Study Report on the IPv4 Address Space Exhaustion Issue (Phase I)

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0 Objectives of this report

The remaining stock of IPv4 addresses, which are currently used as identifiers in the global Internet, is projected to run out sometime between 2010 and 2011. This report identifies, classifies, and examines measures for the IPv4 address space exhaustion issue based on a thorough investigation of its status.

JPNIC prepared and published this report in order to provide JPNIC Members and Internet service providers in general with an accurate understanding about IPv4 address exhaustion issue. It is also intended to make them understand that the issues that should be resolved before the exhaustion must be solved by individual service providers, or through their joint efforts.

Furthermore, by clearly identifying areas where JPNIC should take an initiative to encourage efforts in tackling the issue, the report seeks to enable JPNIC, service providers, as well as each stakeholder to work on IPv4 address exhaustion issue through mutual collaboration.

1 Definition of terms

This section describes the terms used in this report. These terms are used in the following meanings unless otherwise noted:

- IP (Internet Protocol)
  A protocol used for communications on the Internet. Internet Protocol, shortly know asIP, provides two basic functions, routing and fragmentation, to send an IP datagram (IP packet) to a computer identified by a specific IP address. "IP version 4 (IPv4)," which is currently widely used, supports a 32-bit address space. However, the use of "IP version 6 (IPv6)" supporting a 128-bit address has also started to spread.

- BGP (Border Gateway Protocol)
  A routing protocol used to exchange routing information between autonomous systems (ASs) on the Internet.

- SIP (Session Initiation Protocol)
  A call control protocol for Voice over IP (VoIP), which can be used for voice calls as well as voice mail, Internet, fax, and other services.

- SSL (Secure Sockets Layer)
  A protocol that uses electronic certification technology to protect communications on the Internet from eavesdropping, alteration or message forgery.

- NAT (Network Address Translator)

A mechanism or device which establishes a connection when a host on a private, internal network with a private IP address tries to access a host on the Internet, by translating the private IP address of the host to its globally-unique IP address.

- NAT Traversal Technologies
  Technologies used to establish a connection to a host on a private network from the Internet side in NAT.

- UPnP (Universal Plug-and-Play)
  A set of protocols that enable devices connected to a residential network, etc. to communicate with each other by simply being connected. This report refers to the UPnP IGD (Internet Gateway Device) function, which defines NAT Traversal Technologies for broadband routers.

- Translator
  The term "translator" generally refers to a "translation device" or "translation mechanism." However, the term is used particularly in this report to mean a device that enables communication between IPv4 and IPv6 hosts through IP address translation and protocol translation.

- Native connection
  A form of direct connection, which does not use tunneling or a translation device for connection.

- Client, Server, Host
  Client: A client is a computer, which makes connection requests to and receives services from a server in client-server communications.
  Server: A server is a computer, which receives connection requests from clients and provides the services it supports to clients.
  Host: A host is a computer, which is connected to a network regardless of whether it is a client or server.

- Service provider
  When the term "service provider" is used in this report, it simply means a provider who receives IP address space for distributions from Internet Registries, etc. and provides services, including Internet connection to its customers, by constructing a network or system using such addresses.
  Service providers include connection providers who provide Internet connection to users and server providers who provide hosting and other services.
  Access network providers and similar organizations that do not provide Internet connection are not included as "service providers," and are specified on a case-by-case basis.

- User
  Any user of Internet connection service who mainly uses the Internet by accessing

servers on the Internet as a client.

- Customer
  Any customer of service providers, including users and servers.

- ICANN (Internet Corporation for Assigned Names and Numbers)
  A private nonprofit corporation established in October 1998 with the aim of coordinating various Internet resources worldwide. Its major roles are to (1) coordinate the allocation and assignment system of globally unique Internet identifiers such as domain names and IP addresses, (2) coordinate the operation and deployment of the DNS root name server system, and (3) coordinate the development of policies relating to these technical tasks.

- IANA (Internet Assigned Numbers Authority)
  A project group set up by Professor Jon Postel of the Information Sciences Institute (ISI) at the University of Southern California which assumes management over Internet resources such as domain names, IP addresses, and protocol numbers at the global level. Based on the February 2000 agreement among ICANN, the University of Southern California, and the United States Government, IANA functions associated with the global management of resources were transferred to ICANN. Currently, IANA is used as a name for ICANN's resource management and coordination functions.

- Internet Registry
  A body or organization that is responsible for managing and distributing Internet resources such as IP addresses or AS numbers. A generic name for Regional Internet Registries (RIRs), National Internet Registries (NIRs), and Local Internet Registries (LIRs).

- RIR (Regional Internet Registry)
  An Internet Registry that allocates IP address space within a specified area. Currently, there are five RIRs: APNIC, ARIN, RIPE NCC, LACNIC, and AfriNIC. JPNIC allocates IP addresses under APNIC.

- NIR (National Internet Registry)
  An Internet Registry organized for on enonomies basis, which undertakes the IP address allocation service of an RIR at the national level. Under the management of APNIC, JPNIC provides resource services to LIRs in Japan.

- LIR (Local Internet Registry)
  An LIR generally means an Internet Service Provider (ISP), which assigns address space to users of its network services. JPNIC IP Address Management Agents is an equivalent of LIRs in Japan.

- End user

In the context of IP address management, any end user who receives an IP address assignment from an Internet Registry (including LIR) and sets it for use in a device under the control of the end user's organization.

- APNIC (Asia Pacific Network Information Centre)
  APNIC is one of five Regional Internet Registries (RIRs) in the world, and is responsible for IP address management in the Asia-Pacific region.

- ARIN (American Registry for Internet Numbers)
  ARIN is one of five Regional Internet Registries (RIRs) in the world, and is responsible for IP address management in North America and parts of the Caribbean.

- RIPE NCC (RIPE Network Coordination Centre)
  RIPE NCC is one of five Regional Internet Registries (RIRs) in the world, and is responsible for IP address management in Europe, the Middle East, and parts of Asia.

- LACNIC (The Latin American and Caribbean IP address Regional Registry)
  LACNIC is one of five Regional Internet Registries (RIRs) in the world, and is responsible for IP address management in Latin America and the Caribbean.

- AfriNIC (African Network Information Centre)
  AfriNIC is one of five Regional Internet Registries (RIRs) in the world, and is responsible for IP address management in Africa.

2 Overview

The remaining stock of IPv4 addresses, which are currently used as identifiers in the global Internet, is projected to run out in a few years. This report identifies, classifies, and examines measures for the IPv4 address space exhaustion issue based on a thorough investigation of its status.

In conducting the study, a committee of executives was set up to consider the general policy for the IPv4 address space exhaustion issue .

For detailed study, two working groups were established. One was the IP Address Management Policy Working Group, which was responsbible for studying the date of IPv4 address space exhaustion as well as possibility of address recovery and redistribution after the exhaustion. The other was the IP Address Space Exhaustion Countermeasures Working Group, which focused on considering countermeasures against IPv4 address space exhaustion from an operational perspective.

In addition, “Advisory Committee on the IPv4 Address Space Exhaustion”, was formed, consisting of stakeholders who are not Internet Service Providers and have no direct relationships with JPNIC. Feedbacks from the Advisory Committee were incorporated in completing this report.

An overview of the report is as follows:

Study on Projected Date of IPv4 Address Space Exhaustion, and Possibility of Address Recovery and Redistributing after the Exhaustion

According to Geoff Huston’s prediction[1], considered highly reliable within the industry, IPv4 address space held by Internet Registries will run out sometime between 2010 and 2011. On the other hand, as a large portion of the address blocks which have been distributed remain unused, it is generally considered that IPv4 addresses may actually be made available even after address space runs out, by redistributing these unused addresses to meet new demand.

In conducting the study, a more accurate date of IPv4 address exhaustion and the possibility of address recovery after the exhaustion were examined. The following results were achieved:

i) JPNIC has made an independent projection based on various economic indices related to demand factors in information and telecommunication technology. JPNIC’s prediction agrees with Geoff Huston’s projection that the exhaustion of IPv4 address space will take place sometime between 2010 and 2011. This confirms the reliability of Geoff Huston’s projection.

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[1] Geoff Huston *IPv4 Address Report* http://ipv4.potaroo.net/

ii) As part of an investigation of address availability, the possibility of recovery of unused IPv4 address space for redistribution was examined. The following results were achived:

- It requires various issues to be solved, such as the need for justification on legal grounds for recovery, the establishment of recovery procedures, and the lack of incentives to encourage recovery (such as justification of the renumbering cost), etc.
- The total amount of IPv4 address space that can be recovered for redistribution is limited.

<u>Study on Countermeasures for IPv4 address space exhaustion</u>

In parallel with the above study, this report examined how service providers and other stakeholders should deal with the situation in order to continue providing stable Internet connection after the exhaustion of IPv4 address space.

First, this report clarified implications and impacts of IPv4 address space exhaustion itself, and listed measures that can be taken as well as possible issues related to the respective measures. Then the individual issues were evaluated and their solutions were classified, based on the groups that will implement the solutions.

If IPv4 address space is exhausted and no further IPv4 address space can be distributed, service providers will become unable to meet the demand for IPv4 addresses by the increasing number of subsribers and servers. This means that service providers will no longer be able to acquire new customers, expand service areas, or develop new services.

The exhaustion of IPv4 address space affects not only service providers, but also users of the Ineternet in general, as well as vendors who develop and provide hardware and software for network equipment. For the Internet users, it may result in not being able to use the services currently available, or in higher fees as the costs of the countermeasures will be passed on to them. For vendors, on the other hand, it can be both an opportunity to develop new technologies and a risk at the same time.

However, for practical purposes, this report focuses on direct impacts on service providers, and assumes that the above effects are secondary resulting from services provided by service providers.

What Internet Registries can do for these direct impacts is to recover address blocks which have been distributed yet remain unused, and restock them for redistribution to service providers as needed. As mentioned above, this involves various issues to be solved and cannot be a permanent solution since the address space that can be recovered for redistribution is limited. However, it is important for Internet Registries to work on this measure so that the following measures taken by service providers can be implemented effectively.

Measures that can be adopted by service providers are limited to a choice or combination of the following three measures:

(1) Securing IPv4 address space in some way (by generating address space from their own networks, using redistributed addresses, etc.)
(2) Accommodating new customers by using private IPv4 addresses and connecting them to the Internet through NATs
(3) Accommodating new customers by using IPv6

If service providers try to accommodate new customers after IPv4 address space runs out, they will need to adopt one of the above measures. As each of them incurs a certain cost, service providers will have to chose or combine these measures according to their business environment.

The report evaluated these three measures and clarified the following characteristics and issues:

(1) Securing IPv4 address space in some way
   - Network expansion by a service provider will be undertaken most smoothly if only it can generate address space from its own network.
   - This cannot be a permanent solution, as only limited address space is generated, while at the same time it carries the burden of renumbering.
   - It may be possible to use address space, which has been collected and redistributed as a means for securing IPv4 address space, although the effect is unclear.

<u>Although this can be a temporary measure, its effect is extremely limited.</u>

(2) Accommodating new customers by using private IPv4 addresses and NATs
   - This measure has a proven track record at medium and small-scale service providers (mainly CATV service providers).
   - Guaranteeing scalability remains an issue, as there is no track record among large service providers.
   - It is impossible to provide the same level of connection service as the one offered using global IPv4 address space.
     - Some applications may be unavailable.
   - This is not applicable to server providers and new service providers.
     - A new service provider needs to obtain at least one global address.

<u>This measure can be effective for some service providers, but needs to be implemented with awareness of its limitations.</u>

(3) Accommodating new customers by using IPv6
- This is the only sustainably and comprehensively applicable solution. It allows motivation for solving the issue.
- There are many issues to be addressed, such as the small number of devices and applications supporting IPv6 and the high introduction costs.

<u>This is the only measure that takes into account sustainable development of the Internet, but many issues still remain.</u>

When considering measures to be taken by each service provider, based on the above evaluation results, while continuing to cope with the issue using measure (1), which allows accommodation of customers in the conventional method if only address space can be secured, either measure (2) or measure (3), or both of them, are expected to be selected according to the service provider's business environment.

While measure (2) is a limited measure, as measure (3) can be a permanent measure and major domestic service providers have already announced support for IPv6, all service providers are expected to eventually adopt measure (3) at some point.

Conclusion

In view of the results of the study, JPNIC has come to recognize that, for the continuous growth of the Internet, the most effective measure to address IPv4 address space exhaustion is to promote the introduction of IPv6 within each indivual service providers.

When we consider the healthy development of the Internet, efforts must be made to address IPv4 address exhaustion by fully understanding the issues raised by measure (3), as (1) and (2) are limited measures.

However, there are many remaining issues regarding the introduction of IPv6, and it is vital for service providers to solve these issues before introducing IPv6. In particular, it is important to ensure interoperability (using translators, dual stacks, etc.) with existing IPv4 Internet to allow the general internet users to feel safe and comfortable using the IPv6 Internet.

It is extremely effective to secure IPv4 address space during the bridging period until the introduction of IPv6, as it is important as a measure to support the smooth introduction of IPv6. As failure in taking appropriate measures can cause social disruption, further thorough examination is required in the future.

IPv4 address exhaustion has been consistently examined from the standpoint of service providers, but it is clear that the issue will also affect general internet users. However, even at this stage, while the issue is widely recognized by service providers, it is not so widely acknowledged by the general internet users.

It is important for this issue to be properly recognized by the general internet users, in order to facilitate measures to be taken on the user side, as well as for service providers to incorporate users' opinions into their measures and implement them smoothly, in order to have the understanding of users as customers when they deal with the IPv4 address space exhaustion issue.

JPNIC will continue to make further efforts to address the IPv4 address space exhaustion issue, in cooperation with stakeholders, by focusing on the following three points:

i) Examinations regarding IPv6 promotion (Additional examination of measure (3))
   - Technical issues of IPv6 itself
     - Technical factors, development of equipment and devices
     - Network operation technology
   - Difficulties arising from coexistence with the IPv4 Internet
     - Research, etc. of standard specifications for translators
     - Promotion of support for dual stacks for the existing IPv4 hosts
   - Issues in IPv6 promotion
     - Increase incentive for service providers to introduce IPv6; introduction scenarios
     - Trial calculation of cost; risk analysis
     - Investigation of international trends
   - Cross-point estimation
     - Estimate time limit for recycling IPv4 addresses

ii) Examination of the reuse of IPv4 address space which has been distributed but remains unused
   - Examination of various issues regarding recovery, restocking, and redistribution
     - Issues related to the burden of costs for renumbering, etc., arising from recovery
     - Issues related to address fragmentation and routing
   - Participation in global discussions on establishment of policies for recovery, restocking, and redistribution

iii) Examination and implementation of measures to reflect users' opinions
   Examination and implementation of measures in cooperation with stakeholders, largely for raising users' awareness through providing of information

In addition to the above measures, JPNIC will continue work, according to need, on examinning indirect impacts on other sectors, as well as policy developments/changes before, during, and after the IPv4 address exhaustion .

3 Date of IPv4 address space exhaustion and the possibility of recovery and redistribution

3.1 Introduction

It is commonly believed that he commercial use of the Internet in Japan is considered to have begun in 1995. It has been more than 10 years since then, and the time when the Internet was mainly used for web-surfing and e-mail has passed. Currently, its use for shopping, online trading, and music and video broadcasting services has been rapidly expanding, and Internet technology is used even for the restructuring of telephone networks. This trend within Japan is also seen in other countries. In particular, there are notable changes in IPTV, represented by the ADSL television service rapidly expanding in Europe, and Internet development in Asian countries in line with their economic growth. The same situation in Asian countries can be seen in Eastern Europe, where the Internet is expanding with the economic growth after the integration of Eastern and Western Europe.

Under such circumstances, the demand for IPv4 address space, the most fundamental resource for the current Internet, has increased exponentially over the past few years. It is also projected that IPv4 addresses will run out by 2011, and this trend is attracting worldwide attention.

This chapter, while referencing the most widely known projection for address space exhaustion made by Geoff Huston[2], attempts to estimate the demand for IPv4 address space using an independent approach to examine the projection for the date of exhaustion from another perspective.

There are also many opinions that the existing address space (already distributed), including historical address space,[3] contains a considerable number of unused addresses, and recovery of such address space can postpone the date of IPv4 address exhaustion. Efforts associated with historical address space have already been started; however, full consideration has not yet been given to the recovery of unused address space with the primary goal of solving the address exhaustion issue. Therefore, this report examines whether or not the address space, which is expected to be recovered, is sufficient to make a significant contribution to the exhaustion issue, and whether or not the recovered address space is really in a viable condition.

Through the above research, the status of IPv4 address space exhaustion and the

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2 Geoff Huston: Chief Scientist at APNIC, engaged in research regarding routing and addressing, network architecture, QoS, and network operation management.
His prediction on IPv4 address space exhaustion is published on the following website: http://www.potaroo.net/tools/ipv4/index.html

3 The Provider Independent Address has a historical background defined by JPNIC.
For more information, refer to http://www.nic.ad.jp/ja/ip/hr/.

utilization of address space, which had already been distributed are examined below.

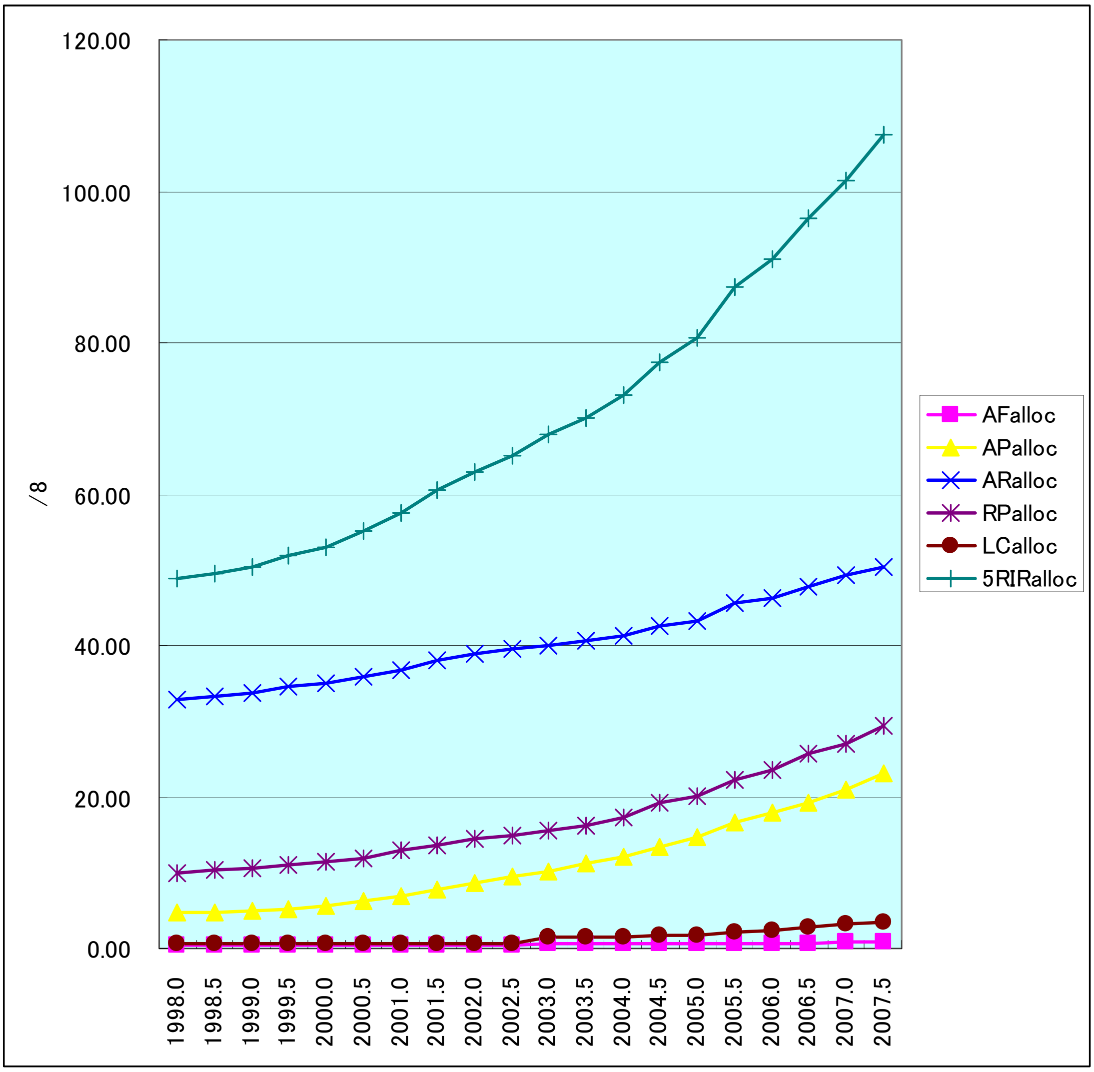
3.2 Validation of the projection of IPv4 address space exhaustion

3.2.1 Macro demand factors of each RIR

(1) Actual address demand status of each RIR

The following figure is an overview of the actual demand status of IPv4 addresses of each RIR in the past 10 years, represented by the number of /8 blocks on a daily basis, based on the data organized by Geoff Huston. The figure shows IPv4 addresses distributed to each RIR in units of /8 blocks, and initially appears as gentle exponential curves, which have a tendency closely resembling the one observed in the early part of the diffusion curve when compared to economic and other statistics.

Figure 3-1 Actual IPv4 address demand status of each RIR



(2) Macro demand factors of IPv4 addresses

(i) Consideration of demand factors

In the Geoff Huston's model, the time variable, which is the most fundamental variable in economic forecasting, is employed as the only explanatory variable from past tendencies of IPv4 address demand, and the most appropriate function is selected from the following three functions: the linear function, the quadratic function, and the exponential function. In the latest model, functions other than linear are employed for each RIR. However, if a detailed analysis is to be made on actual IPv4 address demand, it is apparent that explanatory variables should be extracted from several categories, as in the table below.

In a direct way, IPv4 address space is consumed as a resource by the spread of the Internet. However, as the Internet continues its growth as a social infrastructure, its spread seems to have been driven by commercial activities such as shopping and online games, and the spread is expected to further accelerate in the future, depending on the application fields.

Moreover, these activities are measured in an integrated manner based on macroeconomic indicators. In particular, private-sector capital investments in developed countries, and government investments in other regions, are expected to have more effect on the development of the Internet than other industrial fields.

In undertaking the estimation, the items that have a strong impact on the IPv4 address demand of each RIR have been analyzed and extracted from the actual result data during the period from 1998 to 2007, while selecting data items that can be organized for each RIR from these various indicators.

Table 3-1 Candidates of IPv4 address demand factors

Category	Reference number	Demand factor
Indices related to the spread of the Internet	1	Increase in Internet diffusion rate
	2	Development of broadband (always-connected) access
	3	Increase in PC diffusion rate
	4	Spread of network equipment
	5	Spread of NAT/NAPT devices
New Internet areas	6	Growth of IP (TV) telephone services
	7	Growth of Internet VPN services
Current major usage areas	8	Growth of shopping and financial services
	9	Growth of video delivery service
	10	Growth of interactive entertainment

Category	Reference number	Demand factor
Future application areas	11	Increase in new demand for mobile objects (vehicles, vessels, and aircrafts)
	12	Increase in new usage scenarios such as for mobile devices
	13	Spread of monitoring services for in-house terminals such as intelligent home appliances
	14	Increase in new demand for sensor networks and environment management
Macroeconomic indicators	15	Increase in private ICT investment or increase in expansion speed
	16	Increase in government ICT investment or increase in expansion speed
	17	Improvement in total factor productivity
	18	Increase in GDP per capita or per household
	19	Increase in income per capita or per household
Basic indicators	20	Increase in the white-collar proportion of the workforce
	21	Development of household sophistication
	22	Time

(ii) Examination flow of demand estimation

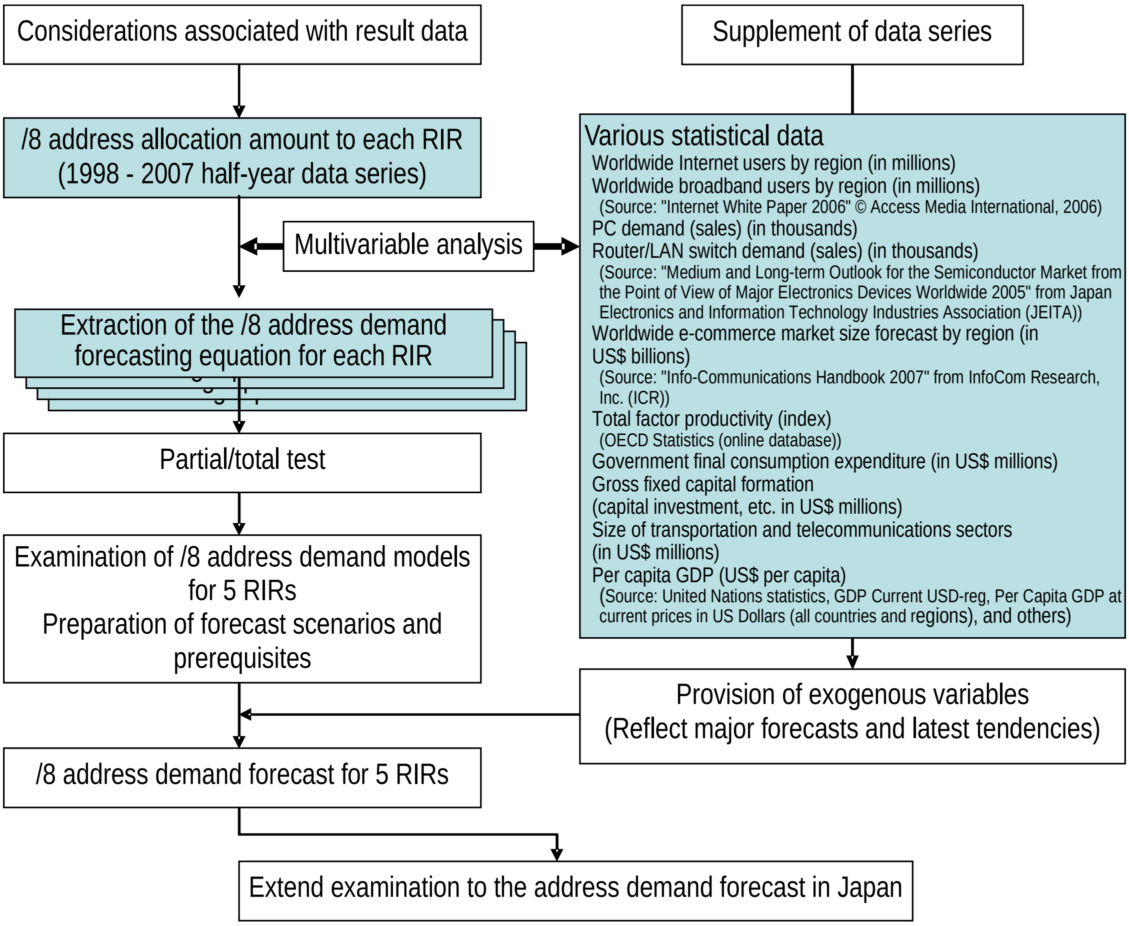
Based on the considerations in the previous section, attempts were made to organize data series during the period from 1998 to 2007. However, there were cases where data for each year was not available and consequently not arranged according to the regional classification of RIRs. Therefore, while using the United Nations statistics as the base, data was extracted from materials of specialized institutions.

Using the above statistics data, a multivariable analysis was then performed for the IPv4 address space in /8 units distributed to each RIR every half year during the period from 1998 to 2007, and the following demand forecasting equation, in the form of a polynomial equation, was derived by extracting the explanatory variables having a strong impact.

/8 address allocation to the corresponding RIR = Constant term + Coefficient 1 × Explanatory variable 1 + Coefficient 2 × Explanatory variable 2 + ……

In actuality, the explanatory variable in the above equation stands for the number of Internet users, the gross fixed capital formation, etc., depending on the RIR. Although it is desirable to perform the extraction from more explanatory variables, available data is unfortunately limited. In this estimation, however, highly accurate results, explanatory enough even compared to the existing macro-scale estimation, were obtained in spite of the limited data available.

Figure 3-2 Examination flow of demand estimation



(3) Address demand estimation equation for each RIR

(i) ARIN region

As a result of the estimation of IPv4 address space to be distributed to the ARIN region using the variables in the table below, favorable results (a multiple correlation coefficient of R = 0.999939 and a multiple determination coefficient of R2 = 0.999878) were obtained as shown in Figure 3-3. Due to the limitation of the data series, estimates were made at five time points from 2003 on, but they are considered to provide reliable data for at least the next five years.

The explanatory variables actually employed are: the gross fixed capital formation, the number of Internet users, and the e-commerce market. A relative comparison of t-values indicates that the e-commerce market has the most explanatory force, but other variables are considered to be sufficiently explanatory.

Since a significant result in terms of its explanatory force was not obtained from the number of broadband users, the number of Internet users is used as a variable.

The situation in the U.S., where as an advanced country in the Internet field enough global addresses have been available, may be affecting the result.

<Equation for demand projection>
■IPv4 allocation to the ARIN region
= 18.34583 + 0.00000428 × GFCF + 0.072027 × Internet + 0.000815 × EC

Table 3-2 IPv4 allocations to the ARIN region and actual figures of candidate explanatory variables (some figures are estimates)

Item	Allocation amount	Gross fixed capital formation	Per capita GDP	Transportation and telecommuni-cations sectors	Number of Internet users	Number of broadband users	E-commerce market	Router/ Switch sales	PC sales
Symbol	ARalloc	GFCF	PerGDP	Trans,St,Cm	Internet	BB	EC	RouterSw	PC
Year	/8	In US$ millions	US$ per capita	In US$ millions	In millions	In millions	In US$ billions	In thousands	In thousands
1998	33.222000	1,815,433	30,128	615,143	64.7	0.1			
1999	34.524368	1,966,871	31,630	656,718	85.0	0.2			
2000	35.893723	2,113,016	33,245	694,561	102.0	6.7			
2001	37.952255	2,100,531	33,849	700,623	161.0	11.7			
2002	39.525452	2,043,492	34,622	709,274	165.0	18.5			48,072
2003	40.656845	2,156,050	36,180	736,223	173.5	36.5	733	31,185	52,540
2004	42.562378	2,379,257	38,476	791,758	182.5	55.9	1,107	35,200	58,770
2005	45.703674	2,642,944	40,742	836,504	203.1	68.9	1,683	39,736	63,300
2006	47.847153	2,835,886	43,124	882,855	213.0	86.0	2,570	44,467	66,700
2007	50.423523				220.2	106.0	3,939	47,553	71,400
2008							6,059	55,201	77,400

Note: Some figures for 2007 and 2008 are estimates, and blank entries indicate no data.

Figure 3-3 Estimation result of IPv4 allocation to the ARIN region

Regression statistics	
Multiple correlation R	0.999939
Multiple determination R2	0.999878
Adjustment R2	0.999511
Standard error	0.086922
Number of observations	5

	Coefficient	Standard error	t
Segment	18.34583	1.028648	17.83489
GFCF	4.28E-06	1.55E-06	2.757563
Internet	0.072027	0.021268	3.386586
EC	0.000815	0.000144	5.6432

(ii) RIPE region

As a result of the estimation of IPv4 address space to be distributed to the RIPE region using the variables in the table below, favorable results (a multiple correlation coefficient of R = 0.998951 and a multiple determination coefficient of R2 = 0.997904) were obtained, as shown in Figure 3-4. The accuracy of the results is slightly less than that of the ARIN region. Due to the limitation of the data series, estimates were made at five time points from 2003 on, but they are considered to provide reliable data for at least the next five years.

The explanatory variables actually employed are: the gross fixed capital formation, the number of broadband users, and the e-commerce market. A relative comparison of t-values indicates that the e-commerce market has the most explanatory force, but other variables are considered to be explanatory to some extent.

In the case of the RIPE region, the number of broadband users gives a more significant result than the number of Internet users, which is considered to reflect the characteristics of the recent development of the Internet in Europe.

< Equation for demand projection >
■IPv4 allocation to the RIPE region
= 8.178377 + 0.00000245 × GFCF + 0.03569 × BB + 0.002302 × EC

Table 3-3 IPv4 allocations to the RIPE region and actual figures of candidate explanatory variables (some figures are estimates)

Item	Allocation amount	Gross fixed capital formation	Per capita GDP	Transportation and telecommuni-cations sectors	Number of Internet users	Number of broadband users	E-commerce market	Router/ Switch sales	PC sales
Symbol	RPalloc	GFCF	PerGDP	Trans,St,Cm	Internet	BB	EC	RouterSw	PC
Year	/8	In US$ millions	US$ per capita	In US$ millions	In millions	In millions	In US$ billions	In thousands	In thousands
1998	10.321133	2,000,966	13,608	643,297	32.9	0.1			
1999	10.966743	2,007,936	13,486	623,937	49.5	0.2			
2000	11.999129	1,902,882	12,638	586,586	72.5	1.6			
2001	13.708964	1,899,095	12,853	602,860	189.9	6.1			
2002	14.901249	2,011,713	14,055	676,864	212.8	13.0			30,469
2003	16.216352	2,432,838	17,098	826,030	225.3	22.6	516	23,130	34,080
2004	19.198016	2,851,349	19,829	955,825	249.8	69.8	774	25,861	40,180
2005	22.176606	3,055,718	20,908	1,005,077	287.6	108.4	1,169	28,453	43,600
2006	25.648704	3,368,633	22,455	1,088,595	330.8	134.0	1,769	31,265	46,200
2007	29.451440	3,700,000			363.5	174.0	2,681	32,842	49,500
2008							4,086	37,345	54,400

Note: Some figures for 2007 and 2008 are estimates, and blank entries indicate no data.

Figure 3-4 Estimation result of IPv4 allocation to the RIPE region

Regression statistics	
Multiple correlation R	0.998951
Multiple determination R2	0.997904
Adjustment R2	0.991616
Standard error	0.477366
Number of observations	5

	Coefficient	Standard error	t
Segment	8.178377	13.68589	0.597577
GFCF	2.45E-06	6.09E-06	0.402067
BB	0.03569	0.044314	0.805374
EC	0.002302	0.001097	2.098324

(iii) APNIC region

As a result of the estimation of IPv4 address space to be distributed to the APNIC region using the variables in the table below, favorable results (a multiple correlation coefficient of R = 0.998732 and a multiple determination coefficient of R2 = 0.997465) were obtained, as shown in Figure 3-5. The accuracy of the results is almost the same as that of the RIPE region and slightly less than the ARIN region. Due to the limitation of the data series, estimates were made at five time points from 2003 on, but they are considered to provide reliable data for at least the next five years.

The explanatory variables actually employed are: the gross fixed capital formation, the number of broadband users, and the e-commerce market. A relative comparison of t-values indicates that the e-commerce market has the most explanatory force, but other variables are considered to be sufficiently explanatory.

Additionally, in the case of the APNIC region, the number of broadband users gives a more significant result than the number of Internet users. The t-values of the e-commerce market and the gross fixed capital formation are well-balanced and close to the absolute values, and provide explanatory force.

<Demand estimation equation>
■IPv4 allocation to the APNIC region
= 1.275726 + 0.00000305 × GFCF + 0.019378 × BB + 0.00239 × EC

Table 3-4 IPv4 allocation to the APNIC region and actual figures of candidate explanatory variables (some figures are estimates)

Item	Allocation amount	Gross fixed capital formation	Per capita GDP	Transportation and telecommuni-cations sectors	Number of Internet users	Number of broadband users	E-commerce market	Router/ Switch sales	PC sales
Symbol	APalloc	GFCF	PerGDP	Trans,St,Cm	Internet	BB	EC	RouterSw	PC
Year	/8	In US$ millions	US$ per capita	In US$ millions	In millions	In millions	In US$ billions	In thousands	In thousands
1998	4.837219	2,103,389	2,090	573,156	28.8	0.1			
1999	5.282990	2,275,230	2,283	625,422	45.3	0.2			
2000	6.203629	2,416,501	2,425	677,516	91.5	5.7			
2001	7.734299	2,247,311	2,241	648,641	161.7	11.6			
2002	9.488083	2,281,926	2,267	677,297	215.1	35.1			61,671
2003	11.146118	2,594,465	2,473	750,775	255.7	53.0	343	16,189	68,420
2004	13.369064	2,993,361	2,743	851,692	312.6	109.9	494	19,880	78,660
2005	16.673187	3,365,499	2,956	880,026	366.7	160.0	724	23,999	87,500
2006	19.276413	3,776,286	3,162	983,702	442.6	207.0	1,063	28,377	95,700
2007	23.150040	4,176,286			520.3	279.0	1,570	32,593	105,100
2008							2,330	39,268	118,300

Note: Some figures for 2007 and 2008 are estimates, and blank entries indicate no data.

Figure 3-5 Estimation result of IPv4 allocation to the APNIC region

Regression statistics	
Multiple correlation R	0.998732
Multiple determination R2	0.997465
Adjustment R2	0.989859
Standard error	0.478144
Number of observations	5

	Coefficient	Standard error	t
Segment	1.275726	13.05318	0.097733
GFCF	3.05E-06	5.89E-06	0.517773
BB	0.019378	0.049387	0.392368
EC	0.00239	0.002779	0.860139

(iv) LACNIC region

As a result of the estimation of IPv4 address space to be distributed to the LACNIC region using the variables in the table below, relatively favorable results (a multiple correlation coefficient of R = 0.989158 and a multiple determination coefficient of R2 = 0.978434) were obtained, as shown in Figure 3-6. Although the accuracy is slightly lower, estimates were made at seven time points from 2001 on, and they provide more reliable data for the next five years than that of the ARIN, RIPE and other regions.

The explanatory variables actually employed are government final consumption expenditure and the number of broadband users. A relative comparison of t-values indicates that the number of broadband users has the most explanatory force. Gross fixed capital formation, which includes private investment, was not reliable enough in terms of its explanatory force for the LACNIC region, as its result data was erratic due to an unstable economic environment. Therefore government expenditure data was employed instead.

Additionally, for the LACNIC region two explanatory variables, the number of Internet users and the e-commerce market, were used as candidates and favorable results (a multiple correlation coefficient of R = 0.981122 and a multiple determination coefficient of R2 = 0.9626) were obtained from them. However, they are not employed in this estimation as of the limitations of the e-commerce market data and as the values of R and R2 are slightly low.

<Demand estimation equation>
■IPv4 allocation to the LACNIC region
= -4.06351 + 0.00000275 × GGFC + 0.017732 × BB

Table 3-5 IPv4 allocation to the LACNIC region and actual figures of candidate explanatory variables (some figures are estimates)

Item	Allocation amount	Government final consumption expenditure	Gross fixed capital formation	Per capita GDP	Transportation and telecommunica-tions sectors	Number of Internet users	Number of broadband users	E-commerce market
Symbol	LCalloc	GGFC	GFCF	PerGDP	Trans,St,Cm	Internet	BB	EC
Year	/8	In US$ millions	In US$ millions	US$ per capita	In US$ millions	In millions	In millions	In US$ billions
1998	0.586029	1,384,099	406,991	4,362	139,979	1.5	0.0	
1999	0.587982	1,470,452	339,087	3,445	129,841	2.3	0.0	
2000	0.589462	1,566,041	371,085	3,638	145,894	4.2	0.1	
2001	0.604858	1,655,122	350,405	3,281	146,095	33.7	0.3	
2002	0.605103	1,783,586	302,197	2,546	125,493	41.3	1.1	
2003	1.515625	1,935,867	307,793	2,720	131,061	47.0	1.3	110
2004	1.698883	2,083,736	379,940	3,247	147,047	63.3	6.0	164
2005	2.197906	2,236,153	471,522	4,061	173,105	79.1	12.1	250
2006	2.826416	2,393,921	530,532	5,058	203,309	99.0	18.0	385
2007	3.475327					122.0	27.0	592
2008								912

Note: Some figures for 2007 and 2008 are estimates, and blank entries indicate no data.
Note: EC is data from regions other than the United States, Europe, Asia, and the Pacific.

Figure 3-6 Estimation result of IPv4 allocation to the LACNIC region

Regression statistics	
Multiple correlation R	0.989158
Multiple determination R2	0.978434
Adjustment R2	0.967651
Standard error	0.193586
Number of observations	7

	Coefficient	Standard error	t
Segment	-4.06351	1.462029	-2.77936
GFCF	2.75E-06	8.08E-07	3.399057
BB	0.017732	0.025801	0.687244

(v) AfriNIC region

As a result of the estimation of IPv4 address space to be distributed to the AfriNIC region using variables in the table below, favorable results (a multiple correlation coefficient of R = 0.99832 and a multiple determination coefficient of R2 = 0.996643) were obtained as shown in Figure 3-7. The accuracy of the results is higher than that of the LACNIC region, but it is a simple structure with only the number of broadband users employed as an explanatory variable. No other variables were explanatory enough to be employed in this estimation. Although the data series contain seven time points from 2001, in this estimation using only the number of broadband users as an explanatory variable, results at five time points from 2003 on which provided the most favorable R and R2 results were employed by changing the estimation period.

In the AfriNIC region, as data on government final consumption expenditure as well as gross fixed capital formation is erratic, it is difficult to correlate them with the IPv4 address allocation amount, which keeps on growing steadily.

<Demand estimation equation>
■IPv4 allocation to the AfriNIC region = 0.518563 + 0.0036372 × BB

Table 3-6 IPv4 allocation to the AfriNIC region and actual figures of candidate explanatory variables (some figures are estimates)

Item	Allocation amount	Government final consumption expenditure	Gross fixed capital formation	Per capita GDP	Transportation and telecommunica-tions sectors	Number of Internet users	Number of broadband users	E-commerce market
Symbol	Afalloc	GGFC	GFCF	PerGDP	Trans,St,Cm	Internet	BB	EC
Year	/8	In US$ millions	In US$ millions	US$ per capita	In US$ millions	In millions	In millions	In US$ billions
1998	0.469269	87,068	104,584	735	40,523	1.3	0.0	
1999	0.475372	89,093	101,997	726	41,233	1.6	0.0	
2000	0.484665	89,821	101,285	738	40,805	3.0	0.0	
2001	0.521378	85,090	97,868	693	41,363	12.9	0.3	
2002	0.538193	85,210	100,552	676	40,767	16.4	0.7	
2003	0.553558	108,221	123,337	790	48,995	19.6	0.6	110
2004	0.574295	130,081	153,018	919	59,574	30.1	1.7	164
2005	0.611954	146,487	180,105	1,054	68,587	42.8	2.9	250
2006	0.733185	162,722	214,832	1,158	76,390	60.5	5.8	385
2007	0.956390					83.5	12.0	592
2008								912

Note: Some figures for 2007 and 2008 are estimates, and blank entries indicate no data.
Note: EC is data from regions other than the United States, Europe, Asia, and the Pacific.

Figure 3-7 Estimation result of IPv4 allocation to the AfriNIC region

Regression statistics	
Multiple correlation R	0.99832
Multiple determination R2	0.996643
Adjustment R2	0.995524
Standard error	0.011137
Number of observations	5

	Coefficient	Standard error	t
Segment	0.518563	0.007499	69.14647
BB	0.036372	0.001219	29.84223

3.2.2 Examination of the address demand forecast model for each RIR

(1) Examination of demand forecast scenarios

A series of examinations, such as identification of explanatory variables and confirmation of the difference between forecasts and actual results was made in the estimation operations in the previous section. As a result, estimation models generally considered to be available for the future estimation operation were obtained, although the estimation models for the LACNIC and AfriNIC regions are lacking in detail due to the data limitations.

As explanatory variables for each RIR region, combinations of some variables from government final consumption expenditure, gross fixed capital formation, the number of

Internet users, the number of broadband users, and the e-commerce market, were used. Various forecasting agencies have published their estimates regarding the first two, therefore this time the forecast scenarios for them were created by referring to their estimates. As for other variables, in principle, the average rates of change in the past three years were used for the forecast scenarios by modifying some figures that seemed to be excessive.

The table below shows the assumptions used as the basis for demand forecasts for each RIR:

Table 3-7 Creation of demand forecast scenarios

	Government final consumption expenditure	Gross fixed capital formation	Number of Internet users	Number of broadband users	E-commerce market
ARIN	-	Although the average growth rate in the past three years is 9%, this time the latest growth rate of 7% is adopted.	The latest growth rate of 3% is adopted.	-	The growth rate of 50% is adopted by referring to past results of 51% to 54%.
RIPE	-	Although the average growth rate in the past three years is 11%, the average rate of 9% in the most recent two years is adopted this time, decremented by 1% from 2011 on.	-	By referring to the average growth rate of 39% in the most recent two years, the growth rate of 30% is adopted, decremented by 10% from 2012 on.	The latest growth rate of 52% is adopted to reflect the strong economic growth in Europe.
APNIC	-	Although the average growth rate in the past three years is 13%, a growth rate of 11% is adopted from now on as it shows a slight decline.	-	The average growth rate of 37% in the past three years is adopted.	The latest growth rate of 48% is adopted to reflect the strong economic growth in Asia.
LACNIC	Although the average growth rate in the past three years is 8%, a growth rate of 7% will be adopted from now on as it shows a slight decline.	-	-	Although the average growth rate in the past three years is 67%, the growth rate of 50% is adopted from 2011 on.	-

	Government final consumption expenditure	Gross fixed capital formation	Number of Internet users	Number of broadband users	E-commerce market
AfriNIC	-	-	-	The average growth rate in the past three years is 92%, and the growth rates of 80%, 70%, and 60% are adopted for the years from 2011 on.	-

Table 3-8 Estimation results for the ARIN region (Gr shows the growth rate)

Year	ARalloc	Project	GFCF	Gr	Internet	Gr	EC	Gr
2003	40.656845	40.661192	2,156,050		173.5		733	
2004	42.562378	42.568984	2,379,257	10%	182.5	5%	1,107	51%
2005	45.703674	45.650117	2,642,944	11%	203.1	11%	1,683	52%
2006	47.847153	47.911565	2,835,886	7%	213.0	5%	2,570	53%
2007	50.423523	50.401715	3,035,886	7%	220.2	3%	3,939	53%
2008		53.514913	3,248,398	7%	226.8	3%	6,059	54%
2009		57.447556	3,475,786	7%	233.6	3%	9,089	50%
2010		62.698008	3,719,091	7%	240.6	3%	13,633	50%
2011		69.888992	3,979,427	7%	247.8	3%	20,449	50%
2012		79.952337	4,257,987	7%	255.3	3%	30,674	50%
2013		94.283377	4,556,046	7%	262.9	3%	46,011	50%

Table 3-9 Estimation results for the RIPE region (Gr shows the growth rate)

Year	RPalloc	Projection	GFCF	Gr	BB	Gr	EC	Gr
2003	16.216352	16.130866	2,432,838		22.6		516	
2004	19.198016	19.434276	2,851,349	17%	69.8	209%	774	50%
2005	22.176606	22.221687	3,055,718	7%	108.4	55%	1169	51%
2006	25.648704	25.282878	3,368,633	10%	134.0	24%	1769	51%
2007	29.451440	29.621411	3,700,000	10%	174.0	30%	2681	52%
2008		35.532362	4,036,017	9%	225.9	30%	4086	52%
2009		43.705817	4,402,548	9%	293.4	30%	6,201	52%
2010		55.199480	4,802,367	9%	381.0	30%	9,411	52%
2011		71.422117	5,190,472	8%	494.7	30%	14,282	52%
2012		92.871189	5,558,036	7%	593.6	20%	21,675	52%
2013		123.762908	5,896,050	6%	712.3	20%	32,894	52%

Table 3-10 Estimation results for the APNIC region (Gr shows the growth rate)

Year	APalloc	Projection	GFCF	Gr	BB	Gr	EC	Gr
2003	11.146118	11.031621	2,594,465		53.0		343	
2004	13.369064	13.711180	2,993,361	15%	109.9	107%	494	44%
2005	16.673187	16.366245	3,365,499	12%	160.0	46%	724	47%
2006	19.276413	19.339618	3,776,286	12%	207.0	29%	1063	47%
2007	23.150040	23.166159	4,176,286	11%	279.0	35%	1570	48%
2008		28.361086	4,635,677	11%	381.1	37%	2330	48%
2009		35.290299	5,145,602	11%	520.5	37%	3448	48%
2010		44.661945	5,711,618	11%	710.9	37%	5104	48%
2011		57.472294	6,339,896	11%	970.9	37%	7553	48%
2012		75.147587	7,037,285	11%	1326.1	37%	11179	48%
2013		99.734564	7,811,386	11%	1811.2	37%	16545	48%

Table 3-11 Estimation results for the LACNIC region (Gr shows the growth rate)

Year	LCalloc	Projection	GGFC	Gr	BB	Gr
2001	0.604858	0.487333	1,655,122		0.3	
2002	0.605103	0.854323	1,783,586	8%	1.1	267%
2003	1.515625	1.276084	1,935,867	9%	1.3	18%
2004	1.698883	1.765522	2,083,736	8%	6.0	362%
2005	2.197906	2.292273	2,236,153	7%	12.1	102%
2006	2.826416	2.830176	2,393,921	7%	18.0	49%
2007	3.475327	3.418407	2,550,000	7%	27.0	50%
2008		4.225908	2,727,563	7%	45.0	67%
2009		5.281056	2,917,490	7%	75.1	67%
2010		6.728981	3,120,642	7%	125.3	67%
2011		8.436835	3,337,939	7%	188.0	50%
2012		10.741783	3,570,368	7%	282.0	50%
2013		13.924490	3,818,982	7%	423.0	50%

Table 3-12 Estimation results for the AfriNIC region (Gr shows the growth rate)

Year	AFalloc	Projection	BB	Gr
2001	0.521378	0.529475	0.3	
2002	0.538193	0.544024	0.7	133%
2003	0.553558	0.540387	0.6	−14%
2004	0.574295	0.580396	1.7	183%
2005	0.611954	0.624043	2.9	71%
2006	0.733185	0.729523	5.8	100%
2007	0.956390	0.955033	12.0	107%
2008		1.358745	23.1	92%
2009		2.135870	44.5	92%
2010		3.631797	85.6	92%
2011		6.122384	154.1	80%
2012		10.045059	261.9	70%
2013		15.760957	419.1	60%

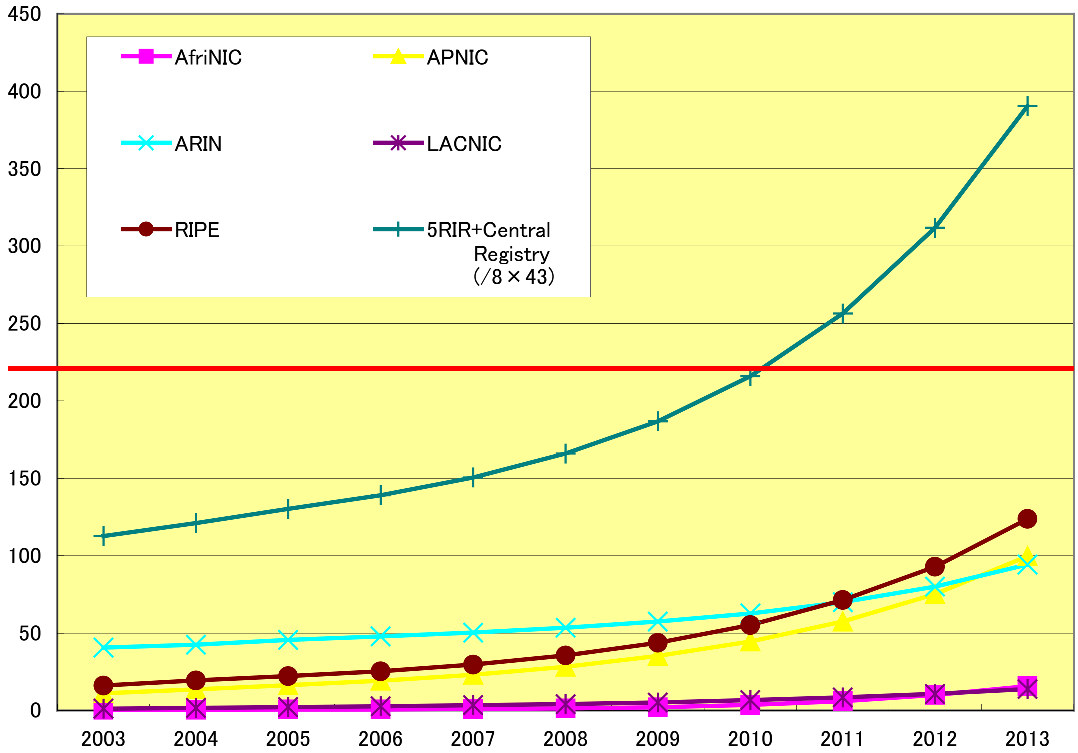
(2) Demand forecast results for each RIR

The table below shows the results of the estimation operation based on the scenarios in the previous section. Against a background of favorable economic conditions and broadband development, IPv4 address space allocations to the RIPE region in /8 units will reach 55.2 by the year 2010. By the same year, allocation to the APNIC region will reach 44.7 and the total allocation to five RIR regions will reach 215.9. The spread of broadband is correlated with economic activities since as an economic infrastructure it stimulates economic activities, and the demand for IPv4 address space is expected to increase exponentially through the synergistic effect between them.

Eventually, it is forecasted that the total allocations to the five RIR regions will reach 256 by the year 2011, and so the date when the upper limit of 200, excluding address space reserved for special purposes, is reached (the date of the IPv4 address space exhaustion) is expected to come earlier than Geoff Huston's prediction.

Table 3-13 Forecast of IPv4 address allocation to 5 RIRs (in terms of the number of /8 blocks)

AD	AfriNIC	APNIC	ARIN	LACNIC	RIPE	5RIR+Central Registry
2003	0.540	11.032	40.661	1.276	16.131	112.640
2004	0.580	13.711	42.569	1.766	19.434	121.060
2005	0.624	16.366	45.650	2.292	22.222	130.154
2006	0.730	19.340	47.912	2.830	25.283	139.095
2007	0.955	23.166	50.402	3.418	29.621	150.562
2008	1.359	28.361	53.515	4.226	35.532	165.993
2009	2.136	35.290	57.448	5.281	43.706	186.861
2010	3.632	44.662	62.698	6.729	55.199	215.920
2011	6.122	57.472	69.889	8.437	71.422	256.342
2012	10.045	75.148	79.952	10.742	92.871	311.758
2013	15.761	99.735	94.283	13.924	123.763	390.466



3.2.3 Address demand factors in Japan

Regarding the JPNIC region (Japan), the allocation amount (per host) was estimated in /32 units based on JPNIC data, and data on the address space that is considered to be directly allocated by APNIC and used within Japan was also collected independently.

In the case of Japan, it is difficult to give an explanation about the continually increasing trend of address consumption as related indicators are not stable due to unstable economic conditions in recent years. Putting it the other way around, the Internet has rapidly expanded in spite of these erratic Japanese economic conditions.

As a result of a multivariable analysis performed in the same way as in the estimation flow of other RIRs, the number of broadband contracts and the e-commerce market (data published by the Ministry of Economy, Trade and Industry (METI) was used for data on Japan; and United Nations statistics were used in the same way as other RIRs for other economic indicators) were proved to have the most explanatory force, and favorable results (a multiple correlation coefficient of R = 0.998446 and a multiple determination coefficient of R2 = 0.996895) were obtained. Although the number of broadband contracts has the greater t-value, it is competitive with the e-commerce market, and the fact that both have a strong impact on the address demand can be said to be a characteristic of Japan.

<Demand estimation equation>
■IPv4 allocation to the JPNIC region
= 40,139,603 + 1677.383 × BBHH + 761.6744 × EC

Table 3-14 IPv4 allocation to the JPNIC region and actual figures of candidate explanatory variables (some figures are estimates)

Item	Allocation amount	Gross fixed capital formation	Per capita GDP	Transportation and telecommunications sectors	Number of Internet users	Number of broadband users	Number of broadband contracts	E-commerce market	Router/ Switch sales	PC sales
Symbol	JPalloc	GFCF	PerGDP	Trans,St,Cm	Internet	BB	BBHH	EC	RouterSw	PC
Year	/32	In US$ millions	US$ per capita	In US$ millions	In millions	In millions	In thousands	In US$ billions	In thousands	In thousands
1998		994,490	30,381	274,811						
1999		1,109,811	34,297	304,618						
2000		1,173,947	36,601	323,136			155			
2001		1,009,216	32,118	285,112			636			
2002	58,153,676	909,553	30,630	275,604	48,900,000	7,286,100	2,837	18,000		11,680
2003	70,275,750	970,289	33,145	297,542	57,220,000	18,700,000	7,806	22,000	7,630	12,970
2004	84,208,072	1,047,845	35,876	322,095	61,640,000	26,550,000	13,641	26,000	8,969	13,800
2005	97,138,688	1,058,945	35,646	313,382	64,160,000	41,170,000	18,630	34,560	10,397	14,200
2006	108,897,120	1,064,687	34,661	309,430	66,010,000	45,820,000	22,345	43,910	11,937	14,700
2007	125,217,352				80,550,000	56,870,000	25,743	53,000	13,169	15,000
2008									15,718	15,200

Note: Some figures for 2007 and 2008 are estimates, and blank entries indicate no data.
Note: As the statistical method for the e-commerce market has been changed from 2005, values for 2004 and previous years are estimates.

Figure 3-8 Estimation result of IPv4 allocation to the JPNIC region

Regression statistics	
Multiple correlation R	0.998446
Multiple determination R2	0.996895
Adjustment R2	0.994825
Standard error	1786179
Number of observations	6

	Coefficient	Standard error	t
Segment	40139603	2774692	14.46633
BBHH	1677.383	343.1992	4.88749
EC	761.6744	222.1339	3.428898

3.2.4 Examination of the address demand forecast model for Japan

(1) Examination of demand forecast scenarios

(i) Number of broadband contracts

The number of broadband subscribers in Japan exceeded 27 million as of the end of September 2007, and the National Broadband Initiative of the Ministry of Internal Affairs and Communications (MIC) aims to achieve 100% broadband coverage in households.

Converting this number into the number of broadband users (BB) gives an estimation of a little less than 57 million as of 2007, but the growth rate has been declining.

In this forecast, since the number of contracts in June 2007 (the latest figure available) showed a 12% increase from the same month last year and the growth rate has shown a decline, this figure is used as the growth rate until 2013. As the migration from ADSL to FTTH, which requires comparatively large construction work, is in progress, it appears that the supply capability will reach its limit as it spreads to rural and regional areas.

Thus the number of broadband contracts as of 2013 will be 50.81 million, and this slightly exceeds the number of total households. However, as there are about 5 million places of business and offices in Japan, and with the number of total households the total is 55 million, the penetration rate as of 2013 does not reach 100% even when the contracts by places of business, etc. are included.

(ii) E-commerce market

The scale of the Japanese B to C e-commerce market (EC) was 4.4 trillion yen in 2006 and is estimated to exceed 5.3 trillion yen in 2007.

The growth rate is assumed to be 24% based on the average growth rate during the past two years. As a result, the market size is estimated to reach 19.3 trillion yen by 2013, accounting for 11% of the total retail sales of 176 trillion yen according to the Commercial Statistics 2004, yet this is considered a modest forecast compared to the actual trend.

Table 3-15 IPv4 address allocation forecast scenarios for the JPNIC region

Year	Result	Forecast	BBHH	Gr (growth rate)	FC	Gr (growth rate)
2002	58,153,676	58,608,478	2,837		18,000	
2003	70,275,750	69,990,091	7,806	175.1%	22,000	22.2%
2004	84,208,072	82,824,317	13,641	74.8%	26,000	18.2%
2005	97,138,688	97,712,713	18,630	36.6%	34,560	32.9%
2006	108,897,120	111,065,846	22,345	19.9%	43,910	27.1%
2007	125,217,352	123,689,213	25,743	15.2%	53,000	20.7%
2008		138,559,416	28,832	12.0%	65,720	24.0%
2009		156,376,662	32,292	12.0%	81,493	24.0%
2010		177,773,627	36,167	12.0%	101,051	24.0%
2011		203,525,872	40,507	12.0%	125,303	24.0%
2012		234,585,066	45,368	12.0%	155,376	24.0%
2013		272,120,044	50,812	12.0%	192,666	24.0%

Note: Figures for 2008 and subsequent years are forecast scenarios.
Note: EC result values for 2002 to 2004 are estimates.

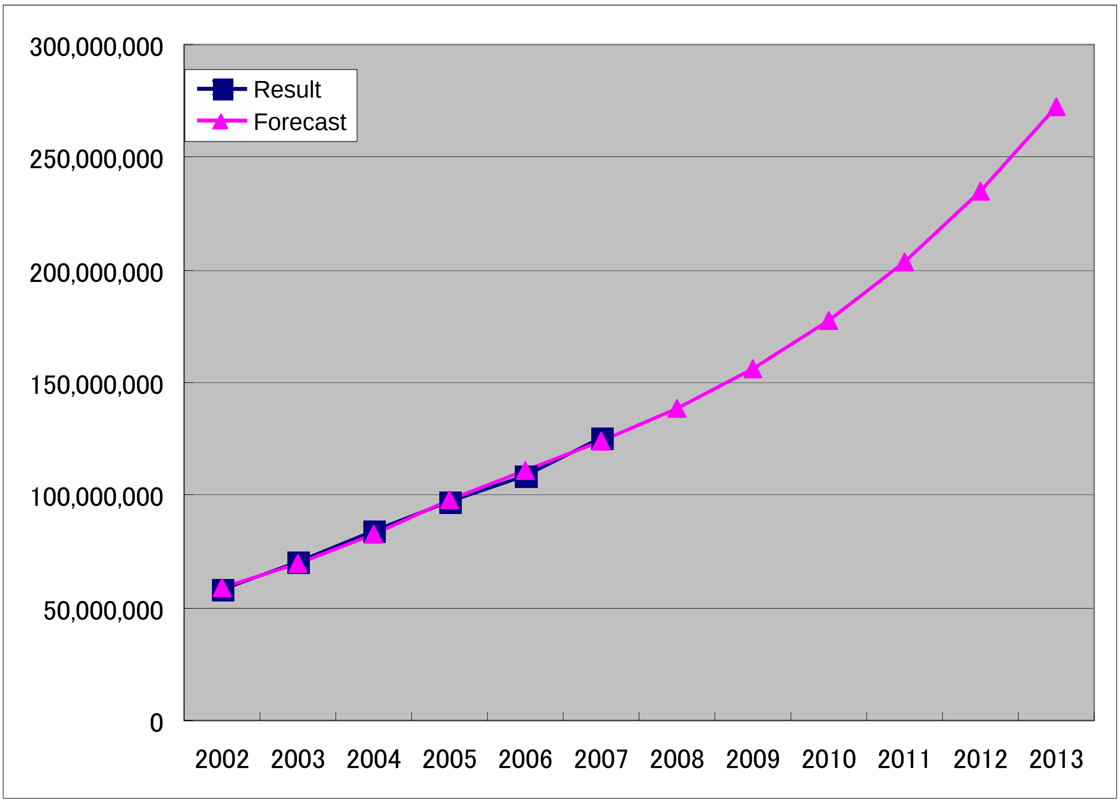
(2) Results of the forecasts of IPv4 address demand in Japan

As a result of the estimation based on the forecast scenarios in the previous section, IPv4 address demand in Japan will exceed 200 million (about 12 in /8 units) by 2011.

The maximum number of broadband contracts is limited to 55 million in the forecast. However, in this forecast the application of the Internet represented by the size of the e-commerce market can expand beyond this figure. If the size of the e-commerce market reaches 25 trillion yen (14% of the total retail sales in 2004) by 2011, double the size of what is currently estimated, then the address demand will be about 300 million (18 in /8 units).

Year	Result	Forecast
2002	58,153,676	58,608,478
2003	70,275,750	69,990,091
2004	84,208,072	82,824,317
2005	97,138,688	97,712,713
2006	108,897,120	111,065,846
2007	125,217,352	123,689,213
2008		138,559,416
2009		156,376,662
2010		177,773,627
2011		203,525,872
2012		234,585,066
2013		272,120,044

Figure 3-9 Address demand forecast in the JPNIC region



3.3 Examination on the possibility of recovery of unused IPv4 address space

3.3.1 Estimation of the utilization state of historical address space

(1) Extraction of address space to be recovered

The historical address blocks subject to recovery are address blocks directly assigned by international IP address assignment institutions prior to the introduction of CIDR (Classless Inter-Domain Routing, RFC1517, September 1993). In general, they can becategorized into two types: address blocks registered to end-user organizations such as enterprises in units of /8 blocks by around 1995, and address blocks registered as Various Registries.

According to the "Internet Protocol v4 Address Space (as of November 1, 2007)" published by IANA, the sizes of each type of address blocks to be recovered are as follows:

Table 3-16 Breakdown of historical PI address space by category

Category	Number of /8 blocks	Remarks
Address blocks assigned to organizations in /8 units	41 (36 organizations)	Those not IANA Reserved, managed by RIRs, or Various Registries
Address blocks considered to have been assigned to organizations in /16 or /24 units	49	Those falling under Various Registries

The total number of /8 address blocks assigned to end-user organizations is 41. However, since there are cases in which multiple address blocks are assigned to a single organization, the number of organizations is thus 36.

Although 49 address blocks are registered as Various Registries, they are managed by multiple RIRs and many of them are considered to have been assigned to end-user organizations in units of /16s or /24s.

For reference, the breakdown of all IPv4 address space including those managed by IANA and RIRs as of November 1, 2007 is shown in the table below.

Table 3-17 Breakdown of all IPv4 address space

Category	Number of /8 blocks	Remark
IANA - Reserved	61	The “IANA Pool” contains 42
Other IANA	18	Multicast × 16 Private Use × 1 Public Data Network × 1
ARIN	27	Including Cable Block × 1
RIPE NCC	26	
APNIC	26	
LACNIC	6	
AfriNIC	2	
Address space assigned to individual organizations in /8 units	41	
Various Registries	49	

(2) Examination of technical validation methods

To examine the possibility of recovery of historical address blocks, the actual state of utilization needs to be investigated. Even if /8 address blocks had been assigned, there is a high possibility of recovery if most of them are unused. Conversely, /8 address blocks have been assigned to end-user organizations that include many global companies, and their address blocks may be divided into subnets for global use. In such cases, it is likely to be very difficult to recover address blocks as one lot.

With regard to the state of utilization of the assigned address space, the IANA registration information is said to have been only partially updated around 2006 or 2007, but, other than that, the actual state is not understood by anyone except the organizations that actually received assignments. Accordingly, the best course of action is to directly ask the relevant organizations about the utilization state of addresses assigned to them, but this involves the issues of contact channels (whom to ask), too much time taken, etc. Therefore, technical validation methods through networks are examined.

The possible technical validation methods are as follows:

(i) Checking the DNS for the registration status of the address representing the organization (registration status research)
(ii) Sending an ICMP Echo request to the address representing the organization to check reachability (ICMP Echo research)
(iii) Performing a port scan, etc. on the address representing the organization (port scan survey)
(iv) Sending an email to the address of the network administrator of the organization (email sending research)

(i) Registration status research

- This research cannot be applied to addresses with no advertised routes. It is generally considered that there still remain organizations that received address assignments to build the network a long time ago that directly enter addresses or use hosts files without using the DNS service. Therefore, this research would not be able to cover all the addresses actually used.

(ii) ICMP Echo research

- This research can be carried out easily.
- This research can be implemented by identifying a host. If reachability to the network is ensured, address utilization state may be investigated more in detail.
- This research is questionable in its effectiveness as ICMP Echo requests from outside sources are likely to be filtered.
- As it could be taken as a DoS attack or similar, it is necessary to give careful consideration to the scope and frequency of this research.

(iii) Port scan research

- Network utilization state, including protocols used, can generally be investigated through port level investigation.

- This research is not appropriate as a research method as scanning many ports could be seen as an attack.

(iv) Email sending research

- This research can be easily carried out by sending an email to the email address of the administrator identified by Whois or other means.
- When sending an email, a questionnaire can be sent at the same time, and reachability can be confirmed by receiving an error mail message (indicating whether the error is in the email address or the site itself).
- If information in Whois is obsolete, the research result can be in error even when the network is available.
- If there is no response to the questionnaire, it is impossible to confirm the internal utilization state of the address block even if the utilization of an address block itself can be confirmed.

(3) Implementation and analysis of technical validation

The email sending research was used from among the above mentioned research methods to investigate the address block utilization state. The purpose of this research was not just to investigate the reachability state of address blocks themselves by simply sending emails, but also to confirm the internal utilization state of the address blocks by sending email questionnaires. The details are described in the next section.

(4) Email questionnaire

The destinations of the email questionnaire are the address blocks assigned to organizations in /8 units, mentioned in (1) above (hereinafter the IANA Registry) and the address blocks considered to have been assigned to organization in /16 or /24 units (hereinafter Various Registries).

Of these blocks, existence confirmation emails containing a questionnaire were sent to /8 × 40 blocks in the IANA Registry which had been successfully identified by Whois or other means (only the 12.0.0.0/8 block was further divided into /24 blocks, and the email address of the representative administrator could not be identified). Specifically, the contents of the email questionnaire were as follows:

Table 3-18 Contents of the email questionnaire

(1) Percentage of addresses used in the total addresses assigned
(2) Use (non-use) of the Internet
(3) Use (non-use) of an intranet
(4) Use (non-use) of an extranet including connection between bases
(5) Intention to migrate from IPv4 to IPv6

The results of the email questionnaire are as follows:

Table 3-19 Results of the email questionnaire

Number of emails sent to /8 address administrators	Number of emails reached	Number of responses to the questionnaire
40 (35 organizations)	37 (32 organizations)	0
10 (MX exists in the same block)	10	0

(5) Organizing the results

Of the 40 email questionnaires sent, four emails were returned as error mails. Two of them were returned due to “No such user” (reply from the postmaster in another domain), another one for the reason of “Host or domain name not found,” and the other one for the reason of “transient non-fatal errors (Insufficient disk space).” Among them, 10 emails were sent to the addresses of administrators whose MX is in the same block, and only one email was returned as an error mail. Given that the reason was “transient non-fatal errors (Insufficient disk space)” and the email was finally delivered to the destination address, the reachability was almost 100%.

Even in the cases where the administrator exists in another address block, 27 out of 30 emails did arrive, and when /8 × 12 blocks assigned for the U.S. Department of Defense (DoD) and related agencies are excluded, 15 out of 18 emails arrived. Although this does not directly show the utilization state of address blocks, it would be natural to presume that many address blocks are being used given that DNS appears to be operating in five cases out of the above.

Unfortunately, as the number of responses to the questionnaire is zero, the breakdown of patterns of address utilization by organizations using address blocks assigned to them has not been clarified at present. An example of an address block whose status has been individually confirmed is given below for reference.

A particular historical address space registered as a /8 address space[4] is used for construct an intranet connecting several bases scattered across the world. Although they are not advertised on the Internet, the assigned global addresses are actually used within the internal network. They have been used for a long time and many connections are established by directly entering addresses, so reorganizing address blocks to generate an empty space is extremely difficult in terms of cost and workload required.

This is just an example, but is assumed that many historical address user organizations that have used IP addresses for a long time have utilization pattern like

4 This expression is used as it is not appropriate to specify and make it public.

the one shown above.

3.3.2 Issues associated with recovery

(1) Technical issues

To recover historical address space, we must also identify and classify technical issues. For that purpose, we have attempted to develop assumed patterns of utilization as follows:

Table 3-20 Assumed utilization patterns of historic PI address space

Utilization state of historic PI address space	State and recovery pattern
The address spaces are not currently used at all.	There is a possibility that the address spaces will become entirely unused due to bankruptcy, organizational restructuring, and other reasons. The whole address space assigned is expected to be recovered, but it may be impossible to detect the contact point of the owner.
Most address blocks remain unused as private addresses are used internally, although some addresses are used for connection to the Internet.	There is a possibility that a partial amount of the all assigned address spaces can be recovered as one lot. It can also be expected to be able to recover all the address spaces assigned by switching the addresses used for connecting to the Internet to the ones provided by service providers, but some incentive would be necessary to encourage recover.
Part of the address blocks remain unused as one lot as a result of network restructuring, although addresses are used both for connection to the Internet and an internal network.	There is a possibility that the address spaces that remain unused can be recovered as one lot. However, whether the size of address blocks is reasonable for recovery and use would be an issue. Addresses used for an internal network cannot be recovered without renumbering, but if the network has a relatively organized structure, the burden required for renumbering would be relatively small.
Addresses are used both for connection to the Internet and an internal network. Ample addresses are used for an internal network, and there are almost no addresses left unused as one lot (unused addresses are sparsely distributed in the address space).	Renumbering is necessary to recover and reuse addresses. Due to the extensive range, the burden of cost and work would be large.

Utilization state of historic PI address space	State and recovery pattern
Addresses are used only for an internal network (addresses provided by service providers are used to connect to the Internet).	Renumbering is necessary to recover and reuse addresses. The burden depends on the size of the network. However, if the internal network is completely closed and not connected to any external network, it would be technically possible to recover and reuse addresses without renumbering.

As a result of organizing recovery patterns by the pattern of address utilization state, the following technical issues have been made clear:

Table 3-21 Technical issues associated with recovery

Issue	Description
Size of address blocks recovered	There is a possibility that a certain size of address blocks can be recovered from an organization having a /8 or /16 address space. However, in the case where an organization has a /24 address space, the size of the partial address space recovered from it will be /25 or less. As it can affect routing, etc., such recovery is unrealistic and ineffective.
Recovery method involving renumbering	When recovering addresses already used after renumbering, the renumbering operation must be performed in such a manner that it does not have an impact on business continuity. However, it involves a lot of work, including remonitoring of the current address utilization state, identifying the extent of the impact, network design after migration, formulation of the migration plan, and handling of failures. It is considered that organizations have little experience in large-scale renumbering (even if any, they are not made public), and preliminary examination of technical issues would be required.
Evaluation of addresses after recovery	It is necessary to technically verify that there are no issues in the reuse of addresses (If a issue occurs, will it have a significant impact on the reachability to the Internet?).

(2) Legal issues

Currently, addresses allocated and assigned by RIRs and NIRs are used in accordance with relevant policies, regulations, and contracts. However, with regard to historical address space, it is often the case that no contracts were exchanged with the assigned organization and no legal grounds for recovery exist. Furthermore, there is a question of by whom and with what authority recovery should be performed (recovery to IANA, or to RIRs?).

Therefore, focusing on historical addresses in Japan, in the shape of encouragement to confirm the information registered to JPNIC, JPNIC has worked to identify historical addresses and migrate and place them under unified control[5]. However, although many historical PI addresses scattered all over the world are nominally registered with one of the RIRs, they are not under effective management and their actual state of utilization has barely been understood.

Legal issues associated with recovery can be organized as follows.

Table 3-22 Legal issues associated with recovery

Issue	Description
Who should recover	• Internet resource management organizations such as IANA and RIRs (There are no legal grounds)
How to recover	• Recovery on a mandatory or quasi-mandatory basis (Legal grounds and recovery conditions need to be clarified) • Recovery by providing incentives, compensation, and so on (Grounds for and the method of taxation on incentives, lack of fairness to organizations assigning address space through service providers) • Voluntary return (There are no legal issues, but recovery does not proceed smoothly)
Monitoring and punishment	• Method and authority to monitor the emergence of black market dealings • Method and authority to impose punishments for black market dealings

(3) Cost issues

The following summarizes the costs that can arise from recovery of historical PI addresses. These include costs arising from individual recovery operations incurred by the parties concerned, as well as costs associated with the Internet as a whole, such as development of structures, enhancement of equipment, etc. Accordingly, whether or not to proceed with the recovery of unused address space in the future would depend on to what extent the Internet community accepts the burden of these costs.

5 See the description in 3.3.4 (3).

Table 3-23 Cost issues associated with recovery

Issue	Description
Structure development cost for coordination of regulations, etc.	Structure development cost associated with organizing technical issues, legal issues, responsive measures, etc.
Renumbering cost	Renumbering cost arising within supply organizations
Address test cost	Cost of preliminary examinations required before reuse[6]
Operational cost for registration, etc.	Registration change fees
Technical adjustment cost for prevent routing failures	Inspection, adjustment, equipment enhancement, etc. to support /24 routing

(4) Identifying and Classifying effective recovery methods and procedures

Based on the discussions to idenfity and classify issues on unused address space recovery held so far, recovery methods and procedures that are considered to be effective, and issues that need further attention, can be summarized as follows:

- At present, it is considered that only a few organizations can return their entire address space.
- If an organization has a /8 or /16 address space, recovery may be possible by dividing it into /24 or more. However, if it has a /24 address space, the entire address space assigned needs to be recovered, and it has minimal effectiveness.
- In view of past results, recovery to IANA and RIRs seems to be difficult.
- In any case, service providers and Internet Registries need to make the necessary preparations. Further studies need to be carried out regarding equipment enhancement to cope with an expected increase in routing of small-scale address blocks, coordination of policies and regulations, responses to technical and legal issues, and the burden of costs associated with them.

3.3.3 Major Points of discussions on address recovery in the ARIN region

(1) Summarizing discussions in ARIN region

Most of the historical address space is held by organizations in the ARIN region, and the largest size of unused address space is expected to be recovered from this region. Therefore, it is important to track, identify and classify what actions are going to be taken by ARIN against the issues of IPv4 address space exhaustion and unused address space recovery. ARIN holds discussions on the issues of address space exhaustion and

[6] For example, if the communication performance of a recovered IP address is deteriorated due to being blocked by packet filters or being on email blacklists due to unauthorized use by a past user, certain procedures or negotiations will be required to restore performance by lifting these measures.

recovery by holding biannual meetings as well as on PPML (Policy Proposal Mailing List) ,and other means. The topics of discussions are as follows:

- Discussions on the update of Whois, charges, and recovery procedures
- Discussions on whether to allow trading of IPv4 address space in the market and the role of ARIN to be played in relation to it
- The possibility of utilization of private addresses in the Class E (240.0.0.0-255.255.255.255) address space as a means of lifetime extension
- Recognition that NATs cannot sufficiently respond to this situation
- Discussions on restricting IPv4 address allocation from RIRs to LIRs and service providers in a phased manner
- Importance of securing credibility of IPv4 applications
- Necessity to encourage migration to IPv6
- Measures to facilitate recovery of IPv4 address space (offer advantages in cost, etc.)

(2) Results

There are various opinions in ARIN region at the individual level, but as a whole, it is currently at the stage of clearly recognizing the exhaustion of IPv4 address space and to encourage IPv6. It has not yet taken proactive actions on recovery at the point this report is written.

3.3.4 Examination of the possibility of address recovery and utilization

(1) Examination of methods of recovery of unused space

Based on the above discussions, possible recovery patterns of unused address space that are considered to be effective, the possibility of recovery, expected sizes of recovery, and effective recovery methods can be summarized as follows:

- Recover address blocks in the units of /24 or shorter prefixes from organizations holding a /8 or /16 address space
- Organizations in the ARIN region having a /8 address space and organizations in Various Registries having a /16 address space can be expected to be suppliers of unused address space. If address blocks are supposed to be supplied in the size of /24 or shorter prefixes, organizations holding a /24 address space need to provide their entire address blocks, which is unrealistic.
- Out of /8 × 41 blocks held in the IANA Registry, /8 × 19 blocks are held by organizations other than governmental organizations such as DoD and network service companies. Based on the above number, the following shows the patterns of sizes of address space that can be recovered:

Table 3-24 Patterns of sizes of address space to be recovered

Percentage of supplier organizations	Percentage of supplied address space out of the total address space held	Total address blocks supplied	Number in units of /24
10%	12.5%	/10 × 1	/24 × 16k
	25%	/9 × 1	/24 × 32k
	50%	/8 × 1	/24 × 65k
20%	12.5%	/9 × 1	/24 × 32k
	25%	/8 × 1	/24 × 65k
	50%	/8 × 2	/24 × 131k
30%	12.5%	/9 × 1.5	/24 × 49k
	25%	/8 × 1.5	/24 × 98k
	50%	/8 × 3	/24 × 196k

- The areas under the control of Various Registries have an underlying address space of /8 × 49, which is almost 2.6 times larger than the above case. As a result of a simple calculation, a space almost 3.6 times larger than the above-mentioned space is expected to be supplied in total. However, since many of the organizations under the control of Various Registries hold address space in /24 units, the estimate has to be reduced by that much. Collectively, it would be appropriate to estimate the total address supply to be almost twice the figures in the above Pattern Table.
- If there is a method, which enables recovery of renumbering costs, etc. and provides incentives exceeding such costs, there is a possibility of address supply.
- It is considered to be easier to provide address blocks partially by dividing them into portions.

(2) Conclusion on unused address space utilization

Based on the above discussions, the possibility of recovery and utilization of unused address space and issues associated with it can be summarized as follows:

- Allowing the partial return of address spaces in fragmented portions will increase the possibility of recovery and reuse.
- The amount of address space supplied is expected to be about a few /8 blocks at maximum. In light of the trend of the past two years, this is only equivalent to the amount that will cover several months' global demand. Thus, utilization of unused address space is effective in the short term, but will not be an effective solution in the long run.
- The burden on service providers will increase due to requirements for equipment enhancement, etc if routing of address blocks fragmented into small portions increases. It is uncertain whether the community as a whole can bear

this cost burden, and reachability to some address blocks may remain unstable.

- It is necessary to create a new scheme that promotes the active return of assigned IP address space and build a global consensus within a short period of time.

(3) Reference: JPNIC's activities to idenfity holders of historical address

To recover unused historical addresses, JPNIC has carried out activities since December 2004 to identify holders of historical address assignees under its management.

In the course of contacting the contact points of historical address records registered in JPNIC's registry database, attempts were made to contact all holders by conducting follow-up investigation even when there were some contact points which were unable to be detected only from the database due to the registered information being obsolete.

Furthermore, for the historical address holders with whom contact was made, JPNIC has implemented procedures, including the exchange of a confirmation note to confirm their compliance with the current address policy, etc., and at the same time, it has accepted the return of unused IP address space from them. **Table 3-25** shows the status as of November 12, 2007.

Table 3-25 Current status of JPNIC's activities to identify historical PI address holders

As of November 12, 2007

More than /7

	Network information record	Network information record (%)	Number of addresses	Number of addresses (%)
Total number of historical PI addresses	3045	100.0	39537664	100.0
Completed procedures	2520	82.8	35998720	91.0
Returned	411	13.5	765440	1.9
To be controlled by APNIC	11	0.4	332800	0.8
IDs/passwords issued (To be controlled by JPNIC)	2098	68.9	34900480	88.3
Incomplete procedures	525	17.2	3538944	9.0
Contact made and procedures underway	378	12.4	3145984	8.0
Contact being attempted	147	4.8	392960	1.0

A little under /10

At this point, historical addresses returned through these activities remain at 16.3% (13.5% out of 82.8% of addresses for which procedures have completed) on a network information record (records of IP addresses assigned) basis, and 2.1% (1.9% out of 91% as above) on a address space basis.

Addresses were returned on a voluntary basis by IP address holders who declared in the procedures that the entire space of their IP addresses remained unused, and return of partial address space was not accepted.

3.4 Summary

The summary of this chapter is as follows:

3.4.1 Summary of validation of the projection of IPv4 address space exhaustion

- Fitting of address demand forecasts based on macro demand factors was performed for each RIR region.
- Growth in the ARIN region is expected to be modest, while growth in the RIPE, APNIC, and AfriNIC regions is expected to be rapid. When taking into account the size of current demand, the impact of the demand in RIPE and APNIC, which is expected to exceed /8 × 213 by the beginning of 2011, is dominant.
- In Japan, growth in address demand is expected to continue to reach 200 million (in /32 units, which is equivalent to about 12 in /8 units), or 1.7 times the present demand, by 2011.

3.4.2 Summary of investigation on the possibility of recovery of unused IPv4 address

- It is considered that there are hardly any historical addresses whose entire assigned space remains unused. Therefore, the issue is how to partially recover the address space.
- In technical pespective, there are the issues of securing the size of recovery and renumbering. When taking routability into account, the recovery size must be /24 or shorter prefixes, and organizations that can meet this requirement are those holding a /8 or /16 address space. As for renumbering, organizations have little experience in large-scale renumbering and preliminary technical examinations may be required.
- There are many issues to be solved related to rules and legal matters, such as coordination with current policy, legal grounds for recovery methods other than voluntary return, etc.
- As a method of recovery of unused address space, the possibility of recovery to Internet Registries is considered to be low.

- Enhancement of network equipment to support routing of fratmented address blocks is an issue for the Internet community as a whole, and further discussions on the cost burden are required.
- The size of the address space that can be reused by recovery is projected to be equivalent to the amount that could at most meet several months' global address demand. Thus, reuse of unused address space is effective in the short term, but its long-term effectiveness is questionable.

4 Issues of associated with each measure against IPv4 address space exhaustion and their solutions

4.1 Introduction

As identifiers in a network using Internet Protocols (IPs), IP addresses are assigned to all hosts connected to a network and used to distinguish hosts from each other. In order to establish communication between any two hosts in an IP network, each host must be uniquely identified. Therefore, the uniqueness of IP address is a major prerequisite for an IP network to function.

The Internet is composed of a number of IP networks all over the world interconnected with each other, and the uniqueness of IP addresses in the Internet is managed and guaranteed by ICANN, IANA, and Internet Registries such as RIR, NIR, and LIR. Thus, IP addresses distributed by Internet Registries, to be used on the Internet are called global IP addresses. The issue of address space exhaustion discussed in this report is the one associated with IP version 4 global addresses.[7]

This chapter discusses what issues can occur when IPv4 address space runs out and what measures should be taken to solve such issues.

Since it has come to be recognized that the date of IPv4 address space exhaustion is drawing closer, discussions on the issues that can occur when IPv4 address space runs out and solutions for them have from time to time been held by the community of Internet technologists. However, so far neither an exhaustive study nor accumulated discussions have been made.

Therefore the IP Address Space Exhaustion Countermeasures Working Group of JPNIC, responsible for the studies in this chapter, proceeded with studies in accordance with the following procedures:

1) Identify issues expected to occur when IPv4 address space runs out
2) List measures for each issue
3) Clarify issues of the measures and consider solutions
4) Analyze issues and solutions
5) Classify solutions by entity implementing them and nature
6) In parallel with 5), evaluate the measures based on the issues and solutions

The structure of this chapter is as follows:

- **"4.2 Who will be directly affected by address space exhaustion and how?"** discusses who will directly face what issues through IPv4 address space

[7] Unless specifically indicated otherwise, the term "IPv4 addresses" in this report shall mean "global IPv4 addresses."

exhaustion.

- **"4.3 Possible measures"** describes possible direct measures against the issues discussed in **4.2** which are currently available.
- **"4.4 Evaluation of measures"** compares major issues of the measures listed in **4.3** to clarify the advantages and disadvantages of each measure.
- **"4.5 Major issues of measures, suggested solutions and those implementing them"** describes issues of respective measures and proposed solutions organized to examine the evaluations in **4.4** and clarifies those who should implement the solutions.
- **"4.6 Considerations of the current status of technical issues"** describes the current status of the technical issues listed in **4.4**.

4.2 Who will be directly affected by address space exhaustion and how?

4.2.1 Who will be affected and how?

Major part of the current Internet consists of IPv4, and it is impossible to directly connect to the Internet without IPv4 addresses[8]. The direct issue that will arise when IPv4 address space runs out and new IPv4 addresses will no longer be available to service providers and users can be straightforwardly expressed as **"new hosts cannot directly connect to the Internet."** Generally speaking, the cases will be as follows:

Table 4-1 Who will be directly affected by IPv4 address space exhaustion and how?

Who	Issue
Connection providers who want to accommodate new users	Cannot meet customers' demand = Cannot expand business
Server providers who want to install new servers	Cannot provide new services, enhance, or expand services
New entrant service provider	Cannot join the Internet

Other than above, general internet users as well as equipment and software vendors may be indirectly affected depending on the responses taken by the service providers corresponding to the above mentioned cases.

For general internet users, the increase in costs incurred by service providers in implementing measures against the address exhaustion may be passed onto them in the form of higher fees. For vendors, the development of technologies to implement

8 The method of connection of closed IP networks to the Internet through NATs (Network Address Translators) has become generally popular among organizations and enterprises, as well as general households. Direct connection here refers to the form of Internet connection without using any such translation mechanisms.

measures, improvement or replacement of their products, provision of new products, etc. may be required. These can be business opportunities, but at the same time, the return of technology development investment cannot be gained if the demand is only temporary.

This report, regarding the above cases as secondary effects, seeks to examine the measures mainly from the point of view of service providers who will be directly affected.

4.2.2 Is there anyone who will not be affected?

As the issue is that **new hosts cannot directly connect to the Internet**, in the following cases where there is **no need to connect new hosts to the Internet** which do not fall under this condition, the Internet can be used without trouble for the moment:

- Internet connection providers with no increase in the number of subscribers
- Servers who have already provided their services
- Service providers having no need to increase the number of servers or expand networks

In other words, the IPv4 Internet, having existing users and servers, will of course continue to operate even when IPv4 address space runs out, therefore even in this situation they will not be affected as long as their life and business are fulfilled.

However, this is based on the premise that the current Internet circumstances continue, and if the circumstances change in various ways, it is highly probable that those corresponding to the above cases would be troubled.

4.3 What Internet Registries can do

4.3.1 Recovery, restocking, and redistribution of unused address space which has already been distributed

What Internet Registries can do as a measure for IPv4 address space exhaustion is to actively recover and restock IPv4 address space, which has already been distributed but remains unused, and redistribute it to service providers who need them. By doing so, it is possible to temporarily avoid being affected by IPv4 address space exhaustion.

4.3.2 Evaluation of effectiveness and issues

According to the current address management policy, unutilized address space must be returned to Internet Registries. Therefore, the above measure will apply to historical addresses distributed before the current address management policy was adopted.

As a related matter, as examined in 3.3, there are legal, technical, and cost-related issues that need to be solved. In addition, further detailed investigation and estimation would be needed in order to examine the effectiveness as a measure for the estimated amount of address space that can be actually recovered.

Due to the issues mentioned above, the effectiveness of this measure is still unclear. However, it will undoubtedly affect the measures taken by service providers described later. Therefore, JPNIC, as an Internet Registry, is required to proactively examine and address these issues.

4.4 Measures that can be taken by service providers

As a result of examining available measures for solving the situation where **new hosts cannot directly connect to the Internet**, and organizing and integrating various proposals, the following three measures are deemed to be available at this stage. Of course, the possibility cannot be denied that totally new methods or innovative measures may emerge other than these three measure. However, this chapter proceeds with the examination by focusing on the above three measure.

4.4.1 Securing IPv4 address space in some way

As both measures described in later sections require expenses and investments associated with equipment, IPv4 address space will have to be secured in some way before adopting these measures. For that, some methods may be considered:

- Generating IPv4 address space from their own networks by achieving more efficient use of address space
  Generate IPv4 address space by reviewing the existing segment structure, changing addresses used for management and monitoring systems for private addresses, using larger servers to reduce the machine count, etc., and accommodating new hosts.

- Receiving redistributions of unused IPv4 address space recovered
  When recovery, restocking, and redistribution of unused IPv4 address space has been successfully achieved by Internet Registries as described above, accommodate new hosts by using the redistributed address space.

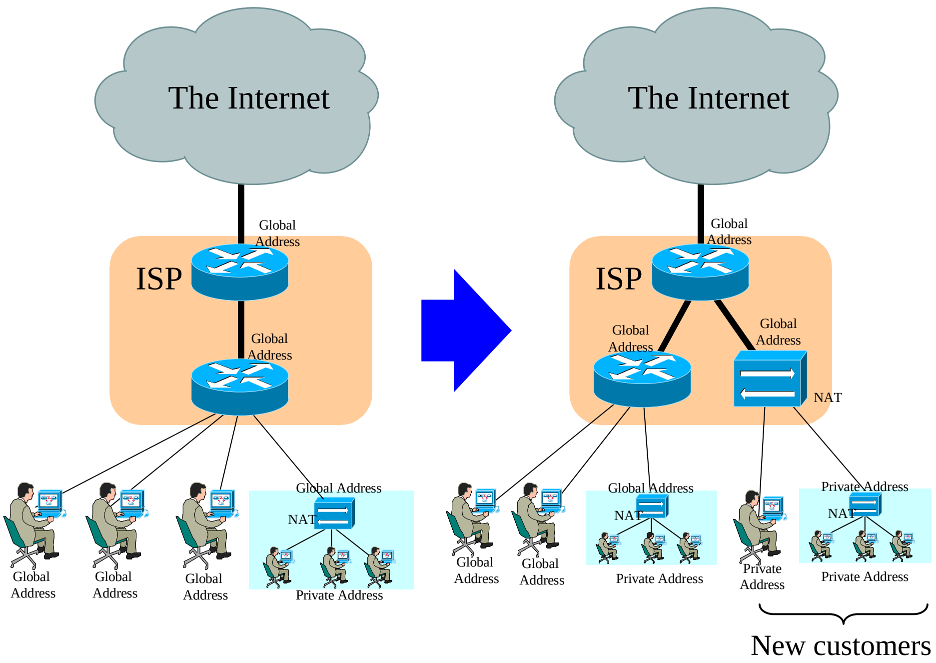
Also, after address space has run out, there could be cases where organizations that have an extra address space for some reason transfer it to other organizations that need it. However, as the address policy does not allow transfer, based on the principle that IP addresses are not properties to be owned, if such a case is found by an Internet Registry, it will demand the organization possessing such an extra address space to return it.

4.4.2 Accommodating new customers by using private IPv4 addresses and connecting them to the Internet through NATs

Closed IP networks, which are not directly connected to the Internet, use private addresses, as they do not need to use global IP addresses.

It is recommended to use private addresses for closed IP networks from the point of view of saving IPv4 address space. In principle, global IP addresses are not currently assigned to methods that do not use direct connection to the Internet. As a method of connecting closed IP networks to the Internet, connection through NATs is widely recognized and established technically. Adopting this method at the level of Internet connection providers allows the accommodation of new customers without using global IPv4 addresses. Given some CATV service providers have already adopted this system, changing to this system is thought to be a possible measure.

Figure 4-1 Accommodation of new customers using private IPv4 addresses and NATs



4.4.3 Accommodating new customers by using IPv6

A new version, Internet Protocol version 6 (IPv6) was developed as an alternative to IPv4, and various basic technologies have already been developed. IPv6 has a much larger address space than IPv4 that allows greater flexibility in network designing and planning for future extensibility. By building IPv6 networks and accommodating new customers in the new networks, service providers can directly connect their new customers to the global Internet without using IPv4 addresses. Even after this system is deployed, the existing IPv4 Internet will remain in use. Utilization of IPv6, which is presented here as a measure, does not mean forcing migration from the existing IPv4 Internet to IPv6 Internet.

4.5 Evaluating the three measures

This report assumes a situation whereby the three measures listed in 4.3 have been applied by service providers on the Internet, clarifies where issues lie, and undertakes a comprehensive evaluation.

The issues arising from the respective measures and proposed solutions organized to examine the evaluations are listed in the next section.

4.5.1 Evaluating "Securing IPv4 address space in some way"

Unlike the other two measures, the advantage of this measure is that the same services as in the past can be provided if only IPv4 address space can be secured. The following can be considered as two measures to secure IPv4 address space:

(1) Service providers generating extra address space from their own networks
(2) Receiving redistributions of unused address space recovered by Internet Registries for use

The major issues anticipated to arise from these measures, including those discussed in Chapter 3, can be summarized as follows:

A) At present, (1) is the only feasible measure. As for (2), rules of partial return, etc. have not been established. As described in Chapter 3, it is uncertain whether this measure can be implemented, due to several issues to be addressed for implementation
B) Even if it becomes possible to implement (2), it is not always possible to secure address space as necessary.
C) The IPv4 address space secured in (2) has the issues of Internet routing, such as scalability, due to fragmentation.
D) As the IPv4 address space provided by recovery and redistribution is limited, this cannot be a permanent measure.

Regarding issue D) above, a definite conclusion has not yet been reached about the amount of IPv4 address space that can be supplied after the stock runs out. In Section **3.3.4** of this report, it is assumed that there is a possibility that /8 × 3 blocks can be redistributed out of the class A address space of /8 × 19 blocks assigned to organizations other than governmental organizations such as DoD and network service companies, if 30% of such organizations provide 50% of their said address space.

Geoff Huston's IPv4 Address Report predicts the time when IANA's unallocated address pool will be exhausted, the time when the unallocated address pool of all RIRs will be exhausted, as well as the transition of the number of addresses assigned but not advertised in the routing system.

According to the prediction, IPv4 addresses assigned but not advertised in the routing system will be exhausted by the middle of 2018. This means all available IPv4 addresses will be advertised in the Internet by this point in time.

However, there are factors that can both extend and shorten the time limit for available IPv4 addresses, considering that unused IP addresses are contained within the address blocks advertised in the Internet (a factor extending the time limit) and that not all unused IPv4 addresses may always be provided for reuse (a factor shortening the time limit).

Thus, it is uncertain whether the system for reuse of IPv4 address space, including recovery and redistribution, can be established, and, even if it is established, it remains questionable whether a timely supply can be provided; and at the same time, even if an ideal reuse system can be achieved, the effect must be described as limited as no more IPv4 address space is provided than the total IPv4 address space.

4.5.2 Evaluating the measure of "Accommodating new customers by using private IPv4 addresses and NATs"

Some CATV service providers provide Internet connection services using private addresses and NATs. This measure can be chosen by service providers below a certain size when subscribers, as clients, communicate with servers connected to the Internet using the IPv4 address system. However, even with the premise that connection services are provided to clients, the following issues remain:

- When connection services are provided using global addresses at present, and the structure of private IPv4 addresses and NATs is employed for new customers, service quality will substantially deteriorate due to restrictions on service conditions.
- More specifically, the communications performance of some applications may deteriorate if they use SIP or UPnP. If broadband routers or devices that function as user NATs are installed in users' homes, the configuration will have multiple NATs, and even applications currently supporting NAT traversal technology will experience issues.[9]
- There are scalability limitations, which means that, based on current achievements, only a maximum of a few tens of thousands of users can be supported by this method.

[9] The details of the NAT environment issues are described in **4.7.3**.

- The use of private addresses may be impossible or limited when access lines to subscribers are provided by access network providers.
- Translators need to be separately installed to communicate with servers connected using only IPv6.
- As user NATs are already installed in users' homes in many cases, when a service provider starts new services using private addresses, there can be conflicts between private addresses used in users' home networks and the service provider's networks. If there is a serious issue, measures need to be taken, such as defining a new private address space for the service provider.

The issues mentioned above are related to accommodation of clients. However, as shown in **Table 4-2**, the major issue with this measure is that it does not work in terms of accommodating new servers.

In principle, a NAT device, by receiving a session start request from a client on the private address side to a server specified by a global address, recognizes the IP addresses of both the client and the server and translates them to establish communication between them.

When a server resides on the private address side, a client on the global address side cannot uniquely specify the server using an IP address. To specify a server with an IP address, multiple global addresses can be given to a NAT device to respond to each specific server, but that does not make sense in this situation as NATs here are measures for dealing with the unavailability of IP addresses.[10]

Given these circumstances, since the measure using private addresses and NATs is cannot be applied to servers, if server providers cannot secure IPv4 address space by any means, including those generating global IPv4 address space by reviewing their network structure, yet still need to increase servers, they would have no other choice but to accommodate servers by using IPv6.

Even if new entrant service providers provide their services using this system, they need to have at least one global address for the upper-level Internet connection, therefore this measure alone cannot work as a solution.

4.5.3 Evaluating "Accommodating new customers by using IPv6"

The following issues exist when accommodating new hosts using IPv6:

- While at present connection services are provided using global IPv4 addresses,

[10] Other than the method using IP addresses, the method using TCP and UDP port numbers can also be available for identifying servers. However, this method is not considered here as in the current situation, where the DNS cannot resolve names, including port numbers, it would be unrealistic for the DNS to distinguish services provided by servers.

and IPv6 is used to accommodate new customers, service quality will substantially deteriorate until IPv6 spreads enough to ensure a large-enough area covered by IPv6 communication.

- More specifically, as new IPv6 clients cannot connect to the IPv4 Internet directly, some measures, such as combining with the Private IPv4 address and NAT method or using translators, will need to be taken.
- New IPv6 servers cannot accept connection requests from clients unless the clients support IPv6 (via native connection or translators).
- When access lines to users are provided by access network providers, the use of IPv6 may be impossible or limited.

In addition, to build and operate networks using this new IPv6 protocol and provide them to customers as commercial services, efforts to ensure the stable operation of the IPv6 Internet require the integration of: IPv6-compatible network equipment; investments and expenses as well as acquisition and accumulation of expertise for IPv6 network construction and operation by service providers; and the existing applications in terminals to be made compatible with IPv6. These must be implemented while continuing the existing IPv4 Internet services.

It is apparent that these issues impose a substantial burden on service providers, and is considered to be a major issue hindering the deployment of IPv6. In addition, it is a great risk for a service provider to start supporting IPv6 ahead of other service providers who do not show a clear intention to support IPv6, and this would be another cause that makes service providers hesitant to deploy IPv6.

However, as this measure does not contain the limitations inherent in the other two measures, of securing IPv4 address space in some way and by accommodating new customers using private IPv4 addresses and NATs, it can be the only permanent and generally-applicable solution.

4.5.4 Adoption of measures by service providers

The following are the three measures examined so far:

(1) Securing IPv4 address space in some way
(2) Accommodating new customers by using private IPv4 addresses and NATs
(3) Accommodating new customers by using IPv6

Service providers are expected to select their measures from among the above in the following way:

First, they will try to deal with the situation using (1) for the moment, which allows accommodation of customers with the same method of service provision as in the past.

Then, they will choose either (2) or (3), or both of them, depending on their business environment and the service contents of each service provider.

While (2) is limited as a measure in terms of its scale and service contents, (3) can be a permanent measure if some issues requiring solution are addressed.

In particular, if IPv6 compliance (IPv4/IPv6 dual stack connection) has progressed on the client side, including existing users, many of the interoperability issues are expected to be overcome. Furthermore, if it is assumed that many service providers take this measure, the costs of equipment and software required to support this measure will be reduced. With respect to IPv6 in particular, issues related to this measure are likely to be reduced and overcome with the spread of IPv6 as some domestic major service providers, including JPNIC Members, have already announced their intention to support it,.

4.5.5 Organizing issues in bilateral communication

Figure 4-2 shows the issues of the three measures when they are implemented on a network. Note that this figure focuses on technical issues in intercommunication between a user and a server, and that issues related to securing IPv4 address space, costs incurred by service providers, and operational issues are ignored.

Needless to say, communication here refers to communication between two (or more[11]) parties, a user and a server, and in the case of the Internet, communication generally occurs over multiple connection providers. When IPv4 addresses no longer become available, issues that arise in communication will differ depending on the measure taken by the service provider that connects two communicating parties.

To organize this point, **Table 4-2** shows the issues classified by measures applied to communication between two parties, a client and a server, over the Internet.

[11] This report focuses its discussion only on IP unicast communication and describes the following assuming communication between two parties.

Figure 4-2 Major issues caused by IPv4 address space exhaustion

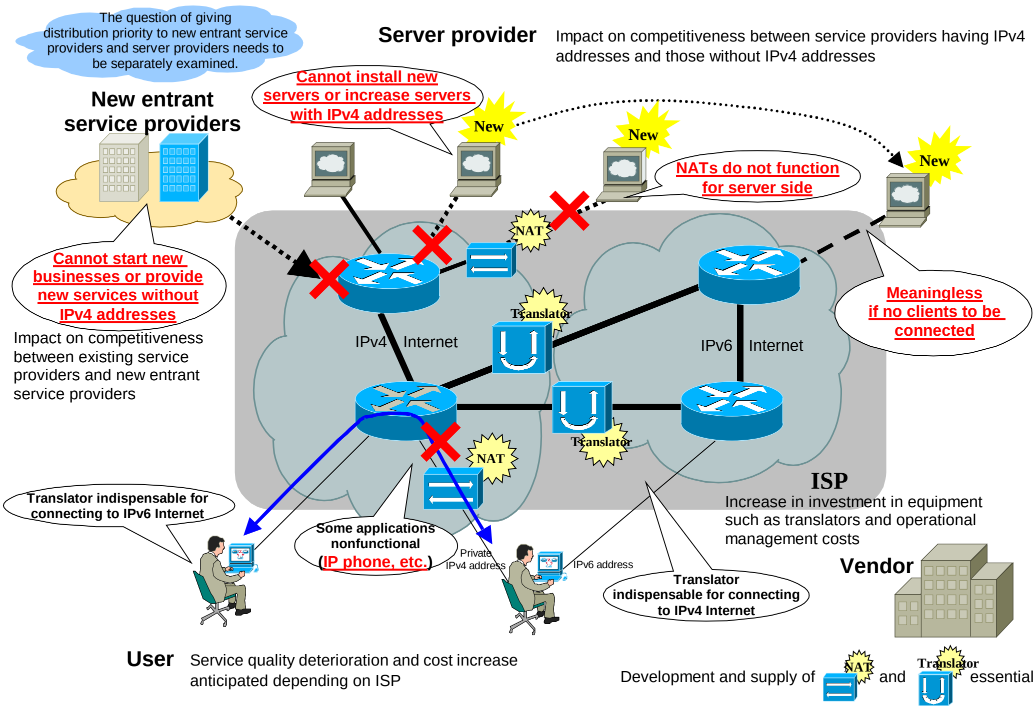


Table 4-2 Applicability evaluation of measures in client/server communication

Client \ Server	IPv4	NAT+private	IPv6	Evaluation of applicability to clients
Securing IPv4	◎ (Native)	×	△ (Client-side translator)	**Difficulties in timely and continuous address provision**
NAT+private	○ (Client-side NAT)	×	△ (Client-side translator)	Scalability concerns
IPv6 compliance	△ (Client-side translator)	×	◎ (Native)	Translator technology not established
Evaluation of applicability to servers	**Difficulties in timely and continuous address provision**	**Cannot be a measure for servers**	Translator technology not established	

The notable point in **Table 4-2** above is that the measure using private IPv4 addresses and NATs cannot be applied to servers. Furthermore, in order for servers to accommodate new customers by using IPv6, the client side (users and connection providers that accommodate users) has to respond by using translators, supporting IPv6, and so forth.

4.5.6 Conclusions

The following outlines the study results of 4.5:

i. All measures have some issues, and solving them requires a certain cost. Service providers need to select and/or combine measures after analyzing the advantages and disadvantages of each measure, including costs.

ii. Securing IPv4 address space in some way has no technical issues and allows accommodating customers in the conventional method if only address space can be secured. However, the amount of IPv4 address space that can be supplied is unknown and the effect is limited, even when address space has been generated from service providers' own networks, or recovery, restocking, and redistribution of unused address space has been successfully achieved by Internet Registries,.
iii. Accommodating new customers by using private IPv4 addresses and NATs can be chosen as a measure to accommodate clients (general Internet users) if the number of users is not large (up to a few tens of thousands of users) in order to maintain existing services (communication with servers connected with IPv4). At present, however, scalability to support large service providers has not been guaranteed.
iv. Accommodating new customers by adopting IPv6 requires efforts at various levels, such as applications, network equipment, network construction and operation, investments and expenses, and knowledge acquisition; and which act as barriers to the deployment of IPv6 for service providers. However, this is the only permanent and generally-applicable measure of the three.
v. After the remaining stock of IPv4 addresses held by Internet Registries runs out, service providers will accommodate new customers by adopting the measure in ii above that allows temporary accommodation of new customers under the conventional method, and then select the measures in iii and iv.
vi. Since the measure in iii is not applicable to the accommodation of new servers, when the measure in ii becomes no longer applicable, only the measure in iv is available. If server providers take the measure in iv, it is necessary for the client side (users and connection providers that accommodate users) to use translators or deploy IPv6 to achieve access from clients.

Needless to say, selection of measures should be made by each service provider from the point of view of economic rationality, etc., but it is expected that service providers will first try to adopt the measure of securing IPv4 address space in some way, which has no technical issues. Then, when this measure is considered to be inapplicable, the measures of accommodating new customers by using private IPv4 addresses and NATs, and accommodating new customers by using IPv6 will be examined.

Although the measure of accommodating new customers by using private IPv4 addresses and NATs may be selected in a situation or a scenario when it is effective, depending on the circumstances of each service provider, all service providers will eventually adopt the measure of accommodating new customers by using IPv6 due to limitations of scalability and service.

The issues associated with vi are not easily solved as the location where issues occur (server provider) and the location where measures are taken (connection provider) differ. Even if server providers try to accommodate new servers using IPv6 as described in iv, when securing IPv4 address space in some way becomes impossible, server providers can hardly justify the deployment of IPv6 in terms of effective investment if the number of accessing users is extremely limited. Additionally, it is difficult for the connection provider side to justify the deployment of IPv6 only for connecting to a very limited number of IPv6 servers.

Such a chain paralysis between server and client sides is a serious issue that prevents the development of the Internet. To prevent the issue, IPv6 compliance must be established in some form by both connection providers and server providers by the time when securing IPv4 address space in some way becomes impossible.

This is indeed a "chicken and egg" issue, and once the current of IPv6 compliance starts to gain headway, solutions of technical issues and reduction of deployment costs are expected to be gradually achieved. As mentioned in 4.5.4, as major service providers have already announced their intention to support IPv6, barriers to the deployment of IPv6 for service providers have started to come down as the current of IPv6 compliance becomes apparent. Thus, the point where the measure of accommodating new customers by using IPv6 is considered to be advantageous from the point of view of cost-effectiveness is not expected to be too far off.

In addressing IPv4 address space exhaustion based on the above considerations, the most effective measure for the overall and continuous growth of the Internet would be to promote the deployment of IPv6 by service providers.

Issues and issues described in **4.5.3**, and **4.6.3** below regarding the deployment of IPv6 exist. The availability of IPv4 addresses is an important factor that determines the grace time for implementing IPv6 deployment plans. In cooperation with stakeholders, JPNIC will advance measures for smooth deployment of IPv6 by service providers by addressing these issues and issues and clarifying points that remain unclear.

Figure 4-3 shows IPv4 address space exhaustion and the limits of reuse of the remaining stock and the direction of measures taken to counter them. **Figure 4-4** shows existing users on the Internet, new users connected by servers supporting IPv6, and the way communication is established with servers.

Figure 4-3 Image of the roadmap for addressing IPv4 address space exhaustion

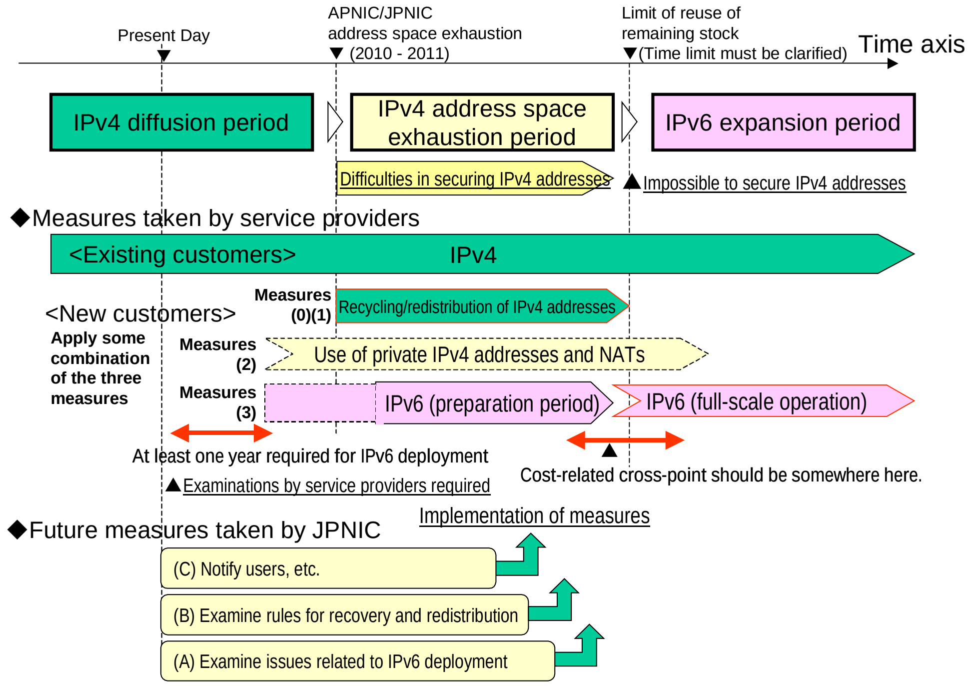
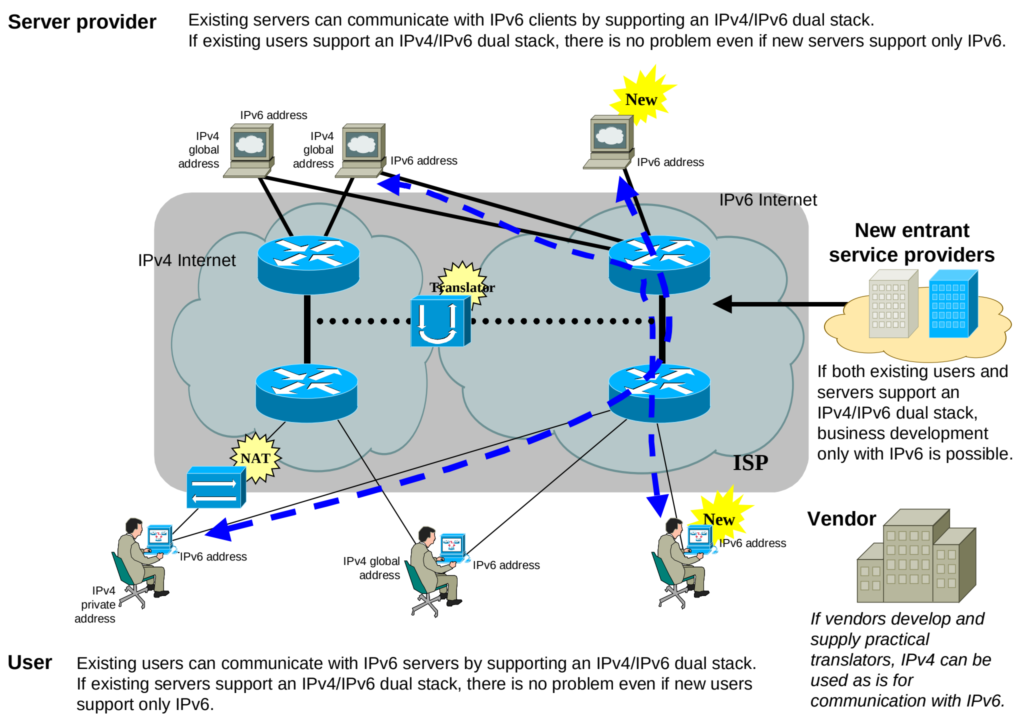


Figure 4-4 Example of a possible ideal structure



4.6 Issues of the three measures and their solutions

This section summarizes issues of each of the three measures and solutions for them to evaluate the three measures in the previous section. This section also sets forth who should implement each solution.

4.6.1 Issues in the method of securing IPv4 address space in some way, and solutions

	Issue	Description	Proposed solution
A	Generating extra address space from own networks requires cost.	To generate block of address space from own networks, all of the following methods require time, labor, and costs for investment or learning: reviewing the segment structure, changing addresses used for management and monitoring systems to private addresses, using larger servers to reduce the machine count, etc.	Absorb increased costs by streamlining efforts, passing costs on service charges, etc.
B	Rules for recovery and redistribution have not been established.	Current address management rules do not allow IPv4 address transfers. Rules for recovery and redistribution specify "return of unused IP addresses to Internet Registries" only on a voluntary basis, and recovery on a mandatory basis is specifically regulated by APNIC and LACNIC only in certain cases.	ICANN, RIRs, NIRs, and related organizations to promote development and review of address management rules to enable the reuse of IPv4 addresses.
C	The number of entries in the BGP routing table may increase.	It is highly likely that the redistributed IPv4 address space is divided into small blocks, and can further increase the number of routing information entries in the BGP routing table, already 240 thousand at present. This has a substantial impact on the Internet routing system as a whole as well as the stability of routers.	Promote consensus building such as operational guidelines in the Internet community in order to maintain normal routing.
D	Addresses may not be supplied in a timely manner.	If relying on recovery and redistribution by Internet Registries, it is not always possible to receive addresses when necessary.	As there is no direct solution to this issue, there is no choice but to adopt other measures if it is critical.

4.6.2 Issues in accommodating new hosts by using private IPv4 addresses and NATs, and solutions

	Issue	Description	Proposed solution
A	New investments and additional costs are required for implementation.	Labor and costs related to investments, design, construction, and operation management for the deployment of NAT-compliant equipment, as well as a reconsideration of network design and operation management methods are required.	Absorb increased costs by streamlining efforts, passing costs on service charges, etc.
B	Some applications may not run properly when using private IPv4 addresses and NATs.	Using NATs both on the service provider side and the user home side may constitute a dual-NAT configuration. In this event, some applications may not run properly, as NAT traversal techniques are not applicable to multiple NATs.	Eliminate the dual-NAT configuration by changing the settings of the user side router or make efforts to improve NAT traversal technologies.
C	An enormous amount of NATLog data needs to be obtained and managed to deal with abuses.	To deal with abuses, an enormous amount of NATLog data needs to be obtained to track the usage of users, but labor and costs are required to store and manage the NATLog data.	Establish a log management system and response flow.
D	Communication may become impossible if the global address on the WAN side of the NAT is put on blacklists.	If the global address assigned on the WAN side of the NAT is put on a blacklist for some reason, routing cannot take place and no users connected to the NAT can gain access.	Ask the administrator to remove the address from blacklists, and monitor malicious users connected to the NAT in order to exclude them.
E	Private addresses used in user networks and service provider networks may overlap each other.	Currently, as only the private address space defined by RFC1918 exists, when addresses in the private address space are used in service provider networks the range of addresses can overlap with the range of addresses already used in user networks.	Other than RFC1918 address space, define private address spaces for service providers by the address policy.
F	The same services as those for existing customers cannot be provided to new customers.	Unlike direct connection to the Internet using existing global addresses, some applications may not run due to the use of a service provider NAT as it prevents direct access from the Internet, or performance may be degraded compared to a direct connection to the Internet.	Offer different service types or provide notification to new customers and ensure they understand the situation before committing.
G	Access network providers do not support the use of private addresses.	Currently, many Internet connection providers rely on access networks provided by access network providers to connect to users' homes, but Internet connection providers do not support the use of private addresses in the access networks.	Negotiate with access network providers or define private address spaces for service providers by the address policy.

	Issue	Description	Proposed solution
H	The configuration of private IPv4 addresses and NATs does not work for servers.	This measure, using the configuration of private IPv4 addresses and NATs, is not effective for servers that are open to access from the global Internet as name resolution and communication mechanisms do not work.	As there is no direct solution to this issue, there is no choice but to adopt other measures if it is critical.
I	A new entrant service provider needs to obtain at least one global address on the Internet side of its NAT.	Even if the customer-side network is built using private addresses when newly establishing Internet connection business, etc., at least one global address is required on the upstream side to gain connectivity to the IPv4 Internet.	As there is no direct solution to this issue, there is no choice but to adopt other measures if it is critical.

4.6.3 Issues in accommodating new customers by using IPv6, and solutions

	Issue	Description	Proposed solution
A	New investments and additional costs are required for implementation.	Labor and costs related to investments, design, construction, and operation management for the deployment of IPv6-compliant equipment, as well as a reconsideration of network design and operation management methods are required.	Absorb increased costs by streamlining efforts, passing costs on service charges, etc.
B	Modification and change of existing terminal and network equipment specifications to support IPv6 are required.	To make services IPv6 compliant, a change of equipment specifications or replacement with IPv6-compliant equipment may be required. For example, as most cable modems currently used for CATV networks do not support IPv6, it is necessary to develop new cable modems and install them in users' homes.	Have vendors develop necessary equipment. Procure necessary equipment supporting IPv6 and carry out replacement operations.
C	New IPv6 clients cannot connect to the IPv4 Internet directly.	As IPv6 and IPv4 are not compatible, new IPv6 clients cannot communicate with IPv4 clients directly. Only IPv6 servers (which initially seem to be small in number) can connect to them.	Promote support for dual stacks on the server side. Promote development of translators used for connection to the IPv4 Internet and deploy and install them.
D	New IPv6 servers cannot receive access from clients if the client side does not support IPv6.	When accommodating a new server using IPv6, clients connecting to the server need to support IPv6, or even when connection is made using IPv4, that relies on measures taken on the access side such as setting up a translator on the connecting side, etc., and there are not many measures performed on the connected (server) side.	Promote support for dual stacks on the client side. Promote development of translators used for connection from IPv4 clients and encourage service providers to deploy them.
E	Existing software and applications do not support IPv6.	Some software and applications currently used widely may not be available, as they cannot communicate directly with the IPv6 environment.	Establish a verification environment promptly to clarify applications that do not support IPv6, and provide notification to customers and ensure they understand the situation before committing.
F	The same services as those for existing customers cannot be provided to new customers.	Unlike existing IPv4 Internet, IPv4 and IPv6 cannot be directly connected with each other, and their service characteristics are not the same due to differences in their protocol specifications.	Offer different service types or provide notification to new customers and ensure they understand the situation before committing.
G	Access network providers do not support the use of IPv6.	Currently, many Internet connection providers rely on access networks provided by access network providers to connect to users' homes, but Internet connection providers do not support the use of IPv6 in access networks.	Negotiate with access network providers.

4.6.4 Classification of solutions and its target entity

Based on the proposed solutions for them, the issues of the respective measures listed in the previous section can be roughly classified as follows:

- Issues requiring cost burdens
- Issues requiring technical solutions
- Issues solved by establishing rules or providing notification
- Issues solved by taking measures for access networks
- Issues with no direct solutions

Issues can also be divided into the following three types based on who implements the solution:

- Issues whose solutions are implemented by hardware or software vendors
- Issues whose solutions are implemented by service providers
- Issues whose solutions are implemented by the cooperation within the community

According to these classifications, issues, proposed solutions, and implementing organizations can be organized as in the table below:

Table 4-3 Issues of respective measures, classification of proposed solutions, and implementing organizations

	Solution		Issue	Type of issue	Solution	Implemented by
(1)	Securing IPv4 address space in some way	A	Generating extra address space from own networks requires costs.	Cost	Absorb increased costs by streamlining efforts and passing on costs in service charges.	Service provider
		B	Rules for recovery and redistribution have not been established.	Rule	Promote development and review of address management rules.	Community
		C	The number of entries in the BGP routing table may increase.	Rule	Promote community preparation of operational guidelines.	Community
		D	Addresses may not be supplied in a timely manner.	No solution	There is no direct solution: adopt other measures.	Service provider
(2)	Accommodating new hosts by using private IPv4 addresses and NATs	A	New investments and additional costs are required for implementing this measure.	Cost	Absorb increased costs by streamlining efforts and passing on costs in service charges.	Service provider
		B	Some applications may not run properly when using private IPv4 addresses and NATs.	Technology	Eliminate the dual-NAT configuration. Improve NAT traversal technologies.	Service provider Vendor
		C	An enormous amount of NATLog data needs to be obtained and managed to deal with abuses.	Cost	Establish a log management system and response flow.	Service provider
		D	Communication may become impossible if the global address on the WAN side of the NAT is put on blacklists.	Cost	Ask for removal of the address from blacklists, and monitor malicious users connected to the NAT in order to exclude them.	Service provider
		E	Private addresses used in user networks and service provider networks may overlap each other.	Rule	Develop a policy to set up private address spaces for service providers to provide their services.	Community
		F	The same services as those for existing customers cannot be provided to new customers.	Rule	Offer different service types or provide notification to customers to ensure they understand the situation before committing.	Service provider
		G	Access network providers do not support the use of private IPv4 addresses.	Access network	Ask access network providers to take measures.	Service provider
		H	The configuration of private IPv4 addresses and NATs does not work for servers.	No solution	There is no direct solution: adopt other measures.	Service provider
		I	A new entrant service provider needs to obtain at least one global address on the Internet side of its NAT.	No solution	There is no direct solution: adopt other measures.	Service provider
(3)	Accommodating new hosts by using IPv6	A	New investments and additional costs are required for implementation.	Cost	Absorb increased costs by streamlining efforts and passing on costs in service charges.	Service provider
		B	Modification and change of specifications of existing terminals and network equipment to support IPv6 are required.	Technology	Develop and deploy necessary equipment.	Vendor Service provider
		C	New IPv6 clients cannot connect to the IPv4 Internet directly.	Technology	Promote support for dual stacks on the server side. Develop and deploy translators.	Service provider Vendor
		D	New IPv6 servers cannot receive access from clients if the client side does not support IPv6.	Technology	Promote support for dual stacks on the client side. Develop and deploy translators.	Service provider Vendor
		E	Existing software and applications do not support IPv6.	Rule	Check software and applications by performing operational verifications and provide notification to customers to ensure they understand the situation before committing.	Service provider
		F	The same services as those for existing customers cannot be provided to new customers.	Rule	Offer different service types or provide notification to customers to ensure they understand the situation before committing.	Service provider
		G	Access network providers do not support the use of IPv6.	Access network	Ask access network providers to take measures.	Service provider

As seen in the above table, (1) and (2) involve one or more issues that have no direct solution, but (3) does not involve such a issue. That means that when its issues are solved, (3) can be the only permanent and generally-applicable measure.

To solve these issues, those in charge of implementing each solution take on the following roles:

Vendors: It is impossible to address the IPv4 address space exhaustion issue if necessary measures are not taken for major network equipment and software, and it is not too much to say that whether the IPv4 address space exhaustion issue can be successfully addressed or not depends on how vendors implement such measures.
In particular, given the conclusion that (3) is the only permanent and generally-applicable measure, vendors are expected to play a significant role.

Service providers: Service providers, as the main players in addressing IPv4 address space exhaustion, must take the most initiative in implementing measures. Accordingly, they have to bear heavy cost burdens, but they cannot develop their business unless such implementation is done. Therefore, it is essential for them to start examining the selection of measures and implementing them as soon as possible.

Community: Making preliminary efforts, such as establishment of address management rules, operating rules, etc., is an important point for facing the date of IPv4 address space exhaustion. It would be more cost-effective if each measure is implemented by service providers in a cooperative way. Therefore, so that service providers can select the most appropriate measures from a wider perspective, it is also important for industry groups to provide information and guidance taking the initiative.

4.7 Current considerations regarding technical issues

This section picks up issues that are considered to be technically significant from among those listed in **4.5**, and thoroughly examines the issues from the technical point of view.

4.7.1 The issues IP telephony services face due to intervening NATs and translators

The following describes the issues that are caused when using a translator, etc., with a 050 or 0AB-J number for IP telephony services under a “private IPv4 addresses and NATs” environment or from an IPv6 network to an IPv4 network.

In broadband services, when global IPv4 addresses can no longer be assigned due to IPv4 address space exhaustion, it is assumed that large NATs will be deployed or that only IPv6 addresses will be assigned in service provider networks. IP phones use the Session Initiation Protocol (SIP) and so require SIP-compliant NAT traversal/protocol conversion technologies.

For general applications, NAT traversal techniques such as UPnP and STUN are often used in order to make calls from outside a NAT to inside it. However, as NAT traversal for SIP requires the rewriting of IP address information in the packet payload, a NAT/ALG (Application Level Gateway) device that provides functions for packet rewriting and protocol conversion needs to be newly deployed. The technical issues mentioned above are currently being steadily improved.

Commercial service guidelines related to the delay during a call using IP phones define the end-to-end one-way delay as follows:

- Services using the 050 number: 400 msec or less
- Services using 0AB-J number: 150 msec or less

Deployment of a NAT/ALG device affects delay in address connection and delay during a call. As NAT/translators are not codec translators as well, the call voice quality (voice clarity) itself is not affected, but qualities that are associated mainly with delay are considered to be affected.

4.7.2 Current state of translator technologies

This section describes the current state of protocol conversion devices (translators) that are required for communication between IPv6 and IPv4 networks.

The technical specifications of translators are as follows:

- SIIT (RFC2765: Stateless IP/ICMP Translation Algorithm)

- NAT-PT (RFC2766: Network Address Translation - Protocol Translation)
- TRT (RFC3142: IPv6-to-IPv4 Transport Relay Translator)

Products supporting these technical specifications are currently available in the market (specific products will be listed below).

In general, as a characteristic of communication through a translator in the IPv6 to IPv4 direction, a static address conversion is allowed as the IPv4 address space (32 bits) can be projected onto the IPv6 address space (128 bits). As many of the actual products require coordination with DNS, the method of coordination with DNS would be an issue.

On the other hand, as a characteristic of communication in the IPv4 to IPv6 direction, it can be noted that dynamic and complicated conversion processing in coordination etc. with DNS is required. In principle, a considerable number of IPv4 addresses are required as addresses after conversion. If the node can be specified by the upper layer protocol, converted addresses can be multiplexed (by using the port number of the upper layer protocol, identifying the URL using HTTP 1.1, etc.).

General translator issues are almost the same as those of NAPT. The following are examples of issues: an IPv4 address embedded in the payload cannot be converted (SIP, HTTP, etc.); retention time for the conversion table; and there are no actual examples of translator products that work in a large-scale environment.

With regard to the trend of standardization of translator technologies, attention paid to related technologies has been decreasing recently, and there have been not been many discussions about existing related specifications. Meanwhile, the RFC concerning the technical standard (NAT-PT) widely used for translators was moved to Historic status for the reason that it could lead to the deployment of NAT in the IPv6 Internet. However, the importance of translation technologies associated with the development of IPv6 has been gaining greater recognition, and the IETF plans to start examining alternative technologies to NAT-PT.

Currently, the following translators are available in the market. Most of the products are thought to use technologies that are an enhancement of NAT-PT technology.

Table 4-4 List of current translator products

Product name	Maker	Remark
TTB Series	Yokogawa Electric Corporation	SIP-ALGs are also supported
Reference URL http://www.yokogawa.co.jp/ipnet/ttb/		
AG8100-T Series	Hitachi, Ltd.	
Reference URL http://network.hitachi.co.jp/gateway/ag8100t.html		
IP Translator Series	SEIKO Precision Inc.	
Reference URL http://www.seiko-p.co.jp/news/news-2003/news_sx3520iptrans.html		
NETSTAGE/IPv6 Access GEAR Standard Edition	Fujitsu Limited	Provided by software?
Reference URL http://globalserver.fujitsu.com/jp/software/netstagev6g/index.html		
SEIL Series	Internet Initiative Japan Inc.	Device to be installed in users' homes
Reference URL http://www.seil.jp/seilseries/seil/_other_s.html		
IPv6-IPv4 converter	silex technology, Inc.	
Reference URL http://www.silex.jp/japan/products/network/others/sx2600cv.html		

There are also other routers supporting IPv6 with NAP-PT functions (from Cisco, Hitachi, etc.).

4.7.3 Current state of NAT traversal technologies and issues in a multi-stage NAT environment

First, the current state of UPnP technologies and the issues in a multi-layer NAT environment will be considered.

The UPnP standard defines a device used to connect to the Internet as an IGD (Internet Gateway Device). An IGD possesses a WAN interface used for connecting service providers and a LAN interface that allows connection with clients. An IGD supports the Port Mapping function, which forwards a communication request addressed to a port number on the WAN side to a client port in a LAN according to the request of the client behind a NAPT. Using the Port Mapping function, an outside connection is established by forwarding a connection from outside to a client behind the IGD.

When trying to use this Port Mapping function for the UPnP IGD in a multi-layer NAT environment, due to the lack of a mechanism to relay a Port Mapping request from an IGD behind a NAT to an IGD having a global IP address, Port Mapping is not set up in the IGD connected to the Internet. Even if this issue is solved, coordination between the IGD having a global IP address and the IGD behind the NAT is required for controlling Port Mapping, but there is no mechanism for sharing port number information between IGDs. Furthermore, considering the difference in the session retention period and that there is no guarantee that the same ephemeral port number is able to be continuously used, it is difficult to use UPnP in a multi-layer NAT environment.

Next, issues of NAT traversal technologies will be considered.

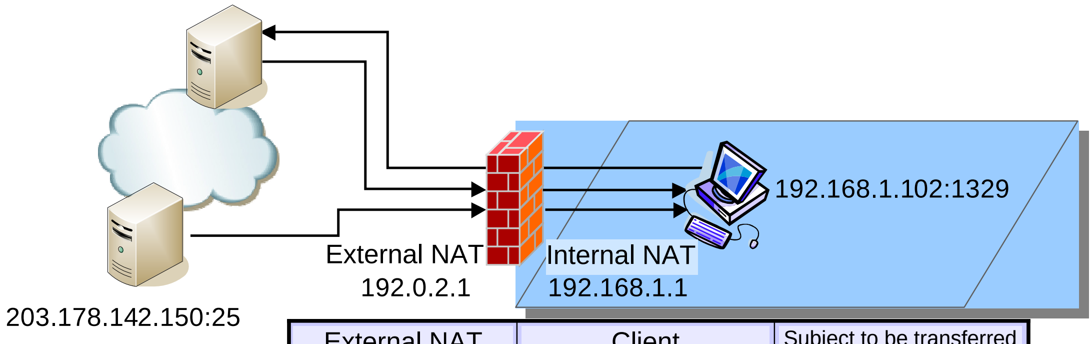
NAPT supports many different types of implementation which allow communication from the outside to inside a NAPT under specific communication conditions. NAT traversal technologies focus on this aspect of it to realize communication from outside to inside a NAPT by identifying the type of NAPT implementation.

In essence, NAT traversal technologies do not assume a multi-layer NAT environment, nor are expected to operate properly in such an environment. In particular, NAT traversal is very difficult in the multi-layer NAT environment in which different types of NAPT implementations are combined as it is necessary to judge multiple NAPT implementations and use an appropriate technique. A type of NAT traversal technology which uses a server outside of a NAT for communication relay is considered to be usable in a multi-layer NAT environment, but there are still issues relating to the timer for NAPT devices, etc. As discussed above, there are many technical constraints on NAT traversal technologies in IPv4. However, as means of communication from outside in an IPv4 multi-layer NAT environment, it is likely that there may be options such as Tredo for IPv6 tunneling technologies.

In the following pages, various NAT implementations are explained individually. These are major implementations organized in the discussions of NAT traversal technologies in RFC3489.

The following explains UDP processing in four different types of NAT implementations. Note that there are also other implementations that are not categorized within these four types.

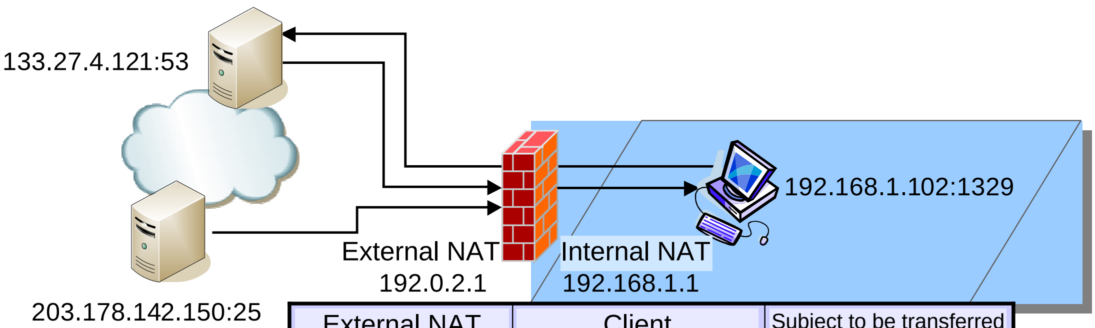
i) Full Cone NAT



External NAT	Client	Subject to be transferred
192.0.2.1:1074	192.168.1.1:1329	*:*

- Operation of a Full Cone NAT
  - ➢ A port number on the external interface of the NAT router and a port number of the client are assigned on a one-to-one basis when a client behind a NAT sends a packet.
  - ➢ When the IP address/port number assigned to the external NAT interface receives a packet, the **packet, from any IP address/port number**, is forwarded to the internal NAT interface.

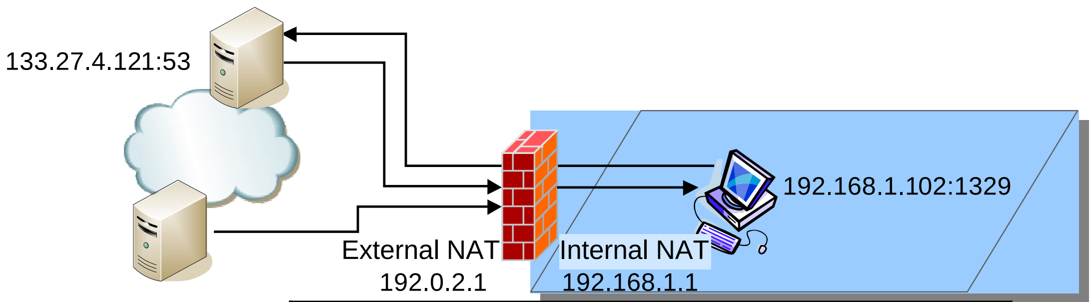
ii) Restricted Cone NAT



External NAT	Client	Subject to be transferred
192.0.2.1:1074	192.168.1.1:1329	133.27.4.121:*

- Operation of Restricted Cone NAT
  - ➢ Ports of client behind a NAT and port numbers on the external interface of the NAT router are assigned on a one-to-one basis.
  - ➢ When the IP address/port number assigned to the external NAT interface receives a packet, the packet is forwarded to the client behind the NAT if it is from the **IP address for which the NAT has an entry (IP address of the connection destination of the client)** regardless of the port number.

iii) Port Restricted Cone NAT

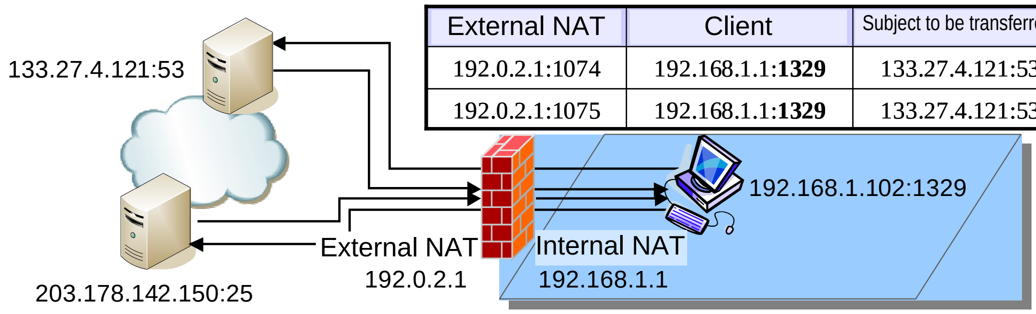


External NAT	Client	Subject to be transferred
192.0.2.1:1074	192.168.1.1:1329	133.27.4.121:53

- Operation of Port Restricted Cone NAT
  - Ports of client behind a NAT and port numbers on the external interface of the NAT router are assigned on a one-to-one basis.
  - When the IP address/port number assigned to the external NAT interface receives a packet, the packet is forwarded to the client behind the NAT if it is from the **IP address and port number for which the NAT has an entry (IP address of the connection destination of the client)**.

iv) Symmetric NAT

External NAT	Client	Subject to be transferred
192.0.2.1:1074	192.168.1.1:**1329**	133.27.4.121:53
192.0.2.1:1075	192.168.1.1:**1329**	133.27.4.121:53



- Operation of a Symmetric NAT
  - NATs other than those explained above.
  - Ports of a client behind a NAT and port numbers on the external interface of the NAT router are assigned on a per-session basis.
  - When the IP address/port number assigned to the external NAT interface receives a packet, the packet is forwarded to the client behind the NAT if it is from the IP address and port number for which the NAT has an entry (IP address of the connection destination of the client).

4.7.4 Issues in the use of digital certificates in an IPv6 environment

This section describes issues in the use of digital certificates in an IPv6 environment.

As a virtual host-related issue in implementing the currently widely used SSL, an IP address is required for each server certificate. For HTTP, a name-based virtual host is realized by using the HTTP/1.1 Host:header and a single IP address. For SSL/TLS, it is impossible to use name-based virtual hosting as the server certificate is exchanged and validated before (at the time of connection establishment) the host is determined by the Host:header. Therefore, in the present situation, sites using SSL/TLS have no other choice but to select IP-based virtual hosting, which requires the number of IP addresses equivalent to the number of server certificates.

Although technology which allows virtual hosting with SSL/TLS using only a single IP address exists, there are functional constraints on certificates, and issues regarding the slow pace of its implementation in Web servers and browsers, etc.

In addition, if only IPv4 has reachability to Certificate Revocation Lists (CRLs) contained in digital certificates, revocation status of digital certificates cannot be checked in an environment supporting only IPv6. General server certificates which use a domain name as a common name are available in both IPv4 and IPv6 environments if the DNS name can be resolved. However, some server certificates[12] use an IPv4 address as the common name, and a specification change is required to support IPv6.

[12] GlobalSign global IP: http://jp.globalsign.com/service/ssl/option/globalip.html

Table 4-5 Technologies allowing SSL/TLS virtual hosting with a single IP address and the issues

	General server certificate	Server certificate extension (specification change)	Protocol specification change
Elemental technology/ Protocol	SSL/TLS	X.509 certificate [RFC3280] containing the subjectAltName attribute	Server Name Indication RFC3546
Implementation	○ Widely implemented in both Web servers and Web browsers		△ Limited
Subject common name	Single	Multiple	Single
Use of multiple certificates	△ (IP addresses equivalent to the number of server certificates are required)	× (All certificate items except the common name are common as the same certificate is used)	○
Examples of products supporting the technology		Server certificate: Entrust Unified Communications Certificates [2] Comodo Unified Communications Certificates [3] CSP SSL Multi-Domain Certificates [4] DigiCert® Unified Communications Certificates [5]	Client: Internet Explorer 7, Firefox 2 Server: mod_ssl + patch [1], or mod_gnutls (Apache module)

* RFC2817 Upgrading to TLS Within HTTP/1.1 and Wildcard Certificates can be listed as other technologies, but they are excluded from this list as the former is very limited in its implementation and the latter is not applicable to other than subdomains.

[1] http://issues.apache.org/bugzilla/show_bug.cgi?id=34607
[2] http://www.entrust.net/ssl-certificates/unified-communications.htm
[3] http://www.comodo.com/msexchange/
[4] http://cspssl.jp/
[5] http://www.digicert.com/unified-communications-ssl-tls.htm

5 Opinions of stakeholders

This chapter summarizes opinions received regarding the IPv4 address space exhaustion issue and the study contained in this report.

Section **5.1** presents the results of a questionnaire conducted with JPNIC Members at the beginning of this study. Section **5.2** presents opinions about the results of this study stated in meetings of the Advisory Committee on the IPv4 Address Space Exhaustion Issue set up to collect opinions of stakeholders in the Internet.

5.1 Questionnaire to JPNIC Members

5.1.1 Outline

Purpose:

The purpose of this questionnaire is to confirm Members' recognition of the address space exhaustion situation in terms of quantitative data and to clarify critical issues to be examined related to the IPv4 address exhaustion issue.

Question items:

(1) Recognition and understanding concerning the address space exhaustion (to determine the results of PR activities related to the address space exhaustion issue)

(2) Existence of concerns about address space exhaustion (to determine importance placed regarding a solution)

(3) Status of measures taken for address space exhaustion (to determine levels of issue consciousness)

(4) Expectations for JPNIC with respect to address space exhaustion (to determine the critical issues of each purpose)

An open-ended question asking about the address space exhaustion was given in addition to the above.

Target: 170 JPNIC Members

Period: July to August 2007

5.1.2 Summary of the results of the questionnaire

- More than 70% of respondents recognize the address space exhaustion including the exhaustion date.
- There are more concerns about continuity and expansion of business than technical concerns.
- About 90% of Members understand the necessity of measures for address space exhaustion, but only about 30% responded that they have "started examination" or

have "already taken measures."

- It is considered necessary to provide information to facilitate examination due to the fact that the number of respondents who started examination remains small in spite of their understanding of the necessity.

- JPNIC is expected, by the Members, to aggregate and communicate the opinions of relevant parties concerned, consider technical countermeasures, and measures for cooperative migration to IPv6, etc.
    - Responses that address the issue as a public interest institution, rather than responses as an Internet Registry, such as change of policies, are required of JPNIC.
- While many Members seem to presuppose migration to IPv6, there are quite a number of opinions that seek measures for the continuous use of IPv4, recovery of unused historical PI addresses, and PR activities for general users, etc.
- Not a few service providers, mainly in regional areas, have concerns about supporting IPv6.

5.1.3 Contents of questions

[Question 1]

Are you aware that IPv4 address space will run out and new IPv4 addresses will no longer be distributed in the near future? (Select one)

1) I do not know about IPv4 address space exhaustion.
2) I know that address space will run out in the near future but I do not know when it will happen.
3) I know about address space exhaustion including the predicted exhaustion date of 2010.

[Question 2]

What concerns does your company have about IPv4 address space exhaustion? (Select as many as apply)

1) Business expansion (growth) may be impaired.
2) The company may not be able to afford the investments required to implement the measures.
3) Issues for business are still unknown.
4) The technical issues are still unknown.
5) The company does not have enough technology to implement the technical measures.
6) Other

[Question 3]

Has your company already started to examine some measures for IPv4 address space exhaustion? (Select one)

1) There is no need to take measures.
2) Whether or not we need to take measures is still unknown.

3) We have not examined any measures, although we understand the necessity.
4) We have started to examine measures.
5) We have already implemented measures.

[Question 4]

What activities do you expect JPNIC to carry out with respect to IPv4 address space exhaustion? (Select as many as apply)

1) Collection of information from Members, designated service providers, industries, and general public and promotion of PR activities
2) Collection and transmission of information in cooperation with the government and other groups
3) Detailed checking and improvement of the accuracy of the predicted date of address space exhaustion
4) Understanding global trends and developing global coordination and cooperation
5) Examine impacts of address space exhaustion on the business of related parties
6) Detailed checking and examination of countermeasures for addressing space exhaustion from a technical point of view
7) Formulation of policies for address space exhaustion
8) Promotion of recovery operations for IPv4 addresses which have already been distributed but remain unused
9) Examination and promotion of migration to the IPv6 Internet
10) Examination of the possibility of other distribution means of addresses

[Question 5]

Please add any other opinions you have regarding IPv4 address space exhaustion.

5.1.4 Answers to Question 1

Question: Are you aware that IPv4 address space will run out and new IPv4 addresses will no longer be distributed in the near future? (Select one)

Answers:

Answers (N = 55)	(Number)	(%)
1) I do not know about IPv4 address space exhaustion.	0	0%
2) I know that address space will run out in the near future but I do not know when it will happen.	13	24%
3) I know about address space exhaustion including the predicted exhaustion date of 2010.	42	76%

5.1.5 Answers to Question 2

Question: What concerns does your company have about IPv4 address space exhaustion? (Select as many as apply)

Answers:

Answers (N = 55)	(Number)	(%)
1) Business expansion (growth) may be impaired.	33	60%
2) The company may not be able to afford the investments required to implement measures.	27	49%
3) Issues for business are still unknown.	12	22%
4) The technical issues are still unknown.	12	22%
5) The company does not have enough technology to implement the technical measures.	16	29%
6) Other	9	16%

Principal answers for 6):

- Vendors have not made their CMTSs (Cable Modem Terminal Systems) compatible with IPv6.
- We do not know how to raise the awareness of general users who are not aware of their use of IP addresses.
- Responses to requests for IPv4 addresses after IPv4 address space exhaustion.
- Although there are issues to be addressed concerning migration, etc., we have no substantial concerns.
- We have no special concerns. Rather, we are worried about public overreaction.
- We are concerned as it seems nothing has been decided. The issue is whether direction can be given while maintaining the basic stance of autonomous distribution as in the past. We don't want to be just following top-down directions from the government, so we think we need to address this issue together hand-in-hand, but…
- We cannot tell how the public will react when they face address space exhaustion.
- We are worrying about whether IPv4 lifetime extension measures and promotion of migration to IPv6 can be implemented in time. We want carriers (e.g. FLET'S or ACCA) to determine their responses quickly.

Remarks: While half the respondents had concerns about the expansion and continuity of their business, as shown by 1) and 2), a relatively small number of Members had technical concerns like 4) and 5).

5.1.6 Answers to Question 3

Question: Has your company already started to examine some measures for IPv4 address space exhaustion? (Select one)

Answers:

Answers (N = 55)	(Number)	(%)
1) There is no need to take measures.	1	2%
2) Whether or not we need to take measures is still unknown.	5	9%
3) We have not examined any measures, although we understand the necessity.	31	56%
4) We have started to examine measures.	12	22%
5) We have already implemented measures.	6	11%

Remark: As indicated in 3), despite their understanding of the necessity, many service providers have not begun examining measures, so it is necessary to provide information to facilitate their examination.

5.1.7 Answers to Question 4

Question: What activities do you expect JPNIC to carry out with respect to IPv4 address space exhaustion? (Select as many as apply)

Answers:

Answers (N = 55)	(Number)	(%)
1) Collection of information from Members, designated service providers, industries, and general public and promotion of PR activities	33	62%
2) Collection and transmission of information in cooperation with the government and other groups	28	53%
3) Detailed checking and improvement of the accuracy of the predicted date of address space exhaustion	22	42%
4) Understanding global trends and developing global coordination and cooperation	25	47%
5) Examine impacts of address space exhaustion on the businesses of related parties	28	34%
6) Detailed checking and examination of countermeasures for addressing space exhaustion from a technical point of view	29	55%
7) Formulation of policies for address space exhaustion	24	45%
8) Promotion of recovery operations for IPv4 addresses which have already been distributed but remain unused	26	49%
9) Examination and promotion of migration to the IPv6 Internet	30	57%
10) Examination of the possibility of other distribution means of addresses	9	17%

Remarks: The fact that many respondents selected 1) and 2) indicates that JPNIC is expected to aggregate the opinions of relevant parties and communicate them to the public. At the same time, the examination of technical countermeasures and migration to the IPv6 Internet are also considered important points that are expected to be carried out by JPNIC. We may consider that responses as a public interest institution, rather than as an Internet Registry, are expected to be carried out by JPNIC.

5.1.8 Answers to Question 5

Question: Please add any other opinions you have regarding IPv4 address space exhaustion. (Free format)

Major answers:

- As a CATV service provider, we feel that migration to IPv6 is a difficult hurdle for us. This is due to the delay in U.S.-led measures for cable Internet equipment and user environments. We want to make preparations by conducting verification tests in the actual environment, but we do not have enough resources on the operator side.
- It is hard to visualize the overall picture of the Internet after IPv4 address space exhaustion.
- From a global perspective, there is a feeling of unfairness in historical PI addresses, etc. for IPv4.
- If end users recognize these issues, it will be easier to promote migration to IPv6.
- Even if IPv4 address space exhaustion is a fact, comments putting pressure on the industry should be refrained from.
- We want positive discussions about smooth migration methods, what should be done by service providers, and so forth, to advance.
- We hope information on network construction technology under the coexisting environment of IPv4 and IPv6 will be provided soon to promote IPv6 compliance.
- Migration to IPv6 should be smooth if it is done within five years after equipment that supports IPv6 becomes widely available. We would appreciate it if manuals or guides that give easy-to-understand technical explanations for migration are made available.
- We hope that IPv6 address allocation conditions will be relaxed to avoid confusion at the time of IPv4 address space exhaustion. It is said that deployment of IPv6 is required within two years, but without conducting verifications first, even its business feasibility cannot be examined. For example, if, in addition to the IPv4 address space actually allocated, allocation of IPv6 address space is made based on experiences of AS operations, etc., it will facilitate migration to IPv6.
- If IPv6 has overwhelming killer contents (transmitted only over v6), it will probably spread itself.
- The activities and standpoint of JPNIC as a resource management organization, not as a communications industry association, should be clarified.
- It is necessary to provide support for the standardization of element technologies to make it easier for providers to use IPv6.

- As our number of users will not increase, we are considering operating using only the current IPv4 addresses (without adding addresses). But as we do not know what the impact, or necessary measures will be, we need information to decide.

Remarks: Overall, respondents seem to feel the necessity of migration to IPv6. However, the information necessary to make decisions regarding it and carry it out is not sufficient, and there were many opinions requesting the provision of such information. Meanwhile, there were quite a number of opinions seeking measures for such things as the continuous use of IPv4 or PR activities for general users.

5.2 Advisory Committee on the IPv4 Address Space Exhaustion Issue

5.2.1 Purpose of establishment

This study was carried out by working groups made up largely by officers, employees, and member organizations of JPNIC, and from the perspective of JPNIC Members consisting largely of Internet connection providers. It is obvious that it is the various stakeholders in the Internet who will be affected by IPv4 address space exhaustion. Therefore, the Advisory Committee on the IPv4 Address Space Exhaustion Issue was set up to gather the opinions of these stakeholders.

The Advisory Committee on the IPv4 Address Space Exhaustion Issue consists of members representing all stakeholders in the Japanese Internet. The Committee held a meeting just before the release of this report, which was prepared as a result of this study, and opinions from various perspectives on the draft of this report were gathered at that stage.

5.2.2 Committee members list

The Advisory Committee on the IPv4 Address Space Exhaustion Issue consists of the following nine members (honorifics omitted):

Shinobu Umino

Executive Vice President, Senior Executive Manager, Business Solutions Sector

NTT DATA Corporation

Masanori Ota

Director, Local Government Wide Area Network National Center

Local Authorities Systems Development Center

Chiharu Kamise

Managing Director

Digital Technology Planning

Fuji Television Network, Inc.

Shigeki Goto

Professor, Department of Computer Science and Engineering

School of Fundamental Science and Engineering

Waseda University Faculty of Science and Engineering

Nobuko Takahashi

Journalist specializing in lifestyle economics

Junji Nomura

Executive Vice President,Mmeber of the Board

Matsushita Electric Works, Ltd.

Keiichi Makizono

Main Technology Division

Corporate Executive Officer, General Manager, Network Group

SOFTBANK MOBILE Corp.

Hiroaki Yasutake

Director and Senior Executive Officer

Deputy General Director

Development and Design General Headquarters

Rakuten, Inc.

Ryozo Yamashita

Senior Technical Officer

Japan Cable and Telecommunications Association

Japan Cable Laboratories

5.2.3 Opinions of the Advisory Committee

(1) Opinions about communication to general users

1) Activities to communicate the address exhaustion issue to users are insufficient.
2) We feel that the address exhaustion issue is not well communicated to the public.
3) The disadvantages as well as the advantages in deploying IPv6 should be presented to users.
4) The use of the mobile Internet has been increasing. We want thorough investigations on the effects on users of the removal of the SIM lock expected to be conducted in the near future.

(2) Opinions about training and enlightenment activities for engineers

1) It is necessary to provide training to engineers to allow understanding of IPv6.

(3) Opinions about the promotion of IPv6 deployment

1) It is necessary to consider the most appropriate deployment method of IPv6: whether it should be tailored to individual user situations, or as a nation-wide initiative.
2) It is desirable that Japan takes the lead in providing IPv6 new services in the world.
3) The important issues among those raised at present should be focused on and strategically addressed.
4) Of the three measures, more emphasis should be placed on the measure using IPv6, and cooperation, in the form of giving incentives to service providers deploying IPv6, is required to promote IPv6.

5) We want JPNIC and related industries to make concerted efforts that will enable us to demonstrate the advantages of IPv6 for its smooth deployment.
6) Information on the number of IPv6 users and IPv6 utilization status should be provided so that investments in IPv6 can be justified.
7) How about developing programs to certify products and service providers supporting IPv6, and preparing test beds and the like for validation?

(4) Opinions about IPv6 technologies and the quality of IPv6 products

1) We will feel strong incentives to deploy IPv6 if the security of the IPv6 Internet can be enhanced.
2) It is necessary to improve the quality of IPv6 products and the reliability of IPv6 in cooperation with those concerned.

(5) Opinions about clarification of timing for implementing measures

1) Clarify the time axis to enable appropriate investments for measures to be made.

(6) Opinions about global trends

1) Preferably, we would like to know if Japan can take a global lead in the deployment of IPv6 and whether it would be advantageous for us.

6 Global trends

This chapter summarizes trends associated with the issue of IPv4 address space exhaustion and promotion of IPv6 development in countries throughout the world.

6.1 Movements of Internet related associations

In 2007, Internet-related associations issued a sequence of statements on the IPv4 address space exhaustion issue, as follows:

- May 21 ARIN Board Advice
  - http://www.arin.net/announcements/20070521.html
- June 19 JPNIC Press Release
  - http://www.nic.ad.jp/ja/pressrelease/2007/20070619-01.html
- June 20 LACNIC Announcement
  - http://lacnic.net/en/anuncios/2007_agotamiento_ipv4.html
- June 21 NIC Mexico Announcement
  - http://www.nic.mx/es/Noticias_2?NEWS=220
- June 29 ICANN Board Resolutions
  - http://www.icann.org/minutes/resolutions-29jun07.htm#n
- July 9 CNNIC Announcement
  - http://www.cnnic.cn/html/Dir/2007/07/09/4698.htm (Chinese)
- August 1 ARIN Board Statement
  - http://www.arin.net/announcements/20070801.html
- August 2 AfriNIC Announcement
  - http://www.afrinic.net/news/position-on-the-future-of-IP.htm
- September 7 APNIC Community Resolution
  - http://www.arin.net/announcements/20070801.html
- October 26 RIPE Community Resolution
  - http://www.ripe.net/news/community-statement.html
- November 12 Internet Society Press Releases
  - http://www.isoc.org/isoc/media/releases/071112pr_ipv6.shtml

The above statements are somewhat different each other, but all of them include the following items:

1. The IPv4 address pool is expected to run out around 2010.
2. IPv6 provides a fundamental solution.
3. Make efforts to communicate and raise awareness of this situation by strengthening cooperation with related organizations.
4. Examine necessary measures, including changes to the address policy.

6.2 Deployment status in each region and country

This section summarizes IPv6 development and promotion activities around the world.

Overview

On a global basis, task forces, including the IPv6 Forum, have been set up in each region, and various activities, including the IPv6 Summit (a conference to introduce case examples of implemented solutions, development and promotion measures, etc.), have been carried out.

At the state level,[13] there are many government-led IPv6 promotion activities. Promotion groups have also been set up as part of such activities, an example of which is the IPv6 Promotion Council[14] of Japan. Some state-owned and major communication service providers in certain countries have progressed in the deployment of IPv6.

There have been no noticeable movements in private companies and communities yet, and future investigations are required.

6.2.1 International IPv6 promotion bodies

International IPv6 promotion organizations are listed below:

1) IPv6 Forum http://www.ipv6forum.org/
   - The IPv6 Forum, established in 1999, has carried out activities for global promotion of IPv6, including promotion activities for the IPv6 Summit and the IPv6 Ready Logo Program in cooperation with chapters[15] in various countries and regional task forces.
2) Asia Pacific IPv6 Task Force (APv6TF) http://www.ap-ipv6tf.org/
3) European IPv6 Task Force (EUv6TF) http://www.eu.ipv6.org/
4) Latin American and Caribbean IPv6 Task Force (LAC IPv6 TF) http://www.lac.ipv6tf.org/
5) North American IPv6 Task Force (NAv6TF) http://www.nav6tf.org

6.2.2 European Union

- Broadband, 3G mobile phones, and IPv6 are included as main themes in the “eEurope2005” action plan announced in 2002 for the promotion of the

[13] Descriptions of state-level efforts are based on the reference to Section 8.5 in IPv6 TextBook (issued by Impress R&D under the editorship of Hiroshi Esaki, ISBN 978-4-8443-2487-4).
[14] http://v6pc.jp/
[15] According to the web page of the IPv6 Forum, 42 chapters by country can be confirmed as of December 2007.

information society.

- In the Framework Programme 6 (FP6), a program for the R&D investment budget started in 2003, IPv6 is positioned as a top priority task in the information society field. It continues to be a top priority also in FP7, started in 2007.

6.2.3 United States

- The Department of Defense and the Department of Commerce formulated plans for a complete migration to IPv6 in 2003.
- The Department of Commerce released "The National Strategy to Secure Cyberspace"[16] describing the necessity of supporting IPv6 on its Web site.
- In 2005, a public hearing about migration to IPv6, "To lead or to follow: The next generation internet and the transition to IPv6"[17] was held; the Government Accountability Office (GAO) issued a report, "Federal Agencies Need to Plan for Transition and Manage Security Risks"[18]; and the Office of Management and Budget (OMB) announced the migration plan to IPv6 (Transition Planning for Internet Protocol Version 6)[19].
- In 2007, the IPv6 Working Group was set up in the Federal Chief Information Officer (CIO) Council's committee.

6.2.4 China

- An IPv6 test network was developed for CERNET (China Education and Research Network) and the CNGI (China Next Generation Internet) is being designed to support IPv6.
- Information and communication networks are being constructed at a rapid pace in China, a huge country with a population of more than 1 billion, and there is great demand for IPv6.

6.2.5 Taiwan

- The IPv6 Forum Taiwan was established by the initiative of TWNIC for the development and promotion of IPv6.
- In September 2007, seven major ISPs cooperatively started to offer a free IPv6 tunnel brokerage service named NICE (Next-generation Internet Connectivity Environment) to users.

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16 http://www.whitehouse.gov/pcipb/

17 http://www.usipv6.com/press_room/downloads/Media_Advisory.doc

18 http://www.gao.gov/new.items/d05471.pdf

19 http://www.google.co.jp/url?sa=t&ct=res&cd=1&url=http%3A%2F%2Fwww.whitehouse.gov%2Fomb%2Fmemoranda%2Ffy2005%2Fm05-22.pdf&ei=rztWR9DjA4GGgAPZnKySDQ&usg=AFQjCNGPT-vpk43ZY1An04f3dwUeQ8mmtw&sig2=4Xb7hnhsMZvGD3AZwzvZvg

6.2.6 Korea[20]

- In 2003, the government drew up the "Basic Plan for the Promotion of IPv6" as part of the "u-Korea (Ubiquitous Korea)" project, and founded the IPv6 Strategic Committee, consisting of researchers and representatives from the industry, government, and academic sectors.
- In 2004, the IPv6 Strategic Committee finalized the "Basic Plan for the Promotion of IPv6."
- An IPv6 test bed, "Korea v6," was created by using the core research network KOREN (Korea advanced Research Network).

[20] This section is based on the reference to the "State of e-Municipality in Korea" by Go Seong Gyu. http://www.computerworld.jp/topics/gov/40561.html

7 Members of this study

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