RFC 6775 Extension

P.Thubert, E. Nordmark, S. Chakrabarti, C. Perkins

IETF 102

Montreal

Unmet expectations

- Solicited node multicast requires highly scalable L2 multicast
  - IEEE does not provide it => turns everything into broadcast
  - IPv6 ND appears to work with broadcast on 802.1 fabrics up to some scale ~10K nodes
- IPv6 ND requires reliable and cheap broadcast
  - Radios do not provide that => conserving 802.1 properties over wireless is illusory
  - RFC 4862 cannot operate as designed on wireless
  - Address uniqueness is an unguaranteed side effect of entropy
- 802.11 expects proxy operation and broadcast domain separation
  - 802.11 provides a registration and proxy bridging at L2
  - Requires the same at L3, which does not exist
  - Implementations provide proprietary techniques based on snooping => widely imperfect

⇒ RFC 6775 solves the problem for DAD in one LL

⇒ This update enable establishing proxy services directly (ND for now), over a LLN, across multiple LLNs

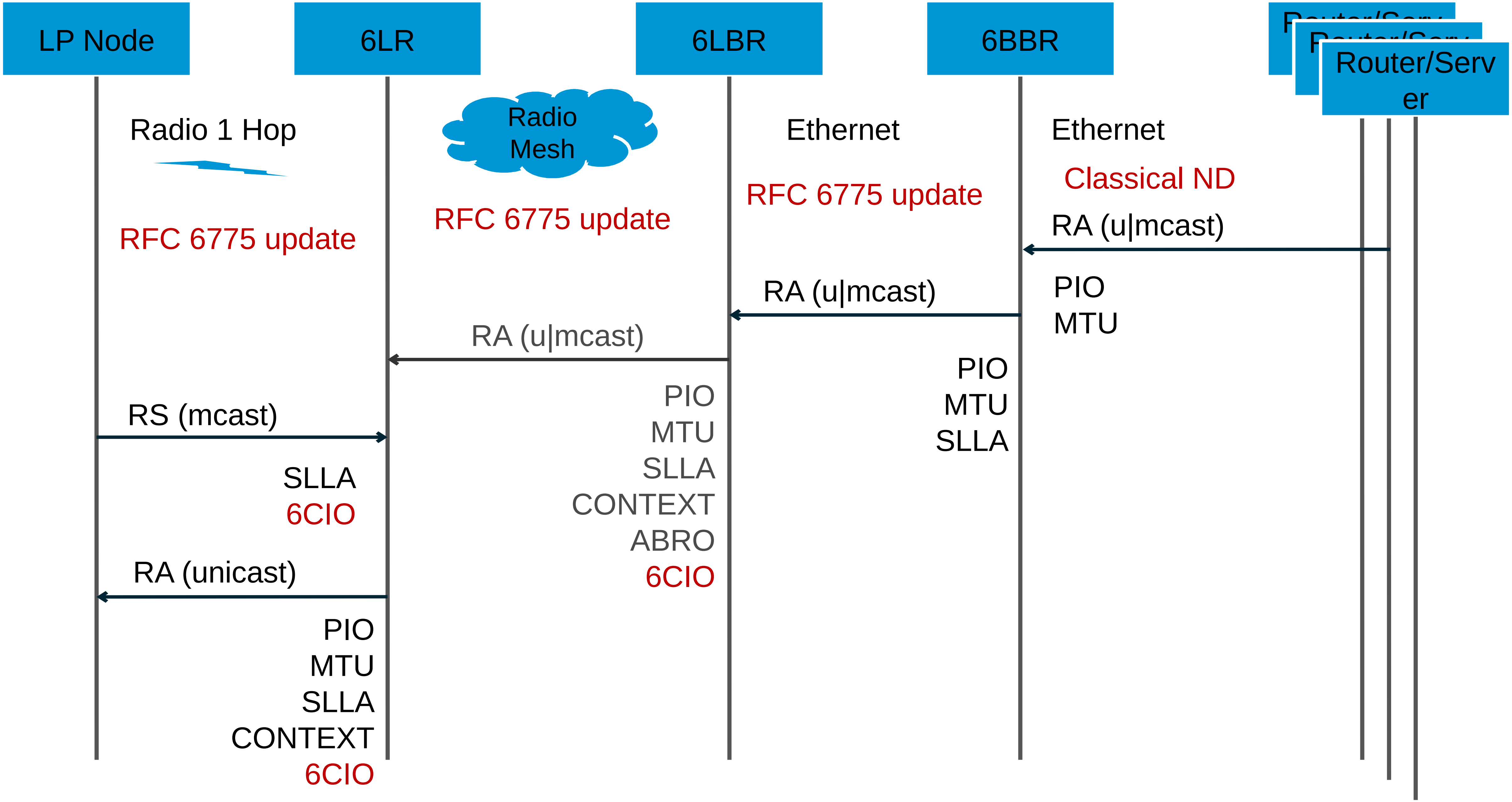
What are the 6LoWPAN ND extensions?

Provide for draft-thubert-6lo-rfc6775-update-reqs

- draft-ietf-6lo-rfc6775-update
  - Simplifies the protocol (no DAR/DAC for LL, no secondary NC)
  - Enables proxy registration
- draft-ietf-6lo-ap-nd
  - Protects addresses against theft (Crypto ID in registration)
- draft-ietf-6lo-backbone-router
  - Federates 6lo meshes over a high speed backbone
  - ND proxy that mimics 802.11 association but at Layer 3

RFC 6775 Update

P.Thubert, E. Nordmark, S. Chakrabarti, C. Perkins



LP Node

6LR

6LBR

6BBR

Router/Server

Radio 1 Hop

Radio Mesh

Ethernet

Ethernet

Classical ND

RFC 6775 update

RFC 6775 update

RFC 6775 update

RA (u|mcast)

PIO
MTU

RA (u|mcast)

PIO
MTU
SLLA

RA (u|mcast)

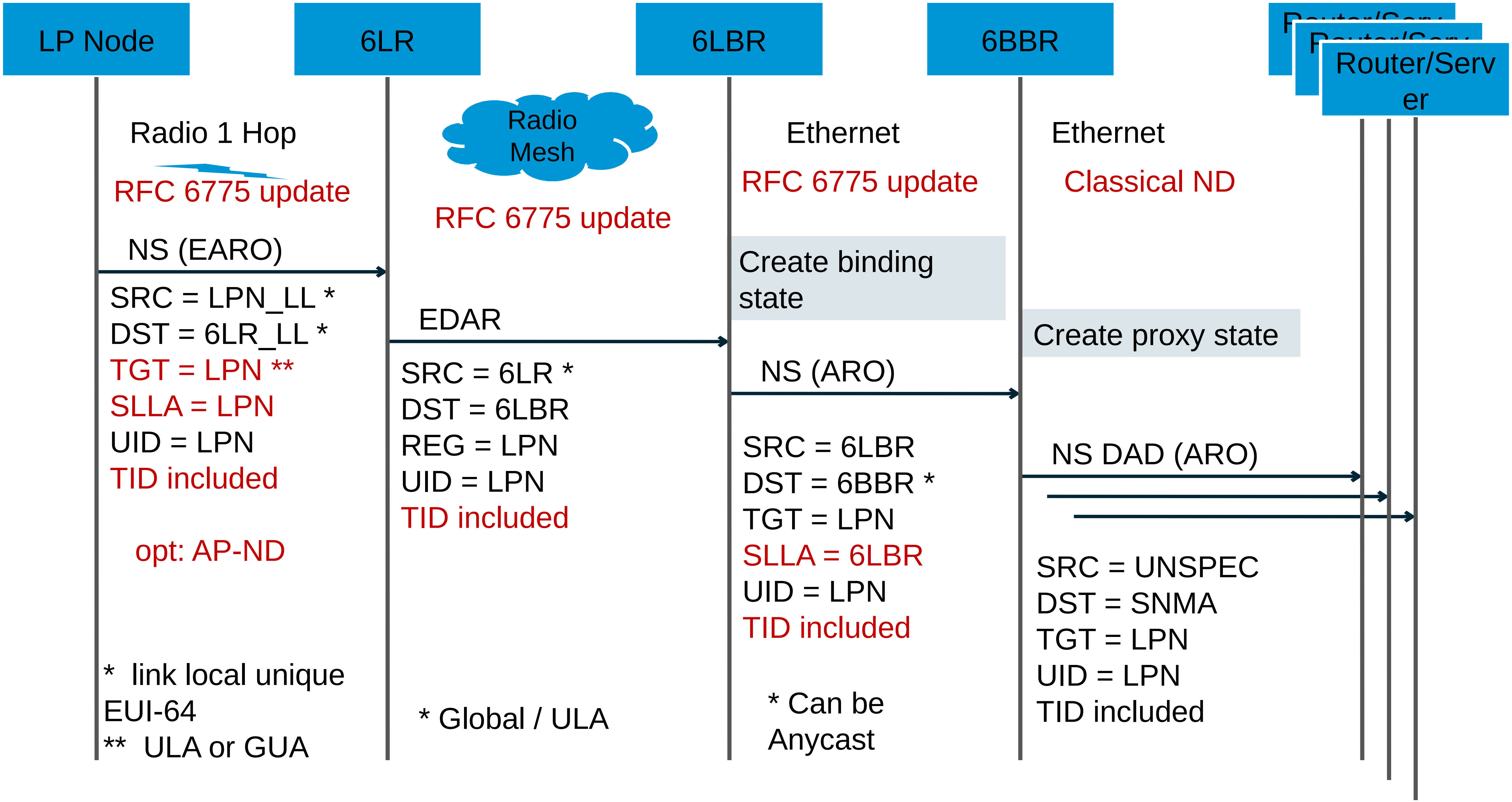
PIO
MTU
SLLA
CONTEXT
ABRO
6CIO

RS (mcast)

SLLA
6CIO

RA (unicast)

PIO
MTU
SLLA
CONTEXT
6CIO



LP Node

6LR

6LBR

6BBR

Router/Serv
er

Radio 1 Hop

RFC 6775 update

NS (EARO)

SRC = LPN_LL *
DST = 6LR_LL *
TGT = LPN **
SLLA = LPN
UID = LPN
TID included

opt: AP-ND

* link local unique
EUI-64
** ULA or GUA

Radio
Mesh

RFC 6775 update

EDAR

SRC = 6LR *
DST = 6LBR
REG = LPN
UID = LPN
TID included

* Global / ULA

Ethernet

RFC 6775 update

Create binding
state

NS (ARO)

SRC = 6LBR
DST = 6BBR *
TGT = LPN
SLLA = 6LBR
UID = LPN
TID included

* Can be
Anycast

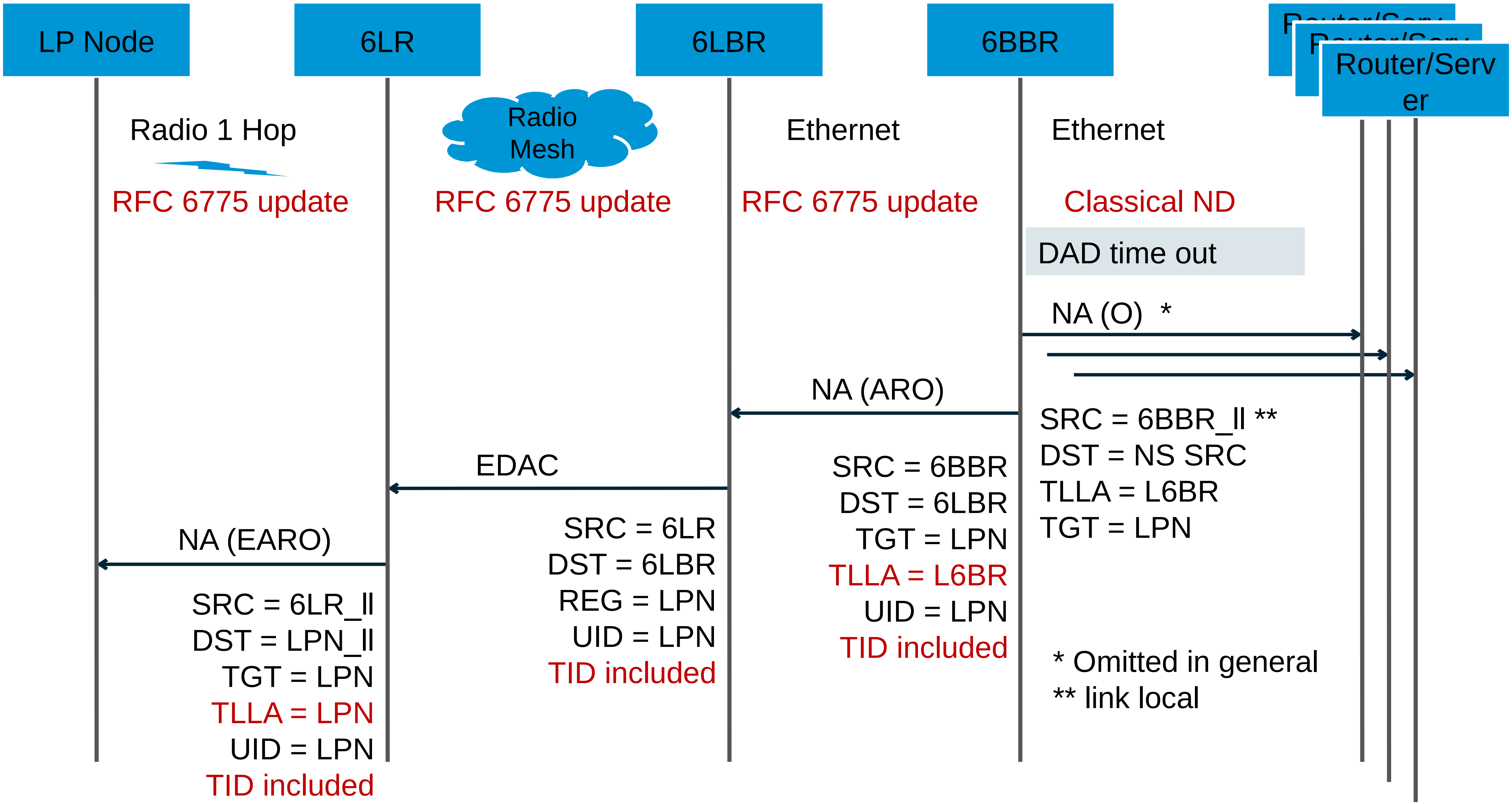
Ethernet

Classical ND

Create proxy state

NS DAD (ARO)

SRC = UNSPEC
DST = SNMA
TGT = LPN
UID = LPN
TID included



LP Node

6LR

6LBR

6BBR

Router/Serv
er

Radio 1 Hop

Radio
Mesh

Ethernet

Ethernet

RFC 6775 update

RFC 6775 update

RFC 6775 update

Classical ND

DAD time out

NA (O) *

SRC = 6BBR_ll **
DST = NS SRC
TLLA = L6BR
TGT = LPN

NA (ARO)

SRC = 6BBR
DST = 6LBR
TGT = LPN
TLLA = L6BR
UID = LPN
TID included

EDAC

SRC = 6LR
DST = 6LBR
REG = LPN
UID = LPN
TID included

NA (EARO)

SRC = 6LR_ll
DST = LPN_ll
TGT = LPN
TLLA = LPN
UID = LPN
TID included

* Omitted in general
** link local

IESG Review (cont.)

RFC 6775 Update

Draft-….-17 to - 18

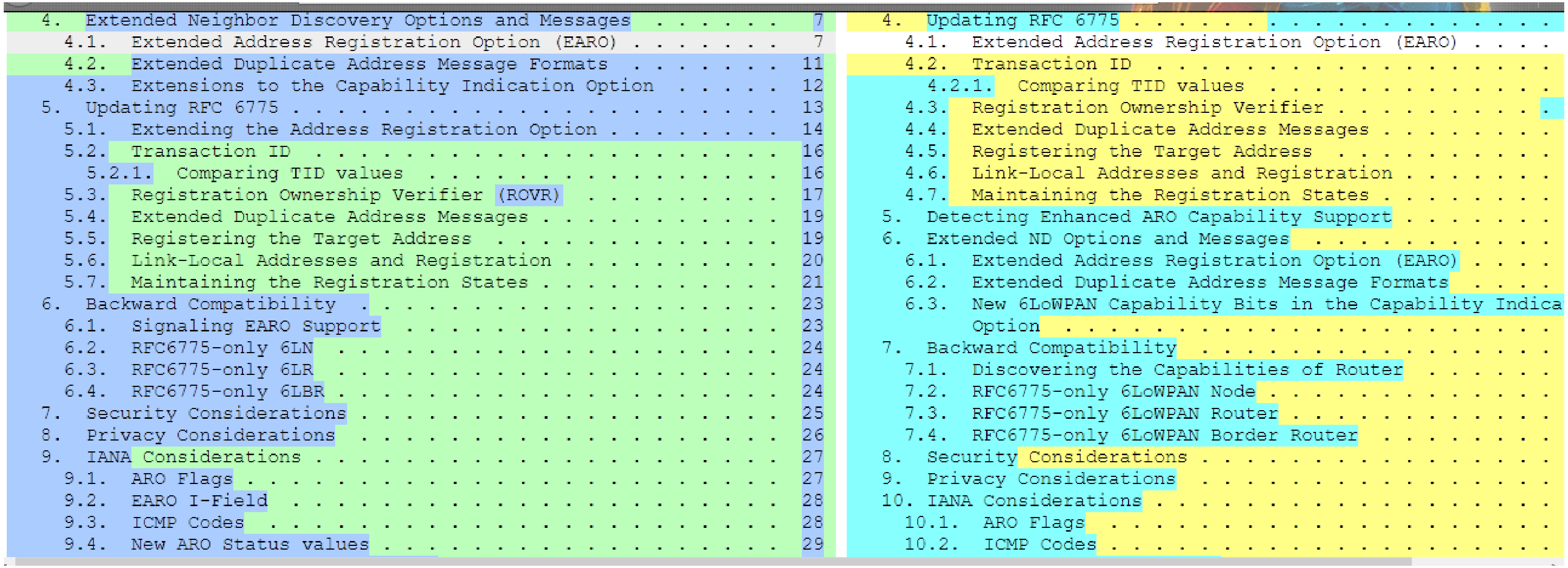
Need to vs. MUST on operator behaviour

- From Dave Thaler (added in 17)
  - “ In order to deploy this, network administrators MUST ensure that 6LR/6LBRs in their network support the number and type of devices that can register to them, based on the number of IPv6 addresses that those devices require and their address renewal rate and behavior. “
- Final text (since 18, with help from Warren Kumari and Ben Campbell)
  - “ Network administrators need to ensure that 6LR/6LBRs in their network support the number and type of devices that can register to them, based on the number of IPv6 addresses that those devices require and their address renewal rate and behavior.
  - “

Mirja Kühlewind (in -18)

- TID Should be zero if the T flag is not set => text added
- Draft reads better if section 6 moves up

-21 -17



Benjamin Kaduk (in -18)

- « In general the Security and Privacy Considerations seem well thought-out «   ^ ^
- Non Zero status: an error?

  RFC 6775 section 8.2.5 has "In the case where the DAC indicates an error (the Status is non-zero)

- ROVER definition (ended up with text below, later split in the document)

```
Enables the correlation between multiple attempts to register a same
IPv6 Address. The ROVR is stored in the 6LR and the 6LBR in the state
associated to the registration.
This can be a unique ID of the Registering Node, such as the EUI-64
address of an interface. This can also be a token obtained with
cryptographic methods which can be used in additional protocol exchanges
to associate a cryptographic identity (key) with this registration
to ensure that only the owner can modify it later.
The scope of a ROVR is the registration of a particular
IPv6 Address and it cannot be used to correlate registrations of
different addresses.
```

Eric Rescorla (in -18)

- « I found this document quite challenging to read. It would be very helpful if it started with a description of the failings of 6775 and a brief overview of how it solves those. »

  - ⇒ Text below was proposed, applied in 18. Upon Charlie’s later review, some migrated to Annex with reqs.
  - ⇒ Missing Eric’s validation. What should we do, put back back in intro or leave in annex?

```
This specification updates 6LoWPAN ND to simplify the registration
operation in 6LoWPAN routers and to extend the protocol as a more
generic registration technique.  The specified updates enable other
specifications to define new services such as Source Address
Validation (SAVI) with [I-D.ietf-6lo-ap-nd], participation as an
unaware leaf to an abstract routing protocol such as the "Routing
Protocol for Low Power and Lossy Networks" [RFC6550] (RPL) with
[I-D.thubert-roll-unaware-leaves], and registration to a backbone
routers performing proxy Neighbor Discovery in a Low-Power and Lossy
Network (LLN) with [I-D.ietf-6lo-backbone-router].
```

Eric Rescorla (in -18)

- « Can you describe here the problem that ARO has that this solves?»
  - ⇒ Text below was proposed, applied in 18. Upon Charlie’s later review, somewhat reworded later
  - ⇒ Missing Eric’s validation.

The Address Registration Option (ARO) is defined in section 4.1 of [RFC6775]. This specification introduces the Extended Address Registration Option (EARO) based on the ARO for use in NS and NA messages. The EARO conveys additional information such as a sequence counter called Transaction ID (TID) that is used to determine the latest location of a registering mobile device. A 'T' flag is added to indicate that the TID field is populated.

The EARO also signals whether the 6LN expects routing or proxy services from the 6LR using a new 'R' flag.

The EUI-64 field is overloaded and renamed ROVR in order to carry different types of information, e.g., cryptographic information of variable size. A larger ROVR size may be used if and only if backward compatibility is not an issue in the particular deployment.

Eric Rescorla (in -18)

- Cross check with AP ND, fixed mismatch in Leftmost vs. Rightmost bits
- Misc. Clarifications
- More comments / fixes on the ROVR field, e.g., be very specific on the length

Ben Campbell (in -18)

- Down references added during IESG review in terminology section
  - ⇒ Not really solved to date. Created a separate reference section

```
11.2.  Terminology Related References

   [RFC4919]  Kushalnagar, N., Montenegro, G., and C. Schumacher, "IPv6
              over Low-Power Wireless Personal Area Networks (6LoWPANs):
              Overview, Assumptions, Problem Statement, and Goals",
              RFC 4919, DOI 10.17487/RFC4919, August 2007,
              <https://www.rfc-editor.org/info/rfc4919>.

   [RFC6606]  Kim, E., Kaspar, D., Gomez, C., and C. Bormann, "Problem
              Statement and Requirements for IPv6 over Low-Power
              Wireless Personal Area Network (6LoWPAN) Routing",
              RFC 6606, DOI 10.17487/RFC6606, May 2012,
              <https://www.rfc-editor.org/info/rfc6606>.
```

Final fixes

RFC 6775 Update

Draft-….-19 to - 21

Charlie Perkins

- As an author and native speaker, Charlie made a final pass on the language and the organization
- Found that text was repeated, other was scattered
- Fixed the language, regrouped items
- E.g., took functional text out of the definition, to appropriate section
- Also removed extraneous references
- Work happened over draft 19-21

Issue 1: EDAR / EDAC extensibility

- The size of the ROVR was inferred from the size of the message
- Did not leave a possibility to insert options
- This might be desirable in the future, e.g., MAC Address option for a MAP server
- Long discussion, tried multiple possibilities
- Ended up with split ICMP Code, similar to what we discussed with Adrian Farrell
- Added in draft -20

RFC 6775 update new features: ICMP code split

```
  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      |CodePfx|CodeSfx|          Checksum             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |    Status     |     TID       |     Registration Lifetime     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
...            Registration Ownership Verifier (ROVR)            ...
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

 +                      Registered Address                       +

 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
Code:                 The ICMP Code [RFC4443] for Duplicate Address
                      Messages is split in two 4-bit fields, the Code
                      Prefix and the Code Suffix.
```

RFC 6775 update new features: ICMP code split

Code:

The ICMP Code [RFC4443] for Duplicate Address Messages is split in two 4-bit fields, the Code Prefix and the Code Suffix. The Code Prefix MUST be set to zero by the sender and MUST be ignored by the receiver. A non-null value of the Code Suffix indicates support for this specification. It MUST be set to 1 when operating in a backward-compatible mode, indicating a ROVR size of 64 bits. It MAY be 2, 3 or 4, denoting a ROVR size of 128, 192, and 256 bits, respectively.

Issue 2: Enabling Other Routing Registrars

- 6BBR is only one possible routing registrar. Others include
  RPL [I-D.thubert-roll-unaware-leaves] and
  RIFT [I-D.ietf-rift-rift]
- Resolution to use a generic term as opposed to mention 6BBR specifically
- Also allow an opaque field. RPL uses it for instance ID.
- Added in draft -19
- Generalization to the term « routing registrars » in -21

RFC 6775 update new features: the Opaque field

```
  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    |    Status     |    Opaque     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Rsvd | I |R|T|     TID       |     Registration Lifetime     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
...            Registration Ownership Verifier (ROVR)          ...
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
  Opaque:
       An octet opaque to ND; the 6LN MAY pass it
       transparently to another process.  It MUST be set to
       zero when not used.
```

RFC 6775 update new features: the I field

```
   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    |    Status     |    Opaque     |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |  Rsvd | I |R|T|     TID       |     Registration Lifetime     |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                                                               |
...            Registration Ownership Verifier (ROVR)             ...
  |                                                               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

I: Two-bit Integer: A value of zero indicates that the Opaque field carries an abstract index that is used to decide in which routing topology the address is expected to be injected.

draft-ietf-6lo-ap-nd

P.Thubert, B. Sarikaya, M Sethi, (and expecting R. Struik but not there yet)

Unmet expectations

- First come first Serve address registration
  - First registration for an address owns that address till it releases it
  - The network prevents hijacking
- Source address validation
  - Address must be topologically correct
  - Source of the packet owns the source address
- First Hop Security only?
  - Proxy ownership and routing advertisements not protected yet

Recent changes

- Simplified the computation of the Crypto-ID
  - Digital signature (SHA-256 then either NIST P-256 or EdDSA) is executed on the concatenation of short modifier and public key
  - Modifier not used to make computation complex as opposed to CGA. This simplifies the operation of a constrained node
  - But 64 bits ROVR might not suffice for adequate protection => Longer ROVR
- Reuse options defined in RFC 3971 for SEND
  - Crypto-ID Parameters Option, a variation of the CGA Option
  - Nonce Option
  - NDP Signature Option, a variation of the RSA Signature Option
    - the option is extended for non-RSA Signatures
    - this specification defines an alias to avoid the confusion.

Security properties

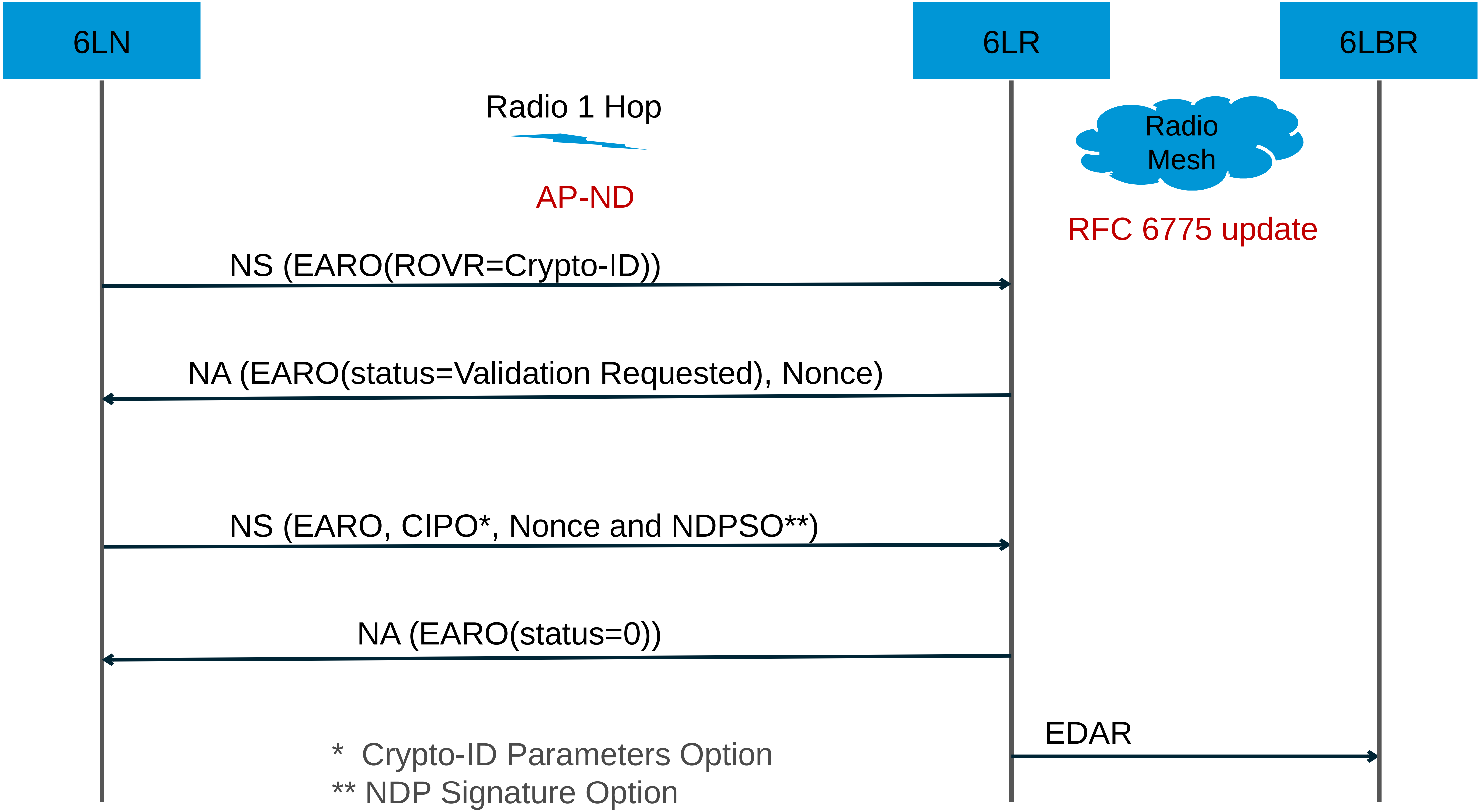
- We made the size of the ROVR tunable so we can get high security
- At the moment a joining 6LN is challenge from the 6LR
  - The 6LBR MUST trust the 6LR
  - A rogue 6LR may pretend that it represents a 6LN that passed the challenge
  - Should we challenge all the way from the 6LBR?
  - Can the Crypto-ID be used in routing protocols, how?

AP-ND Status, talks with Eric Rescorla

- Quite Stable, not republished since IETF 101
- Fixed inconsistency with RFC 6775 update in RFC 6775 update (Eric Rescorla)
- Multiple talks to sync with Eric, but then no change done yet.
- Need to clarify key encoding

  Draft uses DER. Behcet recommended lihter like Jason Web Key.

  Eric: “Aren't you using EC keys? If so, why do you need *either* encoding.” ?
- Remove text on 64-bits identifiers since ROVR is up to 256 bits
- 256 bits solves many concerns about security that Eric had.



6LN

6LR

6LBR

Radio 1 Hop

AP-ND

Radio Mesh

RFC 6775 update

NS (EARO(ROVR=Crypto-ID))

NA (EARO(status=Validation Requested), Nonce)

NS (EARO, CIPO*, Nonce and NDPSO**)

NA (EARO(status=0))

EDAR

* Crypto-ID Parameters Option

** NDP Signature Option

draft-ietf-6lo-backbone-router

P.Thubert

Unmet expectations

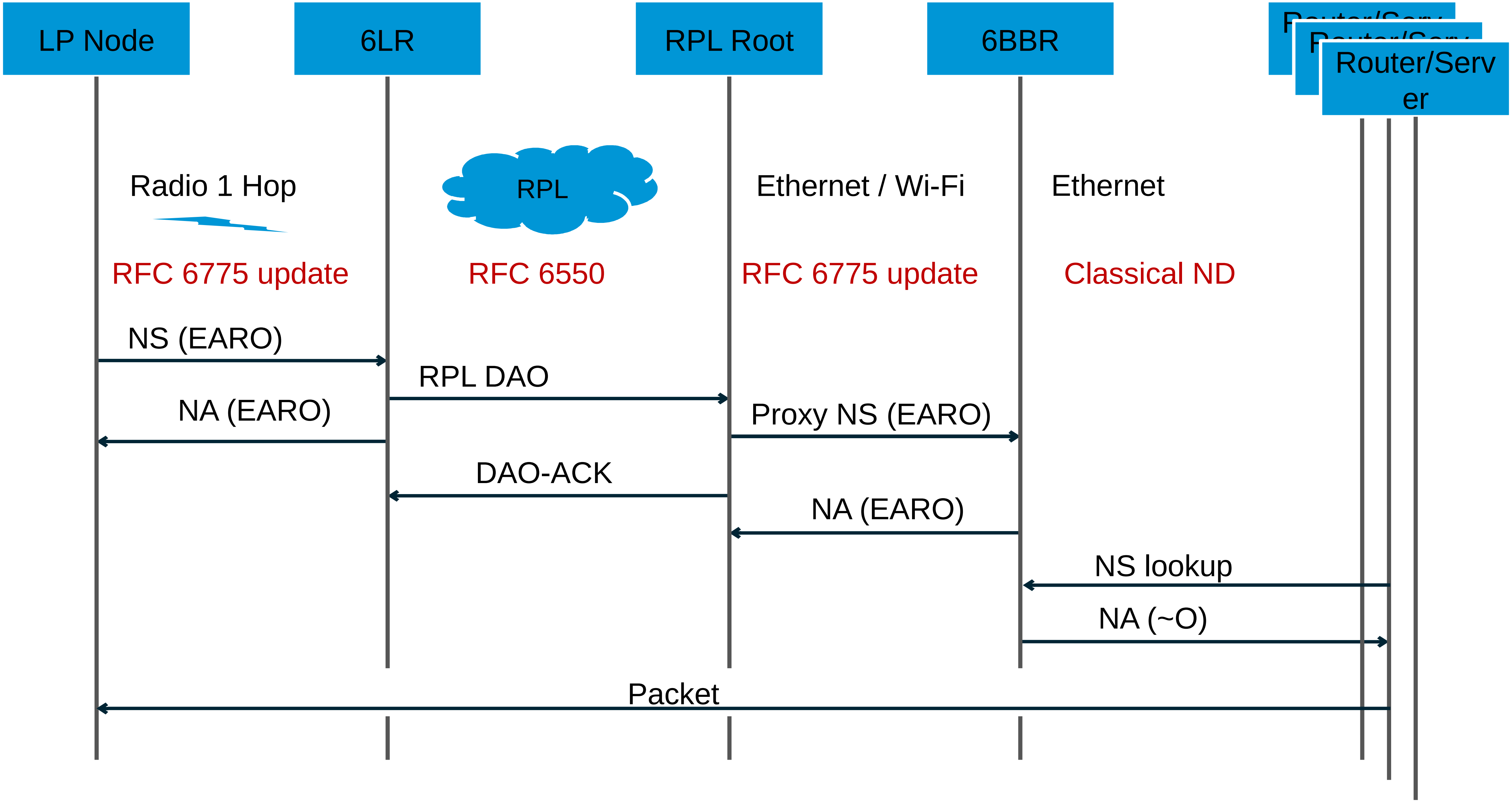
- Scale an IOT subnet to the tens of thousands
  - With device mobility (no renumbering)
  - Controlled Latency and higher Reliability using a backbone
- Deterministic Address presence
  - Route towards the latest location of an address
  - Remove stale addresses

Recent changes

- Uses of the ‘R’ flag

  Indicates the need for proxy operation

- Clarifications
- TBD : RPL Root / 6LBR separation



LP Node

6LR

RPL Root

6BBR

Router/Server

Radio 1 Hop

RPL

Ethernet / Wi-Fi

Ethernet

RFC 6775 update

RFC 6550

RFC 6775 update

Classical ND

NS (EARO)

RPL DAO

NA (EARO)

Proxy NS (EARO)

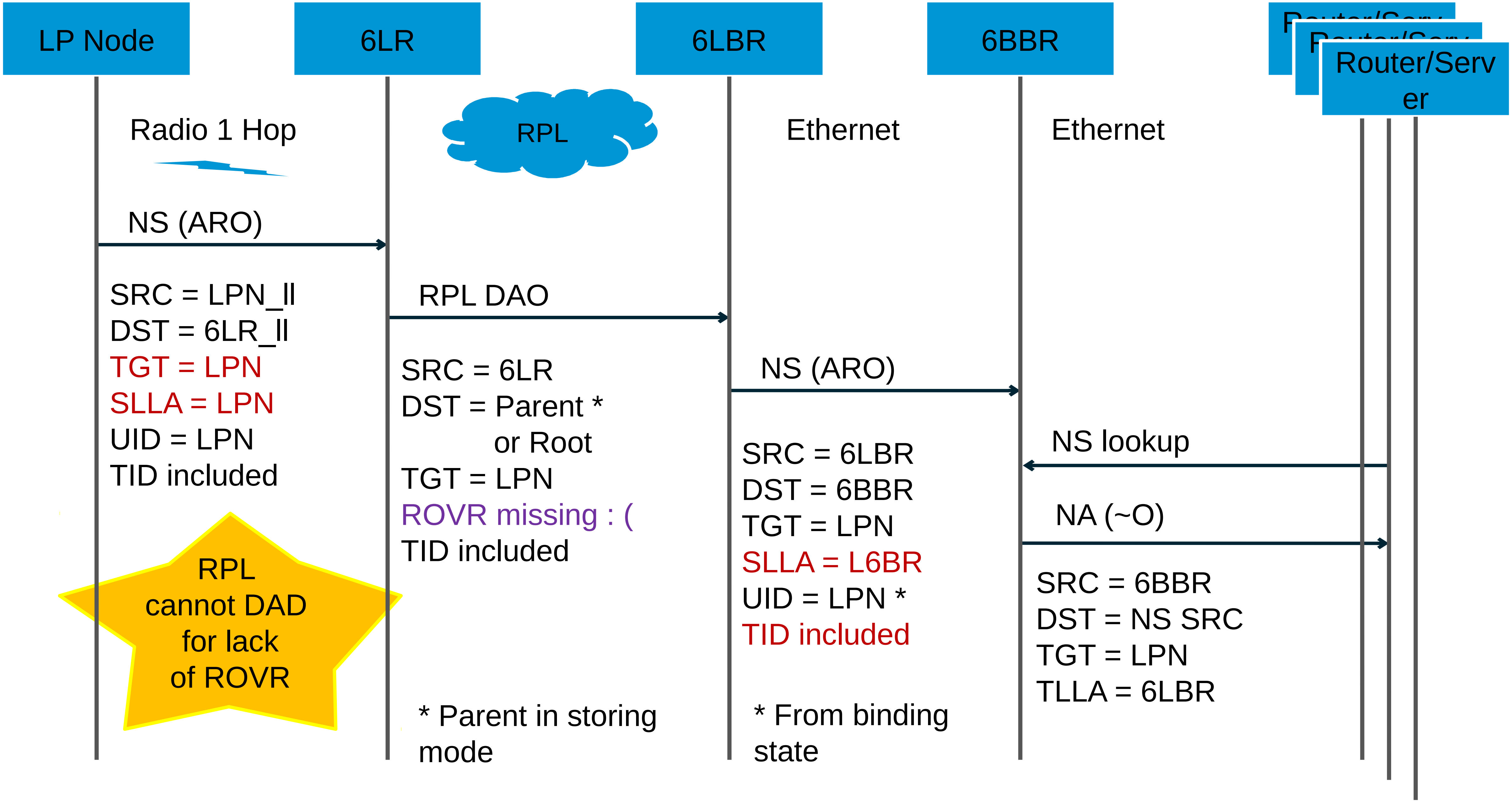
DAO-ACK

NA (EARO)

NS lookup

NA (~O)

Packet



LP Node

6LR

6LBR

6BBR

Router/Server

Radio 1 Hop

RPL

Ethernet

Ethernet

NS (ARO)

SRC = LPN_ll
DST = 6LR_ll
TGT = LPN
SLLA = LPN
UID = LPN
TID included

RPL
cannot DAD
for lack
of ROVR

RPL DAO

SRC = 6LR
DST = Parent *
or Root
TGT = LPN
ROVR missing : (
TID included

* Parent in storing mode

NS (ARO)

SRC = 6LBR
DST = 6BBR
TGT = LPN
SLLA = L6BR
UID = LPN *
TID included

* From binding state

NS lookup

NA (~O)

SRC = 6BBR
DST = NS SRC
TGT = LPN
TLLA = 6LBR

6BBR Status

- Quite Stable, not republished since IETF 101
- WGLC?