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LINUX

# Oracle Linux 7: Optimizing Deployment Flexibility and Increasing ROI

## Delivering Application Services Cost-Effectively

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## Introduction

IT organizations face the challenge of delivering services in sync with shifting business priorities—supplying strategic applications quickly, securely, and with the required quality of service. Solution architects look for deployment methodologies that foster agility, make efficient use of IT resources, and lower capital and operating expenses (CAPEX and OPEX). For this reason many IT departments are deploying applications as virtualized or cloud-based services using open source Linux. This approach is increasingly becoming the deployment standard for delivering enterprise application workloads.

Oracle Linux is an optimal Linux choice for enterprise application delivery regardless of whether deployments are traditional, virtual, or cloud-based. It is developed and extensively tested with demanding mission-critical workloads like Oracle Database, Oracle Fusion Middleware, and Oracle applications (such as Oracle's PeopleSoft, JD Edwards EnterpriseOne, Siebel Customer Relationship Management, etc.) as well as many third-party enterprise applications.

While Oracle Linux is open source and includes standard technologies, tools, and features, Oracle extends the release to deliver a complete, integrated, and supported platform for performance-driven production workloads. In addition to the Red Hat Compatible Kernel (RHCK), Oracle supplies the optimized Unbreakable Enterprise Kernel (UEK), which was first developed to support highly scalable Oracle Engineered Systems. Support for Oracle Linux is affordable and the release is free to download and distribute, unlike other commercial Linux distributions. To add even greater value, Oracle bundles additional capabilities—Ksplice for zero-downtime kernel updates, support for Docker, Linux Containers, OpenStack, Oracle Clusterware for High Availability (HA), and more—at no additional charge with an Oracle Linux Premier Support contract. As a result of these additions, companies receive greater value from their Linux support investment, allowing IT organizations to achieve a higher return on investment (ROI).

This paper describes Oracle Linux 7 features that help IT organizations deploy strategic applications effectively and efficiently. It discusses the advantages of choosing Oracle Linux and how the operating system brings value to enterprise application delivery. It also explores versatile technologies that are supported with Oracle Linux (such as Linux Containers, Docker, Oracle VM, and OpenStack) that allow IT architects to choose how best to deploy and meet requirements for agile cloud and virtualized application environments.

## Lowering the Cost of Ownership

Oracle Linux can help to simplify IT operations and lower administrative and operational expenses. There are a number of ways in which Oracle Linux makes potential savings and efficiencies possible:

» Ksplice technology, which allows administrators to perform kernel patching without a reboot, is included with Oracle Linux Premier Support. Available for either kernel (RHCK or UEK), Ksplice allows administrators to apply kernel updates without interrupting application availability.

» Oracle Linux support contracts include access and support for add-on technologies—including systems management tools, high availability, and support for Docker and OpenStack—at no additional charge. Other commercial Linux vendors charge a significant uplift for these capabilities.

» Oracle Linux is free to download, use, and redistribute without a support contract.

» Customers can choose which systems to place under contract and freely download the same patches and errata—for unsupported systems as well as systems covered under contract.

» Oracle Linux support costs are much lower than support costs for other commercial Linux distributions.

Let's explore how each of these advantages adds value to Oracle Linux deployments.

## How Ksplice Simplifies Operations and Reduces Cost

In day-to-day IT operations, administrators tend to focus on two key responsibilities:

» Keeping systems and servers patched and up-to-date. As software problems and Common Vulnerabilities and Exposures (CVEs) are discovered and addressed, patches must be applied quickly to minimize risk of security exposure, data compromise, and unplanned outages.

» Troubleshooting user and developer problems as well as performance issues across the end-to-end stack.

When it comes to performing these tasks, Oracle Linux's Ksplice technology provides exceptional value. Available exclusively with Oracle Linux Premier Support, Ksplice applies kernel updates while a kernel and applications are running, without requiring a reboot or interruption. Ksplice makes it possible to apply critical security patches, kernel updates, and debugging kernels without the need to coordinate outages and take systems down. Administrators can use Ksplice with both the Unbreakable Enterprise Kernel as well as with the Red Hat Compatible Kernel. For existing Red Hat Enterprise Linux customers, Oracle even offers a 30-day free trial of Ksplice technology (see www.ksplice.com/rhel-signup).

### Using Ksplice for Zero Downtime Kernel Updates

When IT organizations take advantage of Ksplice, they can manage Linux environments with greater availability, increased security, and greater flexibility and control. When a kernel defect or security vulnerability is discovered, Oracle's support organization creates a new set of Ksplice kernel modules and makes them available on the Unbreakable Linux Network (ULN), the Oracle Linux support site.

Administrators can choose to automate the delivery and application of Ksplice kernel modules from ULN repositories. For Linux servers covered by Oracle Linux Premier Support, an updated kernel module can be automatically downloaded from the ULN site and applied, instantly overwriting the relevant portion of the running kernel without any disruption to facilitate a "rebootless" update. Administrators can also opt to apply Ksplice kernel changes manually (rather than automatically through ULN) and create private repositories by downloading module packages from the ULN site.

Other commercial Linux vendors release kernel patches as upgrades that can contain new device drivers and back-ported features. This can pose a problem for IT organizations that need to keep servers on a specific kernel release because of known software incompatibilities or conservative upgrade policies designed to preserve stability.

Recognizing these limitations*, Oracle develops Ksplice modules for every kernel of each given major distribution release*, beginning with the first Oracle Linux 5 update 4 kernel through the most recent Oracle Linux 7 kernel. This allows IT administrators to apply kernel updates that resolve critical problems and CVE security vulnerabilities without introducing device drivers and other features that aren't needed.

As an example, the base RHCK for Oracle Linux 5 update 4 was version 2.6.18-164.el5 with a build date of September 3, 2009. An administrator can run Ksplice on that kernel—which was first released more than five years ago—and apply every Ksplice kernel module released from 2009 to present. Ksplice can bring that kernel fully up-to-date while all of its applications continue to run, without any interruption.[1]

Using offline Ksplice repositories, administrators can opt to apply Ksplice kernel changes manually rather than in an automated manner through ULN. Using the Ksplice offline tools, an administrator can decide whether to upgrade to the latest kernel release or to an intermediate kernel version. In this way administrators can control Ksplice kernel updates and apply updates selectively to reach a specific kernel level.

### Ksplice for improved diagnostics and troubleshooting

Ksplice greatly simplifies diagnostics and troubleshooting since an administrator can swap in a modified kernel without a reboot. When a developer is troubleshooting a potential kernel problem, Oracle support often supplies a debugging kernel targeted specifically at gathering data about the issue. Ksplice dynamically applies the kernel module to the production system without a reboot. Not only can Ksplice apply a debugging kernel to help identify the issue's root cause but also it can install an Oracle support hotfix as a stopgap measure, along with the final errata release, all with zero downtime.

## Reducing Cost and Increasing Efficiencies

Clearly Ksplice is a significant advantage in improving uptime and reducing operational costs. From a business perspective, it can also minimize lost opportunity costs since administrators can apply security patches and updates while revenue-generating systems are still running. Oracle Linux can help organizations lower costs and achieve efficiencies in other ways, allowing companies realize greater value from their software and support investments.

### Greater Value from a Support Contract

Oracle offers two levels of high-quality, enterprise-class support—Basic and Premier—that provide excellent value. Both support levels include these capabilities at no additional charge:

- High Availability (HA) using Oracle Clusterware. For mission-critical applications that require HA—including Oracle Database and Oracle applications as well as other critical business applications—Oracle Clusterware supports application failover between cluster nodes. While other Linux vendors impose a substantial uplift for HA functionality, Oracle Clusterware is included with both the Basic and Premier Oracle Linux levels of support.
- Linux lifecycle management using Oracle Enterprise Manager 12*c*. While other commercial Linux vendors require an add-on at an additional cost to obtain Linux server management functionality, Oracle Linux support subscriptions include access to Oracle Enterprise Manager 12*c*. This is an intuitive management interface that controls Oracle Linux provisioning, patching, monitoring, administration, and configuration management.
- Support for Spacewalk. An Oracle Linux support contract also includes support for Spacewalk, the open-source community project that is the basis for solutions such as Red Hat Satellite Server and SUSE Manager. Customers with Oracle Linux support subscriptions have access to a fully supported Spacewalk build, which can help to simplify platform management during an Oracle Linux evaluation or migration.

1 See the blog "The magic of Ksplice" for more details and console output for this Ksplice example.

The Oracle Linux Premier Support level also includes access to Ksplice, XFS, support for patch back porting, and lifetime sustaining support. In addition, Premier Support also entitles customers to support for Docker and OpenStack (described later in this paper). Details on Oracle Linux support policies are available at oracle.com/us/support/library/enterprise-linux-support-policies-069172.pdf.

### Free to Download, Use, and Distribute

True to the open source philosophy, Oracle provides the Oracle Linux distribution as a free download. Anyone can download the binaries, installation media, and the source code at no charge—even without a support subscription. This applies to errata (bug fixes, security updates) as well, making Oracle Linux an ideal enterprise Linux distribution for both production and testing/development servers. For organizations that want to standardize on a single OS, this means that the same Oracle Linux distribution can be used across the enterprise, with the same patches and security updates. Because IT has the flexibility to deploy the operating system everywhere—whether or not servers carry a support contract—using Oracle Linux increases administrative simplicity and permits more cost-effective operations.

Oracle Linux binaries are freely available to download from edelivery.oracle.com/linux, the Oracle e-delivery site. No site or activation keys are required, allowing administrators to deploy new Oracle Linux servers on demand. Source code for Oracle Linux, including source for the UEK that Oracle optimizes for performance (especially for Oracle Database and Oracle applications), is also publicly available via the Oracle `git` repository (oss.oracle.com/projects).

### Choose Which Systems to Support

While support contracts are crucial for production servers that host business-critical application stacks, there are often many non-production enterprise systems, such as test and development systems, that don't truly require support. Oracle believes that IT should be able to selectively determine which Linux systems need support contracts and therefore makes Oracle Linux patches and security errata freely available on a public yum server (public-yum.oracle.com). No contract is needed to download and install updates from this site. This allows administrators to apply the exact same errata across all Oracle Linux systems in the enterprise, regardless of whether or not they are on support subscriptions. Oracle makes these updates available on the public yum server at the same time as it releases updates on the Oracle Unbreakable Linux Network (ULN), Oracle's access site for Linux support. In this way administrators can retrieve the exact same errata for both supported and unsupported systems. This approach is distinctively different than that of other commercial Linux vendors.

Under a support contract, customers receive access to Oracle's world-class support infrastructure with 24/7 Linux support in 145 countries worldwide. Support is assigned on a per-server basis, and is available for servers that run the Red Hat Compatible Kernel as well as the Unbreakable Linux Kernel. To simplify support engagements, Oracle also offers support for existing server configurations that host Red Hat Enterprise Linux as well as systems with Oracle Linux.

### Lower Software Support Costs

In comparison to support costs for other commercial Linux distributions, the price point for Oracle Linux support is significantly lower. The Oracle VM and Oracle Linux Cost Calculator tool contrasts potential support costs based on publicly available pricing data. By entering a system configuration (the number of sockets and virtual guests), a server quantity, and the term of the subscription (one or three years), the tool generates estimated support expenses. For one or two-socket server configurations (with unlimited virtual guests), Oracle also offers limited-version support contracts at discounted prices.

## Deployment Flexibility and Choice

Oracle Linux Ksplice is a clear benefit in keeping Tier 1 production applications up and running and reducing operational costs. To keep costs down and provision applications quickly, customers seek greater deployment agility, which is why many IT organizations are taking advantage of advances in virtualization and cloud computing technologies. Recognizing the need for deployment choice, Oracle provides Oracle Linux support for many flexible deployment scenarios including:

- Lightweight LXC Linux containers (available in UEK R3 on Oracle Linux 6 and Oracle Linux 7, and with the Oracle Linux 7 RCHK)
- Support for Docker application containers on UEK R3 (support is included with Oracle Linux Premier support)
- Support for hypervisor-based virtual machines in Oracle VM, ideal for virtualizing Tier 1 applications
- Support for OpenStack cloud deployments (OpenStack support is included with Oracle Linux and Oracle VM Premier support and is valid for either Oracle OpenStack or a third-party OpenStack distribution)
- Oracle Engineered Systems: pre-integrated and purpose-built solutions that incorporate Oracle Linux

### Linux Containers (LXC)

Linux Containers (LXC) can host multiple isolated Linux instances (called containers) on a single host. In contrast with hypervisor-based virtualization technologies like Oracle VM, Linux containers are lightweight and share a single kernel image (in contrast, a hypervisor-based virtualization technology such as Oracle VM is able to support different operating systems and different kernels as virtual guests).

Linux Containers can support a single application in a container (an *application container*) or a copy of the Linux operating system in a container (a *system container*) without the additional overhead of a hypervisor. A Linux system container shares the kernel with the host system, which gives the container access to the kernel's loaded modules and drivers. Linux applications generally run in user space and only call a stable set of system libraries to ask for kernel services. For this reason, it's possible to run Oracle Linux 5, Oracle Linux 6, and Oracle Linux 7 containers in parallel on the same system. An application will be compatible as long as it runs in user space and accesses only modules and drivers in the host kernel. In this way an Oracle Linux 6 application can run in a LXC container on an Oracle Linux 7 host, assuming the application doesn't use incompatible kernel modules or drivers.

Linux Containers provide an excellent mechanism for isolating an application process from other processes within a running Linux system. By using Linux kernel resource management and isolation features (Cgroups and namespaces), container processes have a private view of the operating system with their own process ID (PID) space, file system structure, and network interfaces. While containers share the host kernel and hardware resources, they can be constrained to use only a defined set of CPU, memory or I/O resources. By combining containers with other features like the Btrfs file system and Open vSwitch, administrators can quickly set up multiple lightweight isolated Linux instances on a host with a dedicated virtual network segment. The combination of Linux containers and the fast replication capabilities of Btrfs allow administrators to rapidly provision isolated application environments.

For more information on installing and configuring Linux Containers on Oracle Linux, refer to the Linux documentation (the Oracle Linux Administrator's Solution Guide for Oracle Linux 6 (docs.oracle.com/cd/E37670_01/E37355/html/ol_containers.html) or the Oracle Linux 7 Administrator's Guide (docs.oracle.com/cd/E52668_01/E54669/html/ol7-containers.html).

## Docker Technology

Docker is an open source project that enables the fast creation and distribution of application containers across Oracle Linux and other Linux systems. Docker runs a single application in a similar manner to LXC application containers—both technologies provide isolation from other running processes within a single physical system. Also similar to LXC, all Docker application containers execute system calls to the same underlying kernel. Oracle Linux customers that have the Premier level of support automatically receive support for Docker application containers deployed on Oracle Linux UEK R3 at no additional cost.

Docker consists of two parts: the Docker Engine (which packages and runs applications) and the Docker Hub Registry (which enables sharing of Docker images). Oracle publishes RPM packages with the Docker Engine for Oracle Linux 6 and Oracle Linux 7 UEK R3 on the public yum site (public-yum.oracle.com) and ULN. Docker images to deploy Oracle Linux are available on the Docker Hub Registry at registry.hub.docker.com/_/oraclelinux/. Oracle also makes MySQL images available on the Docker Hub Registry.

Docker's strength lies in its ability to capture the precise configuration of an application and its software dependencies into a virtual container that can then be deployed across any number of Linux servers. By using Docker, administrators can deploy application images rapidly, reliably, and consistently without software dependency and portability problems that often derail projects and delay time-to-production. Docker can be used effectively to deploy Linux containers across different machines, making Linux application containers portable. Btrfs provides highly efficient container storage in Docker since modified images can be written out quickly using the Btrfs file system's writable snapshot capability.

Use cases for Docker technology include (but aren't limited to) the following examples:

- Application isolation. As with Linux Containers, Docker enables application deployment in a lightweight, isolated environment. In conjunction with LXC containers, Docker takes advantage of Linux kernel features such as namespaces and Cgroups for resource management.
- Platform neutrality. Docker can help to mitigate issues surrounding application compatibility and server updates. An administrator can deploy a Docker image and support a new application that runs on an older host in a container.
- Rapid deployment. An administrator can install an application in a Docker container with Oracle Linux and save the modified container as an image that can be propagated rapidly. For example, by building an image that contains an Apache HTTP server on Oracle Linux, an administrator can deploy multiple web servers quickly, installing them rapidly across many Linux servers in a data center.
- Software development and testing. Docker is ideal for development environments where it's necessary to manage pipelines and test code in consistent, known software configurations. When a Docker image is captured and created, it contains the complete state of the environment, including installed packages and patches. Docker also enables version control capabilities that resemble `git` capabilities. Storing Docker images in cloud-based repositories (either publicly on the Docker Hub registry or in private internal registries) simplifies software distribution, helping to streamline provisioning.

Customers that choose to use Docker can deploy it on UEK R3 (with either Oracle Linux 6 or Oracle Linux 7), and it is fully supported by an Oracle Linux Premier Support agreement. In conjunction with Oracle Linux Premier Support, Docker deployments can also take advantage of Ksplice updates. By running a Ksplice update in the main Oracle Linux environment, for example, an administrator can easily apply the latest bug fixes and CVEs without impacting applications running across numerous Docker or LXC containers.

For more information, see the Oracle Linux 7 documentation about Docker at docs.oracle.com/cd/E52668_01/E54669/html/ol7-docker.html. Information about the Docker Hub repository and its contents is available at docs.docker.com/userguide/dockerhub/.

## Oracle VM for Hypervisor-Based Virtualization

Many production environments that deploy Tier 1 applications want the advantages of full hypervisor-based virtualization for application isolation, resource management, and high service levels. Oracle VM is Oracle's hypervisor-based virtualization technology and can support multiple guest operating systems (Oracle Linux, Oracle Solaris, Microsoft Windows, and other Linux distributions)—unlike the lightweight container technologies of LXC and Docker. The Oracle VM software (like Oracle Linux) is free to download and use. There are no licensing fees and customers pay only a low annual fee for enterprise-class support of selected servers.

Oracle VM is part of Oracle's end-to-end technology stack. Together with Oracle Linux, it is the most widely deployed application environment internally within Oracle, hosting more than 310,000 virtual machines across Oracle's development and public cloud data centers. In addition to broad internal use, Oracle conducts extensive testing of Oracle Database, Oracle Fusion Middleware, and Oracle applications using Oracle VM in virtualized deployments.

Oracle VM Templates accelerate Tier 1 application provisioning—both for customers and Oracle internally—allowing administrators to stand up complete Oracle application stacks reliably and repeatedly. Templates with complete applications built on Oracle Linux are available for Oracle Database (Real Application Clusters as well as single instance), Oracle E-Business Suite, Oracle PeopleSoft, JD Edwards EnterpriseOne, Oracle Fusion Middleware, and more. (See the complete list of available applications at oracle.com/technetwork/server-storage/vm/overview/templates-101937.html.)

## OpenStack Open Source Cloud Technology

Many IT organizations seek to evolve application provisioning and implement a cloud service delivery model that optimizes agility and data center resource use. OpenStack is open source software technology that provides an efficient means of deploying and managing cloud-based environments. OpenStack can control large pools of compute, storage, and networking resources across a data center, managing them through the OpenStack dashboard or the OpenStack API. It can connect components from different vendors and expose a consistent API regardless of underlying components like hypervisors, network devices, storage systems, and compute servers.

Oracle provides an OpenStack distribution that installs directly on top of Oracle Linux and Oracle VM and is supported for production environments. Available from the Oracle public yum site or the Unbreakable Linux Network, Oracle OpenStack is based on the OpenStack Icehouse release. It allows customers to easily take advantage of the efficiency, performance, scalability, and security of Oracle Linux and Oracle VM, simplifying the deployment of private cloud environments. A typical production cloud implementation installs the OpenStack control node on an Oracle Linux instance and uses Oracle VM to replicate OpenStack compute nodes across multiple servers. The OpenStack compute nodes can then host any guest operating system supported on Oracle VM—Oracle Linux, Oracle Solaris, Microsoft Windows, and other Linux distributions.

For customers that have Oracle Linux Premier Support or Oracle VM Premier Support, support for OpenStack is included at no additional cost. Oracle gives customers a choice of which OpenStack technology they want to deploy—under an Oracle Linux or Oracle VM Premier Support agreement, Oracle supports Oracle OpenStack or any third-party OpenStack distribution. Since Oracle includes OpenStack support with these support contracts, customers can make a single phone call to Oracle and receive support across an end-to-end cloud deployment.

## Oracle Engineered Systems

Many IT departments want to standardize on Linux and build an infrastructure using Linux Containers, Docker, hypervisor-based virtualization, and OpenStack. As discussed, Oracle Linux is a compatible and unifying technology

given any of these deployment approaches. Some organizations, however, prefer to avoid the cost and complexity of designing and implementing IT infrastructure themselves, and look to Oracle to provide optimized infrastructure for Oracle database, middleware, and application workloads. For these customers, Oracle develops and validates purpose-built Oracle Engineered Systems.

Oracle Engineered Systems accelerate time-to-production and take the guesswork out of building IT infrastructure. These systems incorporate state-of-the-art Oracle hardware and software components and are configured according to best practices for a specific workload. Each Oracle Engineered System is fully validated and optimized for performance, scalability, and high service levels.

Oracle Linux is a core technology in all x86-based Oracle Engineered Systems, and is either the base operating system or a key component, as follows:

- **Oracle Virtual Compute Appliance.** This appliance is a turnkey converged infrastructure solution that integrates Oracle VM with compute, network, and storage resources in a software-defined fabric. It supplies a production-ready infrastructure that scales easily from 2 to 25 compute nodes per rack. In conjunction with Oracle VM Templates, this engineered system allows administrators to provision production-ready applications across VMs in a matter of minutes. Oracle Linux can be used as the operating system for virtual guests and Oracle Linux Premier Support is included at no additional charge with Oracle Premier Support for Systems.
- **Oracle Database Appliance.** The Oracle Database Appliance is an entry-level, 2-node database appliance that pre-integrates Oracle RAC, Oracle Linux, Oracle VM, x86 servers, storage, and networking. It is a fully integrated system that delivers highly available, optimized database services for online transaction processing (OLTP) and data warehousing applications.
- **Oracle Exalogic Elastic Cloud.** This Oracle engineered system integrates compute, network, and storage components with Oracle VM virtualization, providing a high-performance infrastructure on which to deploy Oracle business applications, Oracle Fusion Middleware, or other software products. Oracle VM is tightly integrated with the I/O backplane using a technique called Single-Root I/O Virtualization (SR-IOV). SR-IOV allows the same InfiniBand I/O adapter to be shared by up to 63 virtual machines, eliminating overhead and delivering exceptional application performance.
- **Oracle Exalytics In-Memory Machine**. Built using best-in-class hardware, market-leading business intelligence software, and in-memory Oracle Database technology, Oracle Exalytics is an optimized system that provides speed-of-thought analysis with unmatched intelligence, simplicity, and manageability. It is designed specifically for applications that perform business intelligence, modeling, forecasting, and planning.
- **Oracle Exadata Database Machine.** Oracle Exadata features a scale-out design with industry-standard x86 servers and intelligent storage that includes state-of-the-art flash technology and a high-speed InfiniBand internal fabric. It provides extreme performance and availability for Oracle Database workloads—for both OLTP and data warehousing—making it an ideal platform for large-scale database consolidation.

When Oracle Exadata and Oracle Exalogic were first introduced, Oracle created the Oracle Linux UEK to provide a modern high-performance Linux kernel for these engineered systems. Today the UEK is still the kernel of choice for x86-based Oracle Engineered Systems because it is optimized to scale as the number of CPUs, memory, and InfiniBand connects increase. The Oracle Linux team collaborates in ongoing engineering efforts with their counterparts in Oracle Engineered Systems, enhancing the Oracle Linux UEK and optimizing performance, especially in the areas of scalability, memory management, and Infiniband.

## Unbreakable Enterprise Kernel

Oracle tests the Oracle Linux UEK extensively with Oracle workloads, recommending it for Tier 1 Oracle applications and other mission-critical workloads. Internally Oracle deploys the UEK exclusively for its build and QA systems for Oracle Database and other Oracle software products. Furthermore, since it offers optimized performance, the UEK is used in all Oracle Linux benchmarks.

In addition to testing on Oracle hardware and engineered systems, the UEK is certified with many third-party hardware systems, including systems from HP, Dell, Cisco and Lenovo. As a matter of fact, Oracle publishes a Hardware Certification List (HCL) for Oracle Linux and Oracle VM that lists third-party systems on which these products are certified.

The latest version of the Unbreakable Enterprise Kernel (Release 3) is based on the 3.8 mainline Linux kernel. It includes optimizations developed in collaboration with Oracle's database, middleware, and hardware engineering teams to ensure stability and performance for the demanding enterprise workloads. These features—including Linux Containers, Btrfs, DTrace, and more—can be used across multiple major releases (for example, by running the UEK on Oracle Linux 6.4 and later as well as on the current Oracle Linux 7 release). Appendix A describes the features and enhancements that are part of the UEK R3 release and available in Oracle Linux 7:

- Btrfs File System
- DTrace Dynamic Tracing Framework
- Latest Infiniband Stack (OFED) 2.0
- Receive/Transmit Packet Steering and Receive Flow Steering
- Advanced support for large NUMA systems
- I/O affinity
- Improved asynchronous writeback performance
- Task Control Groups
- Hardware fault management
- Power management features
- Data integrity features
- Oracle Cluster File System 2 (OCFS2)

## Achieving Fast and Reliable Deployments with Less Risk

Oracle invests significantly in testing Oracle Linux with Oracle database, middleware, and application workloads, making it an ideal foundation for all enterprise deployments. Because of the extensive testing that Oracle Linux receives running Oracle applications, the operating system can provide the scalability, stability, and resiliency needed to support both Oracle and non-Oracle mission-critical workloads.

Packages released by Oracle as part of Oracle Linux undergo a long testing cycle that includes the routine testing of the full software stack with the help of the Oracle Linux Test Kit (oss.oracle.com/projects/olt/) and other test suites to ensure that the underlying operating system behavior is correct in all circumstances. Oracle's industry-leading QA team has worked with internal teams as well as strategic ISVs and customers for many years. This depth of experience has helped build an extensive and ever-growing test matrix of real-life workloads. Formal QA testing for Oracle Linux, of course, is in addition to the more than 128,000 compute hours per day that the operating system undergoes running Oracle workloads internally within Oracle itself.

Oracle invests in helping enterprises deploy Oracle Linux quickly and with greater confidence. For this reason Oracle has developed Oracle Linux pre-installation packages that resolve software dependencies for common Oracle software deployment scenarios. For example, to optimize security for a database configuration, an administrator can install a minimized Oracle Linux configuration and install the Oracle Database 11*g* or 12*c* pre-installation RPM as follows, before installing the database software:

```
# yum install oracle-rdbms-server-11gR2-preinstall
```
(for Oracle Database 11*g*)

```
# yum install oracle-rdbms-server-12cR1-preinstall
```
(for Oracle Database 12*c*)

Pre-installation RPMs are also available for Oracle E-Business Suite and the Oracle Enterprise Manager 12*c* agent.

Oracle also offers the Oracle Linux and Oracle VM Validated Configuration Program to validate Oracle software configurations that integrate complementary, third-party components and technologies. Oracle partners (such as AMD, Brocade, Cisco, Dell, EMC, Emulex, Fujitsu, HP, IBM, Intel, Microsoft, NetApp, QLogic, and others) take advantage of the program to validate and document Oracle Linux and Oracle VM configurations and publish best practice guidelines. The result is more reliable Oracle Linux and Oracle VM configurations that can be deployed rapidly with lower implementation costs. For more information, visit oracle.com/technetwork/topics/linux/validated-configurations-085828.html.

## Conclusion

Oracle is the only vendor in the industry that offers a complete Linux-based solution stack—applications, middleware, database, management tools, operating system and hardware—along with a single point of support. Customers that deploy Oracle Linux benefit greatly from the latest Linux innovations as well as rigorous testing with real world workloads.

As this paper describes, IT organizations that standardize on Oracle Linux have a number of deployment options from which to choose. With the advent of new advances in open source technologies, IT departments can deploy applications more quickly using lightweight Linux Containers and Docker images, or combine these approaches to improve application isolation, resource control, and rapid provisioning. Traditional virtualization using Oracle VM can be an optimal approach for Tier 1 applications or when application requirements dictate the need for multiple operating systems. To deliver applications as private cloud services, Oracle OpenStack technology may be an ideal approach in conjunction with Oracle VM.

In any of these deployment scenarios, Oracle Linux can add value through its optimized performance and scalability and the ability to perform seamless, zero-downtime upgrades with Ksplice. As the number of application environments expands across data centers, managing them on a day-to-day basis becomes a greater administrative challenge and expense. Customers that have Oracle Linux Premier Support contracts can use Ksplice to help keep their critical application environments—whether using containers, VMs, or OpenStack compute nodes—updated with the latest security errata and bug fixes, without interruption. And Oracle's comprehensive support—providing support for Docker and OpenStack as a part of Oracle Linux Premier Support—helps IT organizations innovate and evolve cost-effectively while building a new generation of agile application solutions.

Get started with Oracle Linux by downloading the software at edelivery.oracle.com/linux. Contact your Oracle representative or visit www.oracle.com/linux (or the references below) to learn more.

## References

| TABLE 1. RESOURCES FOR MORE INFORMATION | |
|---|---|
| **Web Resources** | **Web URL** |
| Oracle Linux Home Page | oracle.com/us/technologies/linux |
| Oracle Linux Download | edelivery.oracle.com/linux |
| Oracle Public Yum server | public-yum.oracle.com/ |
| Oracle Linux Source | oss.oracle.com/git |
| Oracle Linux Blogs | blogs.oracle.com/linux/ |
| Oracle Linux 7 Documentation | docs.oracle.com/cd/E52668_01/index.html |
| Oracle Linux Cost Calculator | oracle.com/us/media/calculator/linuxtco/ |
| Hardware Certification List (HCL) for Oracle Linux and Oracle VM | linux.oracle.com/hardware-certifications |
| **Webcasts and Podcasts** | **Web URL** |
| Building the Modern Cloud-Enabled Data Center with Oracle Linux 7 | w.on24.com/r.htm?e=877873&s=1&k=771B677E7446BAFCBC53A2B654A93719 |
| Oracle Linux 7 Q&A with Wim Coekaerts | streaming.oracle.com/ebn/podcasts/media/20209545_Oracle-Linux-7.mp4 |
| Spacewalk and Ksplice: Keeping Oracle Linux Systems Up to Date and Secure | w.on24.com/r.htm?e=877877&s=1&k=44834EA17D303C812AE38EA6EE567A63 |
| **White papers** | **Web URL** |
| "Oracle Linux: Maximize Value, Minimize Cost" | oracle.com/us/technologies/linux/linux-max-value-min-cost-wp-2209610.pdf |
| "Ksplice: Zero Downtime Updates for Oracle Linux" | oracle.com/us/technologies/linux/ksplice-datasheet-487388.pdf |
| "Ksplice Offline" | oracle.com/us/technologies/linux/ksplice-offline-updates-ds-1898638.pdf |
| "Oracle Linux Management with Oracle Enterprise Manager 12*c*" | oracle.com/us/technologies/linux/linux-with-enterprise-manager-1959006.pdf |
| "Oracle Clusterware for Oracle Linux" | oracle.com/technetwork/database/database-technologies/clusterware/overview/clusterware-for-linux-088663.html?ssSourceSiteId=ocomen |
| "What Makes Oracle Linux the Best Platform for Oracle Database 12*c*" | oracle.com/us/technologies/linux/linux-for-oracle-database-wp-2068570.pdf |

## Appendix A: UEK R3 Features

### Btrfs File System

Btrfs (B-tree file system) is a next-generation file system for Linux. Pronounced as “Butter FS” or “B-tree FS”, it is a GPL-licensed file system first developed by Oracle’s Chris Mason in 2007. Today, its development is still coordinated by Chris Mason in collaboration with many contributors from the Linux community. Btrfs provides a number of features that make it a very attractive file system solution for local disk storage. Oracle is committed to making Btrfs the most reliable and feature-rich file system for Linux.

Btrfs is designed for:

» Large files and file systems from the ground up
» Simplified administration
» Integrated RAID and volume management
» Snapshots
» Checksums for data and meta-data

### DTrace Dynamic Tracing Framework

Both UEK R3 and the Oracle Linux 7 RHCK support the Integration of the DTrace Dynamic Tracing Framework. DTrace is a comprehensive dynamic tracing framework that was initially developed for the Oracle Solaris operating system. DTrace provides a powerful infrastructure to permit administrators, developers, and service personnel to concisely answer arbitrary questions about the behavior of the operating system and user programs in real time.

DTrace support is integrated with UEK R3 and includes user-space statically defined tracing (USDT) probes in user-space executables and libraries. For more information, refer to Oracle Linux 7 Dynamic Tracing Guide at docs.oracle.com/cd/E37670_01/E38608/html/index.html.

### Latest Infiniband Stack (OFED) 2.0

OpenFabrics Enterprise Distribution (OFED) implements Remote Direct Memory Access (RDMA) and kernel bypass mechanisms to deliver high-efficiency computing, wire-speed messaging, ultra-low microsecond latencies and fast I/O for servers, block storage and file systems. This also includes an improved RDS (reliable datagram sockets) stack for high-speed, low-latency networking. As an Infiniband Upper Layer Protocol (ULP), RDS is used to send IPC datagrams (up to 1MB) reliably, and is used currently in Oracle RAC and Oracle Exadata/Oracle Exalogic products.

### Receive/Transmit Packet Steering and Receive Flow Steering

Overall networking performance has been improved—especially at high loads—because of support for receive/transmit packet steering (RPS/XPS).

Receive packet steering (RPS) distributes the load of received network packet processing across multiple CPUs, helping to make sure that the same CPU core handles packets for a specific IP address/port combination. RPS allows protocol processing (e.g., IP and TCP) to be performed on packets in parallel and circumvents performance penalties that can occur due to cacheline bouncing. This enhancement removes a potential bottleneck that can occur if network interrupt processing saturates a single CPU core. This feature has been back-ported into the Unbreakable Enterprise Kernel Release 1 (2.6.32) from the mainline Linux 2.6.35 kernel, and is included by default in the second release of the Unbreakable Enterprise Kernel (2.6.39). To enable RPS, a CPU mask is required in

/sys/class/net/xxx/queues/rx-0/rps_cpus where xxx is the interface name. The CPU mask takes the same form as the masks for the taskset command, for example:

```
echo 0x55 > /sys/class/net/eth0/queues/rx-0/rps_cpus
```

Transmit packet steering (XPS) is the counterpart to RPS on the transmit side. Where RPS selects a CPU based on the receive queue, XPS selects a transmit queue based on the CPU. Each transmit queue can be associated with a number of CPUs which will use the queue to send packets. This is configured as a CPU mask on a per queue basis in /sys/class/net/eth<n>/queues/tx-<n>/xps_cpus.

Receive Flow Steering (RFS) can be considered the second stage of receive packet steering. Developed by Tom Herbert at Google, RFS is an extension of RPS that makes sure that the parallel processing of network packets is done in a coordinated fashion. Instead of performing an IP/Port match, RFS does an application match, directing the flow of traffic to a specific application. If an application issues system calls that trigger network packets to be sent and received, its footprint is logged to the CPU currently executing and incoming application packets are directed to the same CPU, taking advantage of CPU locality to improve performance. The RFS approach is more directed than RPS alone. Together with RPS, RFS can yield tremendous performance improvements—internal Oracle tests, for example, have shown 50% faster IP results over Infiniband on a two-socket system.

### Advanced Support for Large NUMA Systems

The Unbreakable Enterprise Kernel includes a number of additional patches to significantly improve performance on NUMA systems with many CPUs and cores. These include:

- A patch to list message signaled interrupts (MSI) for each device in the sysfs file system. Before, when MSI-X mode was enabled for a PCI device, there was no entry in sysfs that displayed the IRQs. The interrupts were only displayed in /proc/interrupts, but it was impossible to determine what interrupts were used by a device when there were multiple identical system devices. With the help of a modified irqbalance utility, this helps to keep IRQs on NUMA-local CPUs.
- Reduced runqueue lock contention by making improvements around IPC semaphores. This patch tries to reduce runqueue lock contention by ordering wakeups for the CPU that the waiting process was on when it went to sleep.

### I/O Affinity

This is a feature in the block layer for controlling the I/O completion CPU of either all requests on a queue, or on a per-request basis. A sysfs variable (rq_affinity) is exported which, if set, migrates request completions to the CPU that originally submitted the request. This can have a fairly large impact on performance, especially for large NUMA machines. I/O affinity is turned on by default, but it can be controlled via the tunable in /sys/block/xxx/queue/rq_affinity. For example, to enable I/O affinity:

```
echo 1 > /sys/block/sda/queue/rq_affinity
```

## Improved Asynchronous Writeback Performance

The process of writing out "dirty" (modified) memory from the Linux kernel page cache to the disk is called "writeback". It is performed by the `pdflush` kernel thread, based on configurable values defined in `/proc/sys/vm`. Depending on the amount of data and the storage sub-systems involved in this activity, the previous implementation had some drawbacks. Oracle engineers developed a new flushing system that addressed these deficiencies and improved performance for various workloads by implementing these changes:

» Per-device asynchronous dirty page writeback. The `pdflush` subsystem was replaced with dedicated threads on a per-device basis. This allowed buffered writeback to scale to much faster storage.

» Per-device buffered write accounting. The accounting for dirty pages was reorganized, removing stalls and inefficient writeback when devices of different speeds were mixed together.

## Task Control Groups

Task Control Groups (TCG) can track and group processes into user-defined control groups (Cgroups) so that the operating system can treat them as whole and perform scheduling, accounting, and resource allocation accordingly. For example, using TCG, an administrator can associate a set of CPU cores and memory nodes to a group of processes that make up an application or group of applications. This permits the creation of resource subsets in larger systems and enables fine-grained control over memory, CPUs, and devices while isolating applications.

## Hardware Fault Management

Hardware fault management helps to avoid system crashes and improve application uptime. Oracle Linux includes support for Advanced Error Reporting. The AER kernel driver allows the kernel to gather error information from PCI Express devices if errors occur and reports these errors to an administrator who can perform error recovery actions. When an error occurs, the driver captures the error and a message is printed on the console or to a log file.

Machine Check Exception (MCE) is a feature of AMD/Intel 64-bit systems which is used to detect an unrecoverable hardware problem. MCE can detect:

» Communication errors between a CPU and motherboard

» Memory errors, e.g., ECC problems

» CPU cache errors

The `mcelog` daemon handles MCE events on x86-64 machines running Oracle Linux. It accounts and logs CPU and memory errors, supports triggers on error thresholds, and can predictively offline memory pages and CPUs based on error trends. It should be run regularly as a `cron` job on any x86-64 Linux system. The `mcelog` package is included in the distribution and adds an hourly `cron` job to `/etc/cron.hourly/mcelog.cron` on installation to check for new MCEs. If `mcelog` locates a MCE, a log message will be written to `/var/log/mcelog`. This is useful for predicting server hardware failures before an actual server crash occurs.

## Power Management Features

The Unbreakable Enterprise Kernel is tickless. In the tickless kernel, timer interrupts are performed on demand rather than at a predetermined frequency. This allows the CPUs to stay in a low power state when the system is idle, reducing overall power consumption.

By supporting Aggressive Link Power Management (ALPM), SATA links to disks that are currently idle are put into a low-power mode on SATA controllers that support the AHCI specification. The controller automatically puts the link back into the active power state when new I/O requests are scheduled.

## Data Integrity Features

T10 Protection Information (T10-PI) enables applications or kernel subsystems to attach metadata to I/O operations, allowing devices that support T10-PI to verify integrity before passing them further down the stack and physically committing them to disk. Data Integrity Extensions or DIX is a hardware feature that enables exchange of protection metadata between host operating system and HBA and helps to avoid corrupt data from being written, allowing a full end-to-end data integrity check.

## Oracle Cluster File System 2 (OCFS2)

Oracle Linux includes full support for the Oracle Cluster File System (OCFS2), an open source cluster file system included in the mainline Linux kernel. The Unbreakable Enterprise Kernel R3 includes OCFS2 version 1.6 with these new features:

- JBD2 support
- Extended attributes
- POSIX ACLs
- Security attributes
- Metadata checksums
- Indexed directories
- REFLINKs

For more details, see the Oracle Linux Administrator's Guide for Release 7 at docs.oracle.com/cd/E52668_01/E54669/html/index.html or the OCFS2 project documentation at oss.oracle.com/projects/ocfs2/documentation/.

## Latencytop

Latencytop helps to identify where latency in the system is affecting the performance of an application. It is included in Oracle Linux to help locate a resource that is either busy or non-responsive. For more information about this utility, please see blogs.oracle.com/devpartner/entry/whats_new_in_oracle_linux_part_2_latencytop.

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