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                                                  February 25, 2013

         Prefix Delegation extension to Neighbor Discovery protocol
                        draft-kaiser-nd-pd-01

Abstract

   This document describes an extension to the Neighbor Discovery
   protocol (ND). The proposed extension enhances ND by providing it
   with a new option: the Prefix Delegation option (ND-PD). ND-PD
   offers the possibility for routers on a same link to ask for or
   delegate IPv6 prefixes.

Status of this Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   Task Force (IETF). Note that other groups may also distribute
   working documents as Internet-Drafts. The list of current Internet-
   Drafts is at http://datatracker.ietf.org/drafts/current/.

   Internet-Drafts are draft documents valid for a maximum of six months
   and may be updated, replaced, or obsoleted by other documents at any
   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on August 29, 2013.

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[1](). Introduction and motivations

This document describes a new option that extends ND with a PD
mechanism. Using this mechanism, a requesting router can ask for a
global IPv6 prefix to a delegating router that is present on the same
link.

The proposed ND-PD mechanism reaches the same objectives as the
DHCPv6-PD mechanism described in [[DHCPV6_PD]()], but in a faster and
less ressources consuming way. The proposed ND-PD has been initially
thought and designed for highly mobile networks such as vehicular
networks, where opportunities for communicating may be quite short.
Therefore, the less signaling messages are required to auto-configure
mobile nodes, the more time can be exploited by applications during
these short communication windows. Moreover, the default
availability of the ND protocol in any IPv6 stack makes it a strong
candidate to handle the PD service rather than implementing an
additionnal software, especially in hardware and ressources
constrained devices like sensors or on-board devices.

2. Terminology

This document uses the terminology defined in [DHCPV6_PD],
[NEIGHDISC], and [SLAAC]. Also the following additionnal terms are
used:

Requesting router: A router that is asking for prefixes to be
                    delegated.

Delegating router: A router that provides prefixes to requesting
                    routers.

Prefix Information: A logical structure that stores all informations
                    related to a specific prefix.

DPDB: The Delegated Prefixes DataBase (DPDB) is a
                    logical structure that stores all prefixes that
                    have been delegated from a specific delegating
                    router along with other informations related to
                    this delegating router. One DPDB MUST be created
                    on both the requesting and the delegating routers
                    sides for each requesting/delegating routers
                    tuple (see Section 8.1 for more details).

3. Requirements

   The keywords MUST, MUST NOT, REQUIRED, SHALL, SHALL NOT, SHOULD,
   SHOULD NOT, RECOMMENDED, MAY, and OPTIONAL, when they appear in this
   document, are to be interpreted as described in [KEYWORDS].

4. Related works

   A few drafts about providing a PD mechanism to the ND protocol have
   already been proposed in the past.

   In [DRAFT_LUTCHANSKY] the author proposes to add a PD option to the
   Router Solicitation (RS) and Router Advertisement (RA) messages
   generated by routers. A router that needs a global prefix can ask
   for one by including a PD option in a RS message. Then, a router
   that owns prefixes for delegation replies to the request with a RA
   that includes a PD option. The main advantage of this proposal is
   that it is very simple and does not require any additionnal message
   to work. However it lacks of completeness: the handling as well as
   the renewing and releasing of the delegated prefixes are not taken
   into consideration.

   In [DRAFT_HABERMAN] a more complete PD mechanism for ND protocol is
   proposed. The mechanism is based on two new ICMP messages: the
   Prefix Request and the Prefix Delegation. The former is used by a
   requesting router to ask for a prefix. Conversely, the latter is
   used by a delegating router to reply to the request. The proposal
   also includes the possibility for a requesting router to renew a
   delegated prefix that has not expired yet and to return a delegated
   prefix that is no longer required.

   The proposed ND-PD mechanism that is described in this document is
   close to the one described in [DRAFT_HABERMAN]. However, our
   mechanism relies on the creation of new RS/RA options rather than the
   creation of new ICMP messages. Also, the ND-PD service provided by a
   router is advertised using the RA flags option [RAFLAGS]. This
   information enable requesting routers to be aware of the presence of
   routers that provide the ND-PD service on link without firstly asking
   for it.

[5](). Use case example: V2V2I

Figure 1 shows a vehicular scenario. Two vehicles are depicted: a
Leaf Vehicle (LV) and an Internet Vehicle (IV). Both of them embed a
various number of Local Fixed Nodes (LFN) (like, for instance,
sensors) and a Mobile Router (MR) that acts as a gateway between the
network inside the vehicle and the outdoor. The main difference
between the LV and the IV is the number of interfaces that are
embedded on their MR and, consequently, their (in)ability to connect
to an infrastructure network. In this figure, the MR-IV has two
egress interfaces: one connected to the infrastructure (E2) using a
long range communication technology (e.g. 3G or LTE) and the other
one connected to the LV (E1) in an ad-hoc manner using a short range
communication technology (e.g. 802.11p).

The objective in the V2V2I use case is to provide an IPv6 end-to-end
connectivity to the LFN that are embedded in the LV. To this end, a
global and topologically correct IPv6 pefix must be advertised by the
MR-LV on its I1 interface. The MR-LV gets the required prefix by
asking for one to the MR-IV using the ND-PD mechanism. It is assumed
that the MR-IV is provided with IPv6 prefixes by the infrastructure,
either using DHCPv6-PD or any other way.

Details about the messages exchanges generated by ND-PD in the V2V2I
use case can be found in [Section 10](), with the MR-LV being the
requesting router and MR-IV being the delegating router.

```
                                +-----------------+
                                | INTERNET ACCESS |
                                |     VIA THE     |
                                | INFRASTRUCTURE  |
                                |     NETWORK     |
                                +--------+--------+
                                         |
                                         |
                                    E2 | |
   +------------------------+      +------------------------+
   |                        |      |      |          |      |
   |                        |      |      |          |      |
   |    +-----------+       | E1     E1 | |    +-----------+       |
   |    |   MR-LV   |-------|----------------|------|   MR-IV   |       |
   |    +-----------+       |      |      +-----------+       |
   |        I1 |            |      |          I1 |            |
   |           |            |      |             |            |
   |     --------+--------  |      |       --------+--------  |
   |     |    |        |    |      |       |    |        |    |
   |   LFN-1 LFN-2 ... LFN-x |      |     LFN-1 LFN-2 ... LFN-x |
   |                        |      |                        |
   +------------------------+      +------------------------+

            Leaf Vehicle                     Internet Vehicle
```
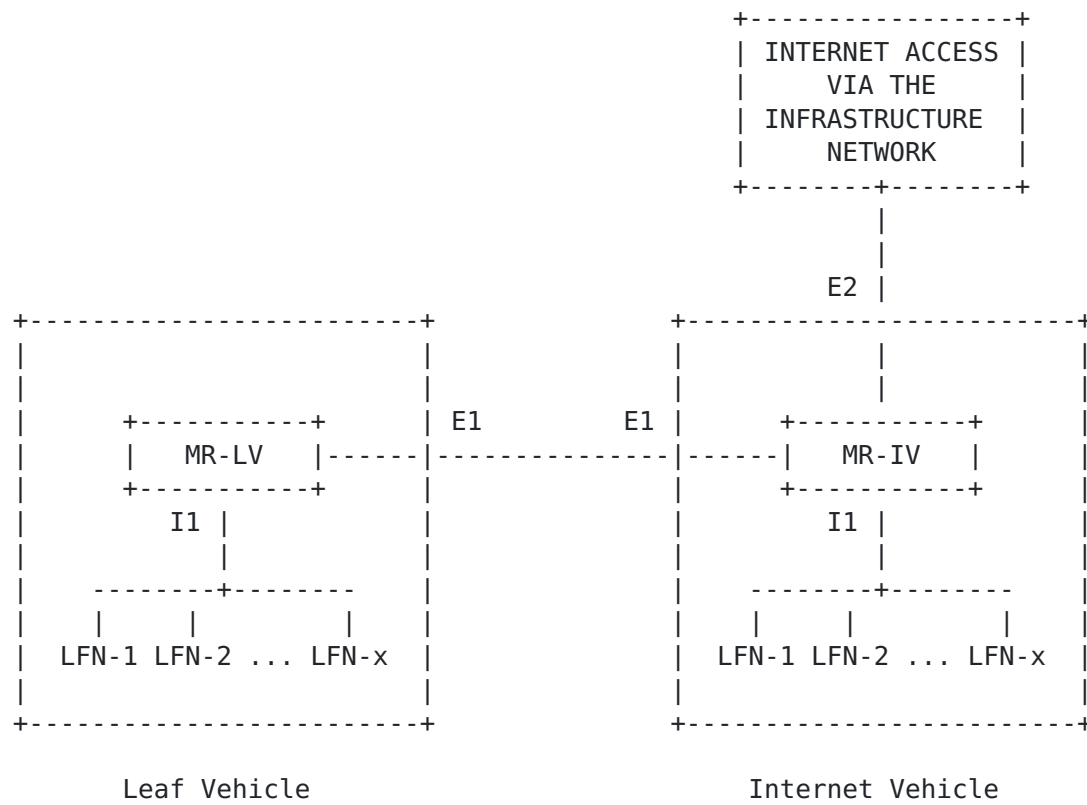
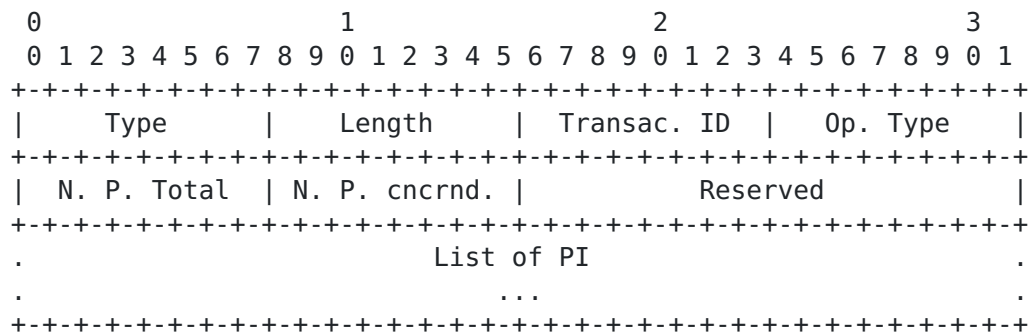   Figure 1: The V2V2I use case

6. **Format of the Prefix Delegation option**

   This section details the format of the option used in the ND-PD
   mechanism. This option is only valid if included in RS or RA
   messages and MUST NOT be included in NS, NA, or Redirect messages.

   The Prefix Delegation option is used to manage everything related to
   the delegation of prefixes. The following operations are considered:

   REQ: Request operation. A requesting router asks for a prefix to
             a delegating router.

   REN: Renew operation. A requesting router asks the delegating
             router that provided it the prefix to extend its lifetime.

   REL: Release operation. A requesting router that does not use
             anymore a delegated prefix informs the delegating router
             that provided it the prefix its intention of releasing it.

   REP: Reply operation. A delegating router replies to a message
             sent by a requesting router.

   SYN: Synchronization operation. When an error is detected, the
             delegating router sends its DPDB to the requesting router in
             order to re-synchronize their DPDB.

   The Prefix Delegation option is composed of a Prefix Delegation
   header that is followed by a list of Prefix Information (PI). The
   format of the Prefix Delegation header is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type     |    Length    | Transac. ID  |   Op. Type    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  N. P. Total | N. P. cncrnd. |            Reserved          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
.                          List of PI                          .
.                             ...                              .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

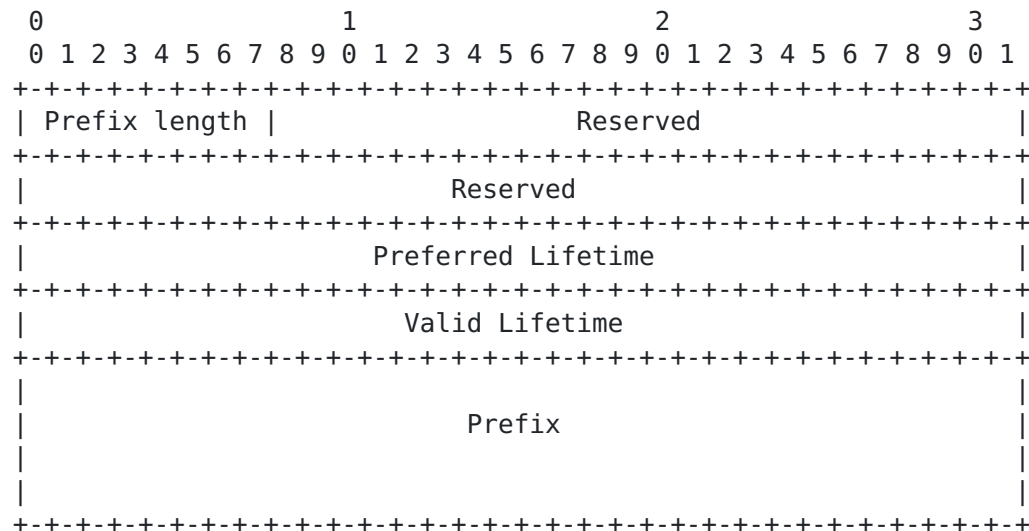   Type: Value that describes the Prefix Delegation option
                   (TBD: IANA).

   Length: Size of the option in blocks of 64 bits (according
                   to [NEIGHDISC]) including the fields "Type" and
                   "Length".

Transac. ID: Identifier of the current messages exchange between
                  the requesting router and the delegating router.

Op. Type: Describes the type of the operation (REQ, REN, REL,
                  REP or SYN).

N. P. Total: The total number of prefixes that have been already
                  delegated by the delegating router to the requesting
                  router (used for synchronization).

N. P. cncrnd.:   The number of prefixes that are concerned by the
                  operation.

Reserved: Unused field. MUST be set to "0" by sender and
                  ignored by recipient.

List of PI: A list of Prefix Informations.

6.1. Format of the Prefix Information

A Prefix Information is a structure that holds all informations
related to a prefix. The format of the Prefix Information is as
follow:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Prefix length |                  Reserved                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Reserved                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Preferred Lifetime                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Valid Lifetime                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                          Prefix                               |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Prefix length: The length of the prefix.

Reserved: Unused field. MUST be set to "0" by sender
                        and ignored by recipient.

   Preferred Lifetime: Time length in seconds (relative to the time
                             the packet is sent) during which addresses
                             generated from this prefix remain preferred
                             (see [SLAAC]). A value of all one bits
                             represents infinity.

   Valid Lifetime: Time length in seconds (relative to the time
                             the packet is sent) during which the prefix
                             is valid and can be used by nodes for auto-
                             configuration (see [SLAAC]). A value of all
                             one bits represents infinity.

   Prefix: The IPv6 delegated prefix. All bits in the
                             prefix positionned after the prefix length
                             MUST be set to "0".

7. Operations details

7.1. Requesting and delegating prefixes

7.1.1. Request

A requesting router requests prefixes from a delegating router with
the REQ operation. REQ operations are only valid if included in a RS
message. This RS message MUST be sent in unicast to a delegating
router present on link (see Section 9 for delegating routers
discovery). The fields of the PD option for a REQ operation MUST be
filled in with the following values:

Transac. ID: An ID of the current messages exchange between the
               requesting router and the delegating router. This ID
               is chosen by the requesting router and MUST be unique
               among all other current transactions that the
               requesting router may have started.

Op. Type: "REQ". It is a request for prefixes.

N. P. Total: The total number of prefixes that have already been
               delegated by the delegating router to the requesting
               router. This value MUST be set to "0" when requesting
               prefixes to the delegating router for the first time,
               even if some prefixes have already been delegated by
               other delegating routers.

N. P. cncrnd.: The number of prefixes that are requested by the
               requesting router.

Reserved: Unused field. MUST be set to "0" by sender and
               ignored by recipient.

List of PI: The list of PI is not necessary with a REQ operation.
               However, if the requesting router has some preferences
               about the parameters of the requested prefixes (e.g.
               the prefix length) it MAY add a PI for each requested
               prefix that describes its preferences. For example,
               if a requesting router requests three prefixes and has
               a preference for one of the three to have a prefix
               length of /48, it SHOULD add one PI with the "Prefix
               Length" field filled in with the value "48".

7.1.2. Reply

A delegating router replies to a REQ operation with a REP operation.
REP operations are only valid if included in a RA message. This RA
message MUST be sent in unicast to the requesting router that
initiated the message exchange. The fields of the PD option for a
REP operation in reply to a REQ operation MUST be filled in with the
following values:

Transac. ID: This ID MUST be the same as the one received with the
               REQ.

Op. Type: "REP". It is a reply.

N. P. Total: The total number of prefixes that have been delegated
               by the delegating router to the requesting router.
               This value MUST include the prefixes that are
               delegated via this message. For example, if a
               requesting router has already recceived a prefix from
               the delegating router and asks for another one, the
               value of this field MUST be "2" (the previously
               delegated plus the new one).

N. P. cncrnd.: The number of prefixes that are delegated via this
               message. It may be possible that this value is lower
               than the one received in the REQ (e.g. if the
               requesting router requested 3 prefixes but only 2 can
               be delegated). If no prefix can be delegated, this
               field MUST be set to "0".

Reserved: Unused field. MUST be set to "0" by sender and
               ignored by recipient.

List of PI: For each delegated prefix a PI that describes it MUST
               be added in the list. If no prefixes are delegated,
               no PI MUST be added.

7.2. Renewing prefixes

7.2.1. Request

A requesting router renews its delegated prefixes with the REN
operation. REN operations are only valid if included in a RS
message. This RS message MUST be sent in unicast to the delegating
router that delegated the concerned prefixes. The fields of the PD
option for a REN operation MUST be filled in with the following
values:

Transac. ID: An ID of the current messages exchange between the
               requesting router and the delegating router. This ID
               is chosen by the requesting router and MUST be unique
               among all other current transactions that the
               requesting router may have started.

Op. Type: "REN". It is a renew of prefixes.

N. P. Total: The total number of prefixes that have been delegated
               by the delegating router to the requesting router.

N. P. cncrnd.: The number of prefixes that are requested to be
               renewed. This value MUST be the same as the "N. P.
               Total" value because the renew operation acts for all
               the delegated prefixes.

Reserved: Unused field. MUST be set to "0" by sender and
               ignored by recipient.

List of PI: As the REN operation acts for all the delegated
               prefixes, no list of PI is necessary.

7.2.2. Reply

A delegating router replies to a REN operation with a REP operation.
REP operations are only valid if included in a RA message. This RA
message MUST be sent in unicast to the requesting router that
initiated the message exchange. The fields of the PD option for a
REP operation in reply to a REN operation MUST be filled in with the
following values:

Transac. ID: This ID MUST be the same as the one received with the
               REN.

Op. Type: "REP". It is a reply.

N. P. Total: The total number of prefixes that have been delegated
               by the delegating router to the requesting router.

N. P. cncrnd.: The number of prefixes that are successfully renewed
               via this message. It MAY be possible that this value
               is lower than the one received in the REN (e.g. if the
               requesting router requested to renew 3 prefixes but
               only 2 can be renewed). If no prefix can be renewed,
               this field MUST be set to "0".

Reserved: Unused field. MUST be set to "0" by sender and
               ignored by recipient.

List of PI: The following cases are possible:

               1. If no prefix is renewed, the list of PI MUST be
                   empty.

               2. If only part of the prefixes are renewed, a PI
                   MUST be added for each successfully renewed
                   prefix.

               3. If all the prefixes are renewed, the list of PI is
                   not necessary, except if the parameters of one or
                   more of the renewed prefixes have changed compared
                   with the last delegation/renew time. As an
                   example, let us consider that the delegating
                   router has delegated two prefixes to the
                   requesting router with preferred and valid
                   lifetimes equal to "10" and "15" respectively.
                   The requesting router now asks for renewing these
                   prefixes. If both prefixes are renewed for the
                   same amount of time (same preferred and valid
                   lifetimes than previously), no PI SHOULD be added.
                   But, if the prefixes are renewed for a different
                   amount of time (e.g. preferred and valid lifetimes
                   equal to "8" and "12" respectively), a PI MUST be
                   added for each renewed prefix.

7.3. Releasing prefixes

7.3.1. Request

A requesting router releases its delegated prefixes with the REL
operation. REL operations are only valid if included in a RS
message. This RS message MUST be sent in unicast to the delegating
router that delegated the concerned prefixes. The fields of the PD
option for a REL operation MUST be filled in with the following
values:

Transac. ID: An ID of the current messages exchange between the
               requesting router and the delegating router. This ID
               is chosen by the requesting router and MUST be unique
               among all other current transactions that the
               requesting router may have started.

Op. Type: "REL". It is a release of prefixes.

N. P. Total: The total number of prefixes that have been delegated
                by the delegating router to the requesting router.
                This value MUST include the prefixes that are included
                in this message as the release operation has not been
                successfully processed yet.

N. P. cncrnd.: The number of prefixes that are requested to be
                released.

Reserved: Unused field. MUST be set to "0" by sender and
                ignored by recipient.

List of PI: If the REL operation concerns all the prefixes that
                have been delegated by the delegating router, the list
                of PI is not needed. If the REL operation concerns
                only part of the delegated prefixes, a PI MUST be
                added for each concerned prefix.

[7.3.2](#). Reply

A delegating router does not reply to a REL operation.

[7.4](#). Prefixes synchronization and error detection

The SYN operation is sent by a delegating router to a requesting
router when an error about the DPDB is detected. SYN operations are
only valid in a RA message. This RA message MUST be sent in unicast
to the requesting router that initiated the message exchange.

The goal of the SYN operation is to re-synchronize the DPDB of the
requesting and the delegating router. Each time a delegating router
receives a RS message with a PD option, it first starts by checking
if the total number of delegated prefixes that the requesting router
has in its DPDB (advertised in the "N. P. Total" field) is the same
as the one the delegating router has in its DPDB. If both values are
the same, the process of the PD option can be continued. Otherwise,
an error occurred and both DPDB MUST be re-synchronized (thus the
operation requested by the requesting router is NOT processed). The
rule is simple: the delegating router sends its DPDB back to the
requesting router via a RA message that includes the PD option with
the SYN operation. Upon reception of the message, the requesting
router updates its DPDB to fit the one advertised by the delegating
router. The requesting router MAY then re-send its initial request.

The fields of the PD option for a SYN operation MUST be filled in
with the following values:

Transac. ID: This ID MUST be the same as the one received in the PD
               option of the RS message sent by the requesting
               router.

Op. Type: "SYN". It is a synchronization operation.

N. P. Total: The total number of prefixes that have been delegated
               by the delegating router to the requesting router.

N. P. cncrnd.: The number of prefixes that are concerned by this
               operation. This value MUST be the same as the one
               above.

Reserved: Unused field. MUST be set to "0" by sender and
               ignored by recipient.

List of PI: The list of all the PI MUST be added.

8. Local operations on requesting and delegating routers

Upon reception of a RS or a RA message, requesting and delegating
routers MUST first check the validity of the message as described in
section 6.1. "Message Validation" of [NEIGHDISC]. The processing of
the message itself along with any option other than the PD option
described in this document is out of the scope of this document.

8.1. Delegated prefixes handling

The delegated prefixes on both the requesting and the delegating
routers are handled using the DPDB. The DPDB is a logical structure
that stores all informations related to a requesting/delegating
routers tuple. One and only one DPDB MUST be created for each
requesting/delegating routers tuple. The DPDB includes but is not
restricted to the following informations:

o The link-local IPv6 address of the requesting router.

o The link-local IPv6 address of the delegating router.

o The Transaction ID used in the last RS or RA message received that
   includes a PD option.

o The Transaction ID used in the last RS or RA message sent that
   includes a PD option.

o The total number of prefixes that have been delegated.

o The shortest preferred and valid lifetimes among the delegated
   prefixes (for an easier handling of the renew operation).

o The list of all the prefixes that have been delegated (list of
   PI).

8.2. Delegating router behaviour

8.2.1. Checking the validity of the PD option

Upon reception of a RS message that includes a PD option, the
delegating router MUST first check that the type of operation of the
PD option is either REQ or REN or REL and that the PD flag (see
Section 9) is not set. If one or both of these conditions are not
met the message MUST be silently discarded.

8.2.2. Checking the synchronization of the DPDB

Before processing the operation, the DPDB synchronization MUST be checked. To this end, the delegating router compares the value of the "N. P. Total" field of the PD option with the total number of delegated prefixes of its DPDB. If both values are the same, the operation can be processed. Otherwise, the delegating router MUST send back to the requesting router a SYN operation in order to re-synchronize both DPDB.

8.2.3. Processing the operations

If the PD option includes a REQ operation, the delegating router checks its possibility to delegate the requested prefixes to the requesting router. For each successfully delegated prefix the delegating router MUST add in its routing table one entry with the following parameters: the destination network is the delegated prefix and the next-hop is the IPv6 address of the requesting router. The delegating router MUST then reply with a RA message that includes a PD option with the REP operation filled accordingly. While the delegated prefixes are not released (either with a REL operation or when their valid lifetime has expired) they MUST NOT be delegated again.

If the PD option includes a REN operation, the delegating router checks its possibility to renew all the prefixes present in the DPDB. For each successfully renewed prefix, the delegating router MUST update the corresponding entry in its routing table. The delegating router MUST then reply with a RA message that includes a PD option with the REP operation filled accordingly.

If the PD option includes a REL operation, the delegating router MUST release the corresponding prefixes. For each successfully released prefix, the delegating router MUST delete the corresponding entry in its routing table.

If the delegating router detects that one or more of the prefixes specified by the requesting router in the REN or REL operations are not valid, the delegating router MUST NOT process the operation and MUST send back to the requesting router a SYN operation to re-synchronize the DPDB.

When the Valid Lifetime of a delegated prefix has expired, the delegating router MUST update its routing table by removing the corresponding entry. The expired prefix is then available for future delegation.

8.3. Requesting router behaviour

8.3.1. Checking the validity of the PD option

Upon reception of a RA message that includes a PD option, the
requesting router MUST first check that the type of operation of the
PD option is either REP or SYN and that the PD flag is set (see
Section 9). If one or both of these conditions are not met the
message MUST be silently discarded.

8.3.2. Checking the synchronization of the messages exchange

In order to ensure that the received RA message is a reply to the
initiated request, the requesting router MUST check that the
"Transac. ID" of the received message fits the one it generated for
its last request.

8.3.3. Processing the operations

If the PD option includes a REP operation, the requesting router is
free of advertising the prefixes included in the REP message on any
of its interfaces except the one from which the REP message was
received. For each prefix that is advertised on an interface, the
requesting router MUST add an entry in its routing table with the
following parameters: the destination network is the advertised
prefix and the output interface is the one where the prefix is
advertised.

If the PD option includes a SYN operation, the requesting router MUST
update its DPDB with the inputs included in the RA message along with
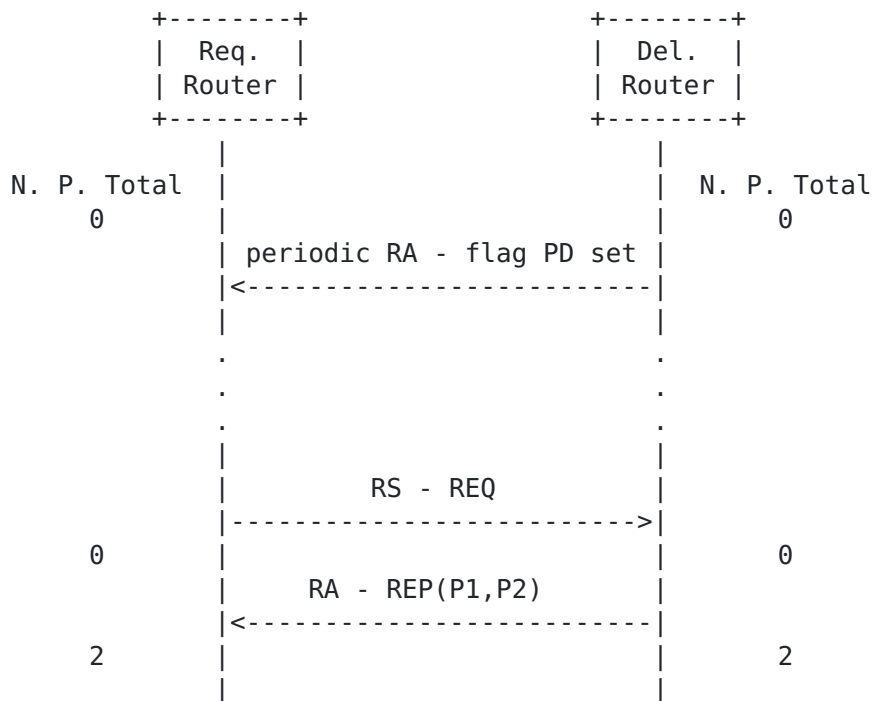its routing table entries. The requesting router MAY then re-send
its initial request.

When the Valid Lifetime of a delegated prefix has expired, the
requesting router MUST update its routing table by removing the
corresponding entry. Also the requesting router MUST stop
advertising this prefix on the corresponding interface.

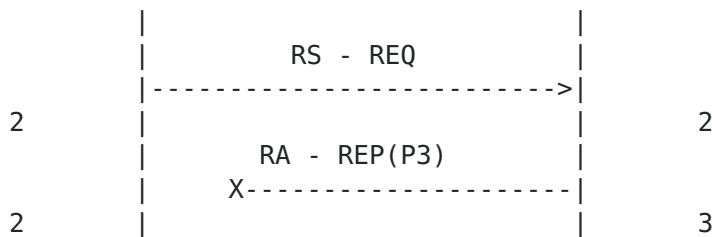## 9. Advertising the ND-PD service

   Each delegating router that delegates prefixes using the ND-PD
   mechanism described in this document MUST advertise this service by
   adding the new PD flag (for Prefix Delegation) in each RA message it
   sends. The PD flag MUST be advertised using the RA flags option
   described in [RAFLAGS].
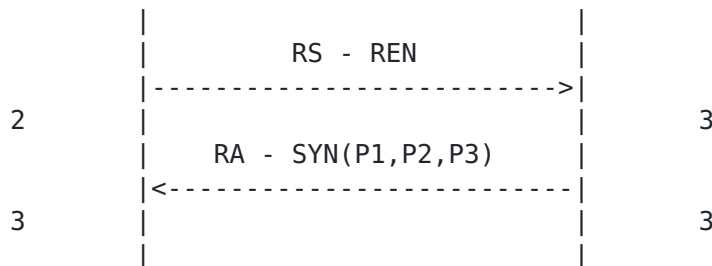
10. Messages exchange diagram

   This section depicts the messages exchanges generated by ND-PD
   between a requesting router and a delegating router. Values under
   "N. P. Total" represent the current total number of delegated
   prefixes that each router has in its DPDB. All messages shown in
   this example include a PD option (except the periodic RA message).
   For each of those messages, the type of operation as well as the
   corresponding PI that are carried out by the PD option are pointed
   out.

```
                  +--------+              +--------+
                  |  Req.  |              |  Del.  |
                  | Router |              | Router |
                  +--------+              +--------+
                      |                       |
     N. P. Total      |                       |   N. P. Total
          0           |                       |        0
                      | periodic RA - flag PD set |
                      |<--------------------------|
                      |                       |
                      .                       .
                      .                       .
                      .                       .
                      |                       |
                      |         RS - REQ      |
                      |-------------------------->|
          0           |                       |        0
                      |      RA - REP(P1,P2)  |
                      |<--------------------------|
          2           |                       |        2
                      |                       |
```
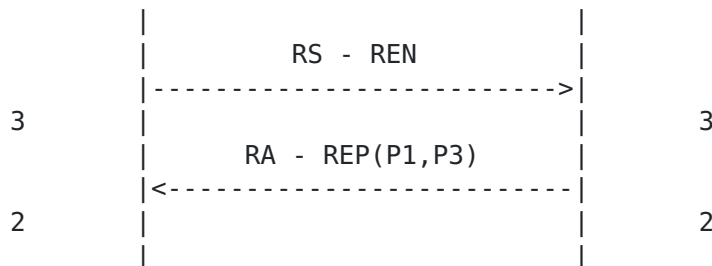
   The delegating router sends periodic RA messages with the PD flag
   set. Upon reception of such message, the requesting router knows
   that the delegating router provides the ND-PD service. At some
   point, the requesting router asks for two prefixes. The delegating
   router accepts the request and delegates prefixes P1 and P2. Both
   DPDB are updated: the total number of delegated prefix for this tuple
   of requesting/delegating routers is set to 2.

```
                      |                       |
                      |         RS - REQ      |
                      |-------------------------->|
          2           |                       |        2
                      |        RA - REP(P3)   |
                      |       X--------------------|
          2           |                       |        3
```

```
                    |                       |
```
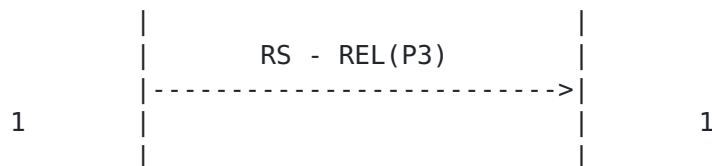
Let us consider that the delegating router now needs one more prefix.
It asks for a new prefix to the delegating router. The delegating
router accepts the request and replies with the new delegated prefix
P3. However, for some reasons, this message never arrives to the
requesting router. Only the DPDB of the delegating router is
updated: the delegating router has delegated three prefixes to the
requesting router but this latter owns only two of them.

```
                    |                       |
                    |       RS - REN        |
                    |---------------------->|
          2         |                       |         3
                    |    RA - SYN(P1,P2,P3) |
                    |<----------------------|
          3         |                       |         3
                    |                       |
```

Let us assume that the Preferred Lifetime of P1 and P2 is now over.
However, the requesting router would like to keep both prefixes
active for more time. Hence, it asks the delegating router to renew
its delegated prefixes. Upon checking the synchronization of the
DPDB, the delegating router detects that the total number of
delegated prefixes is not the same. Therefore, the delegating router
replies with a SYN operation in order to re-synchronize both DPDB.

```
                    |                       |
                    |       RS - REN        |
                    |---------------------->|
          3         |                       |         3
                    |     RA - REP(P1,P3)   |
                    |<----------------------|
          2         |                       |         2
                    |                       |
```

Now that both DPDB are re-synchronized, the requesting router asks
once again for renewing its delegated prefixes. For some reasons,
the delegating router accepts the renew only for P1 and P3 and
replies consequently. Both DPDB are updated.

```
                    |                       |
                    |      RS - REL(P3)     |
                    |---------------------->|
          1         |                       |         1
                    |                       |
```

Finally, the requesting router does not need anymore P3. It thus

releases it and both DPDB are updated.

11. Security Considerations

This section describes the security issues related to prefix
delegation using ND_PD.

The ND_PD mechanism is prone to attacks that may target either the
requesting router or the delegating router, particularly by launching
denial-of-service (DoS) attacks as discussed in [DHCPV6_PD]. If the
requesting router is malicious, it may repeatedly request prefixes to
a delegating router until the exhaustion of all the available
prefixes. This attack could be launched with the same requesting
router identity or with different spoofed link addresses. On the
other side, a malicious delegating router may issue bogus prefixes to
the requesting router which may cause DoS due to unreachability.
Furthermore, the delegated prefixes could be eavesdropped, suppressed
or altered during their transmission to the requesting router,
whereby external attackers aim at using spoofed IP addresses or
launching DoS attacks in the network.

12. IANA Considerations

IANA is kindly requested by the authors to allocate the following values:

o Prefix Delegation option type, which should be added to the
   Neighbor Discovery option type space defined in section 13 of
   [NEIGHDISC]

o Prefix Delegation operation types:

   * REQ

   * REN

   * REL

   * REP

   * SYN

o Space allocation for the PD flag in the RA flags option.

13. Acknowledgements

The authors would like to acknowledge the useful technical
contribution of Sofiane Imadali.

14. References

[KEYWORDS]
          Bradner, S., "Key words for use in RFCs to indicate
          Requirement Levels", BCP 14, RFC 2119, March 1997.

[DHCPV6_PD]
          Troan, O. and R. Droms, "IPv6 Prefix Options for Dynamic
          Host Configuration Protocol (DHCPv6) version 6", RFC 3633,
          December 2003.

[NEIGHDISC]
          Narten, T., Nordmark, E., Simpson, W., and H. Soliman,
          "Neighbor Discovery for IP version 6 (IPv6)", RFC 4861,
          September 2007.

[SLAAC]   Thomson, S., Narten, T., and T. Jinmei, "IPv6 Stateless
          Address Autoconfiguration", RFC 4862, September 2007.

[DRAFT_LUTCHANSKY]
          Lutchansky, N., "IPv6 Router Advertisement Prefix
          Delegation Option",
          draft-lutchann-ipv6-delegate-option-00.txt ,
          February 2002.

[DRAFT_HABERMAN]
          Haberman, B. and J. Martin, "Automatic Prefix Delegation
          Protocol for Internet Protocol Version 6 (IPv6)",
          draft-haberman-ipngwg-auto-prefix-02.txt , February 2002.

[RAFLAGS] Haberman, B. and R. Hinden, "IPv6 Router Advertisement
          Flags Option", RFC 4861, March 2008.

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