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RFC 9018
Interoperable Domain Name System (DNS) Server Cookies

Abstract

DNS Cookies, as specified in RFC 7873, are a lightweight DNS transaction security mechanism that provide limited protection to DNS servers and clients against a variety of denial-of-service amplification, forgery, or cache-poisoning attacks by off-path attackers.

This document updates RFC 7873 with precise directions for creating Server Cookies so that an anycast server set including diverse implementations will interoperate with standard clients, with suggestions for constructing Client Cookies in a privacy-preserving fashion, and with suggestions on how to update a Server Secret. An IANA registry listing the methods and associated pseudorandom function suitable for creating DNS Server Cookies has been created with the method described in this document as the first and, as of the time of publication, only entry.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc9018.

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1. Introduction

DNS Cookies, as specified in [RFC7873], are a lightweight DNS transaction security mechanism that provide limited protection to DNS servers and clients against a variety of denial-of-service amplification, forgery, or cache-poisoning attacks by off-path attackers. This document specifies a means of producing interoperable cookies so that an anycast server set including diverse implementations can be easily configured to interoperate with standard clients. Also, single-implementation or non-anycast services can benefit from a well-studied standardized algorithm for which the behavioral and security characteristics are more widely known.

The threats considered for DNS Cookies and the properties of the DNS Security features other than DNS Cookies are discussed in [RFC7873].

In Section 6 of [RFC7873], for simplicity, it is "**RECOMMENDED** that the same Server Secret be used by each DNS server in a set of anycast servers." However, how precisely a Server Cookie is calculated from this Server Secret is left to the implementation.

This guidance has led to a gallimaufry of DNS Cookie implementations, calculating the Server Cookie in different ways. As a result, DNS Cookies are impractical to deploy on multi-vendor anycast networks because even when all DNS Software shares the same secret, as **RECOMMENDED** in Section 6 of [RFC7873], the Server Cookie constructed by one implementation cannot generally be validated by another.

There is no need for DNS client (resolver) Cookies to be interoperable across different implementations. Each client need only be able to recognize its own cookies. However, this document does contain recommendations for constructing Client Cookies in a client-protecting fashion.

1.1. Terminology and Definitions

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**NOT RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Note: "IP address" is used herein as a length-independent term covering both IPv4 and IPv6 addresses.

2. Changes to RFC 7873

Appendices A.1 and B.1 of [RFC7873] provide example "simple" algorithms for computing Client and Server Cookies, respectively. These algorithms **MUST NOT** be used as the resulting cookies are too weak when evaluated against modern security standards.

Appendix B.2 of [RFC7873] provides an example "more complex" server algorithm. This algorithm is replaced by the interoperable specification in Section 4 of this document, which **MUST** be used by Server Cookie implementations.

This document has suggestions on Client Cookie construction in Section 3. The previous example in Appendix A.2 of [RFC7873] is **NOT RECOMMENDED**.

3. Constructing a Client Cookie

The Client Cookie acts as an identifier for a given client and its IP address and needs to be unguessable. In order to provide minimal authentication of the targeted server, a client **MUST** use a different Client Cookie for each different Server IP address. This complicates a server's ability to spoof answers for other DNS servers. The Client Cookie **SHOULD** have 64 bits of entropy.

When a server does not support DNS Cookies, the client **MUST NOT** send the same Client Cookie to that same server again. Instead, it is recommended that the client does not send a Client Cookie to that server for a certain period (for example, five minutes) before it retries with a new Client Cookie.

When a server does support DNS Cookies, the client should store the Client Cookie alongside the Server Cookie it registered for that server.

Except for when the Client IP address changes, there is no need to change the Client Cookie often. It is then reasonable to change the Client Cookie only if it has been compromised or after a relatively long implementation-defined period of time. The time period should be no longer than a year, and in any case, Client Cookies are not expected to survive a program restart.

```
Client-Cookie = 64 bits of entropy
```

Previously, the recommended algorithm to compute the Client Cookie included the Client IP address as an input to a hashing function. However, when implementing the DNS Cookies, several DNS vendors found it impractical to include the Client IP as the Client Cookie is typically computed before the Client IP address is known. Therefore, the requirement to put the Client IP address as input was removed.

However, for privacy reasons, in order to prevent tracking of devices across links and to not circumvent IPv6 Privacy Extensions [RFC8981], clients **MUST NOT** reuse a Client or Server Cookie after the Client IP address has changed.

One way to satisfy this requirement for non-reuse is to register the Client IP address alongside the Server Cookie when it receives the Server Cookie. In subsequent queries to the server with that Server Cookie, the socket **MUST** be bound to the Client IP address that was also used (and registered) when it received the Server Cookie. Failure to bind **MUST** then result in a new Client Cookie.

4. Constructing a Server Cookie

The Server Cookie is effectively a Message Authentication Code (MAC). The Server Cookie, when it occurs in a COOKIE option in a request, is intended to weakly assure the server that the request came from a client that is both at the source IP address of the request and using the Client Cookie included in the option. This assurance is provided by the Server Cookie that the server (or any other server from the anycast set) sent to that client in an earlier response and that appears as the Server Cookie field in the weakly authenticated request (see Section 5.2 of [RFC7873]).

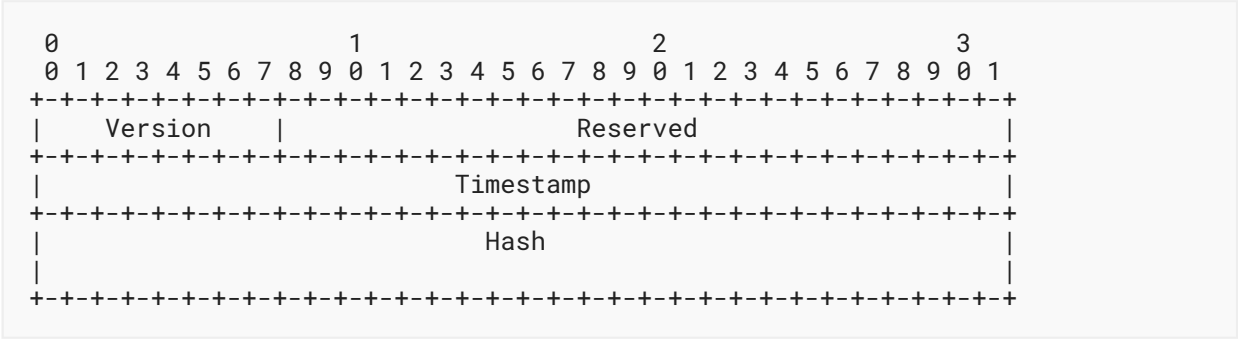
DNS Cookies do not provide protection against "on-path" adversaries (see Section 9 of [RFC7873]). An on-path observer that has seen a Server Cookie for a client can abuse that Server Cookie to spoof request for that client within the time span a Server Cookie is valid (see Section 4.3).

The Server Cookie is calculated from the Client Cookie, a series of Sub-Fields specified below, the Client IP address, and a Server Secret that is known only to the server or only to the set of servers at the same anycast address.

For calculation of the Server Cookie, a pseudorandom function is **RECOMMENDED** with the property that an attacker that does not know the Server Secret, cannot find (any information about) the Server Secret, and cannot create a Server Cookie for any combination of the Client Cookie, the series of Sub-Fields specified below, and the client IP address, for which it has not seen a Server Cookie before. Because DNS servers need to use the pseudorandom function in order to verify Server Cookies, it is **RECOMMENDED** that it be efficient to calculate. The pseudorandom function described in [SipHash-2-4] and introduced in Section 4.4 of this document fits these recommendations.

Changing the Server Secret regularly is **RECOMMENDED** but, when a secure pseudorandom function is used, it need not be changed too frequently. Once a month, for example, would be adequate. See Section 5 on operator and implementation guidelines for updating a Server Secret.

The 128-bit Server Cookie consists of the following Sub-Fields: a 1-octet Version Sub-Field, a 3-octet Reserved Sub-Field, a 4-octet Timestamp Sub-Field, and an 8-octet Hash Sub-Field.



4.1. The Version Sub-Field

The Version Sub-Field prescribes the structure and Hash calculation formula. This document defines Version 1 to be the structure and way to calculate the Hash Sub-Field as defined in this section.

4.2. The Reserved Sub-Field

The value of the Reserved Sub-Field is reserved for future versions of server-side cookie construction. On construction, it **MUST** be set to zero octets. On Server Cookie verification, the server **MUST NOT** enforce those fields to be zero, and the Hash should be computed with the received value as described in Section 4.4.

4.3. The Timestamp Sub-Field

The Timestamp value prevents Replay Attacks and **MUST** be checked by the server to be within a defined period of time. The DNS server **SHOULD** allow cookies within a 1-hour period in the past and a 5-minute period into the future to allow operation of low-volume clients and some limited time skew between the DNS servers in the anycast set.

The Timestamp value specifies a date and time in the form of a 32-bit **unsigned** number of seconds elapsed since 1 January 1970 00:00:00 UTC, ignoring leap seconds, in network byte order. All comparisons involving these fields **MUST** use "Serial number arithmetic", as defined in [RFC1982]. [RFC1982] specifies how the differences should be handled. This handles any relative time window less than 68 years, at any time in the future (2038, 2106, 2256, 22209, or later.)

The DNS server **SHOULD** generate a new Server Cookie at least if the received Server Cookie from the client is more than half an hour old, but it **MAY** generate a new cookie more often than that.

4.4. The Hash Sub-Field

It's important that all the DNS servers use the same algorithm for computing the Server Cookie. This document defines the Version 1 of the server-side algorithm to be:

```
Hash = SipHash-2-4(
    Client Cookie | Version | Reserved | Timestamp | Client-IP,
    Server Secret )
```

where "|" indicates concatenation.

Notice that Client-IP is used for hash generation even though it is not included in the cookie value itself. Client-IP can be either 4 bytes for IPv4 or 16 bytes for IPv6. The length of all the concatenated elements (the input into [SipHash-2-4]) **MUST** be either precisely 20 bytes in case of an IPv4 Client-IP or precisely 32 bytes in case of an IPv6 Client-IP.

When a DNS server receives a Server Cookie version 1 for validation, the length of the received COOKIE option **MUST** be precisely 24 bytes: 8 bytes for the Client Cookie plus 16 bytes for the Server Cookie. Verification of the length of the received COOKIE option is **REQUIRED** to guarantee the length of the input into [SipHash-2-4] to be precisely 20 bytes in the case of an IPv4 Client-IP and precisely 32 bytes in the case of an IPv6 Client-IP. This ensures that the input into [SipHash-2-4] is an injective function of the elements making up the input, and thereby prevents data substitution attacks. More specifically, this prevents a 36-byte COOKIE option coming from an IPv4 Client-IP to be validated as if it were coming from an IPv6 Client-IP.

The Server Secret **MUST** be configurable to make sure that servers in an anycast network return consistent results.

5. Updating the Server Secret

Changing the Server Secret regularly is **RECOMMENDED**. All servers in an anycast set must be able to verify the Server Cookies constructed by all other servers in that anycast set at all times. Therefore, it is vital that the Server Secret is shared among all servers before it is used to generate Server Cookies on any server.

Also, to maximize maintaining established relationships between clients and servers, an old Server Secret should be valid for verification purposes for a specific period.

To facilitate this, deployment of a new Server Secret **MUST** be done in three stages:

Stage 1
: The new Server Secret is deployed on all the servers in an anycast set by the operator.

  Each server learns the new Server Secret but keeps using the previous Server Secret to generate Server Cookies.

Server Cookies constructed with both the new Server Secret and the previous Server Secret are considered valid when verifying.

After stage 1 is completed, all the servers in the anycast set have learned the new Server Secret and can verify Server Cookies constructed with it, but keep generating Server Cookies with the old Server Secret.

Stage 2
: This stage is initiated by the operator after the Server Cookie is present on all members in the anycast set.

When entering Stage 2, servers start generating Server Cookies with the new Server Secret. The previous Server Secret is not yet removed/forgotten.

Server Cookies constructed with both the new Server Secret and the previous Server Secret are considered valid when verifying.

Stage 3
: This stage is initiated by the operator when it can be assumed that most clients have obtained a Server Cookie derived from the new Server Secret.

With this stage, the previous Server Secret can be removed and **MUST NOT** be used anymore for verifying.

It is **RECOMMENDED** that the operator wait, after initiating Stage 2 and before initiating Stage 3, at least a period of time equal to the longest TTL in the zones served by the server plus 1 hour.

The operator **SHOULD** wait at least longer than the period clients are allowed to use the same Server Cookie, which **SHOULD** be 1 hour (see Section 4.3).

6. Cookie Algorithms

[SipHash-2-4] is a pseudorandom function suitable as a Message Authentication Code. It is **REQUIRED** that a compliant DNS server use SipHash-2-4 as a mandatory and default algorithm for DNS Cookies to ensure interoperability between the DNS Implementations.

The construction method and pseudorandom function used in calculating and verifying the Server Cookies are determined by the initial version byte and by the length of the Server Cookie. Additional pseudorandom or construction algorithms for Server Cookies might be added in the future.

7. IANA Considerations

IANA has created a registry under the "Domain Name System (DNS) Parameters" heading as follows:

Registry Name: DNS Server Cookie Methods

Assignment Policy: Expert Review

Reference: [RFC9018], [RFC7873]

Note: A Server Cookie method (construction and pseudorandom algorithm) is determined by the Version in the first byte of the cookie and by the cookie size. Server Cookie size is limited to the inclusive range of 8 to 32 bytes.

Version	Size	Method
0	8-32	Reserved
1	8-15	Unassigned
1	16	SipHash-2-4 [RFC9018] Section 4
1	17-32	Unassigned
2-239	8-32	Unassigned
240-254	8-32	Reserved for Private Use
255	8-32	Reserved

Table 1: DNS Server Cookie Methods

8. Security and Privacy Considerations

DNS Cookies provide limited protection to DNS servers and clients against a variety of denial-of-service amplification, forgery, or cache-poisoning attacks by off-path attackers. They provide no protection against on-path adversaries that can observe the plaintext DNS traffic. An on-path adversary that can observe a Server Cookie for a client and server interaction can use that Server Cookie for denial-of-service amplification, forgery, or cache-poisoning attacks directed at that client for the lifetime of the Server Cookie.

8.1. Client Cookie Construction

In [RFC7873], it was **RECOMMENDED** to construct a Client Cookie by using a pseudorandom function of the Client IP address, the Server IP address, and a secret quantity known only to the client. The Client IP address was included to ensure that a client could not be tracked if its IP address changes due to privacy mechanisms or otherwise.

In this document, we changed Client Cookie construction to be just 64 bits of entropy newly created for each new upstream server the client connects to. As a consequence, additional care needs to be taken to prevent tracking of clients. To prevent tracking, a new Client Cookie for a server **MUST** be created whenever the Client IP address changes.

Unfortunately, tracking Client IP address changes is impractical with servers that do not support DNS Cookies. To prevent tracking of clients with non-DNS Cookie-supporting servers, a client **MUST NOT** send a previously sent Client Cookie to a server not known to support DNS Cookies. To prevent the creation of a new Client Cookie for each query to a non-DNS Cookie-supporting server, it is **RECOMMENDED** to not send a Client Cookie to that server for a certain period, for example five minutes.

Summarizing:

- In order to provide minimal authentication, a client **MUST** use a different Client Cookie for each different Server IP address.
- To prevent tracking of clients, a new Client Cookie **MUST** be created when the Client IP address changes.
- To prevent tracking of clients by a non-DNS Cookie-supporting server, a client **MUST NOT** send a previously sent Client Cookie to a server in the absence of an associated Server Cookie.

Note that it is infeasible for a client to detect a change in the public IP address when the client is behind a routing device performing Network Address Translation (NAT). A server may track the public IP address of that routing device performing the NAT. Preventing tracking of the public IP of a NAT-performing routing device is beyond the scope of this document.

8.2. Server Cookie Construction

[RFC7873] did not give a precise recipe for constructing Server Cookies, but it did recommend usage of a pseudorandom function strong enough to prevent the guessing of cookies. In this document, SipHash-2-4 is assigned as the pseudorandom function to be used for version 1 Server Cookies. SipHash-2-4 is considered sufficiently strong for the immediate future, but predictions about future development in cryptography and cryptanalysis are beyond the scope of this document.

The precise structure of version 1 Server Cookies is defined in this document. A portion of the structure is made up of unhashed data elements that are exposed in cleartext to an on-path observer. These unhashed data elements are taken along as input to the SipHash-2-4 function of which the result is the other portion of the Server Cookie, so the unhashed portion of the Server Cookie cannot be changed by an on-path attacker without also recalculating the hashed portion for which the Server Secret needs to be known.

One of the elements in the unhashed portion of version 1 Server Cookies is a Timestamp used to prevent Replay Attacks. Servers verifying version 1 Server Cookies need to have access to a reliable time value, one that cannot be altered by an attacker, to compare with the Timestamp value. Furthermore, all servers participating in an anycast set that validate version 1 Server Cookies need to have their clocks synchronized.

For an on-path adversary observing a Server Cookie (as mentioned in the first paragraph of Section 8), the cleartext Timestamp data element reveals the lifetime during which the observed Server Cookie can be used to attack the client.

In addition to the Security Considerations in this section, the Security Considerations section of [RFC7873] still applies.

9. References

9.1. Normative References

[RFC1982] Elz, R. and R. Bush, "Serial Number Arithmetic", RFC 1982, DOI 10.17487/RFC1982, August 1996, <https://www.rfc-editor.org/info/rfc1982>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC3339] Klyne, G. and C. Newman, "Date and Time on the Internet: Timestamps", RFC 3339, DOI 10.17487/RFC3339, July 2002, <https://www.rfc-editor.org/info/rfc3339>.

[RFC7873] Eastlake 3rd, D. and M. Andrews, "Domain Name System (DNS) Cookies", RFC 7873, DOI 10.17487/RFC7873, May 2016, <https://www.rfc-editor.org/info/rfc7873>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[SipHash-2-4] Aumasson, J. and D. J. Bernstein, "SipHash: A Fast Short-Input PRF", Progress in Cryptology - INDOCRYPT 2012, Lecture Notes in Computer Science, vol. 7668, December 2012, <https://doi.org/10.1007/978-3-642-34931-7_28>.

9.2. Informative References

[RFC8981] Gont, F., Krishnan, S., Narten, T., and R. Draves, "Temporary Address Extensions for Stateless Address Autoconfiguration in IPv6", RFC 8981, DOI 10.17487/RFC8981, February 2021, <https://www.rfc-editor.org/info/rfc8981>.

Appendix A. Test Vectors

A.1. Learning a New Server Cookie

A resolver (client) sending from IPv4 address 198.51.100.100 sends a query for `example.com` to an authoritative server listening on 192.0.2.53 from which it has not yet learned the server cookie.

The DNS requests and replies shown in this appendix are in a "dig"-like format. The content of the DNS COOKIE Option is shown in hexadecimal format after `; COOKIE:`.

```
;; Sending:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 57406
;; flags:; QUERY: 1, ANSWER: 0, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 2464c4abcf10c957
;; QUESTION SECTION:
;example.com.                IN      A

;; QUERY SIZE: 52
```

The authoritative nameserver (server) is configured with the following secret: e5e973e5a6b2a43f48e7dc849e37bfcf (as hex data).

It receives the query on Wed Jun 5 10:53:05 UTC 2019.

The content of the DNS COOKIE Option that the server will return is shown below in hexadecimal format after `; COOKIE:`.

The Timestamp field Section 4.3 in the returned Server Cookie has value 1559731985. In the format described in [RFC3339], this is 2019-06-05 10:53:05+00:00.

```
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 57406
;; flags: qr aa; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 2464c4abcf10c957010000005cf79f111f8130c3eee29480 (good)
;; QUESTION SECTION:
;example.com.                IN      A

;; ANSWER SECTION:
example.com.         86400   IN      A       192.0.2.34

;; Query time: 6 msec
;; SERVER: 192.0.2.53#53(192.0.2.53)
;; WHEN: Wed Jun  5 10:53:05 UTC 2019
;; MSD SIZE  rcvd: 84
```

A.2. The Same Client Learning a Renewed (Fresh) Server Cookie

40 minutes later, the same resolver (client) queries the same server for `example.org`. It reuses the Server Cookie it learned in the previous query.

The Timestamp field in that previously learned Server Cookie, which is now sent along in the request, was and is 1559731985. In the format of [RFC3339], this is 2019-06-05 10:53:05+00:00.

```
;; Sending:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 50939
;; flags:; QUERY: 1, ANSWER: 0, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 2464c4abcf10c957010000005cf79f111f8130c3eee29480
;; QUESTION SECTION:
;example.org.                IN      A

;; QUERY SIZE: 52
```

The authoritative nameserver (server) now generates a new Server Cookie. The server **SHOULD** do this because it can see the Server Cookie sent by the client is older than half an hour (Section 4.3), but it is also fine for a server to generate a new Server Cookie sooner or even for every answer.

The Timestamp field in the returned new Server Cookie has value 1559734385, which, in the format of [RFC3339], is 2019-06-05 11:33:05+00:00.

```
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 50939
;; flags: qr aa; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 2464c4abcf10c957010000005cf7a871d4a564a1442aca77 (good)
;; QUESTION SECTION:
;example.org.                IN      A

;; ANSWER SECTION:
example.org.         86400   IN      A       192.0.2.34

;; Query time: 6 msec
;; SERVER: 192.0.2.53#53(192.0.2.53)
;; WHEN: Wed Jun  5 11:33:05 UTC 2019
;; MSD SIZE  rcvd: 84
```

A.3. Another Client Learning a Renewed Server Cookie

Another resolver (client) with IPv4 address 203.0.113.203 sends a request to the same server with a valid Server Cookie that it learned before (on Wed Jun 5 09:46:25 UTC 2019).

The Timestamp field of the Server Cookie in the request has value 1559727985, which, in the format of [RFC3339], is 2019-06-05 09:46:25+00:00.

Note that the Server Cookie has Reserved bytes set but is still valid with the configured secret; the Hash part is calculated taking along the Reserved bytes.

```
;; Sending:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 34736
;; flags:; QUERY: 1, ANSWER: 0, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: fc93fc62807ddb8601abcdef5cf78f71a314227b6679ebf5
;; QUESTION SECTION:
;example.com.                IN      A

;; QUERY SIZE: 52
```

The authoritative nameserver (server) replies with a freshly generated Server Cookie for this client conformant with this specification, i.e., with the Reserved bits set to zero.

The Timestamp field in the returned new Server Cookie has value 1559734700, which, in the format of [RFC3339], is 2019-06-05 11:38:20+00:00.

```
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 34736
;; flags: qr aa; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: fc93fc62807ddb86010000005cf7a9acf73a7810aca2381e (good)
;; QUESTION SECTION:
;example.com.                IN      A

;; ANSWER SECTION:
example.com.         86400   IN      A       192.0.2.34

;; Query time: 6 msec
;; SERVER: 192.0.2.53#53(192.0.2.53)
;; WHEN: Wed Jun  5 11:38:20 UTC 2019
;; MSD SIZE  rcvd: 84
```

A.4. IPv6 Query with Rolled Over Secret

The query below is from a client with IPv6 address 2001:db8:220:1:59de:d0f4:8769:82b8 to a server with IPv6 address 2001:db8:8f::53. The client has learned a valid Server Cookie before (on Wed Jun 5 13:36:57 UTC 2019) when the Server had the secret: dd3bdf9344b678b185a6f5cb60fca715. The server now uses a new secret, but it can still validate the Server Cookie provided by the client as the old secret has not expired yet.

The Timestamp field in the Server Cookie in the request has value 1559741817, which, in the format of [RFC3339], is 2019-06-05 13:36:57+00:00.

```
;; Sending:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 6774
;; flags:; QUERY: 1, ANSWER: 0, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 22681ab97d52c298010000005cf7c57926556bd0934c72f8
;; QUESTION SECTION:
;example.net.                IN      A

;; QUERY SIZE: 52
```

The authoritative nameserver (server) replies with a freshly generated server cookie for this client with its new secret: 445536bcd2513298075a5d379663c962.

The Timestamp field in the returned new Server Cookie has value 1559741961, which, in the format of [RFC3339], is 2019-06-05 13:39:21+00:00.

```
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 6774
;; flags: qr aa; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
; COOKIE: 22681ab97d52c298010000005cf7c609a6bb79d16625507a (good)
;; QUESTION SECTION:
;example.net.                IN      A

;; ANSWER SECTION:
example.net.         86400   IN      A       192.0.2.34

;; Query time: 6 msec
;; SERVER: 2001:db8:8f::53#53(2001:db8:8f::53)
;; WHEN: Wed Jun  5 13:36:57 UTC 2019
;; MSD SIZE  rcvd: 84
```

Appendix B. Implementation Status

At the time of writing, BIND from version 9.16 and Knot DNS from version 2.9.0 create Server Cookies according to the recipe described in this document. Unbound and NSD have a Proof-of-Concept implementation that has been tested for interoperability during the hackathon at IETF 104 in Prague. Construction of privacy maintaining Client Cookies according to the directions in this document have been implemented in the getdns library and will be in the upcoming getdns-1.6.1 release and in Stubby version 0.3.1.

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