6LowPAN Network Working Group
Internet draft
Expire: July 31, 2011

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February 21, 2011

Global connectivity for 6lowpan

draft-singh-6lowpan-global-connectivity-00.txt

Abstract

This document describes the short AID (adaptation identifier) in place of full IPv6 address, related AID-IPv6 address translation mechanism and frame format of it for effective IPv6 header compression when a IEEE 802.15.4 node communicate with a IPv6 domain. AID generated by IN-node (a node inside the lowpan) for corresponding IPv6 address of OUT-node (a node outside the lowpan), and AID-IPv6 translation table maintained at gateway and IN-node. Conversely packet carries an AID value in place of OUT-node IPv6 address in adaptation header, and translated back to IPv6 at gateway though AID-IPv6 translation table. Also in this document, effective frame format design specified for adaptation layer for global as well as local communication

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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 "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].

AID: Adaptation Identifier

IN-node: a IEEE 802.15.4 node within the PAN (personal area network)

OUT-node: Any node outside the PAN, connected with IN-node through IPv6 Domine

IN-bound traffic: Flow of packet from outside PAN (OUT-node) to inside PAN (IN-node)

OUT-bound traffic: Flow of packet from inside PAN (IN-Node) to outside the PAN (OUT-node)

AITT: AID-IPv6 Translation Table

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1. Problem statements

1.1 global connectivity of 6lowpan & header compression

6lowpan developed with aim to provide internet connectivity to lowpan (IEEE 802.15.4 network), so IN-node communicates with OUT-node in IPv6 domine. Maximum physical layer packet size of IEEE 802.15.4 is 127 byte, and it left only 102 byte for layers above the MAC layer. Link layer security further consumes 21 byte. IPv6 header is 40 octets in length, and leaves only 41 octets for upper layer. So HC1 header compression was proposed to reduce the IPv6 header size. Further MTU size of IPv6 packet is over 1280 bytes. So it requires fragmentation and reassembling of IPv6 packet. For these reasons an adaptation layer was proposed to accommodate IPv6 packet over IEEE 802.15.4 network.

```
+-------------+   +----------+   +---------+
 |  AID Frame  |    |Gateway   |    |  IPv6   |
|    IEEE    |<-->|AID<->IPv6|<-->| Network |
  |  802.15.4  |    |         |    |       |
+-------------+   +----------+   +---------+
```

Figure 1: Global connectivity

[RFC 4944] define the IPv6 header compression to reduce the size of IPv6 header, and able to compress 40 byte header minimum up to 2 byte. One byte for header compression filed and one byte for hop limit (inline). Field that cannot be compressed is placed inline next to compressed header within the adaptation frame. When a node communicates across IPv6 internet, it requires full IP address of OUT-node, so full IP address has to put it into the inline according to HC1 compression scheme. Due to the state less auto configuration properties, some way we can save 8 byte or 14 byte for a IN-node addresses, depending on EUI-64 addressed or 16 bit short address used for IN-node. So actual compression for IPv6 addresses of IN-node and OUT-node are up to 20-26 byte / 32 byte with HC1 compression scheme, But it is not efficient compression for global communication. To tackle this problem, In [I-D. Global connectivity in 6LoWPAN] author proposed a short length AID assignment at gateway to map unique IPv6 address to achieve good IPv6 addresses compression for global communication. Conversely, packet within PAN carries short length AID in place of full fledges IPv6 address and convert to full IPv6 address at gateway to route over internet. For IN-bound IPv6 packet, procedure is just reverse. In [I-D. Global connectivity in 6LoWPAN], Author proposed two AID, one for Source and one for Destination and mechanism to generate AID for unique IPv6 address. But, Author does not provide any information regarding frame format with AID, presence of link-addresses in adaptation layer, AID field size as well as mobility scenario and AID mechanism.

1.2 hop limit & HC1 compression

In RFC 4944, hop limit (1 byte) field from IPV6 header which is always carried inline. When Mesh header present, it also carries a hopleft field (4 bits). So it gives rise confliction to algorithm that which field to be considered. One possibility is that both fields require simultaneously when hop limit set different for routing within PAN and outside PAN for outbound packet, but it require additional field that inform such situation, but currently this information field is not present in the adaptation header. Conversely, hope limit field in adaptation layer required revision.

1.3 HC1 compression header and mesh header

For transmission of message within the PAN, mesh header defined in [rfc 4944]. In this scenario first four bits of the HC1 never required, as the both origin and destination link layer address present in mesh header, its implicit information. Moreover, with use of AID frame, there are no requirements of first four bits of HC1 header at all.

In HC1 compression, for prefix and II ID for OUT-node, only inline option is possible. Therefore, no compression for IPv6 address of OUT-node. For II ID of IN-node, there is an option IC: Interface identifier elided. How can we derive II ID from link-layer? So always we have to put it inline. One possibility is from mesh header, but use of it for global communication causes extra load on header and so no gain. So HC1 header compression header and mesh frame format required revision.

2 Adaptation Identifier (AID)

In [I-D. Global connectivity in 6LoWPAN] author proposed a two AID value for source and destination node IPv6 address. But Use of AID for an IN-node is inappropriate which cause extra load on adaptation header, extra management and lead to certain difficulties in handling it. AID only require for OUT-node, and translation between AID and IPv6 address take place at gateway. Following session explain AID requirements, size of AID field and AID-IPv6 address translation table (AITT).

2.1 Presence of IN-node link layer address and AID

When the frame contains only AID value and does not contain IN-node link layer address lead to certain issues.

Following issues suggest the requirement of link-layer address in adaptation header.

(1) In case of any desyncronization between the node and gateway regarding AID value, particularly happen in case of a PAN with multiple gateways and IN-node mobility scenario in which If AID value does not exist at gateway , it cannot reply back without source link layer address.

(2) Identify the packet whether it is come from an associate node or not.

So each frame SHOULD contain originator IN-node link layer address regardless of AID value.

2.2 drawback of use of AID value for IN-node

(1) Due to the stateless auto configurability characteristics of IPv6 address, we can configure IPv6 address from link-layer ID or Interface Identifier of a node and prefix ID of gateway. So use of AID for IN-node is illogical in presence (section 2.1) of IN-node link layer address in adaptation header.

(2) 16 bit short ID for a node in PAN was chosen to support 2^16 nodes in PAN. If we use AID for IN-nodes, minimum length of AID field should be 16 bit. Still it is larger and does not provide effective compression

(3) In PAN with multiple gateways and mobile IN-node, gateway may change frequently for IN-node. If we generate AID value of IN-node, it contains many AID values. Therefore, each time node has to confirm gateway first and then select the corresponding AID value. As the different gateway contains different AID value, increase the chance of packet carries wrong source IPv6 address. Further, additional management require handling the AID value at gateway and IN-node.

Above mentioned reasons (section 2.1 & 2.2) suggests that AID value for IN-node IPv6 address SHOULD not use and link-layer ID of IN-node SHOULD be present in packet.

2.3. AID value Generation

In [I-D. Global connectivity in 6LoWPAN] author mentioned that new AID value for IPv6 address is generated by gateway. It works fine in static network and network with single gateways.

But, in case of PAN with multiple gateways and mobile IN-node deal with multiple gateways, it leads certain problems. If new AID value is generated by gateway, different gateways generate different AID values for same OUT-node IPv6 address, so AID value updated with each gateways. Due to mobility, It is possible that packet reach at another gateway, but that contain different IPv6 address for corresponding AID value and wrong IPv6 destination address is embedded into the packet. But it is not possible when AID-value is only generated by IN-node because IN-node provides same AID value for corresponding IPv6 address to all the gateways. Thus, New AID value SHOULD be generated by IN-node only, thus different gateways and IN-node have same AID-values for corresponding IPv6 address.

2.4 AID field & AITT

Now it is clear that AID value SHOULD use for IPv6 address of OUT-node only. But the question is what will be the size of AID field and AITT format. Lets look at different possible scenario.

(1) PAN with single or few destinations

In many practical situations, data collected though sensors and send it to one central storage system, so all nodes within the PAN communicate only one or few node outside the PAN. In this scenario, AID table format shown in figure 2, is sufficient and efficient. As there are only few destinations, shorter AID field required.

```
+----------------------------------+
| AID | IPv6 address | Time-Stamp |
+----------------------------------+
```

Figure 2: AITT without Link-Layer ID

(2) PAN, with multiple destinations

In this scenario, above mentioned table format can work, but due to larger no. of destinations, require larger AID field size. But we can reduce the no. of AID values requirement hence size of AID field by taking the AID value in combination with link-layer ID of IN-node (fig 3). In another term, maximum number of connections to OUT-node, from an IN-node is always less than or equal to connection from all IN-node. This scheme is particularly yielding when different IN-nodes or group of IN-nodes communicate with corresponding different OUT-nodes. It is also efficient for first scenario.

(3)Combination of link-layer ID with AID value in AITT increases the uniqueness of AID value in AITT (fig 3), and it is particularly helpful in PAN with multiple gateways and IN-node mobility scenario as well as it makes the AID management easier.

```
+--------------------------------------------------+
| Link-Layer ID | AID | IPv6 address | Time-Stamp |
+--------------------------------------------------+
```

Figure 3: AITT without Link-Layer ID

3. AID messages & AID values mechanism

3.1 AID messages

3.1.1 AID update message

When, IN-node get AID request message (contain IPv6 address of OUT-node) from gateway, IN-node search for existing AID value for corresponding IPv6 address. If it does not present, IN-node generate a new AID value. IN-node sends Updated information to gateway through AID update message. AID update message contains AID value, IPv6 address, time-stamp and hope limit information. Similarly, when gateway is received IPv6 request message from IN-node, gateway reply back IPv6 address corresponding to AID value through AID update message.

3.1.2 AID request message (Gateway to IN-node)

When AID value does not exist for IPv6 address of IN-bound packet at gateway, it sends the AID request message to IN-node for AID value corresponding to IPv6 address. This message contains IPv6 address and in response, IN-node returns the corresponding AID update message. AID request message contains IPv6 address.

3.1.3 IPv6 request message

When AID value does not exist at gateway or IN-node on receiving AID frame, receiving node sends IPv6 request message to sender to request IPv6 address corresponding to AID value. In response, sender node return AID update message. IPv6 request message contains AID value.

3.2 Mechanism of AID value

3.2.1 For Out bound traffic

1. When IN-node wants to send packet to OUT-node, first it checks the existence of AID value for OUT-node IPv6 address in AITT.

2a. if AID value Present at IN-node for corresponding IPv6 address, it send the AID packet to gateway. But, if gateway does not have AID value, it sends IPv6 request message for corresponding AID value to IN-node, and IN-Node reply back AID Update message

2b. if AID value does not present at IN-node, it generates the new AID value for OUT-node IPv6 address and send AID update message to gateway.

3.2.2 For In bound traffic

1. When Gateway received the packet from OUT-node, it checks the existence of AID value for OUT-node IPv6 address in AITT.

2a. if AID value present at gateway, it send the packet in AID frame to IN-node. But, if IN-node does not have AID value, it send request message to gateway for corresponding IPv6 address. Gateway reply backs the AID update message.

2b. if AID value does not present at gateway, it requests a AID value for given IPv6 address to IN-node, and IN-node reply back AID update message.

3.3 Time stamping & deletion of AID in AID-IPv6 translation table.
Whenever IN-Node generate AID, it also time-stamp the AID value simultaneously and send it with AID update message. Whenever transaction (during packet transmission) or updation take place in AITT, time-stamp field set back to initial value

in correspond AID value. If AID value does not utilized for some threshold period, corresponding row is deleted.

4 Frame Format

4.1. 6lowpan TCP/IP Stake

In figure 4, TCP/IP stake shown for AID based 6lowpan. Physical and MAC layer are similar to IEEE 802.15.4 standards. Adaptation layer lies above the MAC layer and use AID frame structure for OUT-node (global communication) and Local frame structure for IN-node. Routing is take place at adaptation layer and mesh under & mesh over routing is an administrator choice. in both case, packet has to reach at adaptation layer. Transport layer mainly use compressed header format. Security layer is optional. Application layer keep at top above, and only required application are kept according to need.

```
+-------------------------------------------------+
|            Application Layer                    |
|       (Restricted Applications)                 |
|-------------------------------------------------|
| Security Layer |     Transport Layer            |
|  (Optional)    |    (Compressed Header)         |
|                |--------------------------------|
|                |          |AID Frame |Mesh      |
|                | Adaptation |----------|under    |
|                |  Layer    |LocalFrame|routing   |
|-------------------------------------------------|
|        MAC layer (IEEE 802.15.4)                |
|-------------------------------------------------|
|        PHY layer (IEEE 802.15.4)                |
+-------------------------------------------------+
```

Figure 4: AID based 6lowpan TCP/IP stake

4.2 AID-IPv6 address Translation Table (AITT)

AITT translate the IPv6 address to corresponding AID value and vice versa (fig 5 & 6). It is present in IN-node as well as gateway, but AID frame to IPv6 packet and vice-versa translation take place at the gateway using AID-IPv6 table.

```
+-------------------------------------------------------+
|Link-Layer ID|Bit|AID|IPv6 address|hop limit|Timestamp|
+-------------------------------------------------------+
```

Figure 5: AITT for Gateway

```
+------------------------------------------+
|Bit|AID|IPv6 address|hop limit|Timestamp|
+------------------------------------------+
```

Figure 6: AITT for IN-Node

Link Layer ID of IN-nodes: 16 bits short ID or 64 bit
Interface Identifier of IN-node

Bit: Length of AID field in bits (1,2,4,8 bit(s))

AID: AID value

IPv6 address: IPv6 address of corresponding OUT-Node

Hop limit: Hope limit for out bound traffic

Timestamp: Time of last use of AID

4.3. Adaptation Layer Header

Adaptation layer header contains Dispatch field, followed by AID or Local mesh frame and fragmentation header which is optional (fig 7). Dispatch value gives Idea about which type of frame following next (fig 8). Fragmentation header is optional, only present when payload is large and required fragmentation. It is according to [rfc 4944]

```
+---------------------------------------------+
| Dispatch | AID, LMF | Fragmentation header |
  |        | BCH     |     (optional)     |
+---------------------------------------------+
```

Figure 7: Adaptation layer header

4.3.1 Dispatch field

Dispatch field specify the frame type or field carried in to the adaptation header that follow after the dispatch.

```
+------------------------------------------------------+
  | Dispatch  | Header Type                           |
|------------------------------------------------------|
 | 00 000000 | NALP - Not a lowpan frame              |
 | 01 000001 | IPv6 -IPv6 uncompressed frame          |
| 01 000010 | AID_1 -AID frame_1_bit_field_size      |
| 01 000011 | AID_2 -AID frame_2_bit_field_size      |
| 01 000101 | AID_3 -AID frame_4_bit_field_size      |
| 01 000110 | AID_4 -AID frame_8_bit_field_size      |
  | ********* | Reserved                              |
 | 10 100001 | BCF - Broadcast Frame                  |
 | 10 100011 | LMF - Local Mesh Frame                 |
  | ********  | Reserved                              |
| 01 111111 | ESC - Additional dispatch byte follows |
+------------------------------------------------------+
```

Figure 8: Dispatch Type

4.3.2 AID frame

Whenever communication takes place between the IN-node and OUT-node, AID frame is used. Frame contains the AID value for corresponding IPv6 address.

```
+-------------------------------------------------+
   | 01 000010 |           |                    |
| 01 000011 | AID frame  | Fragmentation header |
  | 01 000101 |   header   |     (optional)     |
   | 01 000110 |           |                    |
+-------------------------------------------------+
```

Figure 9 (a): Dispatches for AID frame

```
+-----------------------------------------------------------+
 |Bound| I | G | NH | Fr |hopeleft|   LL ID    |   AID     |
| (1) |(1)|(1)| (4)| (1)|  (4)   | (16 or 64) | (1,2,3,8) |
+-----------------------------------------------------------+
```

Figure 9 (b): AID frame Header

Bound: 0- Outbound packet from PAN (Forward to Gateway)
      1- Inbound packet to PAN (Forward to IN-node at Link
       Layer ID address)

```
  Fr:   0- No fragmentation header follows
        1- fragmentation header follows

   I:   0-  16 bit short ID in II ID field
        1-  64 bit interface identifier in II ID field

   G:   0-  Any gateways
        1-  Gateway specified (next to the AID field)
   NH: First Bit
        0-  No Traffic class & flow lable
        1-  Traffic class & flow label field in Inline
       Second Bit
        0- no more header compression
        1- HC2 header compression bits [rfc draft]
       Third & Fourth Bits
        00- Additional header follow
        01- UDP
        10- ICMP
        11- TCP

  Hopeleft: (4 bits) Hope left within the PAN

  LL ID: 16 bits short ID or 64 bits Link Layer ID

  AID: AID value
```

4.3.3 If gateway specified (G set 1)

```
+-----------------------------------------+
| Dispatch | AID header | F | Gateway ID |
+-----------------------------------------+
```

Figure 10: Gateway specified AID frame header

```
   F: 0- 16 bit address of Gateway
      1- 64 bit address of Gateway
   Gateway ID: 16 bits or 64 bits address of Gateway
```

4.3.4 Local Mesh Frame

Whenever communication occurs between the IN-nodes, Local mesh Frame should use.

As in this scenario,
AID is not required.

```
+------------------------------------------------------+
| 01 100010  |  LMS header  |  Fragmentation Header  |
  |          |              |       (optional)       |
+------------------------------------------------------+
```

Figure 11(a): Local mesh frame

```
+-----------------------------------------------------+
 | V | F | NH | Fr |hopeleft|   source   |   Dest    |
|(1)|(1)| (4)| (1)|  (4)   | (16 or 64) |(16 or 64) |
+-----------------------------------------------------+
```

Figure 11(b): LMS header

V: 0- 16 bit originator ID in source field
    1- 64 bit EUI ID in source field

F: 0- 16 bit originator ID in Destination   field
    1- 64 bit EUI ID in Destination field

NH: Same as in section 4.3.2

Hopleft: Hop count (within the mesh)

Source: 16 bits short or 64 bits EUI address of originator IN-node

Dest: 16 bits short or 64 bits address of final destination IN-node

4.3.5 Local Broadcast frame

Whenever mesh routing required flooding mechanism, for that broadcast header is defined in figure xx. It contains dispatch type followed by sequence number of message.

```
+---------------------------+
| 01 100000 | Sequence No. |
+---------------------------+
```

Figure 12: Local Broadcast Header

Sequence No: This 8-bit field SHALL be incremented by the Originator whenever it sends a new mesh broadcast

5. Header compression efficiency.

During global communication, as per HC1 header compression [RFC 4944], maximum compression is 22 byte out of 40 byte. Further, 1 byte for dispatch and 5 byte for fragmentation header if presents. While in case of AID based global communication, maximum compression is 3 byte and 5 bit out of 40 byte. Further, 1 byte for dispatch and 5 byte for fragmentation header if presents.

6. Formal Syntax

The following syntax specification uses the augmented Backus-Naur Form (BNF) as described in RFC-2234[RFC2234].

7. Security Considerations

TBD

8. IANA Considerations

TBD

9. References

9.1 Normative references

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Acknowledgement

The work was supported by NAP of Korea Research Council of Fundamental Science and Technology.