

610  
Internet-Draft  
Intended status: Standards Track  
Expires: 12 May 2022

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8 November 2021

IPv6 Neighbor Discovery Unicast Lookup  
draft-thubert-610-unicast-lookup-02

Abstract

This document updates RFC 8505 in order to enable unicast address lookup from a 6LoWPAN Border Router acting as an Address Registrar.

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## 1. Introduction

[RFC8505] defines the Routing Registrar and extends [RFC6775] to use a 6LoWPAN Border Router (6LBR) as a central service for Address Registration and duplicate detection amongst Routing Registrars and possibly individual Nodes that access it directly.

[RFC8929] introduces the Backbone Router (6BBR) as a Routing Registrar that performs IPv6 ND [RFC4861] [RFC4862] proxy operation between IPv6 Nodes on a federating Backbone Link and Registering Nodes attached to a LowPower Lossy Networks (LLNs) that register their addresses to the 6BBR. The federated links form a Multilink Subnet (MLSN).

The 6BBRs may exchange Extended Duplicate Address Messages (EDAR and EDAC) [RFC8505] to register the proxied addresses on behalf of the Registering Nodes to the 6LBR. The Registration Ownership Verifier (ROVR) field in the EDAR and EDAC messages is used to correlate attempts to register the same address and to detect duplications. The ROVR can also be used as a proof-of-ownership (see [RFC8928]) to protect the Registered address against theft and impersonation

attacks (more in [I-D.bi-savi-wlan]). Conflicting registrations to different 6BBRs for the same Registered address are resolved using the TID field, which creates a temporal order and enables to recognize the freshest registration.

With [RFC8929], the Link Layer address (LLA) that the 6BBR advertises for a Registered address on behalf of the Registered Node over the Backbone can belong to the Registering Node; in that case, the 6BBR acts as a Bridging Proxy and bridges the unicast packets. Alternatively, the LLA can be that of the 6BBR on the Backbone interface, in which case the 6BBR acts as a Routing Proxy, that receives the unicast packets at Layer-3 and routes them. The 6BBR signals that LLA in a Source LLA Option (SLLAO) in the EDAR messages to the 6LBR, and the 6LBR responds with a Target LLA Option (TLLAO) that indicates the LLA associated to the current registration.

"IPv6 Neighbor Discovery Multicast Address Listener Registration" [I-D.ietf-6lo-multicast-registration] extends [RFC8505] to register anycast and multicast addresses. This entails accepting more than one registration for the same address and the use of the ROVR field as a complement to the index. In that case the 6LBR does not consider multiple registrations as duplicate and retains a state for the anycast addresses that it can use to reply a query.

It results that the 6LBR is capable of providing the LLA mapping for any unicast and anycast address that was proactively registered with an SLLAO. This draft defines the protocol elements and the operations to try a unicast Layer-2 lookup with the 6LBR. This may save a reactive IPv6 ND Neighbor Solicitation (NS) message, which is based on multicast and may be problematic in extensive wireless domains (see [I-D.ietf-mboned-ieee802-mcast-problems]) as well as in large switched fabrics. In case of an anycast address, this draft does not provide a policy/ logic to select between multiple registrations.

The registration and lookup services that the 6LBR provides do not have to be limited to 6BBRs and are available to any node that supports [RFC8505] and [RFC8929] to register an address, and / or this specification to resolve a mapping. The services are available on-link using an IPv6 NDP NS and off-link using a new variation of the Extended Duplicate Address messages called Address Mapping Messages. The policy and security settings that allow the access to the 6LBR are out of scope.

## 2. Terminology

## 2.1. Requirements Language

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.

## 2.2. References

This document uses terms and concepts that are discussed in:

- \* "Neighbor Discovery for IP version 6" [RFC4861] and "IPv6 Stateless address Autoconfiguration" [RFC4862],
- \* Neighbor Discovery Optimization for Low-Power and Lossy Networks [RFC6775], as well as
- \* "Registration Extensions for 6LoWPAN Neighbor Discovery" [RFC8505] and "IPv6 Backbone Router" [RFC8929].

## 2.3. Glossary

This document uses the following acronyms:

6BBR	6LoWPAN Backbone Router
6BBR	6LoWPAN Border Router
6LN	6LoWPAN Node
6LR	6LoWPAN Router
6CIO	Capability Indication Option
AMC	Address Mapping Confirmation
AMR	Address Mapping Request
ARO	Address Registration Option
DAC	Duplicate Address Confirmation
DAD	Duplicate Address Detection
DAR	Duplicate Address Request
EARO	Extended Address Registration Option
EDAC	Extended Duplicate Address Confirmation
EDAR	Extended Duplicate Address Request
DODAG	Destination-Oriented Directed Acyclic Graph
LLN	Low-Power and Lossy Network
NA	Neighbor Advertisement
NCE	Neighbor Cache Entry
ND	Neighbor Discovery
NS	Neighbor Solicitation
ROVR	Registration Ownership Verifier
RA	Router Advertisement
RS	Router Solicitation

TID      Transaction ID

## 2.4. New Terms

This document introduces the following terminology:

**Address Mapping Request** An ICMP message with an ICMP type of 157 (DAR) and a Code Prefix of 1.

**Address Mapping Confirm** An ICMP message with an ICMP type of 158 (DAC) and a Code Prefix of 1.

This document uses terminology defined in [RFC8505], in particular:

**Address Registrar** The Address Registrar is an abstract database that is maintained by the 6LBR to store the state associated with its registrations.

**Address Registration** An Address Registration is an abstract state associated to one registration, in other words one entry in the Address Registrar.

## 3. Overview

Figure 1 illustrates a Backbone Link that federates a collection of LLNs as a single IPv6 Subnet, with a number of 6BBRs providing proxy-ND services to their attached LLNs.

A collection of IPv6 Nodes are present on the Backbone and use IPv6 ND [RFC4861][RFC4862] procedures for DAD and Lookup.

The LLN may be a hub-and-spoke access link such as (Low-Power) Wi-Fi [IEEE Std 802.11] and Bluetooth (Low Energy) [IEEE Std 802.15.1], or a Route-Over LLN such as the Wi-SUN mesh [I-D.heile-lpwan-wisun-overview] that leverages 6LoWPAN [RFC4919][RFC6282] and RPL [RFC6550] over [IEEE Std 802.15.4].

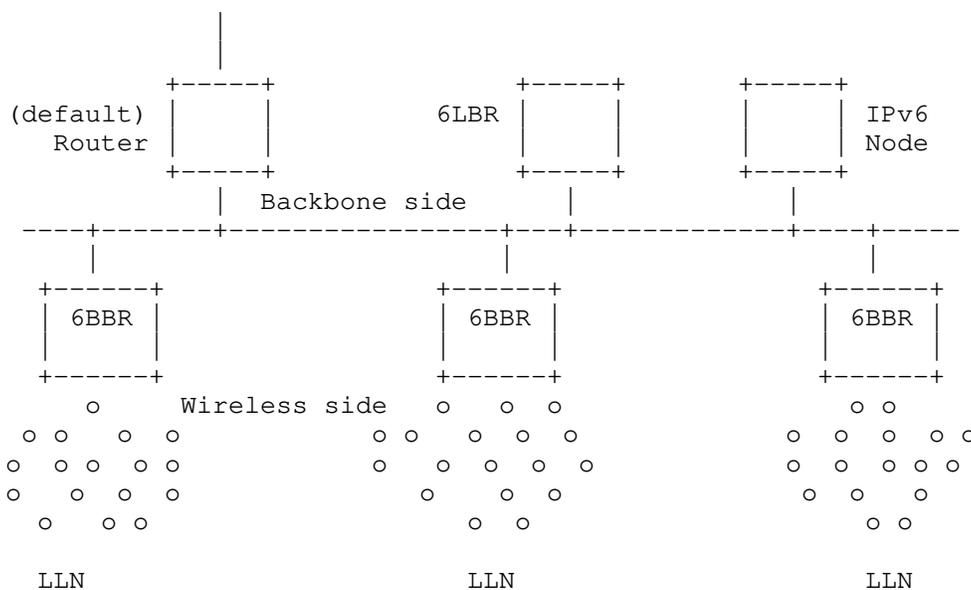


Figure 1: Backbone Link and 6LBR

A 6LBR provides registration services for the purpose of proactive IPv6 ND and maintains a registry of the active registrations for unicast and anycast IPv6 addresses as an abstract data structure called an Address Registrar. An entry in the Address Registrar is called an "Address Registration".

The Address Registration retains:

- \* the value for the ROVR associated to the registration, the current value of the TID, and the remaining Lifetime.
- \* a list of LLAs that are associated with the IPv6 address and can be used in a TLLAO as a response to a lookup.

Examples where more than one address may be available include the case of an anycast address and the case of an LLN address that is proxied by more than one 6BBR.

Unless otherwise configured, a 6LBR does the following:

- \* The 6LBR maintains an entry in the Address Registrar for any type of unicast and anycast addresses including those with link-local scope.

- \* Based on that entry, it provides duplicate avoidance services within the scope of its Address Registrar.
- \* The 6LBR also provides address lookup services for the Registered Address using unicast ICMPv6 DAR and DAC-based Address Mapping messages.

The Address Mapping messages can be exchanged using global unicast addresses as source and destination addresses, so they can be used for both on-link and off-link queries. NS and NA messages may also be used, but in that case the unicast source and destination addresses are link-local addresses and the 6LBR must be on-link.

The 6LBR proactive operations may coexist on the Backbone with reactive IPv6 ND [RFC4861][RFC4862] that rely on multicast for Duplicate Address Detection (DAD) and Address Lookup. Nodes that support this specification operate with the 6LBR before attempting the reactive operation, which may be avoided if the 6LBR is conclusive, either detecting a duplication or returning a mapping.

#### 4. Updating RFC 8505

This specification leverages the capability to insert IPv6 ND options in the EDAR and EDAC messages that was introduced in [RFC8929].

It extends DAR and DAR ICMP messages for address lookup in Section 4.1.2 that use the same ICMP types as EDAR and EDAC but a different Code Prefix.

It also adds a new Status "Not Found" in Section 4.1.3) that indicates that the address being searched is not present in the Address Registrar.

A 6LBR signals itself by setting the "B" bit in the 6CIO of the RA messages that it generates [RFC8505]. This specification adds a new "A" bit in the 6CIO to indicate support of address mapping (see Section 4.1.1).

#### 4.1. Extended Neighbor Discovery Options and Messages

This specification does not introduce new options; it modifies existing options and updates the associated behaviors.

##### 4.1.1. Extending the Capability Indication Option

This specification defines a new capability bit for use in the 6CIO, as defined by [RFC7400] and extended in [RFC8505] for use in IPv6 ND messages.

The new "A" bit indicates that the 6LBR provides address mapping services per this specification.

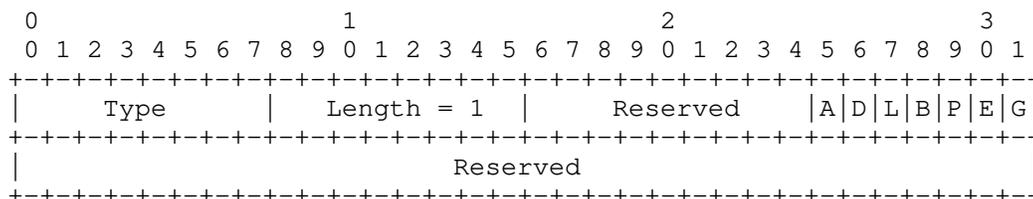


Figure 2: New Capability Bits in the 6CIO

Option Fields:

Type 36

A The 6LBR provides address mapping services.

#### 4.1.2. New Code Prefix for Address Mapping Messages

The Extended Duplicate Address messages share a common base format defined in section 4.2 of [RFC8505], with the ICMP type respectively set to 157 and 158 that is inherited from the DAR and DAC messages defined in section 4.4 of [RFC6775]. The ICMP Code is split in two 4-bit fields, the Code Prefix and the Code Suffix, and the only Code Prefix defined in [RFC8505] is 0, signaling a DAD.

The Address Mapping messages use the same values for the ICMP Type as the corresponding Extended Duplicate Address messages. This specification adds the Code Prefix of 1 to signal Address Mapping. ICMP messages with the ICMP type set to 157 or 158, and a Code Prefix of 1 are thus respectively an Address Mapping Request (AMR) and an Address Mapping Confirm (AMC).

#### 4.1.3. New ARO Status

The Extended Address Registration Option (EARO) is defined in section 4.1 of [RFC8505]. It contains a Status field that is common with with the EDAR and EDAC messages defined in section 4.2 of [RFC8505]. This specification defines a new Status "Not Found" as indicated in Table 1

Value	Description
0..10	As defined in [RFC6775] and [RFC8505]
11	Not Found: The address is not present in the Address Registrar (value to be confirmed by IANA)

Table 1: EARO Status

The Status of "Not Found" can be used in an NA(EARO) and in an AMC messages as a response to an address lookup operation.

#### 4.2. Address Mapping Messages

A 6LBR signals that support by setting the "B" bit in the 6CIO of the RA messages that it generates. A 6LBR that supports this specification MUST also set the "A" bit, indicating support of the Address Mapping messages for address lookup.

In the Address Mapping flow, the querier IPv6 Node uses an AMR message, which is characterized by an ICMPv6 Type of 157 and a Code Prefix of 1. When used on-link, the AMR message SHOULD carry a SLLAO indicating the LLA of the querier. The Code Suffix MUST be set to 0 indicating a ROVR Length of 64 bits. The ROVR, TID and Lifetime fields MUST be set to 0 and ignored by the receiver.

The 6LBR MUST respond with an AMC message, which is characterized by an ICMPv6 Type of 158 and a Code Prefix of 1.

- \* If the address is not present in the Address Registrar then the 6LBR MUST set the status to "Not Found". The Code Suffix MUST be set to 0 indicating a ROVR Length of 64 bits. The ROVR, TID and Lifetime fields MUST be set to 0 and ignored by the receiver.
- \* Else if the address is present in the Address Registrar then the AMC fields MUST be set from the ROVR, TID and remaining Lifetime values in the Address Registration and the Status MUST be set to 0.
- \* If at least one LLA is found in the Address Registration, then the 6LBR MUST place one in a TLLAO option in the AMC message.

The AMC is sent unicast the 6LBR to the querier.

### 4.3. IPv6 ND-based Address Lookup

A 6LBR that is deployed on-link SHOULD provide NS/NA-based services. It signals that support by setting the "L" bit in the 6CIO of the RA messages that it generates, indicating that it is a 6LR [RFC8505].

A 6LBR thus typically sets the "A", the "B", and the "L" bits when attached to a Backbone Link that it serves, as illustrated in Figure 1. In that case, the IPv6 Nodes and 6BBRs can use an NS/NA exchange with the 6LBR for both duplicate detection and lookup services.

The NS(Lookup) is sent unicast from link-local address of the querier to the link-local address of the 6LBR. It carries a SLLAO [RFC4861] and it MUST NOT carry an EARO option to avoid the confusion with a registration.

The 6LBR MUST respond with an NA message that contains an EARO.

- \* If the address is not present in the Address Registrar then the 6LBR MUST set the status to "Not Found". The ROVR, TID and Lifetime fields MUST be set to 0 and ignored by the receiver.
- \* Else if the address is present in the Address Registrar then the EARO fields MUST be set from the ROVR, TID and remaining Lifetime values in the Address Registration and the Status MUST be set to 0.
- \* If at least one LLA is found in the Address Registration, then the 6LBR MUST place one in a TLLAO option in the NA message.

The NA is sent unicast from link-local address of the 6LBR to the link-local address of the querier.

## 5. Backward Compatibility

## 6. Security Considerations

This specification extends [RFC8505], and the security section of that document also applies to this document. In particular, the link layer SHOULD be sufficiently protected to prevent rogue access.

## 7. IANA Considerations

Note to RFC Editor, to be removed: please replace "This RFC" throughout this document by the RFC number for this specification once it is allocated.

IANA is requested to make a number of changes under the "Internet Control Message Protocol version 6 (ICMPv6) Parameters" registry, as follows.

### 7.1. ICMP Codes

IANA is requested to create 2 new subregistries of the ICMPv6 "Code" Fields registry, which itself is a subregistry of the Internet Control Message Protocol version 6 (ICMPv6) Parameters for the ICMP codes.

The new subregistries relate to the ICMP type 157, Duplicate Address Request (shown in Table 2), and 158, Duplicate Address Confirmation (shown in Table 3), respectively. For those two ICMP types, the ICMP Code field is split into 2 subfields, the "Code Prefix" and the "Code Prefix". The new subregistries relate to the "Code Prefix" portion of the ICMP Code. The range of "Code Prefix" is 0..15 in all cases. The policy is "IETF Review" or "IESG Approval" [RFC8126] for both subregistries.

The new subregistries are to be initialized as follows:

Code Prefix	Meaning	Reference
0	Duplicate Address Detection	Duplicate Address Detection
1	Address Mapping	This RFC
2...15	Duplicate Address Detection	

Table 2: New Code Prefixes for ICMP type 157 DAR message

Code Prefix	Meaning	Reference
0	Duplicate Address Detection	Duplicate Address Detection
1	Address Mapping	This RFC
2...15	Duplicate Address Detection	

Table 3: New Code Prefixes for ICMP type 158 DAC message

## 7.2. New ARO Status values

IANA is requested to make additions to the Address Registration Option Status Values Registry as follows:

ARO Status	Meaning	Reference
11 (suggested)	Not Found	This RFC

Table 4: New ARO Status values

## 7.3. New 6LoWPAN Capability Bits

IANA is requested to make additions to the Subregistry for "6LoWPAN Capability Bits" as follows:

Capability Bit	Meaning	Reference
9 (suggested)	AM Support (A bit)	This RFC

Table 5: New 6LoWPAN Capability Bits

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## [IEEE Std 802.11]

IEEE standard for Information Technology, "IEEE Standard 802.11 - IEEE Standard for Information Technology - Telecommunications and information exchange between systems Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.", <<https://ieeexplore.ieee.org/document/9363693>>.

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IEEE standard for Information Technology, "IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements. - Part 15.1: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs)".

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