Reducing DNS Caching

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Reducing DNS Caching
Saleem N. Bhatti, Randall Atkinson
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1. The DNS zero TTL challenge
2. Experiment configuration
3. Observations and analyses
4. Round-up
Motivational example: mobility in ILNP

- ILNP nodes update (topological) Locator value in DNS as they move to different IP networks.
- Movement could happen at any time, so cached Locator values could become stale.
- We need to reduce caching of such values, ideally to zero, so there are no stale values.

**Is zero caching practical?**
Test with A records – nearest equivalent for ILNP.
DNS – a summary [1]

• Scaling – architecture mechanisms:
  – Hierarchical name-space
  – Administrative zones across the name space
  – Delegation of lookups across zones

• Scaling – engineering mechanisms:
  – Administrative zones organised around naming hierarchy
  – DNS protocol permits redirection (referral) to another name server for resolving a name
    – Returned results are cached

• Administratively organised, spatio-temporal caching hierarchy
DNS – a summary [2]

h1.blob.org to lookup h2.flump.com

• DNS resource records (RRs) can be cached for different times.
• Time-To-Live (TTL) value for each RR.

NS RRs (and associated A RRs) returned at steps (3), (5) and (7) can have different TTLs to the A RR returned at step (8).
DNS caching recommendation

• RFC1034 (STD13) on TTL values, p13:

  ... the realities of Internet performance suggest that these times should be on the order of days for the typical host.

• Today, TTLs generally have large values, e.g.: www.sjtu.edu.cn uses TTL of 43200s (12h)

• Small TTL values (i.e. a few seconds or lower) considered “bad” (some exceptions ...)
(Non-)Effectiveness of DNS caching


- DNS caching has reduced effectiveness for edge sites:
  - trace-driven emulation (no experiments)
  - A records could have low TTL (e.g. below 1000s)
  - such low TTL would have low impact on DNS load
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DNS experiments at StA [1]

- Experiments in Q4/2009
- Modify TTL values of records in operational DNS server at School of CS, St Andrews
  - 4 DNS servers: Windows ActiveDirectory
  - ~500 DNS clients: Windows, Linux, MacOSX, BSD
- TTL values for successive 7-day periods during normal semester:
  - changed DNS TTL on ActiveDirectory
  - TTL values used: 1800s, 30s, 0s
- Configured clients not to cache.
DNS experiments at StA [2]

• Passive collection of packets via port mirror:
  – `tcpdump(8)` targeting `port 53`
  – Captured all DNS packets

• Results shown on following slides are for:
  – **A record requests** for **servers** only during the capture period (relevant to ILNP, and less ‘noisy’ data)
  – using 1 second buckets

• Basic statistics:
  – on time-domain data

• Spectral analysis:
  – examination of request rates

• Analysis: home-brew **python** scripts, NumPy package
**2009 data-sets: overall meta-data**

<table>
<thead>
<tr>
<th>Data set name</th>
<th>TTL [s]</th>
<th>Duration [s]$^1$</th>
<th>Total DNS packets captured$^2$</th>
<th>Number of A record requests for 67 servers$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>dns1800</td>
<td>1800</td>
<td>601,200</td>
<td>41,868,522</td>
<td>2,004,133 (4.8%)</td>
</tr>
<tr>
<td>dns0030</td>
<td>30</td>
<td>601,200</td>
<td>71,105,247</td>
<td>2,648,796 (3.7%)</td>
</tr>
<tr>
<td>dns0000</td>
<td>0</td>
<td>601,200</td>
<td>55,868,573</td>
<td>4,501,590 (8.1%)</td>
</tr>
</tbody>
</table>

$^1$ from tcpdump timestamps, rounded to nearest second, 7 days = 604,800 seconds, less 3600s temporal guard band for TTL value changes = 601,200 seconds

$^2$ includes all request and response packets to/from port 53 (TCP and UDP), including erroneous requests, retransmissions etc

$^3$ servers that were active during the 3 weeks of data capture
## 2009 data-sets: internal meta-data

<table>
<thead>
<tr>
<th>Data set name</th>
<th>TTL [s]</th>
<th>Duration [s]$^1$</th>
<th>Total DNS packets captured$^2$</th>
<th>Number of A record requests for 67 servers$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>dns1800-i</td>
<td>1800</td>
<td>601,200</td>
<td>29,486,362</td>
<td>792,339 (2.7%)</td>
</tr>
<tr>
<td>dns0030-i</td>
<td>30</td>
<td>601,200</td>
<td>54,097,231</td>
<td>951,485 (1.8%)</td>
</tr>
<tr>
<td>dns0000-i</td>
<td>0</td>
<td>601,200</td>
<td>30,555,305</td>
<td>1,419,782 (4.7%)</td>
</tr>
</tbody>
</table>

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$^1$ from tcpdump timestamps, rounded to nearest second, 7 days = 604,800 seconds, less 3600s temporal guard band for TTL value changes = 601,200 seconds

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dns1800-i: A queries TTL=1800s

Mean: 1.31 request/s
Std Dev: 2.98 requests/s
Max: 176 requests/s
dns0030-i: A queries TTL=30s

Mean: 1.58 request/s
Std Dev: 3.57 requests/s
Max: 168 requests/s
dns0000-i: A queries TTL=0s

Mean: 2.36 request/s
Std Dev: 3.48 requests/s
Max: 68 requests/s

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2009 Summary of basic statistics

<table>
<thead>
<tr>
<th>Data set name</th>
<th>Mean [reqs/s]</th>
<th>Std Dev [reqs/s]</th>
<th>Maximum [reqs/s]</th>
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<tr>
<td>dns1800-i</td>
<td>1.31</td>
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<td>68</td>
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</tbody>
</table>

60x drop in TTL values results in \( \frac{1}{3} \)x increase in A record requests. 0 TTL gives \( \sim 2x \) increase.
2009 Basic spectral analysis

• Create approximate periodogram by counting occurrences of bucket sizes:
  – have used 1s bucket
  – so size of bucket, $n$, is number of requests/s
  – count occurrence of buckets of size $n$

• Comparison of periodogram:
  – shows changing dynamics of request rates
  – gives a better view of the trends in request rates
2009 periodograms: 1800s

7-day DNS A record query rates, dns2009-1800-i

7-day CDF for DNS A record query rates, dns2009-1800-i
2009 periodograms: 30s

![Graph 1: 7-day DNS A record query rates, dns2009-0030-i](image1)

![Graph 2: 7-day CDF for DNS A record query rates, dns2009-0030-i](image2)
2009 periodograms: 0s

7-day DNS A record query rates, dns2009-0000-i

7-day CDF for DNS A record query rates, dns2009-0000-i
## 2009 Summary of basic statistics

<table>
<thead>
<tr>
<th>Data set name</th>
<th>Mean [reqs/s]</th>
<th>~95% [reqs/s]</th>
<th>~99% [reqs/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>dns1800-i</td>
<td>1.31</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>dns0030-i</td>
<td>1.58</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>dns0000-i</td>
<td>2.36</td>
<td>8</td>
<td>15</td>
</tr>
</tbody>
</table>

~95% centile is the same and is of a low value (8 reqs/s)
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Who would set DNS TTLs so low?

• Real A record values for some services:
  – TTL = 60 seconds: yahoo
  – TTL = 20 seconds: akamai
  – TTL = 0 seconds: St Andrews, Computer Science

• Note that a site would NOT set low TTLs for:
  – Its own NS records, which identify its DNS servers.
  – The A records related to its NS records.
  – A, CNAME, PTR records for services, e.g. email MX
  – A (mobile) site can make remote some or all of its authoritative DNS servers; some sites do so today.
Future work

• More in-depth analyses of traces:
  – possibly some controlled experiments

• Repeat experiments at other sites

• For mobility:
  – Secure DNS Dynamic Update
  – DNSsec (authenticated responses)

• Have started some discussions with various industrial collaborators.
Summary and Conclusion

• Summary:
  – Zero TTL values for edge-site DNS A records possible
  – DNS load with zero DNS TTLs seems manageable
  – (Indeed, 1s TTL is good, perhaps better than zero)

• Conclusion:
  – DNS A records with very low TTL seems practical
Acknowledgements

• Thanks to:
  – Stuart Cheshire (Apple)
  – Dave Thaler (Microsoft)
    for information on OS-specific features of DNS operation in end-hosts

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• Comments from GI2011 reviewers

• A Very Big Thanks to:
  – the Systems Admin Group at cs.st-andrews.ac.uk for implementing DNS TTL changes