



IPv6 Migration Guide

Best Practice Document

Produced by CSC/Funet led working group on AccessFunet

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1 Introduction

This document contains a high-level description of procedures that enable a controlled migration to IPv6 in an organisation currently using IPv4. The working order suggested in this document can be used, for example, as a framework for an IPv6 project plan, or otherwise as support in the planning of IPv6 migration. The starting point of this document was that the IPv4 protocol will be eventually phased out completely.

This document aims to take into consideration the essential matters with regard to migration to IPv6 and their interdependencies so that the IPv6 protocol can be safely added to an existing IPv4 network. In addition to technical matters, administrative issues have also been taken into consideration.

Simplified sections are usually linked to other documents and Web resources discussing the subject in more detail.

All feedback concerning this document is very welcome.

2 Framework of an IPv6 migration project

2.1 1st phase: Preparing for the IPv6 migration

- Administrative issues
 - All parts of the organisation should be informed of the IPv6 migration and reminded that there are no alternatives.
 - The management may create a project for the IPv6 migration.
 - The acquisition of software, hardware and services supporting IPv4 only is discontinued. After this point, IPv6 is taken into account in all acquisitions and competitive tendering. If IPv6-capable alternatives are unavailable at the moment of acquisition, the measures required for the later IPv6 migration of the product or service to be acquired are investigated and planned prior to the acquisition.
 - IPv6 training is arranged for the personnel and IPv6 experience is taken into consideration in the recruitment of administrators.
 - Systems, services and software (hereinafter 'components') that require IPv4 (or do not work in an IPv6-only environment) are identified and listed.
- Software development
 - IPv6 is added to the roadmaps of software developed in-house.
- Addressing and network infrastructure
 - An IPv6 address block is acquired from the local Internet registry.
 - An IPv6 addressing plan is prepared.
- Building a testing platform
 - A network is established for testing purposes in order to prepare for the IPv6 deployment of workstations, servers and services.
 - The testing environment allows the testing of IPv6 functionality on different hardware, in different operating system versions, etc, without the risk of disrupting production.
- End results of the phase
 - The organisation has begun a controlled IPv6 migration.

2.2 2nd phase: Phased deployment of IPv6 in the network

- Network infrastructure
 - IPv6 support is added to the basic network infrastructure: routers, switches, firewalls.
 - IPv6 is taken into use in some basic network services: DNS and NTP servers, syslog servers. New IPv6 services are monitored at least with the same rigour as corresponding IPv4 services.
- Workstations
 - IPv6 is taken into use on the workstations of the network and systems administrators.
- Network management and monitoring systems
 - IPv6 is taken into use in network management systems (e.g. network management servers).
 - IPv6 is taken into use in network monitoring systems (e.g. Nagios monitoring, statistics, etc.).
 - IPv6 support is added into any Netflow collectors and IDS/IPS systems.
 - Only IPv6 management addresses are primarily taken into use for new network equipment, unless an IPv4 is absolutely necessary.
- End results of the phase
 - Network administrators are able to use IPv6 and administer and monitor the IPv6-capable network, systems and services.
 - Maintenance work becomes easier when unnecessary IPv4 implementations for management and monitoring are avoided.

2.3 3rd phase: Preparation for IPv6 deployment on servers

- Administrative issues
 - All of the organisation's internal processes take IPv6 into consideration.
- Support systems
 - IPv6 support is added to all support systems: for example, service management systems, reporting systems, hardware inventory systems, administration tools.

- Network infrastructure
 - IPv6 support is added to all networks without tunnelling.
- End results of the phase
 - All networks support IPv6.
 - All support systems are able to process data from devices and systems using IPv6.
 - All of the organisation's internal processes are ready for IPv6 deployment.

2.4 4th phase: IPv6 deployment on workstations

- Workstations
 - IPv6 is taken into use on all workstations and laptops. The protocol is enabled as a default in the latest versions of typical operating systems. In managed networks, DHCPv6, for example, is used for address assignment when possible.
 - Workstations and laptops are configured to use DNS and NTP over IPv6.
- End results of the phase
 - All of the organisation's workstations and laptops support both IPv4 and IPv6 (dual-stack).

2.5 5th phase: IPv6 deployment on servers and services

- Servers and services
 - IPv6 support is gradually added to all servers and services. IPv6 support can be added to servers and services already in use, or the deployment can be done as new services are installed in the network or old servers are replaced with new ones.
 - All IPv6 services are monitored at least with the same rigour as corresponding IPv4 services so that IPv6-only problems are noticed quickly.

- The IPv6 addresses of the services are added to the Domain Name Service as AAAA records for the same DNS names as for IPv4 services. Separate *.ipv6.organisation.tld names are not used.
- Software development
 - IPv6 support is implemented to all software developed in-house.
- End results of the phase
 - All software developed in-house supports IPv6.
 - All servers and services support both IPv4 and IPv6 (dual-stack).

2.6 6th phase: Eliminating IPv4 dependencies

- Administrative issues / IPv6 migration project
 - A plan is prepared for every IPv4-dependent component, describing how the IPv6 migration will be handled. If the IPv6 migration is impossible, decommissioning is planned for the component taking the remaining expected service life of the systems into consideration.
 - The situation of all IPv4-dependent components is monitored and supervised systematically until all IPv4 dependencies have been eliminated.
- End results of the phase
 - All IPv4-dependencies have been eliminated. All systems, services and software are able to operate in an environment that does not support IPv4.

2.7 7th phase: Decommissioning IPv4 from workstations

- Network infrastructure
 - NAT64 and DNS64 services for workstations are implemented in the network.
- Workstations
 - The use of NAT64 and DNS64 services is piloted at first with a limited user group (for example, the workstations of system and network administrators)
 - Once IPv4 traffic volume has decreased enough, or when continuing IPv4 support for workstations is deemed to be too large a hardship, IPv4 is gradually decommissioned from all workstations. Workstations are configured to use NAT64 and DNS64 services for the use of the remaining IPv4 Internet.

- End results of the phase
 - IPv4 has been decommissioned from all workstations, and all workstations use only IPv6.

2.8 8th phase: Decommissioning IPv4 from servers and services

- Servers and services
 - As IPv4 support is no longer required on servers or services (or when a possibly established separate NAT46 service can provide sufficient IPv4 support), IPv4 is gradually decommissioned from all servers and services.
- End results of the phase
 - IPv4 has been decommissioned from all servers and services. All servers and services use only IPv6.

2.9 9th phase: Decommissioning IPv4

- Network infrastructure
 - IPv4 is decommissioned from the network monitoring and management systems.
 - NAT64, NAT46 and DNS64 services are decommissioned.
 - IPv4 settings and addresses are removed from all routers and other basic network infrastructure.
 - IPv4 addresses are returned to the local Internet registry.
- End results of the phase
 - IPv4 is no longer used anywhere.
 - The IPv6 migration is complete.

3 Other things to be taken into consideration during IPv6 migration

3.1 IPv6 and processes

- It is important that all processes of the organisation take IPv6 into consideration. The IPv6 migration will never be completed, if a part of the organisation creates services supporting only IPv4 or acquires hardware and software supporting only IPv4. IPv4-dependent software, hardware and systems will cause problems later during the migration.

3.2 Using tunnelling in IPv6 deployment

- The use of tunnelling (GRE/IP, IP/IP) is not recommended in IPv6 deployment. IPv6 should be deployed as native. Tunnelling was used in early IPv6 trials, when the majority of hardware did not yet support IPv6. Today, IPv6 support is widely available, so there is no longer a similar justification for using tunnelling.
- The use of tunnelling slows down the IPv6 migration and makes it more complex. It also creates information security threats that do not exist in native traffic.
- GRE and IP/IP may be usable methods to connect IPv6 pockets to each other over trunk connections that do not support IPv6 (for example, remote offices operating on DSL connections).

Teredo and 6to4 tunnelling used by workstations (including Windows by default) cause problems: they should be eliminated by offering native IPv6 transport in workstation networks, allowing better management of the IPv6 traffic of the workstations.

3.3 Monitoring, quality and performance of services

- If IPv6 support is added to a service or a server, the new IPv6 service must be monitored at least with the same rigour as a corresponding IPv4 service. If the IPv6

services are not properly monitored, IPv6 problems remain unidentified and IPv6 users receive poorer service.

- The quality and performance of IPv6 service must be at least as good as that of a corresponding IPv4 service. However, there are challenges. For instance, the offload/IRQ affinity features of network interface cards do not necessarily support IPv6 as comprehensively as IPv4. Acquisitions should take performance differences and functionality into consideration.

3.4 Information security

- The existing information security policies must be separately adapted to the new protocol, and it will also bring about new threats.
- Some information security problems cannot be identified until the system is deployed. This is the only way to get equipment manufacturers to correct problems cropping up, and standardisation can step in to address issues.

3.5 Responsibilities of IPv6 migration

- The responsibilities of the IPv6 migration within the organisation should be clearly defined. Responsibility for the migration can be assigned to, for example, an IPv6 migration project created by the management.
- The party responsible for the IPv6 migration must ensure that all players in the organisation are committed to implementing the IPv6 migration.

3.6 Internal and external cooperation

- A cooperation task force can be established within the organisation to assist in the problems related to the IPv6 migration and distribute IPv6 information (e.g. “IPv6 Task Force”).
- The organisation should also follow external cooperation forums: for example, the [Terena](#) and [IETF's 6man](#), [v6ops](#) and [sunset4](#) working groups.

3.7 Distributing IPv6 awareness within the organisation

- All personnel must understand the issues related to IPv6 at least as well as corresponding IPv4 issues.
- All persons responsible for acquisitions and competitive tendering must be aware of IPv6 issues.

4 Support resources:

4.1 Deployment project:

- **IPv6 for All: A Guide for IPv6 Usage and Application in Different Environments [eBook]**

(Cicileo et al, Internet Society Argentina Chapter, 2009. Translation: LACNIC, 2011)
<<http://www.ipv6tf.org/pdf/ipv6forall.pdf>>

A comprehensive guide discussing all phases of deployment from the perspectives of different organisations.

- **Deploying IPv6 - practical problems from the campus perspective [Presentation]**

(Podermański, Tomáš & Grégr, Matěj. Brno University of Technology, TNC 2012)
< http://www.ripe.net/lir-services/training/material/IPv6-for-LIRs-Training-Course/IPv6_addr_plan4.pdf>

A conference presentation on practical experience and troubleshooting concerning IPv6 deployment on campuses.

- **Deploying IPv6: Gateway To the Next -Gen Internet [Whitepaper]**

(Doyle, Jeff. InformationWeek Analytics, 2011)
<<http://reports.informationweek.com/cart/index/downloadlink/id/5296>>

A Best Practices presentation on a certain model of completing an IPv6 deployment project. Reading the presentation requires website registration.

- **Planning for IPv6 [Book]**

(Hagen, Silvia. O'Reilly Media 2011, ISBN 1449305393)
<<http://shop.oreilly.com/product/0636920020189.do>>

This book helps you plan for IPv6 integration by providing a high-level overview of the technical and nontechnical steps involved.

4.2 Acquisitions, compatibility and dependencies

- **IPv6 Ready Logo Program Approved List**

[<https://www.ipv6ready.org/db/index.php/public/?o=6>](https://www.ipv6ready.org/db/index.php/public/?o=6)

A list of products approved by the IPv6 Ready Logo programme. The programme measures conformance with standards and the interoperability of products by different manufacturers. VTT Technical Research Centre of Finland Oulu is a partner in the programme.

- **IPv6-to-Standard**

[<http://www.ipv6-to-standard.org/>](http://www.ipv6-to-standard.org/)

A listing of systems, software, services, etc. supporting IPv6.

- **Requirements for IPv6 in ICT Equipment**

[<http://www.ripe.net/ripe/docs/current-ripe-documents/ripe-554>](http://www.ripe.net/ripe/docs/current-ripe-documents/ripe-554)

Best Practices acquisition guidelines by RIPE for the public sector and major corporations for competitive tendering on IPv6-compatible network equipment acquisitions.

- **IPv4 Captivity 2011 Dependence on Internet Protocol Version 4 in application software source code**

(van Oosten et al. SIG Trend Report, 2012)

[<http://www.sig.eu/blobs/Research/Scientific%20publication/2012/201204%20SIG%20Trend%20Report%20on%20IPv4%20Captivity%202011.pdf>](http://www.sig.eu/blobs/Research/Scientific%20publication/2012/201204%20SIG%20Trend%20Report%20on%20IPv4%20Captivity%202011.pdf)

A research report annually monitoring the IPv4 dependencies of software products.

- **Microsoft TechNet - Networking and Access Technologies: IPv6**

<<http://technet.microsoft.com/en-us/network/bb530961.aspx>>

A collection of resources by Microsoft on the subject of IPv6

- **IPv6 Support in Microsoft Products and Services**

<<http://technet.microsoft.com/en-us/network/hh994905>>

A list of the IPv6 compatibility of Microsoft software and services

4.3 Addressing planning

- **Preparing an IPv6 Addressing Plan – Manual [eBook]**

(Sander, Steffann (editor), SURFnet, 2010. Translation: RIPE NCC, 2011)

<http://www.ripe.net/lir-services/training/material/IPv6-for-LIRs-Training-Course/IPv6_addr_plan4.pdf>

A comprehensive Best Practices document on the planning of IPv6 addressing in an organisation

- **IPv6 Address Planning and Strategy [Presentation]**

(Siddiqui, Aftab A. , Cybernet, 2012. APNIC 34 Conference)

<http://conference.apnic.net/_data/assets/pdf_file/0004/50827/apnic-ipv6-address-planning-and-strategy_1346218371.pdf>

4.4 Tools for address administration

- **NetDot**

<<http://netdot.uoregon.edu>>

- **HaCi**
<<http://sourceforge.net/projects/haci>>
- **IPAT**
<<http://nethead.de/index.php/ipat>>

4.5 Legislation

- **IPv6: Legal Aspects of the New Internet Protocol [eBook]**
(Mills, David G. (editor), Euro6IX, 2005. ISBN: 84-609-6359-4)
<<http://www.ipv6tf.org/pdf/ipv6legalaspects.pdf>>

This book aims to contribute some basic knowledge about the technical specifications of IPv6 and to analyse, from a legal point of view, the problems and possible solutions that could exist regarding the right to privacy, data protection and intellectual property rights.

4.6 Learning materials

- **IPv6 Technical Overview [Tutorial]**
(Apcar, Jeff, Cisco Systems, 2011)
<http://www.apricot.net/apricot2012/_data/assets/pdf_file/0009/45576/11.pdf>

An extensive technical presentation by Cisco on the basics of IPv6

- **Internet Society FAQ on IPv6 adoption and IPv4 exhaustion**
<http://www.isoc.org/internet/issues/ipv6_faq.shtml>

A “Frequently Asked Questions” document by ISOC on IPv6 adoption

4.7 Network monitoring and control

- **Dual Stack IPv4 + IPv6 monitoring with Nagios [Presentation]**

(Kiviniemi, Teemu. CSC/Funet, 2012)

<<http://www.terena.org/activities/tf-noc/meeting6/slides/20120606-dual-stack.pdf>>

A conference presentation on the dual-stack implementation of Nagios monitoring using the check_v46 plugin

- **6Mon: Rogue IPv6 Router Advertisement detection and mitigation and IPv6 address utilization network monitoring tool [Presentation]**

(Sommarì, Marco. Institute of Informatics and Telematics – CNR Pisa, 2012)

<<https://tnc2012.terena.org/getfile/1560>>

A conference presentation on tools that can be used to monitor and prevent rogue IPv6 router advertisements on networks

4.8 Information security

- **Eight security considerations for IPv6 deployment**

(McPherson, Danny, VeriSign, 2011)

<<http://verisigninc.com/assets/ipv6-security-considerations.pdf>>

Eight possible information security threats that should be taken into consideration during the migration project

- **Guidelines for the Secure Deployment of IPv6 – NIST Special publication 800-119**

(Frankel et al. National Institute of Standards and Technology 2010)

<<http://csrc.nist.gov/publications/nistpubs/800-119/sp800-119.pdf>>

An extensive IPv6 deployment guide produced by the United States Department of Commerce, also taking information security issues into consideration

- **A Complete Guide on IPv6 Attack and Defense [Whitepaper]**

(Pilihanto, Atik. SANS Institute, 2011)

<http://www.sans.org/reading_room/whitepapers/detection/complete-guide-ipv6-attack-defense_33904>

Intrusion Detection, etc.

- **Security challenges in IPv6 from the campus perspective**

(Podermański, Tomáš. Brno University of Technology, NORDUnet Oslo 2012)

<<https://events.nordu.net/plugins/servlet/conference-attachment/talks/23/166>>

A conference presentation on the information security challenges on campuses raised by the new protocol, presented from the perspective of known attacks

4.9 Articles:

- **Why Your Network Should Go IPv6 Only**

(Loughridge, Jeff. Brooks Consulting, 2012)

<<http://packetpushers.net/why-your-network-should-go-ipv6-only/>>

<<http://brooksconsulting-llc.com/wp-content/uploads/2012/04/Why-Your-Network-Should-Go-IPv6-Only.pdf>>

A blog entry and a slideshow presentation on the reasons why an IPv6-only network is a better solution on the long term than dual-stack

- **Top 10 Tasks for IPv6 Application Developers**

(Hogg, Scott. Networkworld 2011)

<<http://www.networkworld.com/community/blog/top-10-tasks-ipv6-application-developers>>

A blog entry on issues that should be taken into consideration when developing dual-stack applications

- **Setting up an IPv6-only network [Mailinglist post]**

(Whinery, Alan, University of Hawai'i, 2009)

<<https://listserv.hawaii.edu/cgi-bin/wa?A2=IPV6-L;JlfFOg;20090220131252-1000>>

Discussion on IPv6 network deployment experiences

4.10 Programming resources

- **IPv6 CARE**

<<http://sourceforge.net/projects/ipv6-care>>

A Linux tool for checking whether an application uses IPv4-specific APIs

- **IPv6 Guide for Windows Sockets Applications**

<<http://msdn.microsoft.com/en-us/library/ms738649.aspx>>

MSDN guide for modifying Windows Socket applications to IPv6 compatibility

- **Beej's Guide to Network Programming Using Internet Sockets (C)**

(Hall, Brian. Jorgensen Publishing, 2012)

<<http://beej.us/guide/bgnet/>>

- **Porting IPv4 applications to IPv4/v6 dual stack (C, Perl, Python)**

(De Long, Oliver. Hurricane Electric, 2009)

<<http://www.lugod.org/presentations/ipv6programming/PortMeth.pdf>>

A presentation on modifying client-server code to dual-stack-compatible code

- **Application Aspects of IPv6 Transition**

<<http://www.ietf.org/rfc/rfc4038.txt>>

- **Basic Socket Interface Extensions for IPv6**

<<http://www.ietf.org/rfc/rfc3493.txt>>

- **Implementing AF-independent application (C)**

<<http://www.kame.net/newsletter/19980604/>>

- **Porting applications to IPv6 HowTo (C)**

<<http://gsyc.escet.urjc.es/~eva/IPv6-web/ipv6.html>>

- **Introduction to IPv6 Programming (C, Java, Perl, PHP)**

<<http://www.euchinagrid.org/IPv6/slides.html>>

- **Linux IPv6 programming Howto (C, Java, Perl)**

<<http://www.tldp.org/HOWTO/Linux+IPv6-HOWTO/chapter-programming.html>>

- **Implementing IPv6 Applications (C, Perl)**

<http://www.6deploy.org/tutorials/210-6deploy_devel_v0_2.pdf>

- **IPv6-Programming (C/C++, JAVA, Python, Perl)**

<<https://edms.cern.ch/document/976004>>

4.11 Deployment on typical server applications

- **How to install Sendmail with IPv6 support**
<<http://www.elandsys.com/resources/sendmail/ipv6.html>>
- **How to enable IPv6 on Postfix**
<<http://www.fix6.net/archives/2011/02/03/how-to-enable-ipv6-on-postfix/>>
- **How to enable IPv6 on Apache2**
<<http://www.fix6.net/archives/2011/02/04/how-to-enable-ipv6-on-apache2/>>
- **Apache IPv6 Configuration: Dual Stacked IPv4 & IPv6 Virtual Hosts**
<<http://www.cyberciti.biz/faq/ipv6-apache-configuration-tutorial/>>
- **How to enable IPv6 on BIND 9**
<<http://www.fix6.net/archives/2011/02/07/how-to-enable-ipv6-on-bind9/>>

4.12 Promoting IPv6 in Finland

- **FICORA's national IPv6 working group**
<<http://www.ficora.fi/index/palvelut/palvelutaiheittain/standardointi/viestintahallinnonteknisettyoryhmat/ipv6.html>>
- **FICORA: A survey on the situation of the IPv6 protocol in Finland in 2012**
<http://www.ficora.fi/attachments/68DG30LI9/IPv6-kysely_2012_-_yhteenveto_2.pdf>

4.13 International cooperation organisations and projects

- **IPv6 Forum**
<<http://www.ipv6forum.org/>>

A list of national IPv6 Task Force organisations

- **6Deploy - IPv6 Deployment and Support**

<<http://www.6deploy.eu/>>

An EU project founded to support IPv6 deployment, arranging, for example, training

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- **Deploy360 | IPv6**

<<http://www.internetsociety.org/deploy360/ipv6/>>

A programme of the Internet Society with the goal of distribution information and experiences in various IPv6 deployments. The site also contains DNSSEC and routing information.

4.14 Usage statistics

- **World IPv6 Launch Measurements**

<<http://www.worldipv6launch.org/measurements/>>

- **Google IPv6 Statistics**

<<http://www.google.com/ipv6/statistics.html>>

- **RIPE NCC IPv6 Statistics**

<<http://www.ipv6actnow.org/info/statistics/>>

- **Akamai IPv6 Traffic Volume**

<<http://www.akamai.com/ipv6>>

- **Akamai: the quarterly State of the Internet report**

<<http://www.akamai.com/stateoftheinternet/>>

- **The IPv6 preparedness of European operators (the RIPv6 rating)**

[<http://ripeness.ripe.net/>](http://ripeness.ripe.net/)

Glossary

DHCP	Dynamic Host Control Protocol
DNS	Domain Name System
GRE	Generic Routing Encapsulation
IETF	Internet Engineering Task Force
NAT	Network Address Translation
NTP	Network Time Protocol

