Cache Effect of Shared DNS Resolver

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Outline

• Related works
• Issue and evaluation
• DNS Traffic data at Univ. of Tsukuba
• Analysis results
  – Number of DNS queries to authoritative servers
  – Amplification Ratio
  – Frequent Queries and Active Clients
• Conclusion
Related works

• In 2002, Jaeyeon et al. reported on DNS performance and the effectiveness of caching.

• In 2012, Fujiwara et al. reported "DNS traffic analysis -- Issues of IPv6 and CDN --"
  – It analyzed a shared resolver in an university.
  – Average cache hit rate was 75.1%.
  – A client query generated 0.00079 Root queries, 0.025 TLD queries and 0.28 other DNS server queries.

• In 2014, Schomp et al. reported "DNS Resolvers Considered Harmful" and proposed
  – removal of shared DNS resolvers
  – use of a full-service resolver at the end clients instead.
Issue and evaluation

• Issue
  – A paper proposed removal of shared DNS resolvers
  – Removal of shared cache increases DNS traffic
  – Need to evaluate effect of local/shared cache

• To Estimate Cache Effects, Minimal Resolver Behavior simulation with real queries from clients
  – captured at one of busy resolvers at University of Tsukuba
Academic Computing & Communication Center offers Full-service resolvers for Campus network of Univ. of Tsukuba

<table>
<thead>
<tr>
<th>Capturing Date</th>
<th>2016.Dec.01 0:00 ～ 24:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capturing Point</td>
<td>Full Resolver of Campus Network</td>
</tr>
<tr>
<td>Number of Clients</td>
<td>6,475</td>
</tr>
<tr>
<td>Number of QNAMEs</td>
<td>290,862</td>
</tr>
<tr>
<td>Average Number of queries / minute</td>
<td>14,650 (244 queries/sec)</td>
</tr>
</tbody>
</table>
Resolver simulation details

• Assumption: Authoritative servers are 3 layered
  – Root, TLD, Organization (second level)
    • Except in jp domain name
  – Each query counts up number of queries counters for Root, TLD, Organization

• Three cache scenarios
  – Without Cache
    • All queries from clients generates queries to Root, TLD, Organization
  – With Local Cache: Cache simulation in each address
  – With Shared Resolver: cache simulation with all queries
Limitations of the simulation

• Ignored: CNAME chain following
• Ignored: Out-of-bailiwick name server name resolution
• Ignored: Domain name existence
• TTL at organization (second, third) level is 300
• Short term evaluation: 1 day

→ This is preliminary result
Result: Number of queries to auth.

Assumption: TTL 300 (5min).

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The graph shows the number of requests per 5-minute interval over a 24-hour period. The x-axis represents time in 6-hour increments from 0:00 to 24:00, and the y-axis represents the number of requests, with markers at 20, 167, 333, and 500 qps.

Three lines are plotted:
- **Without Cache**: The line without markers indicates the highest number of requests.
- **With Local Cache**: The line with markers slightly lower than the 'Without Cache' line.
- **With Shared Cache**: The line with the lowest markers.

The graph illustrates the impact of caching on query performance, with the 'With Local Cache' and 'With Shared Cache' lines showing a reduction in request frequency compared to 'Without Cache'.
Result: Amplification Ratio

- Amplification Ratio vs Time
  - Without/Shared
  - Local/Shared
  - x 12.1
  - x 3.3

Time:
0:00, 6:00, 12:00, 18:00, 24:00

Amplification Ratio:
0, 2, 4, 6, 8, 10, 12, 14, 16, 18

Graph shows the trend of amplification ratio over time for different categories.
Query Amplification Ratio per TTL

![Graph showing query amplification ratio per TTL]

- **TTL 60**
  - Amplification Ratio: 2.6
  - Amplification Ratio: 2.8
  - Amplification Ratio: 7.3

- **TTL 300**
  - Amplification Ratio: 3.8
  - Amplification Ratio: 12.7

- **TTL 1800**
  - Amplification Ratio: 6.0
  - Amplification Ratio: 25.2

Legend:
- Without/Shared
- Local/Shared

Cache TTL vs. Changed TTL value graph with various data points indicating different TTL values and their corresponding amplification ratios.
Number of DNS queries caching mechanism is effective with TLD level

![Graph showing comparison between TLD Access and SLD (Organization level) Access with different cache mechanisms (Without Cache, Local Cache, Shared Cache).]
Shared cache decreases SLD queries a little.
Shared cache decreases TLD queries
Query Amplification Ratio

Shared cache decreases root queries
Removing shared cache is harmful

1/1000 of no cache scenario
1/10.9 of local cache scenario
Frequent Queries and Active Clients

• During the experiments, we found:
  – A few clients repeatedly issue many of the same DNS queries in a short interval, and also
  – a few QNAMEs are repeatedly issued in a short interval
Frequent queries (QNAMEs)

4.3% of qnames

71.7% of queries

Cumulative # of QNAMEs

Cumulative # of queries

Query Interval (sec)
Frequent clients

- 94.5% queries
- 64.4% clients

Cumulative # of clients vs. Query Interval (sec)

Cumulative # of queries
Most active client

(2.1 qps = 630/300sec, log(630)=6.4)
Conclusion

• Removal of shared resolver (replace with local resolver) amplifies the DNS traffic by about 3.3 times.
• The amplification ratio on the root DNS servers is much worse (about 10.9 times).
  – Removal of shared resolver may be harmful
  – (Local cache is useful)
• Some systems (Linux, BSD) lack local cache
  – repeated queries at short intervals (<= 1 min)
  – about 94.5% of client queries
  – the deployment of local cache itself is effective
Future works

• Long term analysis
• Comparison with real traffic
• Detailed full-resolver simulation
• Analysis of new DNS standards that improve name resolution performance
  – RFC 8020: NXDOMAIN: There Really Is Nothing Underneath
  – RFC 8198: Aggressive use of DNSSEC-validated Cache