Strong Cache Consistency Support for Domain Name System

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Motivation

**TTL-Based Cache Consistence:**
- Originally designed for static domain name mapping
- Only weak consistency provided

**Current DNS Cache Updates:**
- Set a short TTL before update (2-3 days)
- Resume to a normal TTL after update (2-3 days)
- Long update delays even changes are anticipated!

**Problems:**
- (in the changing world!) many changes are unexpected while critical services need always-on availability
- Dynamic domain name mapping: widely deployed dynamic DNS solution sets up servers on temporal IPs from DHCP
- Emergence events to support: Web servers are closed/moved at emergence (e.g. 911, nature disaster, etc.)
- Redundant DNS traffic: Content Delivery Network providers use small TTLs to achieve load balance among their surrogates

**Objective**
An effective solution for DNS cache consistency

**Methods**

- Domain Name Collection
  - SOA: authority indication for a zone
  - A: hostnames to IP address mappings
  - PTR: IP addresses to hostname mappings
  - NS: domain name server reference lists for a zone
  - MX: mail exchangers for a domain.

**DNS resource records are changed for different purposes**
- 'A' records -- most used, have significant effects if changed
- our measurements are focused on 'A' records

**Dynamic Lease**

- Lease: a combination of polling and invalidation
- Challenge: lease length selection
  - long leases: more storage overhead
  - short leases: more network traffic

**Assumption:** request intervals follow Poisson distribution with average arrival rate $\lambda$

**Problem definition:**
Storage-constrained lease: minimize the storage allocation

**Optimal solution:**
maximal lease length granted to the caches with the highest query rate (dynamic lease), because:

\[
\Delta M = \frac{1}{\Delta P}
\]

Communication-constrained lease can be defined and solved in a similar way.

**Measurement Results**

<table>
<thead>
<tr>
<th>Class</th>
<th>TTL</th>
<th>Resolution</th>
<th>Duration</th>
<th>Domain number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(0,1m)</td>
<td>20 sec</td>
<td>1 day</td>
<td>405</td>
</tr>
<tr>
<td>2</td>
<td>(1m, 5m)</td>
<td>1 min</td>
<td>3 days</td>
<td>934</td>
</tr>
<tr>
<td>3</td>
<td>(5m, 3h)</td>
<td>5 min</td>
<td>3 days</td>
<td>2020</td>
</tr>
<tr>
<td>4</td>
<td>(1h, 1d)</td>
<td>1 hour</td>
<td>7 days</td>
<td>7217</td>
</tr>
<tr>
<td>5</td>
<td>(1d, 2d)</td>
<td>1 day</td>
<td>1 month</td>
<td>4473</td>
</tr>
</tbody>
</table>

**Our Solution -- DNsCup**
DNS Cache Update Protocol

**Basic idea:** an authoritative name server uses dynamic lease technique to notify relevant caches when its resource record changes.

**Dynamic Lease Performance - Storage**

**Implementation**

- Efficiency
  - UDP: first choice
- Update propagation without NOTIFY
- Robustness
  - Name server repeats sending until ACK received
  - DNS cache validates all records after reboot
- Compatibility
  - Name server supports both TTL and DNScup mechanisms
  - DNS cache can use both TTL and lease
- Security
  - Name server uses TSIG to control updates
  - DNS cache uses ACK to verify updates

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Implementation test bed

**DNS Cache Update Protocol**

1. DNS query (with request rate to local name server)
2. Granted Lease (with adjusted lease length)
3. DNS dynamic update message
4. Dynamic cache update message

**Dynamic Lease Performance - Request**

**Implementation**

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