

White Paper

Impacts of the Operating System on the Performance of Enterprise Networks

JUNOS Software Delivers Continuous Systems Availability, Automated Operational Efficiencies and Greater Flexibility for IT Innovation



Juniper Networks, Inc.
1194 North Mathilda Avenue
Sunnyvale, California 94089
USA
408.745.2000
1.888 JUNIPER
www.juniper.net

Table of Contents

Executive Summary	3
Introduction	3
The Network as IT Foundation	4
The Differences and Advantages of JUNOS Software	5
One OS with One Implementation for Each Feature	5
Benefits of Single Source	6
One Software Release Train with a Disciplined Development Process	7
One Mainline of Code	7
Benefits of Single Software Train	8
Modular Software with One Common Architecture	8
Benefits of Modular Software	9
Advantages of JUNOS Software	9
Operations Impacts of JUNOS Software	9
Continuous Systems	10
Automated Operations	10
Accelerated Innovation	10
Conclusion	11
About Juniper Networks	13

Executive Summary

As the role of IT becomes increasingly strategic, the criticality of the network deepens. Yet for many IT organizations, the existing network infrastructure does not take advantage of recent software engineering innovation, making it more challenging to achieve short-term and strategic goals.

High-performance businesses increasingly look to Juniper Networks to help solve network challenges as they scale, compete and innovate. JUNOS™ software, the trusted network operating system of Juniper Networks, is the foundation of this high-performance network.

What sets JUNOS software apart from other network operating systems is the way it is built:

- **One operating system** with single implementation of features
- **One software release train** extended through a highly disciplined development process
- **One modular software architecture** for every size and type JUNOS device

Customers who deploy JUNOS software benefit from its strategic advantages to meet changing business needs with lower total cost of ownership:

- Continuous Systems: Increase service availability through fault-tolerant, high-performance software design and high availability features along with tools that avert human errors and support proactive operations functions
“Compared to other vendor solutions, Juniper customers report that JUNOS software reduces the frequency of unplanned events by an average of 24% and makes unplanned events an average of 30% shorter. When interviewed, Juniper customers also report that JUNOS software reduces the time they spend troubleshooting an average of 30%.¹”
- Automated Operations: Drive efficiency to lower operations expense through a reduction in complexity, a single implementation of each feature, error-resilient configuration, on-box scripts to automate operations tasks, and the upgrade ease of one release train
“On average, Juniper customers report that JUNOS software reduces time spent monitoring by an average of 24%, ... JUNOS software saves customers an average of 22% time when upgrading at the core.²”
- Accelerated Innovation: Enhance flexibility to deliver new services through an open, standards-based philosophy and graceful software extensibility that adapts to new, perhaps unforeseen, needs with minimal cost and risk.
“Juniper customers report that JUNOS software reduces the time it takes to add infrastructure (routers) or services to the network by an average of 29% and 28% respectively.³”

Introduction

Most IT organizations are under tremendous pressure to shift their spending from the functions necessary to simply run the business to projects that accelerate business growth and innovation, including new ways to increase reliability, drive efficiency and reduce operational expenses. To do this, IT must find ways to cut operational costs while supporting new requirements without increasing risk or sacrificing service quality. These challenges are greatest in systems based on legacy designs with high operational support needs—not just for performing routine tasks, but also for handling intermittent performance issues and failures. Getting ahead of operational budget pressures often requires a fundamental change in the structure and technology of these legacy systems.

¹ Lake Partners

² IBID

³ IBID

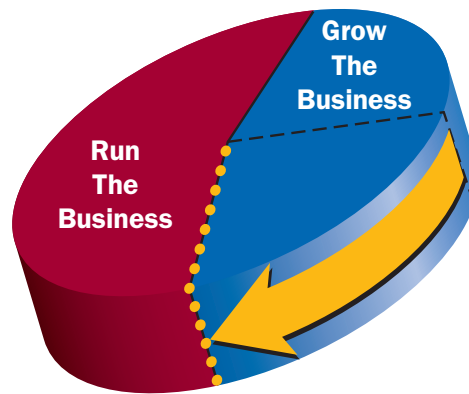


Figure 1: IT Budget Pressures

The Network as IT Foundation

The expanding business perspective on the role of IT leads to new considerations for the network as vital IT foundation. In many high-performance businesses, the view of the network is moving beyond “necessary plumbing” to a central enabler of strategic innovation. Yet for many IT organizations, the network is amongst the oldest infrastructure solution. While new equipment may have been added, much of its structure and technology have remained unchanged for the past decade or more.

These long standing network systems can present roadblocks to achieving contemporary IT goals. For example, the operational requirements to keep the network running – particularly with convergence of applications and increasing congestion levels – may leave few resources for responding to new business demands. And the inherent complexity of the existing solutions can slow deployment and limit options when new application needs necessitate network modifications.

While old hardware and outdated or poorly integrated technologies contribute to the problem, it is the software running in legacy networks that most often consumes operational time, causes the majority of operational headaches, and creates the operational obstacles to change. Largely based on source code initially built decades ago, legacy network software imposes a number of limitations, including:

- **Monolithic software architectures**, which impact network stability, performance and security with co-mingled processes vying for the same shared computing resources within a device platform and where even a small problem in one process can rapidly cascade to affect many others.
- **Complex, error-prone operations tasks**, which add not only time and effort to routine activities but also increase the risk of human error that can cause extensive outages or create security vulnerabilities.
- **Multiple release trains and software versions**, which slow down network upgrades with requirements for extensive testing, qualification and training while impacting the predictable delivery of new service features and fixes.

Additionally, the common practice of relying upon a single vendor for the network leaves IT organizations tied to the pace of innovation set by that one vendor, or, even worse, directly at risk to any development missteps or implementation problems that may occur. Reliance on a single vendor may also leave IT organizations dependent on proprietary mechanisms, tying long-term innovation to all-or-nothing solutions.

While it's sometimes hard for users to envision the fundamental differences they would experience with a network that runs smoothly day after day, reduces operations effort and errors, and is readily changed and upgraded without risks, an open evaluation of alternatives presents the possibilities. Many IT organizations are now recognizing the potential advantages associated with enhancing the network foundation to improve operational results, lower operational costs and create new opportunities for innovation.

The Differences and Advantages of JUNOS Software

High-performance businesses increasingly look to Juniper Networks to help solve network challenges as they scale, compete and innovate. The company's focus on high-performance networks offers a rich portfolio of routing, switching, and security platforms to enable today's new and expanding business applications and services.



JUNOS software, the trusted network operating system of Juniper Networks, is the foundation of the high-performance network. Businesses derive many fundamental advantages from the key differences in how JUNOS software is built:

- one operating system with a single source base and single consistent implementation of features
- one software release train extended through a highly disciplined and firmly scheduled development process
- one common modular software architecture for the many different JUNOS hardware platforms

One OS with a Single Code Source

The truly unique nature of JUNOS software begins with its most fundamental virtue: a single code source. Unlike other network operating systems that share a common name but splinter into many different programs and images, JUNOS software has remained a single, cohesive system throughout its existence. A consistent operating system makes planning easier, implementation faster and day-to-day operation intuitive.

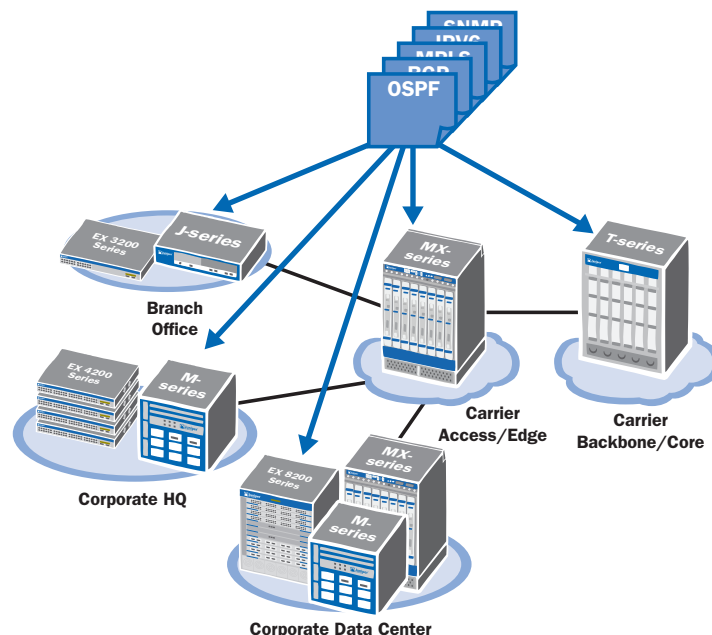


Figure 2: JUNOS - One Implementation of Each Feature

Juniper Networks engineers develop JUNOS software control plane features only once, and then apply and qualify each in the platforms where they are required. For example, enterprise customers get the same hardened implementation of OSPF (Open Shortest Path First) in their JUNOS devices as the largest carriers. The singularly developed feature provides a common user experience on all devices—from the smallest JUNOS-based platforms (the J-Series routers and EX 3200 series switches for branch offices) to the midsize (M-Series routers and EX 4200 series switches for corporate headquarters) to the largest (the multi-chassis TX matrix routers for the central core of the world’s largest carrier networks). By sharing a single source base, the many diverse deployments of JUNOS software have added to the operations feedback over the years, benefiting all users with enhanced approaches and new feature ideas.

Benefits of Single Source

The single source base and consistent implementation of features provide the following key benefits to customers.

- **For those who operate the network**, the training and knowledge required for new features is reduced. With one implementation to study and understand, there’s no need to memorize version-specific details, differences and caveats. A single common interface lets team members generally configure and manage each feature in the same way. Additionally, they can use the same set of tools across many different devices to monitor, manage and update the network.
- **For those responsible for changes to the network**, the inherent interoperability of a single implementation greatly simplifies new feature deployment, software upgrades and other network modifications. For example, a control plane feature validated in one platform doesn’t require extensive re-qualification in other platforms, since the code specifying the feature is the same.

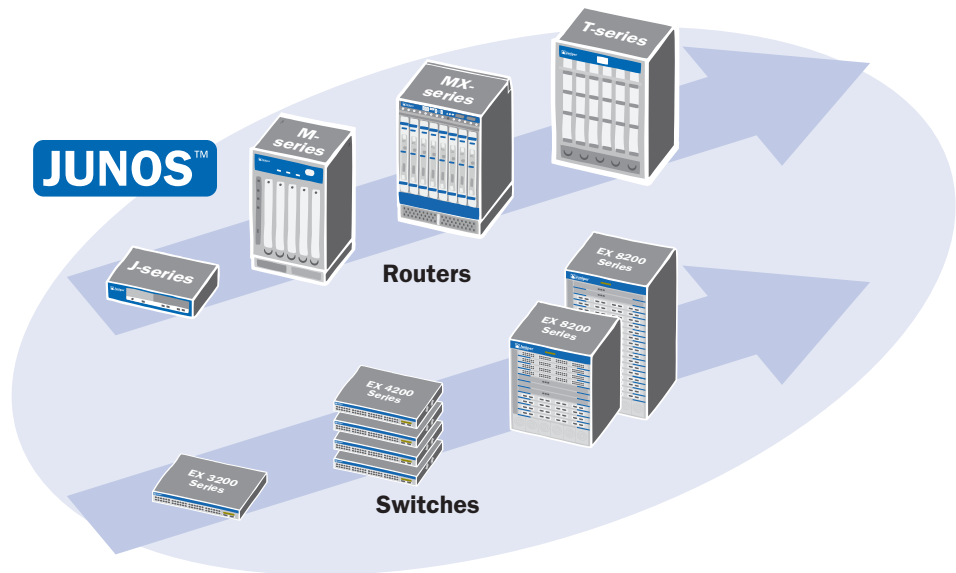


Figure 3: JUNOS - One Operating System, Many Platforms

One Software Release Train with a Disciplined Development Process

Juniper Networks methodically enhances the single JUNOS source base through a highly disciplined development process that follows a single release train (shown in Figure 4). From the very beginning JUNOS engineers have implemented strict principles for development. Many had experienced firsthand what happens when the rules governing product development are loose and the developers do not have control of the code. The software becomes unmanageable and changes bring unpredictable problems that may only become apparent when customers attempt to implement the software.

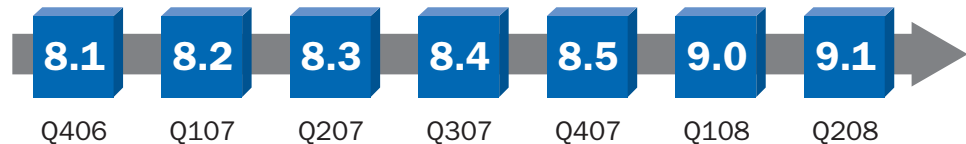


Figure 4: JUNOS - One Predictable Release Train

In the JUNOS development process, quality and schedule are the top priorities. Before any production release, the test engineers must achieve zero critical regression errors for all previously released features, fixing any and all critical bugs. It's unacceptable for a new version to break what was working before. Juniper Networks consistently delivers a new version of JUNOS software every quarter, every year. When a new version of the JUNOS software is released, it is released concurrently for all product lines—routers and switches—to eliminate the risks posed by forcing users to run multiple and potentially incompatible versions of the same operating system throughout their network.

One Mainline of Code

Juniper Networks engineers develop JUNOS software along one main line of code, where each version is a superset of the prior version. In building new features, the engineers adhere to strict development principles. In fundamental ways, these principles have protected the renowned stability of the software as it has evolved to support many new features and platforms over the years. Among the key principles: only add new features to new versions of software.

Preserving the single release train model ensures the single consistent code set. The result is well-understood, extensively tested code. The JUNOS software testing process includes repeated testing with automated regression scripts. Developed over many years, these test scripts are key intellectual property of Juniper Networks. Through the extensive testing of each JUNOS release, bugs and other problems are far more likely to be found and corrected by Juniper engineers before customers ever see the new version.

The simplicity of the single JUNOS release train lies in large contrast to highly complex, fragmented software trains employed by other vendors that result in thousands of operating system versions. Users have to be careful to select the correct software version, one that does not abandon an important feature or hardware support. Sometimes previously patched problems can reappear in a different software version. Customers looking for network-wide features have to meticulously evaluate the documentation to ensure that a version is available for each of their different hardware platforms. This can involve waiting for up to a year or longer for all of the various versions to be coded, tested and released. If any bugs or issues occur after rolling out the new service feature, it's yet another wait for all the fixes to be implemented in all of the different versions, before the service will actually work. All these steps to upgrade, downgrade, upgrade, etc. add to network downtime as the operations team navigates through a constantly churning and complex set of software versions. Further, the uncertainty can create havoc with quarterly budgets and project resources. As a result of these risks, many IT groups avoid software upgrades as much as possible, limiting options for new networking requirements.

Benefits of Single Software Train

As a single network operating system platform with a shared code base and consistent principles of software development and testing along one release train, JUNOS software provides a stable, reliable operating system for Juniper's routing and switching products.

The single release train employed by JUNOS software provides customers with one release to qualify and deploy. For many customers, the testing time of a new release is cut from what was before months to just a few weeks or even days. JUNOS customers don't need to cautiously select from a complex menu of release-specific and feature-specific packages. Adding new features is straightforward. For example, customers who desire MPLS, IPv6 or multicast simply need to enable these features, which are already present in the software. Further, the discipline of the JUNOS development process enables the delivery of dozens of new features in each quarterly release in a highly repeatable way, year after year. Juniper Networks customers can confidently plan the resources and activities required to upgrade to new versions, with most JUNOS users upgrading their largest platforms at least once a year. JUNOS customers have confidence in the reliability and predictable behavior of the software and consider such upgrades a routine maintenance task rather than a risk-bearing, time-consuming network project.

Modular Software with One Common Architecture

Underlying the methodical enhancement of JUNOS software is its modular architecture (shown in Figure 5), which enables flexible but stable innovation across many types of hardware platforms. A small team of engineers manages the software comprising each module, and the same team is responsible for the same module, release after release. The code is thereby much more tightly controlled than if it were a dispersed part of a monolithic code base, many different versions of the same release, or managed by separate release teams. In developing new capabilities, JUNOS software engineers can choose to add new modules or to update existing modules without requiring a complete overhaul of the entire code. Over the years, Juniper Networks has added several dozen new modules and internal interfaces to the original OS to support new capabilities.

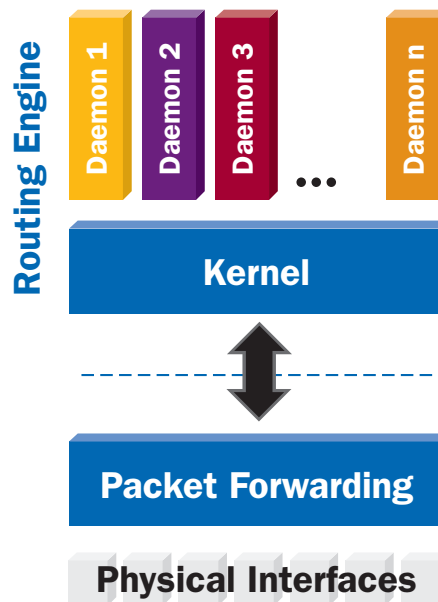


Figure 5: JUNOS – One Modular Architecture

Benefits of Modular Software

The advantages of modularity go far beyond stable, streamlined development. The modular design of the JUNOS architecture fundamentally enhances the fault-tolerance of the software. Each JUNOS daemon runs in its own protected memory space and can restart independently; one module cannot disrupt another by “scribbling” on its memory. If a malfunction in a module causes an issue, the rest of the system continues to function. A monolithic operating system, on the other hand, has no such compartmentalization, and a similar malfunction often causes a full system crash. Additionally, on the rare occasion that there is a software issue with JUNOS production code, the problem can be quickly identified, isolated and fixed.

The JUNOS software architecture also provides complete separation of the routing control and packet forwarding engines, with dedicated resources for each function. As a result, either engine can continue operating should problems occur with the other. For example, the command-line interface (CLI) does not lock up, even during Distributed Denial of Service (DDoS) attacks. The necessary computing resources are always available to the control plane, so operations teams can dynamically add needed filters to drop or rate-limit attack traffic. Similarly, packet forwarding can continue if a problem or restart occurs in the control functions of the routing engine, and throughput remains high, even when using extensive class-of-service policies and security filters.

Advantages of JUNOS Software

The inherent extensibility built into JUNOS software engineering has allowed it to evolve over the years to accommodate increasingly complex application and service needs, with increasingly stringent performance and reliability requirements. Customers deploying JUNOS software benefit from:

- Continuous Systems—improved availability, performance and security to run critical business processes
- Automated Operations—simplified, error-resilient network operations to prevent outages caused by human errors and to lower operational costs
- Flexible Innovation—interoperability and extensibility to meet new business requirements and enable new applications.

Operations Impacts of JUNOS Software

After the conversion to JUNOS software, high-performance businesses will see operational improvements across their many activities. In the Lake Partners research for its [How Operating Systems Create Network Efficiency](#) a total of 122 network operations team leaders were interviewed in early 2007 and asked a variety of questions regarding their daily operations and the hardware currently deployed in their network. Respondents interviewed were from companies in various industry verticals, including but not limited to healthcare, finance, telecommunications, government, and education and were of varied sizes. These interviews were conducted just shortly after availability of the new JUNOS automation scripts so the results of the respondents will likely continue to improve as they adopt these new features and capabilities.

“Lake Partners’ research indicates that operating systems play an important role in network operations. Certainly, every operating system has some features and functionality that make it unique. However, based on customer responses, JUNOS software is most consistently reported to save time and create operational efficiency. Juniper customers recognize and are able to quantify meaningful time savings across a number of key activities.” – Lake Partners 2007

Continuous Systems

From [How Operating Systems Create Network Efficiency](#):

“Respondents conceptualize reliability as the ability to maintain high uptime. Lake Partners measured reliability based on three factors: time spent troubleshooting, frequency of unplanned events, and duration of unplanned events. Reliability is considered higher when operations teams spend less time troubleshooting and have fewer (and/or shorter) unplanned events.”

“Modularity is a huge benefit – it reduces the severity of unplanned events. It is like driving a car – with JUNOS software if one wheel goes flat you can still drive. With other solutions you don’t have that and the whole thing shuts down.” – Network Manager, Government Facility

“Compared to other vendor solutions, Juniper customers report that JUNOS software reduces the frequency of unplanned events by an average of 24% and makes unplanned events an average of 30% shorter. When interviewed, Juniper customers also report that JUNOS software reduces the time they spend troubleshooting an average of 30%.”

Automated Operations

From [How Operating Systems Create Network Efficiency](#):

“Creating operational efficiency means that network operations teams spend less time on frequent system maintenance (i.e. monitoring and upgrading) and more time on critical network tasks. Lake Partners’ research shows that for maintenance tasks, different operating systems had varied impact on network efficiency. In particular, customers perceive that JUNOS software creates significant operational efficiencies. On average, Juniper customers report that JUNOS software reduces time spent monitoring by an average of 24%.”

“The modularity of JUNOS software really helps . . . Juniper allows the system to keep running regardless of what you are doing . . . monitoring, upgrading, etc.” – IT Director, Educational Institution

“Upgrading with JUNOS software is also quicker than with other operating systems. Specifically, JUNOS software saves customers an average of 22% of time when upgrading at the core and 23% when upgrading at the edge.”

Accelerated Innovation

From [How Operating Systems Create Network Efficiency](#):

“In the context of network operations, flexibility is the ability to add infrastructure and new services easily without loss of network stability or reliability. Interestingly, interviewees report that not all operating systems allow for the same level of flexibility. Specifically, they indicate that JUNOS software is significantly easier to deploy than other operating systems.”

“In a lot of cases Juniper comes out ahead when adding infrastructure. Even though I have more experience with other vendors, I find Juniper routers easier to integrate.” – CTO, Technology Company

“Compared to other vendor offerings, Juniper takes an average of 12% less time to deploy at the core and an average of 40% less time to deploy at the edge. Furthermore, Juniper customers report that JUNOS software reduces the time it takes to add infrastructure (routers) or services to the network by an average of 29% and 28% respectively.”

Network Operations Tasks	Average Time Savings of JUNOS Software
Troubleshooting and Unplanned Events	54 %
Monitoring and Optimizing	24 %
Upgrading and Planned Events	23 %
Adding Infrastructure	29 %
Average Time Saved With JUNOS Software	25 %

Table 1: JUNOS Operations Efficiencies (Lake Partners 2007)

Conclusion

The infrastructure foundation supporting IT must be uncompromising in its level of service, cost-effectiveness and ability to adapt.

JUNOS software is the trusted network operating system driving Juniper Networks’ leadership in high-performance networking. The fundamental advantages and unprecedented value of JUNOS software are a singular creation: *one* OS enhanced through *one* release train and constructed from *one* modular architecture—making high-performance business requirements realities. JUNOS software helps customers in very specific ways to improve the availability and delivery of services to users, to reduce operations effort and errors, and to meet new business needs—with a long list of distinct qualities and attributes that set it apart from other network operating systems (summarized in Table 2).

Network Goals	JUNOS Advantage	JUNOS Attributes
Improve the availability, performance and security of services	Continuous Systems	<ul style="list-style-type: none"> • Fault-tolerant modularity - enhances software stability and uptime with independent operation and restart of modules. • Dedicated resources for routing and packet forwarding - provide predictable performance as new services are activated and with a command-line interface (CLI) that doesn't lock-up. • High availability features - preserve forwarding and routing operations during system events with non-stop forwarding, Graceful Routing Engine Switchover, non-stop routing, etc. • Single release train - enables the development control and extensive regression testing that underlie the software stability. • Secure Operating System - protects with secure administration and advanced security features, including Stateful firewall, VPNs, etc. that deliver high throughput with many activated policies. • Automated operations (see row below) - avert human errors and provide proactive measures to reduce the total number, severity and duration of events.
Reduce operations effort and errors	Automated Operations	<ul style="list-style-type: none"> • Single implementation of each feature - provides a common user experience to simplify deployment and training. • Error-resilient configuration - prevents incomplete or incorrect configurations from becoming active in the network. • On-box, custom commit scripts - ensure that configurations are error-free and in compliance to each organization's policies to prevent outages and security vulnerabilities caused by human error. • On-box, custom operation (op) scripts and event policies - automate finding and proactively resolving issues from the first, leading indicators to reduce the number, severity and duration of events. • Single release train - removes significant risk and effort from network upgrades.
Meet new business needs	Accelerated Innovation	<ul style="list-style-type: none"> • Adoption of standards and development for interoperability - JUNOS-based platforms interoperate with a wide spectrum of vendors. • NETCONF/XML interfaces – support flexible integration to management and operations systems. • Systematic development process - predictably provides many new features each quarter to protect investment by meeting new service needs. • Graceful extensibility of JUNOS software – adapts to new, perhaps unforeseen, needs, with minimal cost and risk

Table 2: Network Goals, JUNOS Advantages, JUNOS Attributes

About Juniper Networks

Juniper Networks, Inc. is the leader in high-performance networking. The company offers a high-performance network infrastructure that creates a responsive and trusted environment for accelerating the deployment of services and applications over a single network. This fuels high-performance businesses. Additional information can be found at www.juniper.net.

CORPORATE HEADQUARTERS
AND SALES HEADQUARTERS FOR
NORTH AND SOUTH AMERICA
Juniper Networks, Inc.
1194 North Mathilda Avenue
Sunnyvale, CA 94089 USA
Phone: 888.JUNIPER (888.586.4737)
or 408.745.2000
Fax: 408.745.2100
www.juniper.net

EUROPE, MIDDLE EAST, AFRICA
REGIONAL SALES HEADQUARTERS
Juniper Networks (UK) Limited
Building 1
Aviator Park
Station Road
Addlestone
Surrey, KT15 2PG, U.K.
Phone: 44.(0).1372.385500
Fax: 44.(0).1372.385501

EAST COAST OFFICE
Juniper Networks, Inc.
10 Technology Park Drive
Westford, MA 01886-3146 USA
Phone: 978.589.5800
Fax: 978.589.0800

ASIA PACIFIC REGIONAL SALES HEADQUARTERS
Juniper Networks (Hong Kong) Ltd.
26/F, Cityplaza One
1111 King's Road
Taikoo Shing, Hong Kong
Phone: 852.2332.3636
Fax: 852.2574.7803

Copyright 2007 Juniper Networks, Inc. All rights reserved. Juniper Networks, the Juniper Networks logo, NetScreen, and ScreenOS are registered trademarks of Juniper Networks, Inc. in the United States and other countries. JUNOS and JUNOSe are trademarks of Juniper Networks, Inc. All other trademarks, service marks, registered trademarks, or registered service marks are the property of their respective owners. Juniper Networks assumes no responsibility for any inaccuracies in this document. Juniper Networks reserves the right to change, modify, transfer, or otherwise revise this publication without notice.

**To purchase Juniper Networks solutions, please
contact your Juniper Networks sales representative
at 1-866-298-6428 or authorized reseller.**