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Throughput Evaluation of IPV4/IPV6 Networks

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Abstract— **The work presented in this paper is intended to introduce to both IPv4 and IPv6. This paperis a comprehensive guide to the evaluation of IPv6 from beginning to end and, therefore, it is meant for audiences of varying expertise from beginners to experts who wish to learn about the next generation internet protocol (IPv6), and have a clear unbiased performance overhead of the new internet protocol.**

As of October 2011, about 3% of domain names and 12% of the networks on the internet have IPv6 protocol support. Since 2009, the DNS can be used in IPv6 as major web sites like Google. IPv6 was first used in a major world event during the 2009 Summer Olympic Games. Finally, modern cellular telephone specifications mandate IPv6 operation and deprecate IPv4 as an optional capability.

The paper its main aim is to perform an unbiased empirical performance analysis between the two protocol stacks (IPv4 and IPv6), and how it related to the performance on identical settings.

Over the last decade, many fundamental changes have occurred in data communications and network infrastructure that will be shaping the future of IT for years to come. The Internet is now at the core of communications for worldwide economy and individuals. IPv4 is the basic building block of the Internet and has served well, but it has limitations that hinder its growth. The solution is IPv6, which addresses inherent problems of the earlier version. However, due to the increased overhead in IPv6 and its interaction with the operating system that hosts this communication protocol, there may be network performance issues. The overhead between the IPv4 and IPv6 should be directly proportional to the difference in the *packet's header size*, however according to our findings, the empirical performance difference between IPv4 and IPv6 are taken into consideration.

Here two OSs (W2Kand Linux Ubuntu)are configured with the two versions of IP and empirically evaluated for performance difference. We first examine the performance of IPv4 and IPv6 independently. This is a necessary and crucial step for IPv6's success since clear performance limitations and advantages should be well defined and agreed upon in advance. Here performance related metrics *throughput* is empirically measured on P2P test-bed implementation. The results show that network performance depends not only on IP version and traffic type, but also on the choice of the OS. Our empirical evaluation proved that IPv6 is not yet a mature enough technology. The performance of IPv6 in many cases proved to be worse than IPv4, incurring an overhead much higher than its anticipated theoretical counterpart.

I. INTRODUCTION

The IP is the principal communications protocol, comes under network-layer protocol, used for relaying datagram. IP is responsible for delivering datagram from the source host to the destination host on the basis of addresses. IP encapsulate the data to be delivered and addressing methods. IP was the connectionless datagram service. IP makes no guarantee that the packet will arrive without error. IP packet consists of a segment of data passed down from the transport or higher layer, plus a small *IP header* pretended to the data. *IP Address* is a unique identifier on a TCP/IP network to connect a private network to the Internet. IP address contains four segments of numbers (0 – 255) separated by periods.

Here each node makes its forwarding decision based on the destination address within the IP packet header. The source address is examined when an error occurs. Routing decisions are based on the network-prefix of the IP destination address. The host portion of the IP address is used to differentiate among individual hosts on the same link. The first major version of IP is IPv4, which is the dominant protocol of the internet. Its successor is IPV6. It contains two functions: identifying hosts and providing a logical location service.

II. BACKGROUND INFORMATION

IPv4 vs IPv6

Payload: No identification of Payload for QoS handling by routers is present within the IPV4 header. But it is included in the IPV6 header using flow label field.

Fragmentation: It is supported at both routers and the sending host in IPV4; But in IPV6 it is only supported at the sending host.

Header includes a Checksum must be computed at every intervening node on a per packet basis in IPV4; Rather it does not include a Checksum and relies on other layers to find erroneous packet.

Header includes options potential inefficient use of header bits in IPV4; but all optional data is moved to IPV6 extention headers.

Address Resolution Protocol broadcast ARP request to resolve an IPV4 address to the link layer; Rather ARP request frames are replaced with multicast neighbor solicitation messages.

Internet Group Management Protocol is used to manage local subnet group membership in IPV4; Rather IGMP is replaced with Multicast Listener Discovery Messages.

ICMP router discovery is used to determine the IPV4 address of the best default Gateway; ICMPV4 router discovery is replaced with ICMPV6 router solicitation and Router Advertisement.

Broadcast addresses are used to send traffic to all nodes on a subnet in IPV4 rather there are no IPV6 broadcast addresses: a link-local scope all nodes multicast address is used.

IPV4 must be configured either manually or through DHCP but IPV6 does not require manual configuration or DHCP.

Pointer Resource Records (PRR) in INN-ADDR.ARPA DNS domain map IPV4 addresses to host names; Uses PRR in resource records in the IP6.INT DNS domain to map IPV6 addresses to host names.

III. EXPERIMENTAL SETUP

Two computers with similar hardware (CPU: Intel Pentium C2D, RAM 2GB, NIC PCI Intel Pro 100, HDD1TB) were connected using a cross-over cable and each of the OSs (W2K and Linux Ubuntu) to be tested were installed one at a time on P2P test-bed. IPv4 as the communication protocol was configured first and data was collected. Later this was replaced with IPv6 ensuring that all other parameters remained the same. D-ITG 2.6.1d was the primary tool used to evaluate performance of protocols on both the OSs. For accuracy all tests were executed 20 times, and to get the maximum throughput for a given packet size, each run had duration of 30 seconds.

IV. PERFORMANCE EVALUATION

In this section, we present the results for IPv4 and IPv6 network protocols using both TCP and UDP transport protocols under W2k and Linux Ubuntu OSs. Throughput was empirically measured on P2P test-bed.

Throughput means the rate at which bulk data transfers can be transmitted from one host to another over a long period of time (Mbit/s).

Throughput = W / RTT // W = Window size if no loss
Throughput = W/2RTT // If loss occurs
Avg Throughput = 0.75W/RTT
// between W/2 and W

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 (RTT in microseconds).

Throughput was measured using JPerf, which is simply a java interface for testing and analysis. It is a network testing tool used for measuring the maximum throughput of a network link. Each IP ref test was run for sixty seconds to insure any variance over time would be minimized. Additionally to insure accurate results each sixty second test was run three times for IPv4 and IPv6 and the results were averaged. While the tests were ran, Windows Performance Counters were collected and analyzed.

Initially T**hroughput** values for OSs with IPv4 and IPv6 were obtained by measuring the packet sizes ranging from 64 to1536 Bytes. For small packet sizes (less than 384 bytes) both OSs with both IPv4 &IPv6 portray the same throughput values, steeply increasing as the packet size increase. For most of the larger packet sizes W2K throughput is slightly lower (average 5%) than Linux Ubuntu. Also, IPv4 in most case give a high throughput value thanIPv6 for packet size larger than 384 Bytes. For packet sizes larger than 256 Bytes, IPv4 always gives a slightly better throughput than IPv6. However for small packet sizes the performance is almostidentical.W2K throughput values for most packets sizes(range: 384-1152Bytes) for both TCP and UDP traffic are lower than Linux Ubuntu by up to 5%.

In **UDP throughput**, Linux Ubuntu and W2K mainly show similar behaviours for all packet sizes except between 384-1024 Bytes. In this range, W2K again is a slightly inferior performer toits counterpart. It is worth noting that both TCP and UDP ,throughput values are similar for all combinations of protocols and operating systems.

P2P Test-bed Performance Results

In P2P test bed, there are no routers between the end nodes. The PCs had a direct communication link via twisted pair Ethernet cable from one end to the other. These tests are important to eliminate as many variables as possible and get a base performance evaluation of IPv4 and IPv6. For each experiment, we will be briefly reiterating the results depicted in the graph in case that it is not evident from the figures what the particular outcome may be.

Linux Ubuntu does slightly better than W2Kover the entire packet size spectrum. Under W2K,IPv6 incurs an additional 6% to 13% overhead in the smaller packet sizes and 2% to 4% in the larger one. Under Linux Ubundu, IPv6 incurs a similar overhead, except that it is slightly less in the larger packet sizes.

Linux Ubuntu performs better than W2Kover the entire packet size spectrum. We found a bug in the IPv6 which prevents us from performing and throughput tests for UDP under IPv6 for packet sizes greater than the Ethernet MTU size of 1514 bytes.

Under Linux Ubuntu, IPv6 only incurs a 6% to 1% overhead over IPv4 ranging from the smaller packets to the larger ones and under W2K, IPv6 incurs no overhead to up to 35% on top of IPv4 ranging from the smaller packets to the larger ones.

The TCP transport protocol incurs more CPU overhead than the UDP transport protocol. This was expected since UDP is known to be a lightweight protocol that only has minimal functionality while TCP is rather and utilizes any features that are much more CPU intensive.

It is clear that, IPv6 incurs more overhead than IPv4. Because IPv6 has an IP header that is twice as large as its IPv4 counterpart, and therefore it makes sense that it would take more CPU cycles to process an IPv6 packet than an IPv4 packet as long as the performance characteristics were similar.

Performance Metrics

For this paper we have taken throughput as metric. The majority of the tests were done for a period of about 60 seconds, which netted about 50,000 packets to about 10,00,000 packets, depending on the size of the packets sent and what tests were being completed. The tests dealing with testing the throughput of the UDP transport protocol were limited to 1,472 byte datagrams because of a potential undocumented fragmentation bug in the IPv6 protocol stack.

Throughput

Throughput offers a very clear representation of the real overhead incurred by the header information. Throughput tests push computer hardware to its limits from most points of view since many variables such as OS design, memory allocation/speed, and network link speed can radically alter the performance of the network. A network link only has the total bandwidth capacity to transmit its packets which include all the headers for the different layers and the final payload of usable data. Obviously, no system can ever achieve throughputs of 100% of the bandwidth due to the overhead of header information. Throughput was calculated by sending XX number of packets of YY bytes from a client to a server. At the beginning of the test, the time would be recorded; at the end of the test, again the time would be noted.

As below figure indicates, it can be clearly seen that Linux Ubuntu does slightly better than W2K over the entire packet size spectrum.

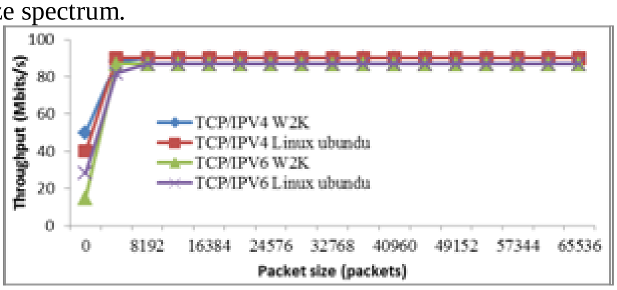

Fig 1: TCP throughput results for IPv4 & IPv6 over W2K&Linux Ubuntu with packet size ranging from 64 bytes to 64 Kbytes

Under W2K, IPv6 incurs an additional 6% to 13% overhead in the smaller packet sizes and 2% to 4% in the larger one. Under Linux Ubuntu, IPv6 incurs a similar overhead, except that it is slightly less in the larger packet sizes. Fig2 depicts the same results from Fig1 however only packet sizes ranging from 64 bytes to 1,408 bytes detail that was just not possible in the global view of the packet size range.

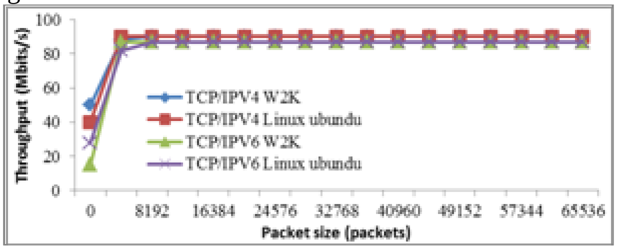

Fig2: TCP throughput results for IPv4 & IPv6 over W2K&LinuxUbuntu with packet size ranging from 64 bytes to 1408 bytes

As Fig3 and Fig4indicate it can be clearly seen that Linux Ubuntu again performs better than W2K over the entire packet size spectrum. Notice that the IPv6 protocol for both W2K and Linux Ubuntu are barely visible. We found a bug in the IPv6 protocol stack which prevents us from performing and throughput tests for UDP under IPv6 for packet sizes greater than the 1514 bytes.

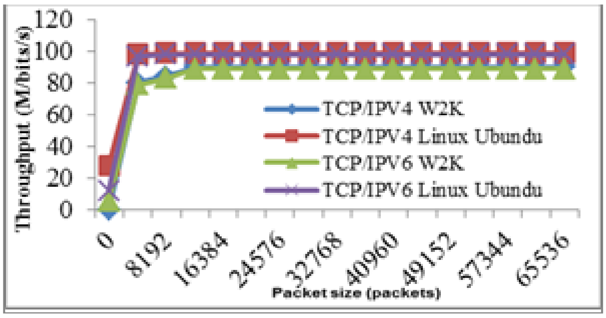

Fig3: UDP throughput results for IPv4 & IPv6 over W2K &Linux Ubuntuwith *packet size ranging from 64 bytes to 64 Kbytes*

Fig4 clearly shows that under Linux Ubuntu, IPv6 only incurs a 6% to 1% overhead over IPv4 ranging from the smaller packets to the larger ones. On the other hand, under W2K, IPv6 incurs no overhead to up to 35% on top of IPv4 ranging from the smaller packets to the larger ones.

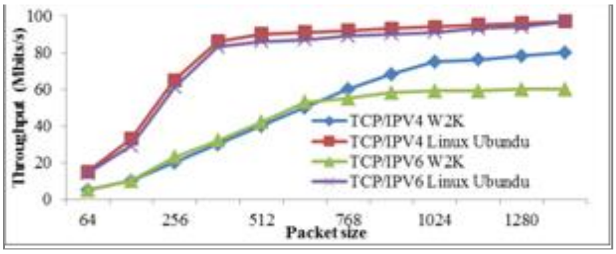

Fig4: UDP throughput results for IPv4 & IPv6 over W2K &Linux Ubuntu with packet size ranging from 64 bytes to 1408 bytes

The above four figures showed that the performance of Linux Ubuntuis slightly better than W2K and IPv6 has little (0-5%) up to 35% significant level. The CPU utilization percentage was observed from the Windows Task Manager under the performance monitor. Fig5 clearly shows that the TCP transport protocol incurs more CPU overhead than the UDP transport protocol. This was expected since UDP is known to be a lightweight protocol that only has minimal functionality while TCP is rather and utilizes any features that are much more CPU intensive.

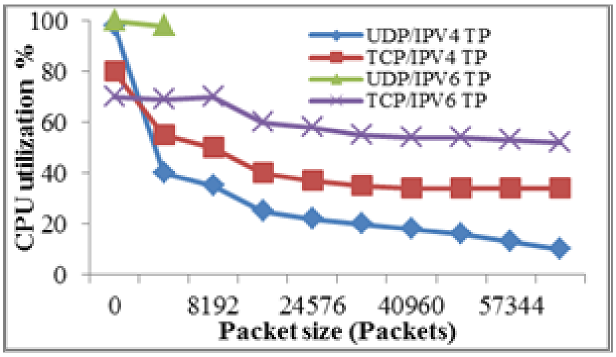

Fig5: CPU Utilization for the throughput in IPV4 and IPV6 running TCP and UDP with packet size ranging from 64 bytes to 64 Kbytes

Furthermore, it is clear that just as expected, IPv6 also incurs more overhead than IPv4. Remember that IPv6 has an IP header that is twice as large as its IPv4 counterpart, and therefore it makes sense that it would take more CPU cycles to process an IPv6 packet than an IPv4 packet as long as the performance characteristics were similar.

V. CONCLUSION

We came to the conclusion that the IPv6 protocol stack needs much improvement to reduce the overhead. Since IPv6 is still maturing, perhaps it is just a matter of time until its performance will finally reflect its theoretical counterpart. We must admit that the toughest part of our work was in configuring the routers. It is very cumbersome and has many bugs with poor documentation and user feedback. In the next paper, we plan to use IBM router and Ericson router as test bed. And also we have proposed to review on the basis of various transition mechanisms. IPv6 also supports prioritizing packets, which might be an easy way to offer a lighter version of QoS without specifying any requirements. According to our evaluation, IPv6 has a performance deficit when utilizing traditional data streams.

This paper has shown that the performance of IPv4 and IPv6depends on the OS. The extent to which performance related metrics valuesdiffer depends on the OS.In near future, this paper can be extended to incorporate more OSs including server environments.

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