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TOWARD IPV4 TO IPV6 MIGRATION WITHIN A CAMPUS NETWORK

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ABSTRACT

The evolution of the Internet has effectively exhausted all unique addresses offered by the current IPv4 protocol. Hence, IPv6 has been developed in response to the predicted long-term demand for addresses by Internet users. This new IP version has a 128-bit address length, which is four times that of IPv4. As the two protocols have different formats and behaviors, efforts are needed to ensure they can directly communicate with each other. Some transition mechanisms have been proposed by IETF to enable IPv4 and IPv6 networks to coexist until the whole Internet is based on an IPv6 network. This paper discusses a general overview of IPv4 and IPv6 addresses, along with IPv4 to IPv6 transition techniques on a campus network. Moreover, we summarize some of the IPv6 test-bed use cases. In addition, we describe a pure IPv6 real test-bed implementation scenario and discuss test results. Finally, we propose some major pre-activities for the design and implementation of an IPv6 network within a campus network.

Keywords: *IPv4 to IPv6 Migration, IPv6 Transition, IPv6 Test-bed, IPv6 Network Setup, Campus Network*

1. INTRODUCTION

IPv6 (Internet Protocol version 6, also known as IP Next Generation, or IPng) has been developed by the Internet Engineering Task Force (IETF) to overcome the shortcomings in the current IPv4. For instance, IPv6 enables 128-bit address lengths, some four times that of IPv4. It is envisaged that this protocol will satisfy the demand for addresses for a long time. In addition, IPv6 has other features that are intended to provide more reliable services, such as stateless address auto-configuration, a simplified header format to reduce the cost of packet handling and bandwidth, built-in security, and better support for quality of service requirements. The current Internet is mostly based on IPv4, which was defined in 1981 at a time when developers could not imagine the scale of addresses required by the Internet today.

1.1 Internet Protocol version 4

IPv4 is the fourth version of the IP. It is currently the most widely used protocol in data communication over different kinds of network. IPv4 is a connectionless protocol used in packet switch layer protocols, such as Ethernet. This protocol is the general standard for information delivery between devices connected to the Internet [1]. IPv4 uses a 32-bit address length, and is limited to 232 (= 4 294 967 296) addresses. The address scheme uses a dotted decimal notation, and has four classes of nets (classes A, B, C, and D; a fifth class, E, is used for research purposes only). Each class has a different number of nets and hosts. The IPv4 packet header, found at the start of every IPv4 packet, is normally 20 bytes in length, but can have additional options after the destination address [2].

1.2 Internet Protocol version 6

IPv6, also known as IPng, was developed by the IETF to overlap with IPv4 and deal with the long-anticipated exhaustion of IPv4 addresses. With its 128-bit address size, IPv6 can support more IP address hierarchies, allowing address auto-configuration for a far greater number of addressable nodes. The new protocol also introduces the concept of scalability for multicast addresses. The new type of addresses introduced by IPv6 is known as anycast, and these can be used to deliver packets to one of the nearest group of hosts in a link [3]. The US Department of Defense is a great proponent of the adoption of IPv6. Currently, the other main market opportunities are the National Research and Education Network, government institutions, enterprises, service

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providers, consumer appliances, home networking, online gaming, and wireless services [4].

2. TRANSITION MECHANISMS

As IPv4 is totally different from and incompatible with IPv6, some transition mechanism is needed to enable these two protocols to communicate with each other [5, 6]. To enable the transition between IPv4 and IPv6, IETF proposed three transition mechanisms.

2.1 Dual Stack Transition Mechanism

The Dual Stack Transition Mechanism (DSTM) is one of the most forthright means by which IPv4 and IPv6 can communicate with each other. DSTM allows a client in a native IPv6 network to communicate with an IPv4 host in an IPv4 network. As the name implies, dual stacking involves the implementation of stacks in both IPv4 and IPv6 clients. This means the host can decide when a connection should be made using IPv4 or IPv6 [7]. Both sides' hosts and routers must support dual stacks and be configured in parallel. When IPv4 communicates with IPv4, DSTM uses the IPv4 network, and when IPv6 communicates with IPv6, it uses IPv6.

2.2 Tunneling Mechanism

The tunneling mechanism is another strategy that enables the transition of packets from IPv4 to IPv6. The principles behind this tunneling are known as encapsulation and de-capsulation. Encapsulation is used when an IPv4 header transfers IPv6 packets from source to destination in an IPv4 network. In contrast, de-capsulation is used when the IPv6/IPv4 host or router receives an IPv4 datagram that is addressed to one of its own IPv4 addresses or to a multicast group address. Packets are verified by checking their source and destination address, and are submitted to the IPv6 layer code on the node [8].

2.3 Translation Mechanism

The third transition mechanism is the translation approach, which enables mutual communication between IPv4 and IPv6. The basic function of this IPv4/IPv6 transition mechanism is to translate IP packets. This exchange method is used when a single IPv6 host communicates with a single IPv4 host. For example, Network Address Translation refers to the translation of an IPv4 address into an IPv6 address, and vice versa, whilst Protocol Translation converts IPv4 packets into the semantically equivalent IPv6 packet, and vice versa [9].

3. IPV6 TEST-BED USE CASES

This section reviews related IPv6 test-bed use cases which provides sufficient guidance for an IPv6 test-bed implementation.

Sailan et al. [10] reviewed IPv4 and IPv6 with the aim of developing an IPv6 test-bed. In their paper, migration paths from IPv4 to IPv6 were reviewed, and some of the IPv6 products were analyzed. The authors compared IPv4 with IPv6 based on some major parameters. In addition, they detailed the advantages of IPv6, and identified the large number of IP addresses, better security, enhanced quality of service support, auto-configuration, enhanced mobility support, and an optimized protocol. Finally, a list of IPv6 support routers for enterprises was given by referring to the IPv6 ready logo program, thus confirming some of the IPv6 support products for the IPv6 test-bed network.

Yussoff and Samad [11] deployed an IPv6 test-bed network before integrating the link with the existing IPv4 network, as well as to gain experience of link characterization and other basic applications of IPv6. Their paper described and evaluated the practical aspects of setting up a native IPv6 network. The complete IPv6 test-bed network was setup using two host computers with a DNS server and a router. Starting with two IPv6 nodes, they installed both nodes with Open BSD 2.9, and configured them with IPv4 addresses, because the installation set was downloaded directly from FTP. Once the nodes had been installed, they used the "pingv6" command to check the connectivity with the second host. To gain experience of another operating system, they installed Windows XP on one of the host computers. In the second step, they connected the two host computers to the IPv6-capable router to set up a native IPv6 local network. The DNS server was used to map host names to IP addresses, thus enabling both IPv4/IPv6 addresses to communicate with each other. Finally, they connected the native IPv6 test-bed network to the IPv6 backbone (6bone). The 6bone enabled the IPv6 native network to communicate with other IPv6 networks through 6to4 or a dual stack router.

Ning [12] described some major IPv6 test-bed networks in universities, IPv6 R&D, and large international and government-sponsored projects in China. The author mentioned some leading universities such as Tsinghua University and Beijing University of Post and Telecommunications

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(BUPT), who built the very first IPv6 test-bed networks in China. Beijing Internet Institute, a high-tech company that works closely with the government of China to promote Internet development, constructed an IPv6 test-bed network at the BUPT, and have so far applied three IPv6 address spaces: 3ffe:81B0::/28 from 6Bone and 2001:03f8::/32, 2001:0d60::/32 from Asia Pacific Network Information Centre (APNIC). The test-bed has tunneled with CERNET, NTT Communications, China Telecom, and some other important IPv6 networks using routers from Hitachi, Nokia, and NEC.

Aazam et al. [13] evaluated the performance of two tunneling techniques, known as Teredo and Intra-Site Automatic Tunnel Addressing Protocol (ISATAP). These protocols were implemented in a real test-bed on Windows XP, Windows Server, and Linux operating systems, and used five to six devices. To test the performance of the two protocols, Aazam et al. set up an IPv6 test-bed network including five nodes (two hosts, one DNS server, two routers) connected by hubs/switches and cables. Host 1 (H1) is a dual stack node residing in an IPv4 network, and this node has to communicate with another dual stack node (H2) residing in an IPv6 network. The traffic from both H1 and H2 goes through an IPv4 network. Thus, the IPv6 packets have to be tunneled through an IPv4 network by default. The IPv6 protocol for Windows XP Professional SP2 and Windows Server 2003 SP1 standard edition was configured as a link-local ISATAP address on the automatic tunneling pseudo-interface for each IPv4 address assigned to a computer. To configure a global ISATAP address, an ISATAP router was used. The ISATAP address performs two functions: (a) it advertises its presence and address prefixes, enabling global ISATAP addresses to be configured; (b) it optionally forwards IPv6 packets between ISATAP hosts on the IPv4 intranet and IPv6 hosts beyond it. Each protocol was implemented on the setup using specific configuration commands, allowing User Datagram Protocol (UDP) audio streaming, video streaming, and ICMP ping traffic to be run. Finally, the performance of both protocols was evaluated based on parameters such as throughput, round trip time, jitter, and end-to-end delay.

The above review will provide useful guidelines for those who would like to migrate from the current IPv4 network to an IPv6 network. These guidelines will enable IPv6 migrants to successfully implement an IPv6 test-bed network.

4. REAL IPV6 TEST-BED IMPLEMENTATION SCENARIO IN A CAMPUS NETWORK

The current study involved the preparation, implementation, testing, and analysis of an IPv6 test-bed. We first considered the existing network devices in terms of functionality and support for the IPv6 network, and then designed and set up a test-bed infrastructure. The actual implementation of the IPv6 test-bed network included the IPv6 address assignment and the initial configuration and setup of the network devices. Finally, we tested the connectivity, bandwidth speed, and IPv6 website validation.

4.1 Methodology and Results

Our research consisted of four major phases:

1- Preparation- In this phase, a survey was performed to check existing network devices for IPv6 test-bed support. Some devices could support IPv6, and some were upgraded to enable IPv6 support. In addition, a case study of Faculty of Information Science and Technology (FIST), Center for Information Technology (CIT) (both faculty and center are in Universiti Kebangsaan Malaysia (UKM)) and Malaysian Research & Education Network (MYREN) was performed to check the physical connectivity of the network devices. Finally, an IPv6 test-bed network was designed. Figure 1 shows a diagram of the IPv6 test-bed network topology.

2- Implementation- In this phase, IPv6 addresses were assigned to the client computers and network devices. The IPv6 test-bed network devices include a Cisco router, Cisco switch, D-Link router, computers, and a printer. These were connected to each other through the communication media. This topology can share resources among other computers inside the Network and Communication Technology (NCT) lab at FIST, and is able to communicate with different networks over the Internet. Figure 2 shows the IPv6 address setup and configuration of the D-Link router, and fig. 3 illustrates the assignment of IPv6 addresses in client computers.

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3- Testing- In this phase, we tested the network connectivity of the IPv6 test-bed. Three connectivity tests were undertaken. First, we tested the IPv6 addresses that had been assigned to the network devices and client computers in our IPv6 test-bed network. Second, we measured the IPv6 connection bandwidth speed. Finally, in the third test, we examined the validation and browsing of IPv6 websites. Figure 4 displays the IP configuration results of currently used IPv6 addresses in our IPv6 test-bed network. Figure 5 shows the connectivity of a client computer with the D-Link router, and fig. 6 shows the hop count limit. Figure 7 shows the gateway ping test result.

4- Analysis of Results- First, we analyzed the results from the connectivity tests to verify the setup of the IPv6 test-bed. We ran ping tests on Google, Yahoo and Facebook sites and received reply from all of them. Second, we examined the speed of the IPv6 test-bed connection. The speed test was done at http://ipv6-test.com, and the result showed that the IPv6 connection speed was 5.98 Mbit/s. Finally, we looked at the test results for the validity of websites under IPv6. To prove that the IPv6 test-bed network was functioning properly, we browsed some IPv6 websites, including Google, Yahoo and Facebook. We could reach the IPv6 websites. All the tests were successful, and the test-bed was functioning properly.

5. PROPOSED GUIDELINES FOR IPV6 NETWORK SETUP

These guidelines have been prepared based on previous experience of deploying IPv6 to campus networks, and take into account the case studies we have reviewed and analyzed throughout this research. They provide some steps that should be considered while migrating from IPv4 to IPv6. The steps include:

1- Survey of the existing network infrastructure – This phase produces an overall survey and list of the available ICT equipment. Test and analyze which devices are able to support IPv6 and which devices are unsupported on IPv6 networks. It is possible that unsupported IPv6 devices can be upgraded or replaced.

2- Survey of the running network applications and services – This phase identifies the needs of clients in an organization. Once the client requirements have been identified, it is necessary to test and analyze the running network applications. Finally, list the applications that need to be upgraded or totally replaced.

3- Develop an IPv6 Strategic Implementation Plan – This is the most important phase. Before migration, a strategic plan should be developed to properly implement an IPv6 network. The strategic plan should generally cover user need assessment, IPv6 address allocation, pure IPv6 test-bed design and implementation, IPv4 to IPv6 migration, hardware and software upgrades, change management, risk management, equipment budget, manpower resources, IPv6 audit, and IPv6 effective implementation.

4- IPv6 Address Allocation Policy – In this phase, an IPv6 address assignment policy is required for the both the IPv6 test-bed network and the future IPv6 network extension.

5- IT Staff Training – As the IPv6 network is totally different from IPv4, it is very important to train IT staff prior to the real implementation. Such training will mitigate the level of risk that occurs while migrating from IPv4 to IPv6. The IT staff training includes major topics such as the organizational benefits of IPv6, its technical specification, security considerations over IPv4, IPv4 to IPv6 transition mechanisms, risks while migrating from IPv4 to IPv6, and IPv6 test-bed network design and implementation.

6- Implement a Pure IPv6 Test-bed Network – As most current network applications are based on the IPv4 network, it is important to implement a pure IPv6 network in part of the organization to avoid dis-connectivity in network applications. The IPv6 test-bed network implementation will

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enable the technical staff to experience some IPv6-only applications.

7- Identify Transition Mechanism – Because IPv4 and IPv6 address types are totally different, we must enable these two protocols to communicate with each other using one of the IETF transition mechanisms described in Section 3.

6. CONCLUSIONS

As IPv6 is a new protocol, there is a considerable amount of research that must be undertaken. In this study, we designed and implemented an IPv6 test-bed network, and prepared guidelines for smooth migration from IPv4 to an IPv6 network. We implemented this network to facilitate the research committee at UKM, by providing the new IP version for their teaching and research purposes. We checked the physical connectivity of the IPv6 test-bed network with PTM and ISP. The test was performed by pinging both the PTM IPv6 router and the ISP IPv6 router. The results showed that the network configuration was replying properly with no packet loss. We also tested the bandwidth speed of the existing IPv6 Internet, and realized a transfer rate consistent with available IPv6 throughput. Furthermore, a ping latency test was performed to check how long it takes for a packet to transfer from the source node to destination network, and vice versa. Finally, we browsed some IPv6-based websites to demonstrate the availability and proper functioning of our IPv6 test-bed network. Our step-by-step guidelines are based on the theoretical and technical aspects that should be considered when extending the current IPv6 test-bed network in the future.

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APPENDIX:

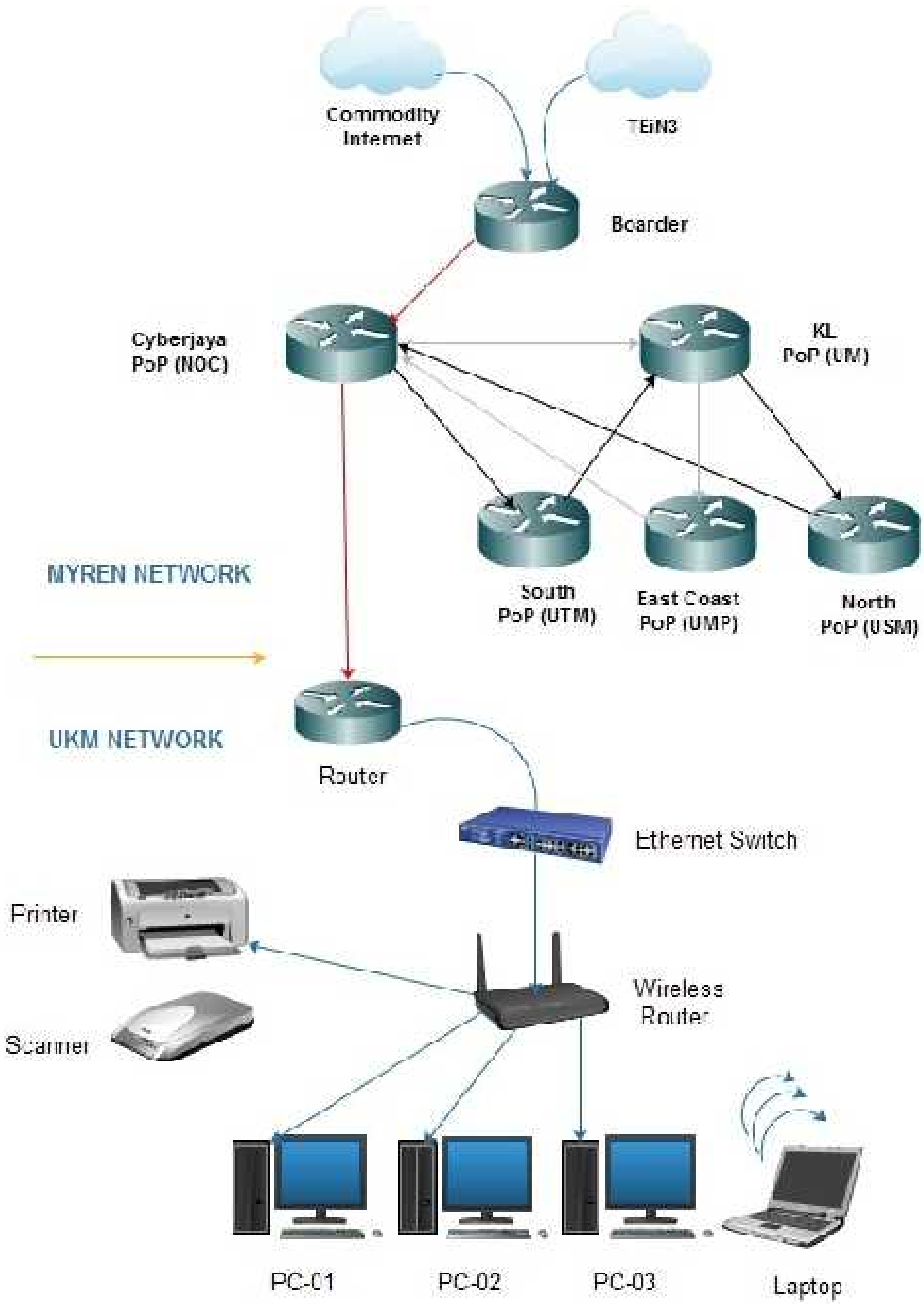

Figure 1: Ipv6 Test-Bed Network Topology Diagram

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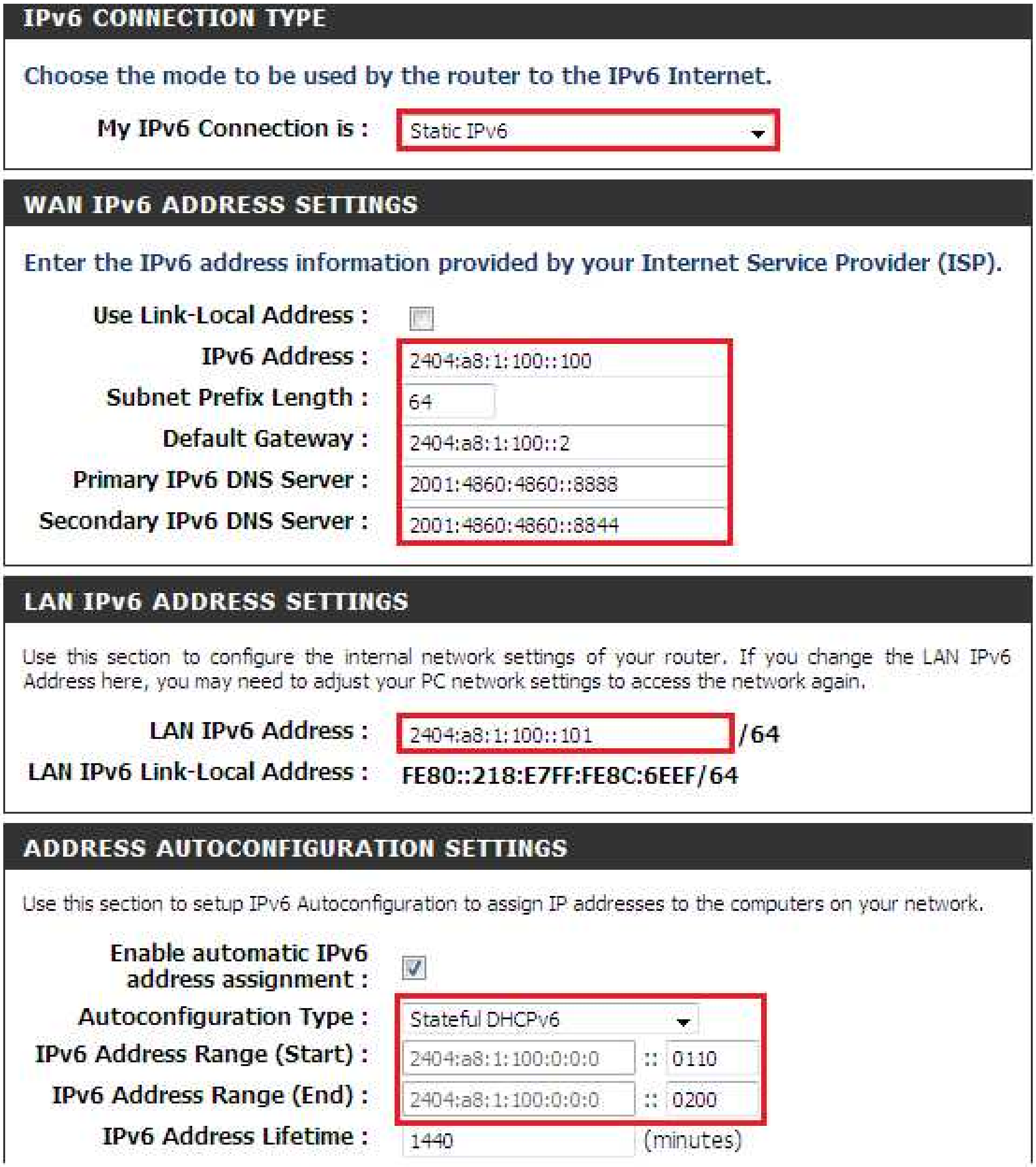

Figure 2: D-Link Ipv6 Address Setup

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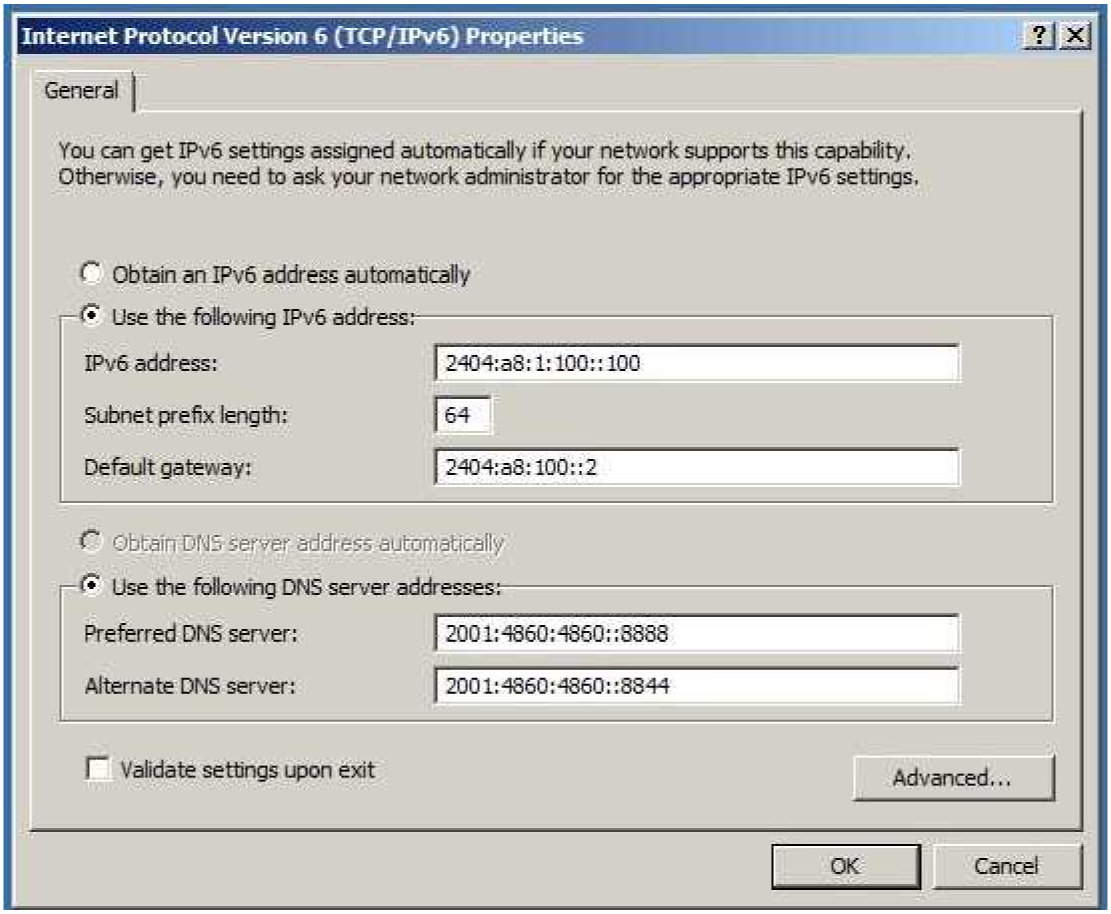

Figure 3: Assigning Ipv6 Addresses

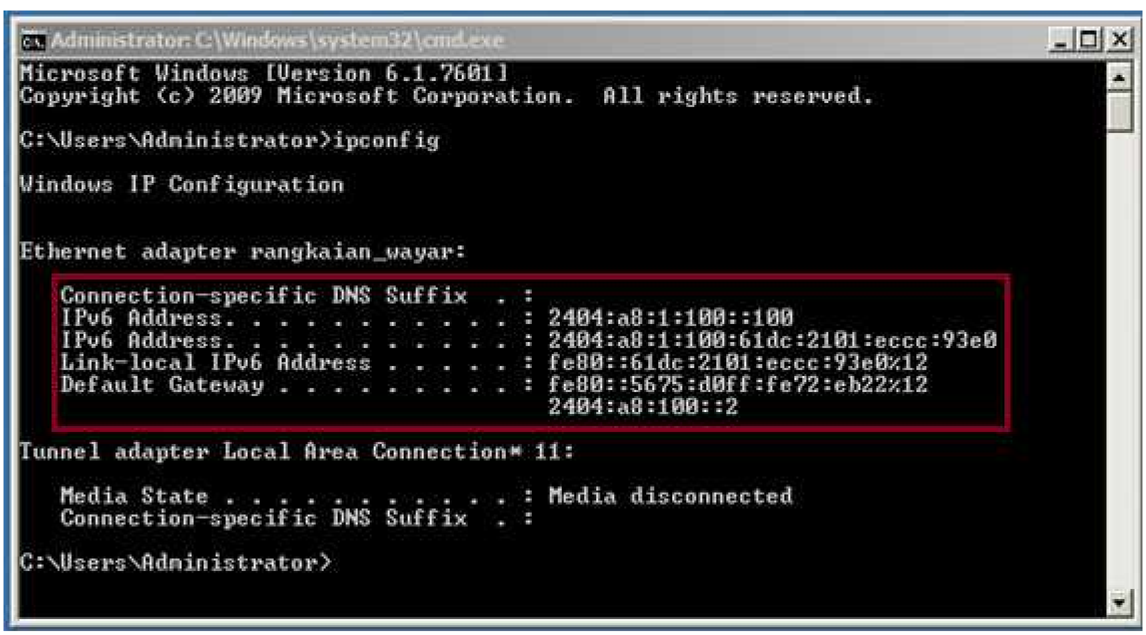

Figure 4: Ipv6 Setup Test Result

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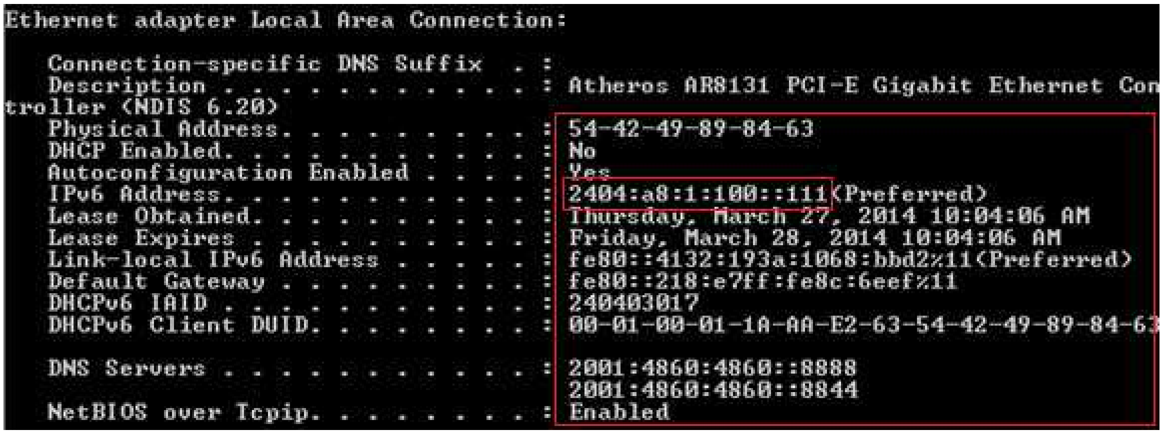

Figure 5: DHCPv6 Address Assignments

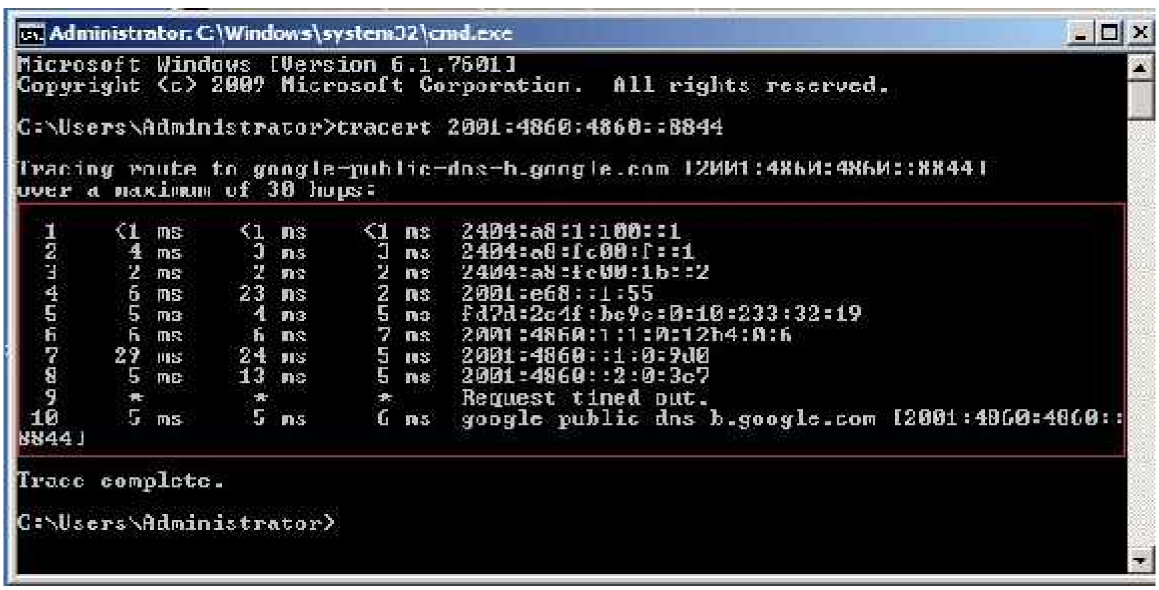

Figure 6: DNSv6 Tracert Ping Test Result

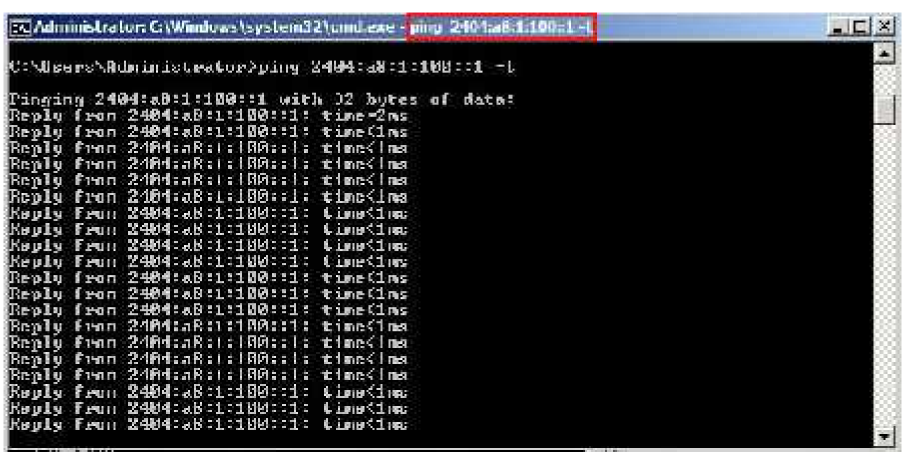

Figure 7: IPv6 Gateway Ping Test Result