Studying DNS Resolver Concentration

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IDS
Measuring the Concentration of DNS Resolvers

• Public DNS resolvers offer an alternative to ISP DNS services
  • Concern: concentration of DNS traffic to a few services

• Our challenge:
  • Measure the share of DNS queries going through Public DNS Resolvers
  • Observe market share of these resolvers
  • Understand drivers for adoption of public DNS resolvers
Measuring Market Share Using APNIC Study

- Ad impression creates request to load “single pixel” in unique subdomain of experimenter domain
- Web server and DNS server are controlled by experimenter

![Diagram of web browser, DNS resolver, web server, and DNS server connections.]

- IP Address in Query =>
  - Resolver AS,
  - Resolver country

- IP Address in HTTP =>
  - User AS,
  - User country
Measurements and Limitations

• Sampling of browser traffic
  • Random sampling world wide
  • Millions of queries
  • Lots of statistics: source IP, DNS resolver IP

• Dependency on Google Ads
  • Less data for some countries, e.g., Russia, China
  • No data for “non browser” traffic, e.g., IOT
  • Sampling of countries depends on Google Ads algorithms

• If user behind Proxy, see proxy IP, proxy-chosen DNS resolver
  • Similar issues with VPN
New ITHI Metrics M10, Concentration of DNS Resolver Services

Global measurements show us global numbers, as here “world wide” shares for July 2022
## Market Share of Public Resolvers, World Wide

<table>
<thead>
<tr>
<th>Date</th>
<th>All Public DNS</th>
<th>Google DNS</th>
<th>Cloudflare</th>
<th>Open DNS</th>
<th>Level3</th>
<th>Green Team DNS</th>
<th>DNS PAI</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/31/2022</td>
<td>19.4%</td>
<td>16.3%</td>
<td>1.7%</td>
<td>0.6%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>3/31/2022</td>
<td>20.2%</td>
<td>17.0%</td>
<td>1.9%</td>
<td>0.7%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.3%</td>
</tr>
<tr>
<td>5/31/2022</td>
<td>20.7%</td>
<td>17.1%</td>
<td>2.1%</td>
<td>0.5%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>7/31/2022</td>
<td>19.6%</td>
<td>16.4%</td>
<td>2.0%</td>
<td>0.5%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>9/30/2022</td>
<td>19.4%</td>
<td>16.2%</td>
<td>2.1%</td>
<td>0.5%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

- No obvious trend, market shares appear stable
- Hard to separate variations from measurement noise.
What Drives Adoption of Public DNS Resolvers?

• Hypotheses
  • User Choice of browser configuration
  • ISP Choice
  • Others?

• Let’s check against the data
Hypothesis: User Choice

- **Hypothesis:**
  - Users configure their browser to use a Public DNS Resolver

- **Supporting evidence:**
  - Functionality is available in several browsers

- **But:**
  - Few users ever change the default software configuration
  - Sample of large consumer ISP shows low PDNS rate

<table>
<thead>
<tr>
<th>CC</th>
<th>AS Name</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>Reliance JIO Infocom</td>
<td>7.5%</td>
</tr>
<tr>
<td>IN</td>
<td>Bharti Airtel Ltd.</td>
<td>1.3%</td>
</tr>
<tr>
<td>ID</td>
<td>Telekomunicasi Cellular</td>
<td>8.5%</td>
</tr>
<tr>
<td>US</td>
<td>Comcast</td>
<td>5.6%</td>
</tr>
<tr>
<td>GB</td>
<td>Sky UK Ltd</td>
<td>1.7%</td>
</tr>
<tr>
<td>GB</td>
<td>British Telecom</td>
<td>3.0%</td>
</tr>
<tr>
<td>SE</td>
<td>Telia Company AB</td>
<td>4.2%</td>
</tr>
<tr>
<td>GB</td>
<td>Virgin Media Ltd</td>
<td>3.3%</td>
</tr>
<tr>
<td>TR</td>
<td>Turk Telekomunikasyon</td>
<td>8.2%</td>
</tr>
<tr>
<td>US</td>
<td>AT&amp;T Inc.</td>
<td>5.6%</td>
</tr>
<tr>
<td>VN</td>
<td>Viettel Group.</td>
<td>9.2%</td>
</tr>
<tr>
<td>FR</td>
<td>Orange S.A.</td>
<td>3.3%</td>
</tr>
<tr>
<td>DE</td>
<td>Deutsche Telekom AG</td>
<td>2.9%</td>
</tr>
</tbody>
</table>
Share of Public DNS per Country Varies Widely

- For 76 countries, < 10%
- But some countries show >90% share:
  - Chad, Sierra Leone, Central African Republic, Maldives, Zambia, Djibouti, Northern Mariana Islands, Somalia
- Cannot be explained by “user choice” alone
Hypothesis: ISP Choice

- Some Internet Service Providers treat DNS as cost center
- Outsource to Public DNS Resolvers for cost reduction
- Certainly explains some of the data that we see
- ... but not all.
<10%, >90% and In Between?

<table>
<thead>
<tr>
<th></th>
<th>AS &lt;10% PDNS</th>
<th>AS In between</th>
<th>AS &gt;90% PDNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>%NB ISP</td>
<td>26%</td>
<td>48%</td>
<td>26%</td>
</tr>
<tr>
<td>%Total Queries</td>
<td>67%</td>
<td>28%</td>
<td>5%</td>
</tr>
<tr>
<td>%PDNS Queries</td>
<td>19%</td>
<td>51%</td>
<td>29%</td>
</tr>
</tbody>
</table>

- Why so much “in between”?
  - Not explained by previous hypotheses
- Hypothesis: fractional deployment
  - Outsource some regions, not others
- Hypothesis: customer categories
  - Business customers outsourcing their traffic
- Something else?
Summary: Two Known Sources of Public DNS traffic

• Users tweaking browser or DNS configurations
  • Few % of users in large ASes
    • Few users change their default configuration

• ISPs treating DNS as cost center, offloading to PDNS
  • Very common in Africa, South Asia
  • Frequent for small ISP
Further Study:
Unknown Sources of Public DNS traffic

• ISPs offloading a fraction of DNS traffic
  • May appear if doing statistics by Address Prefixes

• Enterprise and other organizations choosing DNS provider
  • May appear if isolating statistics for Enterprise Networks

• Users subscribing to VPN or proxy services
  • Will require new methodology

• Some other unknown...
Hypothesis: VPN and Proxies

- New services:
  - Apple’s Private Relay, Cloudflare’s “WARP”, Google syndication, Mozilla VPN
- Cause traffic to appear “from cloud servers”
- Outside measurement hypotheses

- IP Address in HTTP =>
  - User-AS, Proxy AS!
  - User-country Proxy Country

- IP Address in Query =>
  - Resolver-AS, Chosen by Proxy!
  - Resolver-country Chosen by Proxy!