VOLUME 3 NO. 1
JUNE 2006
ISSN 1675-7009

SCIENTIFIC RESEARCH JOURNAL

INSTITUTE OF RESEARCH, DEVELOPMENT AND COMMERCIALISATION

SCIENTIFIC RESEARCH JOURNAL

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SCIENTIFIC RESEARCH JOURNAL

Vol. 3 No. 1 June 2006 ISSN 1675-7009

Scientific Research Journal *Vol. 3 No. 1, 27-36, 2006*

Design and Testing of an Experimental IPv4-to-IPv6 Transition Network

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ABSTRACT

The Internet has been an integral part of the Information and Communication Technology (ICT) community in recent years. New internet users have been growing steadily over the years. This has lead to the depletion of new Internet Protocol (IP) addresses worldwide. To overcome this predicament, the new Internet Protocol version 6 (IPv6) had been introduced. The existing Internet Protocol version 4 (IPv4) is expected to be eventually replaced by this IPv6. The changeover from IPv4 to IPv6 is expected to be implemented progressively. During this transition period, these two protocols are expected to coexist for a number of years. IPv4-to-IPv6 transition tools have been designed to facilitate a smooth transition from IPv4 to IPv6. The two most basic IPv4-to-IPv6 transition tools available are the hybrid stack mechanism and tunneling. Tunneling is the encapsulation of IPv6 traffic within IPv4 packets so they can be sent over an IPv4 infrastructure. This project was initiated to set up an experimental IPv6 testbed, in order to study the performance as well as transition and migration issues of IPv6 networks under controlled conditions. This paper looks at how tunneling can be performed over existing internetwork infrastructure at Fakulti Kejuruteraan Elektrik (FKE), UiTM.

Keywords: *ICT, Internet Protocol, IPv6, IPv4, Transition, Hybrid Stack, Tunneling, Testbed*

ISSN 1675-7009

Introduction

The prospect of an exhausted supply of address space in the current Internet Protocol IPv4, prompted the Internet Engineering Task Force (IETF) to initiate work on the next generation of Internet Protocol (IP) towards the end of the twentieth century. The resulting Internet Protocol version 6 (IPv6) or IP Next Generation offers a 128-bit address space and other upgrades that support the auto configuration of new hosts. IPv6 with its 128 bits address field, is expected to gradually replace the existing 32 bits address field Internet Protocol version 4 (IPv4). For more than twenty years, IPv4 has been widely used in Internet activities around the world. While these gradual changes are taking place, these two protocols are expected to coexist for a number of years during this transition period. To facilitate this, a number of IPv4-to-IPv6 transition tools are available to address the various needs of different networks. The two most basic IPv4-to-IPv6 transition tools available are the hybrid or dual stack mechanism and IPv6 over IPv4 tunneling.

The Internet Engineering Task Force (IETF) started work as early as July 1991, when it began the process of researching the problem, soliciting proposals for solutions, and narrowing in on a conclusion, describing this preliminary process in RFC 1380 [1], published in November 1992. A new research area was then commissioned by the IETF to formally study these issues. This new research area was named the Internet Protocol Next Generation, or IPng, Area. RFC 1550 [2], titled "IP: Next Generation (IPng) White Paper Solicitation" was distributed in December 1993. This RFC invited any interested party to submit comments regarding any specific requirements for the IPng or any key factors that should be considered during the IPng selection process.

RFC 1752 [3], "The Recommendation for the IP Next Generation Protocol," published in January 1995, described four key transition criteria.

The first is incremental upgrade, which allows existing IPv4 hosts to be upgraded at any time without depending on other hosts or routers to be upgraded. The second is incremental deployment, where new IPv6 hosts and routers can be installed at any time without any prerequisites. The third is easy addressing, which allow existing IPv4 hosts or routers that are upgraded to IPv6, to continue using their existing address, without needing new assigned addresses. The last of these four criteria is low start-up costs, where little or no preparation work is needed in order to upgrade existing IPv4 systems to IPv6, or to deploy new IPv6 systems.

RFC 1933 [4] titled “Transition Mechanisms for IPv6 Hosts and Routers” published in April 1996, described two transition mechanisms, a dual IP layer (stack) and IPv6 over IPv4 tunneling.

The first part of this project was to set up an experimental IPv6 network, at FKE, UiTM, utilising the existing UiTM’s IPv4 infrastructure. This IPv6 testbed was then connected to the 6bone network MANIS Tunnel Broker and configured tunnel. Tests were then conducted to verify the connectivity and reliability of the connection. This paper looks at how the transition mechanisms for IPv6 hosts and routers can be implemented, over existing IPv4-based internetwork infrastructure at Fakulti Kejuruteraan Elektrik (FKE), Universiti Teknologi Mara (UiTM), and the experience of connecting to Malaysian Advanced Network Integrated System (MANIS) Tunnel Broker and configured tunnel. The next step was to set up a native IPv6 local area network. This part of the study will be discussed in another paper.

Transition Mechanisms

The IETF NGTrans (Next Generation Transition) working group has designed a set of IPv4-to-IPv6 transition tools to address the various needs of different networks [5]. The transition mechanisms provide the ways and means of implementing a transition strategy. The three main mechanisms include dual stack mechanism, IPv6-over-IPv4 tunneling and translation. The two most basic IPv4-to-IPv6 transition tools are the dual stack mechanism and tunneling.

The tunneling mechanisms include using manually configured tunnels, generic routing encapsulation (GRE) tunnels, semi-automatic tunnel mechanisms such as tunnel broker services, and fully automatic tunnel mechanisms. The scope of this study is confined to configured tunneling and tunnel broker. The tunnel broker technique requires a dual stack host at the client’s end to be connected to the tunnel broker’s facilities.

Dual Stack Mechanism

A dual stack host, implements both IPv4 and IPv6, usually in a single stack in which most of the code is shared by the two protocols [5]. The host supports both IPv4 and IPv6 stacks, known as IPv6/IPv4 nodes [6]. These nodes have the ability to send and receive both IPv4 and IPv6 packets, communicating IPv4 with IPv4 peers, and IPv6 with IPv6 peers.

When both options are available, the host will usually choose the IPv6 path, which increases the value and power of the IPv6 network by creating more users.

Tunneling Mechanism

Tunneling is a process whereby information from one protocol is encapsulated inside the frame or packet of another architecture, thus enabling the original data to be carried over that second architecture [7]. The tunneling mechanism for IPv6/IPv4 is designed to enable an existing IPv4 infrastructure to carry IPv6 packets by encapsulating the IPv6 information inside IPv4 datagrams. Tunneling provides a convenient way for an IPv6 island to connect to other IPv6 islands across an ocean of IPv4 networks [5]. The IETF has drafted several tunneling tools including Configured Tunneling, Automatic Tunneling, Tunnel Broker, 6over4, 6to4, and ISATAP.

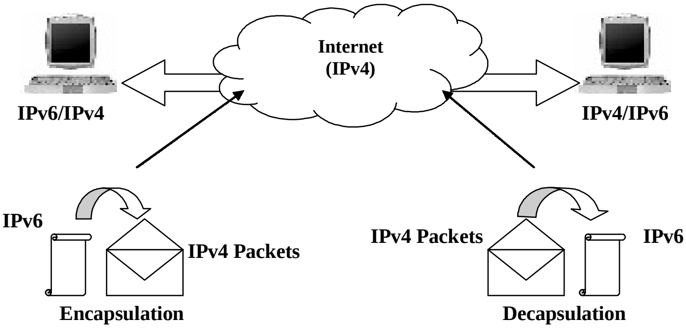


Figure 1: Tunneling – Encapsulation and Decapsulation

Figure 1 illustrates how the tunneling process can be accomplished by the process of encapsulation and decapsulation. The encapsulation process will place the IPv6 information inside IPv4 packets. The dual stack host or router will encapsulate or wrap the IPv6 packet into IPv4 and transmit them over the IPv4 network (tunnel). Figure 2 shows how an IPv6 packet can be encapsulated within the payload of an IPv4 packet.

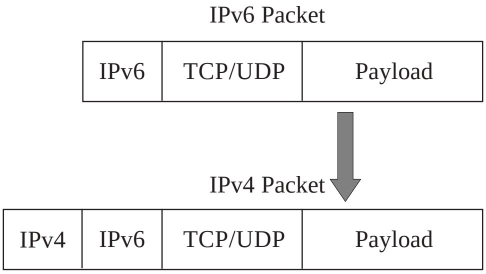


Figure 2: Encapsulating IPv6 in IPv4

At the receiving end, the dual stack host or router will then decapsulate or unwrap the IPv6 packet from the IPv4 packets. Figure 3 shows how an IPv6 packet can be decapsulated from the IPv4 packet.

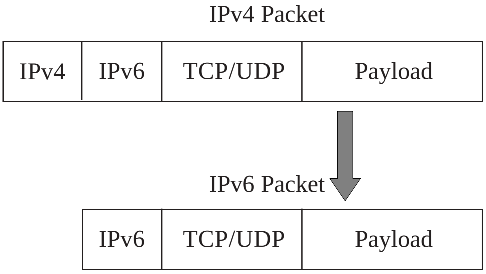


Figure 3: Decapsulating IPv6 from IPv4

A configured tunnel is equivalent to a permanent link between two IPv6 domains over an IPv4 infrastructure. The main function is for stable connections that require regular secure communication between two dual stack routers or between an end system and a dual stack router, or for connection to remote IPv6 networks such as the 6bone. The routers and end systems, if they are at the end of the tunnel, must be dual-stack implementations.

At each end of the tunnel, the IPv4 and IPv6 addresses of the dual-stack router on the tunnel interface are configured, and the source and destination points are identified using IPv4 addresses. Since each tunnel exists between only two routers, adding routers means adding tunnels to cater for all the paths between the routers.

The Experimental IPv6 Network

In this project, two types of IPv6 connections were made to the Malaysian Advanced Network Integrated System (MANIS) network. These were the dual stack host to MANIS Tunnel Broker, and dual stack router to MANIS IPv6 router. With these connections to the Tunnel Broker and MANIS router respectively, the dual stack host and router can then be linked to the 6bone network, an experimental network running in parallel with the Internet. Figure 4 illustrates the dual stack router to MANIS IPv6 router connection employed, for the experimental IPv6 network implemented in this project.

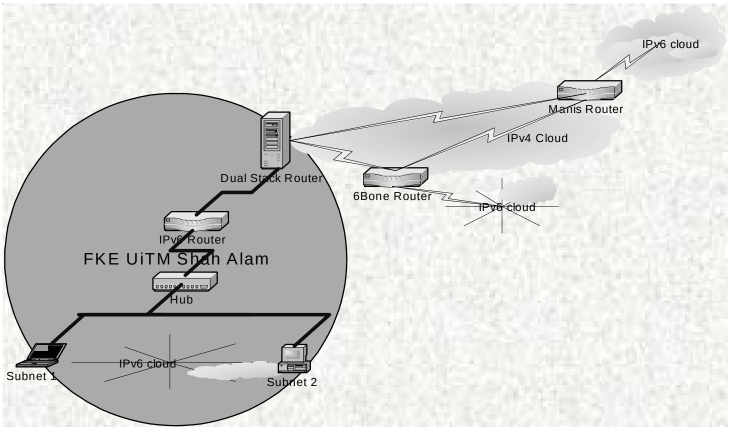


Figure 4: The Experimental IPv6 Network at FKE, UiTM

Tunneling and Dual Stack Router

Figure 5 illustrates the connection made to MANIS IPv6 router through the IPv6 over IPv4 tunnel. OpenBSD Operating System (OS) was used in the dual stack router as it supports IPv6 and supported by MANIS. The dual stack router was then configured. Once the dual stack router has been configured, the tunnel (link) was tested for connectivity and reliability.

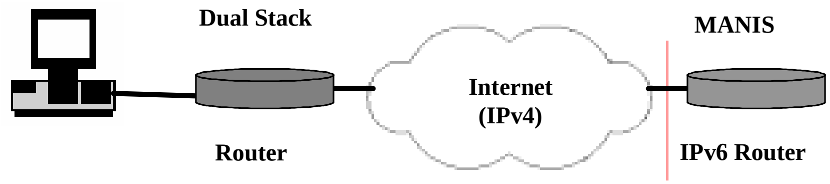
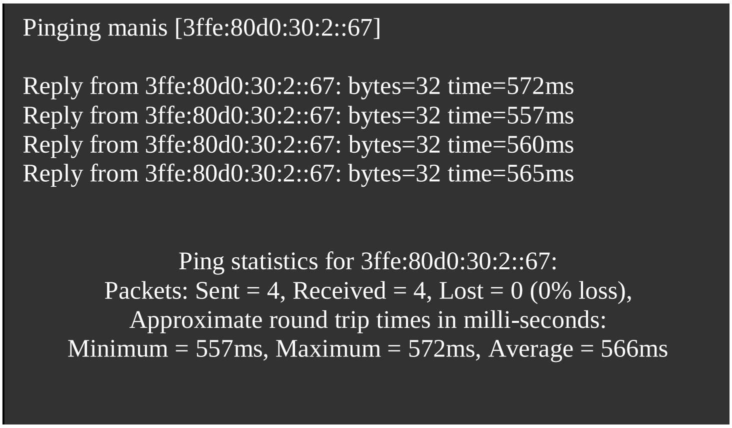


Figure 5: Dual Stack Router Connection

Tests Results

Two of the main tests conducted were to “ping” and to trace the route to various IPv6 servers. Two of the servers selected for these tests were the MANIS server and 6bone server. Figure 6 shows the result of “pinging” Manis server, and Figure 7 illustrates the result of the traceroute test.

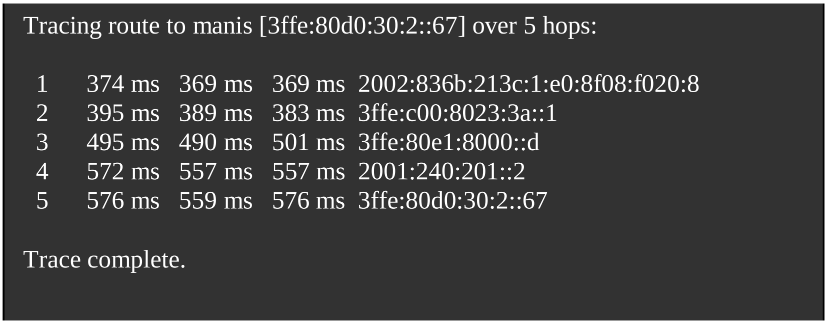


```
Pinging manis [3ffe:80d0:30:2::67]

Reply from 3ffe:80d0:30:2::67: bytes=32 time=572ms
Reply from 3ffe:80d0:30:2::67: bytes=32 time=557ms
Reply from 3ffe:80d0:30:2::67: bytes=32 time=560ms
Reply from 3ffe:80d0:30:2::67: bytes=32 time=565ms


            Ping statistics for 3ffe:80d0:30:2::67:
        Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
          Approximate round trip times in milli-seconds:
   Minimum = 557ms, Maximum = 572ms, Average = 566ms
```

Figure 6: Ping Statistics for Manis



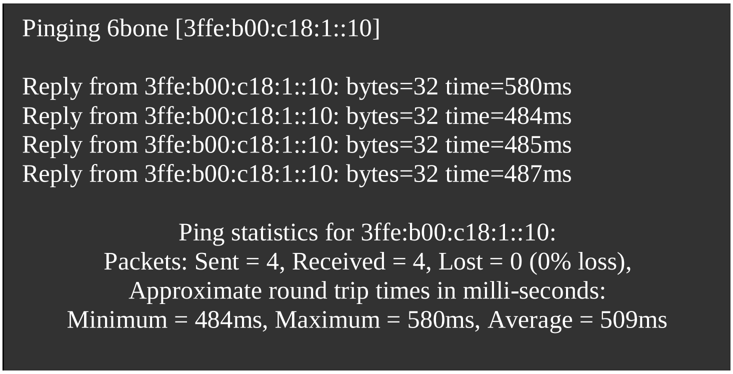
```
Tracing route to manis [3ffe:80d0:30:2::67] over 5 hops:

  1    374 ms   369 ms   369 ms  2002:836b:213c:1:e0:8f08:f020:8
  2    395 ms   389 ms   383 ms  3ffe:c00:8023:3a::1
  3    495 ms   490 ms   501 ms  3ffe:80e1:8000::d
  4    572 ms   557 ms   557 ms  2001:240:201::2
  5    576 ms   559 ms   576 ms  3ffe:80d0:30:2::67

Trace complete.
```

Figure 7: Result of Tracing Route to Manis

Figure 8 shows the result of "pinging" 6bone, while Figure 9 illustrates the result of the traceroute test to 6bone.

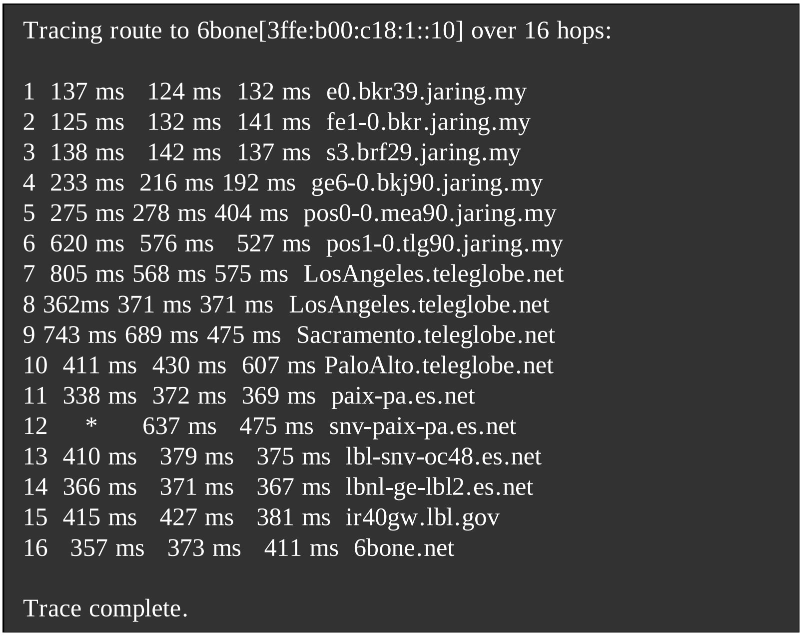


```
Pinging 6bone [3ffe:b00:c18:1::10]

Reply from 3ffe:b00:c18:1::10: bytes=32 time=580ms
Reply from 3ffe:b00:c18:1::10: bytes=32 time=484ms
Reply from 3ffe:b00:c18:1::10: bytes=32 time=485ms
Reply from 3ffe:b00:c18:1::10: bytes=32 time=487ms

                Ping statistics for 3ffe:b00:c18:1::10:
        Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
           Approximate round trip times in milli-seconds:
    Minimum = 484ms, Maximum = 580ms, Average = 509ms
```

Figure 8: Ping Statistics for 6bone



```
Tracing route to 6bone[3ffe:b00:c18:1::10] over 16 hops:

1  137 ms   124 ms  132 ms  e0.bkr39.jaring.my
2  125 ms   132 ms  141 ms  fe1-0.bkr.jaring.my
3  138 ms   142 ms  137 ms  s3.brf29.jaring.my
4  233 ms  216 ms 192 ms  ge6-0.bkj90.jaring.my
5  275 ms 278 ms 404 ms  pos0-0.mea90.jaring.my
6  620 ms  576 ms   527 ms  pos1-0.tlg90.jaring.my
7  805 ms 568 ms 575 ms  LosAngeles.teleglobe.net
8 362ms 371 ms 371 ms  LosAngeles.teleglobe.net
9 743 ms 689 ms 475 ms  Sacramento.teleglobe.net
10  411 ms  430 ms  607 ms PaloAlto.teleglobe.net
11  338 ms  372 ms  369 ms  paix-pa.es.net
12     *      637 ms   475 ms  snv-paix-pa.es.net
13  410 ms   379 ms   375 ms  lbl-snv-oc48.es.net
14  366 ms   371 ms   367 ms  lbnl-ge-lbl2.es.net
15  415 ms   427 ms   381 ms  ir40gw.lbl.gov
16   357 ms   373 ms   411 ms  6bone.net

Trace complete.
```

Figure 9: Result of Tracing Route to 6bone

The results of the two main tests shown above confirmed that the link had been established, and the IPv6 network was operating with consistent reliability over the existing IPv4 network.

Summary

The paper has described the two most basic types of IPv4-to-IPv6 transition tools available, namely the hybrid or dual stack mechanism and IPv6 over IPv4 tunneling. It has also demonstrated the mechanisms of tunneling implemented, utilising dual stack host and dual stack router connected to MANIS IPv6 network. This paper has also described how these transition mechanisms for IPv6 hosts and routers can be implemented, over existing internetwork infrastructure at Fakulti Kejuruteraan Elektrik (FKE), Universiti Teknologi MARA (UiTM), and the experience of connecting to Malaysian Advanced Network Integrated System (MANIS) Tunnel Broker and configured tunnel.

On completion of the first part of the study, a native IPv6 network was set-up as an extension of the testbed. Details of the setting up and tests performed on the native network would be discussed in another paper. Further tests and evaluation were conducted, and more experiments were performed on the IPv6 network at FKE, UiTM. A key part of the IPv6 design is its ability to integrate into and coexist with existing IPv4 networks. Hence transition mechanisms play a crucial role towards the successful implementation of IPv6.

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