

The Internet Protocol Journal

June 1998

Volume 1, Number 1

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
What Is a VPN?—Part I	2
SSL: Foundation for Web Security	20
Call for Papers	30
Book Reviews	31
Fragments	35

FROM THE EDITOR

Welcome to the first edition of *The Internet Protocol Journal* (IPJ). This publication is designed to bring you in-depth technical articles on current and emerging Internet and intranet technologies. We will publish technology tutorials, as well as case studies on all aspects of internetworking.

Our first article is a detailed look at *Virtual Private Networks* (VPNs). Many organizations are turning to VPNs as a cost-effective way to implement enterprise networking, but the industry has not yet settled for a single approach, nor even a single definition of the VPN concept. The article by Paul Ferguson and Geoff Huston is in two parts. Part II will follow in our second issue, due out in September.

When the Internet Protocol suite (TCP/IP) was first designed, security was not a major consideration. Indeed, the primary goal in the early days of networking was sharing of information among academics and researchers. Today, TCP/IP is being used for mission-critical applications and for the emerging area of electronic commerce. As a result, security mechanisms are being added at all levels of the protocol stack. In this issue, we take a closer look at the *Secure Sockets Layer* (SSL), which is used for Web transactions. William Stallings explains how SSL works and how it is becoming the standard for Web security.

If you want to learn about computer networks, many options are available, including conferences, journals, standards documents, Web sites, glossaries and, of course, books. Our *Fragments* page gives you some pointers for further reading, and every issue will include at least one book review.

A detailed description of the scope of this journal can be found on page 30 in our *Call for Papers*. We want your input in this new publication. Please send comments, suggestions or questions to ipj@cisco.com. You may also use this address to request a complimentary copy of the next issue of IPJ. If you would like to write an article, send me e-mail and I will send you author guidelines.

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The Internet Protocol *Journal*

September 1998

Volume 1, Number 2

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F R O M T H E E D I T O R

In This Issue

From the Editor	1
What Is a VPN?—Part II	2
Reliable Multicast Protocols and Applications.....	19
Layer 2 and Layer 3 Switch Evolution.....	38
Book Review.....	44
Fragments	47

We begin this issue with Part II of “What Is a VPN?” by Paul Ferguson and Geoff Huston. In Part I they introduced a definition of the term “Virtual Private Network” (VPN) and discussed the motivations behind the adoption of such networks. They outlined a framework for describing the various forms of VPNs, and examined numerous network-layer VPN structures, in particular, that of controlled route leakage and tunneling. In Part II the authors conclude their examination of VPNs by describing virtual private dial networks and network-layer encryption. They also examine link-layer VPNs, switching and encryption techniques, and issues concerning Quality of Service and non-IP VPNs.

IP Multicast is an emerging set of technologies and standards that allow many-to-many transmissions such as conferencing, or one-to-many transmissions such as live broadcasts of audio and video over the Internet. Kenneth Miller describes multicast in general, and reliable multicast protocols and applications in particular. Although multicast applications are primarily used in the research community today, this situation is likely to change as the demand for Internet multimedia applications increases and multicast technologies improve.

Successful deployment of networking technologies requires an understanding of a number of technology options ranging from wiring and transmissions systems via switches, routers, bridges and other pure networking components, to networked applications and services. *The Internet Protocol Journal* (IPJ) is designed to look at all aspects of these “building blocks.” This time, Thayumanavan Sridhar details some of the issues in the evolution of Layer 2 and Layer 3 switches.

Interest in the first issue of IPJ has exceeded our expectations, and hard copies are almost gone. However, you can still view and print the issue in PDF format on our Web site at www.cisco.com/ipj. The current edition is also available on the Web. If you want to receive our next issue, please complete and return the enclosed card.

We welcome your comments, questions and suggestions regarding anything you read in this journal. We are also actively seeking authors for new articles. The Call for Papers and Author Guidelines can be found on our Web page. Please send your comments to ipj@cisco.com

—Ole J. Jacobsen, Editor and Publisher
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The Internet Protocol *Journal*

December 1998

Volume 1, Number 3

*A Quarterly Technical Publication for
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F R O M T H E E D I T O R

In This Issue

From the Editor	1
SNMPv3	2
CATV Internet Technology ...	13
Digital TV	27
I Remember IANA.....	38
Book Reviews	40
Call for Papers	46
Fragments	47

The *Simple Network Management Protocol* (SNMP) was first standardized in 1988. It quickly became a de facto management standard, not only for Internet technologies, but for a wide range of applications. Like many early Internet protocols, the first two versions of SNMP did not include provisions for security. In 1996, two different proposals for security enhancements to SNMPv2 were put forward, with strong proponents behind each. Everyone agreed that the industry needed just *one* solution, and therefore work proceeded to incorporate the best features of the two security proposals for SNMPv2. The result is SNMPv3, and it is described in this issue by William Stallings.

As the Internet continues to grow, demand for high-speed access for residential users is increasing. Alternatives to traditional dialup service include *Digital Subscriber Line* (DSL) services, wireless solutions, and various television technologies. In this issue, we examine two aspects of Internet access using TV technologies. First, Mark Laubach gives an overview of cable modem technologies and standards, and discusses some deployment issues. In the second article, George Abe looks at the emerging digital television standards and how they could be used to provide Internet access.

The Internet lost one of its most respected pioneers when Jon Postel passed away on October 16, 1998. Jon was well-known as the Director of the *Internet Assigned Numbers Authority* (IANA) and as the editor of the *Request for Comments* (RFC) document series. Included in this issue is "I Remember IANA," a tribute to Jon Postel written by his longtime friend Vint Cerf. The remembrance has also been published as RFC 2468.

With that we have come to the end of 1998 and the end of Volume 1 of *The Internet Protocol Journal*. We wish you a pleasant holiday season and will be back with Volume 2, Number 1 in March 1999. In the meantime, please visit our Web site at www.cisco.com/ipj. There you will find back issues in PDF format, our Call for Papers and guidelines for authors of IPJ articles.

—Ole J. Jacobsen, Editor and Publisher
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The Internet Protocol *Journal*

March 1999

Volume 2, Number 1

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

FROM THE EDITOR

In This Issue

From the Editor	1
Peering and Settlements	2
IPv6.....	17
Secure E-Mail	30
Book Review.....	44
Letter to the Editor	46
Fragments	47

Today's Internet is comprised of numerous interconnected *Internet Service Providers* (ISPs), each serving many constituent networks and end users. Just as individual regional and national telephone companies interconnect and exchange traffic and form a global telephone network, the ISPs must arrange for points of interconnection to provide global Internet service. This interconnection mechanism is generally called "peering," and it is the subject of a two-part article by Geoff Huston. In Part I, which is included in this issue, he discusses the technical aspects of peering. In Part II, which will follow in our next issue, Mr. Huston continues the examination with a look at the business arrangements (called "settlements") that exist between ISPs, and discusses the future of this rapidly evolving marketplace.

In the early 1990s, concern grew regarding the possible depletion of the IP version 4 address space because of the rapid growth of the Internet. Predictions for when we would literally run out of IP addresses were published. Several proposals for a new version of IP were put forward in the IETF, eventually resulting in IP version 6 or IPv6. At the same time, new technologies were developed that effectively slowed address depletion, most notably *Classless Inter-Domain Routing* (CIDR) and *Network Address Translators* (NATs). Today there is still debate as to if and when IPv6 will be deployed in the global Internet, but experimentation and development continues on this protocol. We asked Robert Fink to give us a status report on IPv6.

We've already discussed the historical lack of security in Internet technologies and how security enhancements are being developed for every layer of the protocol stack. This time, Marshall Rose and David Strom examine the state of electronic mail security. We clearly have a way to go before we see "seamless integration" of security systems with today's e-mail clients.

Our first Letter to the Editor is included on page 46. As always, we would love to hear your comments and questions regarding anything you read in this journal. Please contact us at ipj@cisco.com

—Ole J. Jacobsen, *Editor and Publisher*
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June 1999

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F R O M T H E E D I T O R

In This Issue

From the Editor	1
Peering and Settlements	2
Firewalls and Internet Security	24
Was the Melissa Virus So Different?	33
Book Review.....	36
Call for Papers	38
Fragments	39

In this issue, Geoff Huston concludes his two-part article on Interconnection, Peering, and Settlements. Last time Geoff discussed the technical aspects for Internet Service Provider (ISP) interconnection. This time he examines the associated business relationships that arise out of ISP peering arrangements. He also looks at some future directions for the ISP interconnection environment, particularly with respect to Quality-of-Service considerations.

A recurring theme in this journal has been the traditional lack of security in Internet technologies and systems. We have examined several ways in which security has been added at all levels of the protocol stack. This time we look at *firewalls*, a popular way to segregate internal corporate intranet traffic from Internet traffic while still maintaining Internet connectivity. Fred Avolio gives the history of firewalls, their current state, and future directions.

Computer viruses have probably existed for as long as we have had computers. However, the ease with which viruses can be distributed as Internet e-mail attachments has made the problem more prevalent. Recently, the *Melissa* virus achieved some notoriety because of its “self-replication” properties. Barbara Fraser, Lawrence Rogers, and Linda Pesante of the Software Engineering Institute at Carnegie Mellon University examines some of the issues raised by this kind of virus.

This issue is the first anniversary issue of *The Internet Protocol Journal* (IPJ). You can find all of our back issues in PDF format at the IPJ Web site: www.cisco.com/ipj. Please let us know if you have suggestions for articles, books you want to review, or general feedback for this journal. Our contact address is: ipj@cisco.com.

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F R O M T H E E D I T O R

In This Issue

From the Editor	1
Web Caching	2
Gigabit Ethernet	21
One Byte at a Time	26
Letter to the Editor	29
Book Reviews	30
Call for Papers	36
Fragments	37

More and more of the data traffic on the Internet is due to World Wide Web activity. Given the often-complex graphics contents of Web pages, this traffic represents a significant amount of data and leads to an overall requirement for more bandwidth across the system. But building “bigger pipes” is not the only way to achieve better performance. Generally speaking, Web pages are relatively static objects that reside in *one* location and are accessed repeatedly by *many* users, often from “far away.” If the contents of the most frequently accessed pages can be stored by a proxy residing more “local” with respect to the end user, significant reductions in download delay can be accomplished. Since the Internet comprises many expensive international circuits, such local mirroring of content is also highly desirable from the point of view of the Internet Service Providers. Storing information in a proxy server is called *caching*, and it is the subject of our first article. Geoff Huston explains the motivation behind—and the different approaches to—caching.

The most popular Local-Area Network (LAN) technology is *Ethernet*. Invented in 1973 by Bob Metcalfe as a 3-Mbps technology, Ethernet has evolved to the now-familiar 10Base-T and 100Base-T standards. Standardized in 1998, *Gigabit Ethernet* is the subject of our second article. Bill Stallings gives an overview of the Gigabit Ethernet standards and their application in enterprise networks. There is already discussion about 10-Gigabit Ethernet and even 100-Gigabit Ethernet. We will keep you posted on these developments.

Some readers have suggested that we publish a few short articles on limited topics. In this issue we bring you the first in what we hope will become a series of articles under the general heading “One Byte at a Time.” The article is by Tom Thomas and he discusses *active* and *passive* modes of the File Transfer Protocol (FTP). If you have suggestions for future topics in this series, please contact us at ipj@cisco.com

The so-called “Millennium Bug” or “Y2K Problem” has been well reported in all the media. Our *Fragments* section gives some specific information relating to Y2K and the Internet.

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The Internet Protocol Journal

December 1999

Volume 2, Number 4

A Quarterly Technical Publication for
Internet and Intranet Professionals

F R O M T H E E D I T O R

In This Issue

From the Editor	1
Internet Multicast Today	2
The Internet2 Project	20
One Byte at a Time	30
Book Review	33
Call for Papers	35
Fragments	36

In June 1992 when I was editor and publisher of *ConneXions—The Interoperability Report*, we published an article entitled “First IETF Internet Audiocast.” Steve Casner and Steve Deering wrote: “The March Internet Engineering Task Force (IETF) meeting in San Diego was an exciting one for those interested in teleconferencing. In addition to several sessions on teleconferencing topics, we managed to pull off a ‘wild idea’ suggested by Allison Mankin from MITRE: live audio from the IETF site was ‘audiocast’ using IP multicast packet audio over the Internet to participants at 20 sites on three continents spanning 16 timezones.”

Multicast has come a long way since 1992. Today, every IETF meeting features several live streams of not only audio but also video and slide presentations. Multicast continues to be developed in the IETF, as protocols and tools are being revised and refined. In two articles, Jon Crowcroft and Mark Handley describe the technologies behind multicast. The first article, included in this issue, looks at the current state of multicast. The second article, to appear in a future issue of IPJ, will look at the problems that need to be solved before multicast can become a truly scalable service for the Internet.

Research into new, high-speed networking technologies and applications is taking place in many parts of the world. One example of such a research effort can be found in the Internet2 Project. Larry Dunn describes some of the technology and application development being conducted by Internet2 members.

Interest in *IP Version 6* (IPv6) is growing as organizations contemplate a world where millions of devices such as cellphones, PDAs, cable TV set-top boxes and so on are “Internet Ready.” The formation of the *IPv6 Forum* (www.ipv6forum.com) is some indication of this interest. We will look at a particular IPv4-to-IPv6 transition strategy in our next issue. In the meantime, Peter Salus takes a historical look at Internet addressing in our series “One Byte at a Time.”

And so we reach the end of 1999 and the end of Volume 2 of *The Internet Protocol Journal*. We wish you a pleasant holiday season and an uneventful transition to Y2K.

—Ole J. Jacobsen, Editor and Publisher
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The Internet Protocol *Journal*

March 2000

Volume 3, Number 1

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

F R O M T H E E D I T O R

In This Issue

From the Editor	1
Routing IPv6 over IPv4.....	2
IP Security	11
QoS—Fact or Fiction?	27
Book Review.....	35
Call for Papers	38
Fragments	39

Work on a new version of the Internet Protocol, known as IPv6, has been under way for several years in the IETF. There is still some debate about when and how IPv6 will be deployed. Proponents of IPv6 argue that the demand for new IP addresses will continue to rise to a point where we will simply run out of available IPv4 addresses and that we should, therefore, start deploying IPv6 *today*. Opponents argue that such a protocol transition will be too costly and painful for most organizations. They also argue that careful address management and the use of *Network Address Translation* (NAT) will allow continued use of the IPv4 address space for a very long time. Regardless of the timeframe, a major factor in the deployment of IPv6 is an appropriate transition strategy that allows existing IPv4 systems to communicate with new IPv6 systems. A transition mechanism, known as “6to4,” is described in our first article by Brian Carpenter, Keith Moore, and Bob Fink.

In previous editions of this journal, we have looked at various security technologies for use in the Internet. Security mechanisms have been added at every layer of the protocol stack, and IP itself is no exception. IP Security, commonly known as “IPSec,” is being deployed in many public and private networks. In our second article, William Stallings describes the main features of IPSec and looks at how IPSec can be used to build Virtual Private Networks.

Our final article is a critical look at *Quality of Service* (QoS) in the Internet. The need to provide different priorities to different kinds of traffic in a network is well understood and the technical community has been hard at work developing numerous systems to address this need. Geoff Huston looks at the prospects of deploying QoS solutions that will operate across the Internet as a whole.

The Y2K transition has been described as a “nonevent” by many. However, the lessons learned and the collaborative coordination efforts that were put in place for this transition can hopefully be used in the future. A colleague of mine had to call a plumber to his house on New Year’s Eve. When he tried to pay for the repair with a credit card which had “00” as the expiration year, the plumber insisted that this meant the card was invalid. So while most systems were “Y2K compliant,” this particular plumber was clearly not. Do you have a Y2K story to share? Drop us a line at ipj@cisco.com

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In This Issue

From the Editor	1
TCP Performance	2
Internet Mail Standards	25
Book Review.....	37
Fragments	39

FROM THE EDITOR

Two protocols used in the Internet are so important that they deserve special attention: the *Internet Protocol* (IP) from which this journal takes its name, and the *Transmission Control Protocol* (TCP). IP is fundamental to Internet addressing and routing, while TCP provides a reliable transport service that is used by most Internet applications, including interactive Telnet, file transfer, electronic mail, and Web page access via HTTP. Because of the critical importance of TCP to the operation of the Internet, it has received much attention in the research community over the years. As a result, numerous improvements to implementations of TCP have been developed and deployed. In this issue, Geoff Huston takes a detailed look at TCP from a performance perspective and describes several enhancements to the original protocol. In a second article, Geoff will look at the challenges facing TCP in a rapidly growing and changing Internet, and describe work to further augment TCP.

Electronic mail is by far the most used of all Internet applications. The fundamental protocols for delivery and retrieval of e-mail have not changed much since the early days of the ARPANET, but as with TCP, many enhancements have been added to accommodate new uses of e-mail. Today, Internet e-mail supports international character sets, includes the ability to send file attachments, and allows roaming e-mail clients to authenticate themselves to servers. All of this has been made possible by continued development in the *Internet Engineering Task Force* (IETF). In our second article, Paul Hoffman of the Internet Mail Consortium gives an overview of Internet mail standards.

This is the second anniversary issue of *The Internet Protocol Journal* (IPJ). By now more than 10,000 people from virtually every country in the world have subscribed to the paper edition of IPJ. In order to serve our readers better, we are developing an online subscription system, which will be deployed in July 2000. With this new system you will be able to modify your mailing address as well as select your preferred delivery method for the journal. You can choose to receive IPJ on paper, or be notified via e-mail when a new issue becomes available on line. More information about this new system can be found on our Web site at www.cisco.com/ipj. We would love to hear your feedback on this system and any other aspect of IPJ. Please send your comments to ipj@cisco.com

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FROM THE EDITOR

In This Issue

From the Editor	1
The Future for TCP	2
Securing the Infrastructure.....	28
Book Reviews	45
Call for Papers	49
Fragments	50

In our last issue, Geoff Huston described the basic design and operation of the *Transmission Control Protocol* (TCP). He outlined how numerous enhancements to TCP implementations have been developed over time to improve its performance, particularly in the face of congested networks. The Internet is a rapidly changing environment in which both the applications and the underlying transmission systems are undergoing an evolution, if not a revolution. Some of these changes, such as the introduction of wireless devices, affect the way TCP works, because the protocol makes many implicit assumptions about the network over which it operates. In this issue, Geoff looks at the future for TCP and describes techniques for adopting TCP to today's Internet.

Security continues to be a major concern for everyone involved in the design and operation of networks. Widely publicized "hacker attacks," "denial-of-service attacks," and outright online fraud has brought the topic into sharp focus in the last few years. Because security was not part of the original design of the Internet, numerous solutions at every level of the protocol stack have been proposed and implemented over the last three decades. Today's network manager is, therefore, faced with a *system* of security components that must be carefully configured and monitored in order to provide sufficient security without preventing users from getting their work done. In our second article, Chris Lonvick explores a model for evaluating and securing a network.

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December 2000

Volume 3, Number 4

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Internet and Intranet Professionals*

FROM THE EDITOR

In This Issue

From the Editor	1
The Trouble with NAT	2
The Social Life of Routers	14
New Frontiers for Research Networks.....	26
Book Review.....	40
Call for Papers	41
Fragments	42

Numerous technologies have been developed to protect or isolate corporate networks from the Internet at large. These solutions incorporate security, either end-to-end (IP security, or IPSec), or at the Internet/intranet border (firewalls). A third class of systems allows a range of IP addresses to be used internally in a corporate network, while preserving IP address consumption through the use of a *single* public address. This latter class of device is called a *Network Address Translator* (NAT), and while many Internet engineers consider NATs to be “evil,” they are nonetheless very popular. Combining IPSec, NATs, and firewalls can be quite challenging, however. In our first article Lisa Phifer explains the problem and offers some solutions.

Successful network design is the result of many factors. In addition to the basic building blocks of routers, switches and circuits, network planners must carefully consider how these elements are interconnected to form an overall system with as few single points of failure as possible. In our second article, Valdis Krebs looks at how lessons learned from social network analysis can be applied to the design of computer networks.

The current Internet grew out of several government-funded research efforts that began in the late 1960s. Today, basic technology development as well as research into new uses of computer networks continues in many research “testbeds” all over the world. Bob Aiken describes the past, present and future state of network research and research networks.

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The Internet Protocol *Journal*

March 2001

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Internet and Intranet Professionals*

In This Issue

From the Editor	1
The BGP Routing Table	2
LAN QoS.....	16
Book Reviews	24
Call for Papers	29
Fragments	30

FROM THE EDITOR

The rapid growth of the Internet has led to numerous changes to the underlying technologies. In the early days, host names and their corresponding IP addresses were kept in a flat text file (“**HOSTS.TXT**”), updated weekly by the Network Information Center at SRI International. In the mid 1980s it became clear that this method of name/address mapping would not scale, and a new distributed lookup mechanism was designed and deployed. This new method, known as the *Domain Name System* (DNS), has proven successful even in the face of millions of Internet hosts.

Another result of Internet growth is the potential for depletion of the IP Version 4 (IPv4) 32-bit address space. In the early 1990s, this became a matter of great focus for the Internet Engineering Task Force (IETF). The “short-term” fix for this problem was to abandon the original concept of A, B and C address classes and introduce *Classless Interdomain Routing* (CIDR), which consumes addresses in a much more efficient manner—that is to say, more slowly. Address consumption has also been slowed by the use of *Network Address Translation* (NAT) and private address space. Predictions for when the Internet will finally run out of IPv4 addresses varies. The long-term solution is to replace IPv4 with IPv6 which uses 128 bits for addressing.

One area of Internet growth that is currently causing some concern among ISPs is the growing size of the routing table that each router participating in the *Border Gateway Protocol* (BGP) must keep in memory. Our first article, by Geoff Huston, is a detailed look at this problem. Geoff takes an historical look at the BGP routing table, and discusses ways to address some of the issues.

In our March 2000 issue, Geoff Huston wrote an article entitled “Quality of Service—Fact or Fiction?” that discussed the prospects for achieving QoS on an Internet-wide scale. In this issue, Bill Stallings looks at QoS in the LAN environment, which is generally easier to control than the Internet as a whole. LAN QoS has been standardized in IEEE 802.1D which is the subject of this article.

We apologize for the delay in getting our online subscription system up and running. It should be available in the very near future. Meanwhile, please continue to use ipj@cisco.com for any subscription questions or to give feedback on anything you read in this journal.

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In This Issue

From the Editor	1
Mobile IP	2
Goodbye DES, Welcome AES	15
The Middleware Muddle.....	22
Book Review.....	28
Fragments	30

FROM THE EDITOR

A user of a laptop computer “on the road” typically connects to the Internet in one of two ways. The oldest, and most common method, is to dial into an ISP’s network and obtain an IP address using the *Point-to-Point Protocol* (PPP). The other method involves attaching the laptop to a local network (usually via Ethernet) and obtaining an IP address through the *Dynamic Host Configuration Protocol* (DHCP). The “local network” could be anything from the high-speed connection provided in some hotels, to an enterprise network at some corporation or other institution. In all cases, the IP address is fixed for the duration of the network session, and the routing of packets from the laptop back to its “home” network remains a relatively straight-forward task (ignoring NATs, firewalls and other complexities for the moment). Suppose however, the mobile computer is using a wireless connection and traveling between several networks over a short period of time. In this scenario one would still like to maintain network connectivity in a seamless manner. The IETF has been working on Mobile IP to address this problem. Mobile IP is the subject of our first article by Bill Stallings.

The art of cryptography is certainly not new, but its use in computer-communications is a more recent phenomena. The *Data Encryption Standard* (DES) has been widely used since it was standardized in 1977. The strength of a particular encryption scheme depends on the key length and the sophistication of the mathematics involved in transforming the so-called cleartext to the encrypted form. As computers have become more powerful it is now possible to systematically “guess” the 56-bit DES keys in a matter of hours, thus a new encryption standard is needed. This new standard, known as the *Advanced Encryption Standard* (AES), is described by Edgar Danielyan.

Many aspects of computer networking can be described as “controversial,” that is, there are strongly held opinions about a particular technology or its use. In this issue we begin a new series of articles labelled “Opinion,” hoping to bring out some of the different views held by members of the networking community. We hope you will take issue with some of these columns and send us your own opinion piece. We begin the series with an article by Geoff Huston entitled “The Middleware Muddle.” Let us know what you think by sending your comments to ipj@cisco.com

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In This Issue

From the Editor	1
MPLS.....	2
A Unique Root.....	15
Book Review.....	29
Call for Papers	31
Fragments	32

FROM THE EDITOR

Multiprotocol Label Switching (MPLS) is a technology that has received a great deal of attention in recent years. The IETF alone has produced over 300 Internet Drafts and numerous RFCs related to MPLS and continues its work on refining the standards. So, what is MPLS all about? We asked Bill Stallings to give us a basic tutorial.

The tragic events of September 11, 2001 have focused attention on the stability and robustness of the Internet. The Internet played an important role in the aftermath of the terrorist attacks. While popular news Web sites initially appeared overloaded, a great deal of private traffic in the form of instant messaging and e-mail took place. Companies directly or indirectly affected by the events in New York and Washington were quick to use the Web as a way to disseminate important information to their clients as well as to their employees. In many cases, the Internet was used in place of an overloaded telephone network. With this in mind, The *Internet Corporation for Assigned Names and Numbers* (ICANN) has decided to re-focus its next meeting to address issues of Internet stability and security, particularly with regard to naming and addressing. (See "Fragments," page 32.) To provide some background information, we bring you the article "A Unique, Authoritative Root for the DNS," by M. Stuart Lynn, the president and CEO of ICANN. Since this article has been posted for public comment, you are encouraged to address your feedback to: comments@icann.org

We would like to remind our readers to send us postal address updates. The computer-communications industry is one where people change jobs and locations often. While we do receive some address changes automatically when mail is returned to us, it is much more reliable to send us e-mail with the new information. In the near future, readers will be able to make address changes and select delivery options through a Web interface which will be deployed at <http://www.cisco.com/ipj>. Until then, please send your updates to ipj@cisco.com

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The Internet Protocol *Journal*

December 2001

Volume 4, Number 4

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
Scaling Inter-Domain Routing.....	2
Regional Internet Registries ...	17
Book Reviews	30
Letters to the Editor.....	34
Fragments	38
Call for Papers	39

FROM THE EDITOR

In a previous article entitled “Analyzing the Internet BGP Routing Table,” Geoff Huston examined many issues relating to the operation of today’s Internet. In this issue he goes a step further and suggests ways in which the fundamental routing architecture could be changed to solve problems related to routing-table growth. The article is called “Scaling Inter-Domain Routing—A View Forward.”

The IP address space is administered by three entities, namely APNIC, ARIN and RIPE NCC. Collectively referred to as the *Regional Internet Registries* (RIRs), these organizations are responsible for address allocation to their member organizations (typically national registries or large Internet Service Providers). Since the IPv4 address space is a limited resource, this allocation has to be done with care, while accounting for the needs of the address space consumers. We asked the RIRs for an overview of the work they perform. What we received was a joint effort that not only describes the RIR structure, but also gives some historical background on the evolution of IP addressing and routing.

We were pleased to receive a couple of Letters to the Editor recently, both in response to articles in our previous issue. This kind of feedback is most welcome and we encourage you to send your comments and suggestions to ipj@cisco.com

We’d like to remind you that all back issues of *The Internet Protocol Journal* can be downloaded from www.cisco.com/ipj. Click on “IPJ Issues” and you will be taken to the appropriate section.

By the time you read this, our online subscription system should be operational. You will find it at our Web site: www.cisco.com/ipj. Please let us know if you encounter any difficulties by sending e-mail to ipj@cisco.com

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The Internet Protocol *Journal*

March 2002

Volume 5, Number 1

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
IEEE 802.11	2
Code Signing.....	14
Book Review.....	27
Call for Papers	30
Fragments	31

FROM THE EDITOR

Major Internet events such as the IETF meetings, the Regional Internet Registry meetings, APRICOT, SIGCOMM, and NetWorld+Interop to name a few, all provide Internet access for attendees. Commonly referred to as the “Terminal Room,” these facilities have evolved into complex high-speed networks with redundant paths, IPv6 routing, multicast, and more. In the last five years or so, these networks have also been providing wireless access using various flavors of the IEEE 802.11 standard. As I write this, I am sitting in the lobby of the Minneapolis Hilton Hotel, where the 53rd IETF meeting is being held. The lobby area and two floors of meeting rooms have IEEE 802.11 coverage, and a directional high-gain antenna provides access in the pub across the street. Wireless Internet computing is a reality, at least when you have a large gathering of engineers such as an IETF meeting. In our first article, Edgar Danielyan takes a closer look at this technology, its applications and evolution.

More and more software is being distributed via the Internet rather than through the use of conventional media such as CD ROMs or floppy disks. Downloading software via the Internet is very convenient, especially if you have reasonably high bandwidth. However, with this convenience comes a certain risk that you may be receiving a modified copy of the software, perhaps one that contains a virus. Code signing is a method wherein software is cryptographically signed and later verified. Eric Fleischman explains the details of code signing.

I should have known better than to announce the imminent availability of our online subscription system in the previous issue. We are working on it, but it isn't ready yet, so please continue to send your subscription requests and updates to: ipj@cisco.com

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The Internet Protocol *Journal*

June 2002

Volume 5, Number 2

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
BEEP	2
ENUM	13
DHCP	24
Book Review	32
Call for Papers	35
Fragments	36

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FROM THE EDITOR

The networking industry is full of acronyms, as the table of contents for this issue clearly illustrates. According to the dictionary, an acronym is “...a word formed from the initial letter or letters of each of the successive parts or major parts of a compound term.” While neither BEEP nor ENUM are strictly speaking acronyms, these “short names” are becoming ever more prevalent and difficult to keep track of. We promise to continue to provide acronym expansion whenever possible.

BEEP is an example of a technology that came to life in a very short time. While IETF standards often take years from initial idea to protocol specification, BEEP seems to have happened in just over a year. There is already a textbook on BEEP from which our first article is adapted. Marshall Rose gives an overview of the BEEP framework and explains how you can get involved in its further development.

ENUM refers to the use of the *Domain Name System* (DNS) to look up telephone numbers and subsequently route telephone calls to the right destination using the Internet as the underlying routing fabric. This integration of the traditional telephone network with the Internet is becoming a reality and several standardization bodies are working on technologies to make this as seamless as possible. Geoff Huston explains the mechanisms and politics behind ENUM.

Our series “One Byte at a Time” examines the *Dynamic Host Configuration Protocol* (DHCP). This protocol is widely used to provide IP address and other basic routing information to clients. This is particularly useful for mobile devices, but it can be used in any network environment. Since the IP addresses are assigned as leases with a configurable time limit, DHCP also provides for effective address management. Douglas Comer explains the details of DHCP and its predecessor BOOTP.

As always, we appreciate your feedback. Send your comments and questions to ipj@cisco.com

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The Internet Protocol Journal

September 2002

Volume 5, Number 3

A Quarterly Technical Publication for
Internet and Intranet Professionals

In This Issue

From the Editor	1
Visitor Networks	2
Wireless Security	17
The Uncommon Carrier	23
Letters to the Editor	28
Book Review	31
Fragments	33

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FROM THE EDITOR

The *Internet Protocol Journal* (IPJ) does not have a marketing department. New subscribers learn about IPJ through our Web page, or perhaps by picking up a copy at an Internet conference or meeting such as the IETF. Word of mouth is perhaps the most effective “marketing tool.” I was reminded of this in July when an article in IPJ was mentioned on the *SlashDot* Web site. Within a few days we received more than 900 new subscriptions, on the order of ten times the normal sign-up rate. I think this illustrates the power of the Web as a tool for information dissemination.

I am a big fan of visitor networks. Such networks, typically found in larger hotels, allow high-speed access to the Internet for a daily or weekly fee. Although most of the conferences and meetings I attend have purpose-built “terminal rooms,” it is still nice to be able to work in your hotel room at speeds orders of magnitude better than what can be obtained with a dialup modem. Dory Leifer explains how visitor networks are designed and operated in our first article.

In a previous article we explored the basics of IEEE 802.11 wireless networking. Such networks are growing at an amazing rate. Reports about wireless network “wiretapping” are frequently found in the trade press. Gregory R. Scholz describes an architecture for securing wireless networks, using a variety of technologies and protocols.

Geoff Huston is back with another opinion piece, this time discussing the role of the *Internet Service Provider* (ISP) as a “common carrier.” Many ISPs are finding themselves in the middle of disputes between customers, copyright owners, regulators and others. What role should an ISP play in this regard? Geoff provides some answers.

Please continue to provide your feedback to anything you read in this journal. Our “Letters to the Editor” section provides a sample of some of the correspondence we receive. As always, use ipj@cisco.com to contact us.

—Ole J. Jacobsen, Editor and Publisher
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The Internet Protocol *Journal*

December 2002

Volume 5, Number 4

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
Internet Multicast Tomorrow	2
Zero Configuration Networks	20
Book Reviews	27
Letters to the Editor	33
Fragments	35

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FROM THE EDITOR

In December 1999 we published Part One of a two-part article on Internet Multicast. Some readers have asked “what happened to Part Two?” Finally, in this issue we are able to bring you the second article, “Internet Multicast Tomorrow.” Multicast remains a technology with limited Internet-wide deployment, but numerous research activities are underway that may change this situation. Ian Brown, Jon Crowcroft, Mark Handley and Brad Cain provide an overview of current developments in multicast.

If all computer networking was a simple matter of “plug-and-play,” I suppose this journal would not exist. Nevertheless, it is encouraging to see developments that aim to simplify configuration of network devices, particularly those that move around a lot. The Zeroconf working group of the *Internet Engineering Task Force* (IETF) has been developing standards for “configuration-free” networks. Edgar Danielyan explains the details in our second article.

We continue to receive numerous letters in response to our articles. Your feedback is very much appreciated, because it helps us develop material for future issues. Please keep your letters coming to ipj@cisco.com

The long-awaited online subscription system is now ready for deployment and you will be able to try it out in the very near future at www.cisco.com/ipj. With this system, you can update your mailing address as well as select delivery options, online notification of new issues and so on. As with any computer based system, I anticipate that we, with your help, will uncover a few bugs. Please report any problems you may encounter to ipj@cisco.com.

A new important resource is available from the *Internet Society* (ISOC). *The Internet Report* is a catalogue of IETF documents, including RFCs and Internet Drafts, that document the technology, protocols and operating procedures that form the Internet. The report includes RFCs, IETF Working Group drafts as well as individual drafts. The Internet Report is maintained by Geoff Huston. You can access the report online at <http://ietfreport.isoc.org/>

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The Internet Protocol *Journal*

March 2003

Volume 6, Number 1

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
Measuring IP Networks.....	2
Session Initiation Protocol	20
Letters to the Editor.....	31
Book Review.....	36
Call for Papers	39

FROM THE EDITOR

Even the most carefully designed and operated IP network is subject to any number of performance problems ranging from overloaded links and mis-configured routers to server failures. For these situations, the network manager has several diagnostic tools as options. Geoff Huston gives us an overview in an article entitled “Measuring IP Network Performance.”

Voice over IP (VoIP) is an emerging application, as well as a rapidly growing market. Use of the corporate network or the Internet at large to carry telephone traffic has many advantages, not the least economic ones. A successful VoIP network must not only support IP-based telephones, but also provide a means of seamlessly integrating the IP-based network with traditional telephone networks. At the core of VoIP lies the *Session Initiation Protocol* (SIP) and a few related protocols. Bill Stallings describes SIP in our second article.

Book reviews published in *The Internet Protocol Journal* can rarely be characterized as “controversial.” However, when the book in question deals with ICANN, it is perhaps not surprising that strong opinions emerge. Thus, following the review of *Ruling the Root* in our last issue, we received a letter from the author that is included in our “Letters to the Editor” section (along with a response from the book reviewer). I would like to take this opportunity to remind our readers that book reviews do represent the *opinion* of the reviewer and should be read in that light.

Our online subscription system has been up and running for a couple of months. Please give it a try at: www.cisco.com/ipj.

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The Internet Protocol Journal

June 2003

Volume 6, Number 2

A Quarterly Technical Publication for
Internet and Intranet Professionals

In This Issue

From the Editor	1
BGP Communities	2
WAP	10
IPv6 Operations Group	20
The Myth of IPv6	23
Letters to the Editor	30
Book Review	35
Fragments	37
Call for Papers	39

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FROM THE EDITOR

Articles in *The Internet Protocol Journal* broadly fall into three categories. First, we have articles that explain well-established technologies or operational practices. Second, we offer tutorials on new or emerging protocols and systems, not yet deployed but on the horizon. Finally, IPJ brings you insights, lessons learned and opinions on aspects of networking that have not completely lived up to their promises. In this issue, you will find a mixture of all three.

Our first article is an example from the “nuts-and-bolts” category. The *Border Gateway Protocol* (BGP) is one of the core routing protocols that is widely used in the Internet and has been around for a long time. Kris Foster explains how the *BGP Community* attribute can be used in service provider networks.

Efforts to provide cellular telephones with Internet access systems have produced mixed results. Japan has been leading the way in this area with widespread deployment of iMode devices or variants thereof. Having used such a system I must say I am both impressed and somewhat frustrated. It is wonderful to receive e-mail while on a busy Tokyo train, but accessing the Internet on a tiny screen (typically a 2-inch display with a resolution of 120 x 160 pixels) is not particularly rewarding. Not to mention the bandwidth limitations inherent with this technology. Another system, the *Wireless Application Protocol* (WAP) has been implemented in most countries that offer *Global System for Mobile Communications* (GSM) cell phone service. WAP is the subject of our second article. Edgar Danielyan describes the WAP architecture and looks at some of the lessons learned from its deployment.

The push for deployment of *IP Version 6* (IPv6) is taking place on several fronts and we cover some of them in this issue. In the IETF, a recently formed group has been chartered to help design transition strategies from IPv4 to IPv6. We have a short overview of this effort starting on page 20. Additionally, both the U.S. and Japanese governments are promoting the use of IPv6 in various ways. The U.S. Department of Defense has recently adopted IPv6 as one of its official protocols. In Japan the “IPv6 Appli-Contest 2003” is underway in an effort to encourage development of software and applications for IPv6. See “Fragments,” page 37–38 for further details.

Of course, not everyone is convinced that IPv6 is such a good idea, and with that in mind we bring you an opinion piece as well as a Letter to the Editor on this topic.

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The Internet Protocol Journal

September 2003

Volume 6, Number 3

A Quarterly Technical Publication for
Internet and Intranet Professionals

In This Issue

From the Editor	1
Securing BGP: S-BGP	2
Securing BGP: soBGP	15
Virus Trends	23
IPv6 Behind the Wall	34
Call for Papers	40
Fragments	41

FROM THE EDITOR

The task of adding security to Internet protocols and applications is a large and complex one. From a user's point of view, the security-enhanced version of any given component should behave just like the old version, just be "better and more secure." In some cases this is simple. Many of us now use a *Secure Shell Protocol* (SSH) client in place of *Telnet*, and shop online using the secure version of HTTP. But there is still work to be done to ensure that *all* of our protocols and associated applications provide security. In this issue we will look at *routing*, specifically the *Border Gateway Protocol* (BGP) and efforts that are underway to provide security for this critical component of the Internet infrastructure. As is often the case with emerging Internet technologies, there exists more than one proposed solution for securing BGP. Two solutions, S-BGP and soBGP, are described by Steve Kent and Russ White, respectively.

The Internet gets attacked by various forms of viruses and worms with some regularity. Some of these attacks have been quite sophisticated and have caused a great deal of nuisance in recent months. The effects following the *Sobig.F* virus are still very much being felt as I write this. Tom Chen gives us an overview of the trends surrounding viruses and worms.

Closely related to the virus attacks is *spam*. Unfortunately, I know of no complete technical, or even legal, solutions to this growing problem, but I would love to hear your views and solutions. Send your comments to: ipj@cisco.com, but don't use the string "spam" in the subject field or it may get filtered out!

Following Geoff Huston's opinion piece "The Myth of IPv6" in our previous issue, we received a response from *The IPv6 Forum*. The article is entitled "IPv6 Behind the Wall" and is by Jim Bound.

I was very pleased to hear that professor Peter T. Kirstein of University College London had been awarded the Internet Society's *Jonathan B. Postel Service Award* for 2003. I have known Peter since about 1977, when we collaborated on SATNET packet voice conferences between Oslo, London, Boston, and Marina del Rey. Peter is truly an Internet pioneer. (See "Fragments," page 41).

—Ole J. Jacobsen, Editor and Publisher
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The Internet Protocol Journal

December 2003

Volume 6, Number 4

A Quarterly Technical Publication for Internet and Intranet Professionals

In This Issue

From the Editor	1
IPv4: How long do we have? ...	2
Low-tech Network Maintenance	16
Letters to the Editor	23
Book Review	25
Fragments	28

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From The Editor

I will remember 2003 as the year when high-speed Internet access became widely available in public locations such as airports, hotels, and coffee shops. As a frequent traveler, I really appreciate not having to find a suitable telephone jack and corresponding country-specific telephone adapter plug in order to get my e-mail. The IEEE 802.11 “WiFi” standard has truly arrived. I even stayed in a new hotel in Norway that provided WiFi access in every room by placing base stations in the hallways. When I first stepped into my hotel room and noticed that it had only a *digital* telephone and no sign of any Ethernet jacks I worried, but a quick check revealed that I could purchase a scratch-off card at reception that provided me with a username and password valid for 24 hours. A clear example of a “technology generation leap.”

The year 2003 was also the year in which unsolicited e-mail, or “spam,” became a major problem for all Internet users. Various filtering systems have thankfully been devised and deployed, but this problem has no easy solution. It will be interesting to see what impact new antispam legislation will have over the coming months and years.

The first article presents an in-depth look at the IP Version 4 address space and its measured and projected consumption rate. When work first started on the design of IP Version 6, projections indicated that we’d run out of IPv4 addresses within a few years. Geoff Huston takes a fresh look at this in an article entitled “IPv4—How long do we have?”

The job of System Administrator, or “sysadmin,” is a challenging one, and if your job includes keeping the network running 24 hours a day, you will probably appreciate some of the tips in our second article, entitled “Low-Tech Network Maintenance.”

For the second time recently, Queen Elizabeth II has honored an Internet pioneer. Tim Berners-Lee, the inventor of the World Wide Web and director of the *World Wide Web Consortium* (W3C), was made a *Knight Commander, Order of the British Empire* in the 2004 New Years Honours list. (See “Fragments,” page 28).

Which brings us to the IPJ publication schedule. If you are a regular subscriber to the IPJ, you probably have noticed a somewhat irregular publishing schedule in 2003. This December 2003 issue is indeed being published in January 2004. This results from our effort to produce timely quality articles in a world where the experts are not staff writers. Of course, you should still expect to receive four issues per year, and your feedback to ipj@cisco.com will help make IPJ even better.

—Ole J. Jacobsen, Editor and Publisher
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The Internet Protocol *Journal*

March 2004

Volume 7, Number 1

A Quarterly Technical Publication for
Internet and Intranet Professionals

In This Issue

From the Editor	1
High Availability in Routing.....	2
The Lures of Biometrics.....	15
Book Reviews	35
Fragments	38

From The Editor

The operational stability of the global Internet (or any network based on TCP/IP technology) is in large part the result of a carefully configured routing system. Routing continues to be one of the most complex topics in Internet engineering. In our first article, Russ White describes some mechanisms for the design of large-scale, stable routing systems. The article is entitled “High Availability in Routing.”

Security continues to be a high-priority item in computer networks and in society in general. One aspect of security is the identification system by which an individual is given authorized access to a particular facility, be it physical or virtual. Edgar Danielyan gives us an overview of one key element of identification, namely *biometrics*.

The Internet is “going where no network has gone before.” The *National Aeronautics and Space Administration* (NASA) has been working on the *Interplanetary Internet Project* (<http://www.ipnsig.org/>). We hope to bring you an in-depth article about this project in a future issue. An important demonstration of this system took place recently. To quote from the press release:

“A pioneering demonstration of communications between NASA’s Mars Exploration Rover *Spirit* and the *European Space Agency* (ESA) *Mars Express* orbiter has succeeded. On February 6, 2004, while Mars Express was flying over the area Spirit was examining, the orbiter transferred commands from Earth to the rover and relayed data from the robotic explorer back to Earth. The commands for the rover were transferred from Spirit’s operations team at NASA’s *Jet Propulsion Laboratory* (JPL), in Pasadena, California, to ESA’s European Space Operations Centre in Darmstadt, Germany, where they were translated into commands for Mars Express. The translated commands were transmitted to Mars Express, which used them to successfully command Spirit. Spirit used its ultra-high frequency antenna to transit telemetry information to Mars Express. The orbiter relayed the data back to JPL, via the European Space Operations Centre.”

We often receive requests for back issues of IPJ. Although we cannot provide paper copies, all of our previously published editions are available in both PDF and HTML format from the IPJ Website: www.cisco.com/ipj.

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The Internet Protocol *Journal*

June 2004

Volume 7, Number 2

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
Content Networks	2
IPv6 Autoconfiguration	12
DNSSEC	17
Book Review	29
Fragments	31

FROM THE EDITOR

The Internet Protocol Journal continues to be a forum for discussion of current and emerging technologies. In this issue, we first look at *content networking*. One can describe the Internet as a system of interconnected devices, but equally as a collection of information, called *content*, that resides on a distributed set of *servers* and is accessed by numerous *clients*. Our first article is by Christophe Deleuze.

Engineers are hard at work planning for an eventual transition to the next version of IP — IPv6. We've published several articles about IPv6 in previous editions. This time, François Donzé describes the automatic address configuration feature of IPv6. Of note is also the increasing global support for IPv6 deployment, (refer to "Fragments" on page 31).

Our final article returns to our recurring theme: adding security to existing Internet protocols. Because many malicious attacks on the Internet are perpetrated by "spoofing" information in one form or another, it makes sense to look at the *Domain Name System* (DNS), a critical component of the Internet infrastructure. Today, it is possible to create systems which provide fake answers to DNS queries. Miek Gieben explains what is being done to address this issue in his tutorial on DNSSEC, the secure version of the DNS protocols.

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This is the 25th edition of IPJ. The journal now has more than 32,000 subscribers world-wide, and is available on paper and electronically on our Website in PDF and HTML format. The Website, located at www.cisco.com/ipj, contains all our back issues, and will soon offer a cumulative index in ASCII format that will make it easier to find particular articles. As always, we welcome your feedback.

—Ole J. Jacobsen, *Editor and Publisher*
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The Internet Protocol *Journal*

September 2004

Volume 7, Number 3

*A Quarterly Technical Publication for
Internet and Intranet Professionals*

In This Issue

From the Editor	1
Anatomy	2
Letters to the Editor	33
Fragments	36

FROM THE EDITOR

Network Address Translators (NATs) were designed to allow multiple devices in a private address realm to dynamically share a single public IP address. NATs are widely deployed in today's Internet. They provide an effective way of IPv4 address conservation while simultaneously offering some level of security because individual IP addresses on the "inside" are hidden from the "outside," or global Internet. But NATs also present a challenge to existing Internet applications that may depend on globally unique IP addressing for proper operation. To further complicate matters, not all NATs are created equal, leading to unpredictable behavior. This edition of IPJ is almost entirely devoted to an in-depth look at NATs. Geoff Huston looks inside the NAT, and explains the complexities behind each variation of NAT implementation. It seemed only natural that he would name such an exposé "Anatomy."

Many IPJ subscriptions had an official expiration date of September 30, 2004, but I am pleased to report that all these subscriptions have been extended for another year. You should still make sure your delivery address and e-mail is up-to-date in our database by using the link at www.cisco.com/ipj or sending e-mail to ipj@cisco.com with your updated information.

If you're hungry for even more networking-related reading material, look at the Internet Society's publication page at <http://isoc.org/pubs/>. Here you will find The ISP Column, Member Briefings, Articles of Interest, and links to other material.

We didn't have room for a book review in this issue, but we have several in store for future editions. If you'd like to contribute a book review for publication in IPJ, please contact me.

—Ole J. Jacobsen, Editor and Publisher
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