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Improved DNS Server Selection for Multi-Homed Nodes
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Abstract

A multi-homed node can be connected to multiple networks that may utilize different DNS namespaces. The node often receives DNS server configuration information from all connected networks. Some of the DNS servers may have information about namespaces other servers do not have. When the multi-homed node needs to utilize DNS, it has to choose which of the servers to contact to. This document describes a policy based method for helping on selection of DNS server for both forward and reverse DNS lookup procedures with help of DNS suffix and IPv6 prefix information received via DHCPv6.

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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This Internet-Draft will expire on May 15, 2011.

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1. Introduction

A multi-homed node faces several problems over single-homed node as is described in [I-D.ietf-mif-problem-statement]. This document studies in detail the problems local namespaces may cause for multi-homed nodes in the IPv4 and IPv6 domains and provides a solution. The node may be implemented as a host, or as a router such as Consumer Premises Equipment.

When multiple namespaces are visible for a node, some DNS servers have information other servers do not have. Because of that, a multi-homed node cannot assume every DNS server is able to provide any piece of information, but instead the node must be able to ask right server for the information it needs.

An example of an application that benefits from multi-homing is a web browser that commonly accesses many different destinations and should be able to dynamically communicate over different network interfaces.

However, as the IPv4 is being phased out and often uses NATs to achieve similar functions, this document describes a solution only for the IPv6 domain.

In deployments where multiple namespaces are present, selection of the correct destination and source addresses for the actual IP connection is usually crucial as well, as the resolved destination's IP address may be only usable on the network interface over which it was resolved on. Hence solution described in this document is assumed to be often used in combination of tools delivering source and destination address selection policies.

The Appendix A describes best current practices possible with tools preceding this document and on networks not supporting this specification. As it is possible to solve the problem with less efficient and less explicit manners, this document can be considered as an optimization. However, in some environments this optimization is considered essential.

1.1. Requirements Language

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 RFC 2119 [RFC2119].

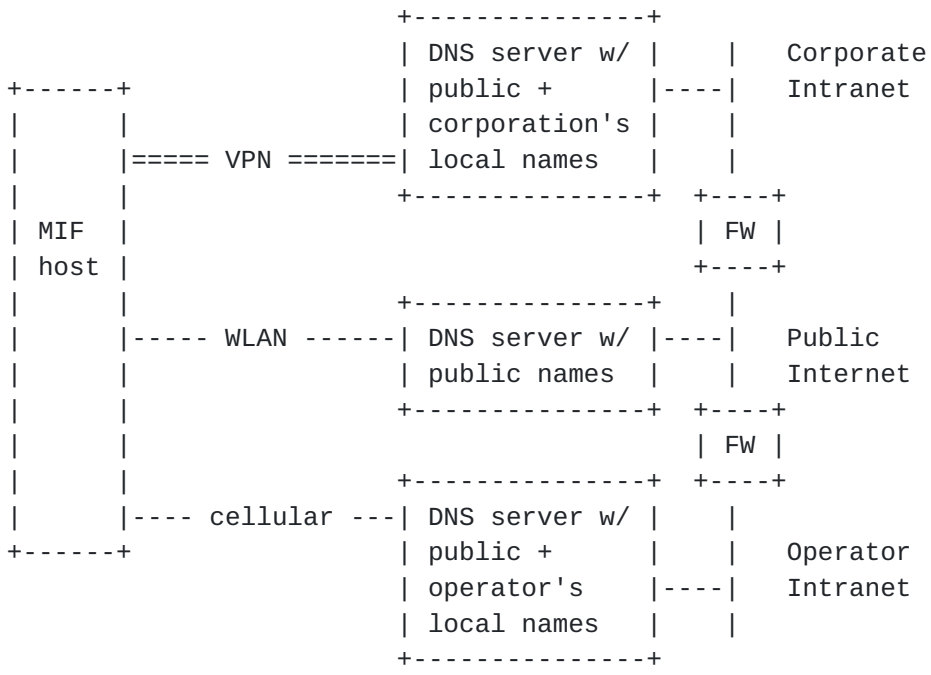
2. Problem description for local namespaces with multi-homed nodes

This chapter describes two host multi-homing related local namespace

scenarios for which the procedure described in chapter 3 provides a solution. Essentially the same challenges may be faced by Consumer Premises Equipment as is described in [I-D.troan-multihoming-without-nat66].

2.1. Fully qualified domain names with limited scopes

A multi-homed host may be connecting to one or more networks that are using local namespaces. As an example, the host may have simultaneously open a wireless LAN (WLAN) connection to public Internet, cellular connection to an operator network, and a virtual private network (VPN) connection to a corporate network. When an application initiates a connection establishment to an FQDN, the host needs to be able to choose the right network interface for making a successful DNS query. This is illustrated in the figure 1. An FQDN for a public name can be resolved with any DNS server of any network interface, but for an FQDN of corporation's or operator's service's local name the host would need to be able to correctly select the right network interface for the DNS resolution, i.e. do interface selection already before destination's IP address is known.

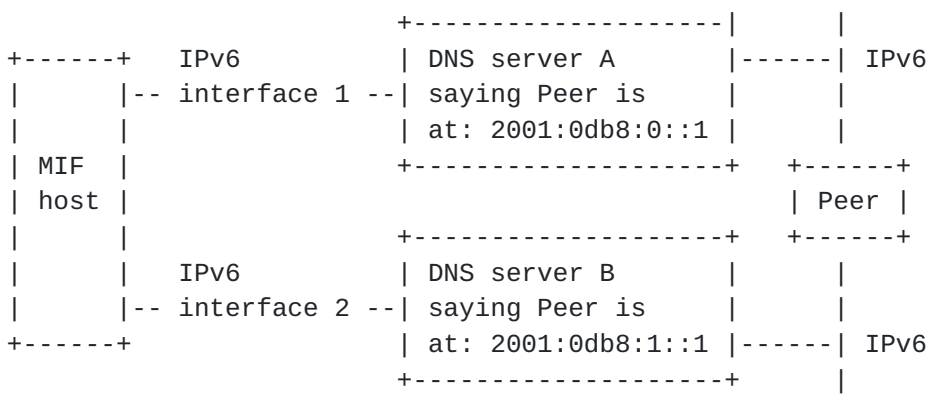


Split DNS and locally scoped names illustrated

Figure 1

2.2. Network interface specific IP addresses

In the second problem an FQDN as such is valid and resolvable via different network interfaces, but to different and not necessarily globally reachable IP addresses, as is illustrated in the figure 2. This is a problem when a host is single-homed, but for multi-homed host this results in additional challenges: the host's source and destination address selection mechanism must ensure the destination's IP address is only used in combination with source IP addresses of the network interface the name was resolved on.

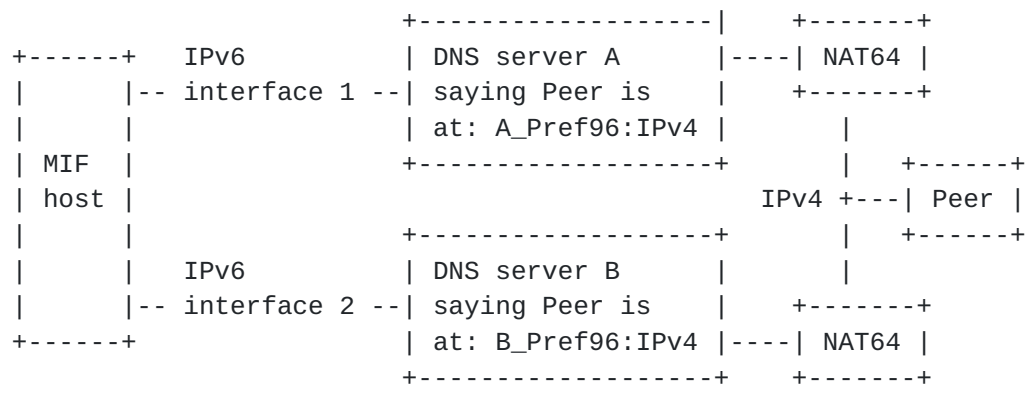


Split DSN and different IP addresses for an FQDN on interfaces 1 and 2.

Figure 2

Similar situation can happen when IPv6 protocol translation is used in combination with AAAA record synthesis proceduce [I-D.ietf-behave-dns64]. A synthesised AAAA record is guaranteed to be valid only on a network interface it was synthesized on. Figure 3 illustrates a scenario where the peer's IPv4 address is synthesized into different IPv6 addresses by DNS servers A and B. The same problem can happen in the IPv4 domain as well if A record synthesis is done, for example as described in Bump-In-the-Stack [RFC2767].

For a related problem for dual-stack hosts in a network with DNS64, where IPv4 should be prioritized over synthesized IPv6, please see [I-D.wing-behave-dns64-config].



AAAA synthesis results in interface specific IPv6 addresses.

Figure 3

A more complex scenario is an FQDN, which in addition to resolving into network interface specific IP addresses, identifies on different network interfaces completely different peer entities with potentially different set of service offering. In even more complex scenario, an FQDN identifies unique peer entity, but one that provides different services on its different network interfaces. The solution described in this document is not able to tackle these higher layer issues. In fact, some of the problems may be solvable only by user intervention.

A thing worth noting is that interface specific IP addresses can cause problems also for a single-homed host, if the host retains its DNS cache during movement from one network interface to another. After the interface change a host could have both positive and negative DNS cache entries invalid for the new network interface. Because of this the cached DNS information should be considered network interface local instead of node global.

3. Improved DNS server selection procedure

This chapter documents a procedure a (stub / proxy) resolver may utilize for DNS server selection in face of multiple namespaces.

Essentially, the resolver shall dynamically build for each DNS query a priority list of DNS servers it will try to contact to. The resolver shall cycle through the list until a positive reply is received, or until all selected DNS servers have been contacted or timed out. (DISCUSS: What about those DNS servers that instead of negative answer always return positive reply with an IP address of some captive portal?)

To prioritize DNS servers in an optimal way, the resolver should ask with DHCPv6 which DNS servers are most likely able to successfully serve forward lookup requests matching to specific DNS suffixes or reverse (PTR record) lookup requests matching to specific IPv6 prefixes.

A resolver lacking more explicit information shall assume that all information is available from any DNS server of any network interface.

Additionally, the resolver may utilize any other information it may have, e.g. possible user's preferences, node's general preferences between network interfaces, differences on trust levels of network interfaces (see Security Considerations), or any other piece of information.

When a resource record is to be resolved, the resolver MUST give highest precedence to the DNS servers explicitly known to serve matching suffixes or prefixes.

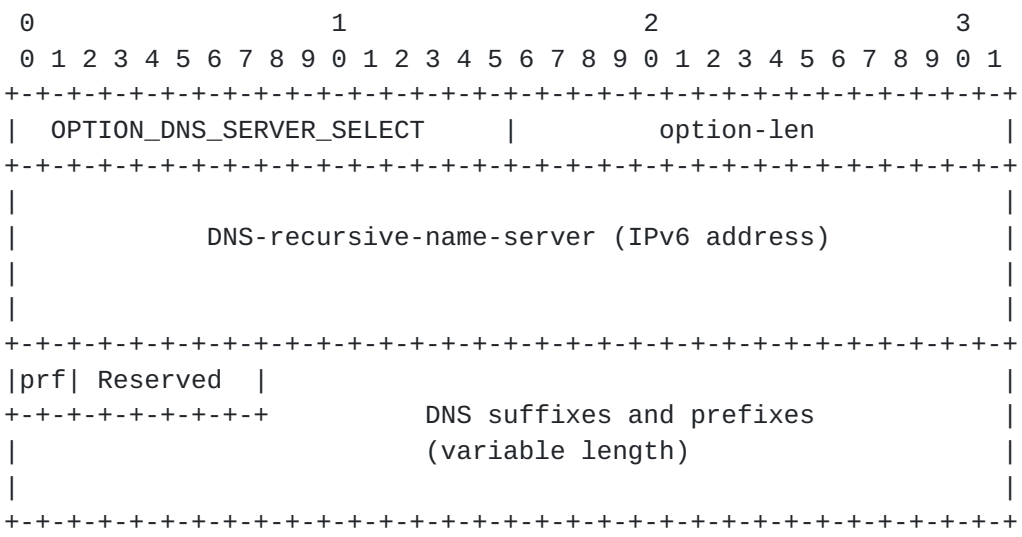
For the scenario where an FQDN maps to same service but different IP addresses on different network interfaces, the source address selection algorithm must be able to pick a source address from the network interface that was used for DNS resolution.

When local namespace are present a negative reply from a DNS server implies only that the particular DNS server was not able to serve the query. However, it is not probable that the secondary DNS servers on the same network interface, on a same administrative domain, would be able to serve either. Therefore, the next DNS server resolver contacts should be from another network interface.

In the case DNSSEC validation of a reply fails the node MUST resend the query to the next preferred DNS server. This is needed to mitigate against attacks that may use this option to redirected queries. A host may blacklist a DNS server continuosly providing responses that fail to validate.

3.1. DNS server selection option

A DHCPv6 option described below is used to inform nodes which DNS server should be contacted when initiating forward or reverse DNS lookup procedures.



option-code: OPTION_DNS_SERVER_SELECT (TBD)

option-len: Lenght of the option in octets

DNS-recursive-name-server: An IPv6 address of a DNS server

prf: DNS server preference:

    01 High
    00 Medium
    11 Low
    10 Reserved - MUST NOT be sent

  (Editor's node: this field is under consideration
   - really needed or not?)

Reserved: Flags reserved for the future. MUST be set to
  zero.

DNS suffixes and prefixes: The list of DNS suffixes for forward DNS
  lookup and prefixes for reverse DNS lookup the DNS server
  has special knowledge about. Field MUST be encoded as
  specified in section "Representation and use of
  domain names" of [RFC3315].
  Additionally, special suffix of "." is used to indicate
  capability to resolve global names. Lack of "."
  suffix on the list indicates DNS server has only local
  information. Prefixes for reverse mapping are encoded as
  defined for ip6.arpa [RFC3152].

Figure 4

The OPTION_DNS_SERVER_SELECT contains one or more DNS suffixes the related DNS server has particular knowledge of (i.e.. local namespaces). The option can occur multiple times in a single DHCPv6 message, if multiple DNS servers are to be configured.

A node can prioritize DNS servers with help of preference field.

IPv6 prefixes should cover all the DNS suffixes configured in this option. Prefixes should be as long as possible to avoid collision with information received on other option instances or with options received from DHCPv6 servers of other network interfaces. Overlapping IPv6 prefixes are interpreted by a node so that the resolver can use multiple DNS servers for queries mathing the prefixes.

As the DNS options of [RFC3646], the OPTION_DNS_SERVER_SELECT option MUST NOT appear in any other than the following messages: Solicit, Advertise, Request, Renew, Rebind, Information-Request, and Reply.

For backwards compatibility reasons the DHCPv6 message containing OPTION_DNS_SERVER_SELECT also possibly contains OPTION_DNS_SERVERS option. In case both options contain the same IPv6 addresses, only one copy of the IPv6 address of the DNS server shall be added to the DNS server list. Priority MUST be set according to the information received in the OPTION_DNS_SERVER_SELECT.

The node SHOULD create a host specific route for the DNS server address. The route must point to the interface DNS server address was learned on. This is required to ensure DNS queries are sent out via the right interface.

In the case of a DNS server replying negatively to a question having matching suffix, it will be for implementation to decide whether to consider that as a final response, or whether to ask also from other DNS servers. The implementation decision may be based, for example, on deployment or trust models.

3.2. Coexistence with RFC3646

The OPTION_DNS_SERVER_SELECT is designed to coexist with OPTION_DNS_SERVERS defined in [RFC3646]. The DNS servers from OPTION_DNS_SERVERS are considered as default name servers with medium preference. When both options are received, from the same or different interface, and OPTION_DNS_SERVER_SELECT also contains default DNS server address, the node SHOULD make decision which one to use based on preferences. If OPTION_DNS_SERVER_SELECT defines

medium preference then DNS server selection decision is implementation specific and may, for example, be based on interface preferences. All default servers are assumed to be able to resolve queries for global names.

The node MUST always use a DNS server that is configured with suffix matching for a queried name, even if that server would be market with lower preference than the DNS server learned via OPTION_DNS_SERVERS.

4. Example of a node behavior

Figure 5 illustrates node behavior when it initializes two network interfaces for parallel usage and learns DNS suffix and prefix information from DHCPv6 servers.

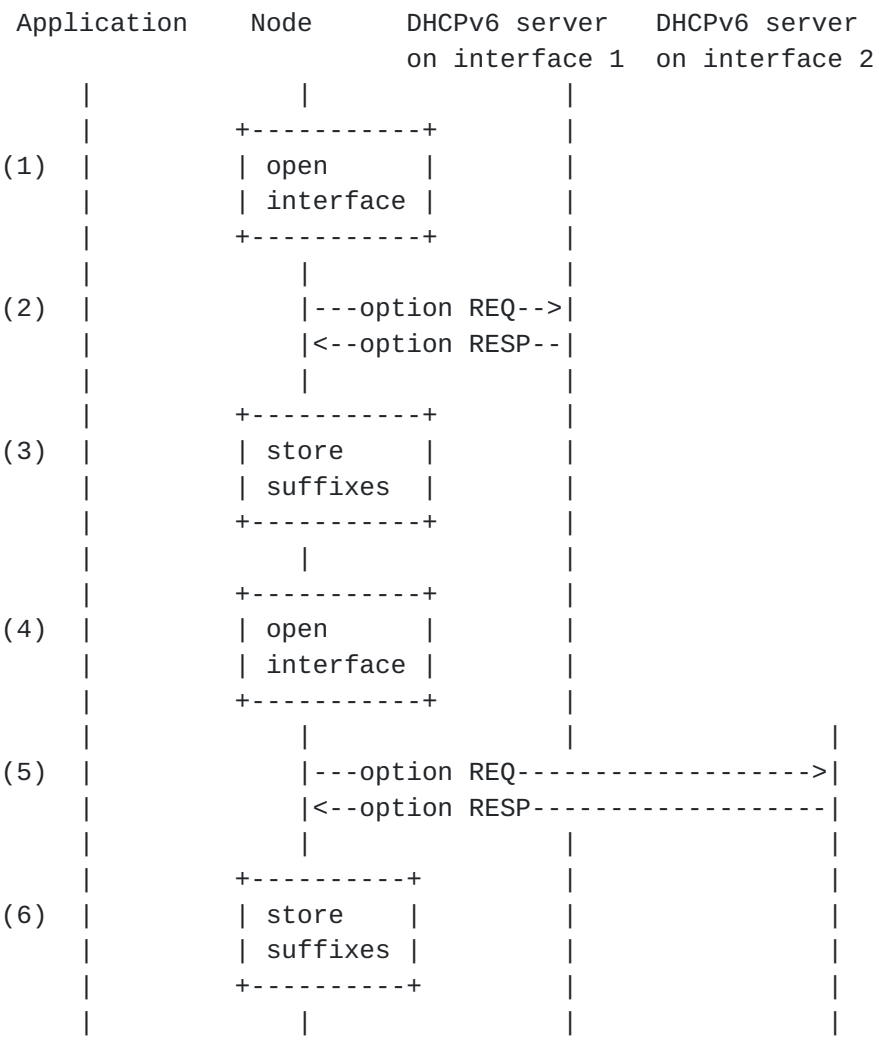


Illustration of learning DNS suffixes

Figure 5

Flow explanations:

1. A node opens its first network interface

2. The node obtains DNS suffix and IPv6 prefix information for the new interface 1 from DHCPv6 server

3. The node stores the learned DNS suffixes and IPv6 prefixes for later use

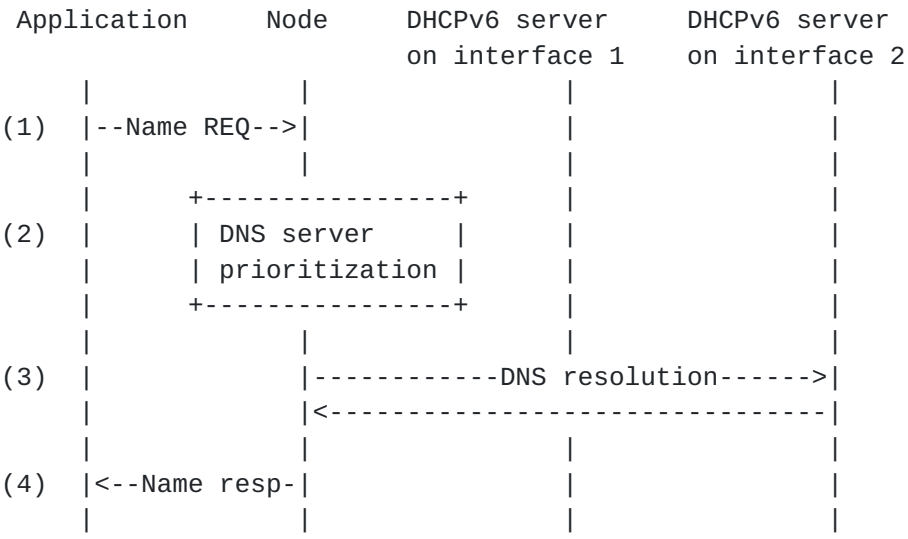
4. The node opens its seconds network interface 2

5. The node obtains DNS suffix, say 'example.com', and IPv6 prefix information, say '8.b.d.0.1.0.0.2.ip6.arpa' for the new interface

2 from DHCPv6 server

6. The node stores the learned DNS suffixes and prefixes for later use

Figure 6 below illustrates how a resolver uses the learned suffix information. Prefix information use for reverse lookups is not illustrated, but that would go as the figure 6 example.



Example on choosing interface based on DNS suffix

Figure 6

Flow explanations:

1. An application makes a request for resolving an FQDN, e.g. 'private.example.com'

2. A node creates list of DNS servers to contact to and uses configured DNS server information and stored DNS suffix information on priorization decisions.

3. The node has chosen interface 2, as from DHCPv6 it was learned earlier that the interface 2 has DNS suffix 'example.com'. The node then resolves the requested name using interface 2's DNS server to an IPv6 address

4. The node replies to application with the resolved IPv6 address

5. Scalability considerations

The size limitations of DHCPv6 messages limit the number of suffixes and prefixes that can be carried in a configuration option. Including the suffixes and prefixes in a DHCPv6 option is best suited for deployments where relatively few carefully selected suffixes and prefixes are adequate.

6. Considerations for network administrators

Network administrators deploying private namespaces should assist advanced hosts in the DNS server selection by providing information described in this memo for nodes. To ensure nodes' source and destination IP address selection also works correctly, network administrators should also deploy related technologies for that purpose.

The solution described herein is best for selecting a DNS server having knowledge of some namespaces. The solution is not able to make the right decision in a scenario where same name points to different services on different network interfaces. Network administrators are recommended to avoid overloading of namespaces in such manner.

To mitigate against attacks against local namespaces, administrators utilizing this tool should deploy DNSSEC for their zone.

7. Acknowledgements

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This document was prepared using xml2rfc template and the related web-tool.

8. IANA Considerations

This memo includes a new DHCPv6 option that requires allocation of a new code point.

9. Security Considerations

The host SHOULD implement DNSSEC to have capability to validate DNS responses received via any of its interfaces. This is particularly important to protect against attacks targeted to very specific private domain names. Such an attack is not as easily detectable as an attack agaist a full domain.

A node with multiple interfaces may receive conflicting DNS server selection rules from its interfaces. These conflicts may be caused by unintentional misconfigurations or by attacks done on purpose. Even a single specific DNS server selection rule from one interface can be considered as a conflict against default DNS server configuration from another interface.

The conflicting policy problem is a generic problem present with any kind of configuration element a node may receive from its interfaces. A node must have a solution in place for conflict resolution and for preventing attackers injecting malicious DNS server selection policies. As the solution must be generic and uniform across different configuration elements, it is not covered in this document. (Editor's note: Solution may, for example, be such that DNS server selection information is only accepted via trusted interfaces. Trusted interface is an implementation/deployment specific choice, possibly made configurable via policies.).

10. References

10.1. Normative References

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10.2. Informative References

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[RFC5006] Jeong, J., Park, S., Beloeil, L., and S. Madanapalli, "IPv6 Router Advertisement Option for DNS Configuration", RFC 5006, September 2007.

Appendix A. Best Current Practice for DNS server selection

On some split-DNS deployments explicit policies for DNS server selection are not available. This section describes ways for hosts to mitigate the problem by sending wide-spread queries and by utilizing possibly existing indirect information elements as hints.

A.1. Sending queries out on multiple interfaces in parallel

A possible current practice is to send DNS queries out of multiple interfaces and pick up the best out of the received responses. A host SHOULD implement DNSSEC in order to be able to reject responses that cannot be validated. Selection between legitimate answers is implementation specific, but positive replies should be preferred.

A downside of this approach is increased consumption of resources. Namely power consumption if an interface, e.g. wireless, has to be brought up just for the DNS query that could have been resolved also via cheaper interface. Also load on DNS servers is increased. However, local caching of results mitigates these problems, and a node might also learn interfaces that seem to be able to provide more responses than other and prefer those - without forgetting fallback required for cases when node is connected to more than one network using local namespaces.

Another downside is revealing to all DNS servers the names a host is connecting to. For example, a DNS server of public hotspot could learn all the private names host is trying to connect on other interfaces.

A.2. Search list option for DNS forward lookup decisions

A host can learn the special DNS suffixes of attached network interfaces from DHCP search list options; DHCPv4 Domain Search Option number 119 [RFC3397] and DHCPv6 Domain Search List Option number 24 [RFC3646]. The host behavior is very similar as is illustrated in the example at section 3.3. While these DHCP options are not intented to be used in DNS server selection, they may be used by the host for smart DNS server prioritization purposes in order to increase likelyhood of fast and successful DNS query.

Overloading of existing DNS search list options is not without problems: resolvers would obviously use the DNS suffixes learned from search lists also for name resolution purposes. This may not be a problem in deployments where DNS search list options contain few DNS suffixes like 'example.com, private.example.com', but can become a problem if many suffixes are configured.

A.3. More specific routes for reverse lookup decision

[RFC4191] defines how more specific routes can be provisioned for hosts. This information is not intented to be used in DNS server selection, but nevertheless a host can use this information as a hint about which interface would be best to try first for reverse lookup procedures. A DNS server configured via the same interface as more

specific routes is likely more capable to answer reverse lookup questions than DNS server of an another interface. The likelyhood of success is possibly higher if DNS server address is received in the same RA [RFC5006] as the more specific route information.

A.4. Longest matching prefix for reverse lookup decision

A host may utilize the longest matching prefix approach when deciding which DNS server to contact for reverse lookup purposes. Namely, the host may send a DNS query to a DNS server learned over an interface having longest matching prefix to the address being queried. This approach can help in cases where ULA [RFC4193] addresses are used and when the queried address belongs to a host or server within the same network (for example intranet).

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