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- Sharma T., Kwatra, G. (2008) Effectiveness of Social Advertising: A Study of Selected Campaigns, Corporate Social Responsibility, Edited by David Crowther & Nicholas Capaldi, Ashgate Research Companion to Corporate Social Responsibility, Chapter 15, pp 287-303.

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- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

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ISSUES RELATING TRANSITION IPv4 TO IPv6 IN INDIA

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ABSTRACT

Although there appears to have been increased interest in routing IPv6 over the public Internet since mid 2007, the adoption and deployment of IPv6 has been relatively limited. The issues relating to IPv4-to-IPv6 migration will be re-addressed, from where respective solutions will be proposed along with decision-making guidelines. This article does not focus on IPv6's contribution to wireless and mobile networks; attention is placed on its deployment in the Internet backbone and enterprise networks. The findings aim to evaluate the needs and requirements of IPv6 in order to ascertain the extent to which it can be made common place.

KEYWORDS

IPv4 to IPv6 Transition, IPv6 Deployment, Migration Strategy.

1. INTRODUCTION

The IPv4 protocol was created in 1981 like a technology supposed to last for a very long time, with an addressing space of 4000 millions of addresses, but the enormous growth of the internet and the way the addresses were assigned (classes A, B and C), resulted in a serious lack of addresses. There are several methods that avoid the total run out of addresses: PPP/DHCP (address sharing), CIDR (classless inter-domain routing) and NAT (network address translation), but do not seem to be enough in a few years, specially having into account the growing number of devices that need a permanent allocation of an IP address (UMTS, DSL, etc), and the applications that are end-to-end, and are not compatible with NAT (IPsec, VoIP, etc.).

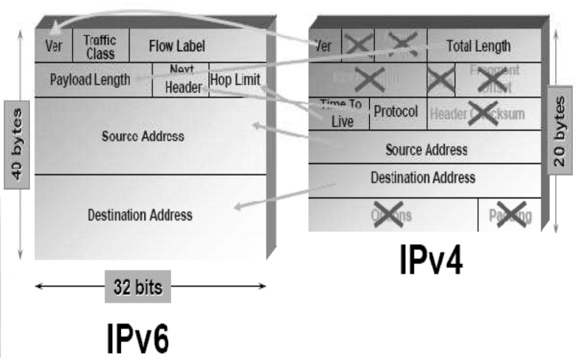
Another problem is that, because of being designed many years ago, the funcionalities involved with security, mobility and quality are handled by additional protocols, because they are not integrated in the protocol itself. So, these 2 problems, plus the fact of the great growth of the number of elements in the routing tables motivated the necessity of a new version of the protocol became very important, so a new working group of the Internet Engineering Task Force (IETF) was created with the name: "IP next generation" (IPng). And some time later, the name was changed to IPv6. The main characteristics of this protocol had to be the following:

- Larger addressing space, structured addresses and no addresses classes.
- Automatic configuration.
- Simplified routing.
- Better structuring options for the networks.
- Improved security features.
- Support for real-time and multimedia Services.

In this paper will be explained the main characteristics of IPv6, as well as the differences between both protocols, and the mechanisms to migrate nowadays networks form IPv4 to IPv6. After this, we will see the some conclusions about the existence of both protocols and the implications that this has in the way the internet works.

2. ELEMENTS OF IPv6

FIGURE 2.1: COMPARISON OF IPv4 AND IPv6 HEADERS



The differences between the headers of IPv6 and IPv4 can be observed in the *figure 2.1:*

- The length of the header is enlarged from 20 bytes (IPv4) to 40 bytes (IPv6).
- The number of bytes of each IP address in the header also increases, as IPv4 has 4 bytes for each address, and IPv6 has addresses of 16 bytes, what means that a very great part of the whole header is only used to represent the IP addresses.
- The number of header fields is reduced from 12 to 8.
- The options field is disappears from the base header, so the header length field is no longer needed, as the header will always have the same length.

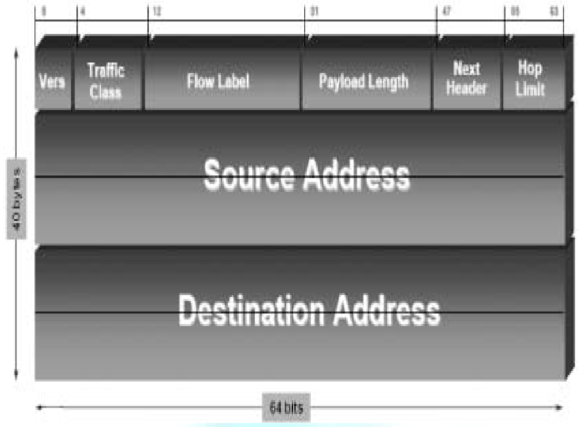
The reason why the number of fields is decreased is the unnecessary redundancy, because, for example, the checksum , whose mission is ensure the integrity of the header, is also realized by other mechanisms of formation of packets (IEEE 802 MAC, framing PPP, ATM adaptation layer,…). Apart from this, the consequences of having errors in the IP header are not very important, so it is not dangerous to eliminate the checksum field.

The fragment offset header is also eliminated, because in IPv6 the fragmentation of the packets is completely different to the IPv4 fragmentation, what means that this field is absolutely useless. In IPv6 the routers do not fragment/defragment the packets, which can only by done end-to-end.

Instead of having the options field, IPv6 uses the "extension headers" that support more functionalities, and that are added to the main header only if needed. With this, we ensure that the length of the base header will always be the same (40 bytes), what implies a greater facility to be processed by the routers and the switches, even by hardware, what means greater prestations.

2.1 STRUCTURE OF IPv6 HEADER

FIGURE 2.2: IPV6 BASE HEADER



In the case of IPv4, the header fields were aligned to 32 bits, but in IPv6 they are aligned to 64 (*figure 2.2*), what allows that the new generations of processors and microcontrollers of 64 bits can process more efficiently the header.

The header fields and their meanings are the following:

- **Version:** This field indicates what version of IP protocol is being used. Its value will be 6, as we are using IPv6. Its length is 4 bits.
- **Traffic Class:** In this field is indicated what kind of traffic is being dealt and what its priority is. The length of this field is 8 bits. There are 2 types of traffic, in the first type, the user expects an answer in case of congestion (e.g. TCP), and in the second one, in case of congestion, the packets are discarded. For each of these types of traffic there are 8 possible priorities, from 0 to 7, being 7 the highest priority, and 0 the lower.
- **Flow Label:** This label is used when the user needs that the packets are handled by the routers in a special way, as high quality services or real time. Its length is 20 bits. Flow is a group of packets with similar values in their headers that need a special handling.
- **Payload Length:** The value of this label indicates the length in bytes of the data that follows the IP header. Its length is 16 bits, so the maximum size of the packet is 64 Kbytes. If the information is bigger than that, is possible to use an extension header of 32 bits that would allow packets up to 4.3 million bytes.
- **Next Header:** This label indicates the type of extension header that follows the base header. It has a length of 8 bits, and its information is coherent with the value of the field protocol in IPv4, as we see in the following table:

TABLE 2.3: NEXT HEADER VALUES

Next Header	Points to
0	Hop-by-Hop Header
2	Internet Group Management Protocol (IGMP)
6	Transmission Control Protocol (TCP)
8	Transmission Control Protocol (TCP)
9	Interior Gateway Protocol (private) (IGP)
17	User Datagram Protocol (UDP)
41	IPv6 (encapsulated, e.g. for 4to6-Addressing)
43	Routing Header
44	Fragment Header
50	Encapsulating Security Payload (ESP) Header
51	Authentication Header (AH)
58	ICMPv6
59	No Extension Header
60	Destination Option Header
80	ISO Internet Protocol
89	Open Shortest Path First (OSPF)

The marked values are new in IPv6, while the others already existed in IPv4

- **Hop Limit:** This field substitutes the TTL field of IPv4. Its length is 8 bits. This value is decreased in one unit every time the packet is handled by a router, and if it is zero, the packet is discarded.
- **Source and Destination Address:** These fields indicate the IP address of the source and the destination. Each address length is 16 bytes.

2.2 FORMAT OF IPv6 PACKET

FIGURE 2.4: STRUCTURE OF THE IPV6 PACKET

The *figure 2.3* shows the structure of the IPv6 packet. We can see that the format is more homogeneous than the IPv4 one, and the handling of options is improved, as we can use a concrete extension header for each special function we need.

With this structure, there are some advantages if compared to IPv4:

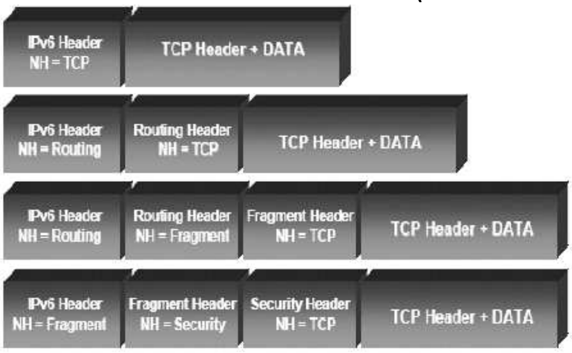
- There is no limit in the number of options we can add to our IP packet.
- Better prestations due to the ordering of the headers:

- Headers processed in routers from left to right.
- Headers processed in destination from right to left.

- Perfect knowledge of behaviour of the system if there are wrong options.

2.3 EXTENSION HEADERS

FIGURE 2.5: EXAMPLES OF COMPLETES IPV6 DATAGRAMS (WITH EXTENSION HEADERS)



In IPv6, the option field of the IPv4 header is substituted by the extension headers, which are added to the datagram between the base header and the upper layer header, as we can see in *Figure 2.4*, and are indicated with a certain value in the next header field of the IPv6 header. A datagram can have no extension headers, one of them, or more than one *[figure 2.4]*.

All the extension headers are processed in the destination, except the hop-by-hop option headers, which contain information that is needed during the routing of the datagram from the source to the destination. This header always follows the base header.

The extension headers are always processed in the order in which they appear, from left to right, to make faster the handling of the datagrams on the routers. Another reason that improves the handling of the IPv6 packets, is that the length of the extension headers is always a multiple of 8 bytes, so that it is aligned in the same way the fields of the base header are.

The different types of extension headers are the following (it is advisable that when there is more than one extension header in a packet, they appear in this order):

- **Hop-by-Hop Option Header:** contains information to be processed by every node that routes the packet to its destination.
- **Destination Option Header:** contains aditional information to be processed by the destination node. If this information is processed by other node, this extension header follows the hop-by-hop header; otherwise, this header is the last one to appear.
- **Routing Header:** is used to indicate certain nodes that the packet has to pass through on its way from the source to the destination. It could define the exact path the datagram has to follow if it contained all the intermediates nodes.
- **Fragment Header:** is used by the source of the packet, to send datagrams whose length is longer than the MTU (Maximum Transmission Unit) of the networks the packet goes through (router sends an ICMP message to the source). While in IPv4 the fragmentation could be done in the routers, in IPv6, the fragmentation can only take place in the source, but the information in this header is the same that in IPv4 (identification, offset and more-fragment-flag).
- **Authentication Header:** is used to ensure the authenticity of the packets (the source node is the right one), the integrity of them (the information was not modified in the intermediate nodes) and to provide protection against the recurrence of packets.
- **Encapsulating Security Payload (ESP) Header:** is used to guarantee the authenticity of the payload only (the authentication header protected the hole packet), but this header is more powerful, as it provides mechanisms for data encryption.

3. CHARACTERISTICS OF IPv6

IPv6 is an evolution of IPv4, not a revolution, as they have many characteristics in common, but, in the case of IPv6, some of them have been improved:

- **Routing:** Hierarchic, based on aggregation of routes, what makes it simpler.
- **Prestations:** Simple header, aligned to 64 bits.
- **Versatility:** Extensible format of options, what means an improved extensibility.
- **Multimedia:** Flows identifier.
- **Multicast:** Is obligatory, and the range control is improved.

Apart from this characteristics, the most interesting, which are reviewed immediately, are mobility, addressing and security and quality of service (QoS).

3.1 MOBILITY

In the last years, there has been an enormous growing of the wireless technologies (e.g. WLAN, Bluetooth, GPRS, UMTS,) and mobile devices (PDAs, laptops,). This implies that there is, among the users, a great interest in being communicated to the internet in a wireless and permanent way. So the goal is to provide connectivity to internet to these wireless devices, and even when they are in movement too.

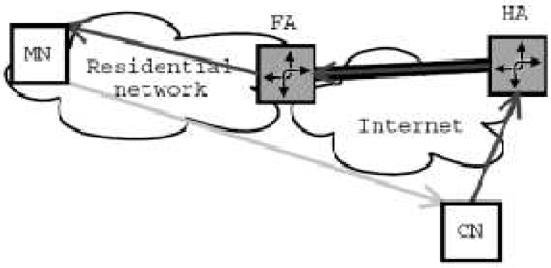
Solving this mobility problem in the network layer provides some benefits:

- The applications do not need to be changed.
- Roaming is provided.
- Allows to connect heterogeneous technologies of the link layer (UMTS, WLAN,).

Having this into account, and after the experience of IPv4, IPv6 provides an improved mobility support, whose mission is providing the mobile users the ability to change the access point, while they keep their network connections. The main advances of MIPv6 compared to MIPv4 are the following:

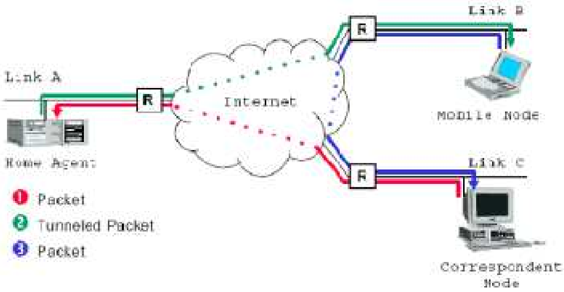
- The mobility problem was taken into account when the IPv6 protocol was being designed, so the mobility support is not an external patch, but it is integrated in the protocol.
- Each foreign agent requires a pool of directions, what means shortage of addresses. IPv6 does not require FA, as the mobile node, with the autoconfiguration mechanism of IPv6, is able to get an address in the foreign network without any external help.
- "Triangle routing" of IPv4 is inefficient (Correspondent node always sends packets to HA, not directly to the mobile node). IPv6 avoids the triangle routing (correspondent node sends packets directly to the mobile node) with the route optimization mechanism.
- IPv4 uses encapsulation for the delivery of packets. In IPv6 the delivery is realized by the Routing Header. The new mechanism reduces overhead.
- Problems with the firewalls avoided.
- Generation of an excessive signalling is no longer needed.
- The handoff time, which deteriorates the communication, is reduced.

FIGURE 3.1: EXAMPLE OF MOBILITY IN IPv4



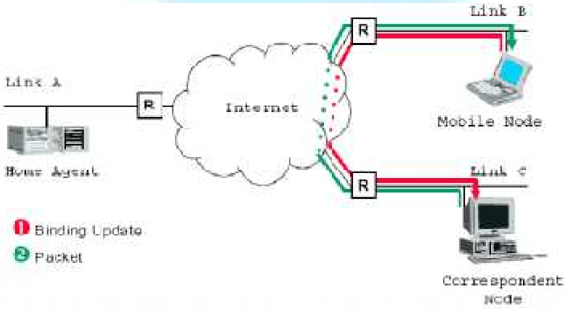
In the *figure 3.1*, we can observe how the communication takes part in IPv4. There is foreign agent, which handles the traffic of the mobile node in the foreign network. We can see the "triangle routing", as all the traffic from the correspondent node has to go through the home agent, and the foreign agent, before reaching the mobile node.

FIGURE 3.2: EXAMPLE OF MOBILITY IN IPv6 WITH TRIANGLE ROUTING



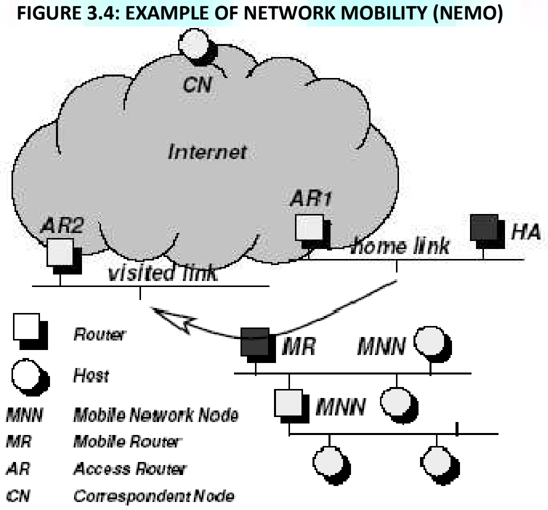
Now, in *figure 3.2* we can see how, in the case of IPv6, there is no foreign agent in the visited network, but there is triangle routing, as the home agent intercepts the traffic from the correspondent node to de mobile node. This problem can be solved using the autoconfiguration mechanism of IPv6.

FIGURE 3.3: EXAMPLE OF MOBILITY IN IPv6 WITH ROUTE OPTIMIZATION



In *figure 3.3* we can see how, using the route optimization, we can route all the messages without the help of the home agent. This is possible because the mobile node sends a binding update message to the correspondent node, so that, the CN is then able to sends packets directly to the MN.

FIGURE 3.4: EXAMPLE OF NETWORK MOBILITY (NEMO)



The main motivation of network mobility is, instead of having many mobile nodes in a network, giving to that network the ability to move, so that, the only mobile element of that network would be the router. In *figure 3.4* is shown the basic way NEMO works: there is a mobile network with its mobile router, and when the mobile networks moves to another situation, the mobile router maintains a tunnel to the home agent of the home network. As the mobile router is the default gateway of the mobile network, all the traffic will be routed through the tunnel to the home agent, and then, once the packets reach the access router of the home network, they would be handled like if the network had not moved from its original network.

3.2 ADDRESSING AND SECURITY

The main point of IPv6 addressing is the 128 bits addresses, which give a wide addressing space (more than 10^{38} addresses). In this case, the addresses are assigned to interfaces, and it is possible that one interface has multiple addresses.

FIGURE 3.5: STRUCTURE OF IPv6 ADDRESS

In the *figure 3.5* is shown the main structure of an IPv6 address, where there is a network prefix, that depends on the topology of the network, and that identifies the network in which the device with that address is connected, and the interface prefix, that identifies a node of that network.

There are 3 different types of IPv6 addresses:

- **Unicast**: identifies a single interface. A packet with an address of this type in the destiny is delivered only to that interface.
- **Multicast**: identifies a set of interfaces. A packet with this address as destiny, is delivered to all the interfaces of the set.
- **Anycast**: identifies also a set of interfaces, but in this case, a packet with this kind of address as destiny, is delivered only to one interface of the set. Usually the next interface, according to the routing protocol.

The main differences between IPv4 and IPv6 addresses are the appearance of the IPv6 anycast addresses, and the disappearance of IPv4 broadcast addresses, that are replaced by the IPv6 multicast addresses.

The **autoconfiguration** is a very important feature of IPv6, as it provides that a node can configurate its address by itself. This characteristic is what allows to say that IPv6 is "plug & play". There are 2 different ways of autoconfiguration in IPv6, the stateless address autoconfiguration, and the stateful autoconfiguration.

1. COMMUNICATION BETWEEN HOSTS IN DIFFERENT PROTOCOL DOMAINS

In the case of the stateless address autoconfiguration, the host does not require any kind of manual configuration, and the routers need only a minimal configuration, or sometimes nothing. The router can create its own address by a combination of information from the routers, and information available locally. The information provided by the routers are the prefixes of the network where the host is connected, and the local information of the router is an interface identifier that, usually, is the MAC address of the interface card. Combining this 2 elements, the IP address is obtained.

With the stateful autoconfiguration, the host obtains the IP addresses of its interfaces from a DHCPv6 server, which has a database with all the addresses that have been assigned to all the interfaces. This kind of autoconfiguration would be like the DHCP protocol of IPv4, but with some improved features.

The **security** in IPv6 is ensured due to the 2 extension headers which are the authentication and the encapsulation security payload (ESP) headers (explained in section 2.3).

While in IPv4, the security was not included in the original protocol itself (IPsec extension), in IPv6, the security is a part of the protocol itself, and provides the same features like IPv4 and IPsec. IPsec is obligatory in IPv6, and provides authentication and encryption in the network layer, what means that is implemented transparently in the network infrastructure. Another important characteristic of IPsec is that it is an end-to-end technology, so in IPv6, with the wide addressing space, it is possible to have secure communications base on the E2E model.

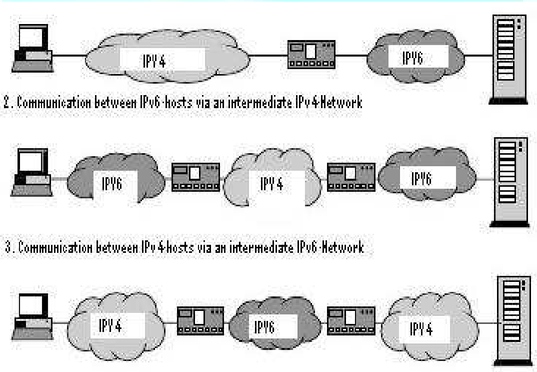
3.3 QUALITY OF SERVICE (QoS)

The quality of service is integrated in IPv6, as there are 2 fields in the base header whose goal is to ensure a certain QoS. These fields are the traffic class, which substitutes the type of service (TOS) field of IPv4, and the flow label, and with them it is possible to give the packets a certain characteristic under the point of view of the QoS (section 2.1).

The goals to achieve by the quality of service mechanisms are:

- Real time applications.
- Less latence and "jitter".
- More tolerance to packet losses.
- Retransmissions are less important.
- More importance of the temporal relationships.

FIGURE 3.6: COMMUNICATION BETWEEN HOSTS.



4. MIGRATION FROM IPv4 TO IPv6

The migration from IPv4 to IPv6 will take a long time, as it is impossible to stop the internet, migrate all the systems and restart all the networks again. So migration will be a slow process (the applications will set the speed or the migration), in which, there will be inter-working and co-existence of both protocols. IPv4 and IPv6 are incompatible, so, in this co-existence of protocols, there will have to be some technics that provide the inter-working of networks and systems using different protocols.

IPv6 has been designed thinking in the migration from IPv4 to it, so although it will be a complicated process because the networks connected are very heterogeneous, and all the elements (hosts, routers, applications, ...) will have to be migrated, there are some tools that will provide the migration. The most important are the following:

-**Double Stack**: works in cases 1, 2 and 3.
-**Tunnels**: works in cases 2 and 3.
-**Translation NAT/PT**: works in all cases, but in 2 and 3 is not recommended

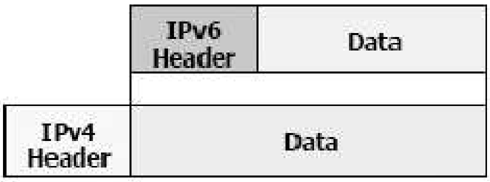
4.1 DOUBLE STACK

In this case, all the routers are able to process both protocols. There are in each router 2 protocol stacks, one for IPv4 and another for IPv6, and depending on the traffic the router is handling, one stack or the other will be uses. This means that the router has 2 routing tables, and for each datagram, 2 routes will be calculated, but only one of them will be the one the packet will follow. In this case, the application will have to know that the routers have a double stack.

4.2 TUNNELS

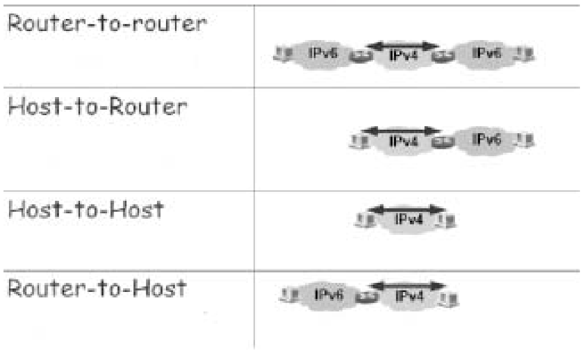
The tunnels are used like a mechanism to transport IPv6 packets through IPv4 networks. The way to do this is encapsulating the IPv6 datagram's in a IPv4 packet, so that the final packet can be handled by the routers of the IPv4 network without problems (*Figure 4.1*).

FIGURE 4.1: TUNNELLING ENCAPSULATING



The tunnels are widely used in nowadays networks. There are several types of tunnels, depending on the systems they interconnect:

FIGURE 4.2: TYPES OF TUNNELS



4.3 TRANSLATION NAT/PT

This technic allows the communication between only-IPv6 and only-IPv4 systems, and it consists in translating the headers of the packets (only the common fields) of IPv6 and IPv4 (*Figure 4.3*).

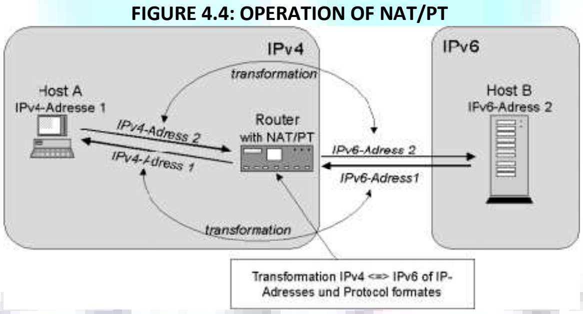
FIGURE 4.3: NAT/PT SCENARIO

This translation of addresses made by NAT/PT has the same problems of the "regular" NAT, as the process is the same:

- Bottle neck, unique failure point.
- Fiability and scalability.
- Limitation of the usable applications, as the E2E communicaton is not possible when using NAT.

Because of all this problems, NAT/PT is not so popular within the internet.

FIGURE 4.4: OPERATION OF NAT/PT



5. CONCLUSIONS

As it has been shown, IPv6 provides solutions to the problems of the growth of internet, specially to the lack of addresses, due to some reasons, like the short number of addresses allocated in the countries of Asia-Pacific, and the existence of many systems that need a permanent allocation of an IP address (3^{rd} generation mobile devices, DSL, modems, etc).

IPv6 also provides funcionalities that improve its behavior in aspects involved with security, mobility, autoconfiguration, ... which are integrated in the protocol itself, not like in the case of IPv4, in which, this funciionalities existed due to the extensions and "patches" added to the protocol.

As the network addressing is no longer needed, in IPv6 the end-to-end communications are possible, what means that we can use many applications that need this funcionality, like IPsec, VoIP, videoconferencing (RTP/RTCP), network gaming, etc. And also IPv6 reduces the complexity of the network administration with features like the addresses autoconfiguration which simplifies the addressing administration, or the elimination of the added funcionality "patches".

Anyway, at the moment IPv6 is only used by universities and by isolated spots, because the internet is such a huge network, and it is very difficult to migrate it all, specially having into account that there are many operators of big networks that prefer to stay in the safe side, or what is the same, operating safely with IPv4: "never touch a running network".

Apart from the fact of the co-existence of IPv4 and IPv6, it also has to be taken into account that there are another protocols that have to be adapted to IPv6 too, for example:

1. ICMPv6 (Internet Control Message Protocol)
2. DNS (Domain Name Service)
3. DHCPv6 (Dynamic Host Configuration Protocol)
4. RIPng for IPv6 (Routing Information Protocol)
5. OSPF for IPv6 (Open Shortest Path First)
6. FTP (File transfer Protocol)

So, because of all this reasons, it will take a long time to migrate the whole internet to IPv6, with all its consequences, as, for example with the migration tool of NAT/PT there are still the same problems of normal NAT, so we will not have all the advantages of IPv6 until the migration stage is finished.

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