

Improve IPv6 Global Connectivity for 6LoWPAN

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Abstract— IEEE 802.15.4 has limitations as short range, low bit rate, low power, and low cost. And IEEE 802.15.4 devices have limitation as computational power, memory, and/or energy availability. IEEE802.15.4 standard's MTU is 127 bytes, among which IEEE 64 bits extended addresses may be used. After an association, 16 bits are used as a unique ID in a PAN L2, Still only 102 bytes are available for payload at MAC layer. Now considering the devices need to communicate with other nodes, 256 bits of the source and destination addresses seem to be cumbersome in a limited MAC payload fields. Therefore 6LoWPAN proposes that the nodes use the compress packet header for solving short MTU. But 6LoWPAN has limitation that in case of communication with dissimilar network. When a 6LoWPAN device communicates with Internet spend 128 bits in destination address. Therefore, we propose a new IPv6 address translation mechanism between IPv6 and ID. This mechanism has ID query and reply for external node. This paper will explain the detailed procedures and performance.

Keywords—IP translation, Global Connectivity, Internet Connectivity, 6LoWPAN, 802.15.4

I. INTRODUCTION

IEEE 802.15.4 has limitations as short range, low bit rate, low power, and low cost. And IEEE 802.15.4 devices have limitation as computational power, memory, and/or energy availability. IEEE802.15.4 standard's MTU is 127 bytes, among which IEEE 64 bits extended addresses may be used. After an association, 16 bits are used as a unique ID in a PAN L2, Still only 102 bytes are available for payload at MAC layer. Now considering the devices need to communicate with other nodes, 256 bits of the source and destination addresses seem to be cumbersome in a limited MAC payload fields. [1],[4],[7].

The IETF 6LoWPAN WG [1] has been working on header compression to reduce transmission overhead, fragmentation to support the IPv6 minimum MTU requirement, and layer-two forwarding to deliver IPv6 datagram over multiple radio hops. 6LoWPAN has limitation that in case of communication with dissimilar network. When a 6LoWPAN device communicates with Internet spend 128 bits in destination address. However, it seems that it is to be improved further.

We propose an IP address translation mechanism. As when a device in IEEE802.15.4 domain needs to communicate with other nodes in IPv6 domain, it acquires its source ID and destination ID for source IP address and destination IP address, respectively from an IP translation-capable gateway. The

device will send the packet using those ID's to the gateway, and then the gateway will translate it to normal IPv6 packet.

In Section 2, we review the previous works related to Internet connectivity in 6LoWPAN. In Section 3, we propose a new mechanism to reduce IPv6 overhead during global connectivity. In Section 4, we compare performance between 6LoWPAN and our proposed one. And finally we summarize it in Section 5.

II. RELATED WORKS

IEEE 802.15.4 standards are not defined higher-level layers and interoperability sub-layers. Therefore vendors provide their own complete networking solutions such as ZigBee, WirelessHART, and MiWi. 6LoWPAN radically alters the landscape by introducing an adaptation layer between the IP stack's link and network layers to enable efficient transmission of IPv6 datagram over 802.15.4 links, dramatically reducing IP overhead [1],[3]. The adaptation layer is an IETF proposed standard and provides header compression to reduce transmission overhead, fragmentation to support the IPv6 minimum MTU requirement, and support for layer-two forwarding to deliver and IPv6 datagram over multiple radio hops [2],[7].

Nowadays, 6LoWPAN is implemented in many forms: Archrock Primer Pack IP [8] or open source implementations such Sensinode Namo Stack and Harvan 6LoWPAN implementation for TinyOS [4], [9]. However still they have an inefficiency of IP overhead in global internet connection.

"Interoperability of 6LoWPAN" [4] proposed a 16-bits short form address instead 128 bitsIPv6 address. In this proposal, a gateway translates a packet that 6LoWPAN external node send to internal node. The gateway translates the 128 bitsIPv6 destination address to a 16 bits short form address. However this proposal has some incomplete case. First, how generate ID for an external node. Second, in case of an internal node sends to an external node, the internal node can't translate IPv6 to ID.

6GLAD [5] proposed a 1:1 translation between link local address and global IPv6 address at the gateway. When an internal node with a link-local address initiates a transmission to an external node with a global address, a link-local address corresponding to the global address is assigned to the internal node by a DSN-ALG-like server, which is called as reverse-NAT mapping. Then the internal node will communicate with the gateway using the 64-bits link-layer address obtained from

each link-local IPv6 address. When the packet traverses the gateway, the link-local address of the destination will be translated to its respective global IPv6 address. Here a DNS-ALG-like server is essential to intercept the DNS query to assign a link-local address to internal node. If DNS query is not intercepted for some reason, or if the server is too “heavy” in some circumstances, it may not be suitable to the 6LoWPAN.

III. PROPOSED IP TRANSLATION MECHANISM

A. Terminology

- Identification (ID): ID is a short form address used between internal nodes and gateway. The ID value for each node will be determined depending on where it is located. ID for internal node is Interface ID, i.e. EUI-64 derived from its IPv6 address, while ID for external node is generated by gateway, based on its MAC address using a new value of 0xFEFE which is newly defined in this proposed scheme. In other words, it is to insert two octets, with hexadecimal values of 0xFE and 0xFE, in the middle of the 48 bits MAC address. Note that the gateway does not need to keep any translation information for internal node in the mapping table.
- Internal node: A node residing in IEEE 802.15.4 network.
- External Node: A node residing outside 802.15.4 network which may communicate with internal nodes. An external node may be general PC's, PDA's, or servers which are connected to Internet or other media except 802.15.4.
- Gateway: Gateway translates ID's and addresses which are used between internal nodes and external nodes. And, gateway allocates ID to replace global IPv6.
- Mapping Table: Mapping table keeps translation information for external nodes, mapping the global IPv6 address field and its ID value.

B. Communication procedures

1) Internal node procedures

An internal node receives data from application layer. At this time, procedure distinguishes two types as Figure 1.

First, the internal node doesn't have ID for destination address in mapping table. Then the internal node requests ID for destination address to gateway. It receives ID for destination address from gateway. And it translates source and destination address to ID.

Second, the internal node has ID for destination address in mapping table. At once, the internal node translates source and destination address to ID.

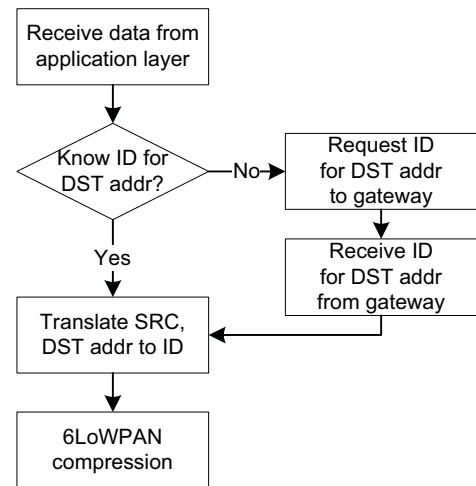


Figure 1. Internal node diagram

2) Gateway procedures

Gateway works between 6LoWPAN network and Internet. The gateway procedures divide into two classes as Figure 2. First, the gateway receives from 6LoWPAN network interface. Second, the gateway receives from Internet interface.

In the first case, it has two cases. The gateway receives the packet that uses ID instead of destination address. In this case, gateway translates ID to destination address. And the gateway decompresses like 6LoWPAN. In another case, the gateway receives the packet that uses destination address. The gateway decompresses like 6LoWPAN without translating ID to destination address.

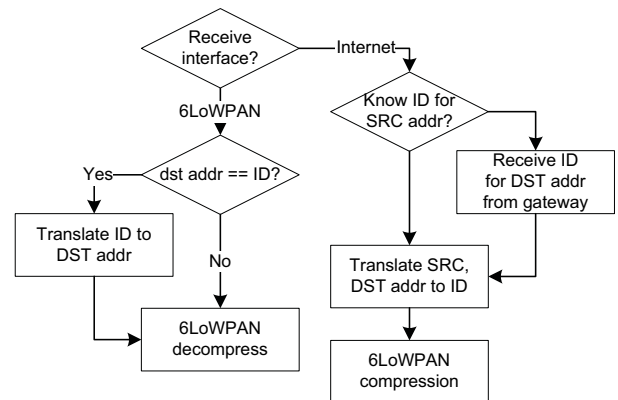


Figure 2. Gateway diagram

C. Mapping table management

Mapping table consists of three fields: IPv6 address, ID, lifetime. IPv6 address is address of 6LoWPAN or Internet. ID is a short form address used between internal nodes and gateway. Lifetime decreases every tick time. When gateway receives related packet or ID query, gateway updates lifetime to related ID. And lifetime meets 0, then its field is removed in mapping table.

D. Packet Format

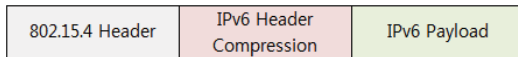


Figure 3. 802.15.4 header and IPv6 header compression

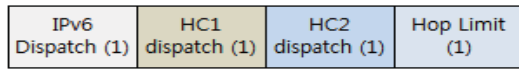


Figure 4. common IPv6 header compression in communication between internal nodes (byte)

The format shown in Figure 3 was usually used in communications in 6LoWPAN. And Figure 4 header format is IPv6 Header Compression in Figure 3. Also, Figure 4 was generally used in communication between each internal include gateway. Our proposed scheme use Query request and Query reply between internal nodes and gateway. For the scheme add to IPv6 dispatch field. Added field as follows:

Table 1. Added IPv6 dispatch filed

Types	IPv6 dispatch value
Query request	01010001
Query reply	01010010

IV.PERFORMANCE

We consider two cases:

- (1) Internal nodes are connected to the gateway with a single hop.
- (2) Internal nodes may be connected to the gateway within two hops.

The header overhead and the efficiency are defined as:

$$efficiency(\%) = \frac{\sum p_6}{\sum (Header\ Overhead + p_6)}$$

$$Header\ Overhead = h_2 + h_m + h_f + h_6$$

Where,

p_6 : IPv6 payload

h_2 : length of 802.15.4 header without mesh

h_m : length of mesh addressing header

h_f : length of fragment header

h_6 : length of IPv6 header compression

1) Single-hop case

It is the case that gateway and internal nodes are connected with one-hop. Figure 3 shows the header formats used in this communications. And Figure 5 shows single-hop network.

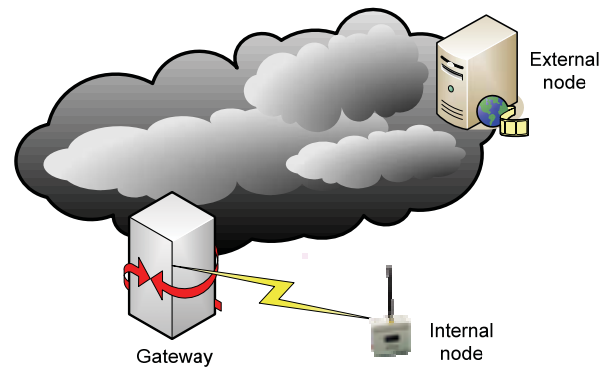


Figure 5. Single-hop network

2) Multi-hop case

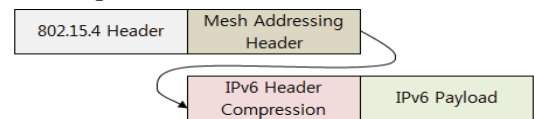


Figure 6. 802.15.4 header, mesh addressing header and IPv6 header compression

It is the case that gateway and internal nodes are connected with multi-hop. Figure 6 shows the header formats used in this communications. Figure 7 shows single-hop network.

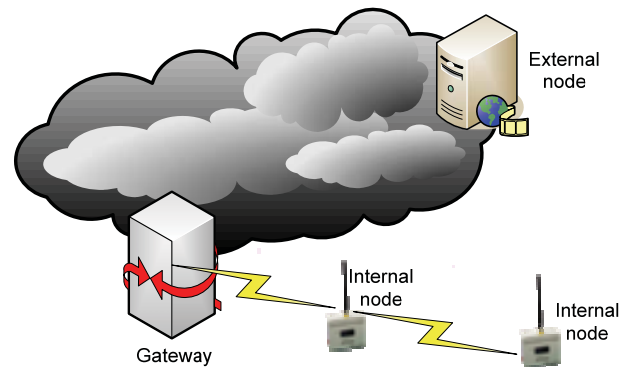


Figure 7. Multi-hop network

3) Performance Analysis

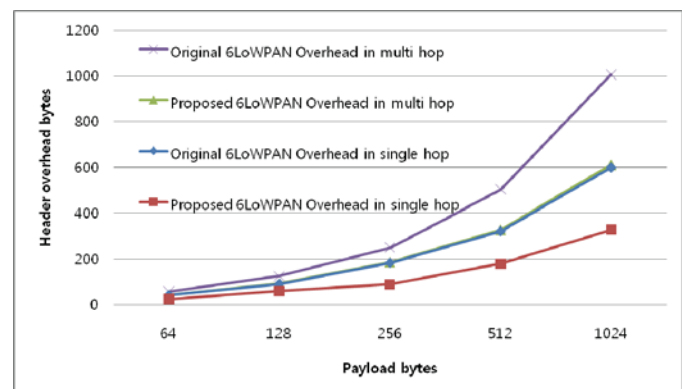


Figure 8. Header overheads bytes by payload bytes

In this analysis, we consider the case that an external node initiates a transmission. Figure 8 shows header overhead bytes through IP payload between 64 and 1024 bytes. In case of single hop and 64 bytes IP payload, original 6LoWPAN spends the overhead of 41 bytes but proposed 6LoWPAN spends just 25bytes. And in case of single hop and 1024 bytes IP payload, original 6LoWPAN spends the overhead of 597 bytes but proposed 6LoWPAN spends just 329 bytes. In case of multi hop 64 bytes IP payload, original 6LoWPAN spends the overhead of 42 bytes but proposed 6LoWPAN spends just 58bytes. And in case of multi hop and 1024 bytes IP payload, original 6LoWPAN spends the overhead of 1007 bytes but proposed 6LoWPAN spends just 610 bytes. In all cases, proposed 6LoWPAN shows lower overhead than original 6LoWPAN.

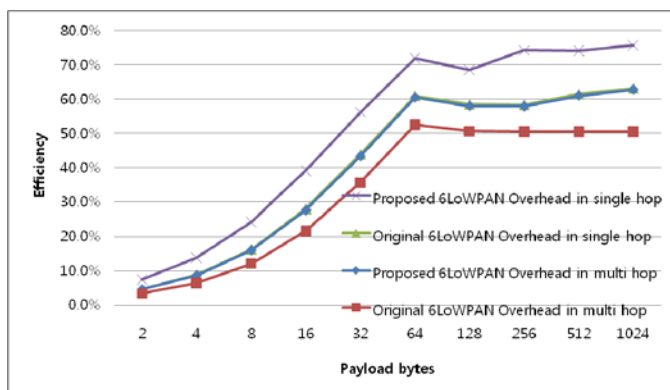


Figure 9. Payload Efficiency

Figure 9 shows the payload efficiency. The payload efficiency defined in front. In case of single hop and 64 bytes IP payload, original 6LoWPAN efficiency is just 61.0% but proposed 6LoWPAN efficiency is 71.9%. And in case of single hop and 1024 bytes IP payload, original 6LoWPAN efficiency is 63.2% but proposed 6LoWPAN efficiency is 75.7%. Proposed 6LoWPAN has good efficiency about 10% than original 6LoWPAN in single hop.

In case of multi hop and 64 bytes IP payload, original 6LoWPAN efficiency is just 52.5% but proposed 6LoWPAN efficiency is 60.4%. And in case of multi hop and 1024 bytes IP payload, original 6LoWPAN efficiency is 50.4% but proposed 6LoWPAN efficiency is 62.7%. Proposed

6LoWPAN has good efficiency about 8% than original 6LoWPAN in multi hop. As above, proposed 6LoWPAN has good efficiency than original 6LoWPAN in all cases.

V. PERFORMANCE

We explained our proposal. Our proposal gateway and internal node have ID and translate between ID and global IPv6 address. Proposed 6LoWPAN has two type procedures. First, internal node doesn't know ID for external node. Then, internal node query and gateway reply about external node. Through this process, internal node and gateway have same mapping table. Second, internal node knows ID for external node. Therefore, internal node sends a packet without query. And, internal node just translates IP in packet to ID. In section 4, we analyzed the header overhead size and payload efficiency. In all cases, our proposal showed excellent performance. The efficiency increasing involves decreasing packet delay time and increasing packet delivery ratio.

ACKNOWLEDGMENT

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