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IPv6 transition techniques – dual stack and tunneling

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Abstract

Objectives: IPv6 is to be used largely in the growing internetworks. At present IPv4 is used extensively. Migrating from IPv4 to IPv6 is a challenge, considering many factors like hardware, applications and networks reach ability. This paper explains the drawbacks of IPv4, advantages of IPv6 and migration techniques to IPv6.
Methods/Analysis: GNS3 is a networking simulator. Using this simulation tools, network topologies can be built, and the routers can be configured. Using this GNS3 simulation tool, two topologies are built with IPv4 and IPv6 to coexist, and only IPv4 networks between two IPv6 networks.
Results/Findings: The appropriate migration techniques, dual stack and tunneling were configured in the routers and end results of reach ability were tested.
Applications: IPv6 can be used in many applications like IoT, vehicle tracking, automatic maintenance of building, in health care, remote monitoring, etc.
Keywords: IPv4 address- Internet protocol Address version 4, IPv6 – Internet protocol Address version 6, NAT – Network address translation, IPsec – IP security, QoS, IPv4 header, IPv6 header, Routing table, Routing crisis, Auto-configuration, Dual Stack, Tunneling, DHCP v6, ISP – Internet Service Provider.

1. Introduction

The current IP version is IPv4 which is published in RFC 791.Even today IPv4 is globally extensively used, and it is a very easy to use and sturdy IP version. In internetworks, implementing and using IPv4 is easy. IPv4 also supports interoperability.

2. The need for IPv6

2.1. The Problems of IPv4

Address scarcity - In IPv4, the address is 32 bits long. The number of IPv4 addresses available is 4,294,967,296. With the exponential growth in internet, public IPv4 addressed are exhausted in 2011 itself. The users, service providers and big organizations are using NAT network address translation. NAT is a process in which one public IPv4 address can be mapped to many private IPv4 addresses and vice versa. This helps to some extent to overcome the scarcity of public IP version 4 addresses, in the service provider level and in big organization level. Each network element in a network doesn't need individual private IP address to connect to the internet.

Address Configuration – In the current scenario, in network implementations using IPv4, the network elements are manually configured. In large networks it is done using Dynamic Host Configuration Protocol (DHCP). But the number of computers and network elements are growing day by day. So a solution for automatically configuring the IP addresses is needed which is not possible in IPv4 version.

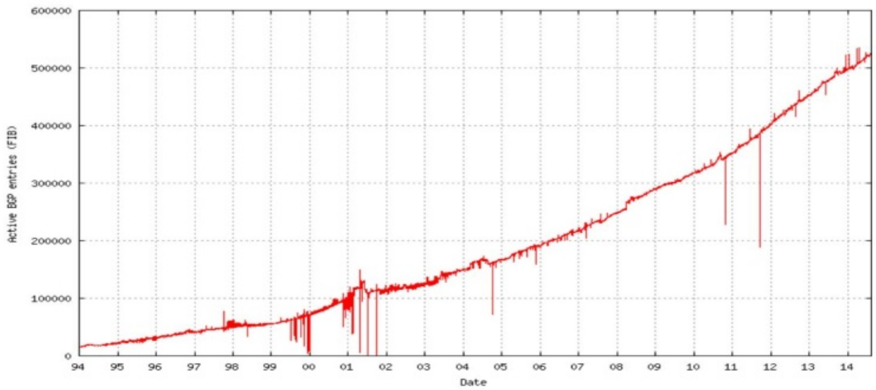
Security at the Internet layer – Nowadays network security is a big concern. When IPv4 was designed in 1981, the network security threats were rare. Even though IP sec was defined in IPv4, it was not a mandatory feature.

Quality of Service–Internet is being widely used for video and voice traffic. To send and receive video and voice packets over internet, which is very time critical, priority should be given to send such packets. For such applications quality of service is very necessary, to give priority in forwarding such packets.

In IPv4, Quality of Service (QoS) has limitations. IPv4 header has 8 bits as TOS field. The type of service field helps in real time delivery of packets by prioritizing the packets. But it is not very effective as expected.

Routing Crisis–During the 80s, addresses delegation was done without optimization and without aggregation. This resulted in large routing table on the backbone [6].

Graph 1. Global routing table size without aggregation



End-to-end applications: Growth of the applications that need IP addresses globally scoped, unique and routable (VoIP, videoconferencing, games) for which NAT is a hindrance. CIDR and super netting is only a temporary solution.

2.2. Benefits of IPv6

Large Address Space: The main problem of address scarcity of IPv4 is completely removed in IPv6. IPv6 provides a good and permanent solution to the address space problem. AS IPv6 is denoted by 128 bits, the available number of addresses is very large. If Ipv6 is implemented each and every citizen, network service providers, big organizations, institutions, even things (internet of things), vehicles, etc can have many IP addresses. Every organization globally can have as many IP addresses as they want to connect eachswitch, router, host, network and any IP based device to the Internet. The number of IPv6 addresses available is 2 (about 3.4×1038) addresses. There will not be address scarcity in many years from now [3][4].

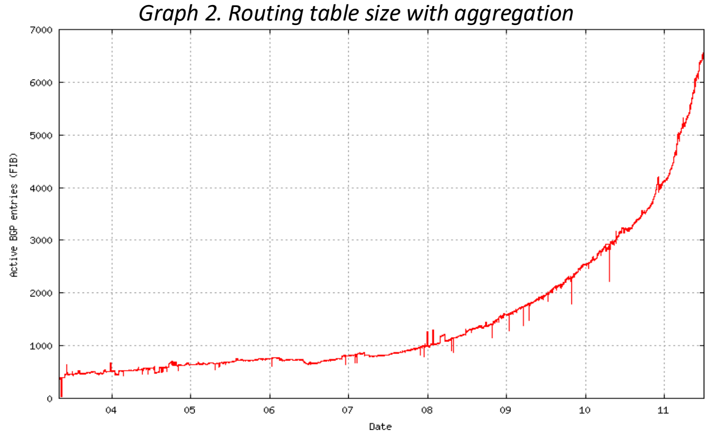
Address auto Configuration: In an IPv6 network, when the hosts or computers are connected, they can automatically configure IPv6 addresses to themselves [1].This is done by the ICMPv6 protocol by sending router solicitation and router advertisement messages [1]. In IPv4 scenario, the network user or administrator has to explicitly configure the IP address for the hosts available in the network, which is a very cumbersome process. But when a host is first connected to the IPv6 network, it sends out a router solicitation packet for the configuration parameters. Routers will respond with a router advertisement packet containing the network layer configuration parameters. Such received information will be used by the host to configure itself. [3]

IP sec Header Support: Internet Protocol security (IPSec) helps in network security. It is a function in network layer. In IPv4, IP sec is an optional one. But in IPv6, IP sec is brought in as a mandatory one. IP sec is available in the IPv6 protocol suite itself. It is optional in IPv4 and because NAT is largely used in IPv4 that IP sec does not work as intended.

IP host mobility: In IPv4, if a host is in mobility, reaching it is a problem. [3]It is not possible to connect to a host in mobility. If the user is in move, different IP addresses are allotted from different networks. But some applications like multimedia messaging and voice integration etc, where Internet Service Providers have to push information to a user, the Internet Service Providers must be able to reach the user always using the same network identifier, irrespective of the point of attachment to the network. IP Host mobility is a new feature, designed in IPv6. [1] Mobile IPv6 (RFC 3775, 3776). The extension header is used for this purpose.

Routing table entries: Aggregation-based address hierarchy which has dramatically increased the efficiency of backbone routing.

Graph 2. Routing table size with aggregation



Other advanced features of IPv6:

1. Better header format
2. Efficient and Extensible IP datagram with no fragmentation by routers
3. Mobility

3. IPv6 header format

Ipv6 header has 40 bytes. IPv6 header has fewer fields than IPv4. The mandatory fields of the IPv6 header are simplified so that routing process is easier. The headers have been designed in such a way and made smaller for faster processing by routers. In IPv4 main header length is variable but in IPv6 it is fixed length of 40 bytes. Optional functions are taken to separate fields of extension headers. In IPv4, packet fragmentation takes place on the path to the destination, depending upon the MTU value of the routers on the path. In IPv6 path MTU discover is done by the source router itself and MTU of the packet is taken in such a way, fragmentation does not take place in the path of the forwarding of packets [6].

Version(4 bits)	Traffic Class (8 bits)	Flow Label (20 bits)
Payload length (16 bits)	Next Header (8 bits)	Hop Limit (8 bits)
Source IP Address (128 bits)		
Destination IP Address (128 bits)		

4. Migration techniques

Because of the advantages of IPv6 like large number of addresses, and other benefits, all the IPv4 networks should be migrated to IPv6 networks. Also the new networks which are built in pure IPv6 should be integrated with the available networks [6].

Unfortunately like other protocols or technologies, IPv6 is not backward compatible to IPv4. IPv4 hosts and routers will not understand IPv6 addresses and will not be able to carry IPv6 traffic. At present, the networks available in the Internet are mostly IPv4. Even though many service providers and organizations have IPv6 networks, the migration has not taken place completely. It is not possible to change from IPv4 to IPv6 in an overnight. Migrating completely to IPv6 is a challenge with respect to hardware, software, applications and cost. So as an interim solution, it is felt that IPv4 and IPv6 networks must coexist, understand each other addresses and forward the packets to the destination. Complete transition may take a long time.

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The following two scenarios have to be handled:

1. IPv6 and IPv4 nodes have to communicate with each other. This problem is solved using Dual Stack Technique.
2. Pure IPv6networks which are apart will have to communicate with each other using the widely available IPv4 networks. This problem is solved using Tunneling technique.

4.1. Dual stack

During the time that the routing infrastructure is being transitioned from IPv4-only, to IPv4 and IPv6, and finally to IPv6-only, nodes must be able to reach destinations using either IPv4or IPv6. Nodes with dual IP stacks will have both IPv4 and IPv6 protocol stacks [7][6].

A dual IP layer architecture contains both IPv4 and IPv6 Internet layers with a single implementation of Transport layer protocols such as Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). .

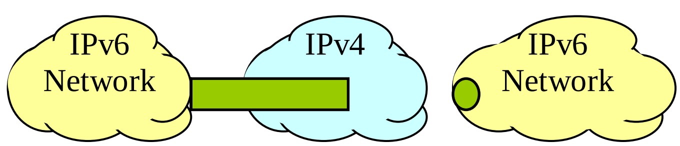
Application Layer	
TCP	UDP
IPv4	IPv6
Network Interface Layer	

4.2. IPv6 over IPv4 tunneling

There are several types of tunnels: 6in4, 6to4, Teredo, TSP and others. Some require public IPv4 addresses for each end of the tunnel, some work even behind NAT. Some require manual setup and others are created automatically. In this scheme, one type of packet is encapsulated in another type for transporting.

In the IPv6 header the protocol field will have the value 41. This indicates that it is an encapsulated IPv6 packet. The Source IP address and the destination IP address will be IPv4 addresses, which are the endpoints of the tunnel.

The sender point of the tunnel is assigned an IPv4 address. The receiver point which can be an intermediate router or the destination network will also be assigned an IPv4 address. The tunnel head end and tail ends are either manually configured as part of the tunnel interface or are automatically derived based on the next-hop address for the destination IPv6 address and the tunnel interface [7].



5. Results

The migration techniques Dual stack and Tunneling were simulated using GNS3 network simulation tools.

5.1. Dual Stack

The network topology used for testing the configurations of Dual stack.

In the above network, routers name v6 and IPv6 will support only ipv6, and routers V4 and ipv4 will understand IPv4 address only. So the routers R1 to R3 were configured with dual stack.

Figure 1 the routing protocol used was OSPF for both IPv4 and IPv6. Now if the reach ability of the packets from v6 to ipv6, and v4 to ipv4 routers is checked by ping command. The success rate is 100 %. Figure 2 below shows.

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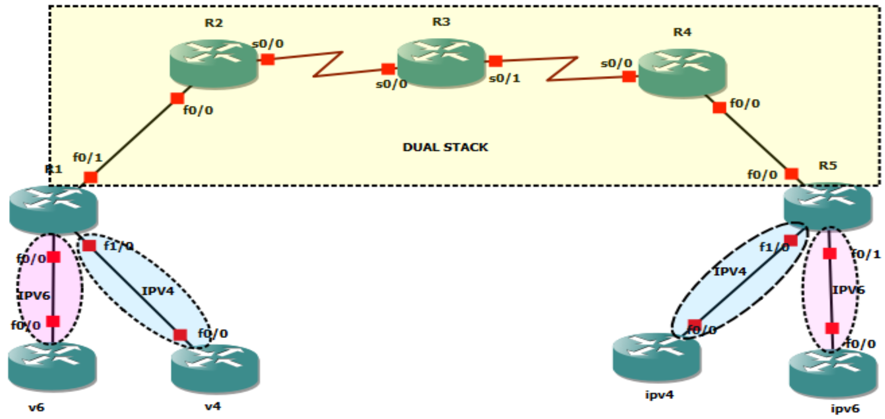

Figure 1. Dual stack router configuration

```
//R1#sh run
Building configuration...
interface FastEthernet0/0
 no ip address
 duplex auto
 speed auto
 ipv6 address 2001:4490:D040:101::1/64
 ipv6 rip merlin enable
!
interface Serial0/0
 no ip address
 shutdown
 clock rate 2000000
!
interface FastEthernet0/1
ip address 10.1.0.1 255.255.255.252
 duplex auto
 speed auto
 ipv6 address 2001:4490:D040:102::1/64
 ipv6 rip merlin enable
!
interface Serial0/1
 no ip address
 shutdown
 clock rate 2000000
          !
          interface Serial0/2
           no ip address
           shutdown
           clock rate 2000000
          !
          interface FastEthernet1/0
           no switchport
          ip address 10.0.0.1 255.255.255.252
          !
          !router rip
           version 2
           network 10.0.0.0
           no auto-summary
```

5.2. Tunneling

The network topology used for testing tunneling.

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Figure 2. Ping results

```
v6#
v6#ping 2001:4490:d040:106::2
Type escapes sequence to abort.
Sending 5, 100-byte ICMP Echos to
2001:4490:D040:106::2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max =
80/99/144 ms
v6#r  1 00:00:17.987: %LINK-3-UPDOWN: Interface
FastEthernet1/2, changed state to up
```

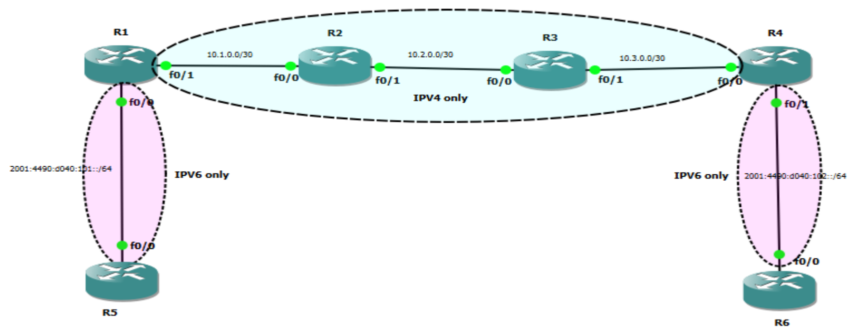

Figure 3. Router configuration for tunneling in R4

```
R4#sh run
Building configuration...
Current configuration : 1219 bytes
!
hostname R4
!
interface Tunnel0
 no ip address
 ipv6 address 3000::2/64
 ipv6 rip merlin enable
 tunnel source FastEthernet0/0
 tunnel destination 10.1.0.1
 tunnel mode ipv6ip
!
interface FastEthernet0/0
ip address 10.3.0.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 no ip address
 duplex auto
 speed auto
 ipv6 address 2001:4490:D040:102::1/64
 ipv6 rip merlin enable
!
router rip
 version 2
 network 10.0.0.0
!
ip forward-protocol nd
ipv6 router rip merlin
line con 0
 exec-timeout 0 0
 privilege level 15
!
End
```

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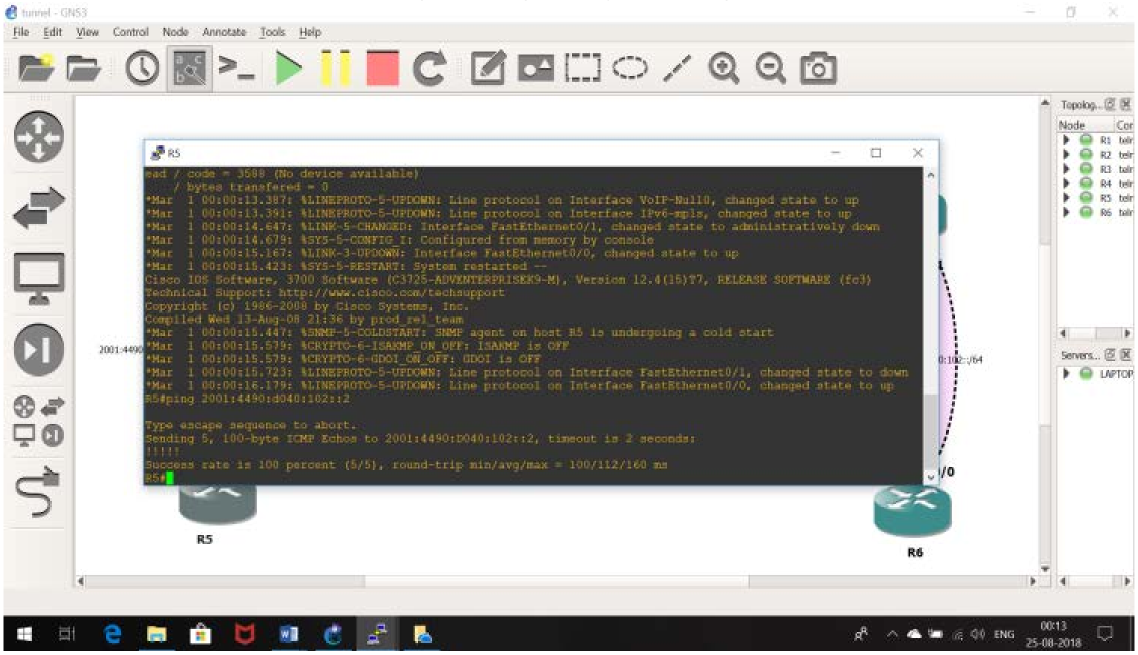
A manual tunnel was created between R1 and R4. R2 and R3 will support IPv4 only. While R1 to R5, and R4 to R6 are IPv6 only. For the IPv6 packets which originate from R5 to reach R6 will pass through the IPv4 only part of the network through the manual tunnel created with head as R1 f0/1 interface and tail end as R4 f0/0 interface. The routing protocol used was ripping. The reach ability from R5 to R6 was checked and the success rate is 100% as shown in Figure 4.

Figure 4. Ping results for tunneling



6. Challenges in migration

6.1. End users

"Small gateways" for private homes do not support IPv6. No large deployment possible. For homes, the upgrade cycle is slower than the core; in some cases hardware is never changed. Individual users will incur the minimum cost[5].

6.2. Enterprises or large organizations

Each organization throughout the internet will incur some cost in transition. Hardware, software, services and other miscellaneous expenses. Primarily in the form of labor and capital expenditures. Expenditure will vary greatly across and within stake holder groups depending on their existing infrastructure and IPv6 related needs [5].

6.3. ISPs

ISPs have to incur largest transition cost. Labor resources will account for the bulk of the transition costs [5].

6.4. For Hardware and Software vendors

Vendors have already started IPv6 complainant products [5].

6.5. Other challenges

As the deployment of IPv6 is in the early stages, the security vulnerabilities exist. Organizations need to focus more on security issues. Trained manpower/expertise not available.

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7. Applications

IPv6 has opened up lots of applications and opportunities. Increased availability of IP addresses has paved way in the explosion of use in the networked devices like smart phones, consumer appliances, embedded systems, remote sensors, etc.

7.1. Internet of things

With IPv6, internet of things IoT is coming up in a big way. Many applications like street light monitoring, smart meters, smart cities, etc use IPv6. IPv6 along with internet of things is being implemented rapidly across the globe [2].

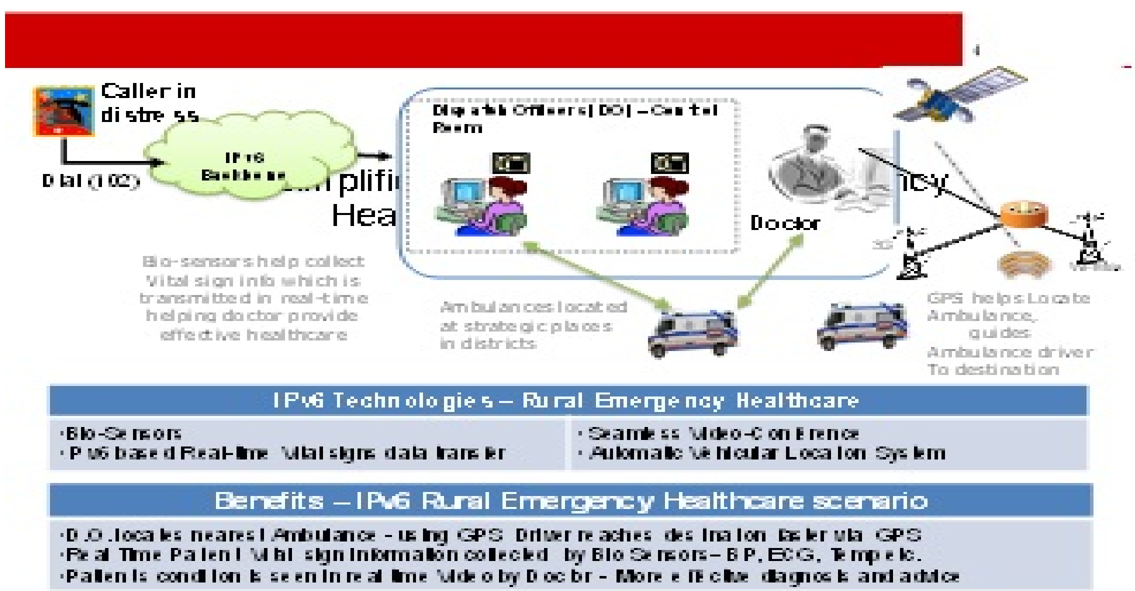
This is achieved with is seamless interconnection between people and things and/or between things and things. IoT is currently being deployed in various sectors such as Agriculture, Aquaculture, Home and Building Automation, Industries and many more.

7.2. Some Applications Relevant for Government Departments for taking up Pilot Projects

1. Centralized Building Management System
2. Intelligent Traffic Management System
3. Rural Emergency Healthcare System
4. Telemedicine (Linking Urban and Rural Hospitals)
5. Distance Education
6. Power Generation and Distribution
7. Logistics and Supply Chain

7.3. Case study

Rural Health Care



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8. Conclusion

The various applications based on IPv6 are booming worldwide. IoT applications are the direct fruit of introduction of IPv6. In India, IoTis growing in a big way, which is a boon for the Economy of our country. Nasscom has predicted $1.5 billion worth business in India alone. ICT applications used in Digital India initiatives of Government of India like Energy saving, smart meters, street light monitoring, transport AIS140 standards, vehicle tracking all use IPv6 complaint network elements and end equipment. Nowadays all hardware equipment is manufactured IPv6 complaint.

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