An Update on IPv6 Fragmentation

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Initial Tests: 2014 (RFC 7872)

- August 2014 and June 2015
- Sent fragmented IPv6 packets towards “well known” IPv6 servers (Alexa 1M and World IPv6 Launch)
- Drop Rate:

<table>
<thead>
<tr>
<th>Dataset</th>
<th>DOB</th>
<th>HBH8</th>
<th>FH512</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web servers</td>
<td>10.91% (46.52%/53.23%)</td>
<td>39.03% (36.90%/46.35%)</td>
<td>28.26% (53.64%/61.43%)</td>
</tr>
<tr>
<td>Mail servers</td>
<td>11.54% (2.41%/21.08%)</td>
<td>45.45% (41.27%/61.13%)</td>
<td>35.68% (3.15%/10.92%)</td>
</tr>
<tr>
<td>Name servers</td>
<td>21.33% (10.27%/56.80%)</td>
<td>54.12% (50.64%/81.00%)</td>
<td>55.23% (5.66%/32.23%)</td>
</tr>
</tbody>
</table>

Table 2: Alexa’s Top 1M Sites Dataset: Packet Drop Rate for Different Destination Types, and Estimated (Best-Case / Worst-Case) Percentage of Packets That Were Dropped in a Different AS.
APNIC Test - August 2017

- Use APNIC IPv6 measurement platform to test the drop rate of IPv6 packets flowing in the opposite direction (server to client)

<table>
<thead>
<tr>
<th></th>
<th>Count</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests</td>
<td>1,675,898</td>
<td></td>
</tr>
<tr>
<td>ACK Fragmented Packets</td>
<td>1,324,834</td>
<td>79%</td>
</tr>
<tr>
<td>Fragmentation Loss</td>
<td>351,064</td>
<td>21%</td>
</tr>
</tbody>
</table>

This is an improvement over the RFC 7872 measurement
Re-work of the 2017 measurement experiment

– Same server-to-client TCP session fragmentation mechanism

– Uses a middlebox to fragment outgoing packets - drop is detected by a hung TCP session that fails to ACK the sequence number in the fragmented packet

– This time we randomly vary the initial fragmented packet size between 1,200 and 1,416 bytes

– Performed as an ongoing measurement
2021 Fragmentation Drop Rate

Use of V6FRAG Drop Rate for World (XA)

This is a significant improvement over 2017 data.

Since 2017 there are 10x the number of IPv6 users and the fragmentation drop rate has come down by 2/3 - we appear to be getting better at handling IPv6 fragments!
More recent IPv6 deployments appear to be a lot better than more mature ones.
This is unexpected. At a total IPv6 packet size of 1408 bytes we did not expect to see higher packet drop rates for this packet size, as there is still an IP encapsulation budget of 92 bytes.
Drop Size Profile by Region

North America

Europe

Asia
Why?

• Drop patterns vary across service providers, so there are probably contributary factors from network equipment and configurations.
Why?

Other potential factors that could contribute:

• Local security policies
• IPv6 EH may trigger “slow path” processing in network equipment that could lead to higher drop rates
• IPv6 Path MTU woes!
Daily Report

https://stats.labs.apnic.net/v6frag
Summary

• The network is improving its handling of fragmented packets
• In 5 years its gone from unusably bad to tolerably poor
• Recent IPv6 deployments appear to show more robust handling of IPv6 packets
• Smaller frags appear to be more robust than larger ones (if you are going to fragment a packet, prefer smaller fragment sizes)
That's it!