kIP: a Measured Approach to IPv6 Address Anonymization
MAPRG Meeting – Prague, July 20, 2017

David Plonka <plonka@akamai.com>

“kIP: a Measured Approach to IPv6 Address Anonymization” (pre-print)
IP Address Anonymization

• **Today we’ll only consider truncation and/or aggregation-based anonymization** e.g., for correlating web analytics with network topology, routing, service providers, and geographic locations.
**Background: IPv4 Address Anonymization by aggregation**

<table>
<thead>
<tr>
<th>IPv4 Address</th>
<th>Count</th>
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<tbody>
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<td>10.0.42.5</td>
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### Background: IPv4 Address Anonymization by aggregation to a fixed length

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<th>IP Address</th>
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</table>

### Result

10.0.42.0/27 32
IP Address Anonymization

• *Truncation-based anonymization is ideal if, and only if, it can be guaranteed to improve privacy.*

We propose *k*IP anonymization, *i.e.*, make an individual appear indistinguishable amongst a set of *k* individuals

## Characteristics of the data sets

<table>
<thead>
<tr>
<th>Data set</th>
<th>Active /48 prefixes (7 days)</th>
<th>Active /64 prefixes (7 days)</th>
<th>Active addresses (7 days)</th>
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</thead>
<tbody>
<tr>
<td>Meeting Network</td>
<td>1</td>
<td>3</td>
<td>15.4K</td>
</tr>
<tr>
<td>EU ISP</td>
<td>163K</td>
<td>21.4M</td>
<td>125M</td>
</tr>
<tr>
<td>JP ISP</td>
<td>2.46M</td>
<td>2.46M</td>
<td>72.2M</td>
</tr>
<tr>
<td>US ISP</td>
<td>8.16K</td>
<td>2.42M</td>
<td>84.5M</td>
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Characteristics of the data sets: *no aggregation?*

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### Characteristics of the data sets: bias?

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kIP: a measurement-based approach...

1. **Temporal & Spatial Address Classification:**
   “address dendrachonology”

2. **Address Activity Matrix Analysis:**
   estimating a lower bound on simultaneously assigned addresses

3. **Anonymous Aggregate (Prefix) Synthesis:**
   then perform ongest-prefix match to produce results
Step 1. Classification: address dendrachronology introduced in "IPv6 Prefix Intelligence," MAPRG Meeting, April 2016
Classification: Discarding [Personally Identifiable] Information

Spatial Characteristic: Discriminating Prefix Length (DPL)

Classifications: Discarding [Personally Identifiable] Information

Discriminating Prefix Length (DPL) 13
Classification: Discarding [Personally Identifiable] Information

Spatial Characteristic: Discriminating Prefix Length (DPL)

Temporal Characteristic: Stable Days (SD)

Classification:
Discarding [Personally Identifiable] Information

20010db8000e00000172cd5fa4bd6b1 75 0d
20010db8000e000002ae748ea083efb 75 0d
20010db8000e000005d58e18441347a 79 1d
20010db8000e000005f1dd3864f2d03 79 0d
20010db8000e00000872ce4d7e0d16c 76 0d
... (1594 more addresses) ...
20010db8000e0000fdbefa6dce8d096c 80 1d
20010db8000e0000fdbf6e62e74a33a4 80 1d
20010db8000e0000fdd4f4f54264cc52 75 0d
20010db8000e0000fdf73310ae0043da 75 2d
20010db8000e0000feedfacedeadbabe 71 3d
Classification: Discarding [Personally Identifiable] Information

2001:0db8:0000:0017:cd5fa4bd6b1 75 0d
2001:0db8:0000:002ae748ea083efb 75 0d
2001:0db8:0000:005d58e18441347a 79 1d
2001:0db8:0000:005f1dd3864f2d03 79 0d
2001:0db8:0000:00872ce4d7e0d16c 76 0d
... (1594 more addresses) ...
2001:0db8:0000:fdbefa6dce8d09dc 80 1d
2001:0db8:0000:fdbe62e74a33a4 80 1d
2001:0db8:0000:fd4f4f54264cc52 75 0d
2001:0db8:0000:fd73310ae043da 75 2d
2001:0db8:0000:feedfacedeadbabe 71 3d

Stateless Classification: (from F. Gont’s IPv6 Toolkit)

$ addr6 --a 2001:0db8:0000:feedfacedeadbabe
unicast=global=global=randomized=unspecified
Classification: Discarding [Personinally Identifiable] Information

20010db8000e000000172cd5fa4bd6b1 75 0d
20010db8000e0000002ae748ea083efb 75 0d
20010db8000e0000005d58e18441347a 79 1d
20010db8000e0000005f1dd3864f2d03 79 0d
20010db8000e000000872ce4d7e0d16c 76 0d
... (1594 more addresses) ...
20010db8000e0000fdbefa6dce8d096c 80 1d
20010db8000e0000fdbf6e62e74a33a4 80 1d
20010db8000e0000fdd4f4f54264cc52 75 0d
20010db8000e0000fdf73310ae0043da 75 2d
20010db8000e0000feedfacedeadbabe 71 3d

Truncate here?
Classification: Discarding [Personally Identifiable] Information

20010db8000e00000172cd5fa4bd6b1 75 0d
20010db8000e000002ae748ea083efb 75 0d
20010db8000e000005d58e18441347a 79 1d
20010db8000e000005f1dd3864f2d03 79 0d
20010db8000e00000872ce4d7e0d16c 76 0d
... (1594 more addresses) ...
20010db8000e0000fdbefa6dce8d096c 80 1d
20010db8000e0000fdba6e62e74a33a4 80 1d
20010db8000e0000fdd4f4f54264cc52 75 0d
20010db8000e0000fdf73310ae0043da 75 2d
20010db8000e0000feedfacedeadbabe 71 3d

Truncate here?
Or here?

Classification:	Discarding	[Personally	Identifiable]	Information
Step 2. Address Activity Matrix Analysis
Related Work: IPv4 Address Activity Matrix introduced in “Beyond Counting …”, MAPRG Meeting July 2016

for each day on which an IP address was active (requested content), we draw a red dot.

Related Work: IPv4 Address Activity Matrix

Beyond Counting: New Perspectives on the Active IPv4 Address Space (Richter et al. IMC 2016): 
Related Work: IPv4 Address Activity Matrix

20k adjacent IP addresses (in active /24s), University Network

IPv6 Address Activity Matrix
## IPv6 Address Activity Matrix

<table>
<thead>
<tr>
<th>Address</th>
<th>Activity</th>
<th>Matrix</th>
</tr>
</thead>
</table>
| 20010db823000a00117ae091b2bdca65 | 67 0d | --------+--------+
| 20010db823000a0021ad6d24641a1314 | 68 0d | ------++--------+
| 20010db823000a003454ae0d20a0df4d | 68 0d | --------+--------#
| 20010db823000a004974fa8b465d4c2a | 68 0d | --------+--------#
| 20010db823000a00503ca91dbe009a63 | 68 0d | --------# # # # ##
| 20010db823000a0068678a645417e731 | 70 0d | --------++--------+
| 20010db823000a006d35ee11ec45f658 | 70 0d | --------+--------#
| 20010db823000a007070a7fc47d502ba | 70 0d | --------+--------#
| 20010db823000a007554b66aa9839665 | 70 0d | --------+--------#
| 20010db823000a0079391bd6fec285bb | 70 0d | --------+--------#
| 20010db823000a007cc39777c76bdef | 70 0d | --------+--------#
| 20010db823000a00890b1f0d14e20ccb | 67 0d | --------++--------+
| 20010db823000a00a0fc1e1848aaeb2e | 67 0d | --------+--------#
| 20010db823000a009309833f8c53926 | 74 0d | --------+--------#
| 20010db823000a00f94dfcec6b8ed61f | 74 0d | --------+--------#
| 20010db823000a00fd2850fe844583e7 | 70 0d | --#--------+

**Legend:**
- # = activity counted during the given hour

**/64 prefix**

16 Temporary SLAAC: 100.00% stable: 0.00%
## IPv6 Address Activity Matrix

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</tbody>
</table>

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### Legend:

- # = Activity counted during the given hour

---

**/64 prefix**

**IID**

---

*Temporary SLAAC: 100.00% stable: 0.00%*
IPv6 Address Activity Matrix

There is an expected maximum Discriminating Prefix Length (DPL) for a set, size $n$, of IPv6 addresses with random IIDs.

At probability of 0.99 (99%), e.g., $n=16$ such addresses have expected max. DPL <= 79 (bits).

Here, where $n=16$, the observed max. DPL was 74 (bits); thus, they have plausibly random IIDs.

2001:db8::/64 16; Temporary SLAAC: 100% stable: 0.00%

legend:
# = activity counted during the given hour
IPv6 Address Activity Matrix

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<td>--#-----+----------+</td>
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<td>----------+---#---+--------</td>
<td></td>
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<tr>
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<td>----------+----------+---##</td>
<td></td>
</tr>
<tr>
<td>20010db823000a00503ca91dbe009a63 68 0d</td>
<td>----------+###---+--------</td>
<td></td>
</tr>
<tr>
<td>20010db823000a0068678a645417e731 70 0d</td>
<td>----------+----------+-------</td>
<td></td>
</tr>
<tr>
<td>20010db823000a006d35ee11ec45f658 70 0d</td>
<td>----------+#-------+--------</td>
<td></td>
</tr>
<tr>
<td>20010db823000a007070a7fc47d502ba 70 0d</td>
<td>----------+#-------+--------</td>
<td></td>
</tr>
<tr>
<td>20010db823000a007554b66aa9839665 70 0d</td>
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</tr>
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</tr>
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<td>20010db823000a00fd2850fe844583e7 70 0d</td>
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<td></td>
</tr>
</tbody>
</table>

Temporary SLAAC: 100.00% stable: 0.00%

Legend:

# = activity counted during the given hour
IPv6 Address Activity Matrix

Legend:
# = activity counted during the given hour
### IPv6 Address Activity Matrix

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<tr>
<th>Address</th>
<th>Activity</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>20010db823000a0021ad6d24641a1314</td>
<td>68</td>
<td>0d</td>
</tr>
<tr>
<td>20010db823000a00fd2850fe844583e7</td>
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<td>0d</td>
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IPv6 Address Activity Matrix

20010db823000a0021ad6d24641a1314 68 0d |--#--+-+------------------------+-|
20010db823000a00fd2850fe844583e7 70 0d |--#--+-+------------------------+-|
20010db823000a007070a7fc47d502ba 70 0d |---------#++-------------------+-|
20010db823000a00503ca91dbe009a63 68 0d |---------#@@@#-------------------+
20010db823004009f4df8edeb61f 74 0d |---------#------------------------+
20010db823000a003454ae00d20a0df4d 68 0d |---------+---#-------------------+
20010db823000a007555b66a9839665 70 0d |---------+---#-------------------+
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20010db823000a009c0e8a89aeb2e 67 0d |---------+---#@@#-------------------+
20010db823000a00f9309833f8c53926 74 0d |---------+---#@@#-------------------+
20010db823000a0090le14fe204ccn 67 0d |---------+---#-------------------+
20010db823000a0079931bd66e6285bb 70 0d |---------+---#-------------------+
20010db823000a004974fa8b4665d4c2a 68 0d |---------+---#-------------------+
20010db823000a0063d535ee1le45f658 70 0d |---------+---#-------------------+
20010db823000a00117ae0912bdca65 67 0d |---------+---#-------------------+
20010db823000a0070391bd66e6285bb 70 0d |---------+---#-------------------+
20010db823000a0016 16 Temporary SLAAC: 100.00% stable: 0.00%

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<td>68 0d</td>
<td>-----&gt;@@@@&lt;+---------+--------</td>
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</tr>
<tr>
<td>20010db823000a0068678a645417e731</td>
<td>70 0d</td>
<td>------+++&gt;--------</td>
</tr>
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<td>67 0d</td>
<td>------+++&gt;@@@&lt;---</td>
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<td>74 0d</td>
<td>------+++&gt;@@@&lt;---</td>
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<td>20010db823000a00890b1f0d14e20ccb</td>
<td>67 0d</td>
<td>------+++&gt;X&lt;--+++</td>
</tr>
<tr>
<td>20010db823000a0079391bd6f6c285bb</td>
<td>70 0d</td>
<td>------++++X&lt;--+++</td>
</tr>
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| 20010db823000a004974fa8b465d4c2a | 68 0d | ------++++++>@@< 
| 20010db823000a006d35ee11ec45f658 | 70 0d | ------+++++++X++++ |
| 20010db823000a00117ae091b2bdca65 | 67 0d | ------+++++++>++< |
| 20010db823000a007ccc39777c76bdef | 70 0d | ------+++++++--X< |

**Legend:**

- `#` = activity counted during the given hour
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Counting Simultaneous SLAAC IIDss

<table>
<thead>
<tr>
<th>Activity</th>
<th>Count during the Given Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>activity counted during the given hour</td>
</tr>
<tr>
<td>X</td>
<td>activity started and ended during the given hour (within this whole window, e.g., 1 day)</td>
</tr>
<tr>
<td>&gt;</td>
<td>starting activity during the given hour (within this whole window, e.g., 1 day)</td>
</tr>
<tr>
<td>&lt;</td>
<td>ending activity during the given hour (within this whole window, e.g., 1 day)</td>
</tr>
<tr>
<td>@</td>
<td>assignment of address inferred throughout the given hour</td>
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Counting Simultaneous SLAAC IIDs

```
012345678901234567890123
20010db823000a0021ad6d24641a1314 68 0d | --X-- +--------+--------+
20010db823000a00fd2850fe844583e7 70 0d | --X-- +--------+--------+
20010db823000a007070a7fc47d502ba 70 0d | ---X-- +--------+--------+
20010db823000a00503ca91debe009a63 68 0d | ---@@< +--------+--------+
20010db823000a00f94dfcec6b8ed61f 74 0d | ---X-- +--------+--------+
20010db823000a003454ae0d20a0df4d 68 0d | +--X-- +--------+--------+
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20010db823000a006d35ee11ec45f658 70 0d | +--X-- +--------+--------+
20010db823000a00117ae091b2dca65 67 0d | +--X-- +--------+--------+
20010db823000a007ccc9777c76bdef 70 0d | +--X-- +--------+--------+
```

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---

34
Counting Simultaneous SLAAC IIDs

<table>
<thead>
<tr>
<th>Address</th>
<th>Activity</th>
<th>Start Time</th>
<th>End Time</th>
<th>Count</th>
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<td></td>
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00010001111233232321122100 => 3 simultaneous IIDs, maximum
### IPv6 Address Activity Matrix: Identity Assignment

<table>
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<tr>
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<th>Activity</th>
<th>Matrix</th>
<th>Identity</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001:db8:230000a0021ad6d24641a1314</td>
<td>68 0d</td>
<td>--X----+---------+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a00fd2850fe844583e7</td>
<td>70 0d</td>
<td>--X----+---------+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a007070a7fc47d502ba</td>
<td>70 0d</td>
<td>-------+X---------+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a00503ca91d6be09a63</td>
<td>68 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a00f94fdec6b8ed61f</td>
<td>74 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a003454ae0d20a0df4d</td>
<td>68 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a0075554b66aa9839665</td>
<td>70 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a0068678a64517e731</td>
<td>70 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a007070a7fc47d502ba</td>
<td>70 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a004974fa8b465d4c2a</td>
<td>68 0d</td>
<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001:db8:230000a007070a7fc47d502ba</td>
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<td>-------+---------+-X+-+--</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Legend:
- ! = infer /64 prefix assigned at the "fencepost" moments between intervals
- 000100011112332321122100 => 3 simultaneous IIDs, maximum
- 000100011112332321122100 => 3 simultaneous IIDs, maximum
- 2001:db8::/64 16; Temporary SLAAC: 100%-------------------------!!!!!!!!!-!!!!!!--?
- 000000001111111101111100 => /64 assignment @ fenceposts
3. Synthesizing Anonymous Aggregates
\[ i = 1 \]
\[ w = 3 \]
\[ f = 2 \]
\[i = 1\]
\[n = 3\]
\[s = 2\]
i = 1
3 = 3
5 = 2

\[ \theta > 1 \circlearrowright 2 < \]
### IPv6 Address Activity Matrix: Identity Assignment

<table>
<thead>
<tr>
<th>IPv6 Address</th>
<th>Activity Matrix</th>
<th>Identity Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001:db8:23000a0021ad6d24641a1314 68 0d</td>
<td>--X--</td>
<td>--X--</td>
</tr>
<tr>
<td>2001:db8:23000a00fd2850fe844583e7 70 0d</td>
<td>--X--</td>
<td>--X--</td>
</tr>
<tr>
<td>2001:db8:23000a007070a7fc47d502ba 70 0d</td>
<td>--X+</td>
<td>--X+</td>
</tr>
<tr>
<td>2001:db8:23000a00503ca91deb009a63 68 0d</td>
<td>-&gt;@@@&lt;</td>
<td>-&gt;@@@&lt;</td>
</tr>
<tr>
<td>2001:db8:23000a00f94dfec6b8ed61f 74 0d</td>
<td>--X</td>
<td>--X</td>
</tr>
<tr>
<td>2001:db8:23000a003454ae0d20a0def4d 68 0d</td>
<td>+--X</td>
<td>+--X</td>
</tr>
<tr>
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<td>--X-</td>
<td>--X-</td>
</tr>
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<td>+--X</td>
<td>+--X</td>
</tr>
<tr>
<td>2001:db8:23000a00a0fc1e1848aeb2e 67 0d</td>
<td>--X-</td>
<td>--X-</td>
</tr>
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<td>2001:db8:23000a00f9309833f8c53926 74 0d</td>
<td>+--X</td>
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</tr>
<tr>
<td>2001:db8:23000a00890b1f0d4e2c0cbb 70 0d</td>
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<td>2001:db8:23000a0079391bd6f6ec285bb 70 0d</td>
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<td>2001:db8:23000a006d35ee11ec45f658 70 0d</td>
<td>+--X</td>
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</tr>
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<td>2001:db8:23000a00117ae091b2bdca65 67 0d</td>
<td>--X-</td>
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</tr>
<tr>
<td>2001:db8:23000a007ccc39777c76bdef 70 0d</td>
<td>+--X</td>
<td>+--X</td>
</tr>
</tbody>
</table>

0001000111112332321122100 => 3 simultaneous IIDs, maximum 16; Temporary SLAAC: 100%--...!!!!!!!!!...??

Legend:
! = infer /64 prefix assigned at the "fencepost" moments between intervals
Step 3. Synthesizing Anonymous Aggregates

Example: $k=2$ aggregates (w=1d, i=1h)

2001:db8:370::/64

2001:db8:370::/55

2001:db8:370::/54
Example: Synthesizing anonymous $k=2$ aggregates ($w=1d$, $i=1h$)
Example: Synthesizing anonymous $k=2$ aggregates ($w=1d$, $i=1h$)
## Results: simultaneously-assigned addresses and prefixes

<table>
<thead>
<tr>
<th>Data set</th>
<th>Active /48 prefixes (7 days)</th>
<th>Active /64 prefixes (7 days)</th>
<th>Simultaneously-assigned /64 prefixes max. (median)</th>
<th>Simultaneously-assigned addresses max. (median)</th>
<th>Active addresses (7 days)</th>
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<tbody>
<tr>
<td>Meeting Network</td>
<td>1</td>
<td>3</td>
<td>3 (2)</td>
<td>309 (84)</td>
<td>15.4K</td>
</tr>
<tr>
<td>EU ISP</td>
<td>163K</td>
<td>21.4M</td>
<td>2.02M (1.52M)</td>
<td>3.80M (2.63M)</td>
<td>125M</td>
</tr>
<tr>
<td>JP ISP</td>
<td>2.46M</td>
<td>2.46M</td>
<td>1.21M (897K)</td>
<td>2.26M (1.54M)</td>
<td>72.2M</td>
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<tr>
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Histogram of anonymous aggregate prefix lengths (w=7d, i=1h)

US ISP median: 40.5K prefixes (8.16K /48s)
Histogram: $k=32$ anonymous aggregate prefix lengths ($w=7d, i=1h$)

- EU ISP median: 37.7K prefixes (163K /48s)
- US ISP median: 40.5K prefixes (8.16K /48s)
Histogram: k=32 anonymous aggregate prefix lengths (w=7d, i=1h)

EU ISP median: 37.7K prefixes (163K /48s)
JP ISP median: 26.3K prefixes (2.46M /48s)
US ISP median: 40.5K prefixes (8.16K /48s)
kIP: a Measured Approach to IPv6 Address Anonymization

MAPRG Meeting – Prague, July 20, 2017

David Plonka <plonka@akamai.com>

“kIP: a Measured Approach to IPv6 Address Anonymization” (pre-print)

The following are supplementary slides
Histogram \( k=256 \) anonymous aggregate prefix lengths (\( w=7d, i=1h \))

- EU ISP median: 3.23K prefixes (163K /48s)
- JP ISP median: 2.23K prefixes (2.46M /48s)
- US ISP median: 5.09K prefixes (8.16K /48s)
What are other applications of address activity matrix analysis and identifying simultaneously-assigned addresses?

Can we find the prefix length of an ISP’s Identity Assignments (e.g., from DHCPv6 IA requests)?
CDF (k=2) anonymous aggregate prefix lengths (w=7d, i=1h)

- US ISP min 304K prefixes
- US ISP max 1.17M prefixes
CDF: $k=2$ anonymous aggregate prefix lengths ($w=7d$, $i=1h$)

- EU ISP min 108K prefixes
- EU ISP max 2.81M prefixes
- US ISP min 304K prefixes
- US ISP max 1.17M prefixes
CDF: $k=2$ anonymous aggregate prefix lengths ($w=7\text{d}, i=1\text{h}$)

- EU ISP min 108K prefixes
- EU ISP max 2.81M prefixes
- JP ISP min 97.3K prefixes
- JP ISP max 1.10M prefixes
- US ISP min 304K prefixes
- US ISP max 1.17M prefixes

Prefix length (bits)
MRA Plot: EU ISP, 21.5M active addrs, 7 days

Prefix length (p)

aggregate count ratio, log scale

- 16-bit segments
- 4-bit segments
- single bits

<table>
<thead>
<tr>
<th>Prefix length (p)</th>
<th>16-bit segments</th>
<th>4-bit segments</th>
<th>single bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65536</td>
<td>32768</td>
<td>16384</td>
</tr>
<tr>
<td>16</td>
<td>16384</td>
<td>8192</td>
<td>4096</td>
</tr>
<tr>
<td>32</td>
<td>8192</td>
<td>4096</td>
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<tr>
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<td>1024</td>
</tr>
<tr>
<td>128</td>
<td>2048</td>
<td>1024</td>
<td>512</td>
</tr>
<tr>
<td>256</td>
<td>1024</td>
<td>512</td>
<td>256</td>
</tr>
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<td>4096</td>
<td>64</td>
<td>32</td>
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<tr>
<td>8192</td>
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<td>16</td>
<td>8</td>
</tr>
<tr>
<td>16384</td>
<td>16</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>32768</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>65536</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

addrs, 7 days
An MRA plot active addresses over time shows that significant subsets of the addresses are covered by the same /56, /60, etc. prefixes...
However, an MRA plot of *simultaneously-assigned addresses at one fencepost moment* shows that subsets of them are not, typically, covered by the same /56 prefix. This strongly suggests that this ISP uses /56 prefixes as the Identity Assignment (IA) to customers.