Inter-Domain Routing Trends

Geoff Huston
gih@apnic.net

APNIC
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Agenda

1. Some data about the network and BGP over 2006
2. Some observations about the distribution patterns of BGP updates
3. Pointers to some possible areas of further study
IPv4 Stats for 2006

<table>
<thead>
<tr>
<th>Category</th>
<th>Range</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefixes</td>
<td>173,800 – 203,800</td>
<td>+17%</td>
</tr>
<tr>
<td>Roots</td>
<td>85,800 – 100,800</td>
<td>+17%</td>
</tr>
<tr>
<td>Specifics</td>
<td>88,000 – 103,000</td>
<td>+17%</td>
</tr>
<tr>
<td>Addresses</td>
<td>87.6 – 98.4 (/8)</td>
<td>+12%</td>
</tr>
<tr>
<td>ASNs</td>
<td>21,200 – 24,000</td>
<td>+13%</td>
</tr>
</tbody>
</table>

AS growth – 13%
BGP growth – 17%

Average advertisement size is getting smaller (8,450 – 8,100)
Average address origination per AS is getting smaller (69,600 – 69,150)
Average AS Path length steady (3.4)
AS transit interconnection degree rising (2.56 – 2.60)

The IPv4 network continues to get denser, with finer levels of advertisement granularity.

More interconnections, more specific advertisements
BGP Stats for 2006

- Number of unique prefixes announced: 354,589
- Prefix Updates: 89,582,323 (average = 2.84 per second)
- Prefix Withdrawals: 30,531,219 (average = 0.96 per second)
- Updated prefixes (year end): 203,635
- Withdrawn prefixes: 150,954
- Average Prefixes per BGP Update: 1.95 (down from 2.1 at the start of 2006)
How “good” is this data?

- Its just one (ordinary) router’s view of a rather complex routing world, not an aggregated view of a larger routing environment. There is some ‘locality’ component in the data.
- It’s not located within the world’s richest connectivity (it may be understating the routing load)
- The data is very noisy (e.g. 150,000 short term (leaked?) prefixes)
- The data is heavily skewed by a ‘heavy tail’ distribution (small number of prefixes and ASs appear to be the subject of a large number of updates)
- So any effort at generating trend data is biased by the small number of these “intense updaters” (making predictive models even more uncertain than normal)
CDF of Updates by Prefix

10% of prefixes are the subject of 60% of updates for 2006

60% of announced prefixes accounted for 10% of the updates
84.205.76.0/24 – a known control point

• Beacon on a 1 hour cycle
  – 12 UP and 12 DOWN events per 24 hours
  – 4,380 beacon events in 2006 (4380 announces and 4380 withdrawals at origin)
  – Recorded 55,634 BGP update events and 4,423 withdrawals for 2006

  – Every withdrawal at origin caused an average of 11 update messages to reach the observation point throughout the year

• BGP appears to be a very efficient event amplifier
CDF of Updates by Origin AS

3% of ASs were the origin AS for 60% of all updates

10% of Updates were associated with 75% of Origin ASs
Example: AS17974: 1.3M updates in 2006

- 17974 TELKOMNET-AS2-AP PT TELEKOMUNIKASI INDONESIA
  Adjacency: Upstream: 1 Downstream: 0
- Upstream Adjacent AS list
  AS7713 TELKOMNET-AS-AP PT TELEKOMUNIKASI INDONESIA
    Upstream: 5
    AS9237 HUTCHECA-AS Corporate Access (HK) Ltd.
    AS11919 LORAL-SKYNET-AR - Loral Skynet Network Services, Inc.
    AS24077 TMHK-TRANSIT-AS-HK-AP TMHK Global Transit
    AS7473 SINGTEL-AS-AP Singapore Telecom
    AS7632 MEGHANTARA-AS-AP PT. Meghantara
So what’s going on?

• It would appear that the BGP update rate is being strongly biased by a small number of origins with two forms of behaviour:
  – Supernova
    Multi-Homing & Traffic Engineering - bursting update rates sustained over weeks / months with a strong component of first hop change and persistent announce and withdrawal of more specifics
  – Background Radiation
    Unstable configuration states – a configuration which cannot stabilise and for a period of hours or days where the convergence to withdrawal causes continual updates
Where is this heading?

• Can we make BGP “scale” better or are we forced to look at a new routing structure?
• Making BGP “scale”:
  – Is there a more effective mechanism for damping unstable routes and paths and /or damping convergence to withdrawal?
  – Can we encourage widespread use of standard mechanisms that limit the propagation of BGP advertisements?
  – Should we consider alternate ways of BGP coping with withdrawal?
    • Does the “origin withdrawal” attribute added to BGP protocol specification make sense?
    • Should we consider “alternate reachability” selective advertisements that address withdrawal / update patterns in BGP convergence by changing the BGP protocol behaviour?
Changing BGP

• It’s now a large system with massive deployment inertia
• Any ‘change” will require piecemeal deployment capability with benefits realized by those who deploy
  – Which implies that use of backward compatible incremental change with piecemeal deployment is the only feasible approach here
  – The 32-bit ASN transition is a useful case study in changing BGP
  • Capability negotiation for peer setup
  • Transitive opaque attributes to signal additional capabilities (such as origin withdrawal)
  • Local changes to BGP processing
Some themes for further study

• How well do we understand BGP today?
  – More observation points
  – Investigation of known BGP pathologies
  – Control points as observation benchmarks

• How well do we understand the BGP of tomorrow
  – What metrics provide reasonable indicators?
  – How stable is the time series data?
  – What is the confidence interval of 3 – 5 year predictors

• How well do we understand the impacts of incremental change to BGP?
  – Modelling connectivity and behaviours
  – Simulation and direct experimentation
Thank You
Additional Material

The following are some graphs of aspects of BGP activity over 2006, with comparisons to comparable 2005 data.
IPv4 in pictures
Total Advertised BGP Prefixes

BGP Table Growth

Month

BGP FIB Entries

2006

2005

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

150000  160000  170000  180000  190000  200000  210000
IPv4 in pictures
Relative Growth: 2005 to 2006

Relative BGP Table Growth
IPv4 in pictures
Total Advertised IPv4 Address Span

Advertised Address Growth

Billions

Month

2005

2006

Advertized Address Span

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
IPv4 in pictures
Relative Growth: 2005 to 2006
IPv4 in pictures
Total Advertised AS Numbers

AS Growth

AS Count

Month

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

2005

2006
IPv4 in pictures

Relative Growth: 2005 to 2006
Update Message Rate

BGP Update Messages per Day

Millions

Update Messages per day

2006

2005
Prefix Update and Withdrawal Rates
Prefix Update Rates

Prefix Update Rates per Day

Prefixes Updated per day

2005

2006

Month

Prefixes Updated per day

Millions

Prefix Updates per Day

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Withdrawal Rates

Prefix Withdrawals Per Day

Month

Prefix Withdrawals

2006

2005
Average Prefixes per BGP Update

Prefixes per BGP Update Message

Date

Daily Average number of Prefixes per Message

Linear Fit - Total Prefixes per update

Prefixes per Update Message
Updated Prefixes per BGP Update Message

![Updated Prefixes per BGP Update Message](image)
## Most Active Prefixes for 2006

### Top 10 Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Updates</th>
<th>Flaps</th>
<th>Re-Homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>209.140.24.0/24</td>
<td>210,574</td>
<td>151,145</td>
<td>1</td>
</tr>
<tr>
<td>61.4.0.0/19</td>
<td>101,901</td>
<td>93,843</td>
<td>35</td>
</tr>
<tr>
<td>61.0.0.0/8</td>
<td>89,768</td>
<td>70,863</td>
<td>5,541</td>
</tr>
<tr>
<td>81.212.141.0/24</td>
<td>69,688</td>
<td>53,445</td>
<td>12,715</td>
</tr>
<tr>
<td>203.199.128.0/19</td>
<td>63,606</td>
<td>51,076</td>
<td>8,592</td>
</tr>
<tr>
<td>152.74.0.0/16</td>
<td>61,409</td>
<td>45,532</td>
<td>0</td>
</tr>
<tr>
<td>84.205.65.0/24</td>
<td>59,744</td>
<td>44,792</td>
<td>8,454</td>
</tr>
<tr>
<td>81.212.149.0/24</td>
<td>59,150</td>
<td>49,159</td>
<td>8,575</td>
</tr>
<tr>
<td>193.242.123.0/24</td>
<td>57,717</td>
<td>34,974</td>
<td>16,468</td>
</tr>
<tr>
<td>84.205.76.0/24</td>
<td>55,634</td>
<td>41,526</td>
<td>9,110</td>
</tr>
</tbody>
</table>
## Active ASNs

### Top 10 AS

<table>
<thead>
<tr>
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<th>Flaps</th>
<th>Re-Homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>17974</td>
<td>1,340,344</td>
<td>983,667</td>
</tr>
<tr>
<td>2.</td>
<td>9121</td>
<td>783,879</td>
<td>542,965</td>
</tr>
<tr>
<td>3.</td>
<td>855</td>
<td>748,611</td>
<td>489,035</td>
</tr>
<tr>
<td>4.</td>
<td>702</td>
<td>517,723</td>
<td>379,880</td>
</tr>
<tr>
<td>5.</td>
<td>15611</td>
<td>517,243</td>
<td>337,669</td>
</tr>
<tr>
<td>6.</td>
<td>8151</td>
<td>425,852</td>
<td>288,042</td>
</tr>
<tr>
<td>7.</td>
<td>12654</td>
<td>396,924</td>
<td>295,083</td>
</tr>
<tr>
<td>8.</td>
<td>4323</td>
<td>393,687</td>
<td>275,477</td>
</tr>
<tr>
<td>9.</td>
<td>4621</td>
<td>370,478</td>
<td>278,650</td>
</tr>
<tr>
<td>10.</td>
<td>17557</td>
<td>368,689</td>
<td>248,680</td>
</tr>
</tbody>
</table>