Fast CEH: an Algorithm to Enhance Performance of IPv6 Packets with CRC Extension Header

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Abstract

One of the benefits of IPv6 protocol is its extensibility of Extension Header. Extension Header is an optional part of IPv6 that is used to support a specific service on the data transmission. CRC Extension Header (CEH) is a new Extension Header proposed to improve IPv6 packets transmission over high speed network. The CEH was introduced to do error detection in Network layer that usually done in Data Link layer. Emulation of CEH showed the enhancement of packet transmission in terms of reduced network latency. However, it caused an overhead in sender as well as in receiver machine. This research aims to decrease the overhead by modifying the algorithm for generation and verification of CEH. The simulation result showed that the network latency reduced was about 34% compared to the former CEH algorithm.

Keywords: *Error Detection, CRC, Extension Header, CEH, IPv6*

1. Introduction

IPv4 address run out is now in reality as shown by the IPv4 Exhaustion Counter [1]. The counter shows in red that the IPv4 address for the Asia Pacific region has exhausted as on April 15, 2011. This fact has to be considered by institutions, companies as well as governments in order to avoid future loss of ICT budgeting. IPv4 to IPv6 transition is a necessity for users who use Internet in their day-to-day life. Everyone, as individual as well as institution needs to consider adopting the new Internet technology if they do not wish to get failure in their Internet connectivity.

IPv6 is not only to meet the shortage of IP address but also to make better Quality of Service (QoS) of Internet usage. The technology brought many benefits including simpler header format that can reduce router task such as no Header Checksum in router, no Fragmentation as well as no Header option processing in routers. IPv6 also introduced Extension header that could be used to provide a specific service on the data transmission. RFC 2460 specified a numbers of Extension header including Hop by Hop Options header, Destination Options header, Routing header, Authentication header and Encapsulating Security Payload header [2]. The RFC 2460 offered chance to create a new Extension header and we can attach any of Extension header as a chain placed after Destination Address field before upper layer header.

Traditional error control is usually done in Data Link layer using FCS (Frame Check Sequence) field. This mechanism is a time consuming task as it has to do the same thing in every router along the packet journey to reach a destination. Incoming port of every router has to check the Cyclic Redundancy Check (CRC) code of each frame as well as generate a new CRC code in the outgoing port. CRC code is generated from the entire data frame. In addition, packets transmission over high speed network is believed to have very small possibility of transmission error caused by the medium. In order to decrease overhead caused by the traditional error control mechanism, authors in [3] had introduced an Extension header called CRC Extension Header (CEH) that do error control in Network layer. This CEH was proposed to decrease the frequency of CRC code verification and generation.

Similar to other IPv6 Extension headers, CEH is generated in the sender and will be verified in the final destination of an IPv6 packet. Data Link layer of every router do not need to verify the CRC code due to it is part of Network layer protocol. Fortunately, Extension header in IPv6 is counted as payload, so routers also do not need to verify the CEH. Result of [3] showed that CEH increases the performance of IPv6 packets transmission over high speed network by about 67%.

However, introducing a new Extension header in IPv6 packet transmission would cause an overhead in terms of processing. Although the overall network latency is lesser, processing time both in sender and receiver would be high. This paper proposes a new algorithm for the generation as well as verification of CEH to decrease the processing time in sender as well in receiver. The rest of this paper is organized as follows; Section II gives an overview of CEH and Section III introduces the new algorithm. Section IV discusses the result while Section V concludes this paper.

2. CRC Extension Header

The concept of CEH is to move the function of error control from Data Link layer to Network layer. This is done on the transmission of IPv6 packets over high speed network. It is believed that high speed media such as fiber optic will produce less error that does not require error detection to be made in every intermediate node devices. As we know when using the Data Link layer error control, every frame will be checked twice in every router. This is for verification of CRC code of incoming frame and generation of new CRC code for outgoing frame.

The use of CEH will decrease the frequency of error detection from every node to only in sender and receiver. There are three rationales for using the CEH that discussed in [4] as follows:

1. Ideal usage of Extension header that is one of the IPv6 advantages.
2. The use of high speed media allows error detection to be carried-out at a higher layer.
3. Higher transfer rate of current underlying technology allows transmitting a packet more than 100 Gbps. Avoiding error check in lower layer will decrease network latency.

The detail concept of CEH is explained in [3]. CEH combines two concepts of protocol which is Frame Check Sequence [5] and Extension header [2]. FCS is a last field of Data Link layer frame that contains CRC code generated from the entire frame. The CRC code first generated in sender and regenerated in every outgoing port of routers. The code will be verified in every incoming port of router before forward to next node. While Extension header is optional additional header in IPv6, It is placed after IPv6 destination address and before upper layer header. The additional header generated in sender would only be verified in the final destination.

From the two concepts, CEH that was proposed as a new IPv6 Extension header is also placed after IPv6 main header as in Figure 1. In general, for IPv6 Extension header, the CEH is generated only at the sender and will be verified in the final destination of the IPv6 packet. Intermediate systems do not need to process the CEH. The format of CEH itself is shown in Figure 1 [6]. It consists of three fields: Next Header, Reserved and CRC-32 code. Next header is 8 bits that indicates the header followed by CEH. Reserved field is for future use and the main part of CEH is the CRC-32 code. The last field is 32 bits code generated from the IPv6 packet including main header and payload excluding hop limit.

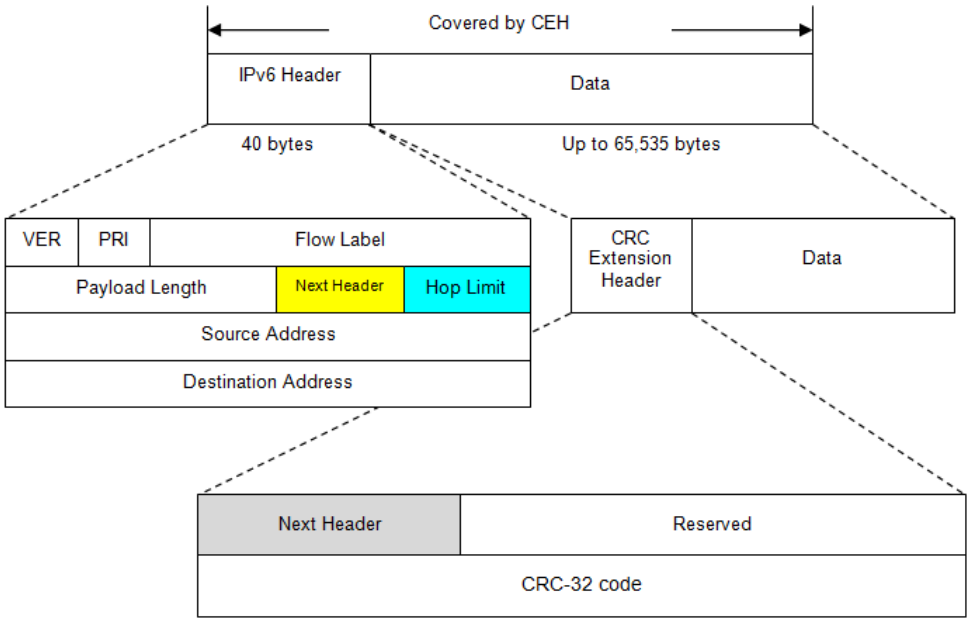

Figure 1. CEH Format in an IPv6 Packet

From the router point of view, using CEH will not add additional load to it. It will just be verified in the final destination indicated by the destination address of the IPv6 packet. Furthermore, experiment conducted by [6] showed network latency of IPv6 packet transmission decreased by 68%. However, it also introduced an overhead in sender as well as in receiver machines. Processing time of an IPv6 packet in sender raised by 15% compared to processing traditional Frame Check Sequence in Data Link layer.

3. Proposed Algorithm

An overhead is something that has to be avoided. This paper proposes a new algorithm in processing CEH at sender and receiver in order to reduce overhead of packet processing time. Critical analysis of [6] was found that the problem that causes an overhead is complexity of the calculation of CEH both in sender and receiver. In the calculation of CRC-32 code, it excluded hop limit value that changes in every router [2] and then inserts it again to the IPv6 packet header [3]. As known hop limit is 8 bit that indicates the maximum number of routers the packets can pass through before reaching the destination. The value of hop limit will be decremented by 1 after the packet pass through a router. By excluding the hop limit value was intended so that the calculation of CRC produces a valid code.

The proposed algorithm also considers the two parts of an IPv6 packet: mutable part and immutable part. Based on RFC 2402 [7], immutable fields in IPv6 base header are Version, Payload Length, Next Header, Source Address and Destination Address for the packet without Routing Extension Header. In the packet with Routing Extension Header, Destination address is considered as mutable but predictable field. While mutable fields in IPv6 base header are Traffic Class, Flow Label and Hop Limit. This research proposes an algorithm that generates a CRC-32 code from IPv6 packet including base header and payload as shown in Figure 1. If a field is mutable, for the purpose of CRC-32 code generation and verification, the value of the fields is set to zero. The algorithm is called Fast CEH as depicted in Figure 2.

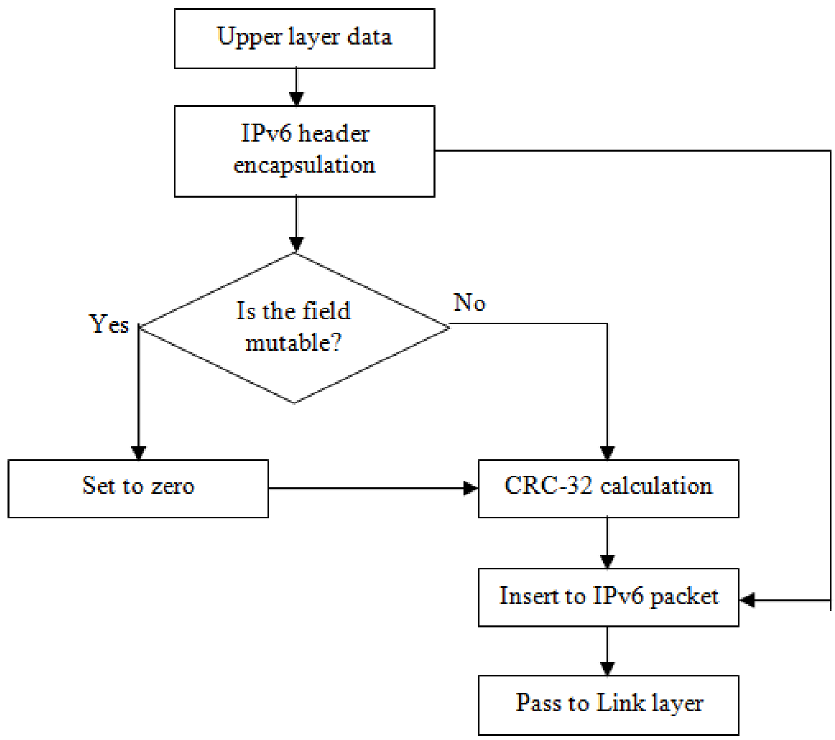

Figure 2. Algorithm of Fast CEH

Data from upper layer protocol is delivered to Network layer to do encapsulation. The data in encapsulated by IPv6 base header that consists of mutable and immutable fields. The mutable fields are set to zero and none for immutable fields. Therefore, CRC-32 generation as well as verification using the same algorithm of CRC code in FCS [5]. Result of the CRC-32 calculation is a code that is to be inserted in the IPv6 packet as Extension header. The complete IPv6 packet is then forwarded to Data Link layer.

In the receiver node, the data was taken from Data Link layer, and then extract the data to get the CRC-32 code from the IPv6 packet. The code is then compared with the new CRC-32 code generated from the IPv6 packet received using the same algorithm used in sender. Result of the comparison is used to decide whether the packet contain error or not. If the comparison of the two CRC-32 code results in the same value, the packet is correct and then forward to upper layer, otherwise discard the packet.

4. Result and Discussion

Simulation results of using Fast CEH algorithm in IPv6 packets transmission over high speed networks are listed in Table 1 and Table 2. Table 1 consists of processing time of IPv6 packet generation in sender as well as packet verification in receiver. The time is measured in milliseconds. Table 2 is comparison between total processing time using normal CEH algorithm and Fast CEH algorithm.

Table 1. Processing Time of Fast CEH Algorithm

Packet Size (bytes)	64	128	256	512	1024	1280	1500
Processing Time in Sender (ms)	0,467	0,481	0,671	0,725	0,777	0,892	0,924
Processing Time in Receiver (ms)	0,092	0,118	0,203	0,406	0,447	0,522	0,548
Total Processing Time (ms)	0,559	0,599	0,874	1,131	1,224	1,414	1,362

Table 2. Comparison of Total Processing Time

Packet Size (bytes)	64	128	256	512	1024	1280	1500
Processing Time of CEH (ms)	1,257	1,285	1,355	1,483	1,681	1,730	1,804
Processing Time of Fast CEH (ms)	0,559	0,599	0,874	1,131	1,224	1,414	1,362
Δ Processing Time (ms)	0,698	0,726	0,481	0,352	0,457	0,316	0,442
Decreasing Processing Time	55%	56%	35%	23%	27%	18%	24%

Processing time both in sender and receiver in Table 1 shows the time is increase with the increasing of IPv6 packet size. This is normal because larger IPv6 packet contains more bytes had to be processed on generating IPv6 packet and also verifying the packet. While the comparison of the processing time in sender and receiver is slightly different. The time in sender is higher than in receiver. Generation of IPv6 packet in sender is began from taking data from upper layer and passing to Data Link layer including CRC-32 code generation. The CRC-32 calculation needs to choose the immutable field of the packet header and set the mutable value fields to be zero then insert the code to the packet as Extension header. These tasks take more time that causes the high processing time in the sender. However, the overall processing time of IPv6 with Fast CEH both in sender and receiver is less than 1 millisecond especially for the small packet that is more exist in today Internet transmission.

The comparison of processing time of IPv6 packets transmission using Fast CEH and the traditional CEH shown in Table 2 exposes the processing time of IPv6 with Fast CEH lesser than IPv6 with CEH. This applies for the overall IPv6 packets transmission in the experiment. The processing time shown in the table is the total processing time in sender and receiver. The mean value of difference of processing time is 34%. The table also presents the percentage of reducing packet processing time for each packet size. The percentage of the processing time reduction varies from 18% to 56%. In order to clarifying the differences, the table could be presented as a graph as shown in Figure 3. The figure demonstrates processing time of Fast CEH graph is in lower position meaning the processing time is lesser. The highest difference is happened in the small packet. It could also be concluded that for small packets the processing time is also small, and so the percentage decrease in processing time is bigger than for large packets. This is also a benefit as the communication packets over the Internet today usually are of small size, therefore the Internet connection will be faster.

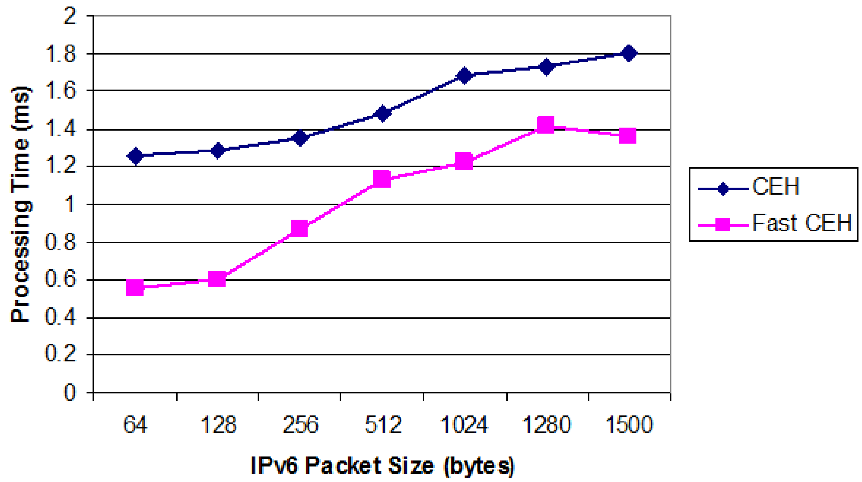

Figure 3. The Difference of Processing Time

5. Conclusion

The exponential growth of Internet has caused IP address running out. Therefore, adoption of IPv6 is a necessity. One benefit of IPv6 is the extensibility of Extension header. By combining the Extension header advantage and FCS concept, we introduced Fast CEH to do error detection faster in the Network layer. The algorithm considered mutable part of IPv6 base header that change in every router. In order to avoid CRC calculation error, the mutable fields is set to zero both in sender and receiver. CEH is an Extension header that is counted as IPv6 payload that routers are not required to process. The simulation result showed that the processing time both in sender and receiver has decreased compared to the existing CEH algorithm. The reduction in total processing time ranges from 18% to 56%. Decreasing the processing time both in sender and receiver could translate to reducing the network latency in IPv6 packets transmission with CRC extension header.

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