Performance Analysis of Video Conferencing over Various IPv4/IPv6 Transition Mechanisms

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Summary
IPv6, the new version of the Internet Protocol IP developed by the Internet Engineering Task Force (IETF), has many advantages, including addressing, auto-configuration, mobility, quality of service, and security. In addition, the network infrastructure and the majority of Internet services are currently available on IPv4, and therefore it is impossible to migrate from IPv4 to IPv6 in a single day. IPv4 and IPv6 have to coexist for a long time, and the deployment of IPv6 can only be done gradually. Several transition mechanisms were developed and can be used for this reason. This research examines and evaluates three transition mechanisms, namely the dual stack, the manual tunnel, and the 6to4 automatic tunnel on a real-time application (video conferencing) using the network simulator OPNET Modeler. Performance parameters such as delay, delay variation, and packet loss are measured for these transition mechanisms. This research showed that the dual stack transition mechanism gave better network performance than the tunneling mechanisms.

Key words:
Dual stack, Manual tunnel, 6to4, Performance evaluation, OPNET, Video conferencing.

1. Introduction

IP version 4 [1] is the dominant version for several years, but lately, it has experienced a number of limitations, including address space given the exponential growth of the Internet size and the number of devices currently connected. IPv6 [2], the new version of the protocol, has not only addressed all the issues related to its predecessor. But it has also added numerous new functions essential for the complex network environment of today, including the auto-configuration, a huge address space of 128 bits instead of 32 bits in IPv4, a better bandwidth management using multicast and anycast, a better quality of service support for all applications, in mobility, and an integrated security by default. In addition, the network infrastructure is currently still in IPv4, and therefore the transition to IPv6 is not an overnight project. The deployment of IPv6 can only be done gradually and step by step. For this reason, the IETF has put in place several transition mechanisms that represent interim solutions awaiting the migration to IPv6.
In this research paper, three IPv4/IPv6 transition mechanisms were examined, namely: the dual stack, the manual tunnel, and the 6to4 automatic tunnel. These mechanisms were evaluated on a network infrastructure of simulation under OPNET Modeler using a real-time application (video conferencing).
The obtained results were compared to those of native IPv4 and IPv6 networks. The comparative analysis of the simulation results is about different parameters such as delay, delay variation, and packet loss. The rest of the document is organized as follows. Section 2 will discuss an overview of IPv4/IPv6 transition mechanisms and their classification. Section 3 will present a state of the art of research work performed in this field. The simulation scenarios for the selected IPv4/IPv6 transition mechanisms will be described in section 4. The results of the simulation and the comparative analysis will be discussed in section 5. Section 6 will describe a global discussion of simulation results. The conclusions and perspectives will be presented in the final section of this paper.

2. IPv4/IPv6 Transition Mechanisms

Transition mechanisms represent techniques allowing to connect hosts/networks using identical or different IP protocols. Several transition techniques were developed and can be used for this reason. These techniques can be classified into three main families: Dual stack, Tunneling, and Translation.

2.1 Dual-Stack

Dual stack [3] is a simple mechanism to set up and is considered the favorite transition technique because it doesn't involve any tunneling mechanism or address translation. This mechanism includes two stacks of IPv4 and IPv6 protocols working in parallel and side-by-side on the same infrastructure and on all equipment connected to the network: computer, router, server, etc.

2.2 Tunneling

Tunneling mechanisms [4] are techniques in which one protocol is encapsulated in another protocol according to the network where the packet has to be routed. Several

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tunneling mechanisms can be used for this reason, and according to their configuration, they can be classified into manual and automatic tunnels.

Manual Tunneling

The manual tunnel [3; 4], also called static tunnel, is a point-to-point tunnel used to allow IPv6 hosts/sites to communicate between them by encapsulating IPv6 packets in IPv4 packets (Protocol v4 number 41) and route them through IPv4 routing infrastructures. Both ends of the tunnel have to be dual stack nodes and configured manually. The node that is performing the tunnel has configuration information that determines the endpoint address of the tunnel. Once the IPv6 packet arrived at the endpoint of the tunnel, it will be decapsulated and then transmit to its destination.

Automatic Tunneling

Automatic tunnels [3] are point-to-multipoint tunnels in which nodes that are performing the tunnel have to be dual stack nodes and affected by IPv6 IPv4-compatible addresses where the IPv4 address of the tunnel endpoint is integrated into the IPv6 IPv4-compatible address. Several automatic tunnels can be used: IPv6 automatic IPv4-compatible tunnel [4], 6to4 [3 ; 4], ISATAP [5; 6], etc.

2.3 Translation

Translation mechanisms [7] were developed for communication between IPv4 and IPv6 hosts/applications. Here, the translation means that a peripheral on the network converts IPv4 packets in IPv6 packets and vice versa. The peripheral has to be able to perform this translation in both directions in order that the bidirectional communication between the end hosts is possible. Several mechanisms can be used for this reason: NAT-PT/DNS-PT [8], NAT64 [9]/DNS64 [10], etc.

3. Related Works

The subject of the translation to IPv6 is discussed for years given the limited address space problem in IPv4 because of the exponential growth of Internet size and number of connected equipment at the current time. In the first instance, we performed a comparative study of the mechanisms of transition from IPv4 to IPv6 [11] in which the mechanisms were classified into three families (Dual stack, Tunneling, and Translation), describing, for each of them, the concerned mechanisms, their principles of working, their field of use, their advantages, and their disadvantages. In the second instance, we focused on studying the performance of these mechanisms. Studies were conducted in this direction. Here are some of them.

Chuangchunsong and his colleagues evaluated the performance of three transition mechanisms, which are 4over6, DS-Lite, and 4rd [12] in terms of delay and reliability. Consequently, this work showed that the technique 4rd gave high performance and reliability compared to other tested mechanisms. The authors Narayan and Tauch, for their part, realized a performance evaluation of two transition mechanisms: configured tunnel and 6to4 [13]. The evaluation was realized on two versions of Windows (Windows server 2003 and 2008) using two kinds of traffic: TCP and UDP. The obtained results showed that the throughput and jitter values for both mechanisms and for both types of traffic (TCP and UDP) are similar. On the contrary, the delay values are different and depend on the choice of the mechanism and the used operating system. In [14], the author Hadiya and his colleagues did the mentioned work in [13] again but on different versions of Windows (Windows Server 2008 and 2012). The obtained results showed that the performance of the two configured transition mechanisms (6to4 and tunnel) are different on the two tested operating systems.

Another performance evaluation of three transition mechanisms (dual stack, 6to4, and NAT-PT) was realized by Hossain and his colleagues in [15] in terms of latency, throughput, and packet loss. Consequently, this work showed that the 6to4 tunneling presents better values compared to other evaluated mechanisms. ISATAP and Teredo are empirically compared on a test design by Aazam and his colleagues [16]. The obtained results showed that ISATAP is better than Teredo. A 6to4 performance evaluation was discussed and compared to IPv4 and IPv6 networks using the VoIP as traffic [17] according to different measurement parameters. Consequently, this work showed that 6to4 mechanisms' performance is higher than IPv4/IPv6 networks.

In fact, the majority of these studies evaluated the performance of some transition mechanisms for given applications or traffics through different parameters. However, according to our research, the study of the impact of packet loss rate and its costs on network performance using real-time applications hasn't been addressed. This fact was a motivation for us to perform this work under OPNET Modeler using video conferencing as a real-time application. It is a question of assessing three transition mechanisms, which are the dual stack, the manual tunnel, and the 6to4 automatic tunnel in terms of three simulation parameters, namely the delay, the delay variation, and the packet loss rate.

4. Simulation Scenarios of IPv4/IPv6 Transition Mechanisms

Our simulation was implemented using the simulation tool Optimized Network Engineering Tool (OPNET) as shown in our simulation network topology represented in Figure 1 below. Two sites IPv6 (A and B) want to communicate between them through an IPv4 backbone. This network topology was configured in five different scenarios. Three transition scenarios (dual stack network, manual tunnel, and 6to4 automatic tunnel) were compared in parallel to two other scenarios (native IPv4 network and native IPv6 network) only if all the entities communicate on IPv4 and IPv6.

In this simulation, we used the version 14.5 of OPNET Modeler to perform simulations on the different selected IPv4/IPv6 transition techniques in which we configured RIPv2 routing on the IPv4 backbone and RIPng routing on IPv6 sites. The real-time application (video conferencing) was used to compare the performance of these mechanisms in terms of delay, delay variation, and packet loss.

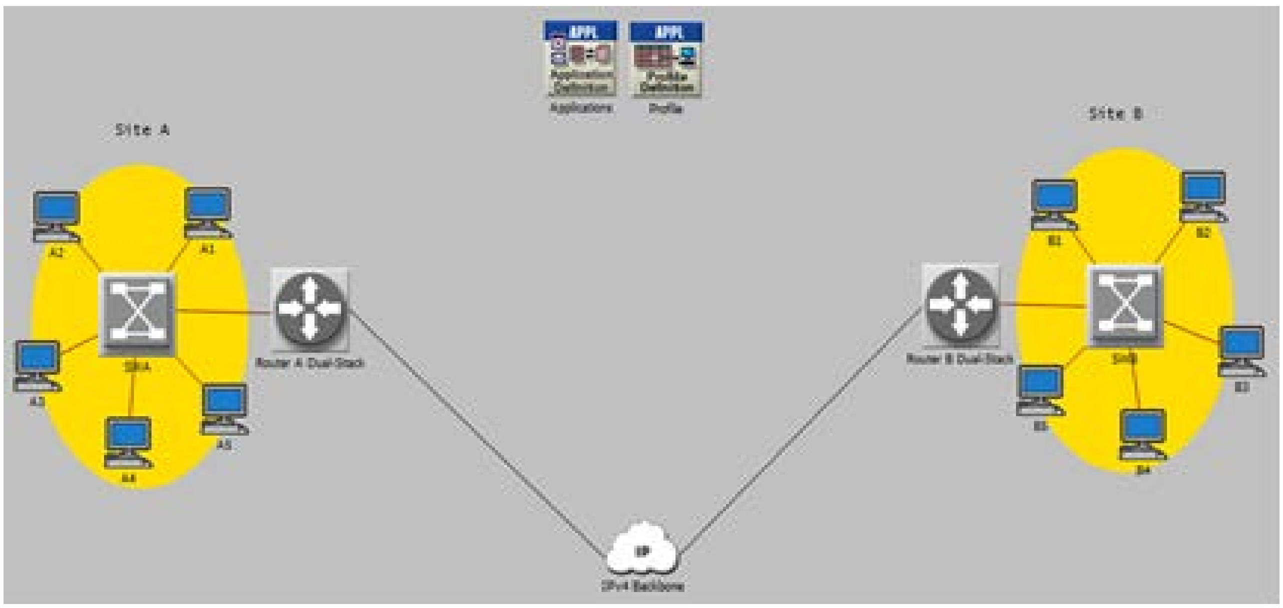

Fig. 1 The typology of simulation network.

5. Simulation Results and Analysis

In this section, we present the simulation results analyzing and comparing the five scenarios. In this simulation, the average values were monitored from the results viewer of OPNET and exported to Excel in order to draw area graphs for comparison purposes.

5.1 Video Conferencing Packet End-to-End Delay

This parameter represents the end-to-end delay that is measured between the moment when a video packet is created and sent from a source until it is received at its destination on both sites going through the IPv4 backbone.

The Video Conferencing Packet End-to-End Delay was monitored for the five proposed scenarios and the results were represented in Figure 2 below.

Comparisons between transition mechanisms regarding the Video Conferencing Packet End-to-End Delay indicate that the dual stack is better than the two other IPv4/IPv6 transition mechanisms with an average delay value of about 9.7 ms for the dual stack compared to 12.2 ms and 14 ms for the 6to4 tunnel and the manual tunnel. That is due to the delay caused by encapsulation and decapsulation processes in the tunneling mechanisms whereas, in the dual stack, both protocols work simultaneously without involving neither encapsulation nor decapsulation. The comparison between the two protocols related to the same criterion indicates that IPv4 has better performance than IPv6. Indeed, IPv4 presents an average delay value of about 6.3 ms compared to 8 ms for IPv6. That is due to the IPv6 header length, which is higher than the one of IPv4.

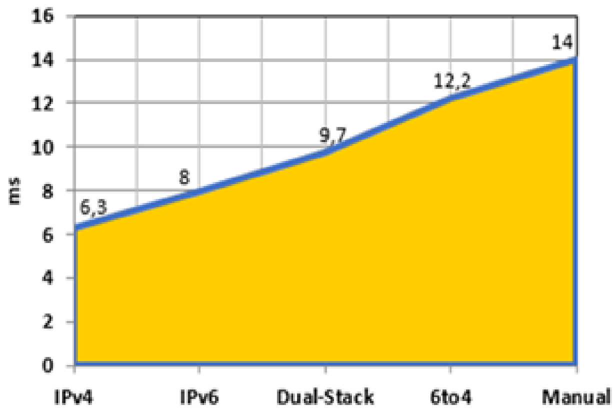

Fig. 2 Video Conferencing Packet End-to-End Delay.

5.2 Video Conferencing Packet Delay Variation

It is the End-to-End delay variation for the selected video packets. This measure has a significant impact on appreciating the quality of video conferencing applications. The best value is the one closest to zero. The average values of Video Conferencing Packet Delay Variation were monitored, and the results were represented in Figure 3 below.

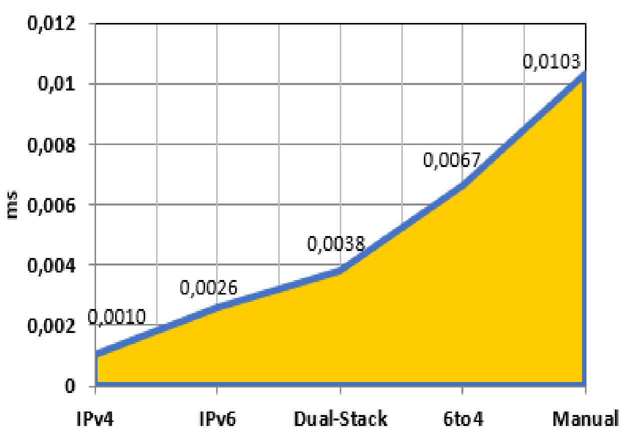

Fig. 3 Video Conferencing Packet Delay Variation.

From Figure 3, it is clear that the dual stack is more efficient than the manual and 6to4 tunneling mechanisms. Indeed, it presents a lower value in terms of Video Conferencing Packet Delay Variation than tunneling mechanisms. The comparison between the two protocols showed that IPv4 provides a lower delay variation than IPv6. It indicates that IPv4 offers a better quality regarding video conferencing applications compared to IPv6.

5.3 Packets Loss Rate

Packet loss occurs when one or more packets of data circulating on a network don't reach their destination. Packet loss is usually caused by network congestion. That is the number of lost packets in percent compared to sent packets. The results of the measured packet loss rate for the five proposed scenarios are represented in Figure 4 below.

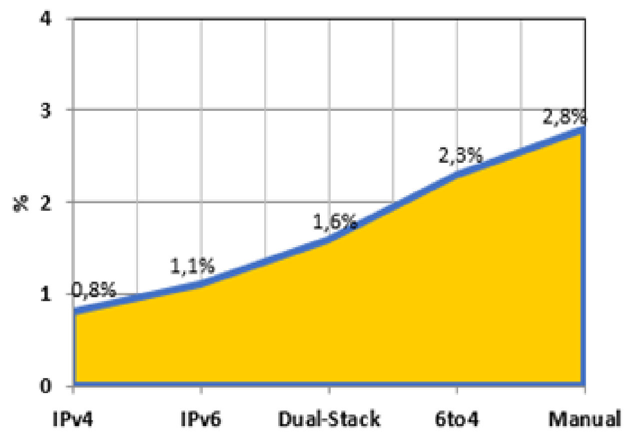

Fig. 4 Video Conferencing Packets Loss Rate.

These results show that the packet loss rates of the manual and 6to4 tunneling mechanisms are higher than the one of the dual stack: indeed, we observe a loss rate of about 2.3% and 2.8% for 6to4 and manual tunneling mechanisms compared to 1.6% for the dual stack. That is due to encapsulation/decapsulation processes of IPv6 packets encapsulated in IPv4 packets by tunneling mechanisms. IPv4 presents a lower loss rate than IPv6.

6. Discussion

Our simulation was conducted on the basis of five scenarios using the OPNET Modeler tool. Three transition scenarios (dual stack network, manual tunnel, and 6to4 automatic tunnel) were compared in parallel to two other scenarios (native IPv4 network and native IPv6 network) on a real-time application (video conferencing) in terms of delay, delay variation, and packet loss.

According to our simulation results, the dual stack mechanism presents better performance than the tunneling mechanisms given in the dual stack the two protocols work simultaneously without involving neither encapsulation nor decapsulation. Furthermore, this mechanism requires that all network peripherals support both protocols (IPv4 and IPv6). In addition, it is necessary to configure each router present in the network with the IPv4 and IPv6 protocols.

Consequently, this transition mechanism can be deployed in a small network.

Regarding the performance of the two studied tunneling mechanisms (6to4 automatic tunnel and manual tunnel), the results are not very satisfactory and it can be explained by the encapsulation/decapsulation processes brought into play. However, according to their uses, the tunneling mechanisms are a good choice for the networks whose peripherals don't support IPv6 yet. In addition, they can be deployed in a very large network with a large number of routers where it is just necessary to configure both ends of the network with IPv4 and IPv6 protocols.

Regarding the performance of IPv4 protocol and IPv6 protocol, the results showed that IPv4 is more efficient than IPv6. In fact, the IPv6 protocol presents a higher delay than IPv4 because of its header length, which is twice the one of IPv4. However, the IPv6 protocol has several advantages such as the address space extended to 2128, security integrated by default, auto-configuration and other advantages in mobility.

7. Conclusions and Perspectives

In this article, we conducted a performance evaluation of IPv4/IPv6 transition mechanisms. Three transition scenarios (dual stack network, manual tunnel, and 6to4 automatic tunnel) were compared in parallel to two other scenarios (native IPv4 network and native IPv6 network). We studied their performance in terms of delay, delay variation, and packet loss in the case of real-time application of video conferencing. The obtained results showed that the dual stack mechanism gave better performance than the tunneling mechanisms (manual tunnel and 6to4 automatic tunnel). That is due to encapsulation and decapsulation processes in the tunneling mechanisms whereas, in the dual stack, both protocols work simultaneously without involving neither encapsulation nor decapsulation. For the comparison between the protocols (IPv4 and IPv6), IPv4 was more efficient than IPv6. This difference is due to the IPv6 header length, which is higher than the one of IPv4.

Our future studies will focus on an experimental evaluation of IPv4/IPv6 transition mechanisms by adding other mechanisms and studying their performance for various types of applications.

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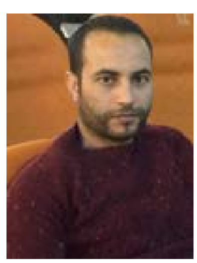

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