6lo C. Pu
Internet Draft Y. Wang
Intended status: Standards Track H. Wang
Expires: March 11, 2018 Y. Yang
P. Wang
Chongqing University of
Posts and Telecommunications
September 7, 2017

Multipath Transmission for 6LoWPAN Networks
draft-pu-6lo-multipath-transmission-01

Abstract

This document provides a multipath transmission method for 6LoWPAN Networks, which can effectively offer the transmission redundancy of packets. It is applicable for high-reliability networks, especially for IPv6-based wireless industrial scenarios.

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF), its areas, and its working groups. Note that other groups may also distribute working documents as Internet-Drafts.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

The list of current Internet-Drafts can be accessed at http://www.ietf.org/ietf/1id-abstracts.txt

The list of Internet-Draft Shadow Directories can be accessed at http://www.ietf.org/shadow.html

This Internet-Draft will expire on March 11, 2018.

Copyright Notice

Copyright (c) 2017 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (http://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction

6LoWPAN has high popularity and applicability, and has more address space that can realize the deployment of large-scale and high-density wireless personal area network devices. However, due to the low processing power, limited energy and poor communication environment in 6LoWPAN, packets are prone to be lost during transmission, which results in transmission failure. In order to increase the communication reliability and improve the transmission performance, it is significant to introduce multipath packet transmission technology in 6LoWPAN. It is well known that RPL as a routing protocol standardized by IETF, is an efficient distance vector protocol for wireless sensor networks, which has designed a series of new mechanisms [RFC6550], and is widely used in 6LoWPAN. Aiming at the explicit demand for 6LoWPAN adopting multipath packet transmission, this document proposes a multipath transmission method based on RPL, which improves the success rate of packets transmission in uplink networks and further enhances the transmission reliability.

2. 6LoWPAN Multipath Header Format

6LoWPAN multipath header designed at the adaptation layer contains the multipath header type field, the sequence number field of the multipath package (SequenceNumber) and the path number field (PathCount) [RFC4944], as depicted in Figure 1.

```
 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 2
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Multipath   |         Sequence Number       |  Path Number  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: 6LoWPAN Multipath Header Format

Field definitions are as follows.

Multipath: Headers of different types at the adaptation layer must have a length of 8-bit header type field. The multipath field is the header type field of 6LoWPAN Multipath Header that uses the Dispatch Value Bit Pattern of 11101000.

Sequence Number: This field contains the unique sequence number SequenceNumber of packets, and its length is 16 bits.

Path Number: This field includes the number of paths PathCount that needs to be filled in the packet, and its length is 8 bit.

3. Architecture

The following figure 2 shows the architecture of the 6LoWPAN protocol stack. In this architecture, the IP layer uses RPL to realize the multipath transmission. Moreover, at the adaptation layer, the multipath transmission entity is achieved by designing a multipath header. The encapsulation of multipath packets and the transmission of multipath packets can be implemented by using above methods.

```
+----------------------------------------------------+
|   COAP           Application Layer           XMPP |
|----------------------------------------------------|
|   UDP             Transport Layer                  |
|----------------------------------------------------|
|  -----                               --------------|
| |RPL|                IP Layer        |   Multipath||
|  -----                               |Transmission||
|                                      --------------|
|----------------------------------------------------|
|                                  ------------------|
|   Header       Adaptation Layer |       Multipath||
|   Compression                   |Transport Entity||
|                                  ------------------|
|----------------------------------------------------|
|   CSMA/CA            Mac Layer                     |
|----------------------------------------------------|
|   Channel Detection     Physical Layer             |
+----------------------------------------------------+
```

Figure 2: 6LoWPAN Protocol Stack Architecture

Before the source node sends a message, it is necessary to determine the number of paths P according to reliability requirements. Then we need to assign one or more paths for each parent node at the IP layer through the rank value. The rank value is calculated according to the residual energy value and the hop value to the sink node from the source node [RFC6551], [RFC6552]. The number of paths is encapsulated into the multipath header of the message at the adaptation layer before sending the message to the parent node. Moreover, each intermediate routing node forwards the message according to the above method until it reaches the sink node.

4. Multipath Distribution

If the required number of paths P is greater than the total number of parent nodes N in the collection of RPL parent nodes, multiple paths are assigned to each parent node according to the size relation among the rank values of all parent nodes. The following formula is used.

Pm = round (P/Rm/R)   where   R = 1/R1 + 1/R2 + … + 1/Rn

Here, round() presents the rounding function, rounding for the calculation result of (P/Rm/R). P is the total number of paths. Pm shows the number of paths allocated for parent node m. Rm represents the Rank value corresponding to the parent node m (m=1,2,…,n). The above situation is shown as Figure 3.

```
+---------------------------------------------------+
|  rank2=500 P2=1                                   |
| +------------>(R1)----> .....                     |
| |                                                 |
| |                                                 |
| |              /---->(R3)---->(R4)----> .....\    |
| |rank1=100 P1=5/                              \   |
|(S) ---------->(R2).....--->(R5)--->(R6)---> ...(D)|
| |P=8           \                              /   |
| |               \---->(R7)---->(R8)----> ...../    |
| |                                                 |
| |rank3=200 P3=2     /----> .....                  |
| +---------------->(R9)                            |
|                     \----> .....                  |
+---------------------------------------------------+
```

Figure 3: The Transmission Process of P>N

If the number of paths P is less than or equal to the total number of parent nodes, P rank values are selected according to the rise order of rank values, and one path is assigned to the parent node corresponding to each rank value, as shown in Figure 4.

```
+---------------------------------------------------+
|   rank2=500 P2=1                                  |
| +---------------->(R1)---->(R2)---->(R3)......... |
| |                                               | |
| | rank1=100 P1=1                                | |
| | /-------------->(R4)---->(R5)---->(R6)......\ | |
| |/                                             \| |
|(S)P=3                                          (D)|
| .\rank3=200 P3=1                               /. |
| . \-------------->(R7)---->(R8)---->(R9)....../ . |
| .                                               . |
| . rank4=600 P4=0                                . |
| ..................(10)....(R11)....(R12)......... |
|                                                   |
+---------------------------------------------------+
```

Figure 4: The Transmission Process of P<=N

5. Packet Replication and Elimination

The process of packet multipath transmission also includes packet replication and elimination. A detailed description is given as following five steps.

1) When the multipath transport entity of the adaptation layer receives the packet from the upper layer of the protocol stack, it first determines the total number of paths P to transmit the packet according to the reliability requirements of the packet. When P is less than or equal to 1, indicating that the packet does not need to use multipath transmission, then the packet can be forwarded directly.

2) When the total number of paths P is larger than 1, the multipath packet allocation method is used to allocate the number of the replicated packets PathCount that needs to be forwarded by each parent node in the collection of RPL parent nodes [I-D.ietf-detnet-architecture], [I-D.ietf-detnet-problem-statement].

3) For the parent node that PathCount is greater than or equal to 1, the multipath transport entity replicates the packet and adds the multipath header at the adaptation layer, and then sends the packet to the parent node. In this case, the packet sequence number SequenceNumber of the multipath header in all replicated packets must be consistent and it can be accumulated when the next new packet is sent. The path number field is filled with the corresponding number of copies PathCount. For the parent node whose number of copies PathCount is less than 1, the source node does not send the packet.

4) After the intermediate routing node receives the packet containing the multipath header, it judges whether the number of paths PathCount in the multipath header is equal to 1. If PathCount is equal to 1, the intermediate node sends the packet directly with the value of each field in the multipath header constant. If PathCount is greater than 1, the node has to replicate PathCount copies of the packet and distributes them to multiple paths. Repeating step 2 and 3, and in step 2, P is equal to PathCount. In step 3, the new multipath header is not added, the SequenceNumber of the packet is unchanged, and the path number field is filled with the new corresponding number of copies.

5) When a destination node receives a packet containing the multipath header, it can distinguish whether the packet has been received according to the source address and the packet sequence

number in the multipath header. If the destination node has not received the packet before, the node forwards the packet to its upper layer protocol directly. Otherwise, the node discards the packet [I-D.ietf-detnet-architecture], [I-D.ietf-detnet-problem-statement].

6. Security Considerations

This document does not add any new security considerations beyond what the referenced technologies already have.

7. IANA Considerations

This document creates an IANA registry for 6LoWPAN Multipath Header Type, and assigns the following dispatch type values:

11101000: for 6LoWPAN Multipath Header Type.

8. References

8.1. Normative References

[RFC6550] Winter, T., Ed., Thubert, P., Ed., Brandt, A., Hui, J., Kelsey, R., Levis, P., Pister, K., Struik, R., Vasseur, JP., and R. Alexander, "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks", RFC 6550, March 2012, <http://www.rfc-editor.org/info/rfc6550>.

[RFC4944] Montenegro, G., Kushalnagar, N., Hui, J., and D. Culler, "Transmission of IPv6 Packets over IEEE 802.15.4 Networks", RFC 4944, September 2007, <http://www.rfc-editor.org/info/rfc4944>.

[RFC6551] Vasseur, JP., Ed., Kim, M., Ed., Pister, K., Dejean, N., and D. Barthel, "Routing Metrics Used for Path Calculation in Low-Power and Lossy Networks", RFC 6551, March 2012, <http://www.rfc-editor.org/info/rfc6551>.

[RFC6552] Thubert, P., Ed., "Objective Function Zero for the Routing Protocol for Low-Power and Lossy Networks (RPL)", RFC 6552, March 2012, <http://www.rfc-editor.org/info/rfc6552>.

8.2. Informative References

[I-D.ietf-detnet-architecture]
Finn, N. and P. Thubert, "Deterministic Networking Architecture", draft-ietf-detnet-architecture-03 (work in progress), August 2017.

[I-D.ietf-detnet-problem-statement]
Finn, N. and P. Thubert, "Deterministic Networking Problem Statement", draft-ietf-detnet-problem-statement-01 (work in progress), September 2016.

Authors' Addresses

Chenggen Pu
Chongqing University of Posts and Telecommunications
2 Chongwen Road
Chongqing, 400065
China

Phone: (86)-23-6246-1061
Email: mentospcg@163.com

Yadong Wang
Chongqing University of Posts and Telecommunications
2 Chongwen Road
Chongqing, 400065
China

Phone: (86)-23-6246-1061
Email: 13618266302@163.com

Heng Wang
Chongqing University of Posts and Telecommunications
2 Chongwen Road
Chongqing, 400065
China

Phone: (86)-23-6248-7845
Email: wangheng@cqupt.edu.cn

Yi Yang
Chongqing University of Posts and Telecommunications
2 Chongwen Road
Chongqing, 400065
China

Phone: (86)-23-6246-1061
Email: 15023705316@163.com

Ping Wang
Chongqing University of Posts and Telecommunications
2 Chongwen Road
Chongqing, 400065
China

Phone: (86)-23-6246-1061
Email: wangping@cqupt.edu.cn