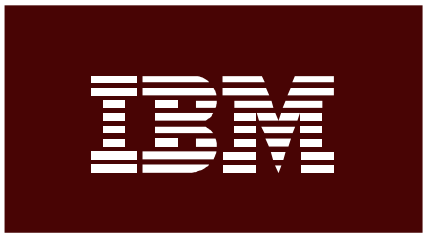

IBM and Red Hat: Collaboration for RHEL 5

White Paper

April, 2007

Introduction

IBM® and Red Hat have collaborated to integrate new technologies in the Linux® kernel that will help customers improve efficiency and gain a competitive edge in their industries. Red Hat's Enterprise Linux (RHEL) 5 delivers new functionality, new virtualization and security innovations, improved scalability and increased performance.

RHEL 5 includes over 200 new features to enhance IBM solutions on System x™, System p™, System z™, and BladeCenter® servers. RHEL 5 features support new IBM hardware (devices and processors), cross-platform functionality, and interoperability of IBM Middleware and hardware. IBM implemented customer requirements, gained community acceptance and performed extensive testing of RHEL 5 on IBM platforms. IBM's collaboration with Red Hat has continued to advance the Red Hat enterprise solution, providing increased customer value in Linux environments ranging from desktop to mainframe deployments.

This paper focuses on RHEL 5 features with special value for IBM platforms and IBM contributions. Key enhancements are reviewed in sections based on the following topics:

- Virtualization
- Kernel
- Networking
- Reliability, Availability, Serviceability
- Security
- Toolchain

For a complete overview of RHEL 5 content, visit the Red Hat web pages at http://www.redhat.com/.

Virtualization

This chapter highlights RHEL 5 specific enhancements for virtualization on System x, System p, System z9™, and System z servers.

Virtualization on System x – Xen

One of the key highlights of RHEL 5 on the System x platform is the virtualization provided by Xen, a lightweight open source hypervisor. Xen provides a single System x server with the capability to run multiple operating systems simultaneously in an isolated manner. This allows sparsely used machines running different operating systems and applications to be consolidated to a single machine, helping to reduce server hardware and operating costs. Xen supports paravirtualized guest operating systems and unmodified guests in hardware-assisted full virtualization mode using Intel® Virtualization Technology (Intel VT) and AMD Virtualization (AMD-V) processors. Xen provides isolated operating environments for applications by running on independent operating system instances. Thus, the impact of a failure of one application on another is reduced without requiring the use of independent hardware.

Xen in the RHEL 5 release provides the following features:

- Security mechanisms to provide isolation and access control between domains and system devices.
- Virtual devices presented to guest operating systems protect them from, or minimize the impact of, failures in real devices.
- Support for 512MB sized domain 0 (the controlling privileged domain) and up to 64GB total system memory.
- Support for up to 32-core SMP systems, and hot-plug re-provisioning of processors to dynamically adjust processor resources.
- Support for Physical Address Extensions, which allows 32-bit operating systems to address more than 4GB of memory.

- Checkpoint and restart functionality for the operating system, as well as certain limited support of the migration of an operating system instance to another physical server. This helps minimize downtime due to server upgrades, hardware failures, and maintenance.

A technology preview of Xen management is included in IBM Virtualization Manager 1.0, an extension of IBM Director which allows users to manage both physical and virtual systems from a single console. Virtualization Manager simplifies management of both VMware and Microsoft® Virtual Server environments. IBM has delivered an implementation, based on the Distributed Management Task Force's (DMTF) Common Information Model (CIM) proposed standard, for the Xen virtual environment. Virtualization Manager integrates with, and complements, VMware VirtualCenter, linking together management for physical and virtual resources. Ongoing Open Source Xen CIM development with IBM's current Director-specific CIM development will be part of future IBM Virtualization Manager releases.

Virtualization on System p servers

System p Advanced POWER™ Virtualization (APV) now scales from Linux images running on one-tenth of a processor to images of 64 processors (with a maximum of 255 partitions for a system). Such Micro-Partitioning™ technology is unique to POWER5™ servers and provides a more flexible environment for Linux environment clients and applications. The virtualization of physical processors in POWER5 systems (or Micro-Partitioning) introduces an abstraction layer that is implemented within the hardware microcode. Partitioning at the hardware level allows the supported operating systems to run on POWER5 technology with little or no changes. The Linux operating system has been adapted and optimized for virtualization.

In addition to virtualizing a processor, APV can also abstract physical I/O from a Linux image. APV allows multiple partitions to share single network cards or storage disks. This highly scalable and flexible technology reduces cost by maximizing hardware utilization and introduces more options for redundancy and reliability.

POWER5 also allows for on-the-fly changes to virtualized resources. RHEL5 is the first Red Hat release that allows dynamic addition of memory resources to a running partition. The dynamic nature of POWER virtualization adds tremendous flexibility in managing multiple server images in a single Power Architecture technology-based system. As another example, a virtual server can be configured to borrow idle processing power from other virtual servers on the same system. Such servers can instantly accommodate increasing workloads without user intervention. This capability is unique to APV.

Virtualization on System z9 and System z (LPAR and z/VM) servers

System z servers provide both hardware (LPAR) and software virtualization (z/VM®). Each of the two virtualization schemes is designed to be robust and to satisfy the needs of mission-critical services in an enterprise. RHEL 5 can run in either an LPAR or a z/VM guest and thus inherits the flexibility, scalability and manageability benefits of System z virtualization. In particular, z/VM V5.2 improves the scalability to host servers with large memory requirements and high network and storage traffic. Using RHEL 5, you can benefit form various improvements related to accurate accounting, performance, and RAS as described in the System z section later in this paper.

Kernel Enhancements

RHEL 5 provides improved features and functionality for the Linux kernel, as well as core enhancements to help improve stability, and scalability. Key kernel enhancements include the following:

- Virtual File System (VFS) enhancements to support shared subtrees of name spaces. These enhancements allow full support for Rational® ClearCase® and Multi-Version File System (MVFS) software available from IBM.
- Madvise (MADV_REMOVE) and lazy paging support for shared memory allocations, which enable autonomic management of DB2® software.

- ext3 file system enhancements allow users to add new space to an existing partition without unmounting the file system first (online resize).
- Robust Virtual Machine design to handle memory pressure handling.
- Flexible resource management (CPUSETS, NUMA enhancements, Pluggable I/O schedulers and fork/exit event notification).
- Delay accounting statistics for enabling enterprise workload manager (eWLM).
- Enhanced device driver support.
- Hotplug Memory Add Support, which allows dynamic increases of memory in the system (in particular for virtual environments).
- Transparent large page support, provided through the introduction of libhugetlbfs. Transparent large pages allows applications to take advantage of large pages with no application source code changes. Mallocs can be backed with large pages with the setting of environment variables. An application's .bss, .data, and .text segments can be backed simply by relinking the executable.

Networking

IBM's contributions to the new networking functionality of RHEL 5 include the following:

- Infiniband is a standards-based high-speed and low-latency interconnect offering an alternative to traditional proprietary interconnects. RHEL5 includes the required functional support for Infiniband through OFED (Open Fabric Enterprise Distribution) 1.1 version of the stack. OFED 1.1 stack contains core IB services modules, upper layer protocols such as IPoIB, user level libraries, diagnostic tools, and cmds/utilities. IBM has made significant contributions to the stack improving stability, performance, and numerous functional enhancements. The stack also includes a driver to support IBM's Galaxy 4x adapter on Power platforms.
- Network File System version 4 (NFSv4) is a standards-based state-oriented network file system protocol with built-in security support. NFSv4 support, available through the RHEL5 kernel, has been further stabilized with patch contributions from IBM.
- IPv6 Advanced Sockets API enables "advanced" IPv6 applications to access features, such as interface identification options and IPv6 extension headers, that are not addressed in the basic sockets API (RFC 2133). The IPv6 Advanced Sockets API also enables hop-by-hop options, destination options and other features making it compliant with RFC 3542.
- The Stream Control Transport Protocol (SCTP) connectx() API in RHEL5 provides a faster way to set up an association with a multi-homed server in a situation where the client is aware of the multiple IP addresses of the server. SCTP allows the caller to specify multiple addresses at which a peer can be reached and let the kernel do the retries.
- Other SCTP enhancements include Multiple SCTP bug-fixes, performance enhancements, and updates to the API to bring it closer to the latest SCTP sockets API draft.

Reliability, Availability, Serviceability

With RHEL 5, numerous RAS enhancements are IBM solutions. Kdump, a new crash dump utility, is a First Failure Data capture (FFDC) mechanism that is supported across multiple architectures. Unlike other crash dump utilities Kdump is reliable because it doesn't depend on the dying kernel to capture the dump. RHEL 5 includes the enhanced analysis tool, Crash, for advanced dump analysis capabilities.

IBM brand hardware capabilities, error recovery, remote management, and service capability are enabled in RHEL 5. IBM solutions with RHEL 5 deliver improved error handling at the hardware level and memory parity error checks. IBM further improved the enhanced error handling (EEH) capabilities on System z and on System p servers. On Power PC® processor-based hardware, EEH helps to detect and recover from a wide assortment of PCI device and bus errors. System z servers now have better instrumentation to analyze problems with SCSI/FCP and networking in guest LANs. IBM platforms also have the ability to manage and service systems remotely with the help of remote management cards in the system.

SystemTap, an advanced RHEL 4 performance analysis and debugging tool, is further enhanced in RHEL 5 with many features like cross-compile and support for System z. SystemTap provides a safe and easy scripting language for system administrators to use in analyzing performance problems that originate anywhere from application programs to device drivers. The tool is also sophisticated enough to support the on-demand probing required in the debugging sessions of experienced system programmers. Because

SystemTap contributes no overhead when not in use and very low overhead when in use, it is a highly-accurate tool for real-time performance analysis of production systems.

Security

With RHEL5, IBM and Red Hat have worked to create a product to be submitted for certification at the EAL4+ level for the LSPP, RBACPP, and CAPP protection profiles This single certification is expected to cover select machines across System x, System p, and System z.

RHEL5 delivers advanced cryptographic performance through enhancements to the PKCS#11 standard compliant openCryptoki package. For System z, openCryptoki has been enhanced to exploit new embedded cryptographic System z instructions, providing improved cryptographic performance. In RHEL5, the openCryptoki package is now also available on the i386, x86_64, and ppc64 architectures. Each of these architectures provides a software library, or token, that allows applications to begin coding to the PKCS#11 standard. This allows an application to be able to seamlessly take advantage of any hardware cryptographic accelerators installed later on the system.

For the System z architecture, RHEL5 also provides a new dynamic OpenSSL engine to exploit the new embedded cryptographic System z instructions, providing improved cryptographic performance within OpenSSL.

Toolchain

RHEL5 brings a number of toolchain-related (gcc, binutils, glibc) security and performance enhancements.

For 32-bit Power PC, RHEL5 provides the -msecure-plt option and makes it the default. The -msecure-plt option allows applications to be divided into pure read-only executable code and read-write no-execute data areas. This is important to preventing so-called “buffer overrun attacks.”

With RHEL5 there is improved signal handling for 32- and 64-bit Power PC so that the run-time stack does not need to be executable.

The gcc compiler added the -fstack-protector feature that detects buffer overflows on the stack.

The GCC-4.1.1 compiler provides numerous code generation improvements over previous gcc-3.4 compilers. GCC-4.1.1 also offers improved VMX/Altivec support for the JS20/JS21 Blades with enhanced autovectorization features.

Key Enhancements by Platform

This section presents key enhancements for System p, System x and System z hardware platforms.

System p (Power Architecture)

Linux on POWER processor-based servers provides supported applications with the following qualities:

- high performance, high scaling, and high capacity within a full family of servers
- high reliability
- leadership virtualization capabilities
- low operating costs compared to alternative server architectures

To help clients provide their companies, customers, and shareholders with competitive advantages and top value, IBM drives innovation and value into their hands through the proven, open, and powerful computing platform of Linux on POWER. RHEL 5 on Power Architecture provides hardware reliability and serviceability, a native virtualization environment, and improved system scalability with regard to number of processors, amount of physical memory, and I/O bandwidth.

System p servers, using IBM POWER5+™ and POWER5 processors, help customers simplify their IT infrastructures at a low cost and increase flexibility while helping them to improve overall performance and efficiency of operations. IBM System p5™ servers running RHEL 5 have achieved industry-leading benchmark results for business and scientific performance. For more information on performance results, see: http://www-03.ibm.com/press/us/en/pressrelease/20745.wss

RHEL 5 delivers the following features for POWER:

- 64-core SMP allows execution of single large OS images that require large amounts of computing power operating on a single large shared memory. This feature is useful in certain high performance computing applications.
- The base page size (used by all applications and the Linux kernel) for RHEL 5 is 64K in size. This feature can provide an application performance increase up to 30% above the use of a 4K base page size.
- NUMA optimization improves the performance of workloads that run across large systems (greater than 4-8 processor cores) by specifying that memory may only be accessed by local processors.
- The iSCSI software initiator allows access to remote iSCSI storage devices across standard (Ethernet) network connections, providing a low cost remote storage solution.
- IBM's XL C/C++ Advanced Edition V8.0.1 for Linux and XL Fortran Advanced Edition V10.1.1 for Linux offers numerous enhancements for use on RHEL 5. The latest IBM compilers offer optimization and performance-tuning features to exploit all Power PC systems, including the latest POWER5, POWER5+, and Power PC 970 hardware architectures. The -qarch and -qtune compiler options include new suboptions to provide code tuning for the new POWER5+ processors. For more information on the IBM compilers, see:
  http://www-306.ibm.com/software/awdtools/xlcpp/features/linux/xlcpp-linux.html
  http://www-306.ibm.com/software/awdtools/fortran/xlfortran/features/linux/xlf-linux.html
- Post-Link Optimizations for Linux on POWER allow performance improvements to applications by reorganizing the compiled application code to reduce page faults, cache misses, and other impediments to performance. For more information about Post-Link Optimizations, visit alphaWorks® at:
  http://www.alphaworks.ibm.com/tech/fdprpro
- Portions of the operating system (such as kernel, libraries, tools) have been tuned to provide better performance on POWER systems.
- VMX exploitation improves performance for applications that require "vector operations" by providing a single instruction that operates on multiple data items at once. This capability is available in systems built around 64-bit Power PC 970FX processors, like the BladeCenter JS20 and JS21 systems.
- Large page support improves performance by using a smaller number of translations that the processor must address (and can cache in the processor) for a given large contiguous range of virtual memory.
- Transparent large page support is provided through the new libhugetlbfs feature. The transparent large pages feature allows applications to take advantage of the Power 16MB lage pages with no application source code changes. Mallocs can be backed with large pages with the setting of environment variables. An application's .bss, .data, and .text segments can be backed simply by relinking the executable.
- Device Driver error log analysis provides a mechanism for analyzing the errors generated by a device and recommending replacement actions.
- iSCSI TCP/IP offload adapter support provides a high performance mechanism for communicating with iSCSI storage devices by offloading the work of the TCP/IP stack to the adapter rather than the operating system.
- Physical memory add allows more physical memory to be added to a Linux partition without rebooting the partition. This allows some adjustment to the size of a partition to accommodate larger workloads. Physical memory cannot be removed from a Linux partition without rebooting the partition. Processors can be added and removed from a Linux partition without rebooting it.
- Serial Attach SCSI are a new type of SCSI storage device that uses serial rather than parallel communication paths. SCSI storage devices are transitioning from parallel to serial interface types.

- PCI-Express support allows BladeCenter JS21 systems to use a faster, higher bandwidth path to the I/O devices, providing better I/O performance and scalability.
- Non-executable stack and heap is a feature that prevents applications from executing code in their stack or heap areas. This feature thwarts the common security problem of buffer overflow attacks, where a security attack causes the overwrite and overflow of application code residing in a buffer that is either in the stack or the heap.
- PCI-Express support allows BladeCenter JS21 systems to use a faster, higher bandwidth path to the I/O devices, providing better I/O performance and scalability.
- High performance time system calls allow timestamps to be generated more quickly, improving the performance of transactional systems like databases.
- 64-bit tracing tools allow tracing of 64-bit applications, easing the debugging and tuning of 64-bit applications.
- gcc-4.1.1 adds support for the latest Power ISA Version 2.03 Instruction Set Architecture, which includes new instructions POWER5+ and improved instruction scheduling and optimizations to fully exploit POWER5/POWER5+ systems. These features are available through the -mcpu= and -mtune= compiler options.
- The oProfile tool allows both timer base and Hardware performance counter profiling of the OS and applications. oProfile is enhanced to support POWER5 and POWER5+ performance counters with this release. These profiles can be used for detailed performance analysis of the operating system and applications and to identify specific areas needing improvement.

System x

System x servers utilize Intel- and AMD-based processors, which are represented in the majority of Linux installments worldwide. The industry leading System x portfolio provides customers with a large variety of choices ranging from scale-out distributed computing single-socket servers to high-end scale-up several-socket servers. Differentiation from other AMD and Intel servers is provided by enabling features that are commonly found in IBM's mainframe class server environments. Leadership systems management capabilities, robustness, high reliability and stability allows RHEL 5 to leverage these high-end features.

RHEL5 delivers the following features to further expand on System x solutions:

- Virtualization is provided to allow users to run multiple virtualized guest operating systems using the Xen virtual machine monitor.
- Support is provided for the latest Intel and AMD processors and chipsets used in recently released IBM System x servers.
- Dual core support (two processor cores per socket) is provided for both Intel and AMD processor packages.
- IBM Extended X-Architecture® (EXA) chipset support enables support for large SMP NUMA-based IBM servers, primarily with 64-bit kernels. The EXA chipset provides the I/O bridge controller and the cache/memory and scalability controller for high-end NUMA platforms.
- Global timesource is provided to synchronize timekeeping for NUMA systems. Support for both the High Precision Event Timer (HPET) and the ACPI PM timer are used to track time consistently in environments with multiple clock sources.
- Intelligent Platform Management (IPMI) support using the OpenIPMI driver and user level interfaces, such as ipmitool, provides the ability to manage and monitor platform hardware in-band or out-of-band. It includes IPMI 2.0 compliance, extensions for SoL, VLAN and DHCP firewall support.
- Serial Attached SCSI (SAS) support, which is SCSI protocol with a serial interface (as opposed to older parallel bus based interface), provides improved I/O bandwidth and performance, including support for LSI and Adaptec SAS-based controllers.
- Advanced Configuration and Power Interface (ACPI) extensions for system reset, PM timer, PCI hotplug, power management and processor throttling, and support for legacy-free systems are provided.
- New System x device support is provided, including ServeRAID™ 8i/8k driver (aacraid) support and synchronization, Broadcom 5706/5708 (bnx2) NIC support, Broadcom 5714/5715 (tg3) NIC support and nVidia, and ATI graphics accelerators.

- Execute Disable (XD), an Intel processor feature that protects against execution of malicious software at the hardware level, is provided.
- Extensions to existing Linux PCI-X and PCI Express hot plug capabilities include support for user-level modification and retrieval of PCI slot attention LED status, retrieval of IBM specific APCI hot plug tables, and ACPI event notification on IBM-specific devices.
- iSCSI allows for remote access to storage devices over standard ethernet connections, providing a low cost remote storage solution.
- PCI Express offers extended PCI configuration space, improved bandwidth, and faster speeds to improve overall performance and scalability.
- Support is provided for large SMP systems environments:
    - 64-core SMP support provides for the execution of multi-threaded applications that require large amounts of computing power while operating on a single large shared memory.
    - Large memory support, 512GB and above, provides support typically required by database and EDA applications. The System x multi-node x460 and x3950 represent servers that take advantage of the large SMP features in RHEL5.
- NUMA support and optimization is provided, which enables the kernel and applications, (through exported APIs), to make intelligent decisions with respect to memory placement and process scheduling on systems that don't have uniform memory characteristics (for example, local and remote memory latencies differ).
- Improved Power Management capabilities are included that provide power cost savings by throttling processor frequency on unused and under-used processors. Full support is provided for Demand Based Switching (Intel) and PowerNow! (AMD) and the ability to manage and control processor pstates from the OS.
- PCI-Express support is provided to allow System x servers to use a faster, higher bandwidth path to the I/O devices, providing better I/O performance and scalability.
- Hot add physical memory support is provided to allow more physical memory to be added to a Linux system while the system is up and running. The Linux kernel can detect and begin to use the new physical memory without rebooting. This allows on demand adjustment of memory to accommodate increased workloads. Only online physical memory add is supported; physical memory cannot be removed from a system without rebooting.
- Support is provided for installing and booting RHEL5 from USB compact-flash devices.
- Support is provided for the Quantum GoVault removable drive, providing a fast, easy to use backup solution for System x servers.
- Software is provided for RAID support through dmraid (device-mapper). dmraid understands several software RAID set formats and offers an alternative to certain vendor proprietary device driver solutions. Installation and migration support is also included.

System z

RHEL 5 on System z servers provides a cost-efficient and reliable scale-up and scale-out application-hosting environment specifically meant to augment z/OS® enterprise deployments. To serve this goal, RHEL 5 exploits the latest features of System z9™, the newest System z architecture level.

RHEL 5 network adapters have been enhanced to enable the Communication Controller for Linux products on System z9 for 374x NCP virtualization. To provide optimal performance in a security-critical environment, RHEL 5 supports the new cryptographic adapters of System z servers and the new crypto instructions for AES and SHA-256 of the System z9 processors, the latter being not only accessible to applications, but also to the kernel.

A new Fibre Channel Protocol (FCP), SCSI over Fibre Channel, Host Bus Adapter Virtualization Technology (N_Port ID Virtualization: logical WWPNs) on System z9 now allows sharing of FCP adapters in a fully SCSI standards-compliant way. This comprises SAN access right management and disk sharing through virtual HBAs.

RHEL 5 contains miscellaneous virtual server enhancements that relate to pre-System z9 machines:

- Linux images use the clock comparator for virtual elapsed time (as opposed to their users consulting a wall clock), a feature which is much more hypervisor-friendly.
- Network traffic can be analyzed on virtual network connections (Guest LANs) and there is support for concurrent I/O through multiple paths for ESCON/FICON (channel)-attached disk storage subsystems using the System z Parallel Access Volume technology.
- Functions to provide LPAR-specific CPU and I/O statistics help to accurately manage and balance workloads distributed across multiple Linux images running on the same System z server.

With RHEL 5 execute in place, support is fully integrated in the ext2 file system. System z customers can leverage this technology by running multiple similar servers in the z/VM Hypervisor. It allows for efficient sharing of memory for executables and library code across multiple Linux guests running in the same z/VM system.

RHEL 5 supports IBM Director 5.1 to provision and manage Linux images in z/VM.

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