this period.
IPv4 Routed Address Span
IPv4 Routed Address Span

(/8 instability removed)
IPv4 Routed Address Span

The graph shows the total announced IPv4 address span (in octets) over time from January 2008 to January 2009. The data is represented by a series of red bars and a blue line, indicating a trend of increasing address span over the period.
IPv4 Routed AS Count
IPv4 Routed AS Count
# IPv4 Vital Statistics for 2008

<table>
<thead>
<tr>
<th>Category</th>
<th>Jan-08</th>
<th>Dec-08</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefix Count</td>
<td>245,000</td>
<td>286,000</td>
<td>17%</td>
</tr>
<tr>
<td>Roots</td>
<td>118,000</td>
<td>133,000</td>
<td>13%</td>
</tr>
<tr>
<td>More Specifics</td>
<td>127,000</td>
<td>152,000</td>
<td>20%</td>
</tr>
<tr>
<td>Address Span</td>
<td>106.39</td>
<td>118.44</td>
<td>11%</td>
</tr>
<tr>
<td>AS Count</td>
<td>27,000</td>
<td>30,300</td>
<td>11%</td>
</tr>
<tr>
<td>Transit</td>
<td>3,600</td>
<td>4,100</td>
<td>14%</td>
</tr>
<tr>
<td>Stub</td>
<td>23,400</td>
<td>26,200</td>
<td>11%</td>
</tr>
</tbody>
</table>
Some Observations

• Growth in IPv4 deployment slowed considerably as of the end of April 2008
  – Is this a possible consequence of the financial crash of 2008?

• Fragmentation of the IPv4 routing space continues to grow at a faster pace than underlying growth of the network itself
IPv4 prefix distribution

• It's all about /24's
IPv4 prefix distribution
IPv6 BGP in 2008
IPv6 BGP Prefix Count
IPv6 Routed Address Span
IPv6 Routed Address Span
IPv6 Routed AS Count
IPv6 Routed AS Count

The graph shows the IPv6 Unique AS Count over time from January 2008 to January 2009. The data points are marked in red, with a linear trend line. The count appears to be increasing steadily over time.
## IPv6 Vital Statistics for 2008

<table>
<thead>
<tr>
<th></th>
<th>Jan-08</th>
<th>Dec-08</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prefix Count</strong></td>
<td>1,050</td>
<td>1,600</td>
<td>52%</td>
</tr>
<tr>
<td><strong>Roots</strong></td>
<td>840</td>
<td>1,300</td>
<td>55%</td>
</tr>
<tr>
<td><strong>More Specifics</strong></td>
<td>210</td>
<td>300</td>
<td>43%</td>
</tr>
<tr>
<td><strong>Address Span</strong></td>
<td>/16.67</td>
<td>/16.65</td>
<td>1%</td>
</tr>
<tr>
<td><strong>AS Count</strong></td>
<td>860</td>
<td>1,230</td>
<td>43%</td>
</tr>
<tr>
<td><strong>Transit</strong></td>
<td>240</td>
<td>310</td>
<td>29%</td>
</tr>
<tr>
<td><strong>Stub</strong></td>
<td>620</td>
<td>920</td>
<td>48%</td>
</tr>
</tbody>
</table>
Trends and Projections
BGP Table Size Projection

• 4 year projection of the IPv4 routing table size
IPv4 Table Size - 12 months

daily average and 60 day sliding window applied to smooth the data
IPv4 Table Size - 60 months
First order differential of the smoothed data
Daily Growth Rates
IPv4 Table Size
Quadratic Growth Model
IPv4 Table Size Quadratic Growth Model - Projection
## BGP Table Size Predictions

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>now</td>
<td>285,000 entries</td>
</tr>
<tr>
<td>12 months</td>
<td>335,000 entries</td>
</tr>
<tr>
<td>24 months</td>
<td>388,000 entries</td>
</tr>
<tr>
<td>36 months*</td>
<td>447,000 entries</td>
</tr>
<tr>
<td>48 months*</td>
<td>512,000 entries</td>
</tr>
</tbody>
</table>

* These numbers are dubious due to IPv4 address exhaustion pressures. It is possible that the number will be larger than the values predicted by this model.
Back in 2006 ....

- This modelling work of the IDR table size was performed at the end of 2005 to generate a 3 and 5 year projection
2006 prediction

RIB SIZE - Predictive Model

3 – 5 Year prediction
<table>
<thead>
<tr>
<th>Period</th>
<th>Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now</td>
<td>285,000 entries (2006: 275,000)</td>
</tr>
<tr>
<td>12 months</td>
<td>335,000 entries</td>
</tr>
<tr>
<td>24 months</td>
<td>388,000 entries (2006: 370,000)</td>
</tr>
<tr>
<td>36 months*</td>
<td>447,000 entries</td>
</tr>
<tr>
<td>48 months*</td>
<td>512,000 entries</td>
</tr>
</tbody>
</table>

* These numbers are dubious due to IPv4 address exhaustion pressures. It is possible that the number will be larger than the values predicted by this model.
Moore's Law

- As long as growth rates stay within the general parameters of Moore’s Law the unit cost of the routing function should not escalate
  - use a function of doubling every two years as the application of Moore’s Law
  - assuming that Moore’s law continues to hold
Projections against Moore's Law

![Graph showing projections against Moore's Law](image)
BGP Table Size

• 3 years = 500,000 IPv4 entries + ? IPv6 entries
  • plan for probably no less than 600,000 entries
• 5 years = ? IPv4 entries + ? IPv6 entries
  • plan for probably no less than 800,000 entries
BGP Metrics

• Is it the size of the RIB or the level of dynamic update that is the concern here?
• Let's look at update trends in BGP...
BGP Update Behaviour

• What trends are visible in the number of BGP updates?
BGP Updates – Announce and Withdrawals
Daily Updates
Best Fit to Updates
BGP Updates – Extended Data Set
BGP Updates – Extended Data Set
BGP Update Projection
Daily Withdrawals
Best Fit to WDLs
BGP Withdrawal Projection
Why is this?

• Why are the levels of growth in BGP updates not proportional to the size of the routing table?
  – growth rates of BGP updates appear to be far smaller than the growth rate of the routing space itself

• What is going on?
Average AS Path Length has remained constant
What is going on?

- The convergence instability factor for a distance vector protocol like BGP is related to the AS path length, and average AS Path length has remained steady in the Internet for some years.
- Taking MRAI factors into account, the number of received Path Exploration Updates in advance of a withdrawal is related to the propagation time of the withdrawal message. This is approximately related to the average AS path length.
- Today’s Internet is more densely interconnected, but is not any more “stringier.”
- This implies that the number of protocol path exploration transitions leading to a prefix withdrawal is relatively stable over time.
The update distribution of BGP is heavily skewed.
What is going on?

- The major component of dynamic BGP load is not an artifact of the larger routing space, but a case of relatively intense levels of BGP path manipulation at or close to origin for TE purposes from a very small subset of origin AS’s
  - the dominant factor behind what is being measured in updates is not implicitly related to network component stability, but more likely to be related to path manipulation associated with TE
A prudent view of capacity planning for 4 – 5 years into BGP's future

• A FIB size of 750,000 entries of IPv4, and a total of 1M entries of IPv4 + IPv6 FIB space
• A BGP update load of 2x the current rates
• No major changes in the BGP use profile, no major changes in the distribution of BGP updates
Some Closing Opinions

• The BGP sky is **not** falling

  The 2008 BGP data appears to indicate that the prospects of the imminent death of BGP through routing table inflation appear to be vastly exaggerated
  
  • The inflation rate of the routing table remains well under Moore’s law
  • The rate of increase of processed updates in the gather data appears to be minimal
  • The rate of increase of withdrawals is slightly larger, but is still slight

  – The network is, on the whole, very stable and BGP is not under immediate stress in terms of scaling pressures
Some Closing Opinions

• This does not model post-V4 address exhaustion scenarios
  – But there is no evidence to be alarmed about excessive fragmentation of the routing space at this stage
A Word of Caution

- This is a simple exercise in statistical curve fits, not a demand level simulation of the players routing environment.
- This exercise does not factor in any IPv4 address exhaustion considerations and scenarios around address movement that may alter the picture of fragmentation of the routing space.
- However the AS growth projections are a strong indicator of underlying industry dynamics in terms of discrete routing entities, and these projections show a modest growth component.

This means that while the projections are very weak in the period of 2011 and beyond, there are grounds to take a conservative view of BGP growth in this phase of the Internet’s evolution.
Thank You

Questions?
Additional Material
Top 10 AS Profile

• The 10 most active Origin ASs are associated with 3,069,860 prefix updates, or 5.53% of the total number of prefix updates for the year.
• Who are they and what are they doing?
# Top 10 AS Profile

<table>
<thead>
<tr>
<th>Rank</th>
<th>AS</th>
<th>Updates</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6389</td>
<td>418,945</td>
<td>0.75%</td>
</tr>
<tr>
<td>2</td>
<td>8159</td>
<td>373,164</td>
<td>0.67%</td>
</tr>
<tr>
<td>3</td>
<td>17974</td>
<td>348,835</td>
<td>0.63%</td>
</tr>
<tr>
<td>4</td>
<td>17488</td>
<td>338,762</td>
<td>0.61%</td>
</tr>
<tr>
<td>5</td>
<td>4621</td>
<td>325,462</td>
<td>0.59%</td>
</tr>
<tr>
<td>6</td>
<td>9835</td>
<td>297,464</td>
<td>0.54%</td>
</tr>
<tr>
<td>7</td>
<td>9498</td>
<td>266,930</td>
<td>0.48%</td>
</tr>
<tr>
<td>8</td>
<td>4323</td>
<td>248,126</td>
<td>0.45%</td>
</tr>
<tr>
<td>9</td>
<td>9829</td>
<td>226,666</td>
<td>0.41%</td>
</tr>
<tr>
<td>10</td>
<td>9583</td>
<td>225,506</td>
<td>0.41%</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>3,069,860</td>
<td>5.53%</td>
</tr>
</tbody>
</table>
#1 AS6389

BELLSOUTH-NET-BLK - BellSouth.net Inc.AS (US)

AS Adjacency:  Up:  1  Down:  44

Originated Prefixes: 4380

Aggregateable: 4096 (!)
Updates originated by AS6389 BELLSouth-NET-BLK - BellSouth.net Inc. (418945)
#2 AS8151

Uninet S.A. de C.V (MX)

AS Adjacency: Up: 7 Down: 44

UP: 1239, 2914, 701, 7018, 18592, 3356, 3549

Originated Prefixes: 1480

Aggregateable: 1073
2. Updates originated by AS8151 Uninet S.A. de C.V. (373164)
#3 AS17974

TELKOMNET-AS2-AP PT Telekomunikasi Indonesia (ID)

AS Adjacency: Up: 3, Down: 0

UP: 18051, 7713, 38513

Originated Prefixes: 484

Aggregateable: 251
3. Updates originated by AS17974 TELKOMNET-AS2-AP PT Telekomunikasi Indonesia (348835)
#4 AS17488

HATHWAY-NET-AP Hathway IP Over Cable Internet (IN)

AS Adjacency: Up: 3 Down: 0

UP: 4755, 9730, 9498

Originated Prefixes: 1488

Aggregateable: 1321 (!)
4. Updates originated by AS17488 HATHWAY-NET-AP Hathway IP Over Cable Internet (338762)
#5 AS4621

UNINET-TH (TH)
AS Adjacency: Up: 3, Down: 28
UP: 11537, 3491, 4561
Originated Prefixes: 184
Aggregateable : 95
5. Updates originated by AS4621 UNSPECIFIED UNINET-TH (325462)
GITS-TH-AS-AP Government Information Technology Services (TH)
AS Adjacency: Up: 2 Down: 1
UP: 4750, 7470
Originated Prefixes: 129
Aggregateable: 78
Updates originated by AS9835 GITS-TH-AS-AP Government Information Technology Services (297464)
BBIL-AP BHARTI Airtel Ltd. (IN)

AS Adjacency: UP: 9 Down: 128

UP: 7473, 1239, 2914, 3356, 3491, 3320, 9730, 6453, 6762

Originated Prefixes: 678

Aggregateable: 407
#8  AS4323

TWTC – Telecom Peering tw telecom holdings, inc. (US)

AS Adjacency: Up: 5 Down: 976

Originated Prefixes: 4203

Aggregatable: 3060 (!)
8. Updates originated by AS4323 TWTC - tw telecom holdings, inc. (248126)
BSNL-NIB National Internet Backbone (IN)

AS Adjacency: Up: 13 Down: 1

UP: 1239, 1273, 6453, 7018, 18101, 15412, 3561, 3356, 9910, 5400, 4755, 9498

Originated Prefixes: 624

Aggregateable: 273
9. Updates originated by AS9829 BSNL-NIB National Internet Backbone (226666)
SIFY-AS-IN Sify Limited (IN)

AS Adjacency: Up: 14 Down: 18

UP: 1239, 1299, 701, 7018, 2697, 10026, 3320, 3356, 3491, 5400, 4755, 9498, 6453, 7473

Originated Prefixes: 1111

Aggregateable: 275
#10 AS9583