Comparison of IPv6 Transition Mechanism

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***Abstract*— Exhaustion of the current version of IPv4 led to the new alternative which is by migrating IPv4 to a new protocol, IPv6. The migration to IPv6 will be facilitated with several transition mechanisms. Even though every process requires compliances with corresponding capabilities, all transition mechanisms have a similar objective which is to ensure smooth transition. This paper focuses on the performance comparison of IPv6 transition namely dual stack and 6to4 tunneling. The evaluations are based on test bed setup where IPv6 transition mechanisms of data transmission were tested. The network performance application software has been applied to end-to-end devices to obtain the throughput and round trip time for TCP and UDP on the transport layer. The performance of IPv6 was compared with the native IPv4 environment. The results proved that dual stack IPv6 transition mechanism is a more preferable method in the case of TCP data transmission.**

***Index Terms*—IPv4, IPv6, TCP, UDP, Dual Stack, Tunneling**

I. INTRODUCTION

Presently, APNIC will no longer release the Internet Protocol version 4 (IPv4) prefix to any telecommunication provider or internet requestor since the number of unused IP address is depleting. As an alternative, Internet Protocol version 6 (IPv6) scheme has been introduced. IPv6 will never be less since the range is indeed uncounted. Nowadays many free online subnet calculators provided through the website meanly for IPv6 to make us ease on IPv6 calculation. Referring to [1], they believed by introducing IPv6, this can be a replacement to IPv4 in the near future. The main purpose is to fulfill the decrement of IPv4 addresses and to mitigate the weaknesses on the current protocol used. Since many years ago, the implementation of IPv6 creates much attention to internet users by ensuring the stability and reliability on the level of implementation for future. Until present, both IPv4 and IPv6 are co-exist and concurrently used in the network.

The transition mechanism is a method of protocol employment on the network which uses both IPv4 and IPv6 protocols simultaneously. This method is being proposed was to ensure the steady of IPv4 to IPv6 alteration. Consequently, the Internet Engineering Task Force (IETF) has assigned dedicated group named the Next Generation Transition (NGTRANS) which a mission to develop the mechanism that can support the process of Pv4 to IPv6 operation [2]. As a result, abundant of analogous transition mechanisms have been actualized and introduced. A wide range of transition techniques have been identified and implemented so far. There are three types of transition methods, known as dual-stack, tunneling and translation techniques. Dual-stack techniques allow IPv4 and IPv6 to co-exist in the same devices and networks. Besides, tunneling techniques can avoid order dependencies when upgrading hosts, routers, or regions. Devices of IPv6-only can communicate with devices of IPv4-only over translation techniques. As stated earlier, in this paper, the transition mechanisms that were compared are dual stack and 6to4 tunnel. The main objective in conducting this project is to compare and evaluate the network performance of IPv6 transition mechanism. The performance test was carried out in the Wide Area Network (WAN) test bed.

II. BACKGROUND

The evolving of the network IPv4 from the small scalability to worldwide Internet over the years has proof and shown in terms of performance, capability and bring to occupy a leading position in the growth of internet usage. From 1981 which TCP/IP is built in version 4 of the internet protocol, however the decreasing of unused addresses and nearly extinct made the IPv4 is very limited.

The invention of IPv6 greatly expanded address space. Moreover, IPv6 is outperformed in generating more than 3.4x1038 unique addresses as compared only 4.3x109 addresses in IPv4. This is because IPv6 addresses have been designed as 128-bit (16-byte) address whereas IPv4 only provides 32-bit (4-byte) addresses. The major improvements of IPv6 are on the header efficiency. IPv6 has no option field and has been replaced by extension header resulted in a fixed length 40-byte IP header compared to 20-byte IP header for IPv4. Furthermore, the processing and IP forwarding is faster since no header checksum and no fragmentation at intermediate nodes. The IPv6 provide reducing the number of required field even though the space of IPv6 is larger than IPv4. Stateless address auto configuration and extensible IP datagram are part of IPv6 advantages.

Tunneling provides a way to utilize an existing IPv4 routing infrastructure to carry IPv6 traffic within Router-to-Router, Host-to-Router or Host-to-Host. The packet of IPv6 encapsulate in the packet of IPv4 during the transition. Configured tunneling is the prearranged addresses for both IPv4 and IPv6 are manually configured. Tunnel broker builds on configured tunnel via IPv4 authenticate scheme to establish mapping and typically default route. The 6over4 tunneling can be any addresses however it requires IPv4 multicast. Automatic tunneling concept require IPv4 address embedded in low 32 bits which requires default route to IPv4 or injecting IPv4 table into IPv6 routing. This project focused on 6to4 tunneling method. The data of IPv6 can be transmitted across, while maintain the IPv4 network with tunneling mechanism. In other words, if the network is insecure, tunneling has been considered a safe route to send data.

6to4 is an automatic tunnel technique which provides a good interim solution with minimal operational complexity. It is technologies which encapsulate the IPv6 header and data within with IPv4 header across IPv4 network. This scenario can belong to global internet network or corporate network. The end device within 6to4 tunneling network can be 6to4 Host/router, 6to4 router or router relay. Each of IPv6 hosts will be connected to IPv4 network. 6to4 router consists of tunneling configuration on the interface. This router will turn to be 6to4 relay router once it is able to communicate with IPv6 internet network. Figure 1 shows the 6to4 tunneling setup and the components with IPv4 and IPv6 internets corresponding position.

The core idea of dual stack technology is the transition mechanism which includes both IPv4 internet layer and IPv6 internet layer. On dual stack, UDP and TCP protocol on host-to-host layer has been on the single implementation contains by dual layer of IP. The dual IP layer also provides the platform which the upper protocol is able to communicate over IPv4, IPv6 or IPv6 in IPv4. By allowing sending and receiving both IP version 4 and version 6, implicitly the compatibility of IPv4 can be preserved.

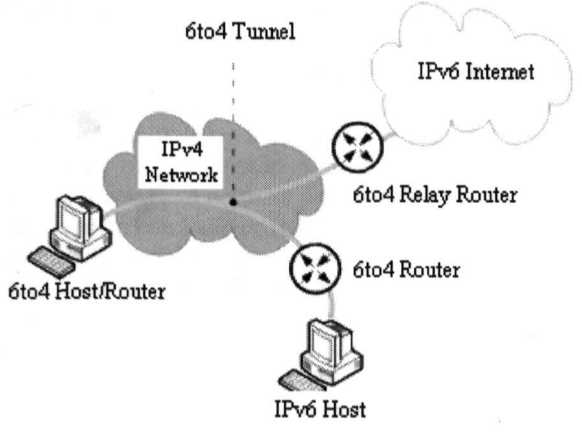

Fig. 1 6to4 tunneling scenario

IPv4 stack application will be chosen by IPv4 packet while IPv6 stack of application will be chosen by IPv6 packet on dual stack basis. The applications will select the correct IP address considering the IP traffic and the requirement of the particular communication. The host or router will be dual stack device when the IPv4 and IPv6 have been configured on the interface. The dual stack host or router will maintain both protocol and able to communicate with the both IP versions system. Figure 2 shows the dual stack setup and the components with IPv4 and IPv6 internets.

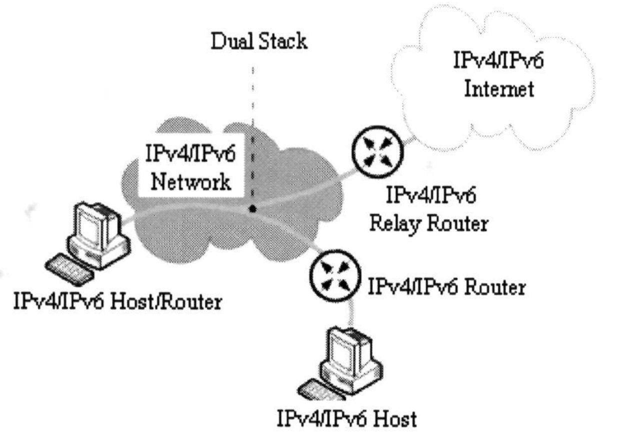

Fig. 2 Dual Stack scenario

III. METHODOLOGY

The test bed was carried out over the real ISP network platform in Malaysia which is under controlled environment with the bandwidth guaranteed but not beyond the upstream. The network performance assessment work flow is shown in Figure 3.

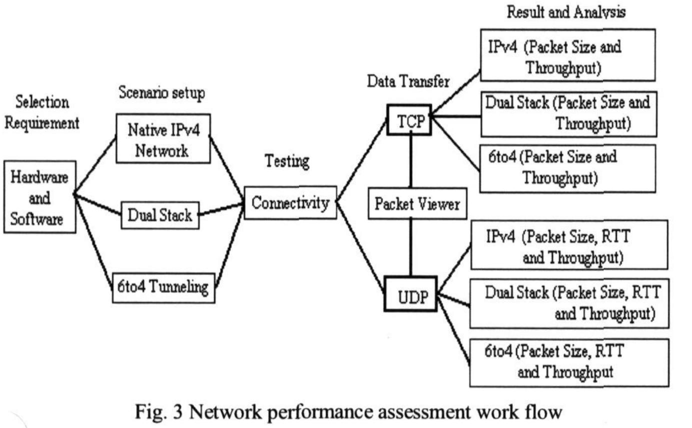

Fig. 3 Network performance assessment work flow

A. Hardware and Software Requirements

This section describes detailed infrastructures of the network on the selection of hardware and software. This is to provide a clear insight towards the requirement that is compatible with new IP version which is IPv6. The specifications of hardware and software details are depicted in Table 1.

Table 1: Hardware and Software specification

Features	Specifications
Operating System	Microsoft Windows 7
Router	Cisco 2800, Cisco 3600x, Juniper mx480

IOS	c2800nm-adventerprisek9-mz.124-24.T4.bin, me360x-universalk9-mz.152-2.S.bin, Junos 11.4R7.5
SFP Module	10/100/1000BaseTX SFP
Packet Viewer	Wireshark 1.8.4
Network Performance Tool	Jperf -2.0.2

B. Scenario Based Setup

This section explains the method of network setup. All network connectivity has been setup under controlled environment in terms of basic devices in network and bandwidth cap. Each device interface facing the host on access network layer, GE port was capped to 100Mbps and 5Mbps for TCP and UDP tests respectively while the backbone network consists of Juniper Router with the bandwidth backhaul of 10GE. The test bed setup of end-to-end host which is a sender and a receiver includes a protocol which is compatible to run IPv4, IPv6 Dual Stack and Tunneling, end device (Cisco Router), Packet viewer, and Network performance tool (JPERF). The connectivity of the network has been set up in 3 different scenarios. Although the environment is different, however the device and equipment used remain the same. This is to maintain the network platform and accumulate the same result and can be compared even under different environment. From this, we will be able to compare the relation between 3 different environments. The test bed setup is depicted in Figure 4.

Test bed was constructed over real core network. It consists of many devices to cater the transmission of the packet and protocol version 4 and version 6. The core network consists of Juniper routers over Multi-Protocol Label Switching (MPLS) technology. The access layer consists of Cisco Switch 3600x where end router will be terminated. The packet viewer has been installed on the Laptop at both end-to-end sites. The application software of network performance has been installed as client (sender) and server (receiver). As in figure 4(a), the router, switch, and host have been placed to construct IPv4 network. Those networks have been configured as IPv4 network A, IPv4 network B and IPv4 internet network. IPv4 network A govern by user as a sender, connecting to IPv4 network B which connected to the receiver via IPv4 internet network which contains several routers, where the internetworking transmission happen between IPv4 network A and IPv4 network B.

Under the same network platform, different scenario has been configured as in figure 4(b) to represent IPv6 Dual Stack network. The client and server at network A and network B have been configured as Dual Stack host which consists of IPv4 and IPv6 addresses. The Dual Stack network which interconnect between client and server able to transmit and receive both stack of IP versions.

The same experiment has been implemented under the same network platform for 6to4 tunneling as in figure 4(c). The end-to-end host connected to network A and network B have been configured using IPv6 while the internet world in the middle has been configured as IPv4 network. Router B and Router C has been configured as tunneling. This tunnel operates in IP version 6.

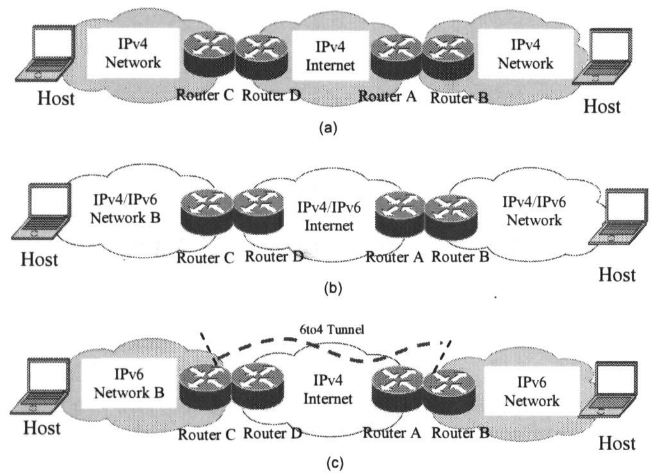

Fig. 4 (a) Native IPv4 (b) Dual Stack (c) 6to4 Tunnel

IV. EXPERIMENTAL PROCEDURE

The network configurations and testing procedures are the most important work in this research. A few experiments have been performed to achieve the objectives of this research. Several performance parameters similar to previous researches have been investigated. Initially, the packet viewer from Wireshark was aimed to monitor the traffic flow. After that, some parameters for instance Round Trip Time [5] and Throughput [6, 7] have been analyzed to achieve the objective of this research

A. Connectivity

After the network configuration is done, network connectivity on different environment platform has been tested with the ping or ping6 command to public Domain Name Server (DNS) respectively. This is to verify there is connectivity between the client and server.

B. Packet Flow

As the testing begin, the packet viewer was used to capture the packet flow to monitor the sending and receiving packet. As shown in Figure 5, the details of packet flow were able to retrieve via packet viewer.

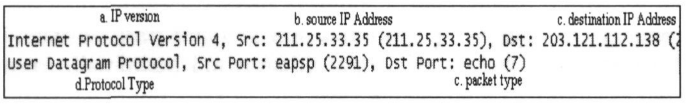

Fig. 5 Sample of UDP packet captured by packet viewer

C. Throughput

The corresponding throughput calculation can be presented in (1).

$$T = P/L \quad (1)$$

Where the symbol T represent as a throughput, P as packet size transmitted while L represent as time cost to transfer the packet. To analyze the throughput, TCP protocol option is being selected using JPERF. Packet size has been set from 64 bytes to 1408 bytes using TCP protocol over 10 seconds transfer time. Each group of environment has been tested 3 times to ensure the accuracy and the average value has been taken.

D. Round TripTime (RTT)

Round-trip time is computed as, the difference between the time a packet is sent and the time an ACK for that particular packet is received. The quality-of-service on each node can be identifying by using RTT test. The respond time on this test has been monitored. The dual stack website has been chosen as data source. The round-trip delay of IPv4 and IPv6 of dual stack and 6to4 tunnel platform has been tested using ICMP and ICMPv6 packet transferred respectively. The packets size transferred from sender to receiver was set between 64 bytes to 1408 bytes. The protocol used in this application is UDP protocol. The RTT can be test using Ping command as the following calculation (2) [10].

$$RTT_{next} = (a * RTT_{old}) + ((1 - a) * RTT_{new}) \quad (2)$$

Where the parameters 'a' is the smoothing factor (value can be from 0 to 1). RTT_0 assumed to be 0 values. The round-trip time TCP has been measured using three-way handshake. The rtt taken from the sender send synchronize (SYN) packet to receiver until the sender receive acknowledge (ACK) packet from the receiver. The rtt value measured from wireshark then applied using equation (2) as RTT_{new} and the $RTT_{average}$ has been calculated.

V. RESULT

Every test has been repeated 3 times to ensure the accuracy of the reading. Time duration transmission of the packet is within 10 seconds for each different scenario. Figure 6 shows the TCP throughput values portray the same pattern on each scenario. By comparing between the graphs depicted below, the volume of TCP throughput native IPv4 provide the highest throughput value over the packet size. For IPv6 transition mechanism, dual stack method achieved higher throughputs compared to 6to4 tunnel method on most packet size.

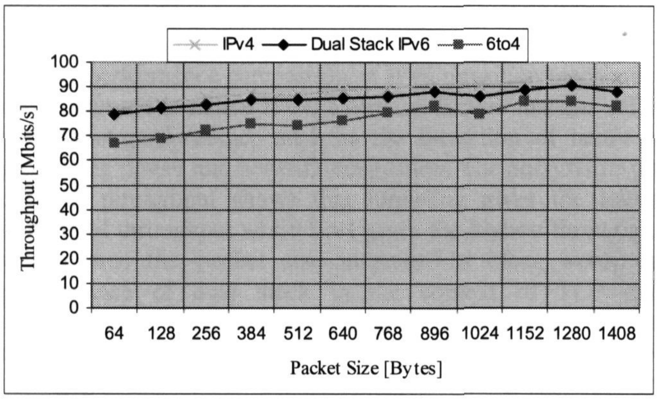

Fig. 6 TCP throughput on IPv6 and native IPv4

UDP throughput can be referred to figure 7. The value of UDP bandwidth has been set to 5Mbps in JPERF same as bandwidth cap on access router interface. The volume of throughput increasing over all value of packet size. The larger size of packet, the bigger value of throughput. UDP throughputs seem increase uniformly on IPv6 transition mechanism and native IPv4.

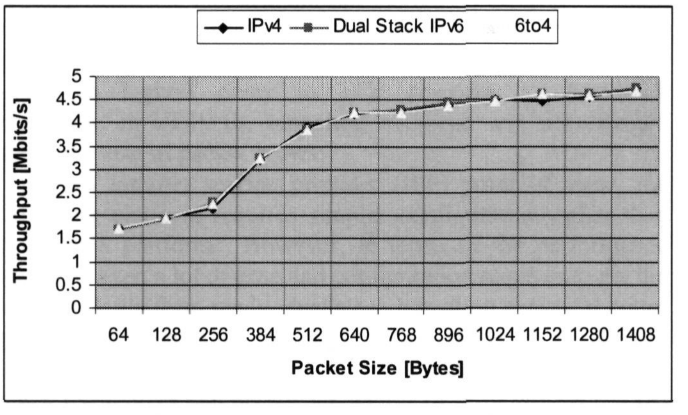

Fig. 7 UDP throughput on IPv6 and native IPv4

RTT TCP has been analyzing through packet viewer. From figure 8, the pattern of RTT value increase with increment of packet size. However 6to4 Tunnel RTT increase sharply compares to steady increase of dual stack IPv6 and native IPv4. The highest RTT value of tunnelling compared to native dual stack and native IPv4 probably because of the higher the size of packet sent will generates more tunneling overhead and will effected the valueof RTT.

The graph of RTT on UDP of IPv6 transition mechanism and native IPv4 is shown in figure 9, the round trip time for 3 scenarios were flapping not uniformly. Generally, the graphs were distributed horizontally when the packet size increase. From the graph, over packet sizes, tunneling RTT produces the nearly similar pattern compared to dual stack and native IPv4. This is probably due to overhead tunneling in UDP yields equivalent values of approximately zero at all levels of data sizes. In the other words the graph proves the fact that tunneling overhead exist at the UDP is not influenced by data sizing.

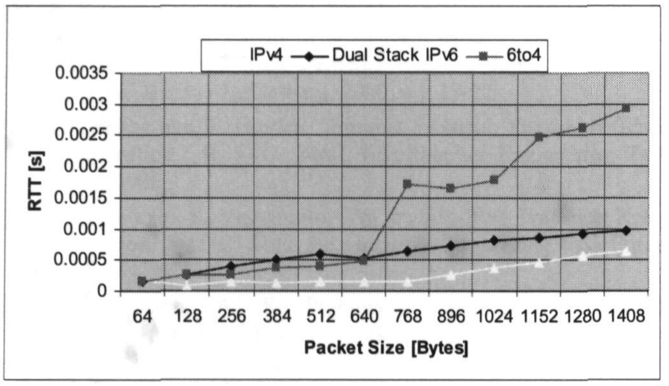

Fig. 8 Round Trip Time (RTT) on TCP IPv6 and native IPv4

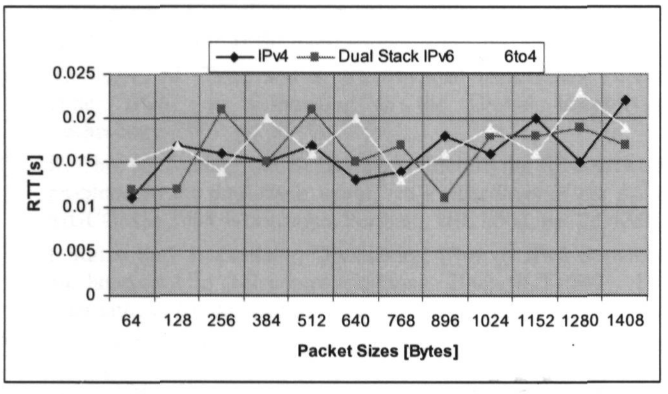

Fig. 9 Round Trip Time (RTT) on UDP IPv6 and native IPv4

VI. DISCUSSION

This research is focused on TCP and UDP transport layer. The traffic was generated by network performance tool which is jperf-2.0.2. Each protocol, the real packet has been transmit across the network by varies the data size. As we mentioned before, test bed has been carried out in a controlled environment until border router. Beyond that, the internet network will be best effort basis. This condition sometimes might give bias situation in collecting the result. Since the research covered over the real network platform, the configurations were required on the routers to transmit the real packet into internet world from client to the server. From jperf-2.0.2 tool, TCP and UDP have been selected to generate the packet across the network. The performance measurement metrics in the performance testing consists of throughput and round-trip-time. Based on the previous studies conducted by different researchers such as Nazrulazhar (2012) and Yingjiao (2011), throughput and round-trip-time are the most common metrics used in the study of network performance evaluation. According to Blum (2003), "The throughput of a network represents the amount of network bandwidth available for a network application at any given moment, across the network links". According to Deveriya (2006) states that "Latency or delay, is the amount of time it takes a packet to traverse from source to destination".

The performance comparison of IPv6 transition mechanism was compared to native IPv4. There are factors that can affect throughput performance such as the limitation of hardware processing power and network congestion. The analysis results of TCP throughput shows that tunneling gives the lowest volume of throughput while IPv4 gives the highest throughput value when the packet size increase. In other word, the performance of dual stack in the context of TCP data transmission generates the higher performance when comparing with tunneling. Native IPv4 shows highest throughput due to the traffic does not require any protocol translation and will produce better performance. However the UDP throughput graphs did not shows a significant difference on transition throughput.

The most significant finding from this research is the RTT produced by TCP and UDP over packet sizes. The graphs on TCP, shows that tunneling produces the highest delay while on UDP, the graphs is not significant and not uniform and we can see that the patterns are up and down in the horizontal way. According to previous research Nazrulazhar (2012), he discovered that the tunneling overhead in TCP was effected when packet size increase but not in UDP. Therefore, through this research paper, this proved the statement from Nazrulazhar (2012) which is increasing of overhead tunneling, 6to4 tunnel generates highest delay in TCP compare to dual-stack transition. In UDP, the tunneling overhead was not effected when the size of packet grows.

From internet service provider (ISP) point of view, the tunneling platform requires simpler configuration rather than dual stack platform. However, in terms of the performance stability, even a lot of time and configuration requires to get the dual stack platform ready, dual stack transition generates better performance and due to the fact that majority of devices connected to the internet are not compatible with IPv6, dual stack technology can ensure the legacy of IPv4 will be coexist with IPv6 in future.

VII. CONCLUSION AND FUTURE WORK

In a nutshell, it is clearly stated that 6to4 tunneling mechanism is not really dependable and an improper tool for long term solution in the state of business or level of industry since the traffic utilization percentage on TCP packet transmission contributes a larger number in network communication. 6to4 tunneling is suitable in the early state of transition. This is because all the transition mechanisms were mostly based on research and theory without considering IPv6 capabilities in the real network. In the near future, thorough research needs to be done on the IPv6 capabilities and its constraint factors which need to be overcome that can improve the network performance. Therefore, from this research, dual stack IPv6 transition obviously better than 6to4 tunnel in terms of performance and round-trip-time. The value of dual stack throughput is higher and round-trip time is better than 6to4 tunnel.

VIII. REFERENCES

[1] E. Karpilovsky, Gerber A., Pei D., Rexford J., and Shaikh A., "Quantifying the Extent of IPv6 Deployment," in Passive and Active Network Measurement. vol. Volume 5448/2009: Springer Berlin / Heidelberg, 2009, pp. 13-22.

[2] S. Deering and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," R. f. C. 2460, Ed.: Internet Engineering Task Force, 1998.

[3] J. Hagino and K. Yamamoto, "An IPv6-to-IPv4 Transport Relay Translator," R. f. C. 3142, Ed.: Internet Engineering Task Force, 2001.

[4] N. Bahaman, A. S. Prabuwono, and M. Z. Mas'ud, "Implementation of IPv6 network testbed: Intrusion detection system on transition mechanism," Journal of Applied Sciences, vol. 11, pp. 118-124, 2011.

[5] J. Udhayan and R. Anitha, "Demystifying and Rate Limiting ICMP hosted DoS/DDoS Flooding Attacks with Attack Productivity Analysis," in Advance Computing Conference, 2009. IACC 2009. IEEE International, 2009, pp. 558-564.

[6] Y. Xinyu, M. Ting, and S. Yi, "Typical DoS/DDoS Threats under IPv6," in Computing in the Global Information Technology, 2007, pp. 55-55.

[7] K. Cho, M. Luckie, and B. Huffaker, "Identifying IPv6 network problems in the dual-stack world," in Proceedings of the ACM SIGCOMM 2004 Workshops, Portland, OR, 2004, pp. 283-288

[8] I. Raicu and S. Zeadally, "Evaluating IPv4 to IPv6 transition mechanisms," in Telecommunications, 2003. ICT 2003. 10th International Conference on, 2003, pp. 1091-1098 vol.2.

[9] L. Yuk-Nam, L. Man-Chiu, T. Wee Lum, aning Cheong, "Empirical Performance of IPv6 vs. IPv4 under a Dual-Stack Environment," in Communications, 2008. ICC '08. IEEE International Conference on, , 2008, pp. 5924-5929.

[10] C. M. Kozierok, The TCP/IP Guide: A Comprehensive, Illustrated Internet Protocols Reference, First ed.; No Starch Press, 2005.

[11] Blum, R. (2003).Network performance open source toolkit: Using Netperf, tcptrace, NIST Net, and SSFNet. Indianapolis: Wiley

[12] Nazrulazhar, Erman (2012). Network Performance Evaluation of 6to4 Tunneling. Melaka: Malaysia.

[13] Yingjiao, Xiaoqing (2011). Research on the IPv6 Performance Analysis Based on Dual-Protocol Stack and Tunnel Transition. Chengdu: China.