AC 2007-1955: IPV6 COURSE DEVELOPMENT FOR INFORMATION TECHNOLOGY CURRICULUMS

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IPv6 Course Development for Information Technology Curriculums

Abstract

The integration of the Internet Protocol version 6 (IPv6) into networks and interest in its capabilities are picking up pace yet most networking courses in Universities currently present only a brief overview of the new protocol. We present a case study of a special topics course on IPv6 taught during the summer semester of 2006. Issues that are addressed include instructor training, textbook selection, equipment compatibility, lab exercise development, student projects, and student feedback. The course emphasized a hands-on approach to IPv6 deployment in a network. Cisco routers were used as the primary networking devices with updated, advanced IP Services IOS. Topics covered include IPv6 address structure and architecture, relevant RFCs, IPv6 header format, stateless auto-configuration, tunneling, IPv6 routing protocols, and IPv6 security considerations. Suggestions for future development and course enhancement include integrating Linux-based networking devices, Quagga, performance measurements on dual stacked routers, and Windows Vista. The success of this special topics summer course has led to the integration of IPv6 topics in other information systems courses.

Introduction

This is a case study of the success of an IPv6 course that is currently taught in the College of Technology and Computer Science at East Carolina University as part of a Bachelor of Science in Information and Computer Technology degree program. The course was piloted in the 2006 summer semester, repeated in the 2007 Spring semester, and is scheduled for the 2007 Fall semester. The IPv6 course discussed in this case study emphasized a hands-on approach to teaching IPv6 network deployment. Extensive use of a remote access system developed at our university allowed remote students to access the console ports of Cisco routers, Linux Workstations and Microsoft Workstations running Windows XP and Server 2003. Remote access to equipment allowed students to perform configuration and troubleshooting tasks 24 hours a day, 7 days a week.

Lectures for the course were conducted on campus in the College's Global Classroom where students could attend in person, view real-time web casts, or watch achieved versions of the lecture.

The foundation for the lab portion of the class is the Cisco 2800 series and 2600 series routers that are part of a standard Cisco Networking Academy CCNP equipment bundle.

Students had to meet one of the following prerequisites in order to attend this pilot course; CCNA certification, Network + certification, or completion of Cisco Networking Academy CCNA semesters 1 – 4. In other words, students needed a solid understanding of general network issues and IPv4.

Purpose of the Class

The purpose of this course was build understanding and knowledge of the IP protocol by providing IT professionals the means to actually perform hands-on configuration of IPv6 on a variety of network devices and operating systems.

Experience gained teaching Cisco CCNA and CCNP courses across the country showed that very few network administrators or networking technicians had any IPv6 exposure or knowledge. Various surveys and verbal polls taken at the beginning of numerous networking classes seemed to support this vacuum of IPv6 knowledge. Research showed these findings correlate with the low IPv6 interest, and the low number of IPv6 deployments within the United States which is lagging behind many parts of the world in IPv6 research, deployments, and training.

The interest in IPv6 has increased significantly over the past two years and will continue to increase at an accelerated rate for years to come. This presents Universities with both a challenge and an opportunity. The challenge consists in updating curriculums to include the new protocol information. Early adopters have the opportunity to distinguish themselves from other university programs by offering IPv6 education and certification. Moreover, the introduction of IPv6 in certification exams such CCNA and CCNP is becoming a driver for IPv6 adoption in education. IPv6 knowledge is in great demand across the communications industry and US federal government agencies.

Motivation behind the class……IPv6 is going to happen

As stated, the United States is lagging behind many parts of the world in IPv6 research, deployments, and training.

Japan, Korea, China, and the European Union have taken a global lead in gaining IPv6 operational deployment expertise. A fact that is highlighted by Microsoft's decision to use a Japanese subsidiary for testing and verifying the IPv6 stacks in its newest operating system, Vista.[1]

Japan, recognized as the world leader in IPv6, was the first country to put forth a national strategy for IPv6, called u-Japan, and has the most significant commercial IPv6 services deployments in the world.

In 2004 Korea unveiled U-Korea, a government subsidized initiative to provide uninterrupted access to internet, services, and mobile networks anytime anyplace. In addition, Korea Telecom is moving ahead with government backing and support to offer IPv6 services to their customers.[2]

China is moving ahead with its IPv6 backbone, the China Next Generation Internet (CNGI) and it's plans to make the 2008 Olympic games use IPv6. The European Union invests aggressively into IPv6 with very successful projects such as 6NET and 6DISS.

In the United States the big push for IPv6 may come from a policy set by the Office of Management and Budget (OMB) that states "all agency infrastructures (network backbones) must be using IPv6 and agency networks must interface this infrastructure by June 30, 2008. Agencies will include progress reports on meeting this target date as part of their Enterprise Architecture (EA) transition strategy." [3]

Another catalyst for IPv6 is the impending exhaustion of the IPv4 space. This can be seen when you look at current statistics. There are only 256 /8 networks in the IPv4 space and there are only 54 /8 blocks remaining in the IANA pool for allocation. (see figure 1) [4]

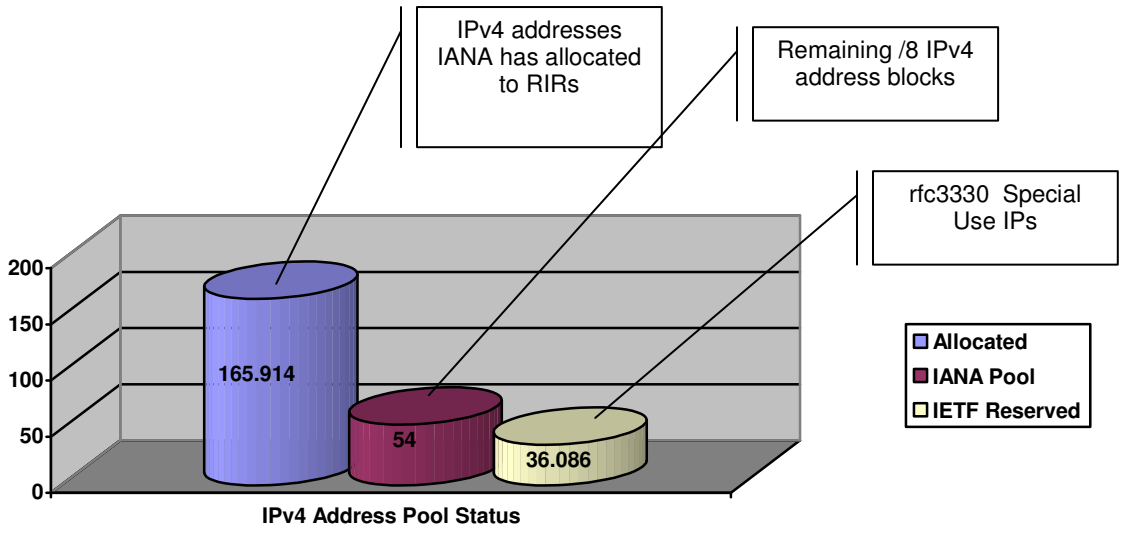


Figure 1. The IPv4 Address Pool[8]

A prime example of the problem of IPv4 exhaustion is Asia which alone has 3.6 billion people, more than the entire rest of the world. Asia has only a 10% Internet penetration rate by population compared to 25% for the rest of the world. Just catching up to the rest of the world would require 500 million IPv4 addresses in Asia alone.

IP addresses in Asia. (see figure 2 and Table 1)[4]

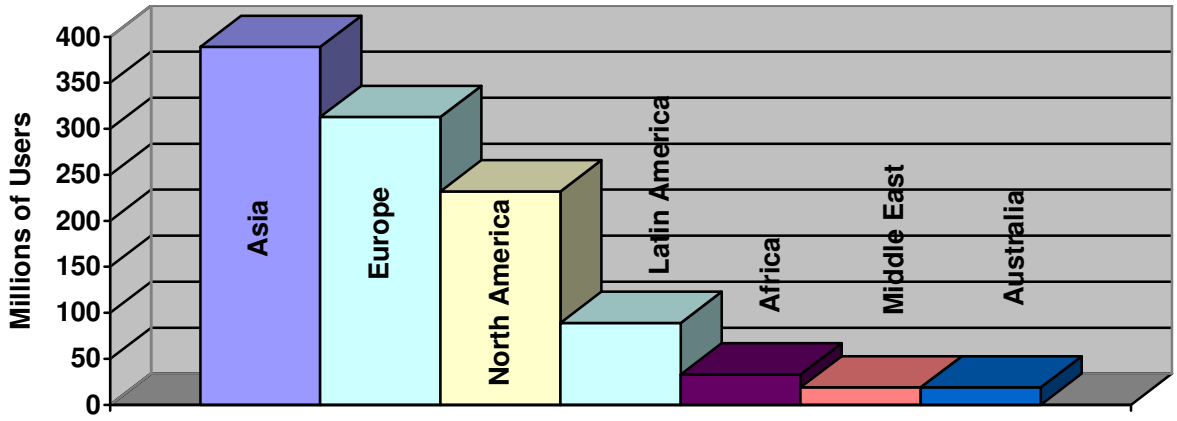


Figure 2. Internet Users by Region[8]

Internet Statistics For Asia

Region	Population (2006)	% of World Pop.	Internet Users	Penetration %	Growth rate 2000-2006
Asia	3,667,774,006	56.40%	387,593,457	10.60%	239.10%
Rest of World	2,831,922,994	43.60%	704,137,404	24.90%	185.40%
World Total	6,499,697,060	100%	1,091,730,861	16.80%	202.40%

Table 1. Internet Statistics for Asia[8]

Class preparation

The development of this IPv6, like any course on a new required significant work, and research up front. The preparing of the pilot course started one full semester before its actual offering.

The first task in developing the class was to define the scope of topics covered. The following materials were quite valuable in preparing for the class and identifying the most important topics that should be covered.

- "Understanding IPv6" by Joseph Davies, Microsoft Press, November 13, 2002.
- "IPv6 Essentials by Silvia Hagen, Orielly Media, 2nd edition, May 17, 2006.

The course material was developed based on the identified important aspects of the technology, the background and framework of existent and successful IPv4 classes, and based on the available lab environment.

Since Cisco networking equipment was readily available it was decided to use this as the core of the course. Students would first learn the mechanics of the IPv6 address space, then move on to configuring Cisco equipment to route IPv6 traffic, and then finally, configure various hosts on the IPv6 network.

Equipment and Software

As was previously stated, the course was taught with existing equipment that is used in a standard Cisco CCNP Academy bundle. These bundles of equipment consist of Cisco 2600, 2801 and 2811 series routers and Catalyst 3560 layer-three switches. Since the goal was to integrate the IPv6 hands-on labs into existent IPv4 course labs, a survey was made of all equipment at hand to ensure that it supported IPv6.

A quick test of IPv6 capability for our Cisco router platforms was to issue the "ipv6 unicast routing" command in global configuration mode. In our case, none of the existent equipment could support IPv6 in their current configuration and it required IOS upgrades. Before upgrading the IOS, we referred to the Cisco feature navigator located at http://tools.cisco.com/ITDIT/CFN/jsp/index.jsp to identify the compatible IOS for each of our router platforms. The feature navigator also provided us the minimum flash memory and RAM required for each IOS.

We discovered that our 2600 series routers required 32MB of flash memory so it was decided to purchase memory modules to upgrade those, and simply upgrade the IOS in the 2801 and 2811 routers. The 2811 routers were configured with 256MB RAM and 64MB of flash memory while the 2801 routers were configured with 128MB RAM and 64MB flash.

The following IOS images were used in this class:

- 2801 routers - c2801-adventerprisek9-mz.123-14.T5.bin
- 2811 routers - c2800nm-advipservicesk9-mz.124-7.bin.
- 2600 routers – c2600-is-mz.12.3-22.bin
- Catalyst 3560 Layer three switches - c3560-advipservicesk9-mz.122-25.SEE.bin

A reference we found very useful in the process of product inventory and upgrade is Cisco's IPv6 Introduction page:
http://www.cisco.com/en/US/products/ps6553/products_ios_technology_home.html

Text and Reference Materials

The textbook we selected for this pilot class is: Ciprian Popoviciu's book, titled Deploying IPv6 Networks, ISBN 1-58705-210-5 and published by Cisco Press.

A supplemental reference books, web sites, and RFCs are listed below.

Published Books:

- "Understanding IPv6" by Joseph Davies, Microsoft Press, November 13, 2002.
- "IPv6 Essentials by Silvia Hagen, Orielly Media, 2nd edition, May 17, 2006.

Web Reference Material:

- The IPv6 forum, http://www.ipv6forum.org/index.php
- IPv6 Information Page, http://www.ipv6.org/
- Estoile web page http://www.estoile.com/links/ipv6
- IPv6 address Report, http://www.potaroo.net/tools/ipv4/
- The IPv6 Portal, http://www.ipv6tf.org/meet/history.php
- IP Version 6, http://playground.sun.com/pub/ipng/html/ipng-main.html

Due to the small number of available texts with up-to-date information covering IPv6, the following RFCs were a valuable resource in course development.

- RFC 4291, "IP Version 6 Addressing Architecture," 2006
- RFC 4193, "Unique Local IPv6 Unicast Addresses," 2005
- RFC 3879, "Deprecating Site Local Addresses," 2004
- RFC 3587, "IPv6 Global Unicast Address Format," 2003
- RFC 3484, "Default Address Selection for IPv6," 2003
- RFC 3306, "Unicast-Prefix-based IPv6 Multicast," 2002
- RFC 2462, "IPv6 Stateless Address Autoconfiguration," 1998
- RFC 1883, "Internet Protocol, Version 6 Specification," 1995
- RFC 1752, "The Recommendation for the IP Next Generation Protocol," 1995

Issues encountered in preparing the class

Verify that all equipment and operating systems are IPv6 compatible: For reference we used the following:

- Fedora Core 5
- Linux Red Hat 9
- Windows 2003
- Windows XP

Other operating systems that we will include in future courses include:

- Open BSD
- Windows Vista
- Mac OS X

Verify that all reference material is current: Deprecated RFCs were a problem encountered just before the course actually started. Some reference materials referenced RFCs that had been deprecated. Here are some examples:

- RFC 2373 IP version 6 addressing architecture [2], drafted in July 1998 is referenced in some books but it has been made obsolete by RFC 3513 Internet Protocol Version 6 Addressing Architecture [3], drafted in April 2003.

- Site local address referenced in some texts and study guides are made obsolete and are replaced by unique local scope addresses in RFC 4193 Unique Local IPv6 Unicast Addresses, October 2005 [4].

Course Structure

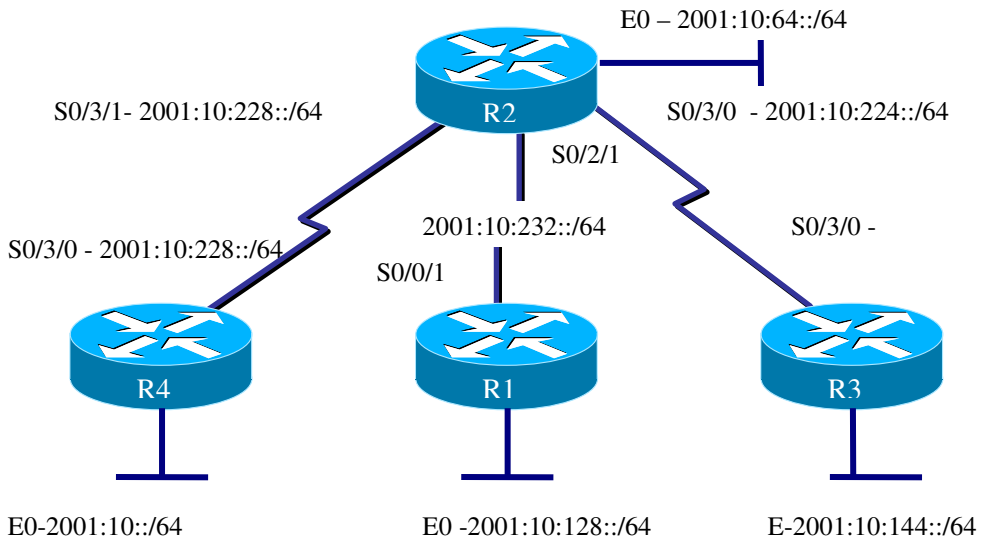
Course was taught on an eleven week schedule.
The course content was developed and delivered to students online using Blackboard. Lectures and demonstrations were presented in the University's Global Classroom and were Web Cast live and also archived for later viewing.

The following topics were covered:

- A brief history lesson of IP to include Methods used to extend the life of IPv4, such as VLSM and CIDR
- A review of Subnetting IPv4 and VLSM and CIDR exercises
- Address allocation methods used by ICANN and current IPv4 allocations
- IANA and the Regional Registries
- The IPv6 address space and architecture
- IPv6 Autoconfiguration
- IPv6 Packet format and extension headers
- Neighbor Discovery Protocol
- IPv6 address provisioning – stateless auto configuration
- DNS Services
- Tunnels
- IPv6 Routing Protocols
- Securing IPv6 Networks
- IPv6 Performance Considerations

Laboratory Exercises

Labs were conducted on equipment located on campus. Equipment is accessible to students anywhere with an Internet connection via secure shell (port 22) through an access server running custom scheduling software. A standard lab topology as shown below was used. This topology allowed for all the flexibility needed to perform all the labs in the course.



Students performed the following hands-on labs

- Basic IPv6 routing on Cisco 2800 platform and use IPv6 show commands to verify
- Stateless autoconfiguration to dynamically assign IPv6 addresses to hosts
- Stateful DHCP for IPv6 to configure IPv6 hosts
- Manually configured tunnels between IPv6 hosts across an IPv4 network
- ISATAP tunnels with Windows XP IPv6 hosts across a Cisco IPv4 network
- Configure NAT-PT to enable IPv6 only hosts to communicate with IPv4 only hosts
- Configure routing protocols such as RIPng, EIGRP for IPv6, OSPFv3, and ISIS for IPv6
- IPv6 access control lists
- Secure router-to-router communication with IPv6 IPsec
- Configuring IPv6 routing on Linux Fedora machines running the Quagga routing suite

Further details on the lab configurations and the remote access tools used for this course are covered in a separate paper; Teaching a Laboratory Based IPv6 Course in a Distance Education Environment submitted by the authors.

Student research papers

Each student was required to write a research paper. Papers were submitted in standard IEEE conference paper format. Grading was done by panel of faculty and by student peers.

Papers submitted by students covered the following topics.

- IP Upgrade – An Engineering Exercise or a Necessity?
- IPv6 and wireless networks
- IPv6, Windows XP and 6to4 tunneling
- Performance testing using Spirent Smartbits and Smart Flow software.
- IPv6 Worldwide Adoption Trends
- IPv6 Practical Information
- IPv6 Security Issues

Post Course Feedback

At the end of the course an audit was performed on its success and the lessons learned. From this stemmed suggestions for future lab enhancement that included integrating other IPv6 enabled platforms into the labs such as, Linux-based networking devices, Quaga, and Windows Vista.

The use of a specialized test tools for traffic generation will allow experiments in router forwarding performance and network convergence performance on dual-stacked network equipment. Data gathered in these experiments may be beneficial to companies needing to incorporate IPv6 into their current IPv4 networks. This type of work will add a new, practical dimension to IPv6 related courses and would open research opportunities for students.

In addition, a post-course survey was give to the students. Students were asked a variety of questions concerning IPv6. The results of the survey found that more than 90% of students worked of organizations that are not using IPv6 and have no formal plan for upgrading at this time.

Conclusions

The course was successful in it's objective of using existing infrastructure and resources to teach a course in IPv6 that included not just theory, but gave hands-on practical experience to the students.

Due to the success of this pilot course and demand by students for more IPv6 exposure, another course has been scheduled for the Spring 2007 semester. This class will also be offered distance education.

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