Measuring the IPv4 transfer markets

Ioana Livadariu, Ahmed Elmokashfi
(Simula Research Laboratory)

Amogh Dhamdhere
(CAIDA/UCSD)
Limited address space assignment
Organizations have to justify the required IPv4 address space

Available IPv4 /8 address blocks per RIR*

- AFRINIC: 1.62
- APNIC: 0.49
- ARIN: 0
- LACNIC: 0.07
- RIPE NCC: 0.93

* Source: NRO Internet Number Resource Report June 2016
IPv4 address space: allocation

**Pre-RIR phase:**
- Classful allocation
- Legacy space

**Need-based allocation phase:**
- Classless allocation
- Hierarchical allocation
- RIR policies
- IPv4 Transfer Markets

**Exhaustion phase:**
- Feb 2011 - IANA
- Apr 2011 - APNIC
- Sep 2012 - RIPE
- Jun 2014 - LACNIC
- Sep 2015 - ARIN

IPv4 Address space management
**IPv4 Transfers**

- **IPv4 address transactions that occur between organizations**
  - Can involve third-parties (**IPv4 brokers**)
  - Regulated by the **RIRs policies**

- Three RIRs have legitimized transfer markets

<table>
<thead>
<tr>
<th>Internet Registry</th>
<th>Intra-RIR Policy</th>
<th>First Published Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIPE</td>
<td>December 2008</td>
<td>October 2012</td>
</tr>
<tr>
<td>ARIN</td>
<td>June 2009</td>
<td>October 2009</td>
</tr>
<tr>
<td>APNIC</td>
<td>February 2010</td>
<td>January 2011</td>
</tr>
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<tr>
<td>ARIN &lt;--&gt; APNIC</td>
<td>July 2012</td>
<td>October 2012</td>
</tr>
<tr>
<td>APNIC &lt;--&gt; RIPE &lt;--&gt; ARIN</td>
<td>September 2015</td>
<td>December 2015</td>
</tr>
</tbody>
</table>
Outline

• Analysis of published transfers:
  • How are transfers evolving over time?
  • What type of addresses are being transferred?
  • Are buyers using the acquired space?
  • Is there a correlation between markets and IPv6 adoption?
  • What is the market value?

• Detecting transfers:
  • Can we detect transfers using publicly available data?
Increasing number of transfers over time

- 80% year on year increase (2013-2015); not much change in 2016
- Approx. 65% of the reported transfers occur within RIPE
How much space is transferred?

- Transferred address blocks account for ~2.67% of the IPv4 space
- 47% of the transferred space comes from ARIN
Which space is being transferred?

- 71% of the transferred space is legacy allocation (>90% ARIN)
- In ARIN, 37% of the blocks are larger than /20, whereas more than 80% transferred blocks are smaller than /20 for RIPE and APNIC
Transferred space = “Used” space?

<table>
<thead>
<tr>
<th>Class</th>
<th>Before</th>
<th>After</th>
<th>% (Total space)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Unrouted</td>
<td>Unrouted</td>
<td>4.04</td>
</tr>
<tr>
<td>B</td>
<td>Routed</td>
<td>Unrouted</td>
<td>1.49</td>
</tr>
<tr>
<td>C</td>
<td>Unrouted</td>
<td>Routed</td>
<td>85.17</td>
</tr>
<tr>
<td>D</td>
<td>Routed</td>
<td>Routed</td>
<td>9.27</td>
</tr>
</tbody>
</table>

Visibility of the transferred blocks in the routing table

94% of the transferred space is routed after the transfer

<table>
<thead>
<tr>
<th>RIR</th>
<th>Time before re-announced (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIPE</td>
<td>1.91</td>
</tr>
<tr>
<td>APNIC</td>
<td>6.2</td>
</tr>
<tr>
<td>ARIN</td>
<td>6.48</td>
</tr>
</tbody>
</table>

Buyers acquire addresses to meet immediate needs
Buyers need addresses more than sellers

- Utilization fraction* = fraction of IP addresses that responds to ICMP requests in a transferred prefix

- Utilization fraction of the transferred space has increased with at least 50% after the transfer date

* Source: ISI Census data
High percentage of the address space is exchanged among the top participants in the market

Percentage of IPv4 address space sold/bought by top 10% dominant players per RIR
RIPE: Four countries dominate the market

- Organizations involved in the IPv4 transfer market come from 64 countries
- Approx. 78% of the address space is exchanged between six countries
- 50% of the sold IPv4 space comes from two countries (Germany and Romania)
- 30% of the IPv4 space is bought by organizations in two countries (Saudi Arabia and Iran)

(IPv4 space bought/IPv4 space sold) and IPv6 adoption* per country within RIPE

* Source: Google IPv6 Statistics
Are markets slowing down IPv6 adoption?

- *Fraction of IPv6 adopters* = fraction of buyers that are originating IPv6 prefixes* after acquiring IPv4 addresses on the transfer market

- Increasing number of buyers that adopt IPv6 across all RIRs
- IPv4 transfers markets do not appear to inhibit the IPv6 adoption

* Source: BGP data (Routeviews and RIPE NCC)
What is the market monetary value?

- Widely known IP transactions:
  
  2011 Microsoft - Nortel*: $11 per IPv4 address
  
  2011 Cerner - Borders**: $12 per IPv4 address

- Prices published by IPv4 Brokers:

<table>
<thead>
<tr>
<th>IPv4 Market Group (retrieved in August 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIR</td>
</tr>
<tr>
<td>APNIC</td>
</tr>
<tr>
<td>ARIN</td>
</tr>
<tr>
<td>RIPE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IPv4Auctions.com - (retrieved in September 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
</tr>
<tr>
<td>/22 Block Registered in ARIN</td>
</tr>
<tr>
<td>/21 Block Registered in ARIN</td>
</tr>
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<td>/23 Block Registered in ARIN</td>
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<td>/24 Block Registered in ARIN</td>
</tr>
<tr>
<td>/19 Block Registered in ARIN</td>
</tr>
</tbody>
</table>

- Monetary aspects of the IPv4 transactions are confidential
- Prices published by IPv4 Brokers offer a partial view of the market value

* Source: http://www.networkworld.com/
**Source: http://www.ipaddressnews.com/
Estimating the market monetary value

• Approach:
  • We model the IPv4 address block prices using a *Hedonic Pricing Method*, which estimates the value of a good by taking into account both internal characteristics and external factors of the good.
  • We use prices reported by IPv4 brokers to fit the hedonic prices model.

• Estimated value of the market: ~$386 M (USD)

*Source: S. Rosen, Hedonic prices and implicit markets: Product differentiation in pure competition*
Can we detect transfers “in the wild”?

- Transfers need to be approved by the RIRs, but there is no mechanism to ensure that organizations report to the RIRs.

- Methodology: Use BGP data (routing table dumps) collected from January 2004 to September 2015 to construct prefix-AS mapping and identify prefixes that change origin AS.
Detecting transfers: filtering approach

- Our approach is prone to false positives due to legitimate reasons
- Design four filters to reduce the number of candidate transfers

<table>
<thead>
<tr>
<th>Filter</th>
<th>Removed prefixes</th>
</tr>
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<tbody>
<tr>
<td>Map2Organization</td>
<td>IPv4 space movement within the same organization</td>
</tr>
<tr>
<td>Transient</td>
<td>Short-lived advertised IPv4 space (e.g. prefix hijacks)</td>
</tr>
<tr>
<td>RIR</td>
<td>IPv4 space advertised by RIRs</td>
</tr>
<tr>
<td>Delegation</td>
<td>Provider-aggregatable address space</td>
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</table>
Evaluating the results

- Filters reduce 65% of the initial number of candidate transfers
- Our methodology infers more than 90% of the detectable published transfers
False positive: examples and causes

108.51.0.0/16: AS 19262 → AS 701
   May-2011 → Jun-2013 → Sep-2015
   Incomplete AS2ORG mapping*

43.230.172.0/22: AS 17676 → AS 58640
   Reallocated address blocks

192.147.142.0/24: AS 7892 → AS 6389
   Non-BGP speaker organizations switching providers

*Source: CAIDA AS2ORG Mapping
Detecting transfers: expanding the methodology

• Possible solution: *Augmenting the data* (DNS names)
  • Changes in DNS resource record
  • Data: *IPv4 Routed /24 DNS Names Dataset*

• Preliminary analysis: Usage of DNS records removes two third of the analyzable candidate transfers
Conclusions

• Increase in the size of the IPv4 transfer markets
• The majority of the transferred blocks are legacy allocations
• Markets seem to serve their intended purpose (i.e. buyers “use” the acquired address space)
• Markets appear not to slow down the IPv6 adoption
• Markets differ across regions in terms of size and type of the transferred blocks, participants

• Detecting transfers is difficult and requires using multiple data sources