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Simple Homenet Naming and Service Discovery Architecture
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Abstract

This document describes a simple name resolution and service discovery architecture for homenets, using the 'home.arpa' domain name hierarchy. This architecture covers local publication of names, as well as name resolution service for local and global names for devices connected to the homenet.

This document does not cover discovery of homenet services by devices not connected to the homenet, nor DNSSEC, nor acquisition and configuration of a global name as an alternative to 'home.arpa'. These topics will be addressed in a separate document.

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1. Introduction

This document describes a simple architecture for providing name service and service discovery for homenets. This allows hosts connected to the homenet to use the Domain Name System to discover services and the hosts providing those services, whether they are on the home network or the Internet. In addition, the architecture provides a way for hosts connected to the homenet that provide services to advertise those services for discovery by other homenet hosts.

This simple architecture is intended to serve as a foundational architecture for naming on home networks. It is expected that all Homenet routers will implement this architecture. It satisfies a subset of the requirements listed in IPv6 Home Networking Architecture Principles [7], and provides a foundation for completely addressing those requirements.

This simple architecture leaves the following requirements from RFC7368 Section 3.7 unaddressed:

- Acquisition of a global name for the homenet, to be used in place of 'home.arpa.'
- Delegation of public reverse trees for prefixes delegated to the homenet: subdomains of 'ip6.arpa' and 'in-addr.arpa'.
- Publication of names on the homenet for general public use on the internet.
- Publication of names on the homenet for use by authorized users of the homenet when connected to other networks.
- Secure delegation, enabling DNSSEC validation of names published on the homenet.

A later document will describe additional functionality that can be implemented on more capable home network routers, so that a home network that has at least one such router, and one or more routers that only implement the architecture described in this document, can work together to provide the full feature set described in RFC 7368.

In general, the set of capabilities required to discover services on any network are:

- A domain name that represents the network, under which names can be published and services advertised
- The ability to publish names that identify hosts and services.
- Advertising locally available services by publishing resource records.
- A service that can be queried for names and resources records in order to discover and use services.
- Advertisement of that service so that hosts can send queries to it.
- Timely removal of published names and resource records when they are no longer in use

A simple homenet naming architecture adds the following considerations:

1. Users cannot be assumed to be skilled or knowledgeable in name service operation, or even to have any sort of mental model of how these functions work. All of the operations mentioned here must reliably function automatically, without any user intervention or debugging.

2. Because user intervention cannot be required, naming conflicts must be resolved automatically, and, to the extent possible, transparently.

3. Hosts are not required to implement any homenet-specific capabilities in order to discover and access services on the homenet.

4. Devices that provide services must be able to publish those services on the homenet, and those services must be available from any part of the homenet, not just the link to which the device is attached.

5. Homenet explicitly supports multihoming: connecting to more than one Internet Service Provider. It therefore must address the problem of multiple provisioning domains [8], in the sense that the DNS may give a different answer depending on whether caching resolvers at one ISP or another are queried.

1.1. Existing solutions

Previous attempts to automate naming and service discovery in the context of a home network are able to function with varying degrees of success depending on the topology of the home network. Unfortunately, these solutions do not fully address the requirements of homenets.

For example, Multicast DNS [5] can provide naming and service discovery [6], but only within a single multicast domain.

The Domain Name System provides a hierarchical namespace [1], a mechanism for querying name servers to resolve names [2], a mechanism for updating namespaces by adding and removing names [4], and a mechanism for discovering services [6]. Unfortunately, DNS provides no mechanism for automatically provisioning new namespaces, and secure updates to namespaces require that the host submitting the update have a public or symmetric key that is known to the network and authorized for updates. In an unmanaged network, the publication of and authorization of these keys is an unsolved problem.

Some managed networks get around this problem by having the DHCP server do DNS updates. However, this doesn't really work, because

DHCP doesn't provide a mechanism for updating service discovery records: it only supports publishing A and AAAA records.

This partially solves the trust problem: DHCP can validate that a device is at least connected to a network link that is actually part of the managed network. This prevents an off-network attacker from registering a name, but provides no mechanism for actually validating the identity of the host registering the name. For example, it would be easy for an attacker on the network to steal a registered name.

Hybrid Multicast DNS [10] proposes a mechanism for extending multicast DNS beyond a single multicast domain. However, in order to use this as a solution, some shortcomings need to be considered. Most obviously, it requires that every multicast domain have a separate name. This then requires that the homenet generate names for every multicast domain. These names would then be revealed to the end user. But since they would be generated automatically and arbitrarily, they would likely cause confusion rather than clarity, and in degenerate cases requires that the end user have a mental model of the topology of the network in order to guess on which link a given service may appear.

At present, the approach we intend to take with respect to disambiguation is that this will not be solved at a protocol level for devices that do not implement the registration protocol.

2. Terminology

This document uses the following terms and abbreviations:

HNR Homenet Router

ISP Internet Service Provider

3. Name Resolution

3.1. Configuring Resolvers

Hosts on the homenet receive a set of resolver IP addresses using either DHCP or RA. IPv4-only hosts will receive IPv4 addresses of resolvers, if available, over DHCP. IPv6-only hosts will receive resolver IPv6 addresses using either stateful (if available) or stateless DHCPv6, or through the Recursive DNS Server Option ([9], Section 5.1) in router advertisements.

All Homenet routers provide resolver information using both stateless DHCPv6 and RA; support for stateful DHCPv6 and DHCPv4 is optional,

however if either service is offered, resolver addresses will be provided using that mechanism as well.

3.2. DNS Service Discovery Registration Protocol

The DNSSD Service Registration protocol [12] requires that DNS updates be validated on the basis that they are received on the local link. To ensure that such registrations are actually received on local links in the homenet, updates are sent to the local relay proxy ([11]) (XXX how?).

The relay proxy encapsulates the update and sends it to whatever Discovery Proxy is listening on the link; the Discovery proxy then either consumes the update directly, or forwards it to the authoritative resolver for the local service discovery zone. If the registration protocol is not supported on the homenet, the Discovery Proxy rejects the update with a ??? RCODE.

3.3. Configuring Service Discovery

Clients discovering services using DNS-SD [6] follow a two-step process. The first step is for the client device to determine in which domain(s) to attempt to discover services. The second step is for the client device to then seek desired service(s) in those domain(s). For an example of the second step, given the desired service type "IPP Printing", and the domains "local" and "meeting.ietf.org", the client device forms the queries "_ipp._tcp.local. PTR ?" (resolved using Multicast DNS) and "_ipp._tcp.meeting.ietf.org PTR. ?" (resolved using Unicast DNS) and then presents the combined list of results to the user.

The first step, determining in which domain(s) to attempt to discover services, is performed in a variety of ways, as described in Section 11 of the DNS-Based Service Discovery specification [6].

The domain "local" is generally always in the set of domains in which the client devices attempt to discover services, and other domains for service discovery may be configured manually by the user.

The device also learns additional domains automatically from its network environment. For this automatic configuration discovery, special DNS queries are formulated. To learn additional domain(s) in which to attempt to discover services, the query string "lb._dns_sd._udp" is prepended onto three different kinds of "bootstrap domain" to form DNS queries that allow the device to learn the configuration information.

One of these bootstrap domains is the fixed string "local". The device issues the query "lb._dns_sd._udp.local. PTR ?" (resolved using Multicast DNS), and if any answers are received, then they are added to the set of domains in which the client devices attempt to discover services.

Another kind of these bootstrap domains is name-based, derived from the DHCPv4 "domain name" option (code 15) [3] (for IPv4) or the DNS Search List (DNSSL) Router Advertisement option [9] (for IPv6). If a domain in the DNSSL is "example.com", then the device issues the query "lb._dns_sd._udp.example.com. PTR ?" (resolved using Unicast DNS), and if any answers are received, then they are likewise added to the set of domains in which the client devices attempt to discover services.

Finally, the third kind of bootstrap domain is address-based, derived from the device's IP address(es) themselves. If the device has IP address 192.168.1.100/24, then the device issues the query "lb._dns_sd._udp.0.1.168.192.in-addr.arpa. PTR ?" (resolved using Unicast DNS), and if any answers are received, then they are also added to the set of domains in which the client devices attempt to discover services.

Since there is an HNR on every link of a homenet, automatic configuration could be performed by having HNRs answer the "lb._dns_sd._udp.local. PTR ?" (Multicast DNS) queries. However, because multicast is slow and unreliable on many modern network technologies like Wi-Fi, we prefer to avoid using it. Instead we require that a homenet be configured to answer the name-based bootstrap queries. By default the domain in the DNSSL communicated to the client devices will be "home.arpa", and the homenet will be configured to correctly answer queries such as "lb._dns_sd._udp.example.com. PTR ?", though client devices must not assume that the name will always be "home.arpa". A client could be configured with any valid DNSSL, and should construct the appropriate bootstrap queries derived from the name(s) in their configured DNS Search List.

HNRs will answer domain enumeration queries against every IPv4 address prefix advertised on a homenet link, and every IPv6 address prefix advertised on a homenet link, including prefixes derived from the homenet's ULA(s). Whenever the "<domain>" sequence appears in this section, it references each of the domains mentioned in this paragraph.

Homenets advertise the availability of several browsing zones in the "b._dns_sd._udp.<domain>" subdomain. By default, the 'home.arpa' domain is advertised. Similarly, 'home.arpa' is advertised as the

default browsing and service registration domain under "db._dns_sd._udp.<domain>", "r._dns_sd._udp.<domain>", "dr._dns_sd._udp.<domain>" and "lb._dns_sd._udp.<domain>".

In order for this discovery process to work, the homenet must provide authoritative answers for each of the domains that might be queried. To do this, it provides authoritative name service for the 'ip6.arpa' and 'in-addr.arpa' subdomains corresponding to each of the prefixes advertised on the homenet. For example, consider a homenet with the 192.168.1.0/24, 2001:db8:1234:5600::/56 and fc01:2345:6789:1000::/56 prefixes. This homenet will have to provide a name server that claims to be authoritative for 1.168.192.in-addr.arpa, 6.5.4.3.2.1.8.b.d.0.1.0.0.2.ip6.arpa and 0.0.9.8.7.6.5.4.3.2.1.0.c.f.ip6.arpa.

An IPv6-only homenet would not have an authoritative server for a subdomain of in-addr.arpa. These public authoritative zones are required for the public prefixes even if the prefixes are not delegated. However, they need not be accessible outside of the homenet.

It is out of the scope of this document to specify ISP behavior, but we note that ISPs have the option of securely delegating the zone, or providing an unsigned delegation, or providing no delegation. Any delegation tree that does not include an unsigned delegation at or above the zone cut for the ip6.arpa reverse zone for the assigned prefix will fail to validate.

Ideally, an ISP should provide a secure delegation using a zone-signing key provided by the homenet. However, that too is out of scope for this document. Therefore, an ISP that wishes to support users of the simple homenet naming architecture will have to provide an unsigned delegation. We do not wish, however, to discourage provisioning of signed delegations when that is possible.

3.4. Resolution of local names

By default, Local names appear as subdomains of 'home.arpa'. These names can only be resolved within the homenet; not only is 'home.arpa' not a globally unique name, but queries from outside of the homenet for any name, on or off the homenet, must be rejected with a REFUSED response. The intended use case for local names is that hosts will attempt to discover or contact other hosts on the homenet that are offering services.

In addition, names of devices on the homenet can appear in the resource records of names that are subdomains of the locally-served 'in-addr.arpa' or 'ip6.arpa zone that corresponding to the RFC1918

IPv4 prefix and the IPv6 ULA that is in use on the homenet. Names ending in 'home.arpa' should never appear in RRDATA for names that are subdomains of reverse mappings for global IP addresses. This should not cause operational problems, since connections between devices on the homenet can be expected to use addresses in the homenet's ULA prefix.

ISP-provided addresses cannot be assumed to be stable. Not only is it possible that the ISP policy is to change addresses over time, but the connection to the ISP may not always be available. The homenet's ULA prefix and RFC1918 prefix, however, can be assumed to be stable. Therefore, IP addresses and names advertised locally MUST use addresses in the homenet's ULA prefix and/or RFC1918 prefix.

It is possible that local services may offer services available on IP addresses in public as well as ULA prefixes. Homenet hybrid proxies MUST filter out global IP addresses, providing only ULA addresses, similar to the process described in section 5.5.2 of [10].

This filtering applies to queries within the homenet; it is appropriate for non-ULA addresses to be used for offering services, because in some cases end users may want such services to be reachable outside of the homenet. Configuring this is however out of scope for this document.

The Hybrid Proxy model relies on each link having its own name. However, homenets do not actually have a way to name local links that will make any sense to the end user. Consequently, this mechanism will not work without some tweaks. In order to address this, homenets will use Discovery Brokers [16]. The discovery broker will be configured so that a single query for a particular service will be successful in providing the information required to access that service, regardless of the link it is on.

Artificial link names will be generated using HNCP. These should only be visible to the user in graphical user interfaces in the event that the same name is claimed by a service on two links. Services that are expected to be accessed by users who type in names should use [12] if it is available.

Homenets are not required to support Service Registration. Service registration requires a stateful authoritative DNS server; this may be beyond the capability of the minimal Homenet router. However, more capable Homenet routers should provide this capability. In order to make this work, minimal Homenet routers MUST implement the split hybrid proxy [11]. This enables a Homenet with one or more Homenet routers that provide a stateful registration cache to allow those routers to take over service, using Discovery Relays to service

links that are connected using Homenet routers with more limited functionality.

3.5. Globally Unique Name

Automatic configuration of a globally unique name for the homenet is out of scope for this document. However, homenet servers MUST allow the user to configure a globally unique name in place of the default name, 'home.arpa.' By default, even if configured with a global name, homenet routers MUST NOT answer queries from outside of the homenet for subdomains of that name.

3.6. DNSSEC Validation

DNSSEC Validation for the 'home.arpa' zone and for the locally-served 'ip6.arpa and 'in-adr.arpa' domains is not possible without a trust anchor. Establishment of a trust anchor for such validation is out of scope for this document.

Homenets that have been configured with a globally unique domain MUST support DNSSEC signing of local names, and must provide a way to generate a KSK that can be used in the secure delegation of the globally unique domain assigned to the homenet.

3.7. Support for Multiple Provisioning Domains

Homenets must support the Multiple Provisioning Domain Architecture [8]. Hosts connected to the homenet may or may not support multiple provisioning domains. For hosts that do not support multiple provisioning domains, the homenet provides one or more resolvers that will answer queries for any provisioning domain. Such hosts may receive answers to queries that either do not work as well if the host chooses a source address from a different provisioning domain, or does not work at all. However, the default source address selection policy, longest-match [CITE], will result in the correct source address being chosen as long as the destination address has a close match to the prefix assigned by the ISP.

Hosts that support multiple provisioning domains will be provisioned with one or more resolvers per provisioning domain. Such hosts can use the IP address of the resolver to determine which provisioning domain is applicable for a particular answer.

Each ISP has its own provisioning domain. Because ISPs connections cannot be assumed to be persistent, the homenet has its own separate provisioning domain.

Configuration from the IPv4 DHCP server are treated as being part of the homenet provisioning domain. The case where a homenet advertises IPv4 addresses from one or more public prefixes is out of scope for this document. Such a configuration is NOT RECOMMENDED for homenets.

Configuration for IPv6 provisioning domains is done using the Multiple Provisioning Domain RA option [CITE].

3.8. Using the Local Namespace While Away From Home

This architecture does not provide a way for service discovery to be performed on the homenet by devices that are not directly connected to a link that is part of the homenet.

4. Management Considerations

This architecture is intended to be self-healing, and should not require management. That said, a great deal of debugging and management can be done simply using the DNS Service Discovery protocol.

5. Privacy Considerations

Privacy is somewhat protected in the sense that names published on the homenet are only visible to devices connected to the homenet. This may be insufficient privacy in some cases.

The privacy of host information on the homenet is left to hosts. Various mechanisms are available to hosts to ensure that tracking does not occur if it is not desired. However, devices that need to have special permission to manage the homenet will inevitably reveal something about themselves when doing so. It may be possible to use something like HTTP token binding [14] to mitigate this risk.

6. Security Considerations

There are some clear issues with the security model described in this document, which will be documented in a future version of this section. A full analysis of the avenues of attack for the security model presented here have not yet been done, and must be done before the document is published.

7. IANA considerations

No new actions are required by IANA for this document.

Note however that this document is relying on the allocation of 'home.arpa' described in Special Use Top Level Domain '.home.arpa'

[15]. This document therefore can't proceed until that allocation is done. [RFC EDITOR PLEASE REMOVE THIS PARAGRAPH PRIOR TO PUBLICATION].

8. Normative References

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