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Decreasing Access Time to Root Servers by Running One on Loopback

Abstract

Some DNS recursive resolvers have longer-than-desired round-trip times to the closest DNS root server. Some DNS recursive resolver operators want to prevent snooping of requests sent to DNS root servers by third parties. Such resolvers can greatly decrease the round-trip time and prevent observation of requests by running a copy of the full root zone on a loopback address (such as 127.0.0.1). This document shows how to start and maintain such a copy of the root zone that does not pose a threat to other users of the DNS, at the cost of adding some operational fragility for the operator.

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1. Introduction

DNS recursive resolvers have to provide answers to all queries from their customers, even those for domain names that do not exist. For each queried name that has a top-level domain (TLD) that is not in the recursive resolver's cache, the resolver must send a query to a root server to get the information for that TLD, or to find out that the TLD does not exist. Typically, the vast majority of queries going to the root are for names that do not exist in the root zone, and the negative answers are cached for a much shorter period of time. A slow path between the recursive resolver and the closest root server has a negative effect on the resolver's customers.

Recursive resolvers currently send queries for all TLDs that are not in their caches to root servers, even though most of those queries get answers that are referrals to other servers. Malicious third parties might be able to observe that traffic on the network between the recursive resolver and one or more of the DNS roots.

This document describes a method for the operator of a recursive resolver to greatly speed these queries and to hide them from outsiders. The basic idea is to create an up-to-date root zone server on a loopback address on the same host as the recursive server, and use that server when the recursive resolver looks up root information. The recursive resolver validates all responses from the root server on the loopback address, just as it would all responses from a remote root server.

The primary goals of this design are to provide faster negative responses to stub resolver queries that contain junk queries, and to prevent queries and responses from being visible on the network. This design will probably have little effect on getting faster positive responses to stub resolver for good queries on TLDs, because the data for those zones is usually long-lived and already in the cache of the recursive resolver; thus, getting faster positive responses is a non-goal of this design.

This design explicitly only allows the new root zone server to be run on a loopback address, in order to prevent the server from serving authoritative answers to any system other than the recursive resolver.

It is important to note that the design being described here is not considered a "best practice". In fact, many people feel that it is an excessively risky practice because it introduces a new operational piece to local DNS operations where there was not one before. The

advantages listed above do not come free: if this new system does not work correctly, users can get bad data, or the entire recursive resolution system might fail in ways that are hard to diagnose.

This design requires the addition of authoritative name server software running on the same machine as the recursive resolver. Thus, recursive resolver software such as BIND will not need to add much new functionality, but recursive resolver software such as Unbound will need to be able to talk to an authoritative server (such as NSD) running on the same host.

Because of the significant operational risks described in this document, distributions of recursive DNS servers MUST NOT include configuration for the design described here. It is acceptable to point to this document, but not to indicate that this configuration is something that should be considered without reading the entire document.

A different approach to solving the problems discussed in this document is described in [AggressiveNSEC].

1.1. Requirements Notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2. Requirements

In order to implement the mechanism described in this document:

- o The system MUST be able to validate a zone with DNSSEC [RFC4033].
- o The system MUST have an up-to-date copy of the DNS root key.
- o The system MUST be able to retrieve a copy of the entire root zone (including all DNSSEC-related records).
- o The system MUST be able to run an authoritative server on one of the IPv4 loopback addresses (that is, an address in the range 127/8 for IPv4 or ::1 in IPv6).

A corollary of the above list is that authoritative data in the root zone used on the local authoritative server MUST be identical to the same data in the root zone for the DNS. It is possible to change the unsigned data (the glue records) in the copy of the root zone, but

such changes could cause problems for the recursive server that accesses the local root zone, and therefore any changes to the glue records SHOULD NOT be made.

3. Operation of the Root Zone on the Loopback Address

The operation of an authoritative server for the root in the system described here can be done separately from the operation of the recursive resolver.

The steps to set up the root zone are:

1. Retrieve a copy of the root zone. (See Appendix A for some current locations of sources.)
2. Start the authoritative server with the root zone on a loopback address that is not in use. For IPv4, this would typically be 127.0.0.1, but if that address is in use, any address in 127/8 is acceptable. For IPv6, this would be ::1.

The contents of the root zone MUST be refreshed using the timers from the SOA record in the root zone, as described in [RFC1035]. This inherently means that the contents of the local root zone will likely be a little behind those of the global root servers because those servers are updated when triggered by NOTIFY messages. If the contents of the zone cannot be refreshed before the expire time, the server MUST return a SERVFAIL error response for all queries until the zone can be successfully be set up again.

In the event that refreshing the contents of the root zone fails, the results can be disastrous. For example, sometimes all the NS records for a TLD are changed in a short period of time (such as 2 days); if the refreshing of the local root zone is broken during that time, the recursive resolver will have bad data for the entire TLD zone.

An administrator using the procedure in this document SHOULD have an automated method to check that the contents of the local root zone are being refreshed. One way to do this is to have a separate process that periodically checks the SOA of the root zone from the local root zone and makes sure that it is changing. At the time that this document is published, the SOA for the root zone is the digital representation of the current date with a two-digit counter appended, and the SOA is changed every day even if the contents of the root zone are unchanged. For example, the SOA of the root zone on January 2, 2015 was 2015010201. A process can use this fact to create a check for the contents of the local root zone (using a program not specified in this document).

4. Using the Root Zone Server on the Loopback Address

A recursive resolver that wants to use a root zone server operating as described in Section 3 simply specifies the local address as the place to look when it is looking for information from the root. All responses from the root server must be validated using DNSSEC.

Note that using this configuration will cause the recursive resolver to fail if the local root zone server fails. See Appendix B for more discussion of this for specific software.

To test the proper operation of the recursive resolver with the local root server, use a DNS client to send a query for the SOA of the root to the recursive server. Make sure the response that comes back has the AA bit in the message header set to 0.

5. Security Considerations

A system that does not follow the DNSSEC-related requirements given in Section 2 can be fooled into giving bad responses in the same way as any recursive resolver that does not do DNSSEC validation on responses from a remote root server. Anyone deploying the method described in this document should be familiar with the operational benefits and costs of deploying DNSSEC [RFC4033].

As stated in Section 1, this design explicitly only allows the new root zone server to be run on a loopback address, in order to prevent the server from serving authoritative answers to any system other than the recursive resolver. This has the security property of limiting damage to any other system that might try to rely on an altered copy of the root.

6. References

6.1. Normative References

- [RFC1035] Mockapetris, P., "Domain names - implementation and specification", STD 13, RFC 1035, DOI 10.17487/RFC1035, November 1987, <<http://www.rfc-editor.org/info/rfc1035>>.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<http://www.rfc-editor.org/info/rfc2119>>.

[RFC4033] Arends, R., Austein, R., Larson, M., Massey, D., and S. Rose, "DNS Security Introduction and Requirements", RFC 4033, DOI 10.17487/RFC4033, March 2005, <<http://www.rfc-editor.org/info/rfc4033>>.

6.2. Informative References

[AggressiveNSEC]

Fujiwara, K. and A. Kato, "Aggressive use of NSEC/NSEC3", Work in Progress, draft-fujiwara-dnsop-nsec-aggressiveuse-02, October 2015.

[Manning2013]

Manning, W., "Client Based Naming", 2013, <http://www.sfc.wide.ad.jp/dissertation/bill_e.html>.

Appendix A. Current Sources of the Root Zone

The root zone can be retrieved from anywhere as long as it comes with all the DNSSEC records needed for validation. Currently, one can get the root zone from ICANN by zone transfer (AXFR) over TCP from DNS servers at `xfr.lax.dns.icann.org` and `xfr.cjr.dns.icann.org`.

Currently, the root can also be retrieved by AXFR over TCP from the following root server operators:

- o `b.root-servers.net`
- o `c.root-servers.net`
- o `f.root-servers.net`
- o `g.root-servers.net`
- o `k.root-servers.net`

It is crucial to note that none of the above services are guaranteed to be available. It is possible that ICANN or some of the root server operators will turn off the AXFR capability on the servers listed above. Using AXFR over TCP to addresses that are likely to be anycast (as the ones above are) may conceivably have transfer problems due to anycast, but current practice shows that to be unlikely.

To repeat the requirement from earlier in this document: if the contents of the zone cannot be refreshed before the expire time, the server MUST return a SERVFAIL error response for all queries until the zone can be successfully be set up again.

Appendix B. Example Configurations of Common Implementations

This section shows fragments of configurations for some popular recursive server software that is believed to correctly implement the requirements given in this document.

The IPv4 and IPv6 addresses in this section were checked recently by testing for AXFR over TCP from each address for the known single-letter names in the `root-servers.net` zone.

The examples here use a loopback address of `127.12.12.12`, but typical installations will use `127.0.0.1`. The different address is used in order to emphasize that the root server does not need to be on the device at "localhost".

B.1. Example Configuration: BIND 9.9

BIND acts both as a recursive resolver and an authoritative server. Because of this, there is "fate-sharing" between the two servers in the following configuration. That is, if the root server dies, it is likely that all of BIND is dead.

Using this configuration, queries for information in the root zone are returned with the AA bit not set.

When slaving a zone, BIND will treat zone data differently if the zone is slaved into a separate view (or a separate instance of the software) versus slaved into the same view or instance that is also performing the recursion.

Validation: When using separate views or separate instances, the DS records in the slaved zone will be validated as the zone data is accessed by the recursive server. When using the same view, this validation does not occur for the slaved zone.

Caching: When using separate views or instances, the recursive server will cache all of the queries for the slaved zone, just as it would using the traditional "root hints" method. Thus, as the zone in the other view or instance is refreshed or updated, changed information will not appear in the recursive server until the TTL of the old record times out. Currently, the TTL for DS and delegation NS records is two days. When using the same view, all zone data in the recursive server will be updated as soon as it receives its copy of the zone.

```

view root {
  match-destinations { 127.12.12.12; };
  zone "." {
    type slave;
    file "rootzone.db";
    notify no;
    masters {
      192.228.79.201; # b.root-servers.net
      192.33.4.12;   # c.root-servers.net
      192.5.5.241;   # f.root-servers.net
      192.112.36.4;  # g.root-servers.net
      193.0.14.129;  # k.root-servers.net
      192.0.47.132;  # xfr.cjr.dns.icann.org
      192.0.32.132;  # xfr.lax.dns.icann.org
      2001:500:84::b; # b.root-servers.net
      2001:500:2f::f; # f.root-servers.net
      2001:7fd::1;   # k.root-servers.net
      2620:0:2830:202::132; # xfr.cjr.dns.icann.org
      2620:0:2d0:202::132; # xfr.lax.dns.icann.org
    };
  };
};

view recursive {
  dnssec-validation auto;
  allow-recursion { any; };
  recursion yes;
  zone "." {
    type static-stub;
    server-addresses { 127.12.12.12; };
  };
};

```

B.2. Example Configuration: Unbound 1.4 and NSD 4

Unbound and NSD are separate software packages. Because of this, there is no "fate-sharing" between the two servers in the following configurations. That is, if the root server instance (NSD) dies, the recursive resolver instance (Unbound) will probably keep running but will not be able to resolve any queries for the root zone. Therefore, the administrator of this configuration might want to carefully monitor the NSD instance and restart it immediately if it dies.

Using this configuration, queries for information in the root zone are returned with the AA bit not set.

```
# Configuration for Unbound
server:
  do-not-query-localhost: no
stub-zone:
  name: "."
  stub-prime: no
  stub-addr: 127.12.12.12

# Configuration for NSD
server:
  ip-address: 127.12.12.12
zone:
  name: "."
  request-xfr: 192.228.79.201 NOKEY # b.root-servers.net
  request-xfr: 192.33.4.12 NOKEY    # c.root-servers.net
  request-xfr: 192.5.5.241 NOKEY    # f.root-servers.net
  request-xfr: 192.112.36.4 NOKEY   # g.root-servers.net
  request-xfr: 193.0.14.129 NOKEY   # k.root-servers.net
  request-xfr: 192.0.47.132 NOKEY   # xfr.cjr.dns.icann.org
  request-xfr: 192.0.32.132 NOKEY   # xfr.lax.dns.icann.org
  request-xfr: 2001:500:84::b NOKEY  # b.root-servers.net
  request-xfr: 2001:500:2f::f NOKEY  # f.root-servers.net
  request-xfr: 2001:7fd::1 NOKEY    # k.root-servers.net
  request-xfr: 2620:0:2830:202::132 NOKEY # xfr.cjr.dns.icann.org
  request-xfr: 2620:0:2d0:202::132 NOKEY # xfr.lax.dns.icann.org
```

B.3. Example Configuration: Microsoft Windows Server 2012

Windows Server 2012 contains a DNS server in the "DNS Manager" component. When activated, that component acts as a recursive server. DNS Manager can also act as an authoritative server.

Using this configuration, queries for information in the root zone are returned with the AA bit set.

The steps to configure DNS Manager to implement the requirements in this document are:

1. Launch the DNS Manager GUI. This can be done from the command line ("dnsmgmt.msc") or from the Service Manager (the "DNS" command in the "Tools" menu).
2. In the hierarchy under the server on which the service is running, right-click on the "Forward Lookup Zones", and select "New Zone". This brings up a succession of dialog boxes.
3. In the "Zone Type" dialog box, select "Secondary zone".

4. In the "Zone Name" dialog box, enter ".".
5. In the "Master DNS Servers" dialog box, enter "b.root-servers.net". The system validates that it can do a zone transfer from that server. (After this configuration is completed, the DNS Manager will attempt to transfer from all of the root zone servers.)
6. In the "Completing the New Zone Wizard" dialog box, click "Finish".
7. Verify that the DNS Manager is acting as a recursive resolver. Right-click on the server name in the hierarchy, choosing the "Advanced" tab in the dialog box. See that "Disable recursion (also disables forwarders)" is not selected, and that "Enable DNSSEC validation for remote responses" is selected.

Acknowledgements

The authors fully acknowledge that running a copy of the root zone on the loopback address is not a new concept, and that we have chatted with many people about that idea over time. For example, Bill Manning described a similar solution but to a very different problem (intermittent connectivity, instead of constant but slow connectivity) in his doctoral dissertation in 2013 [Manning2013].

Evan Hunt contributed greatly to the logic in the requirements. Other significant contributors include Wouter Wijngaards, Tony Hain, Doug Barton, Greg Lindsay, and Akira Kato. The authors also received many offline comments about making the document clear that this is just a description of a way to operate a root zone on localhost, and not a recommendation to do so.

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