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COMPARISON OF THE PERFORMANCE OF IPV4 & IPV6

The performance issues, associated with converting an IPv4 network to an IPv6 network, were discovered. To eliminate the uncertainties related to the Internet performance a set of experiments was conducted in the laboratory network to compare the delays experienced by packets traversing IPv4 network, IPv4 network with NAT, IPv6 network and mixed networks with utilizing tunnels. Very significant variations in the delays were found when using anything other than an IPv4 network.

***Key words**: internet-protocol, IPv4 address exhaustion, IPv6, IPv4 tunnels, IPv6 tunnels, NAT, network performance.*

Досліджено проблеми продуктивності, пов'язані з переходом від IPv4-мереж до IPv6-мереж. Для усунення невизначеностей, пов'язаних із впливом різних типів мереж на продуктивність мережі Інтернет, у лабораторних умовах була проведена серія експериментів, щоб порівняти затримки, що виникають при транспортуванні пакетів в IPv4-мережі, IPv4-мережі з використанням NAT, IPv6-мережі, а також змішаних мережах, які здійснюють передачу пакетів за допомогою технології статичного тунелювання. При використанні не IPv4-мереж були виявлені значні варіації в затримках.

***Ключові слова**: інтернет-протокол, вичерпання IPv4 адрес, IPv6, IPv4 тунелі, IPv6 тунелі, NAT, продуктивність мережі.*

Исследованы проблемы производительности, связанные с переходом от IPv4-сетей на IPv6-сети. Для устранения неопределённостей, связанных с влиянием различных типов сетей на производительность сети Интернет, в лабораторных условиях была проведена серия экспериментов, чтобы сравнить задержки, возникающие при транспортировке пакетов в IPv4-сети, IPv4-сети с использованием NAT, IPv6-сети, а также смешанных сетях, осуществляющих передачу пакетов при помощи технологии статического тунелирования. При использовании не IPv4-сетей были обнаружены значительные вариации в задержках.

***Ключевые слова**: интернет-протокол, исчерпание IPv4 адресов, IPv6, IPv4 туннели, IPv6 туннели, NAT, производительность сети.*

Introduction. The problem of IPv4 address exhaustion is a well known problem that first appeared in the 1980s due to a large unexpected increase in the number of Internet users. The problem has been exasperated by the rate of take up of the internet in developing countries, the introduction of smart mobile devices that are capable of accessing the Internet using IP addresses and virtualization technology. Despite the use of various technologies to mitigate the problem, such as CIDR and NAT, in April 2011 the first Regional Internet Registry (RIR) for the Asia/Pacific Region (APNIC) exhausted its pool of allocated addresses [1]. Additionally RIPE (Réseaux IP Européens) the European RIR ran out of addresses in September 2012. It is predicted that the American Registry for Internet Numbers (ARIN) region will run out of addresses by January 2014. Figure 1 shows the rate of allocation of IPv4 addresses. So dealing with this problem has become high priority in many countries worldwide. IPv6, a new version of the IP protocol, was developed to solve this problem. To highlight the importance of the change from IPv4 to IPv6 a launch test day was announced "Happy World IPv6 Launch Day (June 6, 2012)" to encourage users to test their IPv6 Connections. The main advantage of the IPv6 is the bigger address field, 128 bytes. It allows creation of larger number of the IP addresses [2].

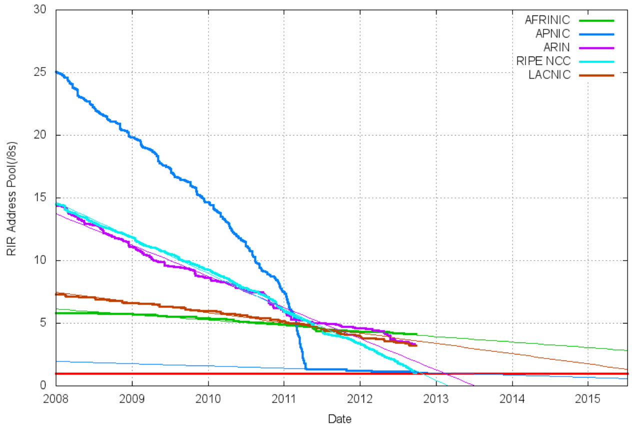

Fig. 1. IPv4 Address exhaustion

However, it is not possible to complete transition from IPv4 to IPv6 addressing in one simple upgrade due mainly to the number of hosts, servers and infrastructure devices that make up the Internet. Coordinating this change is a massive task so this means that both IPv4 and IPV6 protocols will be exist simultaneously on the Internet [3]. Since this will require converting IPv4 packets to IPv6 packets and vice versa it is likely that there will be an effect on the overall performance of the Internet. This paper investigates the performance issues associated with running both protocols at the same time. Investigations will be conducted on both IPv4 and IPv6 networks and in the use of tunneling through the network.

Related work. Despite the fact that the IPv6 protocol has existed for more than 10 years, there are not many academic papers investigating the performance issues between the different networks types. This is a short review of the work.

In 2003 Zeadally et al. performed the series of experiments to discover the performance of IPv4/IPv6 on Windows 2000, Solaris 8 and RedHat 7.3 Operating Systems. [4][5] The papers considered the CPU utilization, latency and throughput of the Operating systems. The main feature of current research is the investigation with both TCP and UDP protocols. Their findings were that there was only a small effect on the performance of the Operating systems with IPv4 and IPv6 networks. A similar set of the experiments to discover IPv4 and IPv6 performance was conducted in 2007 in the Central University of Venezuela [6]. Gamess and Morales conducted the experiments with point-to-point connection using two identical PCs to discover the performance of IPv6 and IPv4 on such operating systems as Windows XP SP2, Solaris 10, and Debian 3.1, for IPv4 and IPv6. The comparison was carried out on the throughput of TCP and UDP protocols. The results of the experiments presented, that a greater throughput was obtained using IPv4 in both UDP and TCP variants than IPv6 [7].

In 2007 in the Chinese University of Hong Kong the performance of the tunneling was investigated by Law et al. [8]. Experiments were conducted over a 6 month period using 7 IPv6/IPv4 dual-stack machines running Windows XP and Fedora Core 5. The results showed that of the 10,534 hosts randomly chosen only 2,014 were reachable from both IPv4 and IPv6. As a result it was concluded that the Windows-based clients using IPv6 showed much lower performance than Unix-based clients. The effect of tunneling IPv6 and native IPv6 are very similar.

Arthur Berger conducted a set of experiments in 2011 to discover the performance of the IPv4 and IPv6 networks [9]. Measurements of the performance of the tunneled networks compared to the native networks was also performed. Another important feature of this investigation was the analysis by geographical areas. The results of the current research showed that the performance of the tunneled network was higher than that of the native IPv6 network.

Research work presented in this paper concentrates on the performance of the network and the infrastructure devices rather than the Operating Systems of the host machines. For these tests Cisco 2600 series routers were used with and advanced IOS Operating system necessary for the support of IPv6.

Investigations. When considering performance of networks there are many variables to be considered however to make results meaningful it is necessary to eliminate some of these variables by keeping them constant. The performance of the IPv4, IPv6 and mixed networks was evaluated using delays caused by the network components.

Laboratory network. This was carried out in laboratory conditions to eliminate the uncertainties due to the Internet variations. A network was built based on the topology covered in the paper Principles of Eliminating Access Control Lists [10]. Results obtained were then extrapolated to the real network. The structure of the used network can be seen in figure 2.

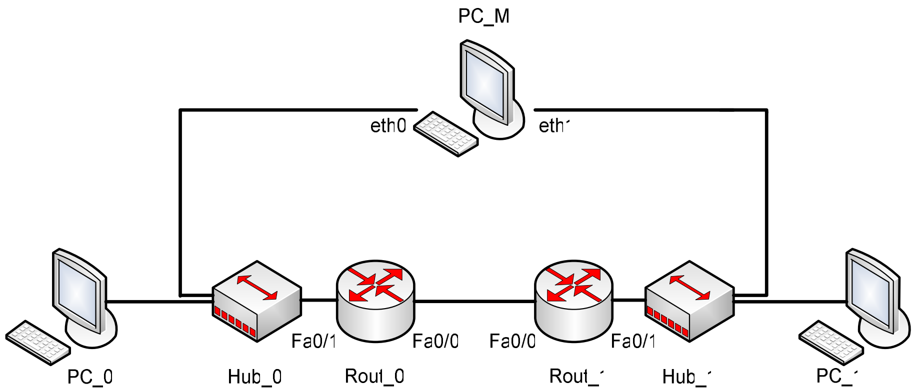

Fig. 2. Network, used in the investigation

Network traffic was generated by the use of the ping utility which sends ICMP Request packets from PC_0 to PC_1 and receives ICMP packets back from PC_1. These packets are captured using the Wireshark utility run on a dual ported Linux machine PC_M. This is quite a unique technique to use since it ensures that time values obtained from either side of the network are synchronized. An initial experiment was conducted to identify the accuracy of the measurements and the delay, which theoretically should be 0 µs but in reality was on average 6 µs. This would be the error bar for the all the results obtained in the work. Statistical parameters such as minimum, maximum, average, mode and standard deviation were used for comparison.

IPv4, NAT and IPv6 tests. All tests were carried out using the same equipment the only difference being the configurations of the router to support the native protocols. As part of the initiative to save IPv4 addresses Network Address Translation (NAT) with private IPv4 Addresses is standard practice in most networks with Internet connectivity. So to make an initial comparison of the basic delays experienced by packets in the network experiments were carried out with IPv4 native network and IPv4 network with NAT enabled and IPv6 native. Table 1 contains the results obtained.

Table 1

Delay in µs for IPv4, IPv4 with NAT and IPv6 network

	Min	Max	Average	Standard Deviation
IPv4 native network	158	373	256	~33
IPv4 network with NAT	358	634	459	~38
IPv6 native network	1110	3048	1318	~232

It can be seen that there is a significant difference between the delay when using IPv4 with NAT and IPv6 networks. Based on the average values the delay in an IPv4 network with NAT are approx. 80 % longer than for the IPv4 native network. Additionally when using a native IPv6 network the difference in the average delay over values, is around 415 %.

Delays were obtained from the times collected in PC_M, Fig 1, using (Teth1 – Teth0). These results were also analyzed using a histogram process and plotted in Fig 3. This makes the comparison to be more easily seen. The x-axis is delay in μs and y-axis is the number of times this value was obtained, 1000 packets were analysed for each network configuration.

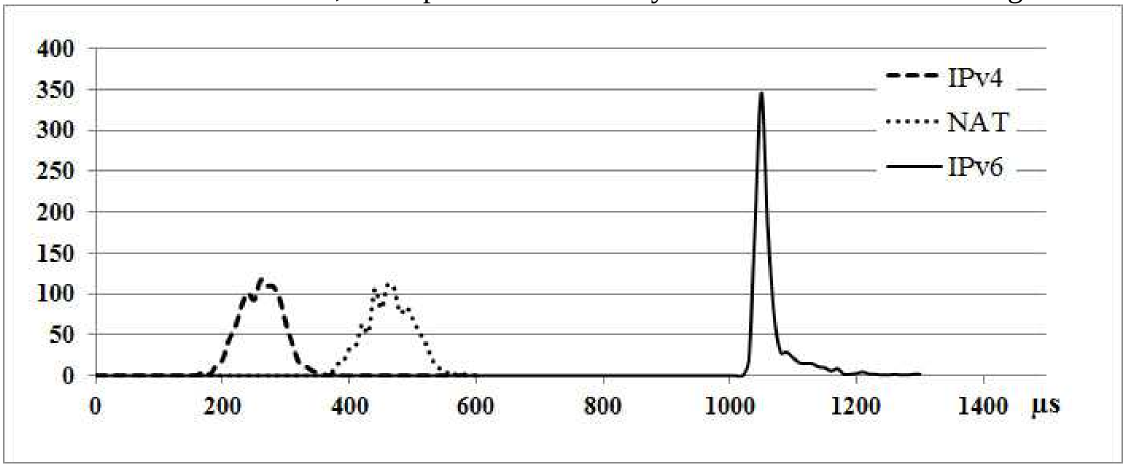

Fig. 3. Comparison of the delay for IPv4, IPv4 with NAT and IPv6

It has been clearly demonstrated that there is an increase in delay when NAT or IPv6 networks are configured.

Performance of IPv4 and IPv6 networks using tunnels. As discussed previously, it is not practical to convert the network in easily so both IPv4 and IPv6 protocols will exist on the same network. Further investigation were conducted to determinate the performance of a networks that contained a mixture of IPv4 and IPv6 protocols. All tests were carried out using the same equipment the only difference being the configurations of tunnels between the routers. In the first set of tests the protocol used was either IPv4 or IPv6 however, these tests use the static tunnel functionality provide in routers. Initially the routers were configured to accept IPv6 packets then pass them through an IPv4 tunnel before being converted back to IPv6 packets referred to as IPv6-IPv4-IPv6 mixed network in table 2. Following this IPv4 packets were passed through an IPv6 tunnel, these are referred to as IPv4-IPv6-IPv4 mixed network in table 2.

Table 2

Delay in μs for IPv4 and IPv6 tunneled networks

	Min	Max	Average	Standard Deviation
IPv6-IPv4-IPv6 mixed network	1952	3369	2131	~166
IPv4-IPv6-IPv4 mixed network	2189	6319	2459	~243

This shows that the IPv4-IPv6-IPv4 network has the largest delay and when compared with an IPv4 network the delay is increased by more than 850 %.

A histogram of the results has been plotted in figure 4 from which it can be clearly seen that the IPv4 network has the best performance.

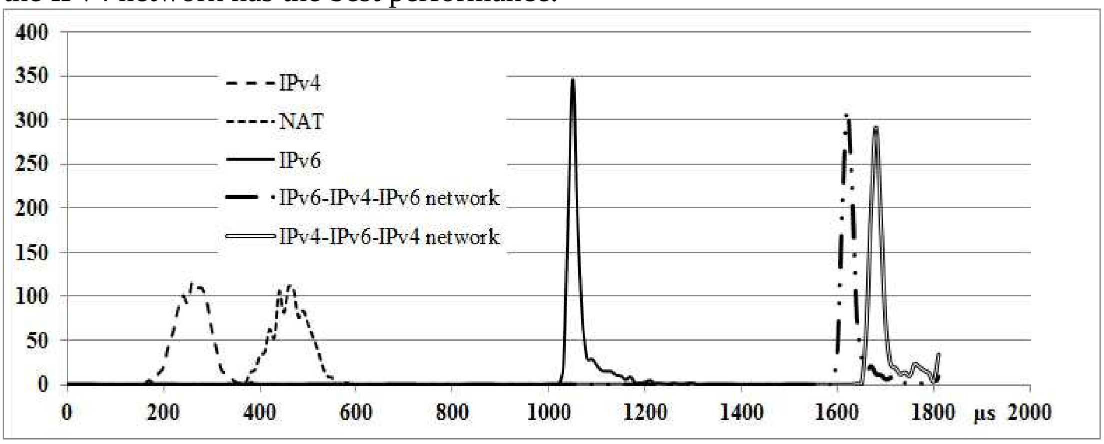

Fig. 4. Delays for Ipv4, IPv6 and tunnel networks

All the technologies designed to solve the problem of the IPv4 addresses space exhaustion impact on the network performance. In fact there is a significant difference between the performances of the different network types. Even the IPv6 native network creates five times longer delay, than IPv4 native network and almost 3 times longer delay than IPv4 network with NAT.

Conclusions. IPv4 address space exhaustion is a very important problem that can no longer be forgotten about. Several technologies, such as NAT, were proposed to solve this, but only the replacement of the old IPv4 version of the IP protocol by the new IPv6 version can completely solve the problem. Converting networks to use the IPv6 protocol involves reconfiguring or replacing every device in the network infrastructure, as well as the servers and host devices. So carrying out this upgrade has to be carried out as a phased project due to the sheer number of devices involved. Hence IPv6 networks and IPv4 network will have to operate simultaneously for the foreseeable future. To accommodate this tunneling technologies are used. All the present technologies and networks will allow the networks to work in the new concurrently but there are performance issues associated with using these conversion techniques.

By carrying out experiments in a laboratory conditions this investigation show that each attempt to deal with the address problem requires the network to be modified and results in increased network delays. Due to the variations in the times that are taken to handle the packets statistical techniques have been used to analyze the data. Average delays for the networks have been calculated and are used as an indication of the typical delay.

The average delay through the IPv4 native network was found to be 256 microseconds and that when using IPv4 network with NAT is almost twice longer, 459 microseconds. However when IPv6 is used in the network the delay is increased to 1318 microseconds, which is 5 times longer than for IPv4. So converting an IPv4 network to a IPv6 network with present routers and Operating systems will have an adverse effect on the performance and hence a great deal of consideration needs to be given before taking this step.

Due to the requirement that IPv4 and IPv6 would have to coexist on the network then a consideration has to be given to the performance of tunnels. These investigations show that this scenario produces the worst performance. A mixed IPv6-IPv4-IPv6 network with static tunnel creates the average delay of 2131 microseconds, and the mixed IPv4-IPv6-IPv4 network with static tunnel creates the average delay of 2460 microseconds. Table 3 shows the % by which the average delay through the network, in Figure 1, is increased above that of an IPv4 network.

Table 3

Comparison of % increase in delay above IPv4 network

	Compared to IPv4 network
IPv4 network with NAT	>80%
IPv6 native network	>415%
IPv6-IPv4-IPv6 mixed network	>730%
IPv4-IPv6-IPv4 mixed network	>850%

Finally it can be concluded that unless it is absolutely necessary then converting from an IPv4 to an IPv6 network utilizing the present equipment is not recommended.

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