IPv6 HD Ratio

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Background

- Current IPv6 Address Allocation policies refer to the use of the Host Density Ratio as a metric for ‘acceptable’ utilization of address space
  - Original Def’n: RFC 1715
  - Re-stated Def’n: RFC 3194

- Current IPv6 Address Allocation policies use an HD-Ratio value of 0.8 as an allocation threshold value

- Why 0.8?
  - This value is based on a small number of case studies described in RFC 1715 – no further analysis of the underlying model or the selection of an appropriate threshold value as an IP network efficiency metric has been published

- Does this HD-Ratio value provide “reasonable” outcomes in terms of address utilization?
The HD Ratio Metric

- IPv4 fixed 80% Density
  \[
  \frac{\text{Host-Count}}{\text{Address-Count}} = 0.8
  \]

- IPv6 0.8 HD Ratio
  \[
  \log(\text{Host-Count}) / \log(\text{Address-Count}) = 0.8
  \]

Under the HD-Ratio, the overall address utilization efficiency level falls exponentially in line with the size of the address block. Large allocations have a very small density threshold, while smaller allocations have a much higher threshold.
## IPv4 / IPv6 Allocation equivalence table

<table>
<thead>
<tr>
<th>End Customer Size</th>
<th>IPv4 Allocation</th>
<th>IPv6 Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>205</td>
<td>/24</td>
<td>/32</td>
</tr>
<tr>
<td>410</td>
<td>/23</td>
<td>/32</td>
</tr>
<tr>
<td>819</td>
<td>/22</td>
<td>/32</td>
</tr>
<tr>
<td>1638</td>
<td>/21</td>
<td>/32</td>
</tr>
<tr>
<td>3277</td>
<td>/20</td>
<td>/32</td>
</tr>
<tr>
<td>7131</td>
<td>/18</td>
<td>/32</td>
</tr>
<tr>
<td>12416</td>
<td>/18</td>
<td>/31</td>
</tr>
<tr>
<td>21618</td>
<td>/17</td>
<td>/30</td>
</tr>
<tr>
<td>37640</td>
<td>/16</td>
<td>/29</td>
</tr>
<tr>
<td>65536</td>
<td>/15</td>
<td>/28</td>
</tr>
<tr>
<td>114104</td>
<td>/14</td>
<td>/27</td>
</tr>
<tr>
<td>198668</td>
<td>/14</td>
<td>/26</td>
</tr>
<tr>
<td>345901</td>
<td>/13</td>
<td>/25</td>
</tr>
<tr>
<td>602248</td>
<td>/12</td>
<td>/24</td>
</tr>
<tr>
<td>1048576</td>
<td>/11</td>
<td>/23</td>
</tr>
<tr>
<td>1825676</td>
<td>/10</td>
<td>/22</td>
</tr>
<tr>
<td>3178688</td>
<td>/10</td>
<td>/21</td>
</tr>
<tr>
<td>5534417</td>
<td>/9</td>
<td>/20</td>
</tr>
<tr>
<td>9635980</td>
<td>/8</td>
<td>/19</td>
</tr>
<tr>
<td>16777216</td>
<td>/7</td>
<td>/18</td>
</tr>
</tbody>
</table>
## IPv6 Address Efficiency Table

<table>
<thead>
<tr>
<th>IPv6 Prefix</th>
<th>Block Size (/48s)</th>
<th>HD = 0.8 Host Count</th>
<th>Address Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>/32</td>
<td>65,536</td>
<td>7,132</td>
<td>11%</td>
</tr>
<tr>
<td>/31</td>
<td>131,072</td>
<td>12,417</td>
<td>9%</td>
</tr>
<tr>
<td>/30</td>
<td>262,144</td>
<td>21,619</td>
<td>8%</td>
</tr>
<tr>
<td>/29</td>
<td>524,288</td>
<td>37,641</td>
<td>7%</td>
</tr>
<tr>
<td>/28</td>
<td>1,048,576</td>
<td>65,536</td>
<td>6%</td>
</tr>
<tr>
<td>/27</td>
<td>2,097,152</td>
<td>114,015</td>
<td>5%</td>
</tr>
<tr>
<td>/26</td>
<td>4,194,304</td>
<td>198,668</td>
<td>5%</td>
</tr>
<tr>
<td>/25</td>
<td>8,388,608</td>
<td>345,901</td>
<td>4%</td>
</tr>
<tr>
<td>/24</td>
<td>16,777,216</td>
<td>602,249</td>
<td>4%</td>
</tr>
<tr>
<td>/23</td>
<td>33,554,432</td>
<td>1,048,576</td>
<td>3%</td>
</tr>
<tr>
<td>/22</td>
<td>67,108,864</td>
<td>1,825,677</td>
<td>3%</td>
</tr>
<tr>
<td>/21</td>
<td>134,217,728</td>
<td>3,178,688</td>
<td>2%</td>
</tr>
<tr>
<td>/20</td>
<td>268,435,456</td>
<td>5,534,417</td>
<td>2%</td>
</tr>
<tr>
<td>/19</td>
<td>536,870,912</td>
<td>9,635,980</td>
<td>2%</td>
</tr>
<tr>
<td>/18</td>
<td>1,073,741,824</td>
<td>16,777,216</td>
<td>2%</td>
</tr>
</tbody>
</table>

Using a fixed 16 bit subnet length
Modelling the HD Ratio

• Does this HD Ratio value produce reasonable outcomes?
  • The approach reported here is to look at recent IPv4 allocation data, and simulate an equivalent IPv6 registry operating user a similar address demand profile
IPv6 Registry simulation exercise

• Use recent RIR IPv4 allocation data to create a demand model of an IPv6 address registry
  • Assume a sequence of IPv6 transactions based on a demand model derived from the sequence of recorded IPv4 allocations
  • Convert IPv4 to IPv6 allocations by assuming an equivalence of an IPv4 end-user-assignment of a /32 with an IPv6 end-user-assignment of a /48
  • IPv4 uses a constant host density of 80% while IPv6 uses a HD-Ratio of 0.8
  • Use a minimum IPv6 allocation unit of a /32
  • Assume IPv4 allocation timeframe mean of 12 months
Allocation Simulation results

Registry Allocations

Prefix Size

AFRINIC
LACNIC
RIPENCC
ARIN
APNIC
ALL

Month
Prefix Distribution

Prefix Length Distribution HD = 0.8
HD Ratio Observations

• One interpretation of the HD Ratio is that it corresponds to a network model where an additional component of internal network hierarchy is introduced for each doubling of the address block size.

• A HD Ratio of 0.8 corresponds to a network with a per-level efficiency of 70%, and adding an additional level of hierarchy as the network increases in size by a factor of 8.
Comparison of HD Ratio and Compound Hierarchy

HD vs Stepped

HD Ratio 0.8
Stepped 70%

Prefix (bit size)
Efficiency

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Interpreting the HD Ratio

• For a /32 allocation the 0.8 HD ratio is comparable to 6 levels of internal hierarchy with 70% efficiency at each level

• For a /24 this corresponds to an internal network hierarchy of 9 levels, each at 70% efficiency

• Altering the HD Ratio effectively alters comparable model rate of growth in internal levels of network hierarchy
HD = 0.94

- This corresponds to a network model that uses base efficiency of 0.75 at each level of internal network structure, with a new level of hierarchy added for each additional 5 bits of address prefix length (x 32)
Varying the HD Ratio
Varying the HD Ratio - Detail

Address Efficiency - /32 through to /18

Prefix length (bits)

Efficiency

0.99 0.98 0.97 0.96 0.95 0.94 0.93 0.92 0.91 0.9 0.89 0.88 0.87 0.86 0.85 0.84 0.83 0.82 0.81 0.8

Stepped

Fixed
Allocation Simulation – HD = 0.94

Registry Allocations (HD = 0.94)
Prefix Distribution – HD = 0.94

Prefix Length Distribution HD = 0.94
Comparison of prefix size distributions

Comparison of Prefix Distributions

- HD = 0.8
- HD = 0.87
- HD = 0.94
Observations

• 80% of all allocations are /31 and /32 for HD ratio of 0.8 or higher
  • Changing the HD ratio will not impact most allocations in a steady state registry function

• Only 2% of all allocations are larger than a /27
  • For these larger allocations the target efficiency is lifted from 4% to 25% by changing the HD Ratio from 0.8 to 0.94 (25% is equivalent to 5 levels of internal hierarchy each with 75% efficiency)

• Total 3 year address consumption is reduced by a factor of 10 in changing the HD ratio from 0.8 to 0.94
What is a “good” HD Ratio to use?

• Need to consider what is common practice in today’s network in terms of internal architecture
  • APNIC is conducting a survey of ISPs in the region on network structure and internal levels of address hierarchy and will present the findings at APNIC 20

• Need to define a common ‘baseline’ efficiency level rather than an average attainable level
  • What value would be readily achievable by large and small networks without resorting to renumbering or internal route fragmentation?

• Need to consider overall longer term objectives
  • Anticipated address pool lifetime
  • Anticipated size of the routing space
Thank you

Questions?