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Scalable DNS-SD (SSD) Threats
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Abstract

mDNS combined with Service Discovery (DNS-SD) extends network resource distribution beyond the reach of multicast normally limited by the MAC Bridge. Since related resources are often not authenticated, either local resources are inherently trustworthy or are subsequently verified by associated services. Resource distribution becomes complex when a hybrid scheme combines adjacent network resources into a common unicast DNS-SD structure. This document explores related security considerations.

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 [RFC2119].

Status of This Memo

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1. Introduction

As described by [IEEE.802-1D.2004], MAC entities normally make services known via multicast announcements that do not extend beyond the Bridge as a basis for networking and layer 3 protocols. mDNS [RFC6762] allows non-centralized resource collection that can be structured as defined in DNS-SD [RFC6763]. This structure, when used in conjunction with DNS [RFC1035], provides an alternative to multicast announcement to deal with wireless links that are orders of magnitude less reliable than their wired counterparts. To improve transmission reliability, [IEEE.802-11.2012] requires positive

acknowledgement of unicast frames but does not support positive acknowledgement of multicast frames. In [IEEE.802-11.2012] wireless networks, multicast frames are transmitted at a lower data rate supported by all receivers. Multicast on wireless networks may thereby lower overall network throughput. Some network administrators block some multicast traffic or convert it to a series of link-layer unicast frames. Other types of wireless networks may impose more demanding limitations as described by [RFC4944]. As a result, it is common to observe much higher loss of multicast frames on wireless compared against wired network technologies.

A namespace structured from adjacent networks using proxy-ed mDNS resources lacks a means to quickly resolve unicast name collision. Although an expensive promiscuous mode of unicast operation at multicast destinations might replicate mDNS features within a unicast environment, not well covered in [RFC4903] are issues related to wireless upstream clients unable to operate in promiscuous mode, indeterminate latency, and PPP links requiring a NAT or IPv4 ARP proxy. As such, a non-hybrid multicast/unicast scheme would be problematic.

Scalable DNS-SD (SSD) proposes to automatically gather autonomously named mDNS [RFC6762] resources of adjacent networks within separate namespace zones or realms as defined by [RFC7368]. Realms are often contained in separate subdomains that correspond with a link-local namespace. Making routable resources visible and accessible from other networks via unicast DNS [RFC1035] structured per DNS-SD [RFC6763] mitigates the level of multicast mDNS traffic in larger networks. Reliance on DNS [RFC1035] might leverage multi-network configurations that use mDNS [RFC6762] that proxy mDNS resources into DNS-SD using [I-D.ietf-dnssd-hybrid].

1.1. Terminology and Abbreviations

o Border: A point, typically resident on a router, between two networks at which filtering and forwarding policies for different types of traffic may be applied.

o ISP: Internet Service Provider. An entity that provides access to the Internet. In this document, a service provider specifically offers Internet access using IPv6 and may also offer IPv4 Internet access. The service provider can provide such access over a variety of different transport methods such as DSL, cable, wireless, and others.

o Realm: A network delimited by a defined border. i.e. a guest network within a homenet may form a realm.

o ULA: IPv6 Unique Local Address [RFC4193].

o Global Namespace: A globally unique namespace accessible for resolution within the root domain.

o Realm Namespace: A realm specific namespace accessible for resolution referenced from a subdomain that may not be within the root domain.

o Local Namespace: A namespace accessible for link-local resolution that may be referenced from an Ambiguous Local Qualified Domain Name (ALQDN) representing a network segment or broadcast domain.

2. Scalable DNS-SD (SSD) Realm and Global Namespace

2.1. Realm and Global Names

Conflicts between realm and global DNS [RFC1035] namespaces may occur. Without adequate feedback and latency constraints, a client may be unable to determine desired service targets. Target assessment may impair network stability when a cache policy renames resources propagated into different realms. Determining actual conflicts might depend on inherent identifiers such as MAC addresses or device specific GUIDs, otherwise conflict resolution may become increasingly byzantine.

2.1.1. SSD Structures

SSD locates SRV and TXT RRsets resources in the forms:

_<sn>._<Proto>.<SrvDOM>.<ParentDOM>.

<Instance>._<sn>._<Proto>.<SrvDOM>.<ParentDOM>.

<sub>._sub._<sn>._<Proto>.<SrvDOM>.<ParentDOM>.

For DNS-SD, Proto="_udp" represents all non-TCP transports otherwise it is "_tcp".

_<sn> = IANA Registered Service Name

To facilitate browsing, DNS-SD also supports a DNS meta-query of PTR RRsets at "_services._dns-sd._udp.<Domain>" which yields service names which may vary by host along with a domain name. Only the first two labels in the PTR rdata are relevant in the construction of subsequent Service Instance Enumeration PTR queries to further discover specific service types.

[I-D.ietf-dnssd-hybrid] conveyance extends '.local.' TLD namespace into '.home.' or an Ambiguous Local Qualified Domain Name (ALQDN) space, such as '.sitelocal.' as described in Section 3.7.4 of [RFC7368] where DNS [RFC1035] can be facilitated using split horizon methods described by [RFC6950] or similar schemes described by [RFC6281]. The scheme supporting DNS should ensure queries against a sitelocal namespace is not forwarded to the Internet and to global root servers.

[I-D.ietf-dnssd-hybrid] suggests a split of traditional namespace that is restricted to letters, digits and hyphens and resolves only address resources, from the rich text namespace resolving PTR, SRV and TXT that facilitate service browsing. These resources are further bifurcated into separate link related namespace resources.

2.1.2. Scope of Discovery

As mDNS [RFC6762] is currently restricted to a single link, the scope of the advertisement is limited, by design, to the shared link between client and the device offering a service. When scaling for multi-links, the owner of the advertised service may propagate to a larger set of links or a larger realm than expected, which may result in unauthorized clients (from the perspective of the owner) connecting to the advertised service. It also discloses information (about the host and service) to a larger set of potential attackers.

If the scope of the discovery is not properly constrained, then information leaks may happen beyond the appropriate network and expose the network to various forms of attack. As such, services normally limited to local link should be assigned a separate subdomain normally not accessible from the Internet.

To reduce the amount of multicast traffic, widely distributing mDNS resources using unicast DNS-SD may scale better, but exposure of mDNS [RFC6762] derived resources to the Internet along with possibly sensitive details has proven problematic as noted by [CERTvu550620]. Protocol vulnerabilities can be found in reports published by a large number of vendors, Computer Emergency Response Teams (CERT), and Computer Security Incident Response Teams (CSIRT). With this diversity of sources, specific concerns may not be captured by Request for Comments (RFC) publications of the Internet Engineering Task Force (IETF).

Services might be sought outside the ".local." domain when applications obtain domain search lists provided by DHCP ([RFC2131] and [RFC3315] for IPv4 and IPv6 respectively or RA DNSSL [RFC6106] also for IPv6. Internet domains need to be published in DNS [RFC1035] as A-Labels [RFC3492] because IDNA2008 compliance depends on A-label enforcement by registrars. Therefore A-Labels and not U-Labels are published in DNS for Internet domains at this time.

The SRV scheme used by mDNS [RFC6762] has also been widely adopted in the Windows OS since it offered a functional replacement for Windows Internet Name Service (WINS) as their initial attempt lacked sufficient name hierarchy. Such common use may represent security considerations whenever these records might become automatically published.

2.1.2.1. Visual Spoofing

Visual selection of autonomously named resources becomes especially salient when names are not ensured to be uniquely represented. mDNS [RFC6762] only requires compliance with [RFC5198] rather than IDNA2008 [RFC5895]. This less restrictive use of namespace may impair the defense of critical services from look-alike attack. mDNS [RFC6762] does not ensure instances are visually unique and allows spaces and punctuation not permitted by IDNA2008.

To better ensure local namespace can be recognized, alternative zones might replace ASCII punctuation and spaces in SrvDOM labels with the '_' character except when located as the leftmost character. Such a convention should reduce visual confusion and handling issues related to end of string parsing, since labels in DNS [RFC1035] normally do

not contain spaces or punctuation. Nevertheless, DNS [RFC1035] is able to handle such labels within sub-domains of registered domains.

2.1.3. Restricted Distribution of Sitelocal Addresses

ULA or [RFC1918] addresses allow safer automatic publication in DNS since these addresses are unlikely to be routed beyond the site. These addresses also provide a simple scheme to ascertain which addresses should be blocked at a network boundary. The use of other addresses MUST require specific administrative confirmations. It should be noted in the Addendum example, the Brother printer published a Globally routable address.

When doing so, address translation or overlays using Unique Local Addresses, ULAs [RFC4193] can offer a significant level of protection since typical link-local addresses are not usable from other networks. Although ULAs are to be treated as being globally routable, both ULA or [RFC1918] addresses typically indicate site local. Section 3.2 of [RFC4193] are locally defined and handled as Global addresses although not intended to be routed beyond the site or to those not having explicit routing provisions.

Section 4.1 of [RFC4193] indicates the default behavior of exterior routing protocol sessions between administrative routing regions must be to ignore receipt of and not advertise prefixes in the FC00::/7 block. A network operator may specifically configure prefixes longer than FC00::/7 for inter-site communication. Specifically, these prefixes are not designed to aggregate. Routers by default do not block ULA prefixes which makes it important to confirm how ULA traffic is handled by the access provider.

ULA or [RFC1918] addresses are not normally routed over the Internet where their use provides a degree of isolation. For either home or enterprise networks, ULAs as an overlay network avoids network address translations and permits local routing isolated from direct Internet access. ULAs also permit local communications to remain unaffected by Internet related link failures or scope limitations imposed by use of multicast protocols.

ULAs avoid a need to renumber internal-only private nodes when changing ISPs, or when ISPs restructure their address allocations. In these situations, use of ULA offers an effective tool for protecting internal-only nodes. As such, more than just the security considerations discussed in mDNS [RFC6762] and DNS-SD [RFC6763] are needed. For example, DNS-SD [RFC6763] states the following: "Since DNS-SD is just a specification for how to name and use records in the existing DNS, it has no specific additional security requirements over and above those that already apply to DNS queries and DNS

updates." This simply overlooks that many devices are not automatically published in DNS nor can it be assumed they are able to handle the access that DNS might permit.

Current BTMM [RFC6281] only publishes ULAs of hosts in DNS able to authenticate when setting up an overlay network. Remaining devices, such as printers, are accessed as services offered by authenticating hosts. DNS resources should never be considered to offer privacy even in split-horizon configurations. DNS is unable to authenticate incoming queries nor can it offer application layer protection. Since many prefixes are expected to be in use within environments served by [I-D.ietf-dnssd-hybrid], errors related to network boundary detections becomes critical. As such, DNS SHOULD NOT publish addresses of devices unable to authenticate sessions traversing the Internet.

2.1.4. Confirming Valid Resources

[RFC6950] Source Address Validation Improvement (SAVI) for DHCP as specified by [RFC7513] may help administrators qualify resources published in DNS. DNS-SD [RFC6763] recommends additional DNS records such as associated PTR and TXT SHOULD be generated to improve network efficiency for both unicast and multicast DNS-SD responses. This behavior further increases some risks related to query/response ratios and the likelihood of exposure of security sensitive information.

This new routable namespace also lacks the benefit of registrar involvement and may not afford an administrator an ability to mitigate nefarious activity, such as spoofing and phishing, without requisite controls having been first carefully established. When a device has access to different realms on multiple interfaces, it is not even clear how simple conflict resolution avoids threatening network stability while resolving names conveyed over disparate technologies.

2.1.5. Selective Forwarding based on IGMP or MLD snooping

Internet Group Management Protocol (IGMP) [RFC3376] supports multicast on IPv4 networks. Multicast Listener Discovery (MLD) [RFC3810] supports multicast management on IPv6 networks using ICMPv6 messaging in contrast to IGMP's bare IP encapsulation. This management allows routers to announce their multicast membership to neighboring routers. To optimize which LANs receive forwarded multicast frames, IGMP or MLD snooping can be used to determine the presence of listeners as a means to permit selective forwarding of multicast frames as well.

2.1.6. VLAN

Use of VLAN such as [RFC5517] can selectively extend multicast forwarding beyond Bridge limitations. While not a general solution, use of VLAN can both isolate and unite specific networks.

2.1.7. DHCP

IP address assignment and host registration might use a single or forwarded DHCP [RFC2131] or [RFC3315] server for IPv4 and IPv6 respectively that responds to interconnected networks as a means to register hosts and addresses. DHCP does not ensure against name or address conflict nor is it intended to configure routers.

2.2. Exfiltration and Poisoning

IP addresses made visible by DNSSEC [RFC4033] or DNS [RFC1035] that conform with DNS-SD [RFC6763] might be used, but the automated population of information into DNS [RFC1035] should be limited to administrative systems.

Automated conversion of mDNS [RFC6762] into unicast DNS [RFC1035] can be problematic from a security standpoint as can widespread propagation of multicast frames. mDNS [RFC6762] only requires compliance with [RFC5198] rather than IDNA2008 [RFC5895]. This means mDNS [RFC6762] will not ensure instances are visually unique and may contain spaces and punctuation not permitted by IDNA2008. As such, this might cause users into becoming misled about the associated service.

SSD MUST include requisite filtering necessary to prevent data ex-filtration or the interception of sensitive services. Any exchanged data must first ensure locality, limit the resources gathered, resolved, and propagated to just those elements that can be effectively administrated. It is critical to ensure normal network protection is not lost for hosts that depend on link-local addressing and exclusion of routable traffic. A printer would be one such example of a host that can not be upgraded.

2.3. Amplification Concerns

It is unknown whether sufficient filtering of mDNS [RFC6762] to expose just those services likely needed will provide sufficient network protection. The extent of using IGMP or MLD for selective forwarding to mitigate otherwise spurious traffic is unknown.

Instance names and <SrvDOM> intended to correspond with link-local domains may use Unicode for Network Interchange [RFC5198] encoding

but excludes ASCII control characters while also allowing escaped periods "\." and other punctuation and spaces.

For DNS-SD, Proto="_udp" represents all non-TCP transports otherwise it is "_tcp".

_<sn> = IANA Registered Service Name

Optional service browsing and various RRsets could result in large responses limited only by an MTU that may become fairly large in various HomeNet networking protocols.

Increased reliance on Resource Record Sets (RRsets) for discovery increases DDoS amplification concerns when overall RRset size is overlooked. The extent of this amplification had been constrained by the minimum MTU first established by [RFC0791] and noted by [RFC1191] of 576 bytes which accommodates 512 byte UDP DNS messages. Most Internet links are now able to handle much larger MTUs. Per [RFC2460], the minimum 1280 byte MTU is specified for IPv6.

To ensure minimal latency, DNS queries are first made using UDP. When a response becomes truncated, TCP is then normally attempted. Reliance on UDP has been relaxed by [RFC5966]. The size of a PTR RRset can be fairly large and result in UDP amplification issues when carried within a large minimum MTU. The potential query/response ratio may have a large impact on ISPs and in turn impact a large number of users.

At each of the DNS-SD SRV and TXT Resource Record Sets locations that offer instance and service enumerations, administration of the resulting RRsets must ensure these resources are suitable for distribution and the DNS-SD query to response ratio is suitable for Internet access.

DNS-SD [RFC6763] should not be viewed as a catalog structure of desired services suitable for Internet use. [I-D.ietf-dnssd-hybrid] is to be used to bridge adjacent networks but this risks conveying resources of hosts unable to safely facilitate Internet access. Since [I-D.ietf-dnssd-hybrid] should opt for the most conservative address mode when selecting addresses to be distributed, ULAs or [RFC1918] address should represent a default option rather than selecting GUAs.

Browsing change notification facilitated with [I-D.ietf-dnssd-push] uses the message structure defined by [RFC2136] but is based on TCP. TCP eliminates spoofed source query attacks and congestion issues. If neither QTYPE nor QCLASS are ANY (255) then this is a specific subscription to changes for the given name. When QTYPE or QCLASS are

ANY (255) then this becomes a wildcard subscription to changes of the given name for any type and/or class, as appropriate.

Browsing resource synchronization should use [I-D.ietf-dnssd-push] instead of depending on expanded RRsets or UDP transactions. Directly using DNS when overloaded would be much slower. This is because DNS [RFC1035] recommends 5 second timeouts with a doubling on two subsequent retries for a total of 35 seconds.

2.3.1. Resource Exhaustion Threats

DNS is currently vulnerable whenever responses are much larger than associated queries which could occur when browsing a domain offering services from a large number of hosts. To mitigate specific problematic query sources, an experimental mode of DNS operation is described in a technical note: DNS Response Rate Limiting [ISC-TN-2012-1-Draft1]. Additional information is available at [RedBarn].

Another experiment is [I-D.ietf-dnsop-cookies] which reduces reliance on DNS Response Rate Limiting and minimizes resources needed to handle random initial exchanges in a manner as described by [RFC6013] for forged sources of initial TCP <Syn> where servers keep client state within encrypted cookies.

3. Protection of SSD related interchange

SSD protocols may require additional steps to ensure against the poisoning of resource collection where close attention should be given to the scope of a ULA or [RFC1918] where the related resources are not to be directly exchanged with the Internet.

3.1. Link-Local

[RFC3927] provides an overview of IPv4 address complexities related to dealing with multiple segments and interfaces. IPv6 introduces new paradigms in respect to interface address assignments which offer scoping as explained in [RFC4291].

3.2. Authorization Issues

DNSSEC [RFC4033] can assert the validity but not the veracity of records in a zone file. The trust model of the global DNS [RFC1035] relies on the fact that human administrators either a) manually enter resource records into a zone file, or b) configure the DNS [RFC1035] server to authenticate a trusted device (e.g., a DHCP server) that can automatically maintain such records.

An imposter may register on the local link and appear as a legitimate service. Such "rogue" services may then be automatically registered in wide area DNS-SD [RFC6763].

3.3. Authentication Issues

Up to now, the "plug-and-play" nature of mDNS [RFC6762] devices have relied only on physical connectivity to the local network. If a device is visible via mDNS [RFC6762], it had been assumed to be trusted. When multiple networks are involved, verifying a host is local using mDNS [RFC6762] is no longer possible so other verification schemes must be used.

3.4. Privacy Considerations

Mobile devices such as smart phones that can expose the location of their owners by registering services in arbitrary zones pose a risk to privacy. Such devices must not register their services in arbitrary zones without the approval of their operators. However, it should be possible to configure one or more "safe" zones, e.g., based on subnet prefix, in which mobile devices may automatically register their services.

As noted in [CERTvu550620] private security information is leaked in many cases. This includes hostnames and MACs, networking details, service related details such as those for Printers and NAS devices. Many consumer printers can not authenticate users or block addresses when connected with IPv6. Once this information is leaked, malefactors are thereby given unlimited access.

4. IANA Considerations

This document requires no IANA consideration.

5. Acknowledgements

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Appendix A. mDNS Example of Device Resolution Information

```
dns-sd -L "Brother MFC-9560CDW" _printer._tcp local
  Lookup Brother MFC-9560CDW._printer._tcp.local

16:00:26.965  Brother\032MFC-9560CDW._printer._tcp.local.
 can be reached at BRN30066C239958.local.:515
(interface 4) Flags: 2 txtvers=1 qtotal=1
pdl=application/vnd.hp-PCL,application/vnd.brother-hbp
rp=duerqxesz5090 ty=Brother\ MFC-9560CDW\
product=\(Brother\ MFC-9560CDW\)
adminurl=http://BRN30066C239958.local./
priority=75 usb_MFG=Brother usb_MDL=MFC-9560CDW
Color=T Copies=T Duplex=F PaperCustom=T Binary=T Transparent=T TBCP=F

Timestamp    A/R Flg if Hostname         Address                  TTL
16:14:34.855 Add  3  4 BRN30066C239958.local.
                       192.168.99.99                              245
16:14:34.856 Add  2  4 BRN30066C239958.local.
                       2699:9999:7300:1510:3205:5CFF:FE23:9958%<0>245

dns-sd -L "Canon MX920 series" _printer._tcp local.
Lookup Canon MX920 series._printer._tcp.local.

16:47:09.676  Canon\032MX920\032series._printer._tcp.local.
 can be reached at 9299990000.local.:515 (interface 4) Flags: 2
 txtvers=1 rp=auto note= qtotal=1 priority=60 ty=Canon\ MX920
 \ series product=\(Canon\ MX920\ series\)
 pdl=application/octet-stream adminurl=http://929999000000.local.
 usb_MFG=Canon usb_MDL=MX920\ series
 usb_CMD= UUID=00000000-0000-1000-8000-F4813999999
 Color=T Duplex=T Scan=T Fax=F mac=F4:81:39:99:99:99

dns-sd -G v4v6 "9299999000000.local."
Timestamp    A/R Flg if Hostname         Address                  TTL
17:07:12.460 Add  3  4 929999000000.local.
                       FE80:0000:0000:0000:F681:39FF:FE92:9999%en0 65
17:07:12.461 Add   2 4 929999000000.local.
                        192.168.99.108                             65
```

Appendix B. Uncontrolled Access Example

The risk is that adequate IPv6 filtering is simply not available on either current printers, scanners, cameras and other devices never intended to be used directly on the Internet.

For example, in the case of a printer:

```
ftp [DNS entry]

Trying 2699:9999:7300:1510:3205:5cff:fe23:9958...
Connected to [DNS entry]
220 FTP print service:V-1.13/Use the network password for the ID if
updating.
Name (BRN30066C239958.local.:dlr): ftp
230 User ftp logged in.
ftp> ls
229 Entering Extended Passive Mode (|||62468|)
150 Transfer Start
total 1
-r--r--r--   1 root     printer   4096 Sep 28  2001 CFG-PAGE.TXT
----------   1 root     printer      0 Sep 28  2001 Toner-Low-------
226 Data Transfer OK.
ftp>
```

From here, I can print a file with no further authentication. But the printer also now appears on the Internet with TCP ports 21,23,25,80,515,631 and 9100 active. I can scan a document that was left in the flatbed. I can send a fax. Or I can print many copies of black pages if I want to do a physical DOS. And, thanks to the globally routable address present, I can reach this from anywhere in the world.

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