6LoWPAN P. Thubert
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6LoWPAN Backbone Router
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Abstract

ISA100.11a is a Working Group at the ISA SP100 standard committee that covers Wireless Systems for Industrial Automation and Process Control. The WG is mandated to design a scalable, industrial grade LowPAN for devices such as sensors, valves, and actuators. The upcoming standard uses the 6LoWPAN format for the network header. It also introduces the concept of a Backbone Router to merge small LoWPANs via a high speed transit and scale the ISA100.11a network. This paper proposes an IPv6 version of the Backbone Router concept.

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1. Introduction

ISA100.11a is a Working Group at the ISA SP100 standard committee that covers Wireless Systems for Industrial Automation and Process Control. The ISA100.11a is mandated to design a scalable, industrial grade wireless network and application layer suite of protocols for low power devices such as sensors and actuators, with a response time on the order of 100ms.

The ISA100.11a WG has also introduced the concept of a Backbone Router that would interconnect small LoWPANs over a high speed transit network and scale a single ISA100.11a network up to the thousands of nodes.

This paper specifies IP layer functionalities that are required to implement the concept of a Backbone Router with IPv6, in particular the application of the "IP Version 6 Addressing Architecture" [RFC4291], " the Neighbor Discovery Protocol" [RFC4861] and "IPv6 Stateless Address Autoconfiguration" [RFC4862]. The use of EUI-64 based link local addresses, Neighbor Discovery Proxying [RFC4389] and Optimistic Duplicate Address Detection [RFC4429] are discussed. Also, the concept of Transit Link is introduced to implement the transit network that is envisioned by ISA100.11a.

An extension to the Neighbor Discovery Protocol is introduced to enable LoWPAN nodes to register to one or more Backbone Routers that acts as white board for address resolution. This feature enables to avoid the use of multicast over a Low power Wireless Personal Area Network for the purpose of address resolution.

The Backbone Router might also acts as proxy for the Neighbor Discovery Protocol for all nodes attached to it through a process of registration and enables to merge multiple LoWPANs via a transit link into a larger link.

A Backbone Router advertises itself using a new option in the ND

Router Advertisement Message. A new anycast address 6LOWPAN_BBR is also introduced for the purpose of reaching the nearest Backbone Router in the absence of any information. This enables to reduce the use of multicast RAs for the router discovery operation. The routing to the nearest router that owns that anycast address is out of scope for this specifiation.

Another anycast address 6LOWPAN-NODE is introduced to enable any LowPAN node to receive a response to its registration whether it completes successfully or not.

The way the PAN IDs and 16-bit short addresses are allocated and

distributed in the case of an 802.15.4 network is not covered by this specification. Similarly, the aspects of joining and securing the network are out of scope.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

Readers are expected to be familiar with all the terms and concepts that are discussed in "Neighbor Discovery for IP version 6" [RFC4861], "IPv6 Stateless Address Autoconfiguration" [RFC4862], "IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals" [RFC4919] and "Transmission of IPv6 Packets over IEEE 802.15.4 Networks" [RFC4944].

Readers would benefit from reading "Mobility Support in IPv6" [RFC3775], "Neighbor Discovery Proxies (ND Proxy)" [RFC4389] and "Optimistic Duplicate Address Detection" [RFC4429] prior to this specification for a clear understanding of the art in ND-proxying and binding. This document defines additional terms:

Transit Link

This is an IPv6 link that interconnects 2 or more backbone routers. It is expected to be deployed as a high speed backbone in order to federate a potentially large set of LoWPANS. Also

referred to as a LoWPAN backbone or transit network.

Backbone Router

An IPv6 router that interconnects the LoWPAN with a Transit Link.

Extended LoWPAN

This is the aggregation of multiple LoWPANs as defined in [RFC4919] interconnected by a Transit Link via Backbone Routers and forming a single IPv6 link.

Binding

The association of the LoWPAN node IPv6 address and Interface ID with associated proxying states including the remaining lifetime of that association.

Registration

The process during which a LoWPAN node sends a Binding ND message to a Backbone Router causing a binding for the LoWPAN node to be registered.

3. Overview

A Transit Link federates multiple LoWPANs as a single IP link, the extended LoWPAN. Each LoWPAN is anchored at a Backbone Router. The Backbone Routers interconnect the LoWPANs over the Transit Link. A node can move freely from a LoWPAN anchored at a Backbone Router to a LoWPAN anchored at another Backbone Router on the same Transit Link and conserve its link local and any other IPv6 address it has formed.

```
                ---+------------------------
                   |          Plant Network
                   |
                +-----+
                |     | Gateway
```

```
               |     |
               +-----+
                  |
                  |      Transit Link
            +--------------------+------------------+
            |                    |                  |
         +-----+             +-----+             +-----+
         |     | Backbone    |     | Backbone    |     | Backbone
         |     | router      |     | router      |     | router
         +-----+             +-----+             +-----+
            o                o   o  o              o o
        o o   o  o       o o   o  o  o         o  o  o  o o
       o  o o  o o       o   o  o  o  o        o  o  o o o
       o   o  o  o          o    o  o           o  o   o
         o   o o               o  o                 o o

         LoWPAN              LoWPAN              LoWPAN
```

Figure 1: Transit Link and Backbone Routers

In order to achieve this, the Transit link is used as reference for Neighbor Discovery operations, by extending the concept of a Home Link as defined in [RFC3775] for Mobile IPv6. In particular, Backbone Routers perform ND proxying for the LoWPAN nodes in the LoWPANs they own through a Primary registration.

The backbone router operation is compatible with that of a Home Agent. This enables mobility support for sensor devices that would move outside of the network delimited by the transit link. This also enables collocation of Home Agent functionality within Backbone Router functionality on the same interface of a router.

The Backbone Router is centric for address resolution inside the LoWPAN. The raison d'etre of the Backbone Router is to eliminate the need of the support for multicasting over the LoWPAN for address resolution that the Neighbor Discovery flows normally require. This is based on a white board registration model that uses anycast and unicast only.

As a result, a LoWPAN node performs unicast exchanges to its Backbone Router to claim and lookup addresses, and the Backbone Router proxies

the ND requests over the Transit Link when necessary.

In turn, the Backbone Routers operate as a distributed database of all the LoWPAN nodes and use the Neighbor Discovery Protocol to share that information across the transit link.

This specification documents a Neighbor Binding protocol that enables a LoWPAN Node to claim and lookup addresses using a Backbone Router as a white board.

This specification also documents the use of EUI-64 based link-local addresses and the way they are claimed by the Backbone Routers over the transit link.

For the purpose of Neighbor Discovery proxying, this specification documents the LoWPAN binding cache, a conceptual data structure that is similar to the MIP6 binding cache.

Another function of the Backbone Router is to perform 6LowPAN compression and expansion between the LoWPAN and the Transit Link and ensure MTU compatibility. Packets flow uncompressed over the Transit Link and are routed normally towards a Gateway or an Application sitting on the transit link or on a different link that is reachable via IP.

4. Neighbor Binding messages

This section introduces message formats for all messages used in this specification. The new messages are all ICMP messages and extend the capabilities of " the IPv6 Neighbor Discovery Protocol" [RFC4861]

4.1. Binding Solicitation message

The Binding Sollicitation has a function similar to that of the Binding Solicitation message in [RFC3775] for Mobile IPv6 and [RFC3963] for NEMO. Any option that is not recognized MUST be skipped silently. The Binding Solicitation message is sent by the LoWPAN node to its Backbone Router to register an address.

```
      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      |     Code      |          Checksum             |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |   Reserved                |O|P|          Sequence #           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                            Lifetime                           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                            Reserved                           |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |                                                               |
     +                                                               +
     |                                                               |
     +                       Binding Address                         +
     |                                                               |
     +                                                               +
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |   option(s)...
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Binding Solicitation message format

IP fields

Source Address: An IP address assigned to the sending interface, or the unspecified address if no address is assigned to the sending interface.

Destination Address: The well-known Backbone Router anycast address 6LOWPAN_BBR or the specific address of a given Backbone Router if available.

Hop Limit: 255

ICMP fields

Type: 8-bit unsigned integer. Value is "to be assigned by IANA".

Code: 0

Checksum: The ICMP checksum. See [RFC4443]

Reserved: This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

P: Primary Flag. Set to indicate that the router is primary and MAY proxy for the node if Proxy ND is used on the transit link. If the flag is not set then the router MUST not proxy for the node.

O: Optimistic Flag. Set to indicate that the node uses optimistic addresses and can accept packets on the Binding Address even before the binding is complete. The Router MUST always use that Binding Address as destination for the response as opposed to the well-known anywast address.

Sequence #: A 16-bit unsigned integer used by the receiving node to sequence Binding Solicitation and by the sending node to match a returned Binding Confirmation.

Lifetime: 32-bit unsigned integer. The number of seconds remaining before the binding MUST be considered expired. A value of zero indicates that the Binding Cache entry for the registered node MUST be deleted.

Binding Address: The link-layer address that the sender wishes to assign or maintain assigned to its interface.

Possible options

Target link-layer address: The link-layer address for the target, i.e., the sender of the message. See [RFC4861]. The link-layer address option MUST be included when the binding is created and MAY be omitted in renewal.

MTU: Specifies the maximum size of a fragmented message that the node stack can recompose. See [RFC4861] and [RFC4944].

4.2. Binding Confirmation message

The Binding Confirmation has a function similar to that of the Binding Ack message in [RFC3775] for Mobile IPv6 and [RFC3963] for NEMO. Any option that is not recognized MUST be skipped silently. The Binding Confirmation message is sent by the Backbone Router node to the LoWPAN node to confirm whether an IP address MAY be assigned

to an interface.

```
     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      |     Code      |          Checksum             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   Reserved                  |X|P|        Sequence #           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                             Lifetime                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                             Reserved                          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    +                                                               +
    |                                                               |
    +                        Binding Address                        +
    |                                                               |
    +                                                               +
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |   option(s)...
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: Binding Confirmation message format

IP fields

Source Address: An IP address assigned to the sending interface of the router.

Destination Address: The well-known LoWPAN node anycast address 6LOWPAN_NODE or the Binding Address for the LoWPAN node.

Hop Limit: 255

ICMP fields

Type: 8-bit unsigned integer. Value is "to be assigned by IANA".

Code: 0

Checksum: The ICMP checksum. See [RFC4443]

Reserved: This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

P: Primary Flag. MUST echo the P flag in the Binding solicitation.

X: Proxy Flag. Indicates that the route actually proxies for the node. This can only happen if the P flag is set as well.

Sequence #: A 16-bit unsigned integer used by the receiving node to sequence Binding Solicitation and by the sending node to match a returned Binding Confirmation.

Lifetime: 32-bit unsigned integer. The number of seconds remaining before the binding MUST be considered expired. A value of zero indicates that the Binding Cache entry for the registered node MUST be deleted.

Binding Address: The link-layer address that the sender wishes to assign or maintain assigned to its interface.

Possible options

Source link-layer address: The link-layer address of the interface from which the Router Advertisement is sent. See [RFC4861].

MTU: Specifies the maximum size of a fragmented message that the router stack can recompose. See [RFC4861] and [RFC4944].

Prefix Information: The preferred address for the router. See [RFC4861] and [RFC3775]. When this information is present, the Source link-layer address option MUST be present as well. The Prefix Information option MUST be included when the binding is created and MAY be omitted in renewal.

5. LowPAN device operations

5.1. Forming addresses

All nodes are required to autoconfigure at least one address, a link-local address that is derived from the IEEE 64-bit extended media access control address that is globally unique to the device. Link-

local address are described in section 2.5.6 of [RFC4291]. Appendix A of that specification explains how the node builds an interface-ID based on the IEEE 64-bit extended MAC address by inverting the "u" (universal/local) bit.

As a result, knowledge of the 64-bit address of another node on the same extended LoWPAN is enough to derive its link-local address and reach it over IP. Another consequence is that the link local address is presumably unique on the Extended LoWPAN, which enables the use of

Optimistic Duplicate Address Detection (oDAD) [RFC4429] over the Transit Link and the LoWPAN. The address MAY be created as optimistic to enable its use in the binding process with the Backbone Router.

Nodes should also autoconfigure the well known anycast address 6LOWPAN_NODE. If they do not, they have to use their link local address in optimistic node and indicate so in the binding flows so that the Backbone Router uses that address in its replies.

Nodes MAY learn the address of the Backbone Routers using traditional means such as configuration or the Neighbor Discovery Protocol Router Advertisement messages. But those messages are multicast and might not be sent at a short interval or at all over the LoWPAN. This specification introduces a new anycast address 6LOWPAN_BBR that the node can use to reach the nearest Backbone Router without previous knowledge of that router address. This specification tolerates movement within the LoWPAN so the node does not have to stick with a given backbone router and MAY keep using the 6LOWPAN_BBR address for all its registrations.

The Link Layer Address associated to the 6LOWPAN_BBR address is that of the PAN coordinator unless the node has a specific reason to select an alternate next hop. It is expected that the selected next hop has a route to the nearest Backbone Router but the routing protocol involved is outside the scope of this specification. It results that the next hop might have to forward the registration message and decrement the Hop Limit. This is why the Backbone Router MUST accept Binding Solicitations with a Hop Limit that is lower than 255 (min value TBD).

The node might also form Unique Local and Global Unicast addresses,

for instance if it needs to be reachable from the outside of the Extended LoWPAN, or if it can manage its own mobility as prescribed by Mobile IPv6 [RFC3775]. In that case, the node needs to bind each individual address individually.

5.2. Binding process

The binding process is very similar to that of a MIP6 mobile node, though the messages used are new Neighbor Discovery ICMP messages . A LoWPAN node address is tentative or optimistic as long as the binding is not confirmed by the Backbone Router.

The LoWPAN node uses unicast Binding Solicitations to perform the binding. The destination Address is that of the Backbone Router or a well know anycast address 6LOWPAN_BBR that indicates the function of the Backbone Routers. The source address is the unspecified address

as long as the address is still optimistic or tentative, and it is the link local address of the node after it is successfully bound.

The acknowledgment to a Binding Solicitation is a unicast Binding Confirmation message that contains the status of the binding. The source of the packet is the link-local address of the Backbone Router. The destination address is a well-know anycast address 6LOWPAN_NODE unless the optimistic bit is set in the Binding Solicitation or the address was already bound, in which case the link local address of the node is used.

Upon successful completion in the Binding Confirmation message, the LoWPAN node sets the address from optimistic or tentative to preferred.

The 'X' flag in the Binding Confirmation message indicates that the Backbone Router has completed DAD and now owns the Binding Address over the Transit Link.

This specification also introduces the concept of secondary binding. For redundancy, a node might place a secondary binding with one or more other Backbone Routers over a same or different LoWPANs. The 'P' flag in the Binding Solicitation message indicates whether the binding is primary (set) or secondary (reset).

5.3. Looking up neighbor addresses

A LoWPAN node does not use multicast for its Neighbor Solicitation as prescribed by the ND protocol [RFC4861] and oDAD [RFC4429]. For lookup purposes, all NS messages are sent in unicast to the Backbone Router, that answers in unicast as well. The message is a standard Neighbor Solicitation but for the destination that set to the Backbone Router address or the well known 6LOWPAN_BBR address as opposed to the solicited-node multicast address for the destination address.

The Target link-layer address in the response is either that of the destination if a short cut is possible over the LoWPAN, or that of the Backbone Router if the destination is reachable over the Transit Link, in which case the Backbone Router will terminate 6LoWPAN and relay the packet.

5.4. Answering address look up

A LoWPAN node does not need to join the solicited-node multicast address for its own addresses and should not have to answer a multicast Neighbor Solicitation. It may be programmed to answer a unicast NS but that is not required by this specification.

6. Backbone router operations

6.1. Exposing the Backbone Router

The Backbone Router forms a link-local address in exactly the same way as any other node on the LoWPAN. It uses the same link local address for the Transit Link and for all the associated LoWPAN(s) connected to that Backbone Router.

The backbone router also configures the well known 6LOWPAN_BBR anycast address on the LoWPAN interfaces where it serves as Backbone Router. Note that The Backbone Router will accept registration packets with a hop limit that is lower than 255 on that specific address.

The Backbone Router announces itself using Router Advertisements (RA) messages that are broadcasted periodically over the LOWPAN. (note: can we merge RA with some other maintenance packet or distribute the

info from the manager in some specific cases like ISA100.11a where such a thing exists?). (also, when the node moves to another LoWPAN, is there a way to let it know faster which is the Backbone Router so that it can stimulate a RA using RS?).

A new option in the RA indicates the Backbone Router capability. In this way a node can learn the PAN-ID and the 16-bit short address for the Backbone Router if it was not already acquired from another process that is not covered by this specification.

The Backbone Router MAY also announce any prefix that is configured on the transit link, and serve as the default gateway for any node on the Transit Link or on the attached LoWPANs.

The transit link Maximum Transmission Unit serves as base for Path MTU discovery and Transport layer Maximum Segment Size negotiation (see section 8.3 of [RFC2460]) for all nodes in the LoWPANs. To achieve this, the Backbone Router announces the MTU of the transit link over the LoWPAN using the MTU option in the RA message as prescribed in section "4.6.4. MTU" of IPv6 Neighbor Discovery [RFC4861].

LoWPAN nodes SHOULD form IPv6 packets that are smaller than that MTU. As a result, those packets should not require any fragmentation over the transit link though they might be intranet-fragmented over the LoWPAN itself as prescribed by [RFC4944]).

More information on the MTU issue with regard to ND-proxying can be found in Neighbor Discovery Proxies [RFC4389] and [I-D.van-beijnum-multi-mtu].

6.2. Binding process

Upon a new binding for a link-local address based on a IEEE 64-bit extended MAC address, the Backbone Router MAY use Optimistic DAD on the Transit Link. Any other Backbone Router that would happen to have a binding for that same address SHOULD yield and deprecate its binding to secondary if it was primary. A positive acknowledgement can be sent to the LoWPAN node right away if oDAD is used on the Transit Link. Note: A new option with a sequence number from the Binding Solicitation should be used to select the winner

The Backbone Router operation on the transit link is similar to that of a Home Agent as specified in Mobility Support for IPv6 [RFC3775]. In particular, the Neighbor Advertisement message is used as specified in section "10.4.1. Intercepting Packets for a Mobile Node" with one exception that the override (O) bit is not set, indicating that this Backbone Router acts as a proxy for the LoWPAN and will yield should another Backbone Router claim that address on the Transit Link. This enables the LoWPAN node to join a different Backbone Router at any time without the complexities of terminating a current binding.

This specification also introduces the concept of secondary binding. Upon a secondary binding, the Backbone Router will not announce or defend the address on the transit link, but will be able to forward packets to the node over its LoWPAN interface. For other addresses, the rules in [RFC3775] apply for compatibility.

The Backbone Router responds to a Binding Solicitation with a Binding Confirmation. The source address is a link local address of the router and the destination is the well known 6LOWPAN_NODE address unless a binding flow has already successfully completed in which case the router MAY use the node's Binding. The router will also use the Binding Address if the 'O' flag is raised in the Solicitation, indicating that the node accepts packets on that address prior to a successful binding but may not accept packets on the 6LOWPAN_NODE address.

If the Backbone Router is primary for a registration (as indicated by the 'P' flag) and it is connected to a Backbone, then it SHOULD perform proxy ND operations on the backbone and indicate so in the Confirmation message using the 'X' flag. In particular it SHOULD reject the registration if DAD fails on the backbone. When oDAD is used over the backbone the Backbone Router MAY issue the Binding Confirmation right away with a positive code, but if a collision is finally detected, it cancels the registration with an asynchronous Binding Confirmation and a negative completion code.

6.3. Looking up neighbor addresses

A Backbone Router knows and proxies for all the IPv6 addresses that are registered to it. When resolving a target address, the Backbone

Router first considers its binding cache. If this address is in the cache, then the target is reachable over the LoWPAN as indicated in the cache. Else, the Backbone Router locates the target over the transit link using standard "Neighbor Discovery" [RFC4861] over that link.

If the target is located over a LoWPAN owned by another Backbone Router, then that other Backbone Router is in charge of answering the Neighbor Solicitation on behalf of the target node.

6.4. Answering address look up

To enable proxying over the Transit Link, a Backbone Router must join the solicited-node multicast address on that link for all the registered addresses of the nodes in its LoWPANs. The Backbone Router answers the Neighbor Solicitation with a Neighbor Advertisement that indicates its own link-layer address in the Target link-layer address option.

A Backbone Router expects and answers unicast Neighbor Solicitations for all nodes in its LoWPANs. It answers as a proxy for the real target. The target link-layer address in the response is either that of the destination if a short cut is possible over the LoWPAN, or that of the Backbone Router if the destination is reachable over the Transit Link, in which case the Backbone Router will terminate 6LoWPAN and relay the packet.

6.5. Forwarding packets

Upon receiving packets on one of its LoWPAN interfaces, the Backbone Router checks whether it has a binding for the source address. If it does, then the Backbone Router can forward the packet to another LoWPAN node or over the Transit link. Otherwise, the Backbone Router MUST discard the packet. If the packet is to be transmitted over the Transit link, then the 6LoWPAN sublayer is terminated and the full IPv6 packet is reassembled and expanded.

When forwarding a packet from the Transit Link towards a LOwPAN interface, the Backbone Router performs the 6LoWPAN sublayer operations of compression and fragmentation and passes the packet to the lower layer for transmission.

7. Security Considerations

This specification expects that the link layer is sufficiently protected, either by means of physical or IP security for the Transit Link or MAC sublayer cryptography. In particular, it is expected that the LoWPAN MAC provides secure unicast to/from the Backbone Router and secure broadcast from the Backbone Router in a way that prevents tempering with or replaying the RA messages.

The use of EUI-64 for forming the Interface ID in the link local address prevents the usage of Secure ND ([RFC3971] and [RFC3972]) and address privacy techniques. Considering the envisioned deployments and the MAC layer security applied, this is not considered an issue at this time.

8. IANA Considerations

This specification requires 2 new ICMP types for the binding flow. The is also a need for 2 new link local anycast addresses, 6LOWPAN_BBR for the routers and 6LOWPAN_NODE the nodes; those addresses used as functional addresses.

9. Acknowledgments

The author wishes to thank Geoff Mulligan for his help and in-depth review.

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Author's Address

Pascal Thubert
Cisco Systems
Village d'Entreprises Green Side
400, Avenue de Roumanille
Batiment T3
Biot - Sophia Antipolis 06410
FRANCE

Phone: +33 4 97 23 26 34
Email: pthubert@cisco.com

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