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Measuring IPv6 Performance in a Newly Deployed IPv6 Campus Network

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Abstract. The implementation of IPv6 in dual-stack environment at Universiti Utara Malaysia campus network has been done successfully but how it performs compared to IPv4 has yet to be measured. A study on the performance of IPv6 network has been done to measure this performance. The study employed a simple performance measurement/testing using ping to a number of IPv6 enabled web servers. The RTT of the ping packets for both IPv4 and IPv6 is compared to see the performance of IPv6 network compared to IPv4 in a dual-stack environment. The study has found that the IPv6 network performance is slightly worse than IPv4 due to some reasons. This paper discusses some of the findings.

Keywords: IPv4, IPv6, Internet Protocol, RTT, dual-stack, hop count

INTRODUCTION

Universiti Utara Malaysia(UUM) is one of the public universities in Malaysia located at State of Kedah in the northern peninsular of Malaysia. It has two campuses, one in the capital city of Malaysia and another campus which is the main campus located at Sintok, Kedah in a 1,061 hectares site. There are currently seventeen faculties called school under three different colleges named College of Arts and Sciences (CAS), College of Business (COB) and College of Law, Government and International Studies. The vast area and a quite number of faculties and buildings with thousands of users, bring challenges to the UUM IT or previously known as UUM Computer Centre to provide a good networking infrastructure to the whole campus. However, with the dedication of the UUM IT staff and support from the university management, a new infrastructure for IPv6 has been successfully deployed by the end of 2013.

The deployment of IPv6 in UUM campus network is not done from scratch but is actually done by upgrading the available IPv4 infrastructure. It is fortunate that the equipment used for IPv4 network is IPv6 compatible. The university just needs to upgrade the software or operating system (Cisco IOS) of all distribution and core switches to support IPv6 except the access switches. For management purposes, the access switches can be accessed using IPv4 address since they are layer 2 OSI devices. The Internet Service Provider is dual-stacked which means the IPv6 host from inside the UUM campus network can also connect to the Internet without any problem. Since the Internet is still using IPv4 besides the new generation Internet address, IPv6, it is necessary to provide the end users with dual-stack connection to the Internet (Figure 1). So, inbound and outbound IPv4 and IPv6 traffic can move seamlessly without much problem. Because of the dual-stack protocols implementation, this paper will investigate the performance of IPv6 in the campus network compared to IPv4.

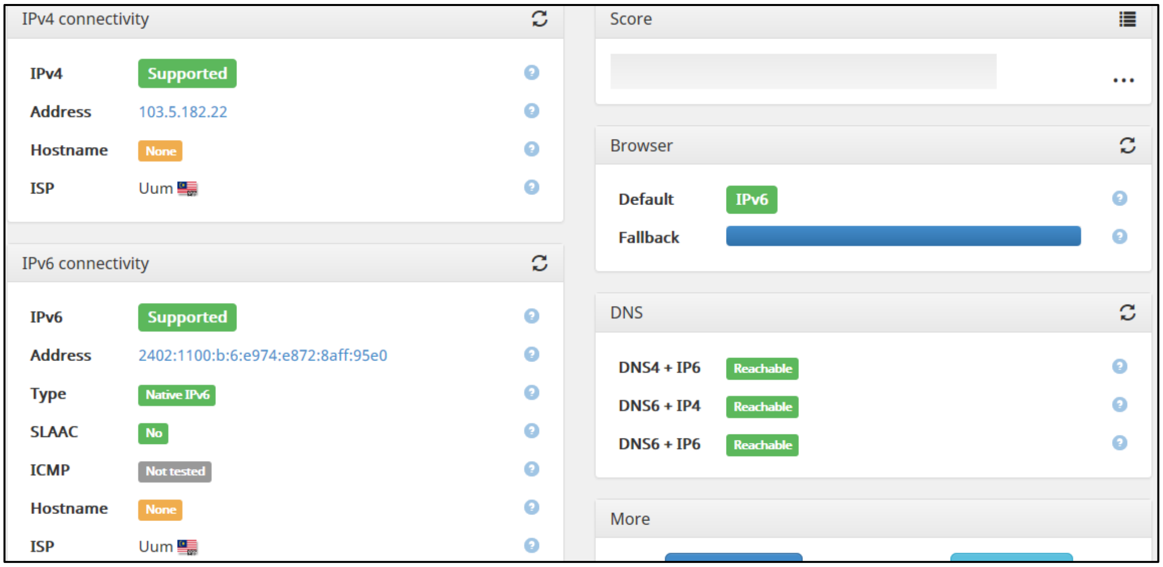

Figure 1: UUM Dual-stack Status tested at http://ipv6-test.com

RELATED WORKS

Law et. al. [1] made a comprehensive empirical measurement of the IPv6 network performance from an end-users perspective by sending probing traffic from their dual-stack IPv6/IPv4 test bed to over 2,000 dual-stack hosts worldwide. They quantifying the performance differences of using IPv6 vs. IPv4 using various network metrics like network connectivity, hop count, RTT, throughput, operating systems dependencies as well as the address configuration latency. They also investigate the performance impact of using IPv6 tunneling brokers instead of native IPv6 services.

Dhamdhere et. al. [2] use historical BGP data and recent active measurements to analyze trends in the growth, structure, dynamics and performance of the evolving IPv6 Internet, and compare them to the evolution of IPv4. Their measurements suggest that performance over IPv6 paths is comparable to that over IPv4 paths if the AS-level paths are the same, but can be much worse than IPv4 if the AS-level paths differ.

Czyz et. al. [3] explore twelve metrics using ten global-scale datasets to create the longest and broadest measurement of IPv6 adoption to date. Using this perspective, they find that adoption, relative to IPv4, varies by two orders of magnitude depending on the measure examined and that care must be taken when evaluating adoption metrics in isolation. Further, they find that regional adoption is not uniform and perhaps most surprisingly over the last three years, the nature of IPv6 utilization-in terms of traffic, content, reliance on transition technology, and performance-has shifted dramatically from prior findings, indicating a maturing of the protocol into production mode.

MEASURING IPv6 PERFORMANCE

Network Performance Metrics

When discussing about network performance, researchers must not be separated from the discussion on network performance metrics. Among networks performance metrics often used by researchers are Network Connectivity, Hop Count, Round Trip Time (RTT) and Throughput. To evaluate networks performance that involves multimedia data, another metrics is use such as Delay, Latency and Jitter, [5] and [11].

For this study, we chose two parameters, namely Hop Count and Round Trip Time (RTT) as the network performance metrics to be measured. Hop Count is the number of hops between the source node and the destination node [9]. Along the path from source node to destination node, data must pass through a number of intermediary devices such as routers. A journey from one device to the other device is counted as one hop.

Round Trip Time is a measure of latency or packet delay from a sending node to a destination node across the networks [6]. To measure RTT, a packet is sent from a client to the server, which receives the packet and sends back the same packet to the client [10]. When parameter for network performance metrics to be measured have been identified, the next step is to select the measurement tools that will be used to measure the Hop Count and Round Trip Time (RTT).

Measurement Tools

i. Ping

Ping, one of the tools in the Internet Control Message Protocol (ICMP) is often used to measure Round Trip Time (RTT). Ping can also be used to test connectivity. ICMP pings are used to measure the RTT for IPv4 networks while ping6, tool found in the ICMPv6 is used to measure the RTT for IPv6 networks. [4], [7] and [9] used ping and ping6 in their study to measure the RTT.

ii. Traceroute

Traceroute/tracert are used to measure the Hop Count. Unix-based operating system used the command 'traceroute' and the Windows-based operating system used the command 'tracert'. Much like ping used for IPv4 networks, traceroute6 / tracert6 used to measure the Hop Count for IPv6 networks. [9] used traceroute/tracert and traceroute6/tracert6 in their study to measure the Hop Count.

Test Bed Platform/Operating System

Many researchers who conduct research related to IPv4 / IPv6 Performance Evaluation using more than one operating system on their test bed platform. They compared IPv4 / IPv6 Network Performance in at least two operating system of Microsoft Windows and Unix-based operating system, particularly Linux and Berkeley Software Distribution (BSD) [6], [9] and [10]. Previous studies indicate the need for comparative performance analysis involves various popular operating systems. In addition to Windows operating system and Linux Distributions, there are also researchers conducted a study using the Solaris operating system.

i. Microsoft Windows

Various versions of the Windows operating system are used by researchers as a research platform. The windows operating system can be categorized into two groups: client version and server version. Among Windows version that is used is Windows 2008 and Windows 2003 (Server) and Windows XP, Windows Vista and Windows 7 (Client) [6], [8], [9] and [10]. Selection of Windows version to be used for the study depends on the latest version of windows which were released before the study was conducted. The selected Windows version must also support IPv6 configuration.

ii. Unix/Linux

There are various versions of the Linux Operating System, better known as Linux Distribution. Among the popular distribution used by researchers to study the network performance of IPv4 / IPv6 networks, was Ubuntu, Fedora and RedHat Linux [6], [9], [10] and [11]. Apart from Linux Distribution, [9], [10] and other researchers also used the Unix Berkeley Software Distribution (BSD), especially FreeBSD to conduct their study.

Result and Analysis

Web service is currently the most widely used service on the Internet [15]. A survey done by Web Technology Surveys (W3 Techs) found that currently IPv6 is used by 5.8% of all the websites [13]. Our test is done on two most popular IPv4 and IPv6 websites on the Internet, Facebook and Yahoo [13]. These dual-stacks websites are chosen because we can better understand the IPv6 performance compared to IPv4. The test is done on dual-stack Windows 7 client assigned with IPv4 and IPv6 address using DHCP and DHCPv6 respectively.

Several tests have been done using ping and tracert to popular websites such as Facebook (www.facebook.com) and Yahoo (www.yahoo.com) on IPv4 only and IPv6 only network by disabling one of the Internet Protocol. The result in Figure 2 shows that IPv6 performs slightly worse than IPv4 where the average RTT for IPv6 is almost 50% higher than the RTT of IPv4 (24ms to 17ms) for Facebook website.

```
C:\Users\User>ping www.facebook.com

Pinging star.c10r.facebook.com [31.13.79.65] with 32 bytes of data:
Reply from 31.13.79.65: bytes=32 time=18ms TTL=83
Reply from 31.13.79.65: bytes=32 time=18ms TTL=83
Reply from 31.13.79.65: bytes=32 time=17ms TTL=83
Reply from 31.13.79.65: bytes=32 time=17ms TTL=83

Ping statistics for 31.13.79.65:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 17ms, Maximum = 18ms, Average = 17ms

C:\Users\User>ping www.facebook.com

Pinging star.c10r.facebook.com [2a03:2880:f00c:701:face:b00c:0:1] with 32 bytes
of data:
Reply from 2a03:2880:f00c:701:face:b00c:0:1: time=17ms
Reply from 2a03:2880:f00c:701:face:b00c:0:1: time=33ms
Reply from 2a03:2880:f00c:701:face:b00c:0:1: time=24ms
Reply from 2a03:2880:f00c:701:face:b00c:0:1: time=24ms

Ping statistics for 2a03:2880:f00c:701:face:b00c:0:1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 17ms, Maximum = 33ms, Average = 24ms
```

Figure 2: Ping Results to Facebook Website

The test result to Yahoo website is much worse for IPv6 compared to IPv4 (Figure 3). The average RTT for IPv4 is only 16ms whereas for IPv6 is 325ms. The IPv6 RTT is 22 times higher than IPv4 RTT. The reasons for this result might be able to be deduced from the tracert result later.

```
Command Prompt

C:\Users\User>ping 106.10.139.246

Pinging 106.10.139.246 with 32 bytes of data:
Reply from 106.10.139.246: bytes=32 time=17ms TTL=51
Reply from 106.10.139.246: bytes=32 time=16ms TTL=51
Reply from 106.10.139.246: bytes=32 time=16ms TTL=51
Reply from 106.10.139.246: bytes=32 time=16ms TTL=51

Ping statistics for 106.10.139.246:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 16ms, Maximum = 17ms, Average = 16ms

C:\Users\User>ping www.yahoo.com

Pinging fd-fp3.wg1.b.yahoo.com [2001:4998:c:a06::2:4008] with 32 bytes of data:
Reply from 2001:4998:c:a06::2:4008: time=327ms
Reply from 2001:4998:c:a06::2:4008: time=328ms
Reply from 2001:4998:c:a06::2:4008: time=334ms
Reply from 2001:4998:c:a06::2:4008: time=314ms

Ping statistics for 2001:4998:c:a06::2:4008:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 314ms, Maximum = 334ms, Average = 325ms
```

Figure 3: Ping Results to Yahoo Website

The tracert test which is also done on Facebook and Yahoo also shows almost the same result as the ping result with a slight better performance for IPv6 compared to the ping test. The average RTT for Facebook IPv6 website is still the same (17 ms) but the average RTT for Yahoo IPv6 website is 82ms which shows improvement from the ping result earlier (Figure 4 and 5). The average RTT is different even though the number of hops is same (13 hops).

```
Command Prompt

C:\Users\User>tracert www.facebook.com

Tracing route to star.c10r.facebook.com [2a03:2880:f00c:701:face:b00c:0:1]
over a maximum of 30 hops:

  1    <1 ms     1 ms     1 ms  2402:1100:b:6::1
  2    <1 ms    <1 ms    <1 ms  2402:1100:0:1::29
  3     1 ms    <1 ms    <1 ms  2402:1100:32::9
  4     1 ms     1 ms     1 ms  2402:1100:32::1
  5     9 ms    12 ms     9 ms  2001:f40:0:1::a:1
  6    10 ms    14 ms    15 ms  2001:f40:0:2::1
  7    15 ms    14 ms    14 ms  2001:f40:0:2::56
  8    14 ms    14 ms    14 ms  2001:4498:4:1::1:5
  9    15 ms    15 ms    15 ms  xe-0-1-0-0.cr6-gw-1-sin-pip.sg.globaltransit.net
 [2001:4498:4::4:3d]
 10    15 ms    15 ms    14 ms  ge-0-0-0.pp6-gw-1-sin-pip.sg.globaltransit.net [
2001:4498:4::4:32]
 11    16 ms    17 ms    16 ms  32934.sgw.equinix.com [2001:de8:4::3:2934:1]
 12    17 ms    17 ms    17 ms  po126.msw01.08.sin1.tfbnw.net [2620:0:1cff:dead:
bef0::12f]
 13    17 ms    16 ms    17 ms  edge-star6-shv-08-sin1.facebook.com [2a03:2880:f
00c:701:face:b00c:0:1]

Trace complete.

C:\Users\User>tracert www.facebook.com
```

Figure 4: IPv6 Tracert to IPv6 Facebook website

```
Command Prompt

C:\Users\User>tracert www.yahoo.com

Tracing route to ds-sg-fp3.wg1.b.yahoo.com [2406:2000:f016:1fe::3001]
over a maximum of 30 hops:

  1     2 ms     1 ms     1 ms  2402:1100:b:6::1
  2     2 ms    <1 ms    <1 ms  2402:1100:0:2::29
  3    <1 ms     1 ms     1 ms  2402:1100:32::9
  4     1 ms     1 ms     1 ms  2402:1100:32::1
  5    11 ms     8 ms     8 ms  2001:f40:0:1::6c:1
  6    64 ms    47 ms    30 ms  xe-5-0-1-0.er6-01-glsfb.ni.time.net.my [2001:f40
:0:2::20:1]
  7    10 ms    14 ms     *     xe-0-1-0-0.cr6-02-glsfb.ni.time.net.my [2001:f40
:0:2::1]
  8    17 ms    14 ms    13 ms  ae-0-0.br6-01-mciwg.ni.time.net.my [2001:f40:0:2
::56]
  9    29 ms    21 ms    15 ms  pat1.sgy.yahoo.com [2001:de8:12:100::37]
 10    14 ms    14 ms    17 ms  2406:2000:f01f:1::
 11    82 ms    85 ms    83 ms  so-4-0-0.pat1.jpe.yahoo.com [2406:2000:f017:2::]

 12    84 ms    83 ms   108 ms  2406:2000:f016::
 13    82 ms    83 ms    82 ms  r2.ycpi.vip.jpx.yahoo.net [2406:2000:f016:1fe::3
001]

Trace complete.
```

Figure 5: IPv6 Tracert Result to Yahoo Website

The tracert to Facebook and Yahoo using IPv4 shows that it has equivalent or higher RTT than IPv6 as shown in Figure 6(17ms) and 7(16ms). The tracert output also shows the location of Yahoo server or site is different for IPv6 (Figure 5) and IPv4 (Figure 7).

This is one of the reasons why the average RTT for IPv4 and IPv6 is different for Yahoo website. Yahoo IPv6 server is located at r2.ycpi.vip.jpx.yahoo.net (Japan) whereas the Yahoo IPv4 server is located at ir1.fp.vip.sg3.yahoo.com (Singapore) which is nearer to UUM.

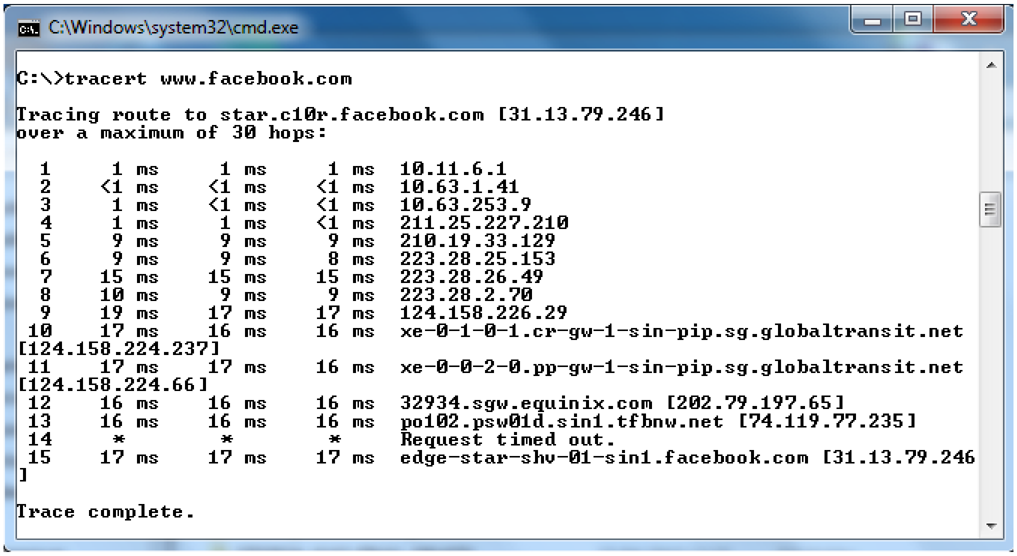

Figure 6: Tracert to Facebook site using IPv4

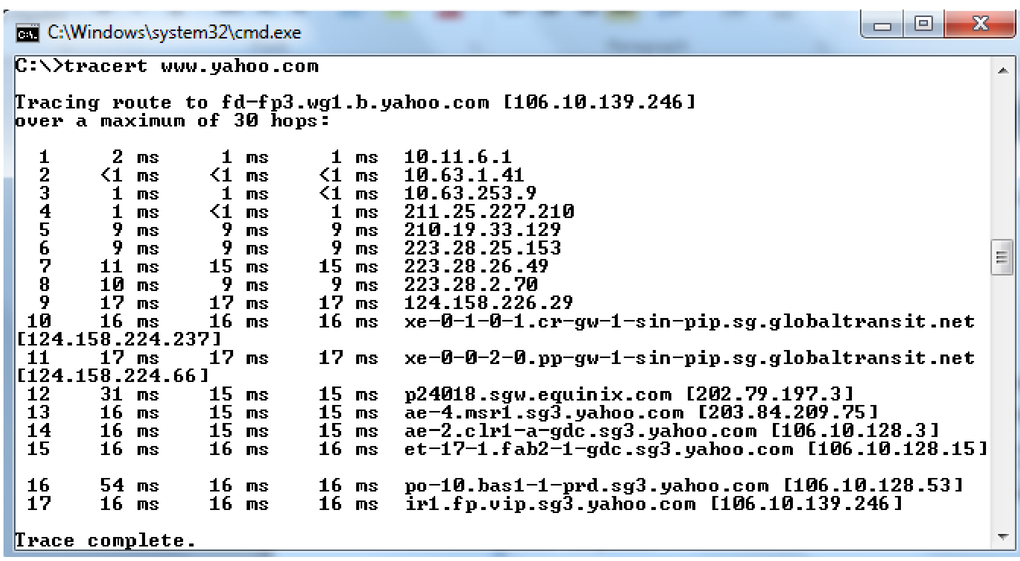

Figure 7: Tracert to Yahoo site using IPv4

CONCLUSION

The previous studies on the performance of IPv6 report that IPv6 on the Internet is still not at par to IPv4 [12], [14]. IPv6 RTTs are higher than IPv4 RTTs in most cases. As shown in Figure 5 and 7, some IPv6 sites are still located at further location than IPv4 sites. The IPv4 and IPv6 RTTs within UUM Sintok campus network shows insignificant difference meaning both IPv4 and IPv6 are performing well in the campus network as found in the test above with average RTT is less than 1ms. In order to convince more people and organizations to adopt IPv6, major and popular websites must provide IPv6 web services near to customer or user locations.

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