

Methodology for One-way IP Performance Measurement on Sub-path or Link in use of IPv6 Extension Header

Jaehoon Jeong, Jungsoo Park, Seungyun Lee, Yongjin Kim
Electronics and Telecommunications Research Institute
{paul,pjs,syl,kimyj}@etri.re.kr

Abstract — This paper proposes a methodology for measurement of one-way IP performance metrics such as one-way delay and delay-jitter of sub-path or link of a specific end-to-end path in IPv6 network as well as end-to-end one-way IP performance metrics. The methodology measures one-way IP performance metrics in use of IPv6 extension header. Because the proposed methodology contributes to the finding of congested link or underutilized link, it can provide important information to configure and manage IPv6 network.

Keywords — one-way, delay, IP, performance, IPv6 extension header, sub-path, link, GPS.

1. Introduction

We need to measure network performance such as delay, loss and jitter in order to manage and configure network. Some tools such as Surveyor, RIPE and AMT have been made and used for end-to-end one-way IP performance measurement [1-3]. Because these can only measure end-to-end IP performance metrics, we can only know the occurrence of congestion in a specific end-to-end path of measured network [4-7]. So we have a difficulty in finding the congested or underutilized position of the measured network with these end-to-end measurement tools. If we try to measure link one-way delay between two direct nodes or sub-path one-way delay between two separate nodes on an end-to-end path of two measurement systems with these tools, measurement system should play a role of router simultaneously. Because the intermediate measurement system for measurement of link or sub-path one-way delay should record timestamp in the passing measurement packet and forward the packet to next router or destination. It is not easy to deploy measurement system as router in a large network. In this situation, we suggest a methodology that can measure link or sub-path one-way delay metrics such as one-way delay and delay jitter easily in IPv6 protocol level in use of IPv6 extension header which is one of powerful functions of IPv6 protocol.

The rest of the paper is structured as follows; Session 2 introduces one-way delay measurement and summaries the IPv6 extension headers related to the paper. Session 3 explains the precondition for one-way delay measurement. Session 4 presents a methodology for link one-way delay measurement. Session 5 presents a methodology for sub-path one-way delay measurement. In Session 6, we present future work and conclude.

2. Related Work

2.1 One-way Delay Measurement

The system for one-way IP performance measurement is an infrastructure that can measure one-way metrics such as one-way delay, one-way loss and delay jitter suggested by IETF's IPPM Working Group [4-8].

2.1.1 System for One-way Delay Measurement

The Measurement Systems that perform actual measurement should be synchronized with GPS to measure one-way delay metrics exactly [3, 9]. Figure 1 shows the synchronization among Measurement Systems and the procedure of one-way delay measurement. Like Figure 1, Measurement System A and Measurement System B are synchronized through GPS and GPS Receiver. After the synchronization among Measurement Systems, Measurement can be started by command of Control System, which plays role in managing and controlling the global system for one-way delay measurement. When Measurement System receives a command indicating the start of measurement from Control System, each Measurement System generates measurement packets and sends them to the other Measurement Systems. When Measurement System receives measurement packet, it stores it in local database. When the session of measurement ends, the raw data stored in each measurement system will be delivered to Control System. Control System processes the data and then stores the result in central database.

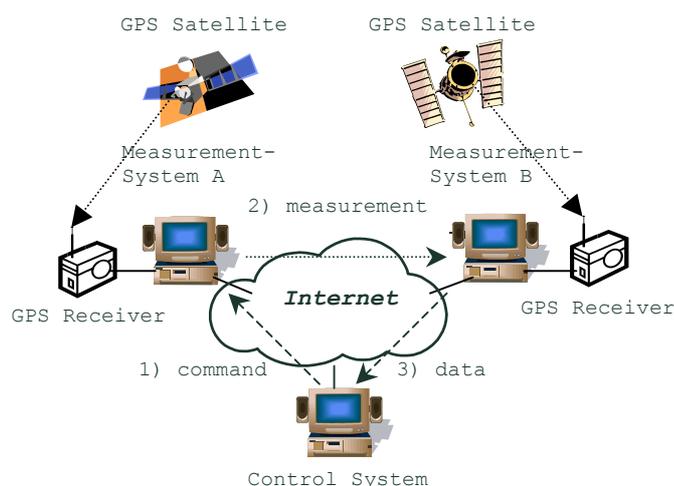


Figure 1. Synchronization among Measurement Systems and Procedure of Measurement

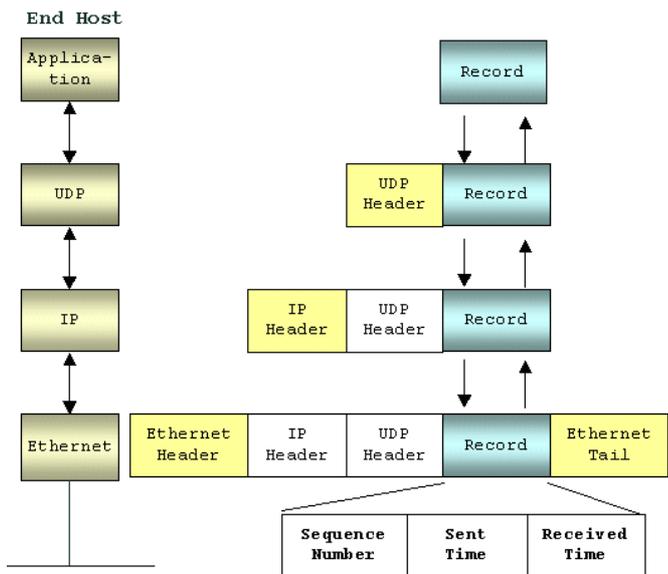


Figure 2. Record for Timestamp and Procedure of Timestamping

2.1.2 Timestamp

To improve the accuracy of measuring one-way delay, the measurement system should timestamp on the fields for time information (Sent Time and Received Time) in the payload which is one of fields in the Ethernet frame just before transmitting the Ethernet frame to the network interface card as well as just after receiving the Ethernet frame from the network interface card like Figure 2 [3]. In this way, we are capable of reducing the delay which can occur through the protocol stacks at end hosts.

2.2 IPv6 extension headers related to the paper

In IPv6, optional internet-layer information is encoded in extension headers separated from basic IPv6 header [10]. The extension header is identified by the next header value of the preceding header. Extension headers must be processed strictly in the order they appear in the packet because the contents and semantics of each extension header determine whether or not to proceed to the next extension header. The following three extension headers are used in the methodology of the paper.

2.2.1 Hop-by-Hop Options Header

The Hop-by-Hop Options header is used to carry optional information that must be examined by every node along a packet's delivery path. It can contain a variable number of type-length-value (TLV) encoded "options", of the following format:

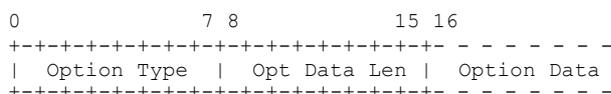


Figure 3. Format of type-length-value (TLV) encoded option

2.2.2 Routing Header

The Routing header is used by an IPv6 source to list one or more intermediate nodes to be "visited" on the way to a packet's destination. Namely, it provides the source routing.

2.2.3 Destination Options Header

The Destination Options header is used to carry optional information that need be examined only by a packet's destinations node(s). It can contain a variable number of type-length-value (TLV) encoded "options" like the Hop-by-Hop Options Header.

3. Precondition

There are two preconditions in one-way delay measurement. The one is that all the routers related to one-way delay measurement as well as all the measurement systems should be synchronized with GPS to guarantee the exact measurement. All the related routers should have GPS receiver like measurement system or other time source in order that they revise their own system time regularly with the time of GPS.

The other is that all the end-to-end paths related to one-way delay measurement are fixed and unique during measurement in order to find the congested or underutilized position in the measured network. Namely, we assume that there are no routing changes and no multipath forwarding and only the amount of traffic transiting through network can affect measurement [11].

4. Link One-way Delay Measurement

4.1 Outline of Link One-way Delay Measurement

We use Hop-by-Hop Options Header to measure link one-way delay metrics such as one-way delay and delay jitter between two direct nodes like Figure 4. When a measurement packet transits along an end-to-end path between two measurement systems, we let all the intermediate routers timestamp in the TLV option included in Hop by Hop Options Header of a measurement packet.

With the timestamps, we can calculate the following link one-way delays;

$$\text{delay}\langle \text{Source}, R1 \rangle, \text{delay}\langle R1, R2 \rangle, \text{delay}\langle R2, R3 \rangle, \text{delay}\langle R3, \text{Receiver} \rangle$$

where $\text{delay}\langle \text{node1}, \text{node2} \rangle$ means link one-way delay from node1 to node2.

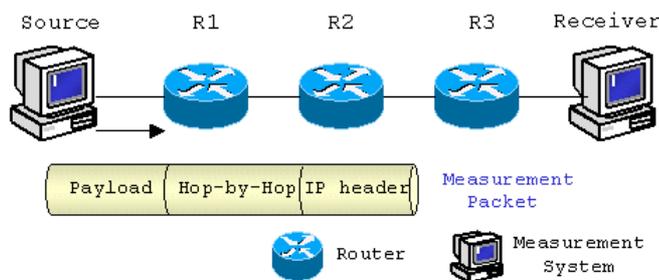


Figure 4. Link One-way Delay Measurement

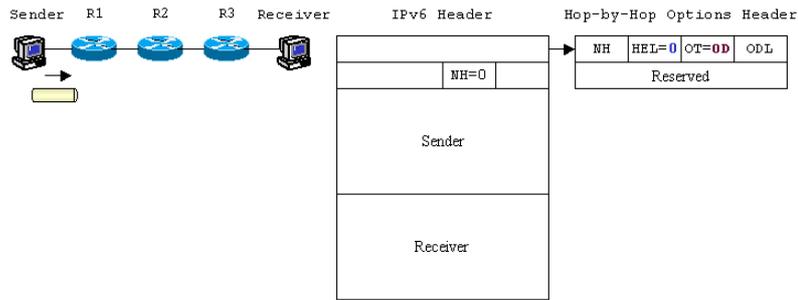


Figure 5. Link One-way Delay Measurement – Step1

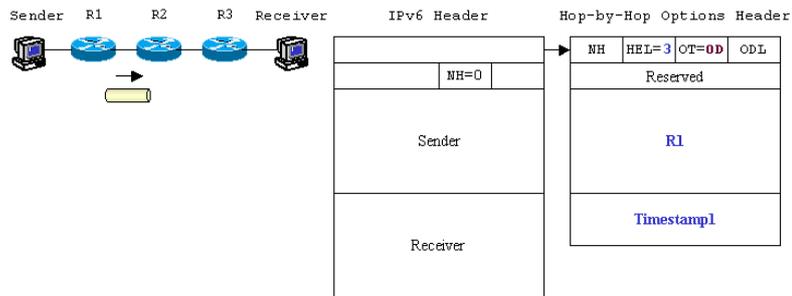


Figure 6. Link One-way Delay Measurement – Step2

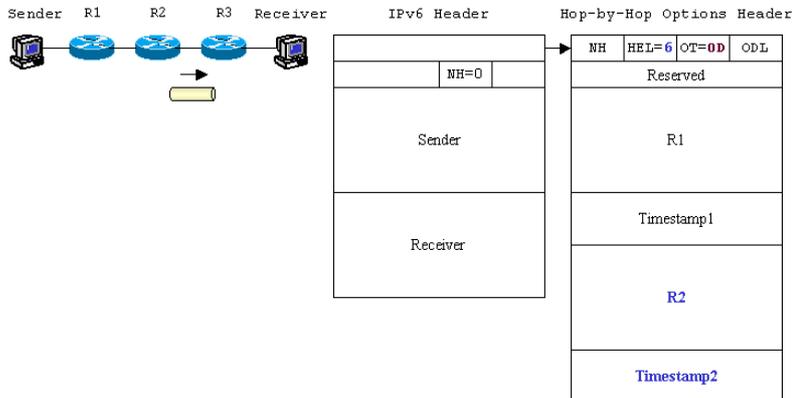


Figure 7. Link One-way Delay Measurement – Step3

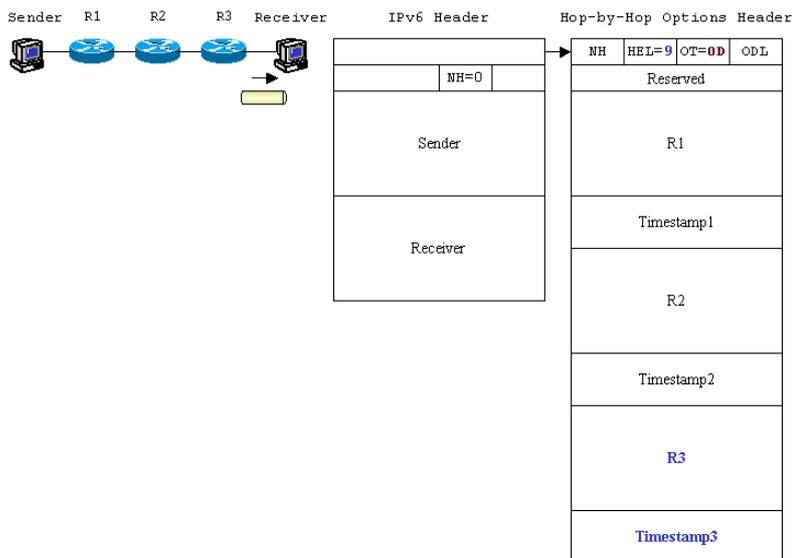


Figure 8. Link One-way Delay Measurement – Step4

4.2 Mechanism of Link One-way Delay Measurement

We explain the mechanism of link one-way delay metrics measurement with Figures from Figure 5 to Figure 8 in 4 steps. First of all, we define a new option type, OD which stands for One-way Delay. It let router write its IP address and timestamp in the payload of Hop-by-Hop Options Header of a measurement packet. Header Extension Length (HEL) of the header increases by 3 whenever the packet transits a router because the size of address field is 16 bytes and the size of timestamp field (second: 4 bytes & micro-second: 4 bytes) is 8 bytes.

Step1. After a measurement packet leaves Sender and before the packet arrives at router R1.

The states of IPv6 Header and Hop-by-Hop Options Header are the same as Figure 5. The value of Next Header of IPv6 Header (NH) is 0, which indicates the next extension header is Hop-by-Hop Options header. Because the minimum size of extension header is 8 bytes, we allocate the remaining 4 bytes as Reserved field. Header Extension Length (HEL) is 0, the unit of which is 8 bytes. Option Type (OT) is OD. Because Option Data Len (ODL) field is not used, it is set to 0. We specify the size of Hop-by-Hop Options Header with HEL.

Step2. After a measurement packet leaves router R1 and before the packet arrives at router R2.

As the measurement packet transits R1, R1 writes its address and timestamps in the payload of Hop-by-Hop Options Header of the packet like Figure 6. HEL becomes 3 because the sum of 16-byte address and 8-byte timestamp is 24 bytes, triple of 8 bytes.

Step3. After a measurement packet leaves router R2 and before the packet arrives at router R3.

Like Step2, when the measurement packet transits R2, R2 writes its address and timestamps in the payload of Hop-by-Hop Options Header of the packet like Figure 7. HEL increases by 3.

Step4. After a measurement packet leaves router R3 and before the packet arrives at Receiver.

The contents of Hop-by-Hop Options Header change like Figure 8 and HEL becomes 9. When Receiver receives the measurement packet, Receiver timestamps in the payload of measurement packet in Ethernet Frame Level and copies the pairs of address and timestamp value from extension header (Hop-by-Hop Options Header) into the payload of the packet before delivering the packet to the upper layer, IPv6 layer.

In this method, we can get link one-way delay metrics as well as end-to-end one-way delay metrics between nodes.

5. Sub-path One-way Delay Measurement

5.1 Outline of Sub-path One-way Delay Measurement

We use Routing Header and Destination Options Header to measure sub-path one-way metrics between two separate nodes on an end-to-end path of two measurement systems like

Figure 9. When a measurement packet transits along an end-to-end path between two measurement systems, we let all the routers specified in Routing Header of a measurement packet timestamp in the TLV option included in Destination Options Header of the packet.

With the timestamps, we can calculate the following sub-path one-way delays;

$\text{delay}[\text{Source}, \text{R1}], \text{delay}[\text{R1}, \text{R2}], \text{delay}[\text{R2}, \text{R3}],$
 $\text{delay}[\text{R3}, \text{Receiver}]$

where $\text{delay}[\text{node1}, \text{node2}]$ means one-way delay from node1 to node2. node1 can be separated from node2 by one or more networks.

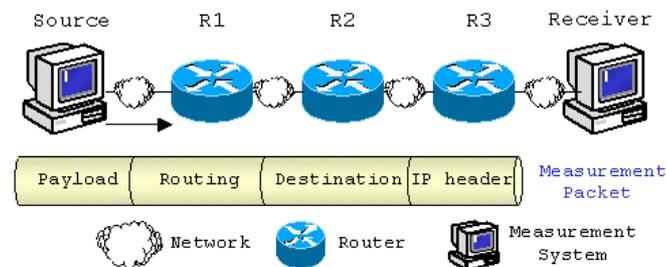


Figure 9. Sub-path One-way Delay Measurement

5.2 Mechanism of Sub-path One-way Delay Measurement

We explain the mechanism of sub-path one-way delay metrics measurement with Figures from Figure 10 to Figure 13 in 4 steps. We define the same option type as in link one-way delay measurement, OD which stands for One-way Delay. When a measurement packet is source-routed by Routing Header, OD let router timestamp in the payload of Destination Options Header of the measurement packet. Header Extension Length (HEL) of the header increases by 1 whenever the packet transits a router because the size of timestamp field (second: 4 bytes & micro-second: 4 bytes) is 8 bytes. Sub-path one-way delay measurement is different from link one-way delay measurement in that a measurement packet of the former is source-routed by Routing Header. The routers only specified by Routing Header timestamp in the TLV encoded option in Destination Options Header.

Step1. After a measurement packet leaves Sender and before the packet arrives at router R1.

The states of IPv6 Header, Destination Options Header and Routing Header are the same as Figure 10. The value of Next Header of IPv6 Header (NH) is 60, which indicates the next extension header is Destination Options Header. Because the minimum size of extension header is 8 bytes, we allocate the remaining 4 bytes as Reserved field. The value of NH of Destination Options Header is 43, which indicates the next extension header is Routing Header. Header Extension Length (HEL) is 0, the unit of which is 8 bytes. Option Type (OT) is OD. Because Option Data Len (ODL) field is not used, it is set to 0. We specify the size of Destination Options Header with HEL. In order that we specify the transit routers (R1, R2 and R3) and the final destination (Receiver), we use Type 0 Routing Header (RT=0) like Figure 10.

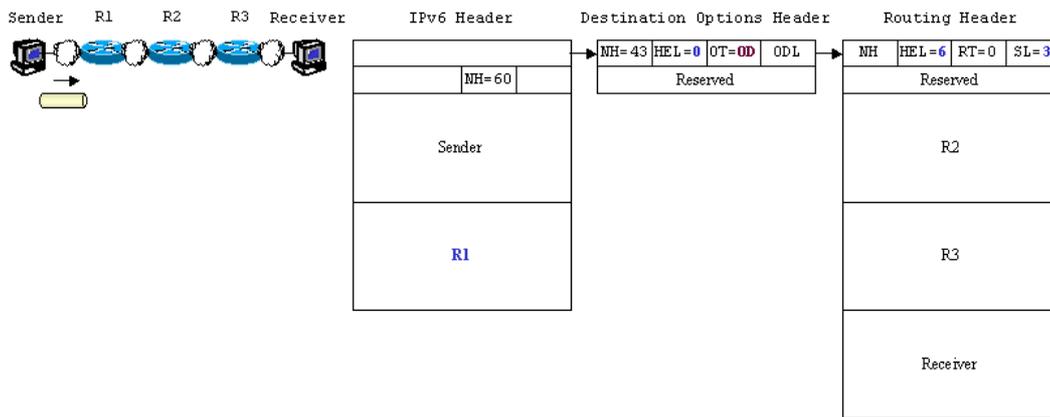


Figure 10. Sub-path One-way Delay Measurement – Step1

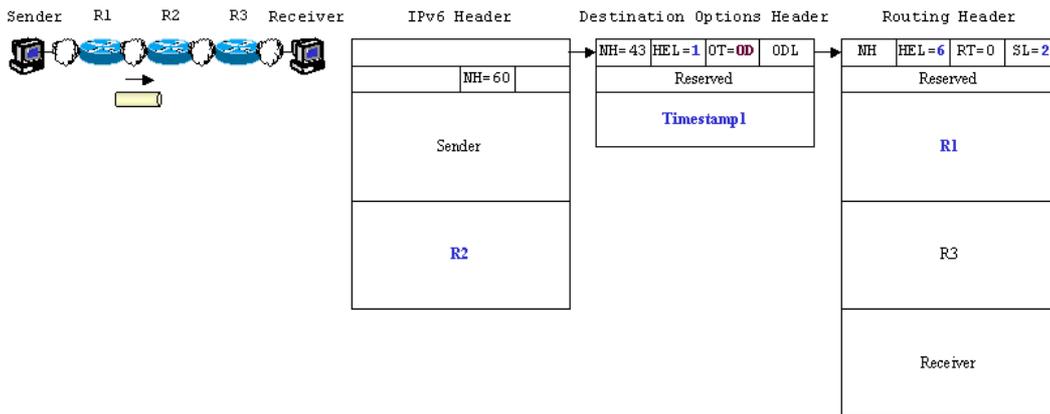


Figure 11. Sub-path One-way Delay Measurement – Step2

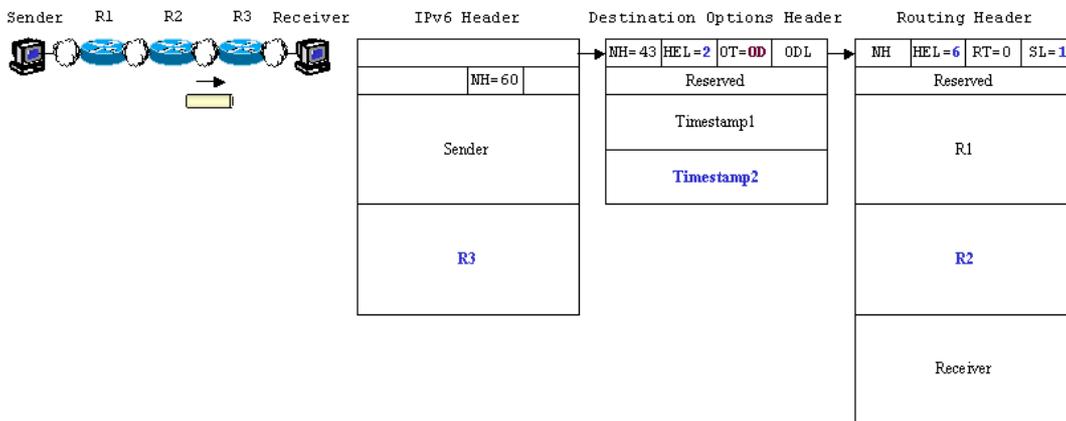


Figure 12. Sub-path One-way Delay Measurement – Step3

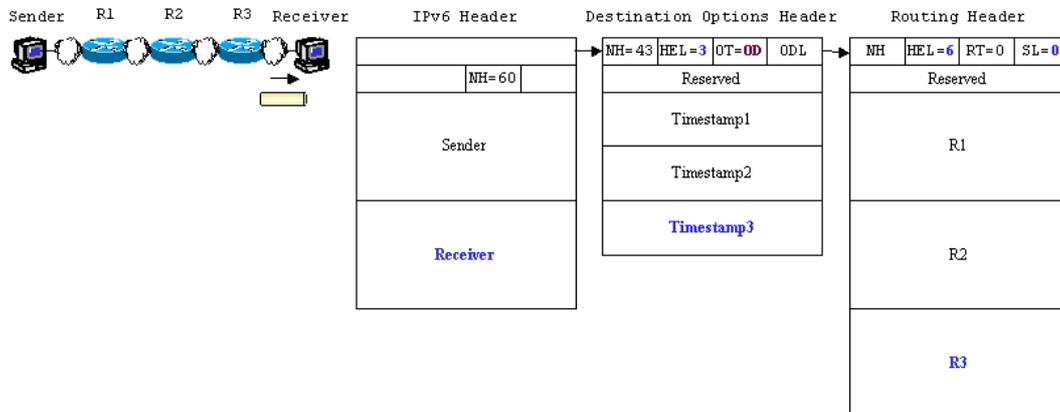


Figure 13. Sub-path One-way Delay Measurement – Step4

We set Segments Left (SL) to 3 because Routing Header contains three addresses. We set the size of Routing Header (HEL) to 6 because Routing Header contains three addresses of 16 bytes ($3 \times 16 = 48 \rightarrow 6 \times 8$).

Step2. After a measurement packet leaves router R1 and before the packet arrives at router R2.

As the measurement packet transits R1, R1 timestamps in the payload of Destination Options Header of the packet and exchanges the destination address (R1) of IPv6 Header with the first address (R2) of Routing Header like Figure 11. R1 modifies HEL of Destination Options Header into 1 and SL of Routing Header into 2 like Figure 11.

Step3. After a measurement packet leaves router R2 and before the packet arrives at router R3.

Like Step2, when the measurement packet transits R2, R2 timestamps in the payload of Destination Options Header of the packet and exchanges the destination address (R2) of IPv6 Header with the second address (R3) of Routing Header like Figure 12. R1 modifies HEL of Destination Options Header into 2 and SL of Routing Header into 1 like Figure 12.

Step4. After a measurement packet leaves router R3 and before the packet arrives at Receiver.

The destination address of IPv6 Header and the contents of Destination Options Header and Routing Header change like Figure 13. When Receiver receives the measurement packet, Receiver timestamps in the payload of measurement packet in Ethernet Frame Level and copies the pairs of address and timestamp value from extension headers (Routing Header and Destination Options Header) into the payload of the packet before delivering the packet to the upper layer, IPv6 layer.

In this method, we can get sub-path one-way delay metrics as well as end-to-end one-way delay metrics between nodes.

6. Conclusion

Because the existing one-way measurement tools can only measure end-to-end IP performance metrics such as one-way delay and delay jitter, we have a difficulty in finding exactly the congested or underutilized position of measured network in network management. If we can measure link one-way delay between two direct nodes or sub-path one-way delay between two separate nodes on an end-to-end path of two measurement systems, we can find bottleneck point exactly and solve the problem related to the point. Of course, we should use passive measurement tool such as cflowd of CAIDA in order to analyze the traffic of the point more in detail [12]. In this paper, we suggested the methodology to measure link one-way delay metrics and sub-path one-way delay metrics (i.e., one-way delay and delay jitter) as well as end-to-end one-way delay metrics (i.e., one-way delay, one-way loss and delay jitter) between two nodes.

In future work, we will simulate our methodology to verify the exactness of one-way measurement that can be affected by

the processing overhead of extension headers in related routers.

The proposed methodology uses extension headers as one of the powerful functions of IPv6 protocol. This function does not exist in IPv4. Thus if we uses the powerful functions of IPv6 well, we will make a various useful measurement tools and manage IPv6 network with the tools better than IPv4 network. In the result, we will be able to expand IPv6 network into the world-wide Internet naturally and quickly.

REFERENCES

- [1] Sunil Kalidindi et al., "Surveyor: An Infrastructure for Internet Performance Measurements", presented at INET'99, San Jose, June, 1999.
- [2] Henk Uijterwaal, Olaf Kolkman, "Internet Delay Measurements using Test Traffic", RIPE NCC, June, 1997
- [3] Jaehoon Jeong et al., "Design and Implementation of One-way IP Performance Measurement Tool", ICOIN-16, Jan, 2002.
- [4] V. Paxson, "Framework for IP Performance Metrics", RFC 2330, May 1998.
- [5] G. Almes et al., "A One-way Delay Metric for IPPM", RFC 2679, Sep, 1999.
- [6] G. Almes et al., "A One-way Packet Loss Metric for IPPM", RFC 2680, Sep, 1999.
- [7] C. Demichelis and P. Chimento, "IP Packet Delay Variation Metric for IPPM", draft-ietf-ippm-ipdv-07.txt, Feb, 2001.
- [8] IETF's IPPM WG, <http://www.ietf.org/html.charters/ippm-charter.html>
- [9] NTP Home Page, <http://www.eecis.udel.edu/~ntp/>
- [10] S. Deering and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", RFC 2460, Dec, 1998.
- [11] C. Dovrolis, P. Ramanathan and D. Moore, "What do packet dispersion techniques measure?", Proceedings of Infocom, Alaska, Jan, 2001.
- [12] CAIDA Traffic Flow Analysis Tool, cflowd, <http://www.caida.org/tools/measurement/cflowd/>