Performance Evaluation of IPv4, IPv6, and ISATAP Routers on Windows Server 2008

Ahmed Jaha

***Abstract*—**There are many software platforms that can be used to implement Internet Protocol (IP) router such as windows, Linux, Solaris, Mac, and BSD. In this paper, the performance evaluation of some IP routers on Windows Server 2008 will be investigated. This work examines and empirically evaluates some IP routers, namely Internet Protocol version 4 (IPv4) router, Internet Protocol version 6 (IPv6) router, and Intra-site Automatic Tunnel Addressing Protocol (ISATAP) router. We measure some of Quality of Service (QoS) performance metrics like throughput, latency, jitter, and packet loss. These metrics are used in our experiments as they have a direct effect on the ultimate performance perceived by end user applications. All experiments were conducted using windows 7 host (IPNet1Client) connected to windows server 2008 host (IPNet2Client) through windows server 2008 router (IPRouter).

***Keywords*—**IPv4, IPv6, ISATAP

I. INTRODUCTION

COMPUTER network consists of two or more computers and other devices such as printers and external hard drives, which are connected together to communicate with each other and share files and the devices. A router is a layer 3 device that directs packets between different computer networks. Networks interconnection helps users of one network to share information and resources with users of other networks. A router gets a destination IP address of received packets, searches the routing tables to get the best match, and forwards these packets to their suitable destination. Although routers are usually hardware-based devices, there are many software platforms that can be used to implement software-based routers such as windows, Linux, BSD, and Solaris but the main two are Windows and Linux platforms [1].

II. IP AND WINDOWS SERVER 2008

Windows Server 2008 was designed to sustain both IPv4 and IPv6 to meet the connectivity and performance desires of today's various networking environments and technologies. These protocols provide IP addresses that are responsible for identify computers and devices so that they can communicate. IPv6 is designed to solve many of the problems of IPv4 such as mobility, auto-configuration, and overall extensibility. IPv6 extends the address space to support the direct connection of huge number of devices to the Internet [2].

ISATAP is an IPv6 transition mechanism intended to send IPv6 packets between dual-stack nodes on top of an IPv4 network. ISATAP identifies a method for generating a link-local IPv6 address from an IPv4 address, and a mechanism to execute Neighbor Discovery on top of IPv4. ISATAP is included in Microsoft Windows XP, Windows Vista, Windows 7, Windows 8, Windows Server 2008 [3].

III. EXPERIMENTAL TESTBEDS

The work in this paper is based on three testbeds were built in the network lab at the College of Industrial Technology to evaluate the performance of some IP routers on Windows server 2008. Hardware components of these testbeds are listed in Table I.

The first testbed has been designed to connect two IPv4 networks through IPv4 router. Software components of this testbed are listed in Table II, and the setup of this testbed is shown in Fig. 1. The second testbed has been designed to connect two IPv6 networks during IPv6 router. Software components of this testbed are illustrated in Table III, and the setup of this testbed is shown in Fig. 2. The third testbed has been designed to connect IPv4 network and IPv6 network through ISATAP router. Software components of this testbed are demonstrated in Table IV, and the setup of this testbed is shown in Fig. 3.

TABLE I
TESTBEDS HARDWARE COMPONENTS

Node	Description
IPNet1Client	Desktop equipped with double Genuine Intel 2600 MHz processor, 512 Mbytes of RAM, and VIA Rhine II Compatible Fast Ethernet Adapter built-in network interface card. It is act as IP network1 client.
IPRouter	Desktop equipped with double Genuine Intel 3000 MHz processor, 512 Mbytes of RAM, Broadcom Extreme Gigabit Ethernet built-in network interface card, and VIA VT6105 Rhine III Compatible Fast Ethernet Adapter network interface card. It is act as IP router.
IPNet2Client	Desktop equipped with double Genuine Intel 2600 MHz processor, 512 Mbytes of RAM, and VIA Rhine II Compatible Fast Ethernet Adapter built-in network interface card. It is act as IP network2 client.

Ahmed Jaha is with the College of Industrial Technology, Misurata, Libya (phone: +218911100899 ; e-mail: goha_99@yahoo.com).

TABLE II
IPV4 TESTBED SOFTWARE COMPONENTS

Node	Description
IPNet1Client	This node is loaded with windows 7. Network and sharing center wizard is used to configure this node to act as IPv4 network1 client [4].
IPv4Router	This node is loaded with windows server 2008. Routing and remote access server setup wizard is used to configure this node to act as IPv4 router [5].
IPv4Net2Client	This node is loaded with windows server 2008. Network and sharing center wizard is used to configure this node to act as IPv4 network2 client [6].

TABLE III
IPV6 TESTBED SOFTWARE COMPONENTS

Node	Description
IPNet1Client	This node is loaded with windows 7. Network and sharing center wizard is used to configure this node to act as IPv6 network1 client [7].
IPv4Router	This node is loaded with windows server 2008. Routing and remote access server setup wizard is used to configure this node to act as IPv6 router [8].
IPv4Net2Client	This node is loaded with windows server 2008. Network and sharing center wizard is used to configure this node to act as IPv6 network2 client [6].

TABLE IV
ISATAP TESTBED SOFTWARE COMPONENTS

Node	Description
IPNet1Client	This node is loaded with windows 7. Network and sharing center wizard is used to configure this node to act as IPv6 network1 client [7].
IPv4Router	This node is loaded with windows server 2008. Routing and remote access server setup wizard is used to configure this node to act as ISATAP router [9].
IPv4Net2Client	This node is loaded with windows server 2008. Network connection wizard is used to configure this node to act as ISATAP network2 client [9].

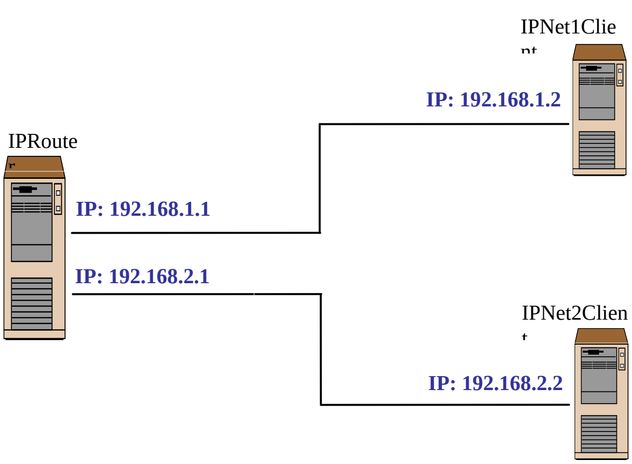

Fig. 1 IPv4 testbed setup

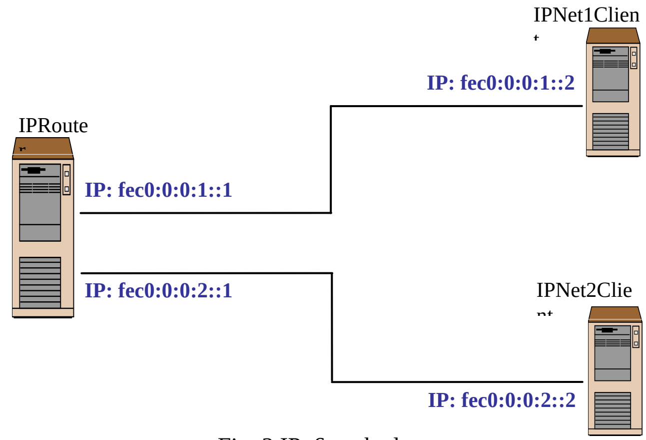

Fig. 2 IPv6 testbed setup

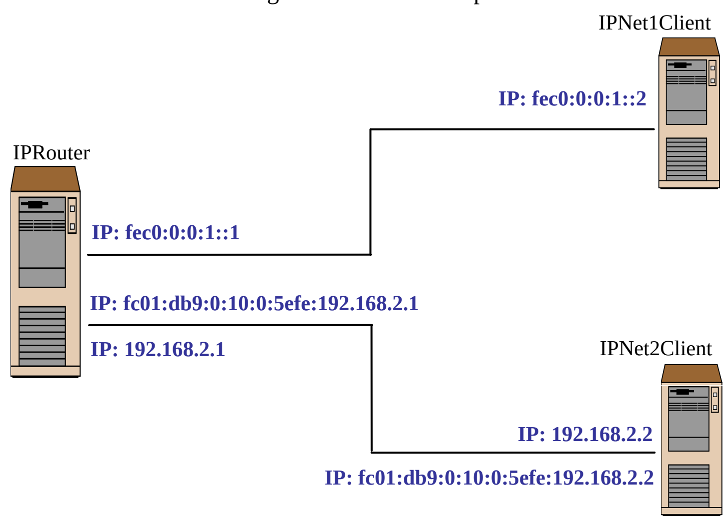

Fig. 3 ISATAP testbed setup

During the experiments, the following parameters were used to quantify the QoS services provided [10]:

- Throughput is a measure of the amount of data that can be sent from end to end in a given amount of time. Throughput estimates, typically obtained through measurements based on the bulk transfer of data, are usually expressed in bits per second or packets per second. Throughput is affected by overhead and latency. While overhead reduces the amount of useful bytes transferred, latency affects the bandwidth-delay product for a TCP connection. Throughput is frequently used as an estimate of the bandwidth of a network.
- Round Trip Time (RTT) is the amount of time it takes one packet to travel from one host to another and back to the originating host.
- Packet delay variation (Jitter) is measured for packets belonging to the same packet stream and shows the difference in the one-way delay that packets experience in the network. Jitter is effectively a variation of packet delay where delays actually impact the quality of service.
- Packet loss is measured as the portion of packets transmitted but not received in the destination compared to the total number or packets transmitted. Packet loss is

caused by line properties (Layer 1), full buffers (Layer 3) or late arrivals (at the application).

IV. Testbeds Experimental Results

Iperf tool has been used to measure both TCP throughput in TCP mode and UDP throughput, packet delay variation (jitter), and packet loss in UDP mode [11]. Psping tool has been also used to measure Round Trip Time (RTT) [12].

The following results were collected from the testbeds that were illustrated in Fig. 1, Fig. 2, and Fig. 3. The same experiments were repeated a number of times to find the average values. TCP throughput is measured according to TCP window size and number of flows. The results of these experiments are illustrated in Fig. 4 and Fig. 5. these results show clearly that the highest TCP throughput values are gained by IPv4 testbed, the midst TCP throughput values are achieved by IPv6 testbed (98.5 % of IPv4 value), and the lowest TCP throughput values are obtained by ISATAP testbed (96.2 % of IPv4 value). Also, Fig. 5 indicates clearly that the throughput values have been decreased when the number of parallel streams is increased.

RTT can be measured by sending packets with a variable packet size from a client to the server. The results of these experiments are illustrated in Fig. 6. These results illustrate clearly that the minimum RTT values are gained by IPv4 testbed, the middle RTT values are obtained by IPv6 testbed (1.04 multiple of IPv4 value), the maximum RTT values are attained by ISATAP (1.09 multiple of IPv4 value).

UDP throughput is measured according to transmission rate of packets. The results of these experiments are illustrated in Fig. 7. These results indicate clearly that the highest UDP throughput values are gained by IPv4 testbed where the decreasing of the UDP throughput values has been started when the transmission rate is exceeding 60 Mbits/sec, the midst values are acquired by the IPv6 testbed (94.6 % of IPv4 value) where the depressing of the UDP throughput values has been started once the transmission rate is exceeding beyond 60 Mbits/sec, and the lowest UDP throughput values are achieved by ISATAP testbed (92.5 % of IPv4 value) where the falling of the UDP throughput values has been started when the transmission rate is exceeding beyond 60 Mbits/sec.

Jitter is measured according to the transmission rate of packets for UDP traffic. The results of these experiments are illustrated in Fig. 8. These results indicate clearly that the lowest jitter values are gained by IPv4 testbed, the low jitter values are achieved by IPv6 (1.13 multiple of IPv4 value), and the highest jitter values are obtained by ISATAP testbed (1.18 multiple of IPv4 value).

Packet loss is measured according to the transmission rate of packets. The results of these experiments are illustrated in Fig. 9. These results illustrate clearly that the lowest packet loss values are gained by IPv4 testbed, the low packet loss values are achieved by IPv6 (1.225 multiple of IPv4 value), and the highest packet loss values are attained by ISATAP (1.45 multiple of IPv4 value).

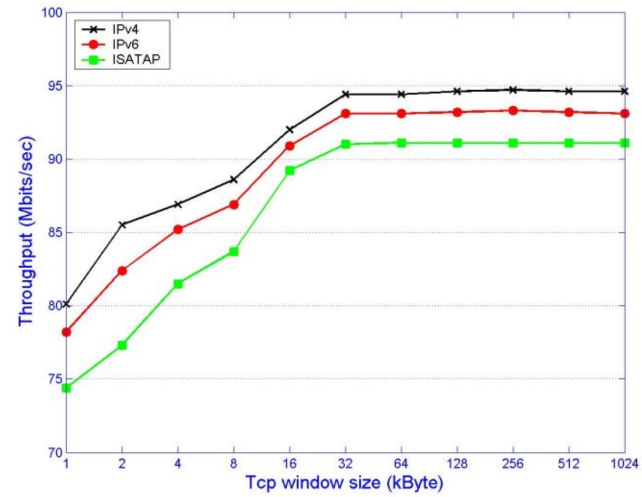

Fig. 4 TCP throughput according to the window size

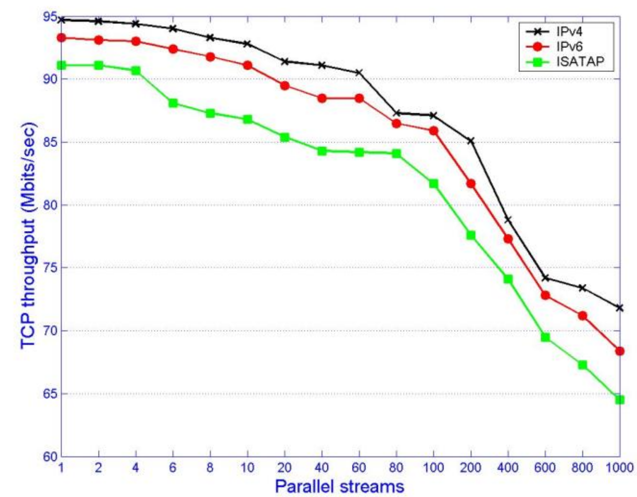

Fig. 5 TCP throughput according to the parallel streams

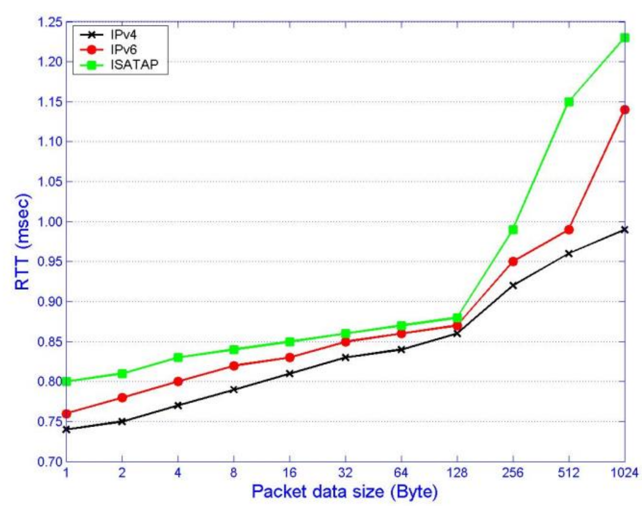

Fig. 6 RTT according to the packet data size.

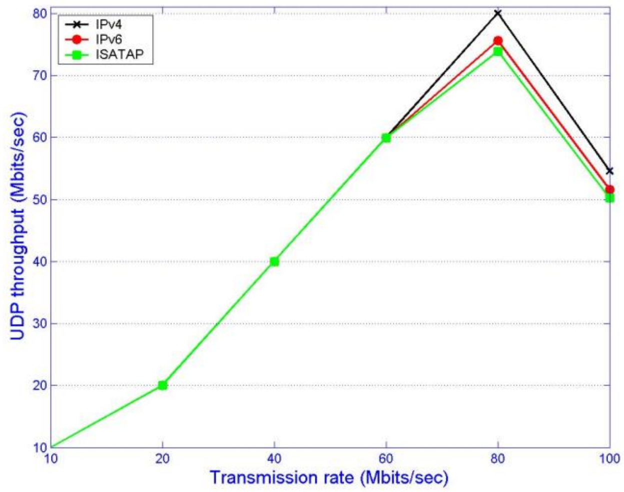

Fig. 7 UDP throughput according to the transmission rate

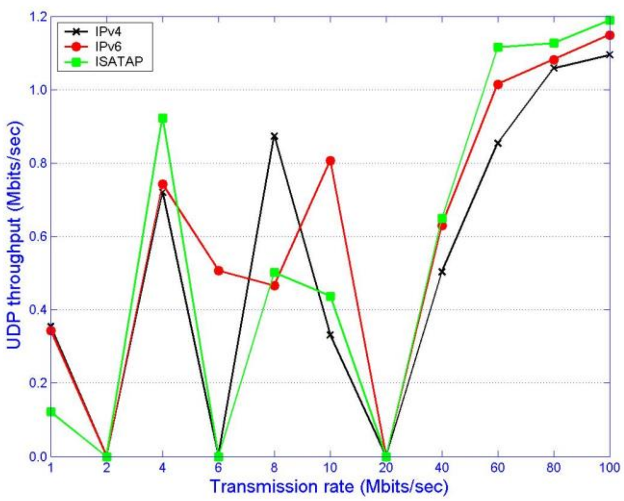

Fig. 8 Jitter according to the transmission rate

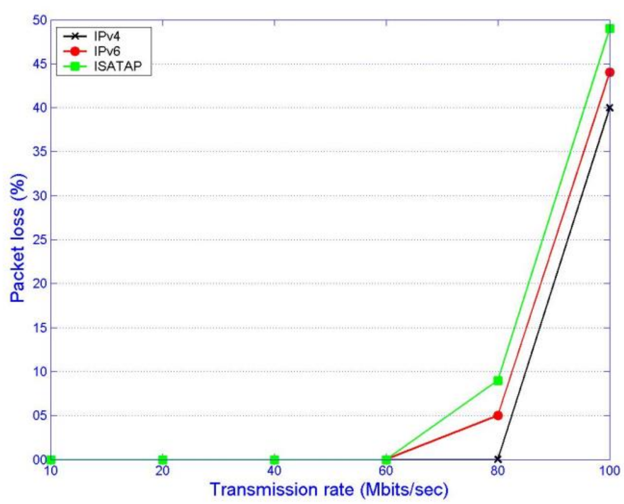

Fig. 9 Packet loss according to the transmission rate.

To determine the grade of the testbeds experimental results that are summarized in Table V, the following TCP and UDP throughput grades are suggested: excellent values are included in the interval [85% , 100%] of IPv4 values, very good values are included in the interval [75% , 85%) of IPv4 values, good values are included in the interval [65% , 75%) of IPv4 values, acceptable values are included in the interval [50% , 65%) of IPv4 values, and weak values are included in the interval [0% , 50%) of IPv4 values. As a result of inversing the previous intervals, the following RTT, jitter, and packet loss grades are suggested: excellent values are included in the interval [1 , 1.176] multiple of IPv4 values, very good values are included in the interval (1.176 , 1.333] multiple of IPv4 values, good values are included in the interval (1.333 , 1.538] multiple of IPv4 values, acceptable values are included in the interval (1.538 , 2] multiple of IPv4 values, and weak values are included in the interval (2 , ∞) multiple of IPv4 values.

The following background colors are used: dark green (excellent), green (very good), yellow (good), red (accepted), and dark red (poor). Therefore, Table V indicates clearly that IPV4 has produced excellent packet loss values, IPv6 has produced very good packet loss values, and ISATAP has produced good packet loss values.

TABLE V
SUMMARY OF TESTBEDS RESULTS

Metrics / Testbed	TCP throughput values in % of IPv4	RTT values in multiple of IPv4	UDP throughput values in % of IPv4	Jitter values in multiple of IPv4	Packet loss values in multiple of IPv4
IPv4	100 %	1.00	100 %	1.00	1.00
IPv6	98.5 %	1.04	94.6 %	1.13	1.225
ISATAP	96.2 %	1.09	92.5 %	1.18	1.45

V. CONCLUSION AND FUTURE WORK

From the results that were collected from the testbeds and the user applications requirements, the following conclusion remarks are gained:

- Due to the smallest overhead size that has been introduced by IPv4 header, Ipv4 has produced the best performance values for both TCP and UDP-based user applications.
- In order to overcome the IPv4 problems, IPv6 has increased the size of IP header. Then, IPv6 has produced the second performance values for both TCP and UDP-based user applications.
- For the reason that ISATAP was developed to help facilitate the transition between existing IPv4 networks to the new IPv6 networks. ISATAP creates an IPv6 network address from an IPv4 address, resulting in increasing the size of IP header. Therefore, ISATAP has produced a lower performance values for both TCP and UDP-based user applications.

- IPv4, Ipv6, and ISATAP have produced a convergent performance values for both TCP and UDP-based user applications.
- This work should be extended to include performance evaluation on other software-based routers (such as BSD, Mac, Solaris, and Linux) and hardware-based routers (such as Cisco, 3Com, Juniper, and ADTRAN).

REFERENCES

[1] "Router (computing)," Retrieved on March 23, 2014 from, http: //en.wikipedia.org/wiki/Router_(computing)

[2] "TCP/IP v4 and v6," Retrieved on March 23, 2014 from, http: //technet.microsoft.com/en-us/network/bb530961.aspx

[3] "ISATAP," Retrieved on March 23, 2014 from, http://en.wikipedia.org /wiki/ISATAP.

[4] Sean Wilkins, "How to Configure a Static IPv4 Address in Windows 7," Retrieved on March 23, 2014 from, www.petri.co.il

[5] Dave Lawlor, "Windows Server 2008 as a LAN Router Running RIP," Retrieved on March 23, 2014 from, http://blog.pluralsight.com/windows-server-2008-as-a-lan-router-running-rip

[6] "Configuring a DHCP server static IP address," Retrieved on March 23, 2014 from, http://technet.microsoft.com/en-us/library/cc755277.aspx.

[7] Erin McManaway, "How to Configure a Static IPv6 Address," Retrieved on March 23, 2014 from, www.ehow.com//how_7421533_configure-static-ipv6-address.html.

[8] "RRAS: To use RRAS server as an IPv6 router, IPv6 forwarding must be enabled," Retrieved on March 23, 2014 from, http://technet.microsoft.com/en-us/library/ee922673(v=ws. 10).aspx.

[9] "Configuring an ISATAP Router with Windows Server 2008 R2 (Part 2)," Retrieved on March 23, 2014 from, www.windowsnetworking.com

[10] "IP Performance Metrics (IPPM) Working Group," IETF, Retrieved on March 23, 2014 from, http://www.ietf.org/html.charters/ippm-charter.html.

[11] "Iperf – The TCP/UDP Bandwidth Measurement Tool," Retrieved on March 23, 2014 from, http://sourceForge.net.

[12] "Psping, TechNet – Microsoft," Retrieved on March 23, 2014 from, http://technet.microsoft.com.

Mr. Ahmed Jaha is currently working as lecturer in the department of electronics engineering at College of Industrial Technology, Misurata, Libya. He has done his Bachelor's degree in computer engineering from Engineering Academy, Tajura, Libya on 01/09/1991. He did Master's degree in electronics engineering, computer section from College of Industrial Technology, Misurata, Libya on 05/08/2008.