

Network Working Group
Internet-Draft
Intended status: Standards Track
Expires: December 19, 2007

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June 17, 2007

Hierarchical Routing over 6LoWPAN (HiLow)
draft-daniel-6lowpan-hilow-hierarchical-routing-01.txt

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Abstract

The EUI-64 identifier of a 6LoWPAN device can be used as the

interface identifier of the IPv6 address, which can be used for on-demand multi-hop routing in 6LoWPAN. One of the distinctive feature of 6LoWPAN is the capability of the dynamic assignment of 16-bit short addresses. By utilizing this dynamically assigned short address, a hierarchical routing which is very scalable can be employed. This document defines a dynamic address assignment scheme and hierarchical routing (HiLow) based on the assignment.

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1. Introduction

6LoWPAN is a low-power wireless personal area network(LoWPAN) which is comprised of the IEEE 802.15.4-2003 standard[ieee802.15.4] devices. In [I-D.ietf-6lowpan-format], the interface identifier [RFC4291] for a 6LoWPAN device is based on the EUI-64 [EUI64] address. The interface identifier can be used for constructing routing tables for multi-hop routing in 6LoWPAN. However, considering the limited capabilities (low power, limited memory space, and small packet size) of 6LoWPAN devices and the large number of devices which is expected to be deployed in 6LoWPAN, the on-demand multi-hop routing with the use of the routing table and the EUI-64 identifier may have limitations of the scalability.

One of the distinctive feature of 6LoWPAN is the capability of the dynamic assignment of 16-bit short addresses. By utilizing this short address, hierarchical routing can be employed. Even though hierarchical routing produces a sub-optimal routing path, it can significantly reduce the overhead of maintaining routing tables.

This document defines a dynamic address assignment scheme and Hierarchical routing for 6LoWPAN (HiLow) based on the assignment.

2. Terminology

Association

A IEEE 802.15.4 device can be assigned a dynamic 16 bit short address during an association operation with a neighbor device (or router) which is also called a parent. After getting the short address, a device can communicate with its parent or child by using only the assigned short address.

Coordinator

A full-function device (FFD) which is the principal controller of a 6LoWPAN. It is also called as PAN coordinator. It MAY initiate the synchronization of the entire 6LoWPAN by transmitting beacons.

Current Node

When a node, a IEEE 802.15.4 device in a 6LoWPAN, receives a IPV6 packet, the node is called the current node in this document.

Depth (D)

The hop distance from the coordinator of a 6LoWPAN to the device. The depth of the coordinator is 0.

Disassociation

The disassociation operation removes an existing association with its neighbor device.

End Device

RFD or FFD in a 6LoWPAN, which is neither the coordinator nor a router.

Full Function Device (FFD)

A device implementing the complete protocol set of IEEE 802.15.4. It is capable of operating as a router (multi-hop packet forwarding) for its associated neighbors.

Maximum Number of Children (MC)

The maximum number of children which a parent can have.

Neighbor Table

A node maintains the neighbor table which has the information of neighbor devices in its personal operating space.

PAN Id

The 16 bit 6LoWPAN identifier which is administratively assigned to a 6LoWPAN.

Personal Operating Space (POS)

The area within the reception range of the wireless transmission of a IEEE 802.15.4 packet.

Reduced Function Device (RFD)

The IEEE 802.15.4 device of 6LoWPAN which does not have enough power and memory space for maintaining a routing table.

Router

a FFD which has the capability of routing packets to the next hop device in 6LoWPAN.

(Short) Address

A 16 bit address dynamically assigned to a device from its parent. The short address is assumed if only 'address' is used in this document.

2.1 Requirements notation

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](#)].

3. Data Structures

3.1 Neighbor Table Entry

The neighbor table includes the following entries:

- o PANId (16 bits)
- o Neighbor.16 bit short address (16 bits)
- o Neighbor.IEEE EUI 64 bit address (64 bits)
- o Neighbor.Device type (2 bits)
 - 00 : Coordinator
 - 01 : Router
 - 10 : End device
 - 11 : Reserved
- o Neighbor.Relationship (2 bits)
 - 00 : Parent
 - 01 : Child
 - 10-11 : Reserved
- o Neighbor.Depth (8 bits)

4. Message Formats

This document assumes that the multi-hop routing occurs in the adaptation layer by following the message format of [\[I-D.ietf-6lowpan-format\]](#). The following shows the message format used for the hierarchical routing.

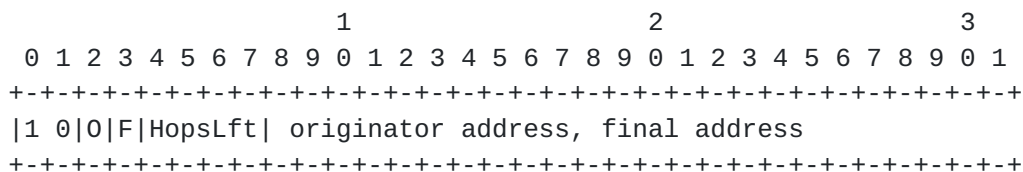


Figure 1: Mesh Addressing Type and Header

Field definitions are as follows:

- 0: This 1-bit field SHALL be zero if the Originator Address is an IEEE extended 64 bit address (EUI-64), or 1 if it is a short 16-bit addresses.

F: This 1-bit field SHALL be zero if the Final Destination Address is an IEEE extended 64 bit address (EUI-64), or 1 if it is a short 16-bit addresses.

Hops Left: This 4-bit field SHALL be decremented by each forwarding node before sending this packet towards its next hop. The packet is not forwarded any further if Hops Left is decremented to 0. The value 0xF is reserved and signifies an 8-bit Deep Hops Left field immediately following, and allows a source node to specify a hop limit greater than 14 hops.

Originator Address: This is the link-layer address of the Originator.

Final Destination Address: This is the link-layer address of the Final Destination.

5. Dynamic Address Assignment for Hierarchical Routing

One of the distinct features of 6LoWPAN is allowing dynamic configuration of the 16 bit short address in the MAC layer. In addition to the EUI-64 address, a IEEE 802.15.4 device can be assigned a 16-bit short address after completing the association operation with its parent (or router). This section describes the assignment of the dynamic address for the hierarchical routing which is specified in the next section.

When a IEEE 802.15.4 device (or child) want to join a 6LoWPAN, it first tries to discover an existing 6LoWPAN. IEEE 802.15.4 specifies active and passive scanning procedures for this discovery operation. By following either one of the scanning procedures, the child device determines whether there is a 6LoWPAN in its POS. If there is no 6LoWPAN in its POS, the child device becomes the initiator (or coordinator) of a new 6LoWPAN and assigns it's short address by 0. Otherwise, the child device can find an existing neighbor device (or parent) which is already a member of the 6LoWPAN. After finding a parent, the child tries to associate with the parent at the IEEE 802.15.4 MAC layer, and receives a 16 bit short address from the parent if the association is successful.

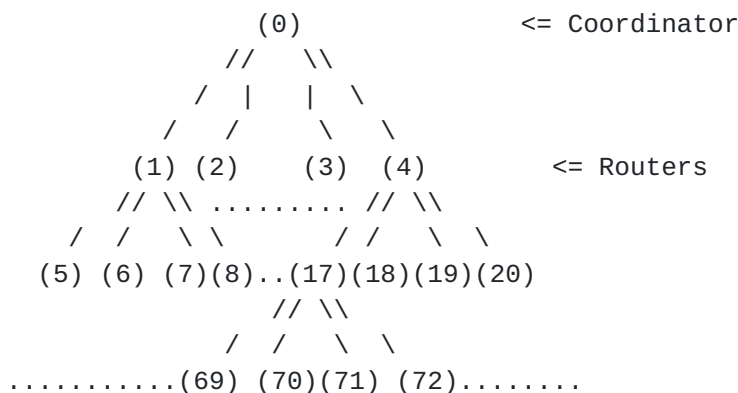
A parent assigns a 16 bit short address to a child by the assignment scheme described in Fig. 2. The scheme requires one parameter, MC, the maximum number of children a parent can have. If the parent does not have any child before this association, the new child becomes the first child and receives a short address by the following fomular:

$$FC = MC * AP + 1$$

, where FC is the first child address, and AP is the address of the parent.

If the new child is not the first child of the parent, it receives the maximum address of the existing children of the parent plus one. For this assignment a router SHOULD maintain a neighbor table which has the information about it's children and parent.

$$MC = 4$$



<Fig. 2. The assignment scheme of the short address>

By the nature of the scheme, it has no depth limitation and is efficient for gradually incremental networks. The only parameter, MC, specifies the maximum number of children a router can have. This scheme conforms well to the homogeneous 6LoWPAN in which the density of the devices is almost constant in the entire network. The future revision of this draft will include the enhancement of adapting to the heterogeneous 6LoWPAN which has some high density areas and some low density areas in the network by relaxing NC.

6. Routing Operations

For the routing operation, the following symbols are defined.

- D : the destination
- C : the current node
- AC : the address of the current node
- AP : the address of the parent of the current node
- SA : the set of the ascendant nodes of the destination
- SD : the set of the descendant nodes of the destination
- AA (D, k) : the address of the ascendant node of depth D of the node k
- DD : the depth of the destination
- DC : the depth of the current node

First of all, it is assumed that every node knows its own depth. When a node receives an IPv6 packet, it is called the current node as described in the terminology section. The address of the parent of the current node, AP, can be calculated as follows:

$$AP = [(AC - 1) / MC]$$

, where $[]$ is the symbol of the floor operation. (For instance, $[8.3]$ becomes 8.)

The current node determines first whether it is either the ascendant or descendant nodes of the destination by using this formula. When the current node receives a packet, the next hop node to forward the packet can be calculated by the following three cases.

If C is the member of SA:

The next hop node is AA(DC+1, D).

If C is the member of SD:

The next hop node is AA(DC-1, C).

Otherwise:

The next hop node is AA(DC-1, C).

7. Route Maintenance

The neighbor table of a node maintains the information of the parent and the children. When a node loses the association from its parent, it SHOULD try to re-associate with its previous parent by utilizing the information in its neighbor table. To identify the loss of the association, a node MAY use the periodical reception of beacons if the 6LOWPAN in the beacon-enabled mode. Sometimes, the association cannot be recovered by the following reasons: drained battery, node's

When the current node tries to forward a packet by using the hierarchical routing, and the next-hop node (one of the nodes in the neighbor table) is not reachable for some reason, it SHALL try to recover the path or to report this forwarding error to the source of the packet. The detailed operation is TBD.

8. Interoperability

The interoperability issues with the external IPv6 networks is out of scope of this document. The use of the short address for mapping into the IPv6 128 bit address is TBD. The interworking with the on-demand routing in the mesh network is TBD.

9. IANA Consideration

The proto_type in the message formats of [Section 4](#) is already shown in [[I-D.ietf-6lowpan-format](#)] and the same value is used to this document. So, there is no IANA consideration.

10. Security Considerations

TBD.

11. Acknowledgments

Thanks to Chae-sung Lim, Waleed Mansoor, Prof. Byeong-Hee Roh, and for their useful discussions and supports for writing this document.

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12.1. Normative References

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Acknowledgement

Funding for the RFC Editor function is provided by the IETF Administrative Support Activity (IASA).

