Constrained Join Proxy for Bootstrapping Protocols
draft-vanderstok-anima-constrained-join-proxy-02

Abstract

This document defines a protocol to securely assign a pledge to an owner, using an intermediary node between pledge and owner. This intermediary node is known as a "constrained Join Proxy".

This document extends the work of [ietf-anima-bootstrapping-keyinfra] by replacing the Circuit-proxy by a stateless constrained Join Proxy, that transports routing information.

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1. Introduction

Enrolment of new nodes into constrained networks with constrained nodes present is described in [I-D.ietf-anima-bootstrapping-keyinfra] and makes use of Enrolment over Secure Transport (EST) [RFC7030]. The specified solutions use https and may be too large in terms of...
code space or bandwidth required. Constrained devices in constrained networks [RFC7228] typically implement the IPv6 over Low-Power Wireless personal Area Networks (6LoWPAN) [RFC4944] and Constrained Application Protocol (CoAP) [RFC7252].

CoAP has chosen Datagram Transport Layer Security (DTLS) [RFC6347] as the preferred security protocol for authenticity and confidentiality of the messages. A constrained version of EST, using Coap and DTLS, is described in [I-D.ietf-ace-coap-est].

DTLS is a client-server protocol relying on the underlying IP layer to perform the routing between the DTLS Client and the DTLS Server. However, the new "joining" device will not be IP routable until it is authenticated to the network. A new "joining" device can only initially use a link-local IPv6 address to communicate with a neighbour node using neighbour discovery [RFC6775] until it receives the necessary network configuration parameters. However, before the device can receive these configuration parameters, it needs to authenticate itself to the network to which it connects. In [I-D.ietf-anima-bootstrapping-keyinfra] Enrolment over Secure Transport (EST) [RFC7030] is used to authenticate the joining device. However, IPv6 routing is necessary to establish a connection between joining device and the EST server.

This document specifies a Join Proxy and protocol to act as intermediary between joining device and EST server to establish a connection between joining device and EST server.

This document is very much inspired by text published earlier in [I-D.kumar-dice-dtls-relay].

2. Terminology

The following terms are defined in [RFC8366], and are used identically as in that document: artifact, imprint, domain, Join Registrar/Coordinator (JRC), Manufacturer Authorized Signing Authority (MASA), pledge, Trust of First Use (TOFU), and Voucher.

3. Requirements Language

In this document, the key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" are to be interpreted as described in BCP 14, RFC 2119 [RFC2119] and indicate requirement levels for compliant STuPiD implementations.
4. Join Proxy functionality

As depicted in the Figure 1, the joining Device, or pledge (P), is more than one hop away from the EST server (E) and not yet authenticated into the network. At this stage, it can only communicate one-hop to its nearest neighbour, the Join Proxy (J) using their link-local IPv6 addresses. However, the Pledge (P) needs to communicate with end-to-end security with a Registrar hosting the EST server (E) to authenticate and get the relevant system/network parameters. If the Pledge (P) initiates a DTLS connection to the EST server whose IP address has been pre-configured, then the packets are dropped at the Join Proxy (J) since the Pledge (P) is not yet admitted to the network or there is no IP routability to Pledge (P) for any returned messages.

Furthermore, the Pledge (P) may wish to establish a secure connection to the EST server (E) in the network assuming appropriate credentials are exchanged out-of-band, e.g. a hash of the Pledge (P)’s raw public key could be provided to the EST server (E). However, the Pledge (P) may be unaware of the IP address of the EST-server (E) to initiate a DTLS connection and perform authentication with.

A DTLS connection is required between Pledge and EST server. To overcome the problems with non-routability of DTLS packets and/or discovery of the destination address of the EST Server to contact, the Join Proxy is introduced. This Join Proxy functionality is configured into all authenticated devices in the network which may act as the Join Proxy for newly joining nodes. The Join Proxy allows for routing of the packets from the Pledge using IP routing to the intended EST Server.

5. Join Proxy specification

The Join Proxy can operate in two modes:

- Statefull mode
5.1. Statefull Join Proxy

In stateful mode, the joining node forwards the DTLS messages to the EST Server.

Assume that the Pledge does not know the IP address of the EST Server it needs to contact. In that situation, the Join Proxy knows the (configured or discovered) IP address of a EST Server that the Pledge needs to contact. The Pledge initiates its request as if the Join Proxy is the intended EST Server. The Join Proxy changes the IP packet (without modifying the DTLS message) as in the previous case by modifying both the source and destination addresses to forward the message to the intended EST Server. The Join Proxy maintains a 4-tuple array to translate the DTLS messages received from the EST Server and forward it to the EST Client. In Figure 2 the various steps of the message flow are shown:

<table>
<thead>
<tr>
<th>EST Client (P)</th>
<th>Join Proxy (J)</th>
<th>EST Server (E)</th>
<th>Message Src_IP:port</th>
<th>Dst_IP:port</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ClientHello--</td>
<td></td>
<td></td>
<td>IP_P:p_P</td>
<td>IP_Ja:5684</td>
</tr>
<tr>
<td>--ClientHello--</td>
<td>--ServerHello--</td>
<td></td>
<td>IP_Jb:p_Jb</td>
<td>IP_E:5684</td>
</tr>
<tr>
<td>&lt;--ServerHello--:</td>
<td>IP_E:5684</td>
<td>IP_Jb:p_Jb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;--ServerHello--:</td>
<td>IP_Ja:5684</td>
<td>IP_P:p_P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>:                :                :</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>:                :                :</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Finished--     :</td>
<td>IP_P:p_P</td>
<td>IP_Ja:5684</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Finished--     :</td>
<td>IP_Jb:p_Jb</td>
<td>IP_E:5684</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;--Finished--    :</td>
<td>IP_E:5684</td>
<td>IP_Jb:p_Jb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;--Finished--    :</td>
<td>IP_Ja:5684</td>
<td>IP_P:p_P</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IP_P:p_P = Link-local IP address and port of Pledge (DTLS Client)
IP_E:5684 = Global IP address and coaps port of EST Server
IP_Ja:5684 = Link-local IP address and coaps port of Join Proxy
IP_Jb:p_Jb = Global IP address and port of Join proxy

Figure 2: constrained statefull joining message flow with EST server address known to Join Proxy.
5.2. Stateless Join Proxy

The Join Proxy is stateless to minimize the requirements on the constrained Join Proxy device.

When a joining device as a client attempts a DTLS connection to the EST server, it uses its link-local IP address as its IP source address. This message is transmitted one-hop to a neighbour node. Under normal circumstances, this message would be dropped at the neighbour node since the joining device is not yet IP routable or it is not yet authenticated to send messages through the network. However, if the neighbour device has the Join Proxy functionality enabled, it routes the DTLS message to a specific EST Server. Additional security mechanisms need to exist to prevent this routing functionality being used by rogue nodes to bypass any network authentication procedures.

If an untrusted DTLS Client that can only use link-local addressing wants to contact a trusted end-point EST Server, it sends the DTLS message to the Join Proxy. The Join Proxy extends this message into a new type of message called Join ProxY (JPy) message and sends it on to the EST server. The JPy message payload consists of two parts:

- Header (H) field: consisting of the source link-local address and port of the Pledge (P), and
- Contents (C) field: containing the original DTLS message.

On receiving the JPy message, the EST Server retrieves the two parts. The EST Server transiently stores the Header field information. The EST server uses the Contents field to execute the EST server functionality. However, when the EST Server replies, it also extends its DTLS message with the header field in a JPy message and sends it back to the Join Proxy. The Header contains the original source link-local address and port of the DTLS Client from the transient state stored earlier (which can now be discarded) and the Contents field contains the DTLS message.

On receiving the JPy message, the Join Proxy retrieves the two parts. It uses the Header field to route the DTLS message retrieved from the Contents field to the Pledge.

The Figure 3 depicts the message flow diagram:
### Join Proxy Message Flow

<table>
<thead>
<tr>
<th>EST Client (P)</th>
<th>Join Proxy (J)</th>
<th>EST Server (E)</th>
<th>Message</th>
<th>Src_IP:port</th>
<th>Dst_IP:port</th>
</tr>
</thead>
<tbody>
<tr>
<td>--ClientHello--&gt;</td>
<td></td>
<td>IP_P:p_P</td>
<td>IP_Ja:5684</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--JPY[H(IP_P:p_P),--</td>
<td>IP_Jb:p_Jb</td>
<td>IP_E:5684</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C(ClientHello)]</td>
<td></td>
<td>IP_Jb:p_Jb</td>
<td>IP_E:5684</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C(ServerHello)]</td>
<td></td>
<td>IP_E:5684</td>
<td>IP_Jb:p_Jb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;--ServerHello--</td>
<td>IP_Ja:5684</td>
<td>IP_P:p_P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IP_Ja:5684</td>
<td>IP_P:p_P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Finished--&gt;</td>
<td>IP_P:p_P</td>
<td>IP_Ja:5684</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--JPY[H(IP_P:p_P),--</td>
<td>IP_Jb:p_Jb</td>
<td>IP_E:5684</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C(Finished)</td>
<td></td>
<td>IP_Jb:p_Jb</td>
<td>IP_E:5684</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C(Finished)]</td>
<td></td>
<td>IP_E:5684</td>
<td>IP_Jb:p_Jb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;--Finished--</td>
<td>IP_Ja:5684</td>
<td>IP_P:p_P</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IP_P:p_P = Link-local IP address and port of the Pledge  
IP_E:5684 = Global IP address and coaps port of EST Server  
IP_Ja:5684 = Link-local IP address and coaps port of Join Proxy  
IP_Jb:p_Jb = Global IP address and port of Join Proxy  

JPY[H(),C()] = Join Proxy message with header H and content C

### 5.3. Stateless Message structure

The JPY message is constructed as a payload with media-type application/multipart-core specified in [I-D.ietf-core-multipart-ct].  
Header and Contents fields use different media formats:

1. header field: application/ CBOR containing a CBOR array [RFC7049] with the pledge IPv6 Link Local address as a 16-byte binary value, the pledge’s UDP port number, if different from 5684, as a CBOR integer, and the proxy’s ifindex or other identifier for the physical port on which the pledge is connected. Header is not DTLS encrypted.

2. Content field: Any of the media types specified in [I-D.ietf-ace-coap-est] and [I-D.ietf-anima-constrained-voucher] dependent on the function that is requested.
The content fields are DTLS encrypted. In CBOR diagnostic notation the payload JPY[H(IP_P:p_P), with cf is content-format of DTLS-content, will look like:

```
[ 60: [IP_p, p_P, ident]
  cf: h’DTLS-content’]
```

Examples are shown in Appendix A.

6. Comparison of stateless and statefull modes

The stateful and stateless mode of operation for the Join Proxy have their advantages and disadvantages. This section should enable to make a choice between the two modes based on the available device resources and network bandwidth.
<table>
<thead>
<tr>
<th>Properties</th>
<th>Stateful mode</th>
<th>Stateless mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Information</td>
<td>The Join Proxy needs additional storage to maintain mapping between the address and port number of the pledge and those of the EST-server.</td>
<td>No information is maintained by the Join Proxy</td>
</tr>
<tr>
<td>Packet size</td>
<td>The size of the forwarded message is the same as the original message.</td>
<td>Size of the forwarded message is bigger than the original, it includes additional source and destination addresses.</td>
</tr>
<tr>
<td>Specification complexity</td>
<td>The Join Proxy needs additional functionality to maintain state information, and modify the source and destination addresses of the DTLS handshake messages</td>
<td>New JPY message to encapsulate DTLS message The EST server and the Join Proxy have to understand the JPY message in order to process it.</td>
</tr>
</tbody>
</table>

Figure 4: Comparison between stateful and stateless mode

7. Discovery

It is assumed that Join Proxy seamlessly provides a coaps connection between Pledge and coaps EST-server. An additional Registrar is needed to connect the Pledge to an http EST server, see section 8 of [I-D.ietf-ace-coap-est]. In particular this section replaces section 4.2 of [I-D.ietf-anima-bootstrapping-keyinfra].

Three discovery cases are discussed: coap discovery, 6tisch discovery and GRASP discovery.

7.1. Join Proxy discovers EST server

7.1.1. Coap discovery

The discovery of the coaps EST server, using coap discovery, by the Join Proxy follows section 6 of [I-D.ietf-ace-coap-est].
7.1.2. Autonomous Network

In the context of autonomous networks, the Join Proxy uses the DULL GRASP M_FLOOD mechanism to announce itself. Section 4.1.1 of [I-D.ietf-anima-bootstrapping-keyinfra] discusses this in more detail. The EST-server announces itself using ACP instance of GRASP using M_FLOOD messages. Autonomous Network Join Proxies MUST support GRASP discovery of EST-server as described in section 4.3 of [I-D.ietf-anima-bootstrapping-keyinfra].

7.1.3. 6tisch discovery

The discovery of EST server by the pledge uses the enhanced beacons as discussed in [I-D.ietf-6tisch-enrollment-enhanced-beacon].

7.2. Pledge discovers Join Proxy

The pledge and Join Proxy are assumed to communicate via Link-Local addresses.

7.2.1. Autonomous Network

The pledge MUST listen for GRASP M_FLOOD [I-D.ietf-anima-grasp] announcements of the objective: "AN_Proxy". See section Section 4.1.1 [I-D.ietf-anima-bootstrapping-keyinfra] for the details of the objective.

7.2.2. Coap discovery

In the context of a coap network without Autonomous Network support, discovery follows the standard coap policy. The Pledge can discover a Join Proxy by sending a link-local multicast message to ALL CoAP Nodes with address FF02::FD. Multiple or no nodes may respond. The handling of multiple responses and the absence of responses follow section 4 of [I-D.ietf-anima-bootstrapping-keyinfra].

The presence and location of (path to) the Join Proxy resource are discovered by sending a GET request to "/.well-known/core" including a resource type (rt) parameter with the value "brski-proxy" [RFC6690]. Upon success, the return payload will contain the root resource of the Join Proxy resources. It is up to the implementation to choose its root resource; throughout this document the example root resource /jp is used. The example below shows the discovery of the presence and location of Join Proxy resources.
REQ: GET coap://[FF02::FD]/.well-known/core?rt=brski-proxy

RES: 2.05 Content
</jp>; rt="brski-proxy";ct=62

Port numbers, not returned in the example, are assumed to be the default numbers 5683 and 5684 for coap and coaps respectively (sections 12.6 and 12.7 of [RFC7252]. Discoverable port numbers MAY be returned in the <href> of the payload (see section 5.1 of [I-D.ietf-ace-coap-est]).

8. Security Considerations

It should be noted here that the contents of the CBOR map are not protected, but that the communication is between the Proxy and a known registrar (a connected UDP socket), and that messages from other origins are ignored.

9. IANA Considerations

This document needs to create a registry for key indices in the CBOR map. It should be given a name, and the amending formula should be IETF Specification.

9.1. Resource Type registry

This specification registers a new Resource Type (rt=) Link Target Attributes in the "Resource Type (rt=) Link Target Attribute Values" subregistry under the "Constrained RESTful Environments (CoRE) Parameters" registry.

rt="brski-proxy". This EST resource is used to query and return the supported EST resource of a Join Proxy placed between Pledge and EST server.

10. Acknowledgements

Many thanks for the comments by Brian Carpenter.

11. Contributors

Sandeep Kumar, Sye loong Keoh, and Oscar Garcia-Morchon are the co-authors of the draft-kumar-dice-dtls-relay-02. Their draft has served as a basis for this document. Much text from their draft is copied over to this draft.
12. Changelog

12.1. 01 to 02

- extended the discovery section
- removed inconsistencies from the flow diagrams
- improved readability of the examples.
- stateful configurations reduced to one

12.2. 00 to 01

- added Contributors section
- adapted content-formats to est-coaps formats
- aligned examples with est-coaps examples
- added statefull Proxy to stateless proxy

12.3. 00 to 00

- added payload examples in appendix
- discovery for three cases: AN, 6tisch and coaps

13. References

13.1. Normative References

[I-D.ietf-6tisch-enrollment-enhanced-beacon]
Dujovne, D. and M. Richardson, "IEEE802.15.4 Informational
Element encapsulation of 6tisch Join and Enrollment
Information", draft-ietf-6tisch-enrollment-enhanced-
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[I-D.ietf-ace-coap-est]
Stok, P., Kampanakis, P., Richardson, M., and S. Raza,
"EST over secure CoAP (EST-coaps)", draft-ietf-ace-coap-
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[I-D.ietf-anima-bootstrapping-keyinfra]
Pritikin, M., Richardson, M., Behringer, M., Bjarnason,
S., and K. Watsen, "Bootstrapping Remote Secure Key
Infrastructures (BRSKI)", draft-ietf-anima-bootstrapping-
keyinfra-22 (work in progress), June 2019.
[I-D.ietf-anima-constrained-voucher]

[I-D.ietf-anima-grasp]

[I-D.ietf-core-multipart-ct]


13.2. Informative References

[duckling]

[I-D.kumar-dice-dtls-relay]
Appendix A.  Stateless Proxy payload examples

Examples are extensions of two examples shown in [I-D.ietf-ace-coap-est].  The following content formats are used:

- 60: application/cbor
- 62: application/multipart
- 281: application/pkcs7-mime; smime-type=certs-only
- 284: application/pkcs8
- 286: application/pkcs10
For presentation purposes the payloads are abbreviated as follows:

cacrts request payload:

\[
<\text{cacrts request payload}> = \langle\emptyset\rangle
\]

cacrts response payload:

\[
<\text{cacrts response payload}> = \text{DTLS\_encrypt}(\text{...})
\]

serverkeygen request payload:

\[
<\text{serverkeygen request payload}> = \text{DTLS\_encrypt}(\text{...})
\]

serverkeygen response payload:

\[
<\text{serverkeygen response payload}> = \text{DTLS\_encrypt}(\text{...})
\]
<serverkeygen response payload> =
DTLS_encrypt(
  84                                      # array(4)
  19 011C                                 # unsigned(284)
  58 8A                                   # bytes(138)
308187020100301306072a8648ce3d020106082a8648ce3d030107046d30
6b02010104200b9a67785b65e07360b6d28cfc1d3f3925c0755799deeca7
45372b021697bd8a6a144034200041bb8c111786f98e4506c03d7e9be82
0d8e38ea97e9d65d52c8460c5852c51dd89a61370a2843760fc859799d78
cd33f3c1846e304f1717f8123f1a284cc99f
19 0119                                 # unsigned(281)
59 01D3                                 # bytes(467)
308201cf06092a864886f70d010702a08201ac0308201bc0201013100300b
06092a864886f70d010701a08201a23082019e30820143a0030201020208
126de8571518524b300a06082a8648ce3d04030230163114301206035504
0a0c0b736b67206578616d706c65301e170d313930313039303835373038
5a170d3339303130343038353730385a301631143012060355040a0c0b73
6b67206578616d706c653059303106072a8648ce3d020106082a8648ce3d
03010703420041bb8c111789f98e4506c03d70efbe820d8e38ea97e9d6
5d52c8460c5852c51dd89a61370a2843760fc859799d78cd33f3c1846e30
4f1717f8123f1a284cc99fa37b30793090603551d103042300302c0609
6086480186f842010d041f161df70656e53534c2047656e57261746564
204365727466666617465301d0603551d0e04160414494eb59dc8dbc
0dbc071c486b777460e5ccee621301f0603551d23041830168014494be598
d82b0dbc071c486b777460e5ccee621300a06082a8648ce3d0403020304
00304622100a4b167d0f9add1920281c6f6a290b8cfdfc99c9f02cc1
cc8fc3a464f79f2c202210081d31ba42751a7b4a34fd1a01fcb08716b9eb
53baadac99e60b08f52429c0fa1003100
)

A.1. cacerts

The request from Join Proxy to EST-server looks like:

Get coaps://192.0.2.1/est/crts
(Accept: 62)
(Content-format: 62)
payload =
  82                                      # array(2)
  18 3C                                   # unsigned(60)
  83                                      # array(3)
  69                                      # text(9)
464538303a3a414238 # "FE80::AB8"
19 237D                                   # unsigned(9085)
65                                      # text(5)
6964656e74 # "ident"

In CBOR Diagnostic:
payload = [60, ["FE80::AB8", 9085, "ident"]]

The response will then be:

```
2.05 Content
(Content-format: 62)
Payload =
84  # array(4)
18 3C  # unsigned(60)
83  # array(3)
69  # text(9)
   464538303A3A414238  # "FE80::AB8"
19 237D  # unsigned(9085)
65  # text(5)
   6964656E74  # "ident"
19 0119  # unsigned(281)
59 027F  # bytes(639)
<caacrts response payload>
```

In CBOR diagnostic:

```
payload = [60, ["FE80::AB8", 9085, "ident"],
            62, h’<caacrts response payload’]
```

A.2. serverkeygen

The request from Join Proxy to EST-server looks like:

```
Get coaps://192.0.2.1/est/skg
(Accept: 62)
(Content-Format: 62)
Payload =
83  # array(4)
18 3C  # unsigned(60)
83  # array(3)
69  # text(9)
   464538303A3A414238  # "FE80::AB8"
19 237D  # unsigned(9085)
65  # text(5)
   6964656E74  # "ident"
19 0119  # unsigned(286)
58 D2  # bytes(210)
<serverkeygen request payload>
```

In CBOR diagnostic:
payload = [60, ["FE80::AB8", 9085, "ident"],
           286, h'<serverkeygen request payload'>]

The response will then be:

```
2.05 Content
(Content-format: 62)
Payload =
83                     # array(4)
18 3C                  # unsigned(60)
83                     # array(3)
69                     # text(9)
        464538303A3A414238 # "FE80::AB8"
19 237D                # unsigned(9085)
65                     # text(5)
        6964656E74       # "ident"
19 011E                # unsigned(286)
59 0269                # bytes(617)
<serverkeygen response payload>
```

In CBOR diagnostic:

```
payload = [60, ["FE80::AB8", 9085, "ident"],
           286, h'<serverkeygen response payload'>]
```

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