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              Hierarchical Routing over 6LoWPAN (HiLow)
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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 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 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.

```
                          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
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |1 0|O|F|HopsLft| originator address, final address
      +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
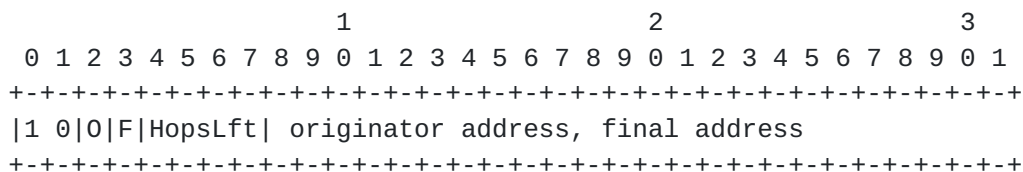
                 Figure 1: Mesh Addressing Type and Header

   Field definitions are as follows:

   O: 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
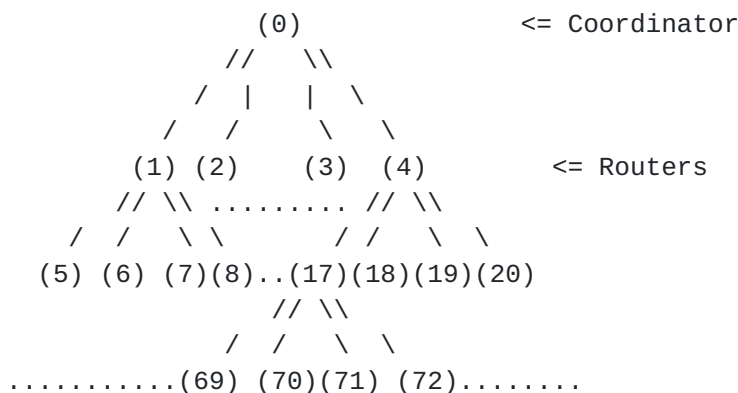parent if the association is successful.

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
```

```
                (0)                 <= Coordinator
              //    \\
            /  |    |  \
           /  /      \   \
        (1) (2)    (3)  (4)         <= Routers
        // \\ ......... // \\
       /  /   \ \      / /   \  \
    (5) (6) (7)(8)..(17)(18)(19)(20)
                  // \\
               /  /    \  \
   ...........(69) (70)(71) (72).........
```

<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 it's own depth.
When a node receives an IPv6 packet, it is called the current node as
described in the teminology 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 decendant nodes of the destination by using this fomular. 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

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for their useful discussions and supports for writing this document.

12. References

12.1. Normative References

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