Generic Address Assignment Option for 6LowPAN Neighbor Discovery
draft-iannone-6lo-nd-gaaao-02

Abstract

This document specifies a new extension to the IPv6 Neighbor Discovery in Low Power and Lossy Networks enabling a node to request to be assigned an address or a prefix from neighbor routers. Such mechanism allows to recursively assign addresses and prefixes to nodes in a 6LowPAN deployment.

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1. Introduction

Low Power and Lossy Networks (LLNs) have adapted the design of Internet protocols to more constrained environments, by taking into consideration of energy saving, limited memory capacity and duty cycling of the LLN devices, as well as low-power lossy transmissions. Since the wireless interface is a major energy drain, protocols aiming at being deployed over LLN must be designed in such a way to reduce as much as possible transmissions, allowing to turn off the radio interface or put the node in sleeping mode.

IPv6 Neighbor Discovery has been also adapted to the LLN environment in [RFC6775], later updated by [RFC8505], [RFC8929], and [RFC9010]. In particular, address assignment is relying on address auto-configuration [RFC4862], since the use of Dynamic Host Configuration Protocol (DHCP [RFC8415]) is not adapted to LLN deployments. Hence, mechanisms to register these self-generated addresses have been designed ([RFC6775], [I-D.thubert-6lo-prefix-registration], [RFC8505], [I-D.ietf-6lo-multicast-registration]).

Recent use cases show however, that there is some advantages in assigning addresses in an algorithmically managed way, which may simplify packet forwarding in some scenarios ([RFC9453], [I-D.ietf-6lo-path-aware-semantic-addressing], [SHENOY21], [BLESS22], [RIDOUX05]), hence reducing the power consumption and memory.
footprint. Algorithmic address assignment has its own pros and cons, as well as deployment requirements. However, they have the common benefit of being easily distributed. In other words, it is not necessary to have a centralized approach, like DHCP, rather a node can obtain an address generated from one of the neighbors by simply running the algorithm.

This situation highlights an existing gap that this document tries to fill: 6LowPAN nodes have no means to directly request an address (or address prefix) from routers that are their direct neighbors. Currently, either auto-configuration is used, or DHCP has to be deployed. The former, is energy efficient, but makes hard to implement solutions like [I-D.ietf-6lo-path-aware-semantic-addressing], [SHENOY21], [BLESS22], and [RIDOUX05]. The latter, on the opposite, allows to use sophisticated assignment algorithms, but remains inefficient from an energy consumption viewpoint.

This document proposes a new Neighbor Discovery Option, namely the Generic Address Assignment Option (GAAO), in order for a node to issue an address or prefix request to neighbors routers. This new GAAO option complements the Extended Address Registration Option, defined in [RFC8505] and further extended in [I-D.thubert-6lo-prefix-registration], [I-D.ietf-6lo-multicast-registration].

2. Requirements Notation

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.

3. Terminology

This document assumes familiarity with the terminology defined in [RFC6775] and [RFC8505]. In particular for the following acronyms:

6CIO: Capability Indication Option

6LBR: 6LoWPAN Border Router

6LN: 6LoWPAN Node

6LoWPAN: IPv6 over Low-Power Wireless Personal Area Network

6LR: 6LoWPAN Router
ARO: Address Registration Option
EARO: Extended Address Registration Option
LLN: Low-Power and Lossy Network
NA: Neighbor Advertisement
ND: Neighbor Discovery
NS: Neighbor Solicitation
RA: Router Advertisement
RS: Router Solicitation

4. Definition of Terms

Address Assignment Function (AAF): The Address Assignment Function (AAF) is an implementation of the algorithm used by 6LRs to assign an address/prefix to requesting nodes. In order to avoid addressing issues, only one single AAF SHOULD be used in a deployment.

5. Algorithmically Assigned Addresses and Prefixes

The IPv6 address assignment model inside a local domain is based on randomly assigned Interface IDentifier (IID), either done in a centralized way using DHCP, which can guarantee no address collision, or by decentralized State-Less Address Auto-Configuration (SLAAC [RFC4862]), which needs additional mechanisms to ensure the uniqueness of addresses. However, there is a third approach for address assignment, which is distributed and collision free: algorithmically generated addresses ([SHENOY21], [BLESS22], [RIDOUX05], [ERIKSSON04]).

The main idea is to use a well-known Address Assignment Function (AAF) to assign addresses and prefixes to nodes joining a network. All nodes MUST use the same AAF in the same network instance. Each node acquiring an address firstly needs to select a neighbor 6LR by choosing among the nodes that replied with a Router Advertisement (RA) after an initial Router Solicitation (RS), as defined in [RFC6775]. Then, the node explicitly asks for an address (or prefix) to the selected 6LR. Depending on the underlying technology and algorithm used the node may confirm its usage. Note that the address request may be triggered at any time, not necessarily when the node bootstraps. The sequence of actions is depicted in {Fig:AAFSeq}
When used, steps 3 and 4 of the sequence of actions MUST be implemented by using the address registration procedure defined in [RFC8505]. Basically it uses an EARO message to register an address, which in this case is not a self-generated address. However, in order to issue the initial request, meaning steps 1 and 2, a new Generic Address Assignment Option (GAAO) is required and proposed, since no existing mechanism can be readily used for this purpose. In the remaining of this document, the format of this option is firstly defined (Section 6), followed by a revised Address/Prefix assignment sequence (Section 7).

6. Generic Address Assignment Option

In order for a node to request the assignment of an address or prefix, the Generic Address Assignment Option (GAAO) message is used. The format of the GAAO message is shown in Figure 2.
Figure 2: Generic Address Assignment Option format.

Option Fields:

Type: 42 (Suggested)

Length: 8-bit unsigned integer. The length of the option in units of 8 bytes. This field is set to 1 plus the size of the ROVR field when the option is used in NS messages. It is augmented by 2 (16 bytes) when this option is used in NA messages because the assigned address/prefix is appended to the option.

ROVR: As defined in [RFC8505].

Status/PfxLen: 8-bits unsigned integer. It indicates the Prefix Length of the assigned address if the assignment is successful. On success, the returned GAAO will have appended to it the assigned address/prefix and in this case the Length field will increased by 2. This field can indicate an error code (See table 1 in [RFC8505] and Section 8 for error codes) if the assignment failed. On failure, the returned GAAO message will not have any address/prefix appended to it. Hence the Length field has not been increased, indicating a failure, whose code is indicated in this field. This field MUST be set to 0 in NS messages.

Opaque: As defined in [RFC8505].

C: Confirmation requested. It MUST be initialized to 0 by in NS
messages by requester and MUST be ignored by the receiver. The 6LR replying to the request with an NA message MAY set this bit to indicate that it requests a confirmation that the address/prefix is accepted and will be used. When the requester receives an NA message with this bit set, it MUST explicitly register the received address/prefix to the same 6LR using the the procedures defined in [RFC8505], [I-D.thubert-6lo-prefix-registration], and [I-D.ietf-6lo-multicast-registration], according to the type of the assigned address/prefix.

F: F-Field as defined in [I-D.thubert-6lo-prefix-registration].

P: P-Field as defined in [I-D.thubert-6lo-prefix-registration] indicating the type of address requested.

I: As defined in [RFC8505].

R (Reserved): This field is unused. It MUST be initialized to 0 by the sender and MUST be ignored by the receiver.

Address Assignment Function(AAF): 1-byte unsigned integer. Describe the Assignment Function (AF), i.e. the algorithm, used to assign the address/prefix. 0 is a special value indicating that the field is not used. On request in an NS message this field CAN be set to 0 to indicate there is no preference on how the address is assigned. If different from 0 it means that it is requested to use a specific known AAF to assign the address/prefix (see Section 8). See Section 10.4 for possible values of this field.

Assignment Lifetime: 16-bit unsigned integer, expressed in minutes. In an NS message the field expresses the minimum desired lifetime. It MAY be set to zero in NS message indicating no particular desired lifetime. In NA messages it expresses the granted maximum lifetime.

Address/Prefix: 128-bits address or prefix returned in a GAAO option in an NA message. This field is not present in GAAO requests in NS messages or in the NA message when an error occurs.

7. Messages Sequence

When a node bootstraps, it typically does multicast a Routing Solicitation (RS) and receives one or more unicast Routing Advertisements (RA) messages from neighbor 6LRs. The node can choose one or more 6LRs from which to request address(es) or prefix(es). A node can perform an address request at any time, not necessarily at boot time. If done at boot time, the request MAY be appended as an option of the first RS message, while responding routers can offer an
address in the RA message. The mechanism is completely optional. If the node requests an address, the node will go through the following steps:

1. The node will issue a NS message with the GAAO option to request an address assignment. This initial GAAO option has length equal to ROVR's length as multiple of 8 bytes plus one (no address appended), Status/PfxLength set to 0. Opaque, as well as the F-bit and I-bits will be set according to local configuration. The C-bit is set to zero. The P-bits are set according to the type of address it is requesting. The AAF is set to zero if no preference for the assignment algorithm. The lifetime field is set to the minimum desired lifetime, or zero otherwise.

2. Assuming no errors occur, the node will receive an NA message with a GAAO option with a length increased by two compare to the corresponding NS message, because of the presence of the address/prefix field. All fields have been copied back except for:

* Pfxlen: now indicating the length of the prefix.

* C: The C bit is set if the 6LR requests a confirmation via a registration procedure.

* AAF: Indicating the Address Assignment Function, i.e., the algorithm, used to assign the address/prefix. If the node is a 6LR it will use the same AAF to generate addresses/prefixes to requesting neighbors nodes.

* Assigned lifetime: the maximum lifetime of the assigned address/prefix.

The message sequence is depicted in Figure 3.

```
6LN     6LR
<p>| |
|       |
|       |</p>
<table>
<thead>
<tr>
<th>NS(GAAO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA(GAAO)</td>
</tr>
<tr>
<td>----------</td>
</tr>
</tbody>
</table>
```

Figure 3: Address/Prefix assignment with GAAO message sequence and no confirmation request.
Depending on the algorithm in use and the underlying technology the address assignment procedure terminates after these two messages. This may be sufficient for instance in deployments where the link layer offers reliable packet delivery.

If the C bit is set, to confirm the acceptance and usage of the proposed address/prefix received in the NA message, the 6LN has to register to the obtained address following the procedures in [RFC8505], [I-D.ietf-6lo-multicast-registration], or [I-D.thubert-6lo-prefix-registration] depending on the type of address.

In the case the complete sequence of actions is depicted in Figure 4.

```
6LN          6LR
|            |
|  NS(GAAO)  |
|----------->|
|            |
|  NA(GAAO)  |
|<-----------|
|            |
|  NS(EARO)  |
|----------->|
|            |
|  NA(EARO)  |
|<-----------|
```

Procedure According to [RFC8505], [I-D.ietf-6lo-multicast-registration], or [I-D.thubert-6lo-prefix-registration] depending on the type of address.

```
... |
| NA(EARO) |
|<--------|
```

Figure 4: Address/Prefix assignment with GAAO message sequence.

### 8. GAAO Error Conditions

The GAAO option uses error codes defined in [RFC6775] and [RFC8505], revised in [RFC9010]. This specification introduces a new status code when the AAF in the GAAO option in an NS message is not supported by 6LR, as follows (see also Section 10):

**AAF Not Supported:** The AAF in the GAAO option in the NS message is not supported by 6LR that received the message.
This status MUST be used when a node requesting an address/prefix did put an AAF value, in the corresponding field, which is not supported by the 6LR receiving the request. When the node receives this status back it can perform one of the following actions:

* Re-issue the same request without specifying an AAF. Meaning set the AAF Field to 0.
* Re-issue the same request with a different AAF.
* Do nothing.

The action to be used is selected by configuration.

9. Signaling GAAO Support

This specification defines five new capability bits for use in the 6CIO as defined by [RFC7400] ("6LoWPAN-GHC: Generic Header Compression for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)"), for use in IPv6 ND messages. A 6LoWPAN node that supports this specification MUST set the M flag.

![Figure 5: New GAAO Capability Bit in the 6CIO.](image)

M: The node supports managed addresses via the Generic Address Assignment Capability.

10. IANA Considerations

This section provides guidance to the Internet Assigned Numbers Authority (IANA) regarding registration of values related to the GAAO specification, in accordance with BCP 26 [RFC8126].

10.1. IPv6 ND Option Types

IANA is requested to make an addition to the "IPv6 Neighbor Discovery Option Formats" registry under the heading "Internet Control Message Protocol version 6 (ICMPv6) Parameters" as indicated in Table 1:
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 (Suggested)</td>
<td>Generic Address Assignment Option</td>
<td>[This Document]</td>
</tr>
</tbody>
</table>

Table 1: New Generic Address Assignment Option.

### 10.2. 6LoWPAN Capability Bits

IANA is requested to make an addition to the "6LoWPAN Capability Bits" registry under the heading "Internet Control Message Protocol version 6 (ICMPv6) Parameters" as indicated in Table 2:

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 (Suggested)</td>
<td>Generic Address Assignment Capability (M) Flag</td>
<td>[This Document]</td>
</tr>
</tbody>
</table>

Table 2: New 6LoWPAN Capability Bit.

### 10.3. GAAO Error code

IANA is requested to make an addition to the "Address Registration Option Status Values" sub-registry under the heading "Internet Control Message Protocol version 6 (ICMPv6) Parameters" as indicated in Table 3:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 (Suggested)</td>
<td>AAF Not Supported</td>
<td>[This Document]</td>
</tr>
</tbody>
</table>

Table 3: New address registration option value.

### 10.4. Address Assignment Function Registry

IANA is asked to create a registry named "Generic Address Assignment Option Parameters".

Such registry should be populated with a one octet sub registry named "Address Assignment Function" and used to identify the used AAF used. The sub registry is populated as shown in Table 4:
| Value     | AAF Name                       | Reference |
|-----------|--------------------------------+-----------|
| 0x00      | No AAF. This can be used only in NS message to indicate that no specific AAF is demanded. | [This Document] |
| 0x01-0xFE | Un-assigned                     |           |
| 0xFF      | Experimental. Used for experimental purposes during implementation of new AAFs. | [This Document] |

Table 4: Allocation Function sub-registry

Values can be assigned by IANA on a "First Come, First Served" basis according to [RFC8126].

11. Security Considerations

This document extends [RFC8505], which already extended [RFC6775], as such the security considerations of both documents apply to this specification. In particular, the link layer SHOULD provide sufficient protection to prevent potential attacks. Recommendations listed in Section 7 of [RFC8505] SHOULD be applied as well to this specification.

Depending on the Assignment Function in use, the number of available addresses may encounter limitations. A rouge node may leverage on this knowledge to carry out address exhaustion attacks by impersonating different nodes and performing multiple requests.

Acknowledgements

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References

Normative References

[I-D.ietf-6lo-multicast-registration]


Informative References


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