

Workgroup: ADD
Internet-Draft:
draft-ietf-add-split-horizon-authority-00
Published: 24 June 2022
Intended Status: Standards Track
Expires: 26 December 2022
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Establishing Local DNS Authority in Split-Horizon Environments

Abstract

When split-horizon DNS is deployed by a network, certain domains can be resolved authoritatively by the network-provided DNS resolver. DNS clients that don't always use this resolver might wish to do so for these domains. This specification describes how clients can confirm the local resolver's authority over these domains.

Discussion Venues

This note is to be removed before publishing as an RFC.

Discussion of this document takes place on the Adaptive DNS Discovery Working Group mailing list (add@ietf.org), which is archived at <https://mailarchive.ietf.org/arch/browse/add/>.

Source for this draft and an issue tracker can be found at <https://github.com/ietf-wg-add/draft-ietf-add-split-horizon-authority>.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

To resolve a DNS query, there are three essential behaviors that an implementation can apply: (1) answer from a local database, (2) query the relevant authorities and their parents, or (3) ask a server to query those authorities and return the final answer.

Implementations that use these behaviors are called "authoritative nameservers", "full resolvers", and "forwarders" (or "stub resolvers"). However, an implementation can also implement a mixture of these behaviors, depending on a local policy, for each query. We term such an implementation a "hybrid resolver".

Most DNS resolvers are hybrids of some kind. For example, stub resolvers frequently support a local "hosts file" that preempts query forwarding, and most DNS forwarders and full resolvers can also serve responses from a local zone file. Other standardized hybrid resolution behaviors include [Local Root](#) [RFC8806], [mDNS](#) [RFC6762], and [NXDOMAIN synthesis for .onion](#) [RFC7686].

In many network environments, the network offers clients a DNS server (e.g. DHCP OFFER, IPv6 Router Advertisement). Although this server is formally specified as a recursive resolver (e.g. [Section 5.1](#) of [RFC6106]), some networks provide a hybrid resolver instead. If this resolver acts as an authoritative server for some names, we say that the network has "split-horizon DNS", because those names resolve in this way only from inside the network.

Network clients that use pure stub resolution, sending all queries to the network-provided resolver, will always receive the split-horizon results. Conversely, clients that send all queries to a different resolver or implement pure full resolution locally will never receive them. Clients that strictly implement either of these resolution behaviors are out of scope for this specification. Instead, this specification enables hybrid clients to access split-horizon results from a network-provided hybrid resolver, while using a different resolution method for some or all other names.

There are several existing mechanisms for a network to provide clients with "local domain hints", listing domain names that have special treatment in this network ([Section 4](#)). However, none of the local domain hint mechanisms enable clients to determine whether this special treatment is authorized by the domain owner. Instead, these specifications require clients to make their own determinations about whether to trust and rely on these hints.

This specification describes a protocol between domains, networks, and clients that allows the network to establish its authority over a domain to a client ([Section 5](#)). Clients can use this protocol to confirm that a local domain hint was authorized by the domain ([Section 6](#)), which might influence its processing of that hint.

This specification relies on securely identified local DNS servers and globally valid NS records. Use of this specification is therefore limited to servers that support authenticated encryption

and split-horizon DNS names that are properly rooted in the global DNS.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [[RFC2119](#)][[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

This document makes use of the terms defined in [[RFC8499](#)], e.g. "Global DNS". The following additional terms are used throughout the document:

Encrypted DNS A DNS protocol that provides an encrypted channel between a DNS client and server (e.g., DoT, DoH, or DoQ).

Split-Horizon DNS The DNS service provided by a resolver that also acts as an authoritative server for some names, providing resolution results that are meaningfully different from those in the Global DNS. (See "Split DNS" in [Section 6](#) of [[RFC8499](#)].)

Validated Split-Horizon A split horizon configuration for some name is considered "validated" if the client has confirmed that a parent of that name has authorized this resolver to serve its own responses for that name. Such authorization generally extends to the entire subtree of names below the authorization point.

3. Scope

The protocol in this document is designed to support the ability of a domain owner to create or authorize a split-horizon view of their domain. The protocol does not support split-horizon views created by any other entity. Thus, DNS filtering is not enabled by this protocol.

The protocol is applicable to any type of network offering split-horizon DNS configuration. The endpoint does not need any prior configuration to confirm that a local domain hint was indeed authorized by the domain.

4. Local Domain Hint Mechanisms

There are various mechanisms by which a network client might learn "local domain hints", which indicate a special treatment for particular domain names upon joining a network. This section provides a review of some common and standardized mechanisms for receiving domain hints.

4.1. DHCP Options

There are several DHCP options that convey local domain hints of different kinds. The most directly relevant is [RDNSS Selection](#) [[RFC6731](#)], which provides "a list of domains ... about which the RDNSS has special knowledge", along with a "High", "Medium", or "Low" preference for each name. The specification notes the difficulty of relying on these hints without validation:

Trustworthiness of an interface and configuration information received over the interface is implementation and/or node deployment dependent, and the details of determining that trust are beyond the scope of this specification.

Other local domain hints in DHCP include the ["Domain Name"](#) [[RFC2132](#)], ["Access Network Domain Name"](#) [[RFC5986](#)], ["Client FQDN"](#) [[RFC4702](#)][[RFC4704](#)], and ["Name Service Search"](#) [[RFC2937](#)] options. This specification may help clients to interpret these hints. For example, a rogue DHCP server could use the "Client FQDN" option to assign a client the name "www.example.com" in order to prevent the client from reaching the true "www.example.com". A client could use this specification to check the network's authority over this name, and adjust its behavior to avoid this attack if authority is not established.

The Domain Search option [[RFC3397](#)][[RFC3646](#)], which offers clients a way to expand short names into Fully Qualified Domain Names, is not a "local domain hint" by this definition, because it does not modify the processing of any specific domain. (The specification notes that this option can be a "fruitful avenue of attack for a rogue DHCP server", and provides a number of cautions against accepting it unconditionally.)

4.2. Host Configuration

A host can be configured with DNS information when it joins a network, including when it brings up VPN (which is also considered joining a(n additional) network, detailed in [Section 8](#)). Existing implementations determine the host has joined a certain network via SSID, IP subnet assigned, DNS server IP address or name, and other similar mechanisms. For example, one existing implementation determines the host has joined an internal network because the DHCP-assigned IP address belongs to the company's IP range (as assigned by the regional IP addressing authority) and the DHCP-advertised DNS IP address is one used by IT at that network. Other mechanisms exist in other products but are not interesting to this specification; rather what is interesting is this step to determine "we have joined the internal corporate network" occurred and the DNS server is

configured as authoritative for certain DNS zones (e.g., *.example.com).

Because a rogue network can simulate all or most of the above characteristics, this specification details how to validate these claims in [Section 6](#).

4.3. Provisioning Domains dnsZones

Provisioning Domains (PvDs) are defined in [[RFC7556](#)] as sets of network configuration information that clients can use to access networks, including rules for DNS resolution and proxy configuration. The PvD Key "dnsZones" is defined in [[RFC8801](#)] as a list of "DNS zones searchable and accessible" in this provisioning domain. Attempting to resolve these names via another resolver might fail or return results that are not correct for this network.

4.4. Split DNS Configuration for IKEv2

In IKEv2 VPNs, the INTERNAL_DNS_DOMAIN configuration attribute can be used to indicate that a domain is "internal" to the VPN [[RFC8598](#)]. To prevent abuse, the specification notes various possible restrictions on the use of this attribute:

If a client is configured by local policy to only accept a limited set of INTERNAL_DNS_DOMAIN values, the client **MUST** ignore any other INTERNAL_DNS_DOMAIN values. ([[RFC8598](#)], [Section 5](#))

IKE clients **MAY** want to require whitelisted domains for Top-Level Domains (TLDs) and Second-Level Domains (SLDs) to further prevent malicious DNS redirections for well-known domains. ([[RFC8598](#)], [Section 9](#))

Within these guidelines, a client could adopt a local policy of accepting INTERNAL_DNS_DOMAIN values only when it can validate the local DNS server's authority over those names as described in this specification.

5. Establishing Local DNS Authority

To establish its authority over some DNS zone, a participating network **MUST** offer one or more encrypted resolvers via DNR [[I-D.ietf-add-dnr](#)] or an equivalent mechanism (see [Section 8](#)). At least one of these resolvers' Authentication Domain Names (ADNs) **MUST** appear in an NS record for that zone. This arrangement establishes this resolver's authority over the zone.

6. Validating Authority over Local Domain Hints

To validate the network's authority over a domain name, participating clients **MUST** resolve the NS record for that name. If the resolution result is NODATA, the client **MUST** remove the last label and repeat the query until a response other than NODATA is received.

Once the NS record has been resolved, the client **MUST** check if each local encrypted resolver's Authentication Domain Name appears in the NS record. The client **SHALL** regard each such resolver as authoritative for the zone of this NS record.

Each validation of authority applies only to the specific resolvers whose names appear in the NS RRSset. If a network offers multiple encrypted resolvers, each DNS entry may be authorized for a distinct subset of the network-provided resolvers.

A zone is termed a "Validated Split-Horizon zone" after successful validation using a "tamperproof" NS resolution method, i.e. a method that is not subject to interference by the local network operator. Two possible tamperproof resolution methods are presented below.

6.1. Using a Pre-configured External Resolver

This method applies only if the client is already configured with a default resolution strategy that sends queries to a resolver outside of the network over a secure transport. That resolution strategy is considered "tamperproof" because any actor who could modify the NS response could already modify all of the user's other DNS responses.

To ensure that this assumption holds, clients **MUST NOT** relax the acceptance rules they would otherwise apply when using this resolver. For example, if the client would check the AD bit or validate RRSIGs locally when using this resolver, it must also do so when resolving NS records for this purpose. Alternatively, a client might perform DNSSEC validation for the NS query used for this purpose even if it has disabled DNSSEC validation for other DNS queries.

6.2. Using DNSSEC

The client resolves the NS record using any resolution method of its choice (e.g. querying one of the network-provided resolvers, performing iterative resolution locally), and performs full DNSSEC validation locally [[RFC6698](#)]. The result is processed based on its DNSSEC validation state ([[RFC4035](#)], [Section 4.3](#)):

Secure: The response is used for validation.

Bogus or Indeterminate: The response is rejected and validation is considered to have failed.

Insecure: The client **SHOULD** retry the validation process using a different method, such as the one in [Section 6.1](#), to ensure compatibility with unsigned names.

7. Examples of Split-Horizon DNS Configuration

Two examples are shown below. The first example shows a company with an internal-only DNS server that claims the entire zone for that company (e.g., *.example.com). In the second example, the internal servers resolves only a subdomain of the company's zone (e.g., *.internal.example.com).

7.1. Split-Horizon Entire Zone

Consider an organization that operates "example.com", and runs a different version of its global domain on its internal network. Today, on the Internet it publishes two NS records, "ns1.example.com" and "ns2.example.com".

First, the host and network both need to support one of the discovery mechanisms described in [Section 4](#). [Figure 1](#) shows discovery using DNR and Pvd.

Validation is then performed using either [an external resolver](#) ([Section 7.1.1](#)) or [DNSSEC](#) ([Section 7.1.2](#)).

Steps 1-2: The client determines the network's DNS server (ns1.example.com) and Provisioning Domain (pvd.example.com) using [DNR](#) [[I-D.ietf-add-dnr](#)] and [Pvd](#) [[RFC8801](#)], using one of DNR Router Solicitation, DHCPv4, or DHCPv6.

Step 3-5: The client connects to ns1.example.com using an encrypted transport as indicated in [DNR](#) [[I-D.ietf-add-dnr](#)], authenticating the server to its name using TLS ([[RFC8310](#)], [Section 8](#)), and sends it a query for the address of pvd.example.com.

Steps 6-7: The client connects to the Pvd server, validates its certificate, and retrieves the provisioning domain JSON information indicated by the associated Pvd. The Pvd contains:

```
{
  "identifier": "pvd.example.com",
  "expires": "2020-05-23T06:00:00Z",
  "prefixes": ["2001:db8:1::/48", "2001:db8:4::/48"],
  "dnsZones": ["example.com"]
}
```


The JSON keys "identifier", "expires", and "prefixes" are defined in [[RFC8801](#)].

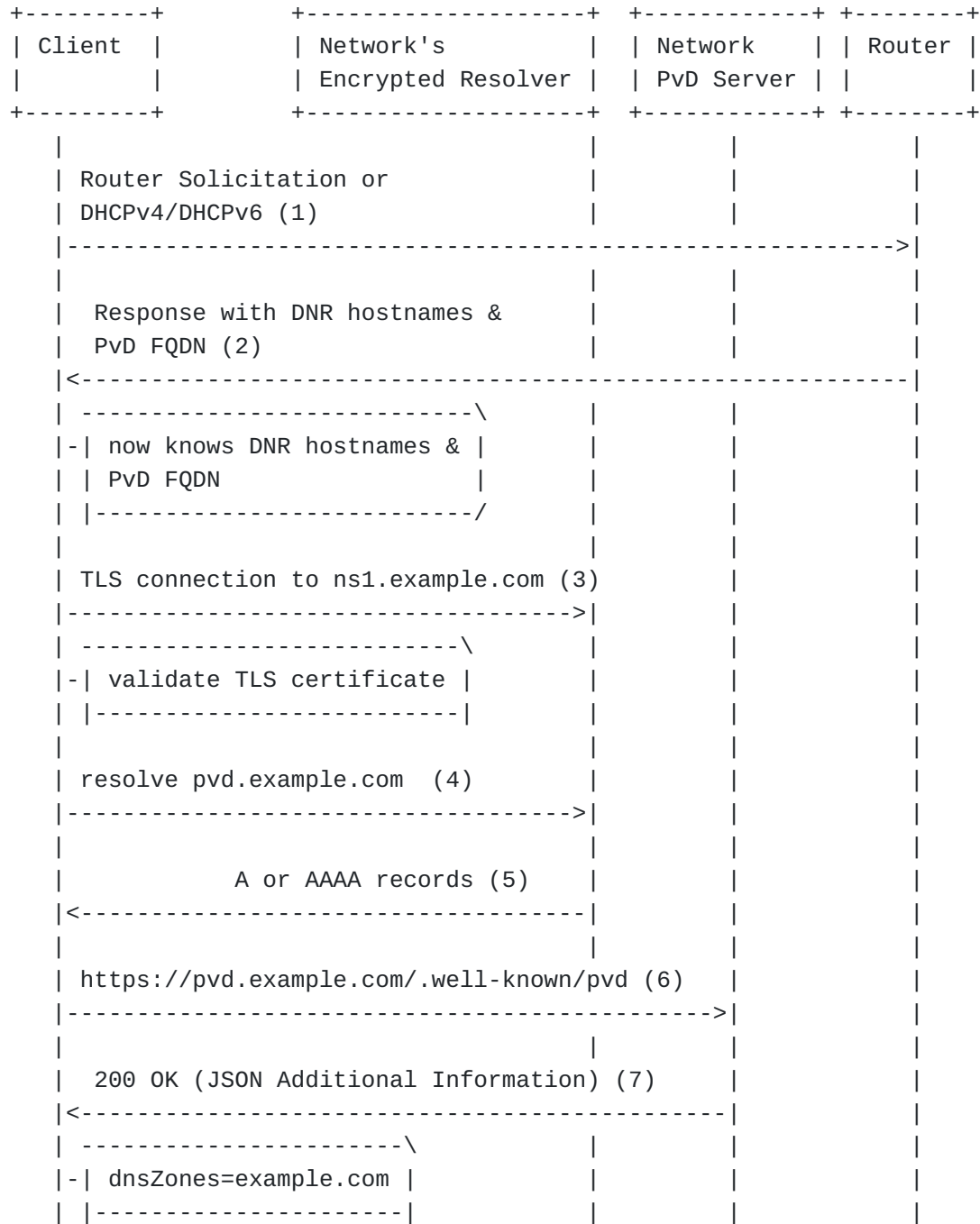


Figure 1: Learning Local Claims of DNS Authority

7.1.1.1. Verification using an external resolver

The figure below shows the steps performed to verify the local claims of DNS authority using an external resolver.

Steps 1-2: The client uses an encrypted DNS connection to an external resolver (e.g., 1.1.1.1) to issue NS queries for the domains in dnsZones. The NS lookup for "example.com" will return "ns1.example.com" and "ns2.example.com".

Step 3: The network-provided DNS servers are listed in the NS record for example.com, which was retrieved from an external resolver over a secure transport, so these ADNs are authorized. When the client connects using an encrypted transport as indicated in [DNR](#) [[I-D.ietf-add-dnr](#)], it will authenticate the server to its name using TLS ([RFC8310](#), [Section 8](#)), and send queries to resolve any names that fall within the dnsZones from PVD.

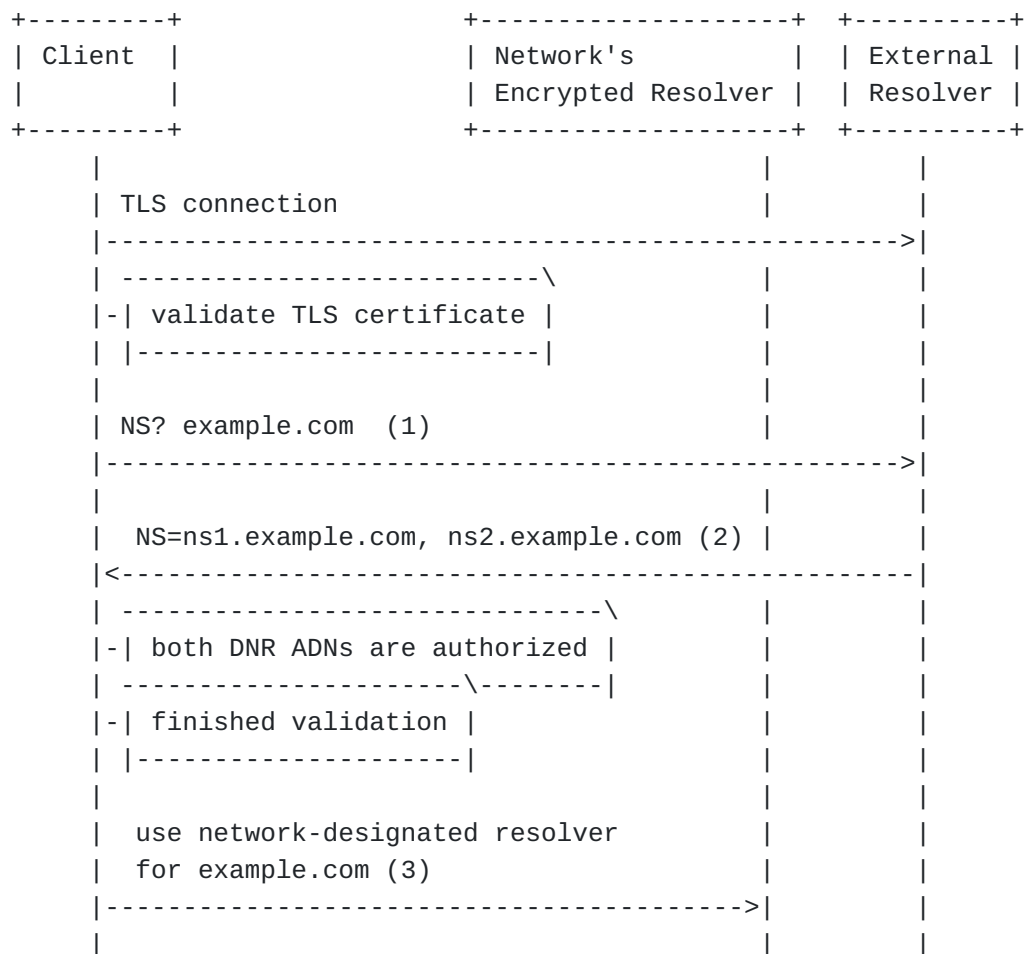


Figure 2: Verifying claims using an external resolver

7.1.2. Verification using DNSSEC

The figure below shows the steps performed to verify the local claims of DNS authority using DNSSEC.

Steps 1-2: The DNSSEC-validating client queries the network encrypted resolver to issue NS queries for the domains in dnsZones. The NS lookup for "example.com" will return a signed response containing "ns1.example.com" and "ns2.example.com". The client then performs full DNSSEC validation locally.

Step 3: The DNSSEC validation is successful and the network-provided DNS servers are listed in the signed NS record for example.com, so these ADNs are authorized. When the client connects using an encrypted transport as indicated in [DNR \[I-D.ietf-add-dnr\]](#), it will authenticate the server to its name using TLS ([\[RFC8310\]](#), [Section 8](#)), and send queries to resolve any names that fall within the dnsZones from PVD.

```
+-----+                               +-----+
| Client |                               | Network's |
|         |                               | Encrypted Resolver |
+-----+                               +-----+

|
| DNSSEC OK (DO), NS? example.com (1)
|----->|
|
| NS=ns1.example.com,ns2.example.com, Signed Answer (RRSIG) (2)
|<-----|
| -----\
|-| DNSKEY+NS matches RRSIG, use NS |
| |-----|
| -----\
|-| both DNR ADNs are authorized |
| |-----|
| -----\
|-| finished validation |
| |-----|
|
| use encrypted network-designated resolver for example.com (3)
|----->|
|
```

Figure 3: Verifying claims using DNSSEC

7.2. Internal-only Subdomains

In many split-horizon deployments, all non-public domain names are placed in a separate child zone (e.g., internal.example.com). In

this configuration, the message flow is similar to [Section 7.1](#), except that queries for hosts not within the subdomain (e.g., `www.example.com`) are sent to the external resolver rather than resolver for `internal.example.com`.

As in [Section 7.1](#), the internal DNS server will need a certificate signed by a CA trusted by the client.

8. Validation with IKEv2

When the VPN tunnel is IPsec, the encrypted DNS resolver hosted by the VPN service provider can be securely discovered by the endpoint using the `ENCDNS_IP*_*` IKEv2 Configuration Payload Attribute Types defined in [[I-D.ietf-ipsecme-add-ike](#)].

Other VPN tunnel types have similar configuration capabilities, not detailed here.

9. Security Considerations

This specification does not alter DNSSEC validation behaviour. To ensure compatibility with validating clients, network operators **MUST** ensure that names under the split-horizon are correctly signed or place them in an unsigned zone.

If an internal zone name (e.g., `internal.example.com`) is used with this specification and a public certificate is obtained for validation, that internal zone name will exist in Certificate Transparency logs [[RFC9162](#)]. In order to not leak the internal domains to an external resolver, the internal domains can be kept in a child zone of the local domain hints advertised by the network. For example, if the PvD "dnsZones" entry is "`internal.example.com`" and the network-provided DNS resolver is "`ns1.internal.example.com`", the network operator can structure the internal domain names as "`private1.internal.example.com`", "`private2.internal.example.com`", etc. The network-designated resolver will be used to resolve the subdomains of the local domain hint "`*.internal.example.com`". Further, adversaries that monitor a network such as through passive monitoring or active probing of protocols, such as DHCP will only learn the local domain hints but not learn the labels below `internal.example.com`. However, security by obscurity may not maintain or increase the security of the internal domain names, as they may be leaked in various other ways (e.g., browser reload).

10. IANA Considerations

This document has no IANA actions.

11. Acknowledgements

Thanks to Mohamed Boucadair, Jim Reid, Tommy Pauly, Paul Vixie, Paul Wouters, Michael Richardson and Vinny Parla for the discussion and comments.

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