UNIX TO LINUX MIGRATION

RICHARD KEECH

ABSTRACT

This paper aims to show the benefits of choosing Linux and migrating existing UNIX environments to the Linux platform. This applies in particular to migrations from RISC-based platforms. It also shows the extent to which Linux is now a trusted, mainstream platform and how any technical risks associated with migrations can be mitigated. This paper addresses a technical audience.

TABLE OF CONTENTS

AIMS

This paper aims to give an introduction to Linux for the technically inclined and educated reader at a level that can allow proper comparisons with UNIX. The paper provides an outline of the key considerations in selecting Linux and migrating from UNIX to Red Hat Enterprise Linux. The intended audience of this paper is enterprise infrastructure architects.

INTRODUCTION TO LINUX

Benefits. The Linux platform offers a low-risk, robust, and value-for-money alternative to traditional UNIX. Linux is now sufficiently mature enough to handle the most demanding workloads at a much lower cost than proprietary UNIX offerings. At the same time, Linux leverages the open source development and subscription model, which guarantees a constant stream of innovation fueled by a healthy multi-dimensional community of users and developers. This is an important aspect, as not only does it truly prevent proprietary lock-in, but also enables a level of access to skills, documentation, on-line forums, and so on, to a level unheard of before with any other operating system.[20]

Maturity. Large-scale commercial deployments of Linux became noticeable in 1998. With the benefit of another decade's rapid development, Linux has reached a degree of maturity that meets or exceeds commercial UNIX. According to IDC,[1] "Linux … early adoption patterns have given way to mainstream deployment."

Scalability. As an example of Linux's capacity to scale up, in June 2008 the US Department of Energy announced the world's fastest supercomputer known as Roadrunner[2] based on Red Hat Enterprise Linux.[3] Another recent example is the New York Stock Exchange Euronext (NYSE Euronext) runs its entire trading operations on Red Hat Enterprise Linux and replaced every popular flavor of UNIX to achieve the scalability and reliability they require.

Feature-rich. Linux now more than holds its own for features compared to UNIX offerings. For some time Linux has included journaling file systems, logical volume management (LVM), advanced multipath IO capabilities, clustering, as well as services for modular provisioning, management, and patching. Today Linux comes standard with server virtualization and world-leading enhanced security such as SELinux.

Solutions. There is a great breadth of solutions and software available on Linux today. Many customers have found that the bundled open source offerings, often referred to as the application stack, meets their needs. If not, then there is a large ecosystem of ISVs to choose from who now fully support Linux. This number continues to grow as more and more customers demand Linux support from their ISVs.

OPEN SOURCE AND LINUX

The open source method. Organizations adopting Linux can be confident in the underlying open source method. According to the Open Source Initiative, "Open source is a development method for software that harnesses the power of distributed peer review and transparency of process. The promise of open source is better quality, higher reliability, more flexibility, lower cost, and an end to vendor lock-in."[29]

Open source maturity. Open source has emerged and matured to the point where it is now broadly accepted. Gartner has stated, "By 2012, more than 90 percent of enterprises will use open source in direct or embedded forms."[4]

Red Hat engineering. Linux distributors such as Red Hat start with the Linux kernel and many other pieces of open source software. Subsequent engineering processes create a coherent, tested, and enterprise-grade product. A key aspect of this process is creating a product life cycle and support services that match that of what businesses require. Specifically for Red Hat Enterprise Linux, this means turning a fast-moving, rapidly changing, innovating code base into something that has a life cycle spanning seven years. In a commercial setting the use of open source has been shown to be safe and free from licensing complications.

Open standards. Open source development has a strong track record in following the most important open standards. Increasingly open source development is at the forefront of setting open standards, as has been seen with the emergence of the Open Doc (ODF) standards. Single vendor standards will never be Open Standards. That's why open source is such a huge contributor to open standards: at the heart of each viable open source initiative or project is a thriving multi-vendor ecosystem. Accordingly, open source development generally has strong imperatives for interoperability.

Access to source code. Openly available source code is a very important strategic factor that mitigates risk because it provides:

- Verifiability. It is possible to verify that code does what it purports to do, and no more. This is relevant, for example, to confirm that a program does not have back doors or other unexpected 'features.'
- Assurance of maintenance. Although Red Hat's support and maintenance is first-class, access to source code means that an organization using Linux always has an alternative, independent of Red Hat. This is a kind of strategic insurance that proprietary software simply cannot provide. Not even through complicated escrow arrangements.
- Local derivatives. Occasionally organizations might find that they need critical new features or capabilities in their software. Often such requirements can be met by working with Red Hat directly. However, access to code gives organizations the ultimate choice about how and when capabilities might be added to their software.

RED HAT ENTERPRISE LINUX

Red Hat Enterprise Linux is the most successful commercially supported Linux distribution.[30] The current release is version 5, released in March 2007. Like its predecessors, Red Hat Enterprise Linux 5 entirely open source and offered commercially via a comprehensive annual support subscription. This subscription model is the basis for Red Hat's successful and sustainable business model. Red Hat Enterprise Linux major releases, for example version 4 to version 5, occur about every two to two and a half years.

Platforms. Red Hat Enterprise Linux is released on the industry's broadest set of architectures: x86, x86_64, ia64, PowerPC (P- and I-Series), and (s390) Z-Series.[31] This breadth gives a wide range of migration options for organizations using multiple CPU architectures.

Support. Red Hat supports Red Hat Enterprise Linux for seven years from the date of initial release.[5] Since Red Hat has no proprietary lock-in, quality support is paramount. One data point showing that Red Hat has been able to give high quality support is the CIO Insight Vendor Value study, which has ranked Red Hat number one enterprise software vendor for four years running.[6] Red Hat takes a highly conservative approach to issuing updates to Red Hat Enterprise Linux so as to reduce the risk of regressions and assure software compatibility[32] across minor releases.[9] Simply put, the stability that users of UNIX are accustomed to is made available for Linux through Red Hat Enterprise Linux. This has been a key enabler for enterprises around the world to reliably switch from proprietary UNIX to Red Hat Enterprise Linux.

Capabilities and features. The core technical capabilities of Red Hat Enterprise Linux are available for review at www.redhat.com/rhel/compare/. The table shown here summarizes some of the key supported extremes for a single node running on the commonly used Intel X86_64 architecture using Red Hat Enterprise Linux 5.

ITEM	VALUE
Max RAM	512 GB
Max physical/logical CPUs	64/255
Max filesystem sizes	16 TB
Max file size	2 TB

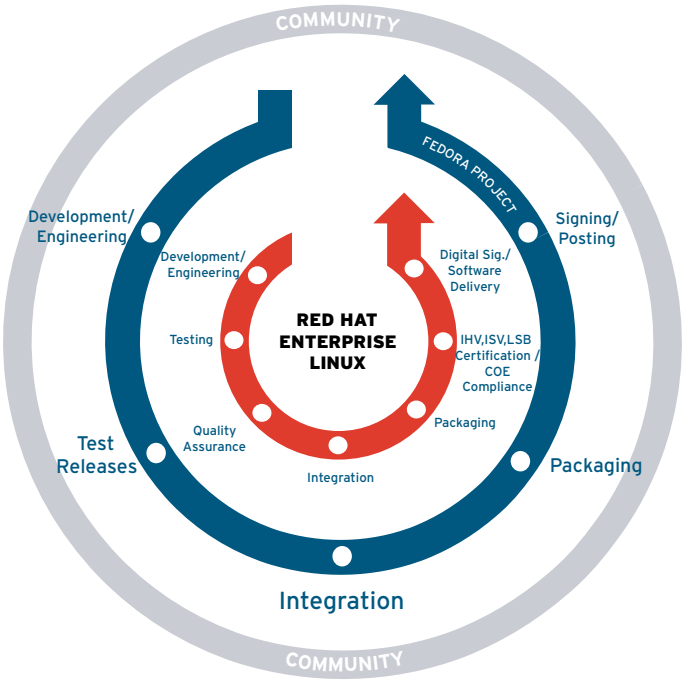
Software packaging. Red Hat uses a modular software packaging technology called RPM.[12] All Red Hat software is issued as RPM packages, regardless of whether it is core operating system or add on software. The use of RPM underlies Red Hat's ability to install and manage software efficiently. The RPM standard has been adopted by nearly all commercial Linux vendors.

ISVs. Increasingly organizations considering Linux migrations will find that their current software stack is already supported on Red Hat Enterprise Linux. Some compatible software can be seen at www.redhat.com/rhel/compatibility/software/. In many cases, support for Red Hat Enterprise Linux is long-standing. For example, in 1998 all the major commercial database vendors announced support within in the space of a few months.[7] Best practice software packaging by ISVs is to use RPM packages.

Variants. Red Hat Enterprise Linux 5 is available in a number of variants. Red Hat Enterprise Linux Server and Red Hat Enterprise Linux Advanced Platform are the server variants. There is also Red Hat Enterprise Linux 5 Desktop. Advanced Platform offers clustering as well as support for unlimited number of virtual machine instances through the integrated virtualization (see Server Virtualization, below).

Red Hat Enterprise Linux vs. Fedora. Red Hat develops Red Hat Enterprise Linux in parallel with another Linux distribution called Fedora.[33] Fedora is Red Hat's community distribution and serves as a proving ground for technologies before they make their way into Red Hat Enterprise Linux. Fedora is released about every six to nine months. Red Hat offers no commercial support for Fedora. Software updates are provided for Fedora, however the approach is far more aggressive than that applied to Red Hat Enterprise Linux. This makes sense considering that the main focus for Fedora is to be bleeding edge. Every six odd months a new Fedora release occurs, and community support of the previous version through on-line forums and email typically stops within months of the new release. IHVs such IBM, HP, and Dell do not certify Fedora on any of their hardware platforms. The relationship between Fedora and Red Hat Enterprise Linux is shown in Figure 1.

FIGURE 1: THE RELATIONSHIP BETWEEN FEDORA AND RED HAT ENTERPRISE LINUX



Updates. Red Hat releases updated software packages, known as errata, to address bugs and security issues as they arise. Updates are classified on a scale from Critical Impact to Low Impact.[11] Because of Red Hat's RPM packaging technology, software errata involve re-issuing of software packages rather than patches to those software packages. This is a great aid to configuration control and management.[34]

Minor releases. Every six months or so Red Hat will consolidate software updates available to that point and release a new point release. These point releases generally also provide additional hardware enablement[10] through updated installation and drivers. ABI compatibility across minor releases is assured.

Red Hat Network. Updates to Red Hat Enterprise Linux are provided via a web-based service known as Red Hat Network (RHN) at rhn.redhat.com. Managed systems register to RHN and can fetch updates from Red Hat via standard web protocols, making it very easy to deploy and integrate the updates into the enterprise management frameworks customers have in place. RHN provides a web-based console facility to monitor and control the state of systems. RHN also provides many other features to aid the management of systems.[13] The RHN portal provides the best means of customers accessing Red Hat's downloadable media sets and packages.

Scaling up management. Beyond per-machine patching, Red Hat Network provides a powerful framework for managing large numbers of systems. RHN can significantly improve administrator efficiency when dealing with large numbers of similar systems by allowing software state to be reported and reconciled, by allowing common configuration files to be maintained and tracked, and by allowing multi-host package installation and upgrade.

Performance. Red Hat Enterprise Linux provides scalable high performance and has excellent driver support for current high-performance hardware. The high performance achievable with Red Hat Enterprise Linux is shown in benchmarks available at www.press.redhat.com/?b=www&s=Benchmarks.

Security. Red Hat Enterprise Linux has been developed with security front of mind[21] and is suitable for use in the most security-conscious organizations. Red Hat Enterprise Linux 5 has achieved a Common Criteria rating of EAL4+[22]. This level was achieved using only software that ships with the core release. In addition, Red Hat Enterprise Linux incorporates Security Enhanced Linux (SELinux),[23] which is enabled by default. Red Hat has a robust and responsive security response process.[24] Red Hat also works closely with the Mitre CVE project[35] and has a very good track record for responding to security issues in a timely fashion.

UNIX VS. LINUX

Linux *is* UNIX. Functionally, as an operating system, Linux can actually be considered a type of UNIX, rather distinct from it. The most fundamental aspect in which Linux varies from UNIX is in the way it is developed, tested, and licensed. Linux largely follows the POSIX and UNIX standard interface definitions, although it is not officially certified as POSIX compatible.[27] The Linux Standards Base[36] and POSIX are expected to converge.[28] The various commercial implementations of UNIX all differ from one another to varying degrees. Generally, a given Linux distribution differs from a UNIX implementation no more than one UNIX implementation differs from another. Frequently Linux occupies a familiar and pragmatic middle ground between different UNIX implementations. For example UNIX variants often fall into either Berkely or System V camps, whereas Linux generally implements a superset of both Berkely and System V interfaces and command behavior.

Many eyes. The fact that Linux is both open source and has a large, diverse, and active community of developers[37] gives great confidence in the degree of scrutiny that Linux code is subject to. There is a saying in the open source world that has become known as Linus' Law: "With many eyes, all bugs are shallow."[38] This unprecedented degree of scrutiny is generally missing from the code bases of commercial UNIX variants and even Microsoft Windows for that matter. According to findings published by Coverity,[25] proprietary software on average has 20-30 defects per every 1000 lines of code (KLOC); a number that has not changed since 1960. In 2004, research showed that 985 defects existed in the 5.7 MLOC of Linux kernel source code: a 99.3% lower defect density. By 2005, the Linux kernel grew 4.7% in size, but defect density decreased by 2.2%. This degree of transparency and broad industry participation underlies the success and robustness of Linux.

Skills leverage. Since Linux is UNIX functionally, it follows that UNIX skills are also Linux skills. To the extent that an administrator skilled in one UNIX flavor can apply their skills on another UNIX flavor, they can also apply their skills on Linux. However, just as there are aspects of UNIX that apply specifically to one vendor, there are also aspects that apply specifically to administering Red Hat Enterprise Linux. An organization considering a UNIX-to-Linux migration can do so with confidence that their staff skills can be leveraged much more effectively than in a migration to a non-UNIX like operating system such as Microsoft Windows. Red Hat offers comprehensive training programs to re-skill UNIX administrators in Red Hat Enterprise Linux.[39]

Hardware support. Traditional UNIX implementations are tightly coupled with hardware. Linux decouples the operating system platform from the hardware vendor and breaks the vendor lock in. Red Hat enjoys very good support from all the well-known server vendors. This applies to vendors of commodity-architecture systems, as well as Itanium and IBM I-, P-, and Z-Series hardware. For more information on certified hardware configuration for Red Hat Enterprise Linux, see hardware.redhat.com.

Hardware alignment and efficiencies. Where traditional RISC-based UNIX systems are used, there tends to be a firm demarcation between the pool of UNIX system resources and the pool of commodity servers used for Microsoft Windows. With Linux deployed on commodity hardware, businesses around the world gain

flexibility and economies of scale in hardware purchasing and management, since systems need no longer be notionally fixed-purpose; Windows or UNIX. For example, in the one blade chassis, a Linux host and a Windows host might be side-by-side.

Application platform. As already discussed, Linux decouples the operating system platform from the hardware vendor/architecture. This has the additional benefit to ISVs of providing a single platform that will most efficiently take their software to the largest range of different supported hardware platforms.

TRENDS

A number of current trends are re-shaping the data center. It is important to consider how Linux sits with these.

SERVER VIRTUALIZATION

Linux has rich support for server virtualization through the libvirt virtualization library in conjunction with a suitable hypervisor. In the Linux space both the Xen hypervisor (www.xen.org) and the KVM hypervisor (kvm.qumranet.com/kvmwiki) are available as open source. Red Hat Enterprise Linux is deployed widely and successfully on VMWare, though Red Hat now offers server virtualization as a native capability at no additional cost.

libvirt. Red Hat has developed the libvirt virtualization API as an open source project with broad industry support.[8] libvirt allows management tools for virtualization to be abstracted away from the underlying virtualization implementation. This is an important piece of technology that ensures open platforms and open standards. Gartner has already recommended customers not standardize on one particular virtualization technology, as all the signs are there for vendor lock-in regarding the virtualization management tools. With libvirt in the middle providing the required abstraction, this lock-in is prevented.

Xen. Red Hat Enterprise Linux 5 ships standard with Xen-based virtualization, allowing multiple guest machine instances to be run simultaneously. Where the host system has the Intel VT or AMD V technology, Xen allows unmodified operating systems (including non-Linux operating systems) to be run as guest systems. Xen is a stand-alone hypervisor layer; the Xen hypervisor is not Linux. It is integrated into Red Hat Enterprise Linux, just like—for example—the Firefox web browser.

KVM. Kernel Virtual Machine, or KVM integrates a hypervisor technology into Linux itself and is a part of the upstream kernel that Linux and the community maintain. This is an important aspect as it will not only make KVM the default hypervisor for Linux in the future, but it also means there are more eyes on the code and greater leverage. For example, in order for Xen-based virtualization to be useful on a laptop based environment, it requires a thorough understanding of the common suspend and resume ability (close the lid / open the lid of the laptop) to ensure running guests are maintained appropriately between power state changes. KVM inherits these types of abilities because it is already part of the Linux kernel. Red Hat has announced[40] future support for KVM, while retaining full support for Xen guest systems. This is a natural evolution, which in the case of Red Hat Enterprise Linux, comes with a compatibility assurance as part of the subscription model.

CLUSTERING

Red Hat Enterprise Linux Advanced Platform includes the Global File System (GFS) clustered file system as well as Red Hat Cluster Suite. GFS allows multiple hosts to directly and concurrently mount SAN volumes (www.redhat.com/gfs). Cluster Suite provides a framework for service failover as well as IP load balancing (www.redhat.com/cluster_suite). A key strength of Cluster Suite is its ability to apply failover clustering to services that are not intrinsically cluster-aware. Cluster Suite can provide strong guarantees of data integrity by using 'fencing' mechanisms to ensure that a failed node is properly isolated prior to re-starting the service on a new node. Cluster sizes can be as large as 128 nodes.

OpenAIS. The core cluster infrastructure components used by GFS and Cluster Suite build on the standards-based, open-source project OpenAIS (www.openais.org). OpenAIS implements the Service Availability Forum (www.saforum.org) Application Interface Specification. Red Hat's use of the OpenAIS architecture is well described in the paper "cman 2.00 and OpenAIS".[26]

RAPID PROVISIONING AND APPLIANCE OS

Red Hat's Kickstart[18] installation technology provides for rapid and repeatable provisioning. With Kickstart it is possible to change the general approach from install-once open-loop to iterative re-installation closed-loop. Installation with this method can be also be the basis for a robust appliance-based approach to reference builds and solution deployment.

Kickstart installations are scripted, not image-based. Kickstart is an integral part of the Red Hat installer, known as Anaconda. Anaconda can either proceed interactively or by reading a file that describes some or all of its inputs. This file is the Kickstart configuration file, which is a human-readable and relatively short text file. In addition to defining the installer behavior, it can also include post-installation scripts that can extend the installation to include arbitrary additional steps that might typically embody customization and hardening in accordance with company standards.

Kickstart vs Jumpstart. Many organizations find themselves currently using Sun Microsystems' Jumpstart facility for automated installation. It is worth noting that Sun's Jumpstart and Red Hat's Kickstart are functionally very similar.[41] Users of Red Hat Enterprise Linux can achieve equivalent profile-driven automated installation, either from local media or across a network. However Red Hat's Kickstart has two important advantages:

- **Simplicity.** Kickstart profiles are normally held in a single text file, while Jumpstart installations require at least two, and typically four separate configuration files describing the target machine state.
- **Not just NFS.** When used for network installs, Jumpstart requires an NFS-mounted volume of the OS media. Kickstart, on the other hand is more flexible and allows media to be available via NFS, HTTP, or FTP.

INSTRUMENTATION AND DEBUGGING

For deep-level troubleshooting and performance analysis, Red Hat Enterprise Linux now includes SystemTap (www.sourceware.org/systemtap/). This provides an event-driven, kernel-level, scriptable framework for gathering information about a running Linux system, which is comparable in capability and scope to Sun's DTrace.[17] In addition to SystemTap, Red Hat Enterprise Linux includes oProfile (oprofile.sourceforge.net) for system-wide sampled profiling and also Valgrind (www.valgrind.org) for building dynamic analysis tools such as as memory-leak detectors.

MIGRATION CONSIDERATIONS

No two migrations from UNIX to Linux are the same. However there are some general considerations and suggestions. The entire latent software stack needs to be qualified on Linux. There needs to be a Linux standard build prepared. There needs to be a re-skilling of the team of administrators.

Test lab or pilot. Broadly speaking an organization can take one of two approaches to the initial Linux adoption. Some choose a test lab approach where a small number of application environments are demonstrated and evaluated on Linux, independent of the running production systems. However, more often organizations initially choose a single lower-risk production environment to re-host as a pilot. The choice between these approaches will be very organization-specific. Given the broad industry support, many will see that the risk of by-passing the test lab is worth it.

QUALIFY THE STACK

The core pre-migration activity that organizations need to perform is to qualify their software stack for Linux. Organizations typically have a broad range of accumulated third-party software components for hardware enablement (such as drivers for failover SAN connectivity), storage enablement (such as volume managers), middleware, monitoring, utilities, databases etc. Only once all the software components are qualified on Linux can the migration proceed.

Compatible software. The starting point in qualifying the stack is to determine whether the relevant ISVs support Red Hat Enterprise Linux. A good aid is Red Hat's software catalog at www.redhat.com/apps/isv_catalog/. Third-party software can also be found on Red Hat Exchange (rhx.redhat.com). Key to the success here is getting Linux versions of software as early in the process as possible and conducting your own qualification tests rather than simply relying on a compatibility matrix from a vendor.

RPMs please. Wherever possible organizations should seek to have as many components of their software stack as possible provided in RPM form. Doing so will ease provisioning, integration, and life-cycle management.

TCO improvements. Much of the latent UNIX system platform cost and management overhead arises from the licensing cost and integration difficulties associated with multiple third-party components in standard environments. Frequently the move to Red Hat Enterprise Linux offers the opportunity to simplify the stack and thus save licensing and management costs. One good example is the widely used EMC Power Path drivers; in Red Hat Enterprise Linux multi-path Fiber Channel connectivity is now fully supported as a native capability through the Linux Device Mapper facility. Another good example is volume management. Increasingly Red Hat customers find that Red Hat Enterprise Linux's native LVM and clustering is able to meet needs previously met by expensive add-ons such as Veritas Storage Foundation.

Driver considerations. Frequently organizations use device drivers from third parties. Usually these drivers come in binary form. Such drivers may increase the integration and management burden compared to native drivers. Also depending on their origin, there can be support implications from using third-party binary-only drivers. Generally, best practice is to use native drivers (the ones that ship standard with Red Hat Enterprise Linux) if available, and failing that use drivers from vendors with whom Red Hat have a support relationship. From a support perspective, binary-only drivers are a black box that Red Hat has no control or visibility into. Having said that, it is quite normal and expected that Red Hat Enterprise Linux be deployed with some proprietary drivers from certified and supported vendors.

Java. Enterprise deployments frequently require a supported Java Virtual Machine (JVM). Red Hat Enterprise Linux cannot ship any of the popular Java implementations in its core release because (at the time of writing) none are open source. However Red Hat does ship JVMs from Sun, IBM, and BEA in the supplementary CD accompanying Red Hat Enterprise Linux 5. Updates to these JVMs are available through Red Hat's normal update channels.

PORTING

Good tools. Some organizations will have in-house developed software in their stack. Assuming good availability of source code, the porting of code from UNIX to Linux is typically straightforward. Red Hat Enterprise Linux ships with a broad range of developer tools and compilers.[19] Unless the in-house code is written in a lesser-known language, or uses an unusual proprietary library, it is likely that the porting will be straightforward.

Alternative. An alternative to traditional source-code recompilation is to re-host UNIX software using a tool like QuickTransit from Transitive (www.transitive.com/). This approach involves using un-modified UNIX executables and running them directly on Linux. This is able to work even though the target machine architecture of the UNIX executables is different from the executing platform. Such an approach could accelerate the migration process in particular for custom in house developed applications.

TRAINING

For organizations considering adopting Red Hat Enterprise Linux, it should be a priority to get key staff trained as early in the process as possible. Although UNIX skills apply well to Linux, there is much to know that is specific to Red Hat Enterprise Linux. It is all too easy for UNIX architects and admins to initially view Linux through the prism of their preferred UNIX flavor. With Red Hat training it becomes much easier for them to appreciate why Linux does things a certain way.

Red Hat Certified Engineer. Red Hat delivers a comprehensive training curriculum, the centerpiece of which is the Red Hat Certified Engineer (RHCE) qualification, which has been available since 1999 and become the de facto Linux certification around the world. UNIX-skilled staff might consider the five-day Red Hat Rapid Track course and exam. For more information see www.redhat.com/training.

PREPARE A LINUX STANDARD BUILD

All organizations have their own particular requirements and standards for system installation and configuration. A key part of adopting Red Hat Enterprise Linux is preparing a suitable build that embodies these organizational standards. Current provisioning methods, typically using Kickstart, are able to codify organizational build requirements in a flexible and repeatable manner. Red Hat's professional services and Advanced Business Partners have considerable experience in preparing Standard Operating Environment (SOE) builds for Red Hat customers.[42]

PILOT DEPLOYMENT

It's difficult to be prescriptive about timing and planning of a pilot deployment because of variations between sites; no two pilot deployments will be the same. However the following are some general thoughts on getting maximum benefit from a pilot project.

Closed-loop is better than open-loop. An open-loop approach would involve an un-repeated sequence of steps starting with base install, then a separate install of each of the other components. A good pilot project would involve installing the target systems using a repeatable provisioning approach that codifies the steps for each component and is then followed by a re-installation. The benefit of this approach is that it captures the learning at every step to:

- give the greatest confidence that all the deployed systems are in a consistent state,
- be largely self-documenting and transparent, and
- give the greatest possible leverage to implementations that follow.

Updates. Aim to have the systems fully up-to-date at the time of commissioning. Once production change control applies it will be much harder to justify the application of software updates. The best way to do this is to ensure that systems are registered to Red Hat Network.

RPM-ify. Sets of locally created files that need to be installed can be turned into RPM packages for the sake of repeatability and manageability. This applies not just to software, but also to things like documentation, fonts, images, icons, and scripts. Sometimes it might even be appropriate to encapsulate a third party's software as an RPM for the sake of modular deployment and ease future upgrading efforts.

CONCLUSIONS

Linux has come of age and is being deployed broadly with great success. Migrating environments from UNIX to Linux is can be achieved with minimal risk on a wide range of hardware. Organizations adopting Linux benefit from the unique features of the open source development model, whether or not they choose to access the source code. Red Hat Enterprise Linux has attracted broad IHV/ISV support and provides a robust alternative to traditional UNIX at a much lower price.

REFERENCES

[1] The Role of Linux Servers and Commercial Workloads; IDC; April 2008
http://www.linuxfoundation.org/publications/IDC_Workloads.pdf

[2] U.S. Department of Energy's New Supercomputer is Fastest in the World; DOE; June 2008
http://www.doe.gov/news/6321.htm

[3] Roadrunner Smashes the Petaflop Barrier; IBM; June 2008
http://www-03.ibm.com/press/us/en/pressrelease/24405.wss

[4] The State of Open Source 2008; Gartner; April 2008
http://www.zdnet.co.uk/misc/print/0,1000000169,39379900-39001068c,00.htm

[5] Red Hat Enterprise Linux Errata Support Policy
http://www.redhat.com/security/updates/errata/

[6] CIO Vendor Value studies
http://www.redhat.com/promo/vendor/
CIO Vendor Value study, 2007
http://www.redhat.com/f/pdf/CIO_vendor_value_survey_2007.pdf

[7] Timeline for Linux in 1998, showing Linux support announcements from Ingres (May), Oracle (July) Informix (July), Sybase (September), DB2 (September)
http://lwn.net/1999/features/1998timeline/

[8] Virtualization Support in Red Hat Enterprise Linux
http://www.redhat.com/rhel/server/advanced/virt.html

[9] Backporting of Security Fixes
http://www.redhat.com/security/updates/backporting/

[10] Red Hat Enterprise Linux Updates
http://www.redhat.com/security/updates/notes/

[11] Classification of Security Issues
http://www.redhat.com/security/updates/classification/

[12] RPM software packaging
http://www.rpm.org/

[13] Red Hat Network overview
https://www.redhat.com/rhn/rhndetails
https://www.redhat.com/f/pdf/rhn/rhn101698_0705.pdf

[14] Benchmarks
http://www.press.redhat.com/?b=www&s=Benchmarks

[15] Worldwide Linux Operating Environments 2008–2012 Forecast: Taking Linux to the Next Level (Excerpt)
http://www.moreinterop.com/pdf/default.aspx?filename=IDC_Worldwide_Linux_Operating_Environments_Excerpt.pdf

[16] Analysis of Linux for Enterprise Applications and Databases: May 2007
http://www.redhat.com/f/pdf/Linux_v_Solaris_Whitepaper.pdf

[17] DTrace vs Systemtap comparison
http://sourceware.org/systemtap/wiki/SystemtapDtraceComparison

[18] Kickstart
https://www.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/5.2/html/Installation_Guide/s1-kickstart2-whatis.html

[19] Developer Tools Guide
https://www.redhat.com/docs/manuals/enterprise/RHEL-4-Manual/devtools/

[20] Unix to Linux Migration
http://www.redhat.com/solutions/business/utol/

[21] Security Features in Red Hat Enterprise Linux 4
http://www.redhat.com/f/pdf/rhel4/RHEL4SecurityFeatures.pdf

[22] Red Hat Enterprise Linux 5 Security
http://www.redhat.com/f/pdf/rhel/security_rhel5_new.pdf

[23] Security Enhanced Linux
http://www.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/5.2/html/Deployment_Guide/ch-selinux.html

[24] Security Measurement
https://www.redhat.com/security/data/metrics/

[25] **http://www.internetnews.com/dev-news/article.php/3524911**

[26] cman 2.00 and OpenAIS
http://sources.redhat.com/cluster/wiki/HomePage?action=AttachFile&do=get&target=aiscman.pdf

[27] Conflicts between ISO/IEC 9945 (POSIX) and the Linux Standard Base
http://www.opengroup.org/personal/ajosey/tr11-11-2005.txt

[28] (LSB) Relationship To ISO/IEC 9945 POSIX
http://refspecs.linux-foundation.org/LSB_3.2.0/LSB-Core-generic/LSB-Core-generic/posixconflicts.html

[29] The Open Source Initiative
http://www.opensource.org/

[30] According to IDC, in 2007 Red Hat's share of the global commercial Linux market is estimated at 62% [15]

[31] The Linux kernel project has target CPU architectures beyond those supported by Red Hat.

[32] Across minor releases the software compatibility is assured at the application binary interface (ABI) level.

[33] Fedora Linux
http://www.fedoraproject.org/

[34] Red Hat software updates are not patches to packages. The installed state of system software can be reckoned simply from the versions of the installed packages.

[35] **http://cve.mitre.org/**

[36] **http://refspecs.linux-foundation.org/**

[37] Being open source in itself is not sufficient to assure a large and diverse community of contributors. Many would say that Open Solaris is an example of open source without the community.

[38] Attributed to Eric Raymond
http://en.wikipedia.org/wiki/Linus's_Law

[39] Red Hat training
http://www.redhat.com/training

[40] KVM announcement
http://www.redhat.com/about/news/prarchive/2008/virtualization.html

[41] **www.sun.com/blueprints/0205/819-1692.pdf**

[42] Red Hat consulting:
http://www.redhat.com/services/professionalservices/

RED HAT SALES AND INQUIRIES

1-888-REDHAT1
www.redhat.com

www.redhat.com
#701325_0708