

Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 5, 2015

Z. Hu
L. Zhu
J. Heidemann
USC/Information Sciences
Institute
A. Mankin
D. Wessels
Verisign Labs
July 4, 2014

Starting TLS over DNS
draft-hzhwm-start-tls-for-dns-01

Abstract

This document describes a technique for upgrading a DNS TCP connection to use Transport Layer Security (TLS) over standard ports. Encryption provided by DNS-over-TLS eliminates opportunities for eavesdropping of DNS queries in the network. The proposed mechanism is backwards compatible with clients and servers that are not aware of DNS-over-TLS.

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 <http://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 January 5, 2015.

Copyright Notice

Copyright (c) 2014 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 (<http://trustee.ietf.org/license-info>) in effect on the date of

Internet-Draft

Starting TLS over DNS

July 2014

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.

1. Introduction

Today, nearly all DNS queries ([[RFC1034](#)] and [[RFC1035](#)]) are sent unencrypted, which makes them vulnerable to eavesdropping by an attacker that has access to the network channel, reducing the privacy of the querier. Recent news reports have elevated these concerns, and ongoing efforts are beginning to identify privacy concerns about DNS ([[draft-bortzmeyer-dnsop-dns-privacy](#)]).

Prior work has addressed some aspects of DNS security, but none addresses privacy between a DNS client and server using standard protocols. DNS Security Extensions (DNSSEC, [[RFC4033](#)]) provide _response integrity_ by defining mechanisms to cryptographically sign zones, allowing end-users (or their first-hop resolver) to verify replies are correct. DNSSEC however does nothing to protect request or response privacy. Traditionally, either privacy was not considered a requirement for DNS traffic, or it was assumed that network traffic was sufficiently private, however these perceptions are evolving due to recent events.

More recently, DNSCurve [[draft-dempsey-dnscurve](#)] defines a method to provide link-level confidentiality and integrity between DNS clients and servers. However, it does so with a new cryptographic protocol and so does not take advantage of TLS. ConfidentialDNS [[draft-wijngaards-confidentialdns](#)] and IPSECA [[draft-osterweil-dane-ipsec](#)] use opportunistic encryption to provide privacy for DNS queries and responses. However, it is unclear how a client can locate an RR specific to its first-hop resolver. Finally, others have suggested DNS-over-TLS. Recent work suggests DNS-over-TLS ([[draft-bortzmeyer-dnsop-privacy-sol](#)]), and the Unbound DNS software [[unbound](#)] includes a DNS-over-TLS implementation. However, neither defines methods to negotiate TLS use over an existing connection; unbound instead requires DNS-over-TLS to run on a different port.

the TO bit set.

DNS clients MAY set the TO bit in the initial query sent to a server using TCP transport to signal their desire that the TCP connection be upgraded to TLS. DNS clients MUST NOT set the TO bit on subsequent queries when using TCP or TLS transport (to avoid ambiguity).

Since the motivation for DNS-over-TLS is to preserve privacy, DNS clients SHOULD use a query that reveals no private information in the initial TO=1 query to a server. To provide a standard "dummy" query, it is RECOMMENDED to send the initial query with RD=0, QNAME="STARTTLS", QCLASS=CH, and QTYPE=TXT ("STARTTLS/CH/TXT")

analogous to administrative queries already in widespread use [[RFC4892](#)].

After sending the initial TO=1 query using TCP transport, DNS clients MUST wait for the initial response before sending any subsequent queries over the same TCP connection.

[2.1.2.](#) Receiving Responses

A DNS client that receives a response using UDP transport that has the TO bit set MUST handle that response as usual. It MAY record the server's support for DNS-over-TLS and use that information as part of its server selection algorithm in the case where multiple servers are available to service a particular query.

A DNS client that receives a response to its initial query using TCP transport that has the TO bit set MUST immediately initiate a TLS handshake using the procedure described in [[RFC5246](#)].

A DNS client that receives a response to its initial query using TCP transport that has the TO bit clear MUST not initiate a TLS handshake and SHOULD utilize the existing TCP connection for subsequent queries. DNS clients SHOULD remember server IP addresses that don't support DNS-over-TLS (including TLS handshake failures) and SHOULD NOT request DNS-over-TLS from them for reasonable period. (We suggest 1 hour, or when the client discovers a new resolver.)

[2.2.](#) Use by DNS Servers

[2.2.1.](#) Receiving Queries

A DNS server receiving a query over UDP MUST ignore the TO bit.

A DNS server receiving a query over an existing TLS connection MUST ignore the TO bit.

A DNS server receiving an initial query over TCP that has the TO bit set MAY inform the client it is willing to establish a TLS session, as described in the next section.

A DNS server receiving subsequent queries over TCP MUST ignore the TO bit. (A client wishing to start TLS after the initial query MUST open a new TCP connection to do so.)

[2.2.2.](#) Sending Responses

A DNS server sending a response over UDP SHOULD set the TO bit to indicate its general support for DNS-over-TLS, as long as it is

willing and able to support a TLS connection with the particular client.

A DNS server receiving an initial query over TCP that has the TO bit set MAY set the TO bit in its response. The server MUST then proceed with the TLS handshake protocol.

A DNS server receiving a "dummy" STARTTLS/CH/TXT query over TCP MUST respond with RCODE=0 and a TXT RR in the Answer section. Contents of the TXT RR are strictly informative (for humans) and MUST NOT be interpreted by the client software. Recommended TXT RDATA values are "STARTTLS" or "NO_TLS".

[2.3.](#) Established Sessions

After TLS negotiation completes, the connection will be encrypted and is now protected from eavesdropping and normal DNS queries SHOULD take place.

Both clients and servers SHOULD follow existing DNS-over-TCP timeout rules, which are often implementation- and situation-dependent. In the absence of any other advice, the RECOMMENDED timeout values are

30 seconds for recursive name servers, 60 seconds for clients of recursive name servers, 10 seconds for authoritative name servers, and 20 seconds for clients of authoritative name servers. Current work in this area may assist DNS-over-TLS clients and servers select useful timeout values [[draft-wouters-edns-tcp-keepalive](#)] [[tdns](#)].

As with current DNS-over-TCP, DNS servers MAY close the connection at any time (e.g., due to resource constraints). As with current DNS-over-TCP, clients MUST handle abrupt closes and be prepared to reestablish connections and/or retry queries. DNS servers SHOULD use the TLS close-notify request to shift TCP TIME-WAIT state to the clients.

DNS servers SHOULD enable fast TLS session resumption [[RFC5077](#)] to avoid keeping per-client session state.

[2.4.](#) Downgrade Attacks and Middleboxes

Middleboxes [[RFC3234](#)] may be present in some networks and have been known to interfere with normal DNS resolution and create problems for DNS-over-TLS. Remarkably, downgrade attacks can affect plaintext protocols that utilize "STARTTLS" signaling in a similar way. A DNS client attempting DNS-over-TLS through a middlebox, or in the presence of a downgrade attack, could have one of the following outcomes (as discussed in prior RFCs [[RFC3207](#)]):

1. The DNS client sends a T0=1 query and receives a T0=0 response. In this case there is no upgrade to TLS and DNS resolution occurs normally, without encryption.
2. The DNS client sends a T0=1 query and receives a T0=1 response, but the TLS handshake fails because the server's certificate cannot be authenticated. In this case the client SHOULD close the established connection and fall back to unencrypted DNS for a reasonable period (as discussed in [Section 2.1.2](#)).
3. The DNS client sends a T0=1 query and receives a T0=1 response, but the middlebox does not understand the TLS negotiation. Middleboxes SHOULD clear T0 in replies if they are not prepared to pass through TLS negotiation. Clients SHOULD retry DNS without T0 set if negotiation fails, and then retry with TLS

after a reasonable period (see [Section 2.1.2](#)).

4. The DNS client sends a T0=1 query but receives no response at all. The middlebox might be silently dropping the query due to the presence of the T0 bit, when it should, in fact, ignore and pass through unknown flag bits [[RFC6891](#)]. The client SHOULD fall back to normal (unencrypted) DNS for a reasonable period (as discussed in [Section 2.1.2](#)).

In general, clients that attempt TLS and fail can either fall back on unencrypted DNS, or wait and retry later, depending on their privacy requirements. If the problem of middleboxes and threat of downgrade attacks is too serious, the IETF might consider allocating a dedicated port for DNS-over-TLS [[RFC6335](#)].

[3.](#) Performance Considerations

DNS-over-TLS incurs additional latency at session startup. It also requires additional state (memory) increased processing (CPU).

1. Latency: Compared to UDP, DNS-over-TCP requires an additional round-trip-time (RTT) of latency to establish the connection. The TLS handshake adds another two RTTs of latency. Clients and servers should support connection keepalive (reuse) and out-of-order processing to amortize connection setup costs. Moreover, TLS connection resumption can further reduce the setup delay.
2. State: The use of connection-oriented TCP requires keeping additional state in both kernels and applications. TLS has marginal increases in state over TCP alone. The state requirements are of particular concerns on servers with many clients. Smaller timeout values will reduce the number of

concurrent connections, and servers can preemptively close connections when resources limits are exceeded.

3. Processing: Use of TLS encryption algorithms results in slightly higher CPU usage. Servers can choose to refuse new DNS-over-TCP clients if processing limits are exceeded.

A full performance evaluation is outside the scope of this

specification. A more detailed analysis of the performance implications of DNS-over-TLS (and DNS-over-TCP) is discussed in a technical report [[tdns](#)].

[4.](#) IANA Considerations

This document defines a new bit ("TO") in the Flags field of the EDNS0 OPT meta-RR. At the time of approval of this draft in the standards track, as per the IANA Considerations of [RFC 6891](#), IANA is requested to reserve the second leftmost bit of the flags as the TO bit, immediately adjacent to the DNSSEC DO bit, as shown in [Section 2](#).

[5.](#) Security Considerations

The goal of this proposal is to address the security risks that arise because DNS queries may be eavesdropped upon, as described above. There are a number of residual risks that may impact this goal.

1. There are known attacks on TLS, such as person-in-the-middle and protocol downgrade. These are general attacks on TLS and not specific to DNS-over-TLS; we refer to the TLS RFCs for discussion of these security issues.
2. Any protocol interactions prior to the TLS handshake are performed in the clear and can be modified by a man-in-the-middle attacker. For this reason, clients MAY discard cached information about server capabilities advertised prior to the start of the TLS handshake.
3. As with other uses of STARTTLS-upgrade to TLS, the mechanism specified here is susceptible to downgrade attacks, where a person-in-the-middle prevents a successful TLS upgrade. Keeping track of servers known to support TLS (i.e., "pinning") enables clients to detect downgrade attacks. For servers with no connection history, clients may choose to refuse non-TLS DNS, or they may continue without TLS, depending on their privacy requirements.

4. This document does not propose new ideas for certificate

authentication for TLS in the context of DNS. Several external methods are possible, although each has weaknesses. The current Certificate Authority infrastructure [[RFC5280](#)] is used by HTTP/TLS [[RFC2818](#)]. With many trusted CAs, this approach has recognized weaknesses [[CA Compromise](#)]. Some work is underway to partially address these concerns (for example, with certificate pinning [[certificate pinning](#)], but more work is needed. DANE [[RFC6698](#)] provides mechanisms to root certificate trust with DNSSEC. That use here must be carefully evaluated to address potential issues in trust recursion. For stub-to-recursive resolver use, certificate authentication is sometimes either easy or nearly impossible. If the recursive resolver is manually configured, its certificate can be authenticated when it is configured. If the recursive resolver is automatically configured (such as with DHCP [[RFC2131](#)]), it could use DHCP authentication mechanisms [[RFC3118](#)]).

Ongoing discussion of opportunistic TLS (connections without CA validation, [[draft-hoffman-uta-opportunistic-tls](#)]) may be relevant to DNS-over-TLS.

[6.](#) Acknowledgments

We would like to thank Stephane Bortzmeyer, Brian Haberman, Paul Hoffman, Kim-Minh Kaplan, Bill Manning, George Michaelson, Eric Osterweil and Glen Wiley for reviewing this Internet-draft, and to Nikita Somaiya for early work on this idea.

Work by Zi Hu, Liang Zhu, and John Heidemann in this paper is partially sponsored by the U.S. Dept. of Homeland Security (DHS) Science and Technology Directorate, HSARPA, Cyber Security Division, BAA 11-01-RIKA and Air Force Research Laboratory, Information Directorate under agreement number FA8750-12-2-0344, and contract number D08PC75599.

[7.](#) References

[7.1.](#) Normative References

- [RFC1034] Mockapetris, P., "Domain names - concepts and facilities", STD 13, [RFC 1034](#), November 1987.
- [RFC1035] Mockapetris, P., "Domain names - implementation and specification", STD 13, [RFC 1035](#), November 1987.

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), March 1997.
- [RFC5077] Salowey, J., Zhou, H., Eronen, P., and H. Tschofenig, "Transport Layer Security (TLS) Session Resumption without Server-Side State", [RFC 5077](#), January 2008.
- [RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", [RFC 5246](#), August 2008.
- [RFC6891] Damas, J., Graff, M., and P. Vixie, "Extension Mechanisms for DNS (EDNS(0))", STD 75, [RFC 6891](#), April 2013.

[7.2](#). Informative References

- [CA_Compromise] Infosec Island Admin, "CA Compromise", January 2012, <<http://www.infosecisland.com/blogview/19782-Web-Authentication-A-Broken-Trust-with-No-Easy-Fix.html>>.
- [RFC1939] Myers, J. and M. Rose, "Post Office Protocol - Version 3", STD 53, [RFC 1939](#), May 1996.
- [RFC2131] Droms, R., "Dynamic Host Configuration Protocol", [RFC 2131](#), March 1997.
- [RFC2595] Newman, C., "Using TLS with IMAP, POP3 and ACAP", [RFC 2595](#), June 1999.
- [RFC2818] Rescorla, E., "HTTP Over TLS", [RFC 2818](#), May 2000.
- [RFC3118] Droms, R. and W. Arbaugh, "Authentication for DHCP Messages", [RFC 3118](#), June 2001.
- [RFC3207] Hoffman, P., "SMTP Service Extension for Secure SMTP over Transport Layer Security", [RFC 3207](#), February 2002.
- [RFC3234] Carpenter, B. and S. Brim, "Middleboxes: Taxonomy and Issues", [RFC 3234](#), February 2002.
- [RFC3501] Crispin, M., "INTERNET MESSAGE ACCESS PROTOCOL - VERSION 4rev1", [RFC 3501](#), March 2003.
- [RFC4033] Arends, R., Austein, R., Larson, M., Massey, D., and S. Rose, "DNS Security Introduction and Requirements",

- [RFC4892] Woolf, S. and D. Conrad, "Requirements for a Mechanism Identifying a Name Server Instance", [RFC 4892](#), June 2007.
- [RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", [RFC 5280](#), May 2008.
- [RFC6335] Cotton, M., Eggert, L., Touch, J., Westerlund, M., and S. Cheshire, "Internet Assigned Numbers Authority (IANA) Procedures for the Management of the Service Name and Transport Protocol Port Number Registry", [BCP 165](#), [RFC 6335](#), August 2011.
- [RFC6698] Hoffman, P. and J. Schlyter, "The DNS-Based Authentication of Named Entities (DANE) Transport Layer Security (TLS) Protocol: TLSA", [RFC 6698](#), August 2012.
- [certificate_pinning] OWASP, "Certificate and Public Key Pinning", <https://www.owasp.org/index.php/Certificate_and_Public_Key_Pinning>.
- [[draft-bortzmeyer-dnsop-dns-privacy](#)] Bortzmeyer, S., "DNS Privacy issues", [draft-bortzmeyer-dnsop-dns-privacy-01](#) (work in progress), November 2013, <<http://tools.ietf.org/html/draft-bortzmeyer-dnsop-dns-privacy-01>>.
- [[draft-bortzmeyer-dnsop-privacy-sol](#)] Bortzmeyer, S., "Solutions to DNS privacy issues", [draft-bortzmeyer-dnsop-privacy-sol-00](#) (work in progress), December 2013, <<http://tools.ietf.org/html/draft-bortzmeyer-dnsop-privacy-sol-00>>.
- [[draft-dempsky-dnscurve](#)] Dempsey, M., "DNSCurve", [draft-dempsky-dnscurve-01](#) (work in progress), August 2010, <<http://tools.ietf.org/html/draft-dempsky-dnscurve-01>>.

[[draft-hoffman-uta-opportunistic-tls](#)]

Hoffman, P., "Opportunistic Encryption Using TLS",
[draft-hoffman-uta-opportunistic-tls-00](#) (work in progress),
February 2014, <[http://tools.ietf.org/html/
draft-hoffman-uta-opportunistic-tls-00](http://tools.ietf.org/html/draft-hoffman-uta-opportunistic-tls-00)>.

[[draft-osterweil-dane-ipsec](#)]

Osterweil, E., Wiley, G., Mitchell, D., and A. Newton,

Hu, et al.

Expires January 5, 2015

[Page 10]

Internet-Draft

Starting TLS over DNS

July 2014

"Opportunistic Encryption with DANE Semantics and IPsec:
IPSECA", [draft-osterweil-dane-ipsec-00](#) (work in progress),
February 2014,
<[http://tools.ietf.org/html/
draft-osterweil-dane-ipsec-00](http://tools.ietf.org/html/draft-osterweil-dane-ipsec-00)>.

[[draft-wijngaards-confidentialdns](#)]

Wijngaards, W., "Confidential DNS",
[draft-wijngaards-dnsop-confidentialdns-00](#) (work in
progress), November 2013, <[http://tools.ietf.org/html/
draft-wijngaards-dnsop-confidentialdns-00](http://tools.ietf.org/html/draft-wijngaards-dnsop-confidentialdns-00)>.

[[draft-wouters-edns-tcp-keepalive](#)]

Wouters, P. and J. Abley, "The edns-tcp-keepalive EDNS0
Option", [draft-wouters-edns-tcp-keepalive-00](#) (work in
progress), October 2013, <[http://tools.ietf.org/html/
draft-wouters-edns-tcp-keepalive-00](http://tools.ietf.org/html/draft-wouters-edns-tcp-keepalive-00)>.

[tdns]

Zhu, L., Hu, Z., Heidemann, J., Wessels, D., Mankin, A.,
and N. Somaiya, "T-DNS: Connection-Oriented DNS to Improve
Privacy and Security", Technical report ISI-TR-688,
February 2014, <Technical report, ISI-TR-688,
<ftp://ftp.isi.edu/isi-pubs/tr-688.pdf>>.

[unbound]

NLnet Labs, Verisign labs, "Unbound", December 2013,
<<http://unbound.net/>>.

Authors' Addresses

Zi Hu
USC/Information Sciences Institute

4676 Admiralty Way, Suite 1133
Marina del Rey, CA 90292
USA

Phone: +1 213 587-1057
Email: zihu@usc.edu

Hu, et al.

Expires January 5, 2015

[Page 11]

Internet-Draft

Starting TLS over DNS

July 2014

Liang Zhu
USC/Information Sciences Institute
4676 Admiralty Way, Suite 1133
Marina del Rey, CA 90292
USA

Phone: +1 310 448-8323
Email: liangzhu@usc.edu

John Heidemann
USC/Information Sciences Institute
4676 Admiralty Way, Suite 1001
Marina del Rey, CA 90292
USA

Phone: +1 310 822-1511
Email: johnh@isi.edu

Allison Mankin
Verisign Labs
12061 Bluemont Way
Reston, VA 20190

Phone: +1 703 948-3200
Email: amankin@verisign.com

Duane Wessels
Verisign Labs
12061 Bluemont Way
Reston, VA 20190

Phone: +1 703 948-3200
Email: dwessels@verisign.com