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Connection Identifiers for DTLS 1.2
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Abstract

This document specifies the Connection ID (CID) construct for the Datagram Transport Layer Security (DTLS) protocol version 1.2.

A CID is an identifier carried in the record layer header that gives the recipient additional information for selecting the appropriate security association. In "classical" DTLS, selecting a security association of an incoming DTLS record is accomplished with the help of the 5-tuple. If the source IP address and/or source port changes during the lifetime of an ongoing DTLS session then the receiver will be unable to locate the correct security context.

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[1.](#) Introduction

The Datagram Transport Layer Security (DTLS) protocol was designed for securing connection-less transports, like UDP. DTLS, like TLS, starts with a handshake, which can be computationally demanding (particularly when public key cryptography is used). After a

successful handshake, symmetric key cryptography is used to apply data origin authentication, integrity and confidentiality protection. This two-step approach allows endpoints to amortize the cost of the initial handshake across subsequent application data protection. Ideally, the second phase where application data is protected lasts over a longer period of time since the established keys will only need to be updated once the key lifetime expires.

In the current version of DTLS, the IP address and port of the peer are used to identify the DTLS association. Unfortunately, in some cases, such as NAT rebinding, these values are insufficient. This is a particular issue in the Internet of Things when devices enter extended sleep periods to increase their battery lifetime. The NAT rebinding leads to connection failure, with the resulting cost of a new handshake.

This document defines an extension to DTLS 1.2 to add a CID to the DTLS record layer. The presence of the CID is negotiated via a DTLS extension.

2. Conventions and Terminology

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 [RFC 2119](#) [[RFC2119](#)].

This document assumes familiarity with DTLS 1.2 [[RFC6347](#)].

3. The "connection_id" Extension

This document defines the "connection_id" extension, which is used in ClientHello and ServerHello messages.

The extension type is specified as follows.

```
enum {  
    connection_id(TBD1), (65535)  
} ExtensionType;
```

The extension_data field of this extension, when included in the ClientHello, MUST contain the ConnectionId structure. This structure contains the CID value the client wishes the server to use when sending messages to the client. A zero-length CID value indicates that the client is prepared to send with a CID but does not wish the server to use one when sending. Alternatively, this can be interpreted as the client wishes the server to use a zero-length CID; the result is the same.


```
struct {  
    opaque cid<0..2^8-1>;  
} ConnectionId;
```

A server willing to use CIDs will respond with a "connection_id" extension in the ServerHello, containing the CID it wishes the client to use when sending messages towards it. A zero-length value indicates that the server will send with the client's CID but does not wish the client to include a CID (or again, alternately, to use a zero-length CID).

Because each party sends the value in the "connection_id" extension it wants to receive as a CID in encrypted records, it is possible for an endpoint to use a globally constant length for such connection identifiers. This can in turn ease parsing and connection lookup, for example by having the length in question be a compile-time constant. Implementations, which want to use variable-length CIDs, are responsible for constructing the CID in such a way that its length can be determined on reception. Such implementations must still be able to send CIDs of different length to other parties. Note that there is no CID length information included in the record itself.

In DTLS 1.2, CIDs are exchanged at the beginning of the DTLS session only. There is no dedicated "CID update" message that allows new CIDs to be established mid-session, because DTLS 1.2 in general does not allow TLS 1.3-style post-handshake messages that do not themselves begin other handshakes. When a DTLS session is resumed or renegotiated, the "connection_id" extension is negotiated afresh.

If DTLS peers have not negotiated the use of CIDs then the [RFC 6347](#)-defined record format and content type MUST be used.

If DTLS peers have negotiated the use of a CIDs using the ClientHello and the ServerHello messages then the peers need to take the following steps.

The DTLS peers determine whether incoming and outgoing messages need to use the new record format, i.e., the record format containing the CID. The new record format with the the `tls12_cid` content type is only used once encryption is enabled. Plaintext payloads never use the new record type and the CID content type.

For sending, if a zero-length CID has been negotiated then the [RFC 6347](#)-defined record format and content type MUST be used (see [Section 4.1 of \[RFC6347\]](#)) else the new record layer format with the `tls12_cid` content type defined in Figure 3 MUST be used.

When transmitting a datagram with the `tls12_cid` content type, the new MAC computation defined in [Section 5](#) MUST be used.

For receiving, if the `tls12_cid` content type is set, then the CID is used to look up the connection and the security association. If the `tls12_cid` content type is not set, then the connection and security association is looked up by the 5-tuple and a check MUST be made to determine whether the expected CID value is indeed zero length. If the check fails, then the datagram MUST be dropped.

When receiving a datagram with the `tls12_cid` content type, the new MAC computation defined in [Section 5](#) MUST be used. When receiving a datagram with the [RFC 6347](#)-defined record format the MAC calculation defined in [Section 4.1.2 of \[RFC6347\]](#) MUST be used.

4. Record Layer Extensions

This specification defines the DTLS 1.2 record layer format and [\[I-D.ietf-tls-dtls13\]](#) specifies how to carry the CID in DTLS 1.3.

To allow a receiver to determine whether a record has a CID or not, connections which have negotiated this extension use a distinguished record type `tls12_cid(TBD2)`. Use of this content type has the following three implications:

- The CID field is present and contains one or more bytes.
- The MAC calculation follows the process described in [Section 5](#).
- The true content type is inside the encryption envelope, as described below.

Plaintext records are not impacted by this extension. Hence, the format of the `DTLSPlaintext` structure is left unchanged, as shown in Figure 1.

```
struct {
    ContentType type;
    ProtocolVersion version;
    uint16 epoch;
    uint48 sequence_number;
    uint16 length;
    opaque fragment[DTLSPlaintext.length];
} DTLSPlaintext;
```

Figure 1: DTLS 1.2 Plaintext Record Payload.

When CIDs are being used, the content to be sent is first wrapped along with its content type and optional padding into a `DTLSInnerPlaintext` structure. This newly introduced structure is shown in Figure 2. The `DTLSInnerPlaintext` byte sequence is then encrypted. To create the `DTLSCiphertext` structure shown in Figure 3 the CID is added.

```
struct {  
    opaque content[length];  
    ContentType real_type;  
    uint8 zeros[length_of_padding];  
} DTLSInnerPlaintext;
```

Figure 2: New `DTLSInnerPlaintext` Payload Structure.

`content` Corresponds to the fragment of a given length.

`real_type` The content type describing the payload.

`zeros` An arbitrary-length run of zero-valued bytes may appear in the cleartext after the type field. This provides an opportunity for senders to pad any DTLS record by a chosen amount as long as the total stays within record size limits. See [Section 5.4 of \[RFC8446\]](#) for more details. (Note that the term `TLSTransportRecord` in [RFC 8446](#) refers to `DTLSInnerPlaintext` in this specification.)

```
struct {  
    ContentType special_type = tls12_cid;  
    ProtocolVersion version;  
    uint16 epoch;  
    uint48 sequence_number;  
    opaque cid[cid_length];           // New field  
    uint16 length;  
    opaque enc_content[DTLSCiphertext.length];  
} DTLSCiphertext;
```

Figure 3: DTLS 1.2 CID-enhanced Ciphertext Record.

`special_type` The outer content type of a `DTLSCiphertext` record carrying a CID is always set to `tls12_cid`(TBD2). The real content type of the record is found in `DTLSInnerPlaintext.real_type` after decryption.

`cid` The CID value, `cid_length` bytes long, as agreed at the time the extension has been negotiated.

`enc_content` The encrypted form of the serialized `DTLSInnerPlaintext` structure.

All other fields are as defined in [RFC 6347](#).

5. Record Payload Protection

Several types of ciphers have been defined for use with TLS and DTLS and the MAC calculation for those ciphers differs slightly.

This specification modifies the MAC calculation defined in [[RFC6347](#)] and [[RFC7366](#)] as well as the definition of the additional data used with AEAD ciphers provided in [[RFC6347](#)] for records with content type `tls12_cid`. The modified algorithm MUST NOT be applied to records that do not carry a CID, i.e., records with content type other than `tls12_cid`.

The following fields are defined in this document; all other fields are as defined in the cited documents.

`cid` Value of the negotiated CID.

`cid_length` 1 byte field indicating the length of the negotiated CID.

`length_of_DTLSInnerPlaintext` The length (in bytes) of the serialised DTLSInnerPlaintext.
The length MUST NOT exceed 2^{14} .

Note "+" denotes concatenation.

5.1. Block Ciphers

The following MAC algorithm applies to block ciphers that do not use the with Encrypt-then-MAC processing described in [[RFC7366](#)].

```
MAC(MAC_write_key, seq_num +  
    tls12_cid +  
    DTLSCiphertext.version +  
    cid +  
    cid_length +  
    length_of_DTLSInnerPlaintext +  
    DTLSInnerPlaintext.content +  
    DTLSInnerPlaintext.real_type +  
    DTLSInnerPlaintext.zeros  
)
```

5.2. Block Ciphers with Encrypt-then-MAC processing

The following MAC algorithm applies to block ciphers that use the with Encrypt-then-MAC processing described in [[RFC7366](#)].


```
MAC(MAC_write_key, seq_num +
    tls12_cid +
    DTLSCipherText.version +
    cid +
    cid_length +
    length of (IV + DTLSCiphertext.enc_content) +
    IV +
    DTLSCiphertext.enc_content);
```

5.3. AEAD Ciphers

For ciphers utilizing authenticated encryption with additional data the following modification is made to the additional data calculation.

```
additional_data = seq_num +
    tls12_cid +
    DTLSCipherText.version +
    cid +
    cid_length +
    length_of_DTLSInnerPlaintext;
```

6. Examples

Figure 4 shows an example exchange where a CID is used unidirectionally from the client to the server. To indicate that a zero-length CID we use the term 'connection_id=empty'.


```

Client                                     Server
-----                                     -----

ClientHello                               ----->
(connection_id=empty)

                                     <----- HelloVerifyRequest
                                     (cookie)

ClientHello                               ----->
(connection_id=empty)
(cookie)

                                     ServerHello
                                     (connection_id=100)
                                     Certificate
                                     ServerKeyExchange
                                     CertificateRequest
                                     <----- ServerHelloDone

Certificate
ClientKeyExchange
CertificateVerify
[ChangeCipherSpec]
Finished                               ----->
<CID=100>

                                     [ChangeCipherSpec]
                                     <----- Finished

Application Data                         =====>
<CID=100>

                                     <===== Application Data

```

Legend:

<...> indicates that a connection id is used in the record layer

(...) indicates an extension

[...] indicates a payload other than a handshake message

Figure 4: Example DTLS 1.2 Exchange with CID

Note: In the example exchange the CID is included in the record layer once encryption is enabled. In DTLS 1.2 only one handshake message is encrypted, namely the Finished message. Since the example shows

how to use the CID for payloads sent from the client to the server only the record layer payload containing the Finished message contains a CID. Application data payloads sent from the client to the server contain a CID in this example as well.

7. Security and Privacy Considerations

The CID replaces the previously used 5-tuple and, as such, introduces an identifier that remains persistent during the lifetime of a DTLS connection. Every identifier introduces the risk of linkability, as explained in [[RFC6973](#)].

In addition, endpoints can use the CID to attach arbitrary metadata to each record they receive. This may be used as a mechanism to communicate per-connection information to on-path observers. There is no straightforward way to address this with CIDs that contain arbitrary values; implementations concerned about this SHOULD refuse to use connection ids.

An on-path adversary, who is able to observe the DTLS protocol exchanges between the DTLS client and the DTLS server, is able to link the observed payloads to all subsequent payloads carrying the same connection id pair (for bi-directional communication). Without multi-homing or mobility, the use of the CID is not different to the use of the 5-tuple.

An on-path adversary can also black-hole traffic or create a reflection attack against third parties because a DTLS peer has no means to distinguish a genuine address update event (for example, due to a NAT rebinding) from one that is malicious. This attack is of concern when there is a large asymmetry of request/response message sizes.

With multi-homing, an adversary is able to correlate the communication interaction over the two paths, which adds further privacy concerns. The lack of a CID update mechanism makes this extension unsuitable for mobility scenarios where correlation must be considered.

Importantly, the sequence number makes it possible for a passive attacker to correlate packets across CID changes. Thus, even if a client/server pair do a rehandshake to change CID, that does not provide much privacy benefit.

The CID-enhanced record layer introduces record padding; a privacy feature not available with the original DTLS 1.2 RFC. Padding allows to inflate the size of the ciphertext making traffic analysis more

difficult. More details about the padding can be found in [Section 5.4](#) and [Appendix E.3 of RFC 8446](#).

8. IANA Considerations

IANA is requested to allocate an entry to the existing TLS "ExtensionType Values" registry, defined in [\[RFC5246\]](#), for connection_id(TBD1) as described in the table below. IANA is requested to add an extra column to the TLS ExtensionType Values registry to indicate whether an extension is only applicable to DTLS.

Value	Extension Name	TLS 1.3	DTLS Only	Recommended	Reference
TBD1	connection_id	-	Y	N	[[This doc]]

Note: The value "N" in the Recommended column is set because this extension is intended only for specific use cases. This document describes an extension for DTLS 1.2 only; it is not to TLS (1.3). The DTLS 1.3 functionality is described in [\[I-D.ietf-tls-dtls13\]](#).

IANA is requested to allocate tls12_cid(TBD2) in the "TLS ContentType Registry". The tls12_cid ContentType is only applicable to DTLS 1.2.

9. References

9.1. Normative References

- [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>>.
- [RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", [RFC 5246](#), DOI 10.17487/RFC5246, August 2008, <<https://www.rfc-editor.org/info/rfc5246>>.
- [RFC6347] Rescorla, E. and N. Modadugu, "Datagram Transport Layer Security Version 1.2", [RFC 6347](#), DOI 10.17487/RFC6347, January 2012, <<https://www.rfc-editor.org/info/rfc6347>>.
- [RFC7366] Gutmann, P., "Encrypt-then-MAC for Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)", [RFC 7366](#), DOI 10.17487/RFC7366, September 2014, <<https://www.rfc-editor.org/info/rfc7366>>.

- [RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", [RFC 8446](#), DOI 10.17487/RFC8446, August 2018, <<https://www.rfc-editor.org/info/rfc8446>>.

9.2. Informative References

- [I-D.ietf-tls-dtls13]
Rescorla, E., Tschofenig, H., and N. Modadugu, "The Datagram Transport Layer Security (DTLS) Protocol Version 1.3", [draft-ietf-tls-dtls13-31](#) (work in progress), March 2019.
- [RFC6973] Cooper, A., Tschofenig, H., Aboba, B., Peterson, J., Morris, J., Hansen, M., and R. Smith, "Privacy Considerations for Internet Protocols", [RFC 6973](#), DOI 10.17487/RFC6973, July 2013, <<https://www.rfc-editor.org/info/rfc6973>>.

9.3. URIs

- [1] <mailto:tls@ietf.org>
- [2] <https://www1.ietf.org/mailman/listinfo/tls>
- [3] <https://www.ietf.org/mail-archive/web/tls/current/index.html>

Appendix A. History

RFC EDITOR: PLEASE REMOVE THE THIS SECTION

[draft-ietf-tls-dtls-connection-id-06](#)

- Updated IANA considerations
- Enhanced security consideration section to describe a potential man-in-the-middle attack concerning address validation.

[draft-ietf-tls-dtls-connection-id-05](#)

- Restructured [Section 5](#) "Record Payload Protection"

[draft-ietf-tls-dtls-connection-id-04](#)

- Editorial simplifications to the 'Record Layer Extensions' and the 'Record Payload Protection' sections.
- Added MAC calculations for block ciphers with and without Encrypt-then-MAC processing.

[draft-ietf-tls-dtls-connection-id-03](#)

- Updated list of contributors
- Updated list of contributors and acknowledgements
- Updated example
- Changed record layer design
- Changed record payload protection
- Updated introduction and security consideration section
- Author- and affiliation changes

[draft-ietf-tls-dtls-connection-id-02](#)

- Move to internal content types a la DTLS 1.3.

[draft-ietf-tls-dtls-connection-id-01](#)

- Remove 1.3 based on the WG consensus at IETF 101

[draft-ietf-tls-dtls-connection-id-00](#)

- Initial working group version (containing a solution for DTLS 1.2 and 1.3)

[draft-rescorla-tls-dtls-connection-id-00](#)

- Initial version

[Appendix B.](#) Working Group Information

RFC EDITOR: PLEASE REMOVE THE THIS SECTION

The discussion list for the IETF TLS working group is located at the e-mail address tls@ietf.org [1]. Information on the group and information on how to subscribe to the list is at <https://www1.ietf.org/mailman/listinfo/tls> [2]

Archives of the list can be found at: <https://www.ietf.org/mail-archive/web/tls/current/index.html> [3]

[Appendix C.](#) Contributors

Many people have contributed to this specification and we would like to thank the following individuals for their contributions:

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Additionally, we would like to thank the Connection ID task force team members:

- Martin Thomson (Mozilla)
- Christian Huitema (Private Octopus Inc.)
- Jana Iyengar (Google)
- Daniel Kahn Gillmor (ACLU)
- Patrick McManus (Mozilla)

- Ian Swett (Google)
- Mark Nottingham (Fastly)

The task force team discussed various design ideas, including cryptographically generated session IDs using hash chains and public key encryption, but dismissed them due to their inefficiency. The approach described in this specification is the simplest possible design that works given the limitations of DTLS 1.2. DTLS 1.3 provides better privacy features and developers are encouraged to switch to the new version of DTLS.

Finally, we want to thank the IETF TLS working group chairs, Chris Wood, Joseph Salowey, and Sean Turner, for their patience, support and feedback.

[Appendix D](#). Acknowledgements

We would like to thank Achim Kraus for his review comments and implementation feedback.

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