

Network Working Group	C. Huitema
Internet-Draft	Private Octopus Inc.
Intended status: Informational	D. Kaiser
Expires: June 22, 2020	University of Luxembourg
	December 20, 2019

DNS-SD Privacy and Security Requirements
draft-ietf-dnssd-prireq-03

Abstract

DNS-SD (DNS Service Discovery) normally discloses information about devices offering and requesting services. This information includes host names, network parameters, and possibly a further description of the corresponding service instance. Especially when mobile devices engage in DNS Service Discovery over Multicast DNS at a public hotspot, serious privacy problems arise. We analyze the requirements of a privacy respecting discovery service.

Status of This Memo

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on June 22, 2020.

Copyright Notice

Copyright (c) 2019 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

*1. [Introduction](#)

-1.1. [Terminology](#)

*2. [Threat Model](#)

*3. [Threat Analysis](#)

-3.1. [Service Discovery Scenarios](#)

o3.1.1. [Private Client and Public Server](#)

o3.1.2. [Private Client and Private Server](#)

o3.1.3. [Wearable Client and Server](#)

-3.2. [DNS-SD Privacy Considerations](#)

o3.2.1. [Information made available via DNS-SD Resource Records](#)

o3.2.2. [Privacy Implication of Publishing Service Instance Names](#)

o3.2.3. [Privacy Implication of Publishing Node Names](#)

o3.2.4. [Privacy Implication of Publishing Service Attributes](#)

o3.2.5. [Device Fingerprinting](#)

o3.2.6. [Privacy Implication of Discovering Services](#)

-3.3. [Security Considerations](#)

o3.3.1. [Authenticity, Integrity & Freshness](#)

o3.3.2. [Confidentiality](#)

o3.3.3. [Resistance to Dictionary Attacks](#)

o3.3.4. [Resistance to Denial-of-Service Attacks](#)

o3.3.5. [Resistance to Sender Impersonation](#)

o3.3.6. [Sender Deniability](#)

-3.4. [Operational Considerations](#)

o3.4.1. [Power Management](#)

o3.4.2. [Protocol Efficiency](#)

- o3.4.3. [Secure Initialization and Trust Models](#)
- o3.4.4. [External Dependencies](#)
- *4. [Requirements for a DNS-SD Privacy Extension](#)
 - 4.1. [Private Client Requirements](#)
 - 4.2. [Private Server Requirements](#)
 - 4.3. [Security and Operation](#)
- *5. [IANA Considerations](#)
- *6. [Acknowledgments](#)
- *7. [Informative References](#)
- *[Authors' Addresses](#)

[1. Introduction](#)

DNS-SD [\[RFC6763\]](#) over mDNS [\[RFC6762\]](#) enables zero-configuration service discovery in local networks. It is very convenient for users, but it requires the public exposure of the offering and requesting identities along with information about the offered and requested services. Parts of the published information can seriously breach the user's privacy. These privacy issues and potential solutions are discussed in [\[KW14a\]](#), [\[KW14b\]](#) and [\[K17\]](#).

There are cases when nodes connected to a network want to provide or consume services without exposing their identity to the other parties connected to the same network. Consider for example a traveler wanting to upload pictures from a phone to a laptop when connected to the Wi-Fi network of an Internet cafe, or two travelers who want to share files between their laptops when waiting for their plane in an airport lounge.

We expect that these exchanges will start with a discovery procedure using DNS-SD [\[RFC6763\]](#) over mDNS [\[RFC6762\]](#). One of the devices will publish the availability of a service, such as a picture library or a file store in our examples. The user of the other device will discover this service, and then connect to it.

When analyzing these scenarios in [Section 3.2](#), we find that the DNS-SD messages leak identifying information such as the service instance name, the host name, or service properties.

[1.1. Terminology](#)

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 [\[RFC2119\]](#).

Identity

In this document, the term "identity" refers to the identity of the entity (legal person) operating a device.

Disclosing an Identity In this document "disclosing an identity" means showing the identity of operating entities to devices external to the discovery process; e.g., devices on the same network link that are listening to the network traffic but are not actually involved in the discovery process. This document focuses on identity disclosure by data conveyed via messages on the service discovery protocol layer. Still, identity leaks on deeper layers, e.g., the IP layer, are mentioned.

Disclosing Information In this document "disclosing information" is also focused on disclosure by data conveyed via messages on the service discovery protocol layer.

2. Threat Model

This document considers the following attacker types sorted by increasing power. All these attackers can either be passive, i.e. they just listen to network traffic they have access to, or active, i.e. they additionally can craft and send (malicious) packets.

external An external attacker is not on the same network link as victim devices engaging in service discovery; thus, the external attacker is in a different multicast domain.

on-link An on-link attacker is on the same network link as victim devices engaging in service discovery; thus, the external attacker is in the same multicast domain. This attacker can also mount all attacks an external attacker can mount.

MITM A Man in the Middle (MITM) attacker either controls (parts of) a network link or can trick two parties to send traffic via him; thus, the MITM attacker has access to unicast traffic between devices engaging in service discovery. This attacker can also mount all attacks an on-link attacker can mount.

3. Threat Analysis

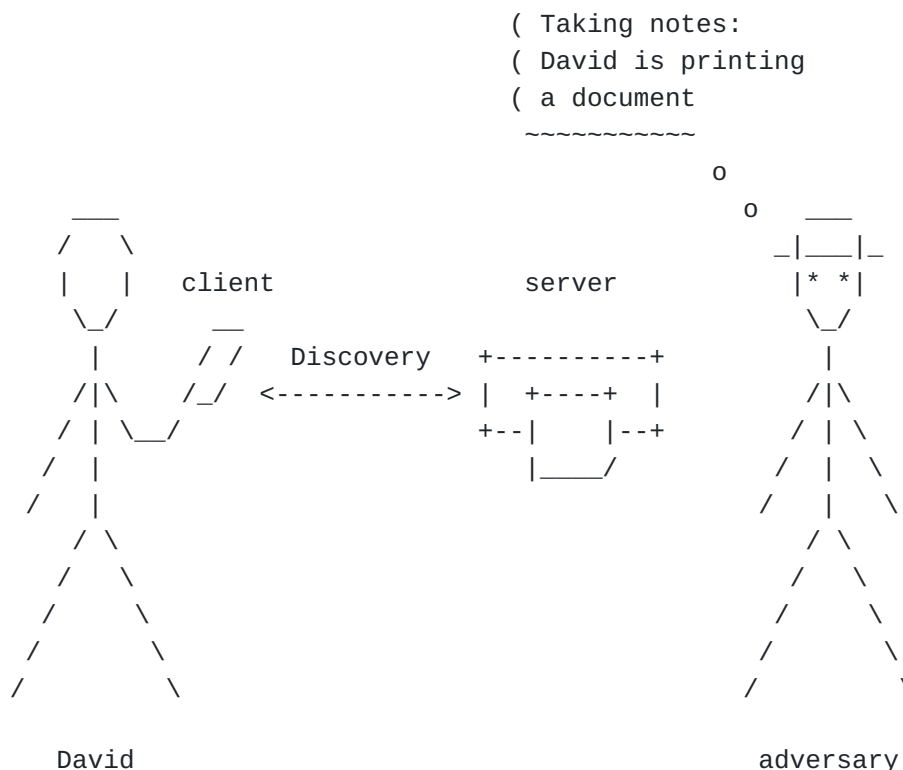
In this section we analyse how the attackers described in the previous section might threaten the privacy of legal persons operating devices engaging in service discovery. We focus on attacks leveraging data transmitted in service discovery protocol messages.

3.1. Service Discovery Scenarios

In this section, we review common service discovery scenarios and discuss privacy threats and their privacy requirements. In all three of these common scenarios the attacker is of the type passive on-link.

3.1.1. Private Client and Public Server

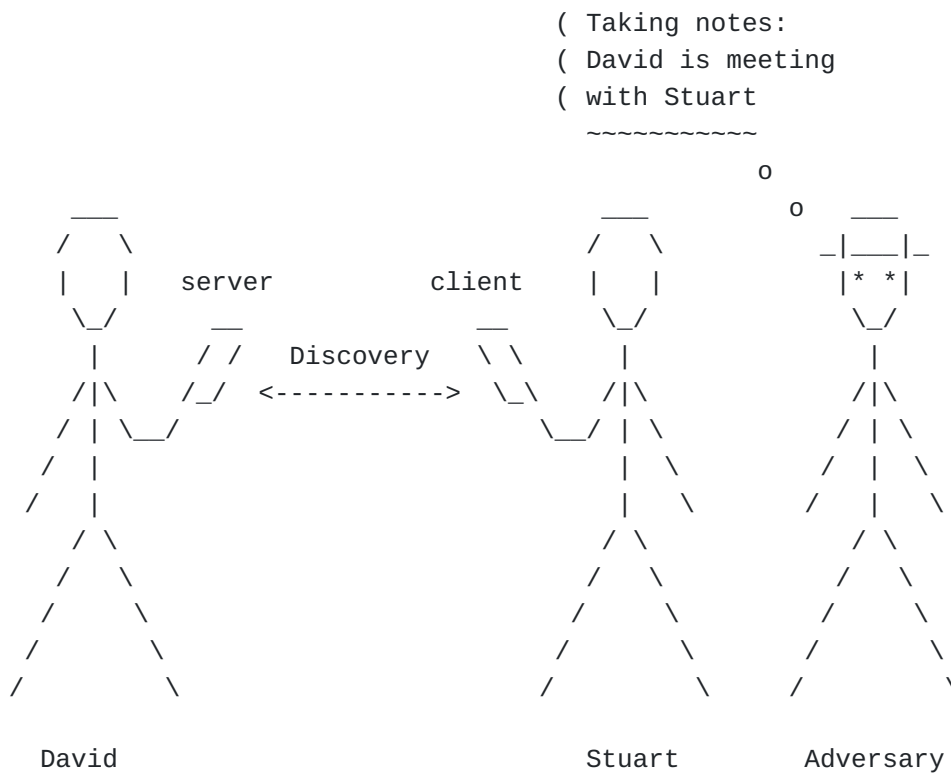
Perhaps the simplest private discovery scenario involves a single client connecting to a public server through a public network. A common example would be a traveler using a publicly available printer in a business center, in an hotel, or at an airport.



In that scenario, the server is public and wants to be discovered, but the client is private. The adversary will be listening to the network traffic, trying to identify the visitors' devices and their activity. Identifying devices leads to identifying people, either just for tracking people or as a preliminary to targeted attacks. The requirement in that scenario is that the discovery activity should not disclose the identity of the client.

3.1.2. Private Client and Private Server

The second private discovery scenario involves a private client connecting to a private server. A common example would be two people engaging in a collaborative application in a public place, such as for example an airport's lounge.



In that scenario, the collaborative application on one of the devices will act as a server, and the application on the other device will act as a client. The server wants to be discovered by the client, but has no desire to be discovered by anyone else. The adversary will be listening to network traffic, attempting to discover the identity of devices as in the first scenario, and also attempting to discover the patterns of traffic, as these patterns reveal the business and social interactions between the owners of the devices. The requirement in that scenario is that the discovery activity should not disclose the identity of either the client or the server.

3.1.3. Wearable Client and Server

The third private discovery scenario involves wearable devices. A typical example would be the watch on someone's wrist connecting to the phone in their pocket.

(Taking notes:
 (David' is here. His watch is
 (talking to his phone



This third scenario is in many ways similar to the second scenario. It involves two devices, one acting as server and the other acting as client, and it leads to the same requirement of the discovery traffic not disclosing the identity of either the client or the server. The main difference is that the devices are managed by a single owner, which can lead to different methods for establishing secure relations between the devices. There is also an added emphasis on hiding the type of devices that the person wears. In addition to tracking the identity of the owner of the devices, the adversary is interested in the characteristics of the devices, such as type, brand, and model. Identifying the type of device can lead to further attacks, from theft to device specific hacking. The combination of devices worn by the same person will also provide a "fingerprint" of the person, allowing identification.

3.2. DNS-SD Privacy Considerations

While the discovery process illustrated in the scenarios in [Section 2](#) most likely would be based on [\[RFC6762\]](#) as a means for making service information available, this document considers all kinds of means for making DNS-SD resource records available. These means comprise but are not limited to mDNS [\[RFC6762\]](#), DNS servers ([\[RFC1033\]](#) [\[RFC1034\]](#), [\[RFC1035\]](#)), e.g. using SRP [\[I-D.ietf-dnssd-srp\]](#), and multi-link [\[RFC7558\]](#) networks.

The discovery scenarios in [Section 3.1](#) illustrate three separate abstract privacy requirements that vary based on the use case. These are not limited to mDNS.

1. Client identity privacy: Client identities are not leaked during service discovery or use.
2. Multi-entity, mutual client and server identity privacy: Neither client nor server identities are leaked during service discovery or use.
3. Single-entity, mutual client and server identity privacy: Identities of clients and servers owned and managed by the same legal person are not leaked during service discovery or use.

In this section, we describe aspects of DNS-SD that make these requirements difficult to achieve in practice.

Client identity privacy, if not addressed properly, can be thwarted by a passive attacker (see [Section 2](#)). The type of passive attacker necessary depends on the means of making service information available. Information conveyed via multicast messages can be obtained by an on-link attacker, while unicast messages are only available to MITM attackers. Using multi-link service discovery solutions [\[RFC7558\]](#), external attackers have to be taken into consideration as well, e.g., when relaying multicast messages to other links.

Server identity privacy can be thwarted by a passive attacker in the same way as client identity privacy. Additionally, active attackers querying for information have to be taken into consideration as well. This is mainly relevant for unicast based discovery, where listening to discovery traffic requires a MITM attacker; however, an external active attacker might be able to learn the server identity by just querying for service information, e.g. via DNS.

[3.2.1. Information made available via DNS-SD Resource Records](#)

DNS-Based Service Discovery (DNS-SD) is defined in [\[RFC6763\]](#). It allows nodes to publish the availability of an instance of a service by inserting specific records in the DNS ([\[RFC1033\]](#), [\[RFC1034\]](#), [\[RFC1035\]](#)) or by publishing these records locally using multicast DNS (mDNS) [\[RFC6762\]](#). Available services are described using three types of records:

PTR Record: Associates a service type in the domain with an "instance" name of this service type.

SRV Record: Provides the node name, port number, priority and weight associated with the service instance, in conformance with [\[RFC2782\]](#).

TXT Record: Provides a set of attribute-value pairs describing specific properties of the service instance.

3.2.2. Privacy Implication of Publishing Service Instance Names

In the first phase of discovery, clients obtain all PTR records associated with a service type in a given naming domain. Each PTR record contains a Service Instance Name defined in Section 4 of [\[RFC6763\]](#):

Service Instance Name = <Instance> . <Service> . <Domain>

The <Instance> portion of the Service Instance Name is meant to convey enough information for users of discovery clients to easily select the desired service instance. Nodes that use DNS-SD over mDNS [\[RFC6762\]](#) in a mobile environment will rely on the specificity of the instance name to identify the desired service instance. In our example of users wanting to upload pictures to a laptop in an Internet Cafe, the list of available service instances may look like:

Alice's Images	. _imageStore._tcp	. local
Alice's Mobile Phone	. _presence._tcp	. local
Alice's Notebook	. _presence._tcp	. local
Bob's Notebook	. _presence._tcp	. local
Carol's Notebook	. _presence._tcp	. local

Alice will see the list on her phone and understand intuitively that she should pick the first item. The discovery will "just work". However, DNS-SD/mDNS will reveal to anybody that Alice is currently visiting the Internet Cafe. It further discloses the fact that she uses two devices, shares an image store, and uses a chat application supporting the _presence protocol on both of her devices. She might currently chat with Bob or Carol, as they are also using a _presence supporting chat application. This information is not just available to devices actively browsing for and offering services, but to anybody passively listening to the network traffic, i.e. a passive on-link attacker.

3.2.3. Privacy Implication of Publishing Node Names

The SRV records contain the DNS name of the node publishing the service. Typical implementations construct this DNS name by concatenating the "host name" of the node with the name of the local domain. The privacy implications of this practice are reviewed in [\[RFC8117\]](#). Depending on naming practices, the host name is either a strong identifier of the device, or at a minimum a partial identifier. It enables tracking of both the device, and, by extension, the device's owner.

3.2.4. Privacy Implication of Publishing Service Attributes

The TXT record's attribute-value pairs contain information on the characteristics of the corresponding service instance. This in turn

reveals information about the devices that publish services. The amount of information varies widely with the particular service and its implementation:

- *Some attributes like the paper size available in a printer, are the same on many devices, and thus only provide limited information to a tracker.

- *Attributes that have freeform values, such as the name of a directory, may reveal much more information.

Combinations of attributes have more information power than specific attributes, and can potentially be used for "fingerprinting" a specific device.

Information contained in TXT records does not only breach privacy by making devices trackable, but might directly contain private information about the user. For instance the `_presence` service reveals the "chat status" to everyone in the same network. Users might not be aware of that.

Further, TXT records often contain version information about services allowing potential attackers to identify devices running exploit-prone versions of a certain service.

3.2.5. Device Fingerprinting

The combination of information published in DNS-SD has the potential to provide a "fingerprint" of a specific device. Such information includes:

- *List of services published by the device, which can be retrieved because the SRV records will point to the same host name.

- *Specific attributes describing these services.

- *Port numbers used by the services.

- *Priority and weight attributes in the SRV records.

This combination of services and attributes will often be sufficient to identify the version of the software running on a device. If a device publishes many services with rich sets of attributes, the combination may be sufficient to identify the specific device.

A sometimes heard argument is that devices providing services can be identified by observing the local traffic, and that trying to hide the presence of the service is futile. However,

1. Providing privacy at the discovery layer is of the essence for enabling automatically configured privacy-preserving network applications. Application layer protocols are not forced to leverage the offered privacy, but if device tracking is not

prevented at the deeper layers, including the service discovery layer, obfuscating a certain service's protocol at the application layer is futile.

2. Further, in the case of mDNS based discovery, even if the application layer does not protect privacy, typically services are provided via unicast which requires a MITM attacker, while identifying services based on multicast discovery messages just requires an on-link attacker.

The same argument can be extended to say that the pattern of services offered by a device allows for fingerprinting the device. This may or may not be true, since we can expect that services will be designed or updated to avoid leaking fingerprints. In any case, the design of the discovery service should avoid making a bad situation worse, and should as much as possible avoid providing new fingerprinting information.

3.2.6. Privacy Implication of Discovering Services

The consumers of services engage in discovery, and in doing so reveal some information such as the list of services they are interested in and the domains in which they are looking for the services. When the clients select specific instances of services, they reveal their preference for these instances. This can be benign if the service type is very common, but it could be more problematic for sensitive services, such as for example some private messaging services. One way to protect clients would be to somehow encrypt the requested service types. Of course, just as we noted in [Section 3.2.5](#), traffic analysis can often reveal the service.

3.3. Security Considerations

For each of the operations described above, we must also consider security threats we are concerned about.

3.3.1. Authenticity, Integrity & Freshness

Can we trust the information we receive? Has it been modified in flight by an adversary? Do we trust the source of the information? Is the source of information fresh, i.e., not replayed? Freshness may or may not be required depending on whether the discovery process is meant to be online. In some cases, publishing discovery information to a shared directory or registry, rather than to each online recipient through a broadcast channel, may suffice.

3.3.2. Confidentiality

Confidentiality is about restricting information access to only authorized individuals. Ideally this should only be the appropriate trusted parties, though it can be challenging to define who are "the

appropriate trusted parties." In some uses cases, this may mean that only mutually authenticated and trusting clients and servers can read messages sent for one another. The "Discover" operation in particular is often used to discover new entities that the device did not previously know about. It may be tricky to work out how a device can have an established trust relationship with a new entity it has never previously communicated with.

3.3.3. Resistance to Dictionary Attacks

It can be tempting to use (publicly computable) hash functions to obscure sensitive identifiers. This transforms a sensitive unique identifier such as an email address into a "scrambled" but still unique identifier. Unfortunately simple solutions may be vulnerable to offline dictionary attacks.

3.3.4. Resistance to Denial-of-Service Attacks

In any protocol where the receiver of messages has to perform cryptographic operations on those messages, there is a risk of a brute-force flooding attack causing the receiver to expend excessive amounts of CPU time and, where applicable, battery power just processing and discarding those messages.

Also, amplification attacks have to be taken into consideration. Messages with larger payloads should only be sent as an answer to a query sent by a verified client.

3.3.5. Resistance to Sender Impersonation

Sender impersonation is an attack wherein messages such as service offers are forged by entities who do not possess the corresponding secret key material. These attacks may be used to learn the identity of a communicating party, actively or passively.

3.3.6. Sender Deniability

Deniability of sender activity, e.g., of broadcasting a discovery request, may be desirable or necessary in some use cases. This property ensures that eavesdroppers cannot prove senders issued a specific message destined for one or more peers.

3.4. Operational Considerations

3.4.1. Power Management

Many modern devices, especially battery-powered devices, use power management techniques to conserve energy. One such technique is for a device to transfer information about itself to a proxy, which will act on behalf of the device for some functions, while the device itself goes to sleep to reduce power consumption. When the proxy determines

that some action is required which only the device itself can perform, the proxy may have some way, such as Ethernet "Magic Packet", to wake the device.

In many cases, the device may not trust the network proxy sufficiently to share all its confidential key material with the proxy. This poses challenges for combining private discovery that relies on per-query cryptographic operations, with energy-saving techniques that rely on having (somewhat untrusted) network proxies answer queries on behalf of sleeping devices.

3.4.2. Protocol Efficiency

Creating a discovery protocol that has the desired security properties may result in a design that is not efficient. To perform the necessary operations the protocol may need to send and receive a large number of network packets. This may consume an unreasonable amount of network capacity, particularly problematic when it is a shared wireless spectrum. Further it may cause an unnecessary level of power consumption which is particularly problematic on battery devices, and may result in the discovery process being slow.

It is a difficult challenge to design a discovery protocol that has the property of obscuring the details of what it is doing from unauthorized observers, while also managing to do that efficiently.

3.4.3. Secure Initialization and Trust Models

One of the challenges implicit in the preceding discussions is that whenever we discuss "trusted entities" versus "untrusted entities", there needs to be some way that trust is initially established, to convert an "untrusted entity" into a "trusted entity".

One way to establish trust between two entities is to trust a third party to make that determination for us. For example, the X.509 certificates used by TLS and HTTPS web browsing are based on the model of trusting a third party to tell us whom to trust. There are some difficulties in using this model for establishing trust for service discovery uses. If we want to print our tax returns or medical documents on "our" printer, then we need to know which printer on the network we can trust to be "our" printer. All of the printers we discover on the network may be legitimate printers made by legitimate printer manufacturers, but not all of them are "our" printer. A third-party certificate authority cannot tell us which one of the printers is ours.

Another common way to establish a trust relationship is Trust On First Use (TOFU), as used by ssh. The first usage is a Leap Of Faith, but after that public keys are exchanged and at least we can confirm that subsequent communications are with the same entity. In today's world, where there may be attackers present even at that first use, it would be preferable to be able to establish a trust relationship without requiring an initial Leap Of Faith.

Techniques now exist for securely establishing a trust relationship without requiring an initial Leap Of Faith. Trust can be established securely using a short passphrase or PIN with cryptographic algorithms such as [Secure Remote Password \(SRP\)](#) or a Password Authenticated Key Exchange like [J-PAKE](#) using a [Schnorr Non-interactive Zero-Knowledge Proof](#).

Such techniques require a user to enter the correct passphrase or PIN in order for the cryptographic algorithms to establish working communication. This avoids the human tendency to simply press the "OK" button when asked if they want to do something on their electronic device. It removes the human fallibility element from the equation, and avoids the human users inadvertently sabotaging their own security. Without these techniques, users who try to print their tax return on a printer they've never used before will be tempted to just go ahead if the name looks right. With these techniques they'll be prompted to enter a pairing PIN, and *cannot* ignore that warning. They can't just press an "OK" button. They have to walk to the printer and read the displayed PIN and enter it. And if the intended printer is not displaying a pairing PIN, or is displaying a different pairing PIN, that means the user may be being spoofed, and the connection will not succeed, and the failure will not reveal any secret information to the attacker. As much as the human desires to "just give me an OK button to make it print", and the attacker desires them to click that OK button, too, the cryptographic algorithms do not give the user the ability to opt out of the security, and consequently do not give the attacker any way to persuade the user to opt out of the security protections.

[3.4.4. External Dependencies](#)

Trust establishment may depend on external, and optionally online, parties. Systems which have such a dependency may be attacked by interfering with communication to external dependencies. Where possible, such dependencies should be minimized. Local trust models are best for secure initialization in the presence of active attackers.

[4. Requirements for a DNS-SD Privacy Extension](#)

Given the considerations discussed in the previous sections, we state requirements for privacy preserving DNS-SD in the following subsections.

Defining a solution according to these requirements will lead to a solution that does not transmit privacy violating DNS-SD messages and further does not open pathways to new attacks against the operation of DNS-SD.

However, while this document gives advice on which privacy protecting mechanisms should be used on deeper layer network protocols and on how to actually connect to services in a privacy preserving way, stating corresponding requirements is out of the scope of this document. To mitigate attacks against privacy on lower layers, both servers and

clients must use privacy options available at lower layers, and for example avoid publishing static IPv4 or IPv6 addresses, or static IEEE 802 MAC addresses. For services advertised on a single network link, link local IP addresses should be used; see [\[RFC3927\]](#) and [\[RFC4291\]](#) for IPv4 and IPv6, respectively. Static servers advertising services globally via DNS can hide their IP addresses from unauthorized clients using the split mode topology shown in [\[I-D.ietf-tls-esni\]](#). Hiding static MAC addresses can be achieved via MAC address randomization (see [\[RFC7844\]](#)).

4.1. Private Client Requirements

For all three scenarios described in [Section 3.1](#), client privacy is a requirement. Client privacy, as a requirement, can be subdivided into:

1. DNS-SD messages transmitted by clients MUST NOT disclose the client's identity, either directly or via inference, to nodes other than select servers.
2. DNS-SD messages transmitted by clients MUST NOT contain linkable identifiers that allow tracing client devices.
3. DNS-SD messages transmitted by clients MUST NOT disclose the client's interest in specific service instances or service types to nodes other than select servers.

Listing and resolving services via DNS-SD, clients typically disclose their interest in specific services types and specific instances of these types, respectively.

Privacy solutions fulfilling these requirements must be resilient to fingerprinting attacks (see [Section 3.2.5](#)) that could be used for breaching these requirements.

4.2. Private Server Requirements

Servers like the "printer" discussed in scenario 1 are public, but the servers discussed in scenarios 2 and 3 are by essence private. Private servers have server privacy as a requirement, which can be subdivided into:

1. DNS-SD messages transmitted by servers MUST NOT disclose the server's identity, either directly or via inference, to nodes other than authorized clients. In particular, Servers MUST NOT publish static identifiers such as host names or service names. When those fields are required by the protocol, servers should publish randomized values. (See [\[RFC8117\]](#) for a discussion of host names.)
2. DNS-SD messages transmitted by servers MUST NOT contain linkable identifiers that allow tracing servers.

3. DNS-SD messages transmitted by servers MUST NOT disclose service instance names or service types of offered services to unauthorized clients.
4. DNS-SD messages transmitted by servers MUST NOT disclose information about the services they offer to unauthorized clients.
5. DNS-SD messages transmitted by servers MUST NOT disclose static IPv4 or IPv6 addresses.

Offering services via DNS-SD, servers typically disclose their hostnames (SRV, A/AAAA), instance names of offered services (PRT, SRV), and information about services (TXT). Heeding these requirements protects a server's privacy on the DNS-SD level.

4.3. Security and Operation

In order to be secure and feasible, a DNS-SD privacy extension must also heed the following security and operational requirements. All scenarios require:

1. DoS resistance: The privacy protecting measures added to DNS-SD MUST neither add a significant CPU overhead on nodes, nor cause significantly higher network load. Further, amplification attacks MUST NOT be allowed.

5. IANA Considerations

This draft does not require any IANA action.

6. Acknowledgments

This draft incorporates many contributions from Stuart Cheshire and Chris Wood. Thanks to Florian Adamsky for extensive review and suggestions on the organization of the threat model.

7. Informative References

[I-D.ietf-dnssd-srp]	Cheshire, S. and T. Lemon, " Service Registration Protocol for DNS-Based Service Discovery ", Internet-Draft draft-ietf-dnssd-srp-02, July 2019.
[I-D.ietf-tls-esni]	Rescorla, E., Oku, K., Sullivan, N. and C. Wood, " Encrypted Server Name Indication for TLS 1.3 ", Internet-Draft draft-ietf-tls-esni-05, November 2019.
[K17]	Kaiser, D., " Efficient Privacy-Preserving Configurationless Service Discovery Supporting Multi-Link Networks ", 2017.
[KW14a]	

	Kaiser, D. and M. Waldvogel, " Adding Privacy to Multicast DNS Service Discovery ", DOI 10.1109/TrustCom.2014.107, 2014.
[KW14b]	Kaiser, D. and M. Waldvogel, " Efficient Privacy Preserving Multicast DNS Service Discovery ", DOI 10.1109/HPCC.2014.141, 2014.
[RFC1033]	Lottor, M., " Domain Administrators Operations Guide ", RFC 1033, DOI 10.17487/RFC1033, November 1987.
[RFC1034]	Mockapetris, P., " Domain names - concepts and facilities ", STD 13, RFC 1034, DOI 10.17487/RFC1034, November 1987.
[RFC1035]	Mockapetris, P., " Domain names - implementation and specification ", STD 13, RFC 1035, DOI 10.17487/RFC1035, November 1987.
[RFC2119]	Bradner, S., " Key words for use in RFCs to Indicate Requirement Levels ", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997.
[RFC2782]	Gulbrandsen, A., Vixie, P. and L. Esibov, " A DNS RR for specifying the location of services (DNS SRV) ", RFC 2782, DOI 10.17487/RFC2782, February 2000.
[RFC3927]	Cheshire, S., Aboba, B. and E. Guttman, " Dynamic Configuration of IPv4 Link-Local Addresses ", RFC 3927, DOI 10.17487/RFC3927, May 2005.
[RFC4291]	Hinden, R. and S. Deering, " IP Version 6 Addressing Architecture ", RFC 4291, DOI 10.17487/RFC4291, February 2006.
[RFC5054]	Taylor, D., Wu, T., Mavrogiannopoulos, N. and T. Perrin, " Using the Secure Remote Password (SRP) Protocol for TLS Authentication ", RFC 5054, DOI 10.17487/RFC5054, November 2007.
[RFC6762]	Cheshire, S. and M. Krochmal, " Multicast DNS ", RFC 6762, DOI 10.17487/RFC6762, February 2013.
[RFC6763]	Cheshire, S. and M. Krochmal, " DNS-Based Service Discovery ", RFC 6763, DOI 10.17487/RFC6763, February 2013.
[RFC7558]	Lynn, K., Cheshire, S., Blanchet, M. and D. Migault, " Requirements for Scalable DNS-Based Service Discovery (DNS-SD) / Multicast DNS (mDNS) Extensions ", RFC 7558, DOI 10.17487/RFC7558, July 2015.
[RFC7844]	Huitema, C., Mrugalski, T. and S. Krishnan, " Anonymity Profiles for DHCP Clients ", RFC 7844, DOI 10.17487/RFC7844, May 2016.
[RFC8117]	Huitema, C., Thaler, D. and R. Winter, " Current Hostname Practice Considered Harmful ", RFC 8117, DOI 10.17487/RFC8117, March 2017.
[RFC8235]	

	Hao, F., " Schnorr Non-interactive Zero-Knowledge Proof ", RFC 8235, DOI 10.17487/RFC8235, September 2017.
[RFC8236]	Hao, F., " J-PAKE: Password-Authenticated Key Exchange by Juggling ", RFC 8236, DOI 10.17487/RFC8236, September 2017.

Authors' Addresses

Christian Huitema Huitema Private Octopus Inc. Friday Harbor, WA
98250 U.S.A. EMail: huitema@huitema.net URI: <http://privateoctopus.com/>

Daniel Kaiser Kaiser University of Luxembourg 6, avenue de la Fonte
Esch-sur-Alzette, 4364 Luxembourg EMail: daniel.kaiser@uni.lu URI:
<https://secan-lab.uni.lu/>