

Consultation paper No. - 8 /2005



TELECOM REGULATORY AUTHORITY OF INDIA

Consultation paper

On

Issues Relating To Transition From IPv4 To IPv6
in India

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Preface

One of the objectives of NTP99 is to create a modern and efficient telecommunication infrastructure, which takes into account the convergence of data, media, telephony, and consumer electronics to propel India into becoming an IT Superpower. TRAI has taken many initiatives to enable the country to meet above objective in consultations with stakeholders and public at large.

The TRAI's recommendations on accelerating growth of Internet and Broadband served as the basis for the National Broadband Policy 2004, issued by Government. To achieve targets of this policy, the Internet and Broadband connections would require large supply of IP addresses, which may not be easily available through the present version of Internet, i.e., IPv4. The next generation Internet protocol, i.e., IPv6 is seen as one solution for this, in addition, it is claiming to provide better security, QoS, Mobility support.

The primary motivation for the deployment of IPv6 is to expand the available address space on the Internet, thereby enabling millions of new devices, viz. Personal Digital Assistants (PDAs), cellular phones, home appliances in addition to computers/ PC to be made always connected to Internet.

TRAI has been monitoring development of IPv6 in India and worldwide. In the recommendations on Broadband, the need for further analysis and discussion on transition to IPv6 was recognised due to anticipated growth of Internet and Broadband connections. Govt. of India has already constituted a group called IPv6 Implementation Group (IPIG) to speed up and facilitate the adoption of IPv6 in the country. For giving a fillip to this effort, the present consultation paper proposes to solicit specific information, action requirements, and coordination efforts needed for helping this group.

This consultation paper provides the necessary platform for discussing the various issues related to transition from IPv4 to IPv6 like role of Regulator/ Licensor, need for National IPv6 backbone, need for National agency for

managing IP addresses and IPv6 transition strategy for ISPs. The consultation paper has already been placed on TRAI's website (www.trai.gov.in).

I request that valuable comments on this consultation paper please be furnished to Secretary TRAI by September 23, 2005. For any further clarification on the matter, Shri S.N.Gupta, Advisor (Converged Network) may be contacted at Ph No. : 011-26167914, Fax : 011-26191998, e-mail : trai09@bol.net.in.

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1. Background

The rapid success of Internet, leading to accelerated consumption of IP addresses, has led to the anxiety about shortage of IP addresses in the coming years in the country. In addition it is given to understand that the Next Generation Internet Protocol (IPv6) can help in solving the problems related to QOS & Security aspects of the Internet. As a part of Broadband consultations the stakeholders also raised the issue pertaining to IPv6, wherein Authority had decided to discuss this issue in the future, as well as to consider the plans to foster the potential migration of the industry to IPv6.

In order to get an overview of various issues involved in the migration from IPv4 to IPv6, TRAI had commissioned a study on the 'Issues relating to migration from IPv4 to IPv6'. The study brought out the following important issues for discussion and consideration:

- i) India has merely 2.8 million IPv4 addresses compared to 40 million acquired by China. (Any common US university has more IP addresses than total IP India). USA ISP Level-3 alone has more IP addresses than China. India has 0.17 of an address block, while the US has full 75 blocks.
- ii) If India wants to achieve 20 % penetration of the Internet, and three people share each IP address it would need 101/8 blocks. This is more than the remaining global IP address space of 82 / 8 blocks. APNIC the IP address registry for Asia-Pacific won't be able to provide this vital resource and therefore India will have to rely on Network Address Translation (NAT) technique, which may further add complexity to its Internet infrastructure. Such reliance on conventional technique may make the transition to IPv6 even costlier in the future.
- iii) So far the Indian industry has not engaged into large-scale deployment of IPv6, and have a risk of lagging behind in this technology, if immediate steps are not taken.

The above situation prompted TRAI to initiate consultation process with the stakeholders on this important topic related to the growth of Internet and Broadband in the country.

2. Introduction

IPv4, the current version of Internet Protocol (IP), was developed about 25 years ago at the beginning of Internet. This version of IP (known as version 4 or IPv4) has not been substantially changed since it was published in 1981(RFC 791). Although IPv4 has proven to be robust, easily implemented and interoperable, the initial design did not anticipate the following;

- The exponential growth of the Internet and the impending exhaustion of the IPv4 address space
- The ability of internet backbone routers to maintain large routing tables
- The need for simpler and automatic configuration of IP addresses.
- The requirement of security at IP layer
- The need for better support for real-time delivery of data also called quality of service (QOS) for applications like VOIP, VOD etc.

The major weaknesses of Ipv4 and the perceived benefits of IPv6 are analysed in the next chapter.

3. Major Weaknesses of Current Generation Internet (IPv4) & benefits of IPv6

3.1 IPv4 Weaknesses:

Major weakness of IPv4 is its limited addressing space, as in this an address consists of just 32 bits thereby limiting the total number of addresses to about 2 billion only. The rapid growth of Internet, leading to accelerated consumption of IP addresses, has led to the anxiety about shortage of IP addresses in coming years specially in Asia Pacific region. Already, the limits of IPv4's addressing system have started pushing the usage of processes such as Network Address Translation (NAT) and the Classless Interdomain Routing (CIDR) diagram to aggregate IP addresses, which are supposed to have their associated problems.

3.2. Perceived Benefits of IPv6:

IPv6, developed by the IETF in the mid Nineties, is the Next Generation (version 6) of the Internet Protocol (IP). IPv6 improves on the addressing capacities of IPv4 by using 128 bits for addressing instead of 32, thereby making available an almost infinite pool of IP addresses. Also IPv6 is supposed to be providing various enhancements with respect to security, routing, address auto configuration, mobility & QOS etc.

The following are the important features of IPv6 protocol, which may play an important role in the growth of Internet in the country due to its advance capabilities.

(i) New Header Format:

The IPv6 header has a new format that is designed to keep header overhead to a minimum. The streamlined IPv6 header is more efficiently processed at intermediate routers with lower processing costs.

(ii) Large Address Space:

IPv6 has 128 bits (16 bytes) source and destination IP addresses. This will enable to accommodate 2^{128} hosts. Even though only a small number of IPv6 addresses are currently allocated for use by hosts, there are plenty of addresses available for future use. With a much larger number of available addresses, address conservation techniques, such as deployments of NAT will no longer be necessary.

(iii) Efficient and Hierarchical Addressing and Routing Infrastructure :

IPv6 global addresses used on the IPv6 portion of the Internet are designed to create an efficient, hierarchical, and summarisable routing infrastructure that is based on the common occurrence of levels of Internet service providers.

(iv) Stateless and stateful address configuration

IPv6 supports both stateful address configuration, such as address configuration in the presence of a DHCP server, and stateless address configuration (address configuration in the absence of a DHCP server). With stateless address configuration, hosts on a link automatically configure themselves with IPv6 addresses for the link (called link-local addresses) and with addresses derived from prefixes advertised by local routers. Even in the absence of a router, hosts on the same link can automatically configure themselves with link-local addresses and communicate without manual configuration.

(v) Built-in Security

Support for IPSec is an IPv6 protocol suite requirement. This requirement provides a standards-based solution for network security needs and promotes interoperability between different IPv6 implementations.

(vi) Support for QOS

New fields in the IPv6 header define how traffic is handled and identified. Traffic identification using a Flow Label field in the IPv6 header allows IPv6

routers to identify and provide special handling for packets belonging to particular packet flow between source and destination. Support for QOS can be achieved even when the packet payload is encrypted through IPsec.

(vii) Extensibility:

IPv6 can easily be extended for new features by adding extension headers after the IPv6 header.

3.3 In addition, IPv6 can make available almost unlimited address space thereby enabling static/ global address allocation which can have following advantages: -

- i) As per Clause 1.10.3 of the ISP license agreement ISP are required to log all user activity and archive it. Such an archive is required by law enforcement agencies when the need arises. The lack of end user addressability with static IP address may not serve the purpose of logging information fully. In cases where a static private address is used, it is possible to trace the end user, but in cases where DHCP is used for private addresses, there may be absolutely no clue about the end user. So, for true accountability, there is a need to have a static IP address allocated.
- ii) By having IP addresses delegated directly to the ISPs, the ISPs can provide a better user experience with fault tolerant topologies, fault tolerant service access and so on. The ISP can allocate static IP addresses to each of its customers and therefore enable the users to use the newer services that may work or may not work efficiency with NAT. Allocating static IP addresses to the subscriber end point provides a specific identity to that user. Therefore, that user can be easily be monitored for acceptable use (as well as accounting) in an unambiguous manner.

3.4 Highlights of the key differences between IPv4 and IPv6:

S. No.	IPv4	IPv6
(i)	Source and destination addresses are 32 bits (4 bytes) in length.	Source and destination addresses are 128 bits (16 bytes) in length.
(ii)	IPSec support is optional.	IPSec support is required.
(iii)	No identification of packet flow for QoS handling by routers is present within the IPv4 header.	Packet flow identification for QoS handling by routers is included in the IPv6 header using the Flow Label field.
(iv)	Fragmentation is done by both routers and the sending host.	Fragmentation is not done by routers, only by the sending host.
(v)	Header includes a checksum.	Header does not include a checksum.
(vi)	Header includes options.	All optional data is moved to IPv6 extension headers.
(vii)	Address Resolution Protocol (ARP) uses broadcast ARP Request frames to resolve an IPv4 address to a link layer address.	ARP Request frames are replaced with multicast Neighbour Solicitation messages.
(viii)	Internet Group Management Protocol (IGMP) is used to manage local subnet group membership.	IGMP is replaced with Multicast Listener Discovery (MLD) messages.
(ix)	ICMP Router Discovery is used to determine the IPv4 address of the best default gateway and is optional.	ICMP Router Discovery is replaced with ICMPv6 Router Solicitation and Router Advertisement messages and is required.
(x)	Broadcast addresses are used to send traffic to all nodes on a subnet.	There are no IPv6 broadcast addresses. Instead, a link-local scope all-nodes multicast address is used.
(xi)	Must be configured either manually or through DHCP.	Does not require manual configuration or DHCP.
(xii)	Uses host address (A) resource records in the Domain Name System (DNS) to map host names to IPv4 addresses.	Uses host address (AAAA) resource records in the Domain Name System (DNS) to map host names to IPv6 addresses.
(xiii)	Uses pointer (PTR) resource records in the IN-ADDR.ARPA DNS domain to map IPv4 addresses to host names.	Uses pointer (PTR) resource records in the IP6.ARPA DNS domain to map IPv6 addresses to host names.

4. **Alternative solution for IP Address space problem:**

To solve the problem of IP Address space in Ipv4, other technologies have been made use of historically. One of the most important of these is ***IP Network Address Translation (NAT)***. IP Network Address Translation (IP NAT or NAT) is a technique that allows an organization to set up a network using private addresses, while still being able to communicate on the public Internet. A NAT-capable router translates private to public addresses and vice-versa as needed. This allows a small number of public IP addresses to be shared amongst a large number of devices.

However, there are drawbacks to this technique as well, such as performance reduction due to address translation, problems with security protocols (IPSec), compatibility problems with certain applications (peer to peer communication) and complexity.

Other technique used is Classless Inter-Domain Routing (CIDR) diagram to aggregate IP addresses. This also is supposed to have its associated problems.

5. National Scenario

5.1 Relevant Existing Government Policies:

(i) The Ten Point Agenda declared by Hon'ble Minister of Communications and Information Technology on 26.05.2004 includes IPv6 under point 6 as following:

“Migration to New Internet Protocol IPv6: *Worldwide the new IPv6 is being implemented on the Internet to accommodate increased number of users and take care of security concerns. It would be my endeavour to bring about migration to IPv6 in India by 2006.”*

(ii) In the Broadband Policy 2004, Government has envisaged Broadband and Internet subscribers of 20 million and 40 million by 2010 respectively through various Internet and Broadband Technologies.

Broadband policy has also defined Broadband as an “always-on data connection” that is able to support various interactive services. In order to be truly interactive, each Broadband connection may require a permanent IP address assigned to end-user.

(iii) In order to fulfill these government policies/ objectives, India's Internet and Broadband Infrastructure should be globally competitive, secured and affordable. The present generation Internet (IPv4) may not be enough to help in achieving these objectives.

5.2 IPv6 Implementation Group:

Department of IT commissioned several projects to facilitate the efforts of stakeholders regarding the adoption of IPv6, in creating test beds and supporting R&D activities. In addition an inter agency IPv6 Programme Implementation Group (IPIG) was constituted to track and review the IPv6 implementation from time to time. Senior officers from DIT, NSC, TRAI, DRDO, ISPAI, COAI, academic institutions etc. are the members of IPIG.

5.3 Institutional Activities:

Some of the Universities/ R&D institutions have been studying the technical aspects of IPv6 in India. IPv6 forum of India is organising workshops involving the industry, ISPs, academic and research institutions to bring awareness among stakeholders. BITS Pilani is the first institution in India to connect to 6Bone (IPv6 international test bed network) and is developing IPv6 native support products. Similarly, ERNET of DIT in association with IIT Kanpur has taken up a project of setting up of IPv6 test bed at few locations in the country.

5.4 Industry Efforts:

It is understood that ISPAI is motivating the member ISPs to start obtaining IPv6 address space from Asia-Pacific Network Information Centre (APNIC) and some of the ISPs have already obtained the addresses. Few ISPs are experimenting with IPv6 tunnelling over IPv4 by exchange of experimental packets to get a feel of the capabilities of IPv6. Some ISPs are getting their router software upgraded to IPv6 to make their network IPv6 compliant.

6. International Scenario

Many countries around the globe like Japan, Korea, China, European Union, USA have set up national IPv6 networks to enable the network operators and software developers to get a hands-on feel of this technology. Some of the important ones are described below:

6.1 Europe

The European Commission (EC) initiated an IPv6 Task Force in April 2001 to design an "IPv6 Roadmap 2005" and delivered its recommendations in January 2002, which were endorsed by the EC. A phase II IPv6 Deployment Task Force was enacted in Sep, 2002 with a dual mandate of initiating country/regional IPv6 Task Forces across the European states and seeking global cooperation around the world.

For its part, the European Commission (EC) funded a joint program between two major Internet projects—6NET and Euro6IX—to foster IPv6 deployment in Europe. The Commission committed the financial support to enable the partners to conduct interoperability testing, interconnect both networks, and deploy advanced network services, including support to some 40 IPv6 research projects on the continent.

The EC IPv6 Task Force and the Japanese IPv6 Promotion council, forged a strategic alliance to foster IPv6 deployment worldwide.

6.2 Japan

Japan took political leadership in the design of a roadmap for IPv6 in the fall of 2000 in a policy speech by Prime Minister. The Japanese government mandated the incorporation of IPv6 and set a deadline of 2005 to upgrade existing systems in every business and public sector. Japan sees IPv6 as one of the ways of helping them leverage the Internet to rejuvenate the Japanese economy. The IPv6 Promotion Council was created to address, in a comprehensive way, all issues related to the deployment and rollout of IPv6. In 2002–2003, the Japanese government created a tax credit program that exempted the

purchase of IPv6-capable routers from corporate and property taxes. Under the framework of the Japanese government's e-Japan initiative, the Ministry of Public Management, Home Affairs, Post and Telecommunications has sponsored an "IPv6 promotion council," which, among other things, has established and promoted an IPv6 Ready Logo program and allocated the equivalent of \$70 million for IPv6 research and development

6.3 South Korea:

In 2001, the South Korean Ministry of Information and Communication announced its intention to implement IPv6 within the country. In September 2003, the Ministry adopted an IPv6 Promotion Plan with commitment for funding IPv6 routers, digital home services, applications, and other activities.

6.4 China:

In December 2003, the Chinese government issued licenses and allocated budget for the construction of the China Next Generation Internet (CGNI). The goal is to have that network fully operational by the end of 2005. China and Japan have declared jointly in the 7th Japan-China regular bilateral consultation toward further promotion of Japan-China cooperation that IPv6 is an important matter in the area of info-communications field.

7. Present Practice of IP Address Allocation

- 7.1 Internet resources such as IP addresses, Autonomous System Numbers (ASN) etc. are assigned by the Internet Assigned Numbers Authority (IANA). These resources are delegated to the Regional Internet Registries in the world (RIR) for further distribution to end users or National Internet Registries (NIR), that would further the process of distribution.
- 7.2 A NIR is an agency, typically instituted by the government or an industry coalition endorsed by the government that undertake to provide Internet resource delegation and registration services. Each country or economy (as appropriate) can have an NIR. The NIRs serve to provide a local service point for delegation of IP addresses to the service providers and users in that specific country/ region. The delegation of such resources should be done in accordance with policies of the RIRs that specify the policies from time to time.
- 7.3 Internet in India has been present since the late 1980s when ERNET first interconnected academic and R&D institutions to the Internet. Subsequently, the deregulation of the services provision saw a large increase of service providers that were licensed. Presently, there are 380 plus licensees of which about 180 are operational. All these operational ISPs either go to the Asia-Pacific Network Information Centre (APNIC) for their address resource requirements or to their upstream Indian ISP that provides them these resources. To be able to obtain these resources directly from APNIC, it is required that they become members of APNIC. The membership is annual and has a certain cost that varies with the size of the ISP.
- 7.4 Currently, 30 odd ISPs out of the 180 operational ISPs are members of the APNIC. Most of these ISPs are big ISPs (category A or B). This implies that the rest of the ISPs are sourcing the addresses from their upstream Indian ISPs. In most cases, the ISPs have a large customer base that is served through NAT boxes to make optimal use of the available IP addresses. The lack of direct and independent registration by the ISPs is due to several reasons, including that of costs and lack of awareness.

8. **The Need and Benefits of having a Indian National Internet Registry (INNIR)**

8. In order to procure IP addresses from APNIC, ISPs either should take membership of APNIC or approach upstream ISP. Each member of APNIC requires to pay annual membership fee. While the APNIC does not refuse a non-member, however, it requires a strong justification as to why an applicant is not sourcing their IP address requirement from their upstream ISP.

9.1 Small ISPs either do not know the APNIC procedures or do not understand the operational processes and therefore prefer to source the IP addresses from their upstream ISP.

9.2 Creating an national internet registry for managing IP addresses in India can have the following benefits:

- i) If the National Registry is created it becomes a single agency to maintain the IP address pool as per the demand and policies of the nation. This can also enable to allocate the IP addresses in a contiguous manner within the nation to ensure that there is enough aggregation of roots on the backbone.
- ii) Policy maker/ licensor have a single point of contact & control over the usage of these resources. Currently, there is no comprehensive view of the nation's requirements, use or demand to aid policy making.
- iii) The user community i.e., the ISPs will deal with an Indian agency rather than a foreign one for their resource requirements. This can have an impact on the costs they incur in operationalising their Internet infrastructure as well as understanding of Policies. Policies mentioned in the local language can have a dramatic impact on the small ISPs understanding of Internet operational policies.
- iv) With all IP addresses being allocated locally the registration information will be instantly accessible to law enforcing agencies.

9. Creation of National IPv6 Backbone: India next Generation Internet (INGI)

For conducting research and demonstration of IPv6 native support products, presently institutions in India are required to be connected to IPv6 international test bed network like 6Bone. To enhance the integration of the national networks and increase the operational experience on novel Internet services and applications based on the use of IPv6, there is a need to create a large-scale national production IPv6 test bed similar to the European Geant or the Chinese Next Generation Internet (CNGI).

This IPv6 backbone may be created by agencies like TEC, C-DOT and Institutions like IITs and IISc. The Government may need to provide initial funding for the test beds.

10. Transition Mechanisms for IPv6

To coexist with an IPv4 infrastructure and to provide an eventual transition to an IPv6-only infrastructure, generally following mechanisms are used:

- Dual IP layer
- IPv6 over IPv4 tunneling
- DNS infrastructure

These are described briefly as following: -

(i) Dual IP Layer

The dual IP layer is an implementation of the TCP/IP suite of protocols that includes both an IPv4 Internet layer and an IPv6 Internet layer. This is the mechanism used by IPv6/IPv4 nodes so that communication with both IPv4 and IPv6 nodes can occur. A dual IP layer contains a single implementation of Host-to-Host layer protocols such as TCP and UDP. All upper layer protocols in a dual IP layer implementation can communicate over IPv4, IPv6, or IPv6 tunneled in IPv4.

Figure below shows a dual IP layer architecture.

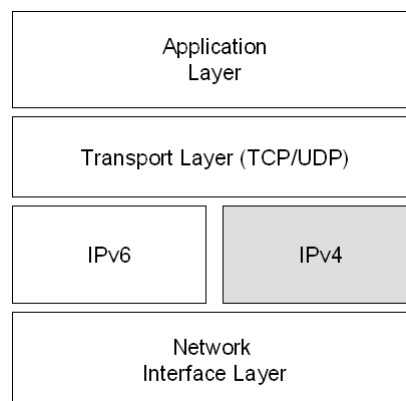


Figure: A Dual IP Layer Architecture

ii) IPv6 over IPv4 Tunneling

IPv6 over IPv4 tunneling is the encapsulation of IPv6 packets with an IPv4 header so that IPv6 packets can be sent over an IPv4 infrastructure. Within the IPv4 header:

- The IPv4 Protocol field is set to 41 to indicate an encapsulated IPv6 packet.
- The Source and Destination fields are set to IPv4 addresses of the tunnel endpoints. The tunnel endpoints are either manually configured as part of the tunnel interface or are automatically derived from the sending interface, the next-hop address of the matching route, or the source and destination IPv6 addresses in the IPv6 header.

Figure below shows IPv6 over IPv4 tunneling.

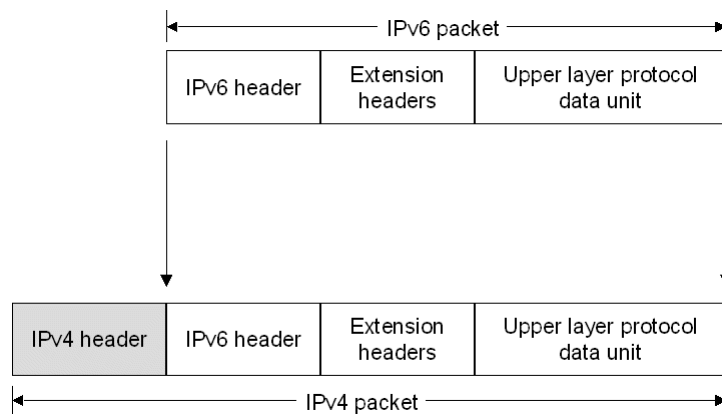


Figure: Tunneling IPv6 over IPv4 packets

For IPv6 over IPv4 tunneling, the IPv6 path maximum transmission unit (MTU) for the destination is typically 20 less than the IPv4 path MTU for the destination. However, if the IPv4 path MTU is not stored for each tunnel, there are instances where the IPv4 packet will need to be fragmented at an intermediate IPv4 router. In this case, IPv6 over IPv4 tunneled packet must be sent with the Don't Fragment flag in the IPv4 header set to 0.

iii) DNS Infrastructure

A Domain Name System (DNS) infrastructure is needed for successful coexistence of IPv6 and IPv4 because of the prevalent use of names (rather than addresses) to refer to network resources. Upgrading the DNS infrastructure consists of populating the DNS servers with records to support IPv6 name-to-address and address-to-name resolutions. After the addresses are obtained using a DNS name query, the sending node must select which addresses are to be used for communication.

11. Cost Implication of IPv6 Transition

11.1 The potential costs associated with deploying IPv6 comprise a mixture of hardware, software, manpower, and miscellaneous costs. Each organization or user throughout the Internet supply chain will incur some costs in transition to IPv6, primarily in the form of manpower and capital expenditures required to integrate IPv6 capabilities into existing networks.

11.2 Expenditure and support activities will vary greatly across and within stakeholder groups depending on their existing infrastructure and IPv6-related needs. By and large, ISPs offering service to a large group of customers will likely to incur the most transition costs, while independent users will bear little, if any, costs. Factors influencing these costs include

- the type of Internet use or type of service being offered by each ISP;
- the transition mechanism(s) that the organization intends to implement (e.g., tunneling, dual-stack, translation, or a combination);
- the organization-specific infrastructure comprised of servers, routers, firewalls, billing systems, and standard and customized network-enabled software applications;
- the level of security required during the transition; and
- the timing of the transition.

Table 11.2.1 provides a list of potential costs incurred by stakeholder group and gives a percentage breakdown by cost category. Table 11.2.2 provides an item-by-item list of the costs to deploy IPv6 by stakeholder group; this is a relative comparison of costs and should not be used to infer the actual size of each cost. The following sections are qualitative in nature and focus on the costs likely to be

incurred by each stakeholder group and how the timing of the transition affects these costs.

Table 11.2.1 : Overview of IPv6 Costs

Stakeholders	Total Cost	Transition Cost Breakdown ^a			Timing Issues	Key Factors in Bearing Costs
		HW	SW	Labor		
Hardware Vendors	Low ^b	10%	10%	80%	Currently most are providing IPv6 capabilities	Rolling in IPv6 as standard R&D expense; international interest and future profits incentivize investments
Software Vendors	Low/Medium ^c	10%	10%	80%	Currently some are providing IPv6 capabilities	Interoperability issues could increase costs
Internet Users	Low/Medium	10%	20%	70%	Very few currently running IPv6; HW and SW will become capable as routine upgrade; size of enabling cost should decrease over time	Users will wait for significantly lower enablement costs or (more probably) a killer application requiring IPv6 for end-to-end functionality before enabling
Internet Service Providers (ISPs)	High ^d	15%	15%	70%	Very few are offering IPv6 service; no demand currently; very high cost currently to upgrade major capabilities	ISPs see low or nonexistent ROI, high costs, and high risk

Source: RTI estimates based on discussions with 26 industry stakeholders, RFC responses, and extensive literature review.

^a These costs are estimates based on conversations with numerous stakeholders and industry experts. Several assumptions underlie them. First, it is assumed that IPv6 is not enabled (or “turned on”) or included in products and no IPv6 service is offered until it makes business sense for each stakeholder group. Additionally, the hardware and software costs are one-time costs. However, labor costs could continue for as long as the transition period and possibly longer.

^b For hardware vendors producing high-volume parts that require ASIC changes, the costs could be very high and would not be offered until the market is willing to pay.

^c Software developers of operating systems have and will incur a relatively low cost; however, application developers will incur greater costs, designated as *medium*.

^d The cost for ISPs is particularly high if the ISP manages equipment at user sites, because premises equipment is more costly to manage and maintain.

Table 11.2.2: Relative Costs of IPv6 Deployment by Stakeholder Group^a

Item	Hardware, Software, Service Providers	ISPs	Enterprise Users
Hardware			
Replace interface/line cards	L		M
Replace routing/forwarding engine(s) ^b	M	M	
Replace chassis (if line cards will not fit)		M	M
Replace firewall		M	M
Replace billing systems		L	
Software			
Upgrade network monitoring/management software		L	L
Upgrade operating system		M	S
Upgrade applications:			
• Servers (Web, DNS, FTP, mail, music, video, etc.)			S
• ERP software (e.g., PeopleSoft, Oracle, SAP, etc.)			L
• Other organization-specific, network-enabled applications			L
Labour			
Train networking/IT employees	L	L	L
Design IPv6 transition strategy and a network vision	M	L	M/L
Implement transition:			
• Install and configure any new hardware	S	L	L
• Configure transition technique (e.g., tunneling, dual-stack, NAT-PAT translation)	M	M	M
• Upgrade all software (see Software section above)		S/M	S/M
• Extensively test before “going live” with IPv6 services		L	L
Maintain new system		M/L	M/L
Other			
IPv6 address block(s)			S
Lost employee productivity ^c		M	M
Security intrusions ^d		L	L
Foreign activities		M	M
Interoperability issues		M/L	M/L

Source: Estimates based on discussions with 26 industry stakeholders, RFC responses, and literature review.

The relative designation (S = small, M = medium, and L = large) indicates the estimated level of cost to members of the specific stakeholder group. These costs are not incremental, rather they reflect differences in costs between stakeholder groups.

^bThe “brains” of the router, usually in the line card form.

^cBecause of unexpected down-time during transition period.

^dBased on unfamiliar threats.

11.3 Cost implications for vendors & network providers: -

11.3.1 Vendors that provide products and services include: networking hardware companies, such as router and firewall manufacturers; networking software companies, including operating system and database management application developers; and service vendors comprising of companies that offer training, service and support. These companies need to integrate IPv6 capabilities into their products and services, if they have not already done so, as a precursor to all user transitions. Once IPv6-capable products are installed in user networks, ISPs will be enabled to offer IPv6 service and users will be able to purchase IPv6-enabled devices and applications. Many companies in this category are already developing, and some are even selling, IPv6 products and services.

11.3.2 The majority of the costs being incurred by hardware and software developers include labor-intensive research and development (R&D) costs and training costs. These costs, however, have not been large enough to deter development of IPv6 capabilities. R&D activity has generally been conducted in small intra-company groups dedicated to developing IPv6-capable products with, to date, limited, small-scale interoperability testing with other hardware and software makers. Based on industry experience with the early deployments of IPv4 equipment, large-scale deployment may bring to light additional interoperability problems.

11.3.3 The future cost of interoperability testing could be substantial but such testing is essential if IPv6 is to become seamlessly pervasive. Without interoperability testing, IPv6 capabilities could have little practical use. Recently, the Department of Defence, in collaboration with several industry stakeholders and the University of New Hampshire, launched provide some insight into which stakeholder groups will end up bearing the costs or appropriating the benefits associated with IPv6. The following sections are qualitative in nature and focus on the costs likely to be incurred by each stakeholder group and how the timing of the transition affects these costs.

In the next several years, global activities may likely affect IPv6 transition costs borne by hardware, software, and service vendors. As products mature, less vulnerability will be found, thus lowering implementation costs.

11.4 Cost implications to ISPs

11.4.1 ISPs comprise two main groups, which often overlap—regional and national companies that provide internet access service to corporate, governmental, non-profit, and independent Internet users and national companies that own and maintain the backbone hardware and software of the Internet. Often companies that own the backbone Internet infrastructure provide Internet access service to customers through a subsidiary. Today, most backbone transport networks have already upgraded their major routers and routing software to accommodate IPv6. Thus, the focus should be on smaller ISPs that have large customer service provision capabilities. This group will likely incur the bulk of the transition costs as they enable IPv6 hardware and software applications and work through system interoperability problems. To date, however, there has apparently been little demand for IPv6 service or applications in the United States. As a result, given the costs to reconfigure networks, experts and industry stakeholders agree that U.S. ISPs are currently not positioned to realize a positive return on investment from large-scale offerings of IPv6 service.

11.4.2 For ISPs to offer a limited amount of IPv6 service, they would need to integrate some transition mechanism(s), such as tunneling. The costs of doing so will probably not be large. If several routers and service provisioning software are upgraded and limited testing is performed, IPv6 service could be provided to a limited number of Internet users today at minimal additional cost. Currently ISPs are performing some limited testing. However, before ISPs elect to offer widespread IPv6 service, they will need assurances that current service offerings would not be affected in any way. This would likely require much more testing and significant additional hardware, software, and training costs, possibly increasing the

costs by 100 to 200 percent more than would be incurred for a more limited service roll-out, depending on the number of affected customers and the nature of an ISP's infrastructure.

11.4.3 Assuming that IPv6 products and services in the Asian market are transferable to the U.S. market, those ISPs offering IPv6 services abroad will have absorbed some of the initial development costs. R&D costs attributable to IPv6 implementation, like any other advanced technology, can be borne by early adopters. However, excessive delay by U.S. developers may not allow them to charge early adopter premiums if mature competing products from foreign markets are already in place. However, such costs are not likely to be a dominant factor for most application services.

11.4.4 In the United States today, NTT/Verio is currently the only ISP providing end-to-end IPv6 service; however, they began replacing and upgrading hardware and software components to be IPv6 capable as early as 1997. By spreading out transition costs, including hardware and software costs, training, and the development of network administration software tools, NTT/Verio was able to upgrade for almost no additional costs above standard upgrade, training, and testing costs. Although the transition may not be as inexpensive for other ISPs, NTT/Verio's experience illustrates how careful planning can help reduce transition costs.

11.4.5 Almost all experts agree that a shift to IPv6 over a short period of time will be more expensive than performing the transition as part of a normal life-cycle update. Transition technologies were specifically designed to enable a prolonged overlap and to minimize deployment and operational interdependencies. Rather than forcing a short-term shift, many experts suggest that a reasonable deployment plan would focus on replacing as much IPv4-only hardware and software as possible through normal life-cycle updates. Over any period of acquisition, turning on IPv6 for routine use should only occur after a critical mass of IPv6-enabled replacement technology and training are in hand.

11.4.6 Thus, until customers begin demanding IPv6 service, most ISPs have no incentive to incur any major additional costs; in 5 to 10 years, however, as more hardware and software become IPv6 capable through cyclical replacements, continued standardization efforts of the IETF, and testing by many parties, ISPs will probably be in a position to recoup investment costs associated with IPv6 transition.

12. Issues for consultations

Responses of the various stakeholders are requested on the following issues: -

- i) Whether IPv6 is the only remedy to address the shortage of IP addresses or alternate methods like NAT & CIDR on existing technology (IPv4) can be used?
- ii) Whether licensor/ regulator has any regulatory role to play in the transition from IPv4 to IPv6 for the country or the industry can handle it of its own?
- iii) If yes, what regulatory steps and policy initiatives are required?
- iv) Whether IPv6 migration can help improving QOS of Internet services for the end user?
- v) Which transition mechanism/ strategy is best suited for migration from IPv4 to IPv6? How the DNS infrastructure can be upgraded? Give detailed comments.
- vi) Whether Permanent (Static) IP addresses should be mandated for end-to-end "Always-on" Broadband Connection? If yes, how these addresses should be obtained?
- vii) Is there any problem with the existing system of IP address allocation in India?
- viii) If yes, which is the most suited agency to handle IP address allocation at National level?
- ix) Should a neutral, non-profit autonomous agency be established to manage IP addresses for the country?
- x) If yes, should this be created under the aegis of Government, National Internet Exchange of India (NIXI) or a separate Agency?
- xi) Is there a need to create a national test bed for National IPv6 Backbone? If yes, how it should be created and funded?
- xii) ISPs being main stakeholders having to bear the transition cost, what should be the IPv6 transition strategy for ISPs in India.
- xiii) As an ISP are you involved in any experimentation with IPv6 in an effort to move towards commercial IPv6 based service? Please provide details.
- xiv) Any other issue/ comments pertaining to transition to IPv6.