

UPGRADE is the European Journal for the Informatics Professional, published bimonthly at <http://www.upgrade-cepis.org/>

UPGRADE is the anchor point for UPENET (UPGRADE European NETWORK), the network of CEPIS member societies' publications, that currently includes the following ones:

- **Mondo Digitale**, digital journal from the Italian CEPIS society AICA
- **Novática**, journal from the Spanish CEPIS society ATI
- **OCG Journal**, journal from the Austrian CEPIS society OCG
- **Pifororiki**, journal from the Cyprus CEPIS society CCS
- **Pro Dialog**, journal from the Polish CEPIS society PTI-PIPS

Publisher

UPGRADE is published on behalf of CEPIS (Council of European Professional Informatics Societies, <http://www.cepis.org/>) by **Novática** (<http://www.ati.es/novatica/>), journal of the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática* <http://www.ati.es/>)

UPGRADE monographs are also published in Spanish (full version printed; summary, abstracts and some articles online) by **Novática**, and in Italian (summary, abstracts and some articles online) by the Italian CEPIS society ALSI <http://www.alsi.it/> and the Italian IT portal **Tecnoteca** <http://www.tecnoteca.it/>

UPGRADE was created in October 2000 by CEPIS and was first published by **Novática** and **INFORMATIK/INFORMATIQUE**, bimonthly journal of SVI/FSI (Swiss Federation of Professional Informatics Societies, <http://www.svifsi.ch/>)

Editorial Team

Chief Editor: Rafael Fernández Calvo, Spain, rfoalvo@ati.es

Associate Editors:

François Louis Nicolet, Switzerland, nicolet@acm.org

Roberto Carniel, Italy, carniel@dgt.uniud.it

Zakaria Maamar, Arab Emirates, Zakaria.Maamar@zu.ac.ae

Soraya Kouadri Mostéfaoui, Switzerland,

soraya.kouadrimostefaoui@unifr.ch

Editorial Board

Prof. Wolfried Stucky, CEPIS Past President

Prof. Nello Scarabottolo, CEPIS Vice President

Fernando Piera Gómez and

Rafael Fernández Calvo, ATI (Spain)

François Louis Nicolet, SI (Switzerland)

Roberto Carniel, ALSI – Tecnoteca (Italy)

UPENET Advisory Board

Franco Filippazzi (Mondo Digitale, Italy)

Rafael Fernández Calvo (Novática, Spain)

Veith Risak (OCG Journal, Austria)

Panicos Masouras (Pifororiki, Cyprus)

Andrzej Marciniak (Pro Dialog, Poland)

English Editors: Mike Andersson, Richard Butchart, David Cash, Arthur Cook, Tracey Darch, Laura Davies, Nick Dunn, Rodney Fennemore, Hilary Green, Roger Harris, Michael Hird, Jim Holder, Alasdair MacLeod, Pat Moody, Adam David Moss, Phil Parkin, Brian Robson

Cover page designed by Antonio Crespo Foix, © ATI 2005

Layout Design: François Louis Nicolet

Composition: Jorge Llácer-Gil de Ramalos

Editorial correspondence: Rafael Fernández Calvo rfoalvo@ati.es

Advertising correspondence: novatica@ati.es

UPGRADE Newslist available at

<http://www.upgrade-cepis.org/pages/editinfo.html#newslist>

Copyright

© Novática 2005 (for the monograph and the cover page)

© CEPIS 2005 (for the sections MOSAIC and UPENET)

All rights reserved. Abstracting is permitted with credit to the source. For copying, reprint, or republication permission, contact the Editorial Team

The opinions expressed by the authors are their exclusive responsibility

ISSN 1684-5285

Monograph of next issue (June 2005):
"Free Software Engineering"
(The full schedule of UPGRADE
is available at our website)

Monograph: IPv6 - More than A Protocol (published jointly with Novática*)

Guest Editors: *Jordi Domingo-Pascual, Alberto García-Martínez, and Matthew Ford*

- 2 Presentation
IPv6: A New Network Paradigm — *Jordi Domingo-Pascual, Alberto García-Martínez, and Matthew Ford*
- 5 IPv6 Deployment State 2005 — *Jim Bound*
- 9 Internet Protocol version 6 Overview — *Albert Cabellos-Aparicio and Jordi Domingo-Pascual*
- 15 Transition of Applications to IPv6 — *Eva M. Castro-Barbero, Tomás P. de Miguel-Moro, and Santiago Pavón-Gómez*
- 19 Service Deployment Experience in Pre-Commercial IPv6 Networks — *Rüdiger Geib, Eduardo Azañón-Teruel, Sandra Donaire-Arroyo, Aurora Ferrándiz-Cancio, Carlos Ralli-Ucendo, and Francisco Romero Bueno*
- 27 Security with IPv6 — *Latif Ladid, Jimmy McGibney, and John Ronan*
- 31 Tools for IPv6 Multihoming — *Marcelo Bagnulo-Braun, Alberto García-Martínez, and Arturo Azcorra-Saloña*
- 36 NEMO: Network Mobility in IPv6 — *Carlos J. Bernardos-Cano, Ignacio Soto-Campos, María Calderón-Pastor, Dirk von Hugo, and Emmanuel Riou*
- 43 IPv6 Status in The World and IPv6 Task Forces — *Jordi Palet-Martínez*

MOSAIC

- 49 Mobile Networks
QoS and Micromobility Coupling: Improving Performance in Integrated Scenarios — *Luis-Angel Galindo-Sánchez and Pedro-Manuel Ruiz-Martínez*
- 56 Performance Analysis
The Design of A Dynamic Zero-Copy Communication Model for Cluster-Based Systems — *Appolo Tankeh and Dominique A. Heger*
- 64 News & Events: European Commission; ECDL; EUCIP - AICA, Italy; IPv6 Summit - ATI, Spain

UPENET (UPGRADE European NETWORK)

- 66 From **Pro Dialog** (PTI-PIPS, Poland)
IT Teaching
Today's Concepts of Teaching Computer Science Basics and Occupational Profile of Software Engineer — *Henryk Budzisz, Krzysztof Kadowski, and Walery Susłow*
- 73 From **Novática** (ATI, Spain)
Information Society
Beyond The Internet: The Digital Universal Network — *Fernando Sáez-Vacas*

* This monograph will be also published in Spanish (full version printed; summary, abstracts, and some articles online) by **Novática**, journal of the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática*) at <http://www.ati.es/novatica/>, and in Italian (online edition only, containing summary, abstracts, and some articles) by the Italian CEPIS society ALSI (*Associazione nazionale Laureati in Scienze dell'informazione e Informatica*) and the Italian IT portal Tecnoteca at <http://www.tecnoteca.it/>.

Presentation

IPv6: A New Network Paradigm

Jordi Domingo-Pascual, Alberto García-Martínez, and Matthew Ford

1 Introduction

The new version of the IP protocol, IPv6 (Internet Protocol version 6), provides extended networking functionality – a much larger address space, restoration of end-to-end connectivity to facilitate peer-to-peer communication and end-to-end security, better auto-configuration tools, and several other protocol enhancements – that could make it a new networking paradigm. This special issue is devoted to presenting all these new possibilities from a critical point of view.

The need for a new IP protocol arose in the early 90s when depletion of Internet address space became a major concern for the technical community. The IETF (Internet Engineering Task Force) began work on short-term solutions, such as replacing the classful addressing model with CIDR (Classless Interdomain Routing, RFC 1519 [1]) and deploying a more efficient model for address delegation based on RIRs (Regional Internet Registries). But even assuming these measures were to be deployed successfully, address exhaustion was still expected to occur in the near future – for example, RFC 1744 [2] predicted address exhaustion for 2006 at the latest. A long-term solution involving a major redesign of the IP protocol was required. Several ideas were discussed and the result was IPv6, for which the first version of the basic set of standards was released at the end of 1995.

While the major driver for these new developments was the need to increase available address space, IPv6 was also seen as an opportunity to refine parts of the IP protocol on the basis of experience gained over many years of IPv4 (Internet Protocol version 4) deployment. The header was reorganised to enable more efficient processing while providing improved extension header support. Auto-configuration was a fundamental design criterion, leading to the integration of the Router Advertisement mechanism, and the specification of a basic, single-segment, fully-automatic configuration mode. Finally, many other features were also included, such as native multicast support for IPv6 hosts and routers, and flow identifiers.

2 Problems and Challenges: Are We Running out of IP Addresses?

However, despite the initial expectations raised, IPv6 is clearly far from being extensively deployed, and therefore it is too early to claim any success for it yet. There are several reasons for this. The first is that the dire warnings regarding IPv4 address exhaustion have not yet materialised. Recent studies [3] analysing past data forecast that IPv4 addresses will hold out beyond 2030 unless new conditions arise that bring about a change in the current trend in address consumption, such as a strong demand for addresses for mobile devices or the addition of a large number of users in China or India. There are several explanations for this change in

The Guest Editors

Jordi Domingo-Pascual is Full Professor of Computer Science and Communications at the *Universitat Politècnica de Catalunya* (UPC) in Barcelona, Spain. There he received an engineering degree in Telecommunication (1982) and a Ph.D. Degree in Computer Science (1987). In 1983 he joined the Computer Architecture Department. He is co-founder and researcher of the Advanced Broadband Communications Centre of the University (CCABA) that participated in the Spanish National Host and in the PLANBA demonstrator (1994). He was visiting researcher at the International Computer Science Institute in Berkeley (California, USA) for six months. His research topics are Broadband Communications and Applications, IP/ATM integration, QoS management and provision, traffic engineering, IP traffic analysis and characterisation, group communications and multicast. Since 1988 he has participated in the following projects: RACE projects Technology for ATD (R1022) and EXPLOIT; Spanish Broadband projects (PLANBA) AFTER, TR1 and IRMEM; ACTS projects INFOWIN, MICC, and IMMP; IST projects LONG, ENET and EuQoS; EU VI FP NoE E-NEXT; Spanish research projects CASTBA, MEHARI, SABA, MIRA, SABA2, CARISMA and SAM; and in the research project of an experimental next generation network in Catalunya i2CAT. More detailed information may be found in: <<http://www.ac.upc.edu/homes/jordid/>> and <<http://www.ccaba.upc.edu>>. <jordi.domingo@ac.upc.edu>.

Alberto García-Martínez is an Associate Professor in the Telematics Engineering Dept. of the *Universidad Carlos III de Madrid*, Spain. He received his PhD. in Telematics Engineering from the *Universidad Politécnica de Madrid* (UPM) in 1999. He has participated in several national and international research projects on IPv6 and QoS, and has published several papers on the subject. <alberto@it.uc3m.es>

Matthew Ford is Commercial Technology Adviser to the UK IPv6 Task Force Steering Committee and Chair of the EC IST IPv6 Cluster. He joined BT in 1998 and initially worked to develop network security designs for a range of platforms, and to research emerging security technologies like DNSsec and security for MobileIP. More recently, he has focused on IPv6 technology research, development, standardisation and deployment. He has been and is involved in ground-breaking networking technology research projects of the EC's IST Programme such as 6WINIT, 6LINK, SEINIT, and Euro6IX. Mat is regularly invited to speak on the subjects of IPv6 and network security at international conferences and has chaired several large international gatherings of networking professionals. He holds an MA from the University of Glasgow, in Scotland (United Kingdom), and an MSc from the London School of Economics. He is an Associate Member of the Institute of Electrical Engineers. <matthew.ford@bt.com>

expectations: tough political control from the RIRs over address assignment, address reuse in dial-up accesses, and so on, but the deployment of NATs (Network Address Translators) has probably played the most important part in slowing down address consumption. NATs allow the reuse of a few publicly registered addresses in the provision of connectivity to a much larger number of systems. NATs are in widespread use, and are now serving both large organisations and residential users. Although their implementation has deferred the address scarcity problem, this has not been achieved without cost. Firstly, connectivity has become asymmetric because some nodes are more capable of receiving externally-initiated communications than others. Secondly, end-to-end functions depending on the preservation of the original IP address throughout the communication, such as IPsec security, are now precluded. Addressing these issues is now one of the goals of IPv6 supporters.

There have also been technological obstacles to the success of IPv6. While basic IPv6 standards have been available for some time, the standardisation process has not been smooth in some key areas, since several important issues, such as DHCPv6 or Mobile IPv6, have taken a considerable amount of time to resolve. There have also been some changes made to the core specification in recent years, such as the deprecation of site-local addresses, or updates to the programming interfaces. There are also some problems to which we are only now beginning to find solutions, such as multihoming in IPv6, or what security model to be deployed.

But even once the technology is fully available, there will still be a great many challenges to be overcome. One of the biggest of these is the requirement for applications using the socket interface to be ported to a new programming interface to be able to use IPv6, due to dependencies imposed by the socket interface on the specific protocol to be used. Fortunately, most operating systems already provide support for IPv6. Communication hardware providers have been less enthusiastic, and have provided – barring some notable exceptions – inferior support for IPv6, compared to IPv4, in terms of both functionality and performance. Major service providers have also been understandably reluctant to change equipment in their operational networks to support a protocol with a relatively low number of users and applications. It is clear that the migration process will entail significant costs and complexities for networking organisations. Finally, there have been no new killer IPv6-based applications or services to attract users.

3 The Good News

Notwithstanding the points raised above, there is some good news for IPv6, and this could be a key moment in the migration process. The achievement of a critical mass of IPv6 users may become a reality with the strong political support coming from many Asian countries. Additionally, specifications for some 3G mobile networks require the deployment of IPv6, so some near-term growth in the number of IPv6 users can be expected. IPv6 is also seen as an opportunity for European and Asian communication hardware and software providers that have lagged behind North American providers in sales for IPv4 equipment to gain a new advantage. This, along with the enthusiastic work of organisations promoting IPv6, such as the IPv6 Forum, or the numerous IPv6 Task Forces all over the world, has generated political awareness in the European Union. An example outcome of this political interest is the growing trend for the requirement of IPv6 support in newly-issued public contracts. Some technologies that can only be deployed in their current form using IPv6 are also generating some expectations, such

as the deployment of end-to-end security on the network layer, which requires public addressability that can only be provided by IPv6; or the possibility of providing full multihoming support for small networks or even residential users. Some of these technologies may evolve sufficiently to convince even the last remaining dyed in the wool IPv6-agnostics.

4 What Is in This Monograph

This is an exciting moment: a lot of interesting work has been done and we have a great many lessons to assimilate, but this may just be the moment when we start to see IPv6 become a reality. For this monograph we have invited authors with extensive experience in the research and promotion of IPv6 to provide a broad view of the current state of IPv6 in articles addressing different perspectives of IPv6 deployment. This edition is structured as follows:

"*IPv6 Deployment State 2005*", by **Jim Bound**, Chief Technology Officer of the IPv6 Forum, provides an insight into current IPv6 deployment models and views, and how IPv6 is moving towards production deployment. He presents an overview of the current state of deployment and pays special attention to the influence security has on this deployment.

"*Internet Protocol version 6 Overview*", by **Albert Cabellos-Aparicio** and **Jordi Domingo-Pascual**, presents a general overview of the basic features of IPv6 that provides essential background for the rest of the papers. First, the authors present the header format used by IPv6, dealing with the new extension header definition in some detail. They move on to talk about the addressing architecture, IPv6's most important contribution. Another basic topic they cover is the neighbour discovery mechanism and auto-configuration models and tools. Finally, they describe some mechanisms currently available for network migration from IPv4 to IPv6.

The main problems and solutions for migrating applications to IPv6 are addressed in "*Transition of Applications to IPv6*", authored by **Eva M. Castro-Barbero**, **Tomás P. de Miguel-Moro**, and **Santiago Pavón-Gómez**. Firstly, they identify the dependencies that applications have on particular IP versions. Then, they present some tools that enable IPv6 communication without needing the source code to be modified. They go on to give some recommendations about how to port an application to IPv6, or better still (although requiring greater effort), how to transform it to support both IPv4 and IPv6. Finally, they discuss the requirements for applications in transition scenarios for gradual migration.

Some examples of services and applications deployed on pre-commercial networks are presented in "*Service Deployment Experience in Pre-Commercial IPv6 Networks*", by **Rüdiger Geib**, **Eduardo Azañón-Teruel**, **Sandra Donaire-Arroyo**, **Aurora Ferrándiz-Cancio**, **Carlos Ralliuendo** and **Francisco Romero-Bueno**. These services are being developed by the development team at Euro6IX, an IST (Information Society Technologies)-funded project, to be implemented on their multi-provider IPv6 network. All the applications share a tight integration with the provider environment. The first application is a graphical network management tool for IPv6 multi-provider networks. The second is an IPv6-enabled intrusion detection system. And the third is a Voice-over-IP application able to benefit from the network Quality-of-Service support.

End-to-end security is one of IPv6's most promising features, and is the theme of the article "*Security with IPv6*" by **Latif Ladid** (Chair of the European IPv6 Task Force and

President of the IPv6 Forum), **Jimmy McGibney** and **John Roman**. The authors present the security challenges posed by the network layer, followed by a description of IPsec and the benefits that IPv6 can provide to network layer security, based on the end-to-end model and the extended number of bits available in the IPv6 address. Security when transitioning is also considered.

Multihoming, the ability to obtain connectivity through multiple providers, is the key topic of "*Tools for IPv6 Multihoming*", by **Marcelo Bagnulo-Braun**, **Alberto García-Martínez** and **Arturo Azcorra-Saloña**. Current multihoming support for IPv4 is first shown to be limited. Then, an architecture based on the exchange of information by the end hosts for the provision of multihoming is described and some security considerations addressed. This architecture is currently under discussion in the IETF.

"*NEMO: Network Mobility in IPv6*" by **Carlos-Jesús Bernardos-Cano**, **Ignacio Soto-Campos**, **María Calderón-Pastor**, **Dirk von Hugo** and **Emmanuel Riou**, deals with network mobility in an IPv6 environment. This article describes the network mobility solution defined by the IETF

NEMO Working Group and analyses its limitations. Some of the contributions to the network mobility research area developed within the framework of the IST European project DAIDALOS (Designing Advanced network Interfaces for the Delivery and Administration of Location independent, Optimised personal Services) are also presented.

Last, but not least, "*IPv6 Status in The World and IPv6 Task Forces*", by **Jordi Palet-Martínez**, presents an overview of the initiatives and efforts undertaken in Europe to

promote IPv6, with the IPv6 European and National Task Forces being key actors in these efforts. Task Force structure, objectives and achievements are presented, taking the Spanish Task Force as an example.

Finally, we would like to thank the authors for all the effort and in-depth knowledge that they have put into these articles, and also the Editors of **UPGRADE** and **Novática** for the opportunity given to us of editing this monograph, that we hope will not only be interesting and thought-provoking reading for you, our readers, but that it will pique your curiosity about IPv6's potential to usher in a new networking paradigm.

References

- [1] V. Fuller, T. Li, J. Yu, K. Varadhan. Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy. RFC 1519, September 2003.
- [2] G. Huston. Observations on the Management of the Internet Address Space. RFC 1744, December 1994.
- [3] Geoff Huston. IPv4—How long do we have? Cisco IP Journal, <<http://www.cisco.com/ipj>>, January 2004.

Useful References on IPv6

The following references, combined with those included in the papers this monograph consists of, enlarge the field of IPv6 for readers interested in knowing more about this matter.

Books

- Christian Huitema. IPv6 the New Internet Protocol (second edition). Prentice Hall, 1997.
- Silvia Hagen Hagen. IPv6 Essentials. O'Reilly, 2002.
- Niall Richard Murphy, David Malone. IPv6 Network Administration. O'Reilly & Associates, 2005.
- Hesham Soliman Soliman. Mobile IPv6. Pearson Education, 2004.
- Jun-Ichiro Itojun Hagino. IPv6 Network Programming. Butterworth-Heinemann, 2004.
- Mark Miller, P. E. Miller. Implementing IPV6: Supporting the Next Generation Internet Protocols (2nd edition). Hungry Minds, 2000.
- Buck Graham. TCP/IP Addressing : Designing and Optimizing your IP Addressing Scheme (2nd edition). Morgan Kaufmann, 2000.
- Joseph Davies. Understanding IPv6. Microsoft Press, 2002.
- Pete Loshin IPv6: Theory, Protocol, and Practice (2nd edition). Elsevier Science & Technology Books, 2003.
- Hyewon Keren Lee. Understanding IPv6. Springer-Verlag New York LLC, 2005.
- Marcus Goncalves, Kitty Niles. IPv6 Networks. McGraw-Hill Osborne, 1998.

Web Sites

- IPv6 Forum. <<http://www.ipv6forum.com>>.
- 6Link. <<http://www.6link.org>>.
- IPv6 Cluster. <<http://www.ist-ipv6.org>>.
- IETF IPv6 Working Group. <<http://www.ietf.org/html.charters/ipv6-charter.html>>.
- IETF IPv6 Multihoming Working Group. <<http://www.ietf.org/html.charters/multi6-charter.html>>.
- IETF IPv6 Operations Working Group. <<http://www.ietf.org/html.charters/v6ops-charter.html>>.
- The IPv6 Portal. <<http://www.ipv6tf.org/>>.
- IPv6 News: HS247. <<http://hs247.com/>>.
- Freenet6. <<http://www.freenet6.net/>>.
- Spanish Chapter of the IPv6 Task Force. <<http://www.spain.ipv6tf.org/>>.

Publications

- IEEE Communications Magazine. <<http://www.comsoc.org/pubs/commag/>>.
- Communications of the ACM. <<http://www.acm.org/pubs/cacm/>>.
- IEEE Network. <<http://www.comsoc.org/pubs/net/>>.
- IPv6style. <<http://www.ipv6style.jp/en/index.shtml>>.

Events

- IPv6 Forum Summits. <<http://www.ipv6forum.com>>.
- IPv6 Workshop at SAINT – International Symposium on Applications and the Internet. <<http://www.saint2005.org>>.