Performance Evaluation of IPv6 Jumbogram Packets Transmission using Jumbo Frames

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***Abstract*—IPv6 is an ultimate solution to the Internet address exhaustion. It is believed, the protocol will be requested by not only human but also everything on the earth surface. Furthermore, the improvement on the protocol is important to achieve IP packets transmission efficiently. Processing technology has been improved to become very fast packet processing both in host as well as intermediate systems. The lower layer technologies have supported to transmit Gigabits data per second. However, there is a limitation on transferring large data due to the current MTU on the widely used link layer technology which is Ethernet is still 1500 bytes. This research aims to evaluate performance of IPv6 packets transmission using jumbo frames. The evaluation was done by transmitting IPv6 packets larger than 1500 bytes in Windows operating systems. The results show, transmitting larger packets size using jumbo frame can increase the network throughput by up to 117%.**

Keywords—jumbo frame; IPv6; MTU; transmission

I. INTRODUCTION

Internet is an emerging technology that grow extremely fast. In only two decades, it has reached all over the world with millions users connected. Based on the World Internet Statistic, since 2000 until 2017, the Internet growth is 931% [1]. The users need Internet address to be connected to the giant Internet. However, with the current Internet technology, IPv4, it only provides 32 bits for Internet address. The maximum address space in is only 4.3 millions addresses that is too small compared to the current human populations that reach 7 millions. Fortunately, the IETF has developed IPv6 with larger address space [2]. It provides 128 bits for Internet address. This huge address space not only solves the Internet address exhaustion but also provide more addresses for the Internet of Thing concept [3].

IPv6 header consists of IPv6 main header and IPv6 extension header. There is the payload length field in the IPv6 main header that indicates the size of data from upper layer. The size of the field is 16 bits that means it can identify payload length until 65,565 bytes. This is in line with the current need of file size that usually transmitted by Internet users, based on [4] the average file size is listed in Table 1. However, there is a threshold in the lower layer technology that is used in today's Internet infrastructure. The widely used technology which is Ethernet, is still standardized to use frame size 1518 bytes due to the MTU (maximum transmission unit) is 1500 bytes by default. The Gigabit Ethernet generation has been developed to provide large MTU, but the default is still 1500 bytes. Furthermore, if the Internet users aim to send PNG image file (4 kB), it will be fragmented become three separate Internet packets.

TABLE 1 TYPICAL FILE SIZE IN INTERNET

Image	Document	Media
PNG : 2 – 4 kB	DOCX : 4 – 8 kB	eBook : 1 – 5 MB
GIF : 6 – 8 kB	PDF : 18 – 20 kB	MP3 song : 3 – 4 MB
JPG : 9 – 12 kB	ODT : 80 – 90 kB	DVD Movie : 4 GB
TIFF : 900 – 1.000 kB		HD Movie : 5 – 8 GB
BMP : 900 – 1.000 kB		Blu-Ray Movie: 20-25 GB

The fragmentation affects the performance of the IP packets transmission especially throughput. Smaller packet indicates smaller throughput. In addition, the fragmentation is done by intermediate nodes in IPv4 infrastructure. It can reduce the performance of forwarding task on routers. Routers should check the packets size and fragment it if needed before forwarding the packet. It requires some amount of time. The development of IPv6 aimed to reduce this kind of overhead by implementing path MTU discovery before sending the packets. However, it still needs time to check the MTU along the transmission line. In addition, the small MTU limits throughput in IP based network infrastructures [5].

The throughput can be increased by transmitting large packets. It not only reduces load in routing and switching devices while but at the same time also reduces network overhead [6]. Furthermore, increasing MTU size is believed to be able to increase the network throughput. A number of researchers as well as industries have studied the possibility on increasing MTU size such as [5, 7-9].

In order to accommodate the intention of transmitting large file size, IETF has defined IPv6 Jumbogram in RFC 2675 [6]. The document defined an IPv6 Jumbogram is an IPv6 packet containing a payload longer than 65,535 bytes. It also described the IPv6 Jumbo Payload option. To be able to transmit IPv6 Jumbograms packet, it should be supported by links that has MTU greater than 65,575 bytes. However, the transmission of Jumbogram packet is only utopia since most of the current network infrastructure still uses MTU of 1500 bytes.

This research aims to know the performance of IPv6 Jumbograms packets transmission using jumbo frames in the current network infrastructure. Jumbo frame is defined as a frame that has MTU larger than 1500 bytes. This will be done by experimenting IPv6 packets transmission on various sizes from 1500 bytes up to 65000 bytes. The largest size is the Jumbogram size.

The rest of this paper consists of related works on IP packets transmission using jumbo frames in Section 2 followed by description of methodology in Section 3. Section 4 provides experimental results and also discussion of the performance of IPv6 Jumbograms packet transmission using jumbo frames. The last section is the conclusion of the paper.

II. Related Works

The issues on transmitting large file have attracted the attention of a number of researchers from both industrial and academics. Small Tree Communication published a white paper describing the importantance of jumbo frames on Gigabit and 10 Gigabit Ethernet. It described the capability of Gigabit Ethernet on transmitting IP packet. 10 Gigabit Ethernet is able to transmit 10 billion bits of data every second. The capability cannot be used optimally due to the limit of MTU [10].

Ethernet alliance [11] also released a paper on Ethernet Jumbo Frame on 2009. They defined the jumbo frames as all layer two frames that have MTUs larger than the standard, originally specified Ethernet payload size of 1500 bytes. The document provided the pros and cons on the usage of jumbo frames that can be summarized as follows: larger MTUs allow greater efficiency in data transmission since each frame carries more user data (payload or MTU) while protocol overhead and underlying per-packet delay remain fixed. Sending data in jumbo frames resulted in fewer frames being sent across the network. Processing fewer frames generates conservation of CPU cycles and thus greater throughput. However, larger frames consume more Ethernet link transmission time, causing greater delays for those packets that follow and thus increasing lag time and latency.

Performance evaluation on TCP/IP jumbo frames was done in [5] and [7, 8]. The effect of IPv6 packets size transmission was evaluated in [12]. The evaluation was made to support the hypothesis that the use of jumbo frames is considered one of the methodologies that can be employed to increase data throughput on networks. However, the transmitting of large IP packets in normal frame increases processing time as well as network latency. It implemented jumbo frames on a test-bed network implementing Windows Server 2003/2008 for both IPv4 and IPv6. It concluded that jumbo frames give higher throughput than normal frames for both TCP and UDP traffic types. IPv6 delay values are significantly lower than IPv4 for TCP traffic type. Jitter values and UDP packet dropped values are comparable between jumbo and normal frames.

Authors of [8] presented results of simulations for a series of Ethernet-based Xnet Super Jumbo Frame. The experiments were conducted prior to and at Supercomputing ’05, for up to 64000 bytes path MTU. Cumulative jumbo frame research spanning several years, combined with theoretical calculations and extrapolations from experimental data obtained during Supercomputing ’05 indicates the possible practical feasibility of SJF-based network mechanics as a potential means to realize practical long term performance goals for high throughput streaming. Some of the lessons and implications of the SJF approach are discussed in relation to the evolution of novel network architectures, particularly in relation to explicit path systems for the high performance computing community, pending deployment of 40 and/or 100 Gb Ethernet. Based on their search for equipment capable of performing Layer 2 functionality at 64000 B, it seems unlikely that the 16 bit length indicator of IPv4 will be fully utilized, in the near future; due to wide spread tacit equipment implementation limitations adopted.

Research on IPv6 Jumbogram was done in [13] and [14]. It uses Scapy and SendIP to create the Jumbogram on both LAN and WAN. By making use of this IPv6 Jumbo Payload option, it becomes theoretically possible to attach a payload of 4 GiB of data to a single, unfragmented IPv6 packet. The author examined the possibility of practically implementing the use of Jumbograms on a network that consists of IPv6 nodes that understand and support a path Maximum Transmission Unit (MTU) greater than 65,575 bytes (that is, 65,535 bytes + 40 bytes for the IPv6 header).

However, there is no both hardware and software MTU support for anything larger than 65,575 bytes. The author believes that the entire concept of Jumbograms has been superseded by superior data transmission technologies such as channel-based communication. At the time of the publication of the IPv6 Jumbograms RFC (2675), Jumbograms were targeted mainly on the supercomputing technologies that existed then with the eye on the future, not knowing that soon after, newer technologies such as Fiber Channel would become the inexpugnable de facto standard.

Author of [14] did research on using IPv6 Jumbogram on Wifi channel in relation with MTU size. It concludes that increasing the MTU for data networks may create the opportunity to use IPV6 Jumbograms. Jumbograms fragmentation has been greatly reduced, due to its new MTU value and the decreased production of new headers that allow the transmission of more data and extend the capabilities of a data network regarding the supported applications. The characteristics of the channel in terms of capacity and distance are not relevant in the use of Jumbograms unless it is the BER. The size of the packets to transmit is increased, when BER value decreases. With a BER of 1×10^{-10} it can be used with Jumbograms.

Our main contribution in this paper is to get new findings on transmitting IPv6 Jumbogram using jumbo frames by experimenting as well as quantifying its performance with respect to QoS parameters. The experiments represent the existing network infrastructure that is fast Ethernet dominantly that uses MTU of 1500 bytes and also increase the MTU by using Gigabit Ethernet technology.

III. Methodology

Based on the discussion of related works on increasing MTU size as well as IPv6 Jumbogram, there is no implementation on transmitting IPv6 Jumbogram due to the infrastructure limitation. This research aims to do performance evaluation on transmitting IPv6 Jumbogram using jumbo frame. Jumbogram in IPv6 is defined as if the packet size larger than 65,535 bytes. RFC 2675 defined MTU size to transmit IPv6 Jumbogram is minimum 65,575 bytes. In this research we transmit IPv6 Jumbogram with MTU larger than 1500 bytes and lower than 65,575 bytes.

In order to transmit the IPv6 Jumbogram, we installed a topology as depicted in Figure 1. The two computers are basically a peer to peer network that uses Gigabit Ethernet as the layer 2 technology. We did not use any intermediate routers to avoid potential overhead due to intermediate devices processing. This topology is used to measure QoS parameters such as throughput, jitter and latency (delay). Disabling routers will neglect any influence network performance. Furthermore, accurate results will be obtained.

The hardware benchmark consists of two workstations. Workstation 1 and Workstation 2 were running under OS Windows Server 2012 R2 64-bit. Both machines are AMD Phenom(tm) II X4 840 Processor 3.20 GHz with 2 GB RAM. The important hardware is the network card used. Both workstations use Realtek RTL8168B/8111B Family PCI-E Gigabit Ethernet NIC (NDIS 6.0). As medium on the experiments, we use UTP Cat 5e. In order to run the experiment software D-ITG-2.8.1 was used.

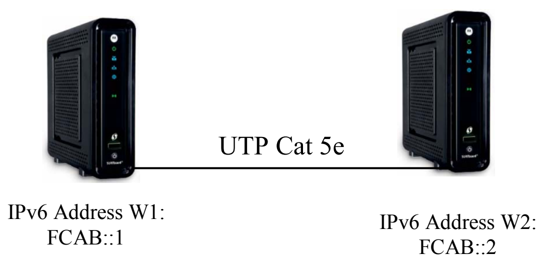

Figure 1 Experimental Network Topology

W1 as the sender transmits TCP packets with various sizes from 1500 up to 65000 bytes. The packet size is sent using normal frame (MTU = 1500 bytes) and jumbo frame (MTU = 4000 bytes). There are 100000 packets per second during 30 second. In order to record the QoS result, ITGDec function as part of D-ITG software was run in the receiver (W2). The receiver records network latency that is defined as the time needed by the entire packets sent to completely reach the destination from the time the first bit is sent out from the source. From the latency, the throughput is then calculated by dividing the total bits sent and the latency. The ITGDec is also showed the jitter of the packets transmission.

IV. Result and Discussion

Measurements were done with some parameters that include latency (delay), jitter and throughput. This section analyzes the results in order to know the performance of IPv6 packets transmission using jumbo frame by comparing with the normal frame transmission. The packets size is gradually increased from 1500 bytes up to 65000 bytes to observe the impact of packets size on MTU size performance.

Table 2 is the results obtained from the experiments on transmitting IPv6 packets with MTU of 1500 bytes and MTU of 4000 bytes. MTU of 1500 bytes represents the widely used MTU on current computer networks. The used of MTU 4000 bytes to understand the impact of using jumbo frame on IPv6 packet transmission.

TABLE 2 Network Parameters

Packet Size (byte)	Latency (ms)		Jitter (ms)		Throughput (Mbps)	
	1500	4000	1500	4000	1500	4000
1500	2.3	1.21	0.15	0.145	5.22	10.00
3000	2.66	1.27	0.15	0.155	9.02	18.89
6000	5.315	2.20	0.17	0.21	9.03	21.82
12000	7.4	3.05	0.245	0.29	12.97	31.47
24000	5.8	2.885	0.405	0.47	33.10	66.55
48000	6.06	2.555	0.645	0.645	63.37	150.29
65000	8.345	4.225	0.48	0.56	62.31	123.07

A. Latency analysis

In Table 2, we sent the same packets size for both MTU size. We can see the differences between the two on the recorded latency. The differences can be seen on Figure 2. Overall, IPv6 packets transmission using MTU of 4000 bytes require smaller time than using MTU of 1500 bytes. This is evidence that transmitting jumbo frame can increase the transmission rate or decrease the latency.

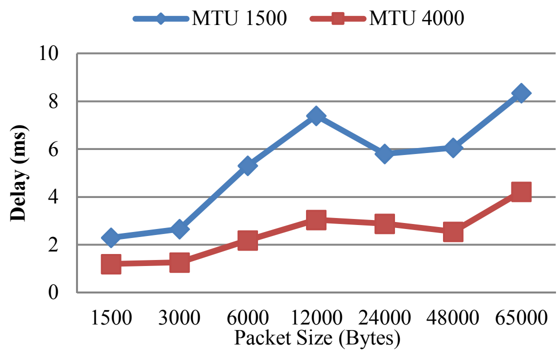

Figure 2 Network Latency Comparison of MTU 1500 bytes and MTU 4000 bytes

Transmitting using large frame size is able to carry more packet data in fewer frames. For example, if we transmit 6000 bytes of IPv6 packet, there are 4 frames on MTU of 1500 bytes; in opposite we just need 2 frames on MTU of 4000 bytes. Logically, to transmit the 6000 bytes, the usage of MTU 4000 bytes could reduce the latency. From Table 2, we know it can reduce the latency by up to 59% as shown in Table 3.

TABLE 3 PERCENTAGE OF DECREASING LATENCY

MTU	1500	3000	6000	12000	24000	48000	65000
1500	2.3	2.66	5.315	7.4	5.8	6.06	8.345
4000	1.21	1.27	2.20	3.05	2.885	2.555	4.225
%	48%	52%	59%	59%	50%	58%	49%

As defined, the latency is the time required to transfer all bit from sender to receiver. The usage of large MTU reduces the number of frame, and furthermore the entire packet will reach the destination faster than the smaller frame size. The latency consists of propagation time, transmission time, queuing time and processing delay. Since the sender machine, medium and receiver machine is the same, propagation time and transmission time is also the same. Hence, the dominant factor is queuing and processing time in receiver to process the frame when arrived. In case of large number of frame, the receiver has to reassemble the frames to become a full packet.

B. Jitter analysis

Jitter is defined as the differences of delay between packets that is transmitted. This will be a problem if the value of jitter is high. Based on the Table 2, the jitter values are comparable between MTU 1500 bytes and MTU 4000 bytes. Figure 3 shows the jitter value. The highest jitter for both MTU size happened on packet size of 48000 bytes. The others have small differences that reaches 0.08 ms on packet length 65000 bytes.

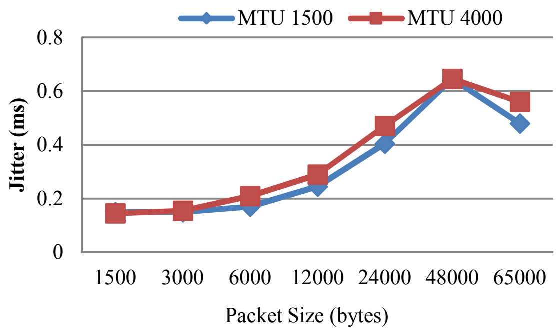

Figure 3 Jitter Comparison of MTU 1500 bytes and MTU 4000 bytes

This result indicates that transmitting IPv6 packets using jumbo frame does not have any affect on jitter, even though, the packet length has reached the size of IPv6 Jumbogram (larger than 65575 bytes). The Figure 3 also justifies that jitter for transmitting jumbo frame less than 1 ms.

C. Throughput analysis

Throughput represents how fast data packets can be sent through a network. This can be calculated by comparing the total bits on the packets sent and the latency. Throughput is the important parameter on QoS analysis. The experiments on transmitting IPv6 packets using two types of MTU can be used to justify whether the large frame size can increase the throughput. Figure 4 demonstrates the throughput on the two MTU sizes.

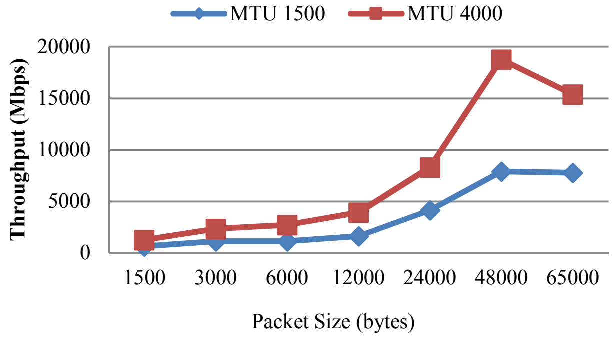

Figure 4 Throughput Comparison of MTU 1500 bytes and MTU 4000 bytes

From the figure, we can see that the throughput for large frame size (4000 bytes) is higher than the small frame size (1500 bytes). For the shortest packet (1500 bytes), the throughput is comparable because the packet is only one frame for both MTU size. The graph is exponentially rising as the larger packet length. This is because the longer packet size results in large number of frame if we use small MTU size. The increasing throughput on IPv6 packets transmission with MTU 4000 bytes is shown in Table 4.

TABLE 4 PERCENTAGE OF INCREASING THROUGHPUT

MTU	1500	3000	6000	12000	24000	48000	65000
1500	5.22	9.02	9.03	12.97	33.10	63.37	62.31
4000	10.00	18.89	21.82	31.47	66.55	150.29	123.07
%	92%	109%	142%	143%	101%	137%	98%

In average, transmission of IPv6 packet using jumbo frame can increase the network throughput as high as 117%. Theoretically, this can be happen since the MTU increased more than two times while the number of frame reduced. In the future, if the MTU size is increased up to 9000 bytes, the network throughput will increase by more than four times.

V. CONCLUSION

Larger packets size as well as large frame size is able to reduce network delay and at the same time increases the throughput of the network. However, it does not have any affect on the value of jitter. Transmitting small packet and large packet yielded the same jitter value. In this research, we use UTP Cat 5e medium that has a very low bit error rate. Furthermore, the BER is neglected in the analysis. Large packet data that was sent through large frame can reduce the number of frame transmitted. However, this research is only experimented on Windows machine. It is recommended to extend the research using other OS such as Linux, Mac and FreeBSD. This research may also be scaled on a larger network such as Internet with intermediate systems.

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