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## An Overview of Oracle Solaris 10 Security Controls

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## Introduction

The purpose of this document is to extend upon the foundation of security recommendations provided by the [Oracle Solaris 10 security benchmark \(v5.0.0\)](#) published by the Center for Internet Security (CIS). The CIS Solaris 10 Security Benchmark is predominantly written as a (Level 1) “how to” guide for organizations wanting to rapidly harden their Oracle Solaris 10 configurations. As such, it does not include content or recommendations focused on the security controls found in Oracle Solaris 10 that fall outside of the area of system hardening and security configuration validation.

This document complements the CIS Solaris 10 Security Benchmark by providing a more complete overview of the security features and capabilities found in Oracle Solaris 10, including those that were not appropriate for the CIS guide. Specific recommendations and references for more detailed information are provided wherever possible.

This document has been created as a companion to the Solaris 10 Security Benchmark for Solaris 10 10/09. While many of the controls discussed in this document were available in earlier updates to the Solaris 10 Operating System, some of the functionality discussed may not be present in those older versions.

This document is divided into two discrete sections:

- Installation Considerations. This section discusses security issues and options that must be understood prior to the initial installation of Oracle Solaris 10. Actions taken as a result of these recommendations will often be applied during the software installation process.
- Configuration Considerations. While the default implementation of Oracle Solaris provides a very robust security configuration, organizations are encouraged to tailor the software based upon their specific requirements, threat profiles and use cases. This section covers a selection security controls and topics that are not implemented by default in Oracle Solaris 10. These capabilities can be implemented or configured post-installation to improve upon the default security posture of the system.

## Change Log

TABLE 1. CHANGE LOG

DATE	VERSION	AUTHOR	DESCRIPTION
08/15/11	2.1	Glenn Brunette	Updated URLs.
03/17/2010	2.0	Glenn Brunette	Updated to include support for Solaris 10 5/08, Solaris 10 10/08, Solaris 10 5/09 and Solaris 10 10/09. Changes included support for ZFS root file systems, ZFS per-user and per-group quotas, ZFS delegated administration, and ZFS command history. Further, additional technical edit and cleanup, URL updating, etc. was completed to ensure content is still accurate. Removed management considerations as the content was either covered in the CIS Security Benchmark or outdated.
09/25/2007	1.0	Glenn Brunette	Initial version that includes support for Solaris 10 03/05, Solaris 10 1/06, Solaris 10 6/06, Solaris 10 11/06 and Solaris 10 8/07.

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In addition, Oracle would also like to thank the following organizations for their contributions, support and feedback without which this document would not have been possible:

- Center for Internet Security (CIS): <http://www.cisecurity.org/>
- U.S. Defense Information Systems Agency (DISA): <http://www.disa.mil/>
- U.S. National Institute of Standards and Technology (NIST): <http://www.nist.gov/>
- U.S. National Security Agency (NSA): <http://www.nsa.gov/>

## Installation Considerations

The purpose of this section is to discuss security issues present prior to and during the initial installation of an instance of Oracle Solaris. Careful consideration of these issues is recommended in order to avoid having to reinstall the operating system. Post-installation considerations and recommendations are covered in the section titled [Configuration Considerations](#).

### Disk Partitioning

With the introduction of ZFS-based root file systems, the nature of disk partitioning has changed. Previously, with UFS-based root file systems, administrators had to define a disk partitioning layout prior to installation. This layout created a number of disk partitions each having its own allotment of disk space. Such hard constraints are no longer necessary with the introduction of ZFS. When ZFS is chosen as the root file system, several data sets will be automatically created from a default ZPOOL (i.e., `rpool`). The only configuration choice asks whether to keep `/var` on a separate data set from the root file system. If additional data sets are desired, they must be created post-installation.

The guidance described below was originally developed for UFS-based root file systems where hard disk partitioning played a more prominent role. The concepts, however, apply equally to ZFS-based root file systems (where the notion of disk partitions is replaced by ZFS data sets and the notion of hard space limits is replaced with ZFS quotas and reservations).

While there is no single recipe for defining disk partitioning and file system layout, there are a number of considerations that should be taken into account in order to produce a configuration that is more likely to meet an organization's specific requirements. For example:

- How will the system and any running applications be impacted if the available space in a file system is exhausted?
- Does a specific application, data set or directory require special treatment? Should it be mounted read-only, for example? Are programs, `set-uid` or otherwise, permitted to be run from that location?
- Is there a need to ensure that specific users or services use only a specified amount of storage under a given file system?
- Are there differing administrative requirements for a given file system and its content?

The list goes on and on. The answers to each of these questions may require the use of a specific file system layout (e.g., placing applications and data on separate file systems), mount options (e.g., read-only, do not honor set-id bit, do not honor executable bit, require quota, etc.), or administrative practices. Nowhere is this more critical than when working with security relevant directories, data and services.

For example, if a mail server were configured to have a single UFS or ZFS root file system (that combines `/usr`, `/var`, `/opt`, etc.), then that system could be significantly impacted if the volume of incoming messages caused that combined file system to become full. In addition to not being able to receive new messages, audit records and log messages generated by the system would not be able to be recorded either. Given the importance of auditing and log information, organizations often require that they be stored on separate partitions with a dedicated amount of disk space. The same case could occur if audit information was on a partition that included a world writable file. In this case, a malicious user could use all of the available space causing audit records to be lost.

Additionally, disk space set aside for users and often applications is kept separate from partitions designated for the operating system. This too is done in order to help ensure that the operating system or application is not impacted should a user or other application consume all of the available space on a file system since it is often not predictable how an application will behave when confronted with this kind of failure.

As a general recommendation, organizations may want to consider making `/var`, `/var/mail` (if system is a mail server), `/var/audit` (if Solaris auditing is configured), `/opt`, and `/export` (if used for applications or home directories) separate UFS file systems (or ZFS data sets) in order to mitigate the risk of issues such as those discussed above. When using ZFS data sets associated with the same underlying ZFS pool, it is important that quotas and reservations (discussed below) be properly implemented to constrain disk utilization across the ZFS pool. As with any recommendation, organizations are strongly encouraged to evaluate their own requirements and situation to determine the applicability of the recommendation before taking action.

In addition to deciding how to partition disks and create file systems, organizations should also consider how those file systems will be mounted and used on their systems. More information on additional capabilities such as quotas and mount options can be found in the section [File System Security](#).

## Software Installation Clusters

An Oracle Solaris system is installed using one of the Oracle provided (and supported) installation mechanisms (e.g., Graphical or Console Installer, JumpStart, etc.) This initial information must be based upon one of the Oracle provided (and supported) software installation clusters (i.e., metaclusters). The following is the list of available metaclusters in Oracle Solaris 10:

**TABLE 2. AVAILABLE METACLUSTERS**

METACLUSTER	DESCRIPTION
Reduced Networking SUNWCrnet	Contains the packages that provide the minimum code that is required to boot and run an Oracle Solaris system with limited network service support. The Reduced Network Support Software Group provides a multiuser text-based console and system administration utilities. This software group also enables the system to recognize network interfaces, but does not activate network services.
Core SUNWCreq	Contains the packages from the Reduced Networking Software Group plus those that provide the minimum code that is required to boot and run a networked Oracle Solaris system.
End User SUNWCuser	Contains the packages from the Core Software Group plus those that provide the minimum code that is required to boot and run a networked Oracle Solaris system and the Java Desktop System (CDE and GNOME).
Developer SUNWCprog	Contains the packages for the End User Software Group plus additional support for software development. The additional software development support includes libraries, include files, man pages, and programming tools. Compilers are not included.
Entire SUNWCall	Contains the packages for the Developer Solaris Software Group and additional software that can be useful for some server deployments.
Entire + OEM SUNWCXall	Contains the packages for the Entire Solaris Software Group plus additional hardware drivers, including drivers for hardware that is not on the system at the time of installation.

For more information on Oracle Solaris software installation clusters, see the *Installation Guide: Basic Installations* for Oracle Solaris 10:

<http://download.oracle.com/docs/cd/E19253-01/index.html>

It should be mentioned that organizations should choose the software installation cluster that most closely aligns with their specific requirements – noting that individual software packages and clusters can be added or removed as necessary. There are times, however, when organizations want to more substantively customize the installation of Oracle Solaris. For this, see the [Minimization](#) section. When selecting an appropriate Oracle Solaris software installation cluster, be sure to take into account support requirements as some software packages may require specific installation clusters in order to qualify as a supported configuration.

## Minimization

The term minimization as applied to operating system installation goes back many years although there has often been some debate over its true meaning. In order to provide a clear discussion of this topic, the following definitions will be provided:

- **Reduced Installation.** A reduced installation (or reduced software installation) is an Oracle Solaris configuration created by installing fewer than all of the software packages delivered by Oracle Solaris. This includes installations that are based on any software installation cluster that is not SUNWCXall as well as any configuration where individual software packages or clusters have been removed.
- **Minimal Installation.** A minimal installation is a special case of a reduced installation whereby the only software packages that are installed (or remain) are those that directly contribute to the operational, management or support requirements of the system. All unnecessary software is removed (or not installed in the first place). Minimal installations are highly dependent on the actual hardware and software configuration being used (including any Oracle and third-party software and devices).

For purposes of comparison, the following chart illustrates the differences between each of the default Oracle Solaris installation clusters with respect to size, number of packages as well as number of `set-uid` and `set-gid` programs. This information was collected from a system running Oracle Solaris 10 10/09:

TABLE 3. DIFFERENCE BETWEEN DEFAULT SOLARIS INSTALLATION CLUSTERS

SOFTWARE INSTALLATION CLUSTER	SIZE	# PACKAGES	# SET-UID FILES	# SET-GID FILES
Reduced Networking SUNWCrnet	538M	157	31	12
Core SUNWCrreq	573M	216	38	13
End User SUNWCuser	2.8G	791	68	20
Developer SUNWCprog	3.5G	1041	69	20
Entire SUNWCXall	3.5G	1098	83	21

Regardless of the actual approach taken, reduced or minimal installations are supported only if they comply with the requirements defined in article ID 1011286.1 (which can be found at <https://support.oracle.com/CSP/ui/flash.html>). Also see “Recommendations for Creating Reduced or Minimal Oracle Solaris Configurations” at <http://www.oracle.com/technetwork/articles/servers-storage-admin/o11-070-minimal-solaris-485313.html>.

In addition, Oracle has published a number of articles and documents related to this topic. While many were developed for older versions of the Solaris OS, their approach remains valid even if the specific list of packages or dependencies has changed. For example:

- Blog: “Foundation for Minimal Solaris 10 Systems”:  
[http://blogs.oracle.com/gbrunett/entry/foundation\\_for\\_minimal\\_solaris\\_10](http://blogs.oracle.com/gbrunett/entry/foundation_for_minimal_solaris_10)
- Archived Oracle technical papers:  
“Part I: Minimizing Domains for Sun Fire V1280, 6800, 12K and 15K Systems”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-005-minimizing-domains-p1-438967.pdf>  
“Part II: Minimizing Domains for Sun Fire V1280, 6800, 12K and 15K Systems”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-006-minimizing-domains-p2-438969.pdf>

“Minimizing the Solaris Operating Environment for Security: Updated for the Solaris 9 Operating Environment”: <http://www.oracle.com/technetwork/server-storage/archive/a11-023-minimizing-sol9-oe-security-440782.pdf>

In addition, an open-source tool called the Solaris Package Companion has been made available by the OpenSolaris Install Community. This tool can be used to ask interesting questions about an operating system distribution including:

- What clusters or packages are contained in a given metacluster?
- What packages are contained in a given cluster?
- What metacluster or cluster contains a given package?
- On what other packages does a given package or cluster depend?
- Which packages depend on a given package?

Answers to these and many other questions are essential for organizations wanting to build reduced or minimal configurations. For more information on the Solaris Package Companion tool as well as examples of typical usage, see:

[http://hub.opensolaris.org/bin/view/Project+svr4\\_packaging/package\\_companion](http://hub.opensolaris.org/bin/view/Project+svr4_packaging/package_companion)

## Configuration Considerations

Every organization has its own security policies, standards, and requirements. As a result, there is often no single answer as to how a system should be configured. The goal of this section is to amplify the general recommendations made in the CIS Solaris 10 Security Benchmark while at the same time providing an overview of additional security features and capabilities available in Oracle Solaris 10. Where appropriate, specific recommendations will also be provided.

### Non-Executable Stacks

The concept of non-executable stacks has been introduced earlier in the CIS Solaris 10 Security Benchmark in the section called “Enable Stack Protection.” The goal of this section is to provide some additional information for those looking to implement this feature on SPARC, Intel and AMD platforms as well as to provide specific guidance for developers of software that may want to enable this feature in their software by default. A three-part series of blog articles has been devoted to this subject matter and can be found at:

- Part 1: [http://blogs.oracle.com/gbrunett/entry/solaris\\_non\\_executable\\_stack\\_overview](http://blogs.oracle.com/gbrunett/entry/solaris_non_executable_stack_overview)
- Part 2: [http://blogs.oracle.com/gbrunett/entry/solaris\\_non\\_executable\\_stack\\_continued](http://blogs.oracle.com/gbrunett/entry/solaris_non_executable_stack_continued)
- Part 3: [http://blogs.oracle.com/gbrunett/entry/solaris\\_non\\_executable\\_stack\\_concluded](http://blogs.oracle.com/gbrunett/entry/solaris_non_executable_stack_concluded)

This capability was introduced as a global kernel configuration parameter in the Solaris 2.6 operating system and has been used as a workaround to mitigate the risk of quite a few vulnerabilities in the past. That said, this will not prevent all types of buffer overflow exploits. For example, see:

<http://seclists.org/bugtraq/1999/Mar/0004.html>

Oracle takes a “defense in depth” approach to mitigating these issues, including architectural (design) and code level reviews of privileged code, the reduction of privileges where possible using Oracle Solaris 10 privileges, the use of privilege bracketing, as well as features such as non-executable stacks. Together, these efforts serve to significantly improve the security services and code in Oracle Solaris.

### File System Security

#### UNIX Permissions

The first line of defense for protecting objects in a file system is the default UNIX permissions assigned to each and every file system object. UNIX permissions support assigning unique access rights to the owner of the object, a group assigned to the object as well as anyone else. These rights are generally referred to as user, group and world permissions. For more information on these permissions and how they can be set, refer to the `chmod(1)` manual page.

While the assignment of owners, groups and permissions will vary widely based upon the file system object in question, there are a few common recommendations that should be followed including those covered previously in Section 5, “File/Directory Permission/Access,” of the Benchmark. As a general rule, assign the least amount of privilege that is required for services or users accessing the object. This includes read, write and execute access as well as special permissions such as `set-uid` and `set-gid`.

That said, it is important to remember that Oracle does not support changing the default file ownership, group, or permissions of files shipped in Oracle Solaris. If there are questions about the validity or security of a given setting, please contact Oracle directly to address any concerns.

### Access Control Lists

In addition to UNIX permissions, Oracle Solaris supports access control lists (ACLs) on both the UFS and ZFS file systems. Access Control Lists offer organizations the ability to more finely control access to individual or groups of file system objects. ACLs differ between the UFS and ZFS implementations so each will be discussed independently.

- **UNIX File System (UFS) Access Control Lists.** Based upon a version of a POSIX draft for ACLs (POSIX 1003.1e/1003.2c, which was withdrawn), UFS access control lists include support for twelve different access modes that can be assigned to specific users or groups. Typically, ACLs are used to restrict or grant read, write or execute access to specific users or groups. In addition, ACLs can be used to assign default permissions for objects created under specified directories (for users, groups, or world). Prior to Oracle Solaris 10, UFS ACLs were set using `setfacl` and queried using `getfacl`. While these commands can be used in Oracle Solaris 10, many find that using the enhanced `chmod(1)` and `ls(1)` commands provide a simpler, easier-to-use method for managing ACLs.

In the following example, the `chmod(1)` command is used to add an ACL to the file `sample-file` granting read and write access to the user `joe`:

```
$ ls -lv sample-file
-rw-r--r--  1 john  john      0 Sep 17 21:42 sample-file
          0:user::rw-
          1:group::r--
          2:mask:r--
          3:other:r-

$ chmod A+user:joe:rw- sample-file

$ ls -lv sample-file
-rw-r--r--+ 1 john  john      0 Sep 17 21:42 sample-file
          0:user::rw-
          1:user:joe:rw-          #effective:r--
          2:group::r--          #effective:r--
          3:mask:r--
          4:other:r-
```

It should be noted that the effective rights for user `joe` are still read-only. In cases such as this, it is necessary to recalculate the permissions (ignoring the default permissions mask) in order to ensure that sufficient rights are granted to satisfy the ACLs that have been created. To do this use the following command:

```
$ getfacl sample-file | setfacl -r -f - sample-file
```

After running this command, the user `joe` has both read and write access to the file `sample-file`:

```
$ ls -lv sample-file
-rw-r--r--+ 1 john john          0 Sep 17 21:42 sample-file
  0:user::rw-
  1:user:joe:rwt
  2:group::r--
  3:mask:rw-
  4:other:r--
```

- **ZFS Access Control Lists.** Based upon the NFSv4 access control list model, ZFS ACLs are set using `chmod(1)`, queried using `ls(1)`, and supported by over fifteen different access modes that can be assigned to specific users or groups. A few such modes not available with UFS ACLs include `add_file`, `write_xattr`, `delete`, and `write_acl`. Each of these is described in more detail in `chmod(1)`. Collectively, these modes enable organizations to control access to files and directories with a high degree of precision.

In the following example, a ZFS ACL is used to enforce a policy stating that files created under the `archive` directory are not permitted to be removed (even by the owner of the file):

```
$ id
uid=101(gbrunett) gid=101(gbrunett)

$ mkdir archive
$ chmod A+everyone@:delete_child/delete:file_inherit/dir_inherit:deny \
./archive

$ ls -ldv ./archive
drwxr-xr-x+ 2 gbrunett gbrunett 2 Sep 18 22:52 ./archive
  0:everyone@:delete_child/delete:file_inherit/dir_inherit:deny
  1:owner@::deny
  2:owner@:list_directory/read_data/add_file/write_data/add_subdirectory
    /append_data/write_xattr/execute/write_attributes/write_acl
    /write_owner:allow
  3:group@:add_file/write_data/add_subdirectory/append_data:deny
  4:group@:list_directory/read_data/execute:allow
  5:everyone@:add_file/write_data/add_subdirectory/append_data
    /write_xattr /write_attributes/write_acl/write_owner:deny
  6:everyone@:list_directory/read_data/read_xattr/execute
    /read_attributes /read_acl/synchronize:allow
```

```
$ cp /etc/motd ./archive/
$ ls -l archive/
total 2
-rw-r--r--+ 1 gbrunett gbrunett      53 Sep 18 22:53 motd
$ rm archive/motd
rm: archive/motd not removed: Permission denied
```

This should be considered a representative example only. While the file itself may not be deleted in this example, the content contained in this file can be altered as in:

```
$ echo "Hello World" > archive/motd
```

```
$ cat archive/motd
Hello World
```

In addition to the actual ACL modes, ZFS also provides two ACL-related parameters that can be assigned to file systems: `aclmode` and `aclinherit`. Respectfully, these parameters define how ACLs can be modified by `chmod(2)` operations and how ACL entries are inherited when files and directories are created. More information on these settings and their possible values can be found in `zfs(1M)`. These settings can be queried using the `zfs(1M)` command:

```
$ zfs get aclmode,aclinherit pool/saved
NAME      PROPERTY      VALUE      SOURCE
pool/test  aclmode      groupmask  default
pool/test  aclinherit   secure     default
```

The recommendations from the [UNIX Permissions](#) section apply to access control lists as well. For more information and examples on setting or querying access control lists, see `chmod(1)`. Further, a mapping of NFSv4 and POSIX draft ACLs can be found at:

<http://tools.ietf.org/html/draft-ietf-nfsv4-acl-mapping>

## Mount Options

As discussed in the section titled [Disk Partitioning](#), there are often very good reasons to consider the use of special mount options for UFS file systems or ZFS data sets. Included in the table below are a few useful file system mount options that organizations may want to use to further restrict the capabilities of specific file systems. It is strongly recommended to exercise caution when selecting individual mount options as these restrictions may cause programs relying on the disabled functionality to fail.

**TABLE 4. USEFUL FILE SYSTEM MOUNT OPTIONS**

MOUNT OPTION	ZFS PROPERTY	DESCRIPTION
nodevices	devices	Disallow the opening of device-special files. This option should be used on all file systems that do not contain (or need to support) device special files.
noexec	exec	Disallow the execution of programs from the file system. This option should be used on all file systems that do not contain (or need to support) executable files or memory mapped executable data. Note that the use of this option will not prevent the execution of interpreted scripting code (e.g., Bourne shell, Perl, etc.) when the interpreter itself exists on a file system where execution is permitted.
nosetuid	setuid	Disallow the execution of programs in the file system that have the set-uid bit set. This option is highly recommended whenever the file system is shared by way of NFS using the root= option. Further, this option should be used on all file systems that do not contain (or need to support) set-uid execution.
nosub	N/A	Disallow clients from mounting sub-directories of shared directories.
nosuid	N/A	This is a convenience option combining both nodevices and nosetuid.
noxattr	xattr	ZFS or tmpfs only. Disallow the use of extended file attributes on the file system. Oracle Solaris does not use extended file attributes by default. This option can be used on all file systems that do not contain (or need to support) extended file attributes.
ro	readonly	Disallow write access to the file system, making it read-only.
size	N/A	tmpfs only. Define the maximum size of the file system. This option can be used to force the size of the file system to be less than the amount of virtual memory on the system.

For more information on each of these options, including examples of how they can be used, see `mount(1M)`, `mount_ufs(1M)`, `mount_tmpfs(1M)`, and `zfs(1M)`, respectively. In addition, for more information on the potential dangers of extended file attributes, see:

“Hiding within the Trees”: <http://www.usenix.org/publications/login/2004-02/pdfs/brunette.pdf>

## Quotas and Reservations

While both UFS and ZFS support the notion of file system quotas to control how much available storage space can be used on a given file system, their implementations differ. Given this, each is discussed separately:

- **UFS Quotas.** Quotas on a UFS file system specify the number of blocks and inodes that can be consumed by a user on a file system. The number of blocks and inodes is often specified with both “soft” and “hard” values. Soft limits may be temporarily exceeded and the user will be warned about the violation. Hard limits are those that cannot be exceeded and attempts to use more blocks or inodes beyond a user's hard limit will be denied. For more information on UFS quotas, see `quota(1M)`, `edquota(1M)`, `repquota(1M)`, `quotacheck(1M)` and `quotaon(1M)`.

In the following example, a quota is set on the `/export/home` file system for the user `gbrunett`:

[manually configure `/export/home` to use quotas by editing `/etc/vfstab` as follows]

```
# grep "/export/home" /etc/vfstab
/dev/dsk/c0d0s7 /dev/rdsk/c0d0s7 /export/home ufs      2      yes      rq
# mount -o remount,quota /export/home
# cd /export/home
# touch quotas
# chmod root:root quotas
# edquota gbrunett
```

[manually enter the quota information for `gbrunett` using form displayed using `/usr/bin/vi`]

```
# quotaon -v /export/home
/export/home: quotas turned on

# quota -v gbrunett
Disk quotas for gbrunett (uid 101):
Filesystem    usage  quota  limit   timeleft  files  quota  limit ...
/export/home      0     0    5000            0     0   2000
```

After these steps have been completed, the user `gbrunett` will receive an error message if the defined quota has been exceeded, as in the following example:

```
$ mkfile 100m test-file
quota_ufs: over hard disk limit (pid 5618, uid 101, inum 25822, fs
/export/home)
test-file: initialized 5079040 of 104857600 bytes: Disc quota exceeded
```

In addition, administrators can use the `repquota(1M)` command to get a report showing usage for file systems with quotas enabled:

```
$ repquota /export/home
      Block limits          File limits
User    used   soft   hard  timeleft   used   soft   hard ..
gbrunett --  4992     0    5000                  4       0   2000
```

- **ZFS Quotas.** Prior to Oracle Solaris 10 10/09, ZFS did not have the ability to set utilization quotas on a per-user or per-group basis. ZFS quotas could only be applied to a file system or volume as shown in the following examples:

```
# zfs set quota=1G pool/zones
# zfs get quota pool/zones
NAME      PROPERTY  VALUE      SOURCE
pool/zones  quota     1G        local
```

A ZFS quota can also be reported using the following command:

```
# zfs list -o name,mountpoint,quota,used pool/zones
NAME      MOUNTPOINT      QUOTA      USED
pool/zones  /pool/zones      1G      157M
```

To work around the per-user limitation that existed prior to Oracle Solaris 10 10/09, organizations used a per-user ZFS file system model so that quotas could then be applied to each user's file system. In the following example, two user home directories are created on a ZFS pool that is then mounted as `/export/home`. Once completed, the home directories will exist under `/export/home` and each will have its own quota assigned.

```
# zfs create -p -o quota=500M pool/home/gbrunett
# zfs create -p -o quota=200M pool/home/gmb
# zfs set mountpoint=/export/home pool/home
# zfs list -ro name,mountpoint,quota,used pool/home
NAME      MOUNTPOINT      QUOTA      USED
pool/home      /export/home      none      57K
pool/home/gbrunett  /export/home/gbrunett  500M      18K
pool/home/gmb      /export/home/gmb      200M      18K
```

Starting in Oracle Solaris 10 10/09, ZFS was enhanced to include support for quotas associated with specific users or groups. To set and query a per-user quota on a given file system, the following commands can be used:

```
# zfs set userquota@gbrunett=1g pool/home
# zfs get userquota@gbrunett pool/home
NAME          PROPERTY          VALUE          SOURCE
pool/home     userquota@gbrunett  1G           local
```

Alternatively, the `userspace` sub-command of `zfs(1M)` can be used to identify user quotas that are associated with a given file system:

```
# zfs userspace pool/home
TYPE      NAME      USED   QUOTA
POSIX User gbrunett 23.5K    1G
POSIX User root      3K     none
```

Note that the name associated with the user quota property can take a variety of forms including a POSIX name or numeric identifier or a SID name or numeric identifier. Per-group quotas are managed in a similar manner, as shown in the following example:

```
# zfs set groupquota@webservd=1g pool/apps/htdocs
# zfs get groupquota@webservd pool/apps/htdocs
NAME          PROPERTY          VALUE          SOURCE
pool/apps/htdocs groupquota@webservd  1G           local
```

The `zfs(1M)` `groupspace` sub-command can be used to also identify group quotas that are associated with a given file system:

```
# zfs groupspace pool/apps/htdocs
TYPE      NAME      USED   QUOTA
POSIX Group root      3K     none
POSIX Group webservd  0      1G
```

In addition to quotas, ZFS also supports the notion of reservations. Reservations set aside an allotted amount of storage capacity whereas quotas typically enforce a maximum level of utilization. ZFS reservations are also set using the `zfs(1M)` command, as in the following example:

```
# zfs set reservation=512M pool/zones
# zfs get reservation pool/zones
NAME          PROPERTY          VALUE          SOURCE
pool/zones   reservation     512M         local
```

The impact of this reservation can be best seen in the before and after views of the storage pool itself:

```
# zfs list pool
NAME    USED   AVAIL   REFER  MOUNTPOINT
pool   4.15G  7.36G    23K   /pool      (Before)
pool   4.65G  6.86G    23K   /pool      (After)
```

For more information, see:

- “Setting ZFS Quotas and Reservations” in Chapter 6, “Managing Oracle Solaris ZFS File Systems,” of the *Oracle Solaris ZFS Administration Guide*: [http://download.oracle.com/docs/cd/E19253\\_01/index.html](http://download.oracle.com/docs/cd/E19253_01/index.html)
- Blog: “ZFS End-to-End Data Integrity”:  
[http://blogs.oracle.com/bonwick/entry/zfs\\_end\\_to\\_end\\_data](http://blogs.oracle.com/bonwick/entry/zfs_end_to_end_data)

### ZFS Delegated Administration

Starting with Oracle Solaris 10 10/08, ZFS was enhanced to provide support for delegated administration. This functionality allows an administrator to assign or revoke various fine-grained permissions enabling otherwise unprivileged users to perform administrative actions on a ZFS data set or volume. As of Oracle Solaris 10 10/09, there are 50 discrete permissions that can be assigned to or revoked from specific users or groups. To see a complete list of privileges, see `zfs(1M)`. In the following example, the ability to create, mount, and snapshot a specific file system (e.g., `pool/home/gbrunett`) is assigned to the user `gbrunett`:

```
# zfs allow gbrunett create,mount,snapshot pool/home/gbrunett
# zfs allow pool/home/gbrunett
----- Permissions on pool/home/gbrunett -----
Local+Descendent permissions:
        user gbrunett create,mount,snapshot
```

This example allows the user `gbrunett` to create ZFS snapshots of his home directory for backup and recovery purposes (subject to any limits imposed by any disk space quotas):

```
$ zfs snapshot pool/home/gbrunett@backup
$ zfs list -t snapshot
NAME                                     USED   AVAIL   REFER  MOUNTPOINT
pool/home/gbrunett@backup                  0      -      40K     -
```

Note that this privilege assignment does not permit the user to remove any snapshots that are created, however as additional privileges (e.g., `destroy`) are required:

```
$ zfs destroy pool/home/gbrunett@backup  
cannot destroy 'pool/home/gbrunett@backup': permission denied  
  
# zfs allow gbrunett destroy pool/home/gbrunett  
  
$ zfs destroy pool/home/gbrunett@backup
```

To revoke and verify the removal of these delegated privileges, the following commands can be used:

```
# zfs unallow gbrunett pool/home/gbrunett  
  
# zfs allow pool/home/gbrunett  
  
#
```

Extreme care should be exercised when delegating administrative rights to data sets or volumes, particularly those that may be shared by multiple users or applications. While the use of ZFS delegated administration can help to simplify some management practices, all such assignments should be vetted to avoid assigning excessive or inappropriate privileges to specific users or groups.

### ZFS Command History

Starting in Oracle Solaris 10 10/08, command history was added to ZFS. Administrators can list the actions taken, on a given ZFS pool or across all pools, using the `history` sub-command of `zpool(1M)`:

```
# zpool history -l  
2010-02-11.11:39:42 zfs create rpool/apps [user root on myhost:global]  
2010-02-11.11:39:52 zfs create rpool/apps/htdocs [user root on myhost:global]  
2010-02-11.11:40:09 zfs set groupquota@webservd=1g rpool/apps/htdocs [user  
root on myhost:global]
```

This output can be useful to determine which users (on which system and in which zones) performed administrative operations on data sets or volumes associated with a given ZFS pool. The above example captures the output associated with creating a file system (`rpool/apps/htdocs`) and assigning a group quota to it.

### Universal Serial Bus (USB) Support

In some cases, it may be useful or necessary to disable USB support on a system either for all devices or for some specific classes of devices. This is most often done, in concert with restrictions placed on volume management, to help prevent infiltration of malicious or otherwise unauthorized content as well as to limit the potential for exfiltration of sensitive information.

To disable all USB support on a system, each of the USB related packages should be removed (or just not installed in the first place.) This approach will cause a system to no longer recognize USB devices. Care should be taken with this approach especially on systems with USB keyboards or mice. This approach should only be used in cases where no USB support is needed or expected. For Solaris 10 10/09, the list of packages includes those defined in the SUNWCusb package cluster:

SUNWlibusbugen	SUN libusb ugen plugin
SUNWuacm	CDC ACM USB-to-serial driver
SUNWuedg	USB Digi Edgeport serial driver
SUNWugen	USB Generic Driver
SUNWugenu	UGEN Headers
SUNWuksp	USB Keyspan serial driver
SUNWukspfw	USA49WLC firmware for USB Keyspan serial driver
SUNWuprl	Prolific PL2303 USB-to-serial driver
SUNWusb	USB Device Drivers
SUNWusbs	USB generic serial module
SUNWusbu	USB Headers

As package names and contents may change between releases of Oracle Solaris, it is recommended that you verify the list against the actual release of the operating system being used. This list can be easily generated using the Solaris Package Companion tool discussed in the [Minimization](#) section. A similar approach can be used to remove device driver support from Solaris for other mechanisms such as IEEE 1394 (Firewire) and Infiniband.

In addition, it is possible to disable USB support for specific classes of devices. For more information, see “Disabling Specific USB Drivers” in Chapter 8, “Using USB Devices (Tasks),” of the Oracle Solaris 10 *System Administration Guide: Devices and File Systems*:

<http://download.oracle.com/docs/cd/E19253-01/index.html>

In order to best leverage this approach, refer to the **usba(7D)** manual page for a mapping of USB client driver names to descriptions. For example, if an organization wanted to disable support for USB printers, the **usbprn** driver class would be used:

[Before starting, be sure to save a backup copy of the **/etc/Driver\_aliases** file.]

```
# grep usbprn /etc/Driver_aliases
usbprn "usbif,class7.1"

# update_drv -d -i '"usbif,class7.1"' usbprn
```

[The system must be restarted to complete this operation.]

## Pluggable Authentication Modules (PAM)

Originally developed by Sun in 1995 and first exposed in the Solaris 2.6 operating system, the Pluggable Authentication Module (PAM) framework provides organizations with the ability to customize the user authentication experience as well as account, session and password management functionality in Oracle Solaris. `login` and other system-entry services use the PAM architecture to ensure that all entry points for the system have been secured. This architecture enables the replacement or modification of authentication modules in the field to secure the system against any newly found weaknesses without requiring changes to any of the system services (that use the PAM architecture).

By default, the PAM policy (as defined in `/etc/pam.conf`) is configured to use password-based authentication although support for Kerberos V5 authentication can be configured if required. Sample configurations for Kerberos can be found in `pam_krb5(5)`. `rhosts` authentication is also configured using PAM and is covered earlier in the CIS Solaris 10 Benchmark and so will not be covered here. In addition to authentication, PAM also includes modules which provide support for functionality such as password complexity checks, password history, account lockout and much more. These controls are also discussed in more detail in the CIS Solaris 10 Benchmark.

For more information on the Pluggable Authentication Modules functionality in the Solaris OS, see:

- OpenSolaris Community Project: Pluggable Authentication Modules (PAM):  
<http://hub.opensolaris.org/bin/view/Community+Group+security/pam>
- Archived Oracle technical papers:

“Extending Authentication in the Solaris 9 OS Using Pluggable Authentication Modules (PAM): Part I”: <http://www.oracle.com/technetwork/server-storage/archive/a11-003-authentication-sol9-oe-pam-438965.pdf>

“Extending Authentication in the Solaris 9 OS Using Pluggable Authentication Modules (PAM): Part II”: <http://www.oracle.com/technetwork/server-storage/archive/a11-004-authentication-sol9-oe-pam-2-438966.pdf>
- “Authentication Services and Secure Communication” in the Oracle Solaris 10 *System Administration Guide: Security Services*: <http://download.oracle.com/docs/cd/E19253-01/index.html>

## Password Security

Oracle Solaris 10 has a number of features that can be used to promote strong user passwords and help defend against attacks involving brute force guessing. Many of these features have been discussed earlier in the CIS Solaris 10 Benchmark sections:

- “Set Strong Password Creation Policies.” This section covers the minimum password length, required password composition (e.g., alphabetic, numeric, special characters, etc.), maximum number of consecutive repeating characters, whether passwords may contain white space or be a rotation of the user's name, or found in a banned word list. This section also covers how soon a password can be reused (i.e., password history).
- “Set Password Expiration Parameters on Active Accounts.” This section defines for how long a password may remain valid before it must be changed and how soon after a password change that a user can initiate a subsequent password change.
- “Verify Delay between Failed Login Attempts Set to 4.” This section defines the time interval that must pass after a failed authentication attempt before the user can be prompted again to authenticate to the system.
- “Set Retry Limit for Account Lockout.” This section enables account lockout and sets the maximum number of consecutive failed authentication attempts before an account is locked.

## Pluggable Crypt

In addition to these actions, organizations may want to consider altering the default algorithm used to store user passwords. By default, Oracle Solaris uses the traditional UNIX crypt algorithm. This algorithm limits passwords to a maximum of eight characters and is not considered sufficiently secure for current systems. This algorithm is enabled primarily for backwards compatibility. Rather, Oracle recommends that organizations consider using one of the following algorithms that are also provided by default in Oracle Solaris 10:

- **SHA256 / SHA512.** Introduced in the Solaris 10 10/08 release, the `crypt_sha256` and `crypt_sha512` modules implement a one-way password hashing mechanism based upon the SHA-2 family of algorithms. The algorithm identifiers for `crypt.conf(4)` and `policy.conf(4)` are 5 and 6 respectively. These modules are designed to make it difficult to crack passwords that use brute force attacks based on high speed SHA256 or SHA512 implementations that use code inlining, unrolled loops, and table lookups. The maximum password length for `crypt_sha256` and `crypt_sha512` is 255 characters. These modules support a rounds parameter that specifies the number of additional rounds of the algorithm to use in generation of the salt; the default number of rounds is 5000. For more information on these modules, see `crypt_sha256(5)` and `crypt_sha512(5)`.
- **Sun MD5.** The `crypt_sunmd5` module is a one-way password hashing module for use with `crypt(3C)` that uses the MD5 message hash algorithm. The algorithm identifier for `crypt.conf(4)` and `policy.conf(4)` is md5. This module is designed to make it difficult to crack passwords that use brute force attacks based on high-speed MD5 implementations that use code inlining, unrolled loops, and table lookups. The maximum password length for `crypt_sunmd5` is 255 characters. This module also supports a rounds parameter that specifies the number of additional rounds of MD5 to use in generation of the salt; the default number of rounds is 4096. For more information on this module, see `crypt_sunmd5(5)`.
- **BSD MD5.** The `crypt_bsdmd5` module is a one-way password hashing module for use with `crypt(3C)` that uses the MD5 message hash algorithm. The algorithm identifier for `crypt.conf(4)` and `policy.conf(4)` is 1. The output is compatible with `md5crypt` on BSD and Linux systems. The maximum password length for `crypt_bsdmd5` is 255 characters. For more information on this module, see `crypt_bsdmd5(5)`.
- **Blowfish.** The `crypt_bsdbf` module is a one-way password hashing module for use with `crypt(3C)` that uses the Blowfish cryptographic algorithm. The algorithm identifier for `crypt.conf(4)` and `policy.conf(4)` is 2a. The maximum password length for `crypt_bsdbf` is 255 characters. For more information on this module, see `crypt_bsdbf(5)`.

To enable one of these alternate algorithms, the `/etc/security/policy.conf` file is modified. In particular, the `policy.conf` file contains three parameters related to this functionality. They include:

- `CRYPT_ALGORITHMS_ALLOW`. This parameter specifies the algorithms that are allowed to be used for new passwords.
- `CRYPT_ALGORITHMS_DEPRECATED`. This parameter will deprecate the use of specific algorithms.
- `CRYPT_DEFAULT`. This parameter defines the default algorithm to be used.

For example, to set Sun MD5 as the default password algorithm, the following change should be made in the `/etc/security/policy.conf` file:

```
CRYPT_DEFAULT=md5
```

If an organization wants to deprecate the use of the traditional crypt algorithm at the same time, this additional change should be made:

```
CRYPT_ALGORITHMS_DEPRECATED=__unix__
```

If an organization wanted to increase the number of rounds completed by the Sun MD5 module from 4096 to 8000, the following line would need to exist in `/etc/security/crypt.conf`:

```
md5      crypt_sunmd5.so.1      rounds=8000
```

Note that simply making these changes will not change existing user accounts. These values are inspected and used only during a password change event. So, if these values are changed, they will not take effect for a user until that user changes his or her password. To force a user to change his or her password at next login, use the command:

```
# passwd -f <user_name>
```

Organizations should carefully consider their existing environment before implementing this change. The SHA256 and SHA512 algorithms were introduced in Solaris 10 10/08 and the MD5 and Blowfish algorithms are not available on older releases of the Solaris OS (prior to Solaris 9 02/02). Further, some Solaris services will not properly authenticate users whose passwords are computed using these, non-default algorithms. An example of one such service is the Solaris Management Console, which is covered by the following bug report:

```
4760846 smc and the enhanced crypt(3c) seem to be incompatible
```

Further, environments leveraging a networked naming service (e.g., NIS, NIS+, LDAP) should also determine if there exists any interoperability issues with any of their non-Solaris 10 clients.

For more information on the pluggable crypt functionality, see:

- “Changing the Default Algorithm for Password Encryption” in Chapter 3, “Controlling Access to Systems (Tasks),” of the Oracle Solaris 10 *System Administration Guide: Security Services*:

<http://download.oracle.com/docs/cd/E19253-01/index.html>

- “OpenSolaris, Pluggable Crypt, and the Sun MD5 Password Hash Algorithm”:

<http://www.crypticide.com/dropsafe/article/1389>

- Blogs:

“Solaris Password Security”: <http://www.cuddletech.com/blog/pivot/entry.php?id=778>

“Directory Server 6.1 and UNIX Crypt”:

[http://blogs.oracle.com/Ludo/entry/directory\\_server\\_6\\_1\\_and](http://blogs.oracle.com/Ludo/entry/directory_server_6_1_and)

## Role-based Access Control (RBAC)

Oracle Solaris Role-based Access Control (RBAC) is an alternative to the all-or-nothing superuser model. RBAC is in keeping with the security principle of least privilege by allowing organizations to selectively grant privileges to users or roles based upon their unique needs and requirements. In general, organizations are strongly encouraged to use Oracle Solaris RBAC to restrict access to privileged operations rather than granting users complete access to the `root` account.

Oracle Solaris RBAC was introduced in the Solaris 8 operating system and has been enhanced and expanded with each new release of Solaris. Oracle Solaris RBAC functionality contains several discrete elements that can be used individually or together including authorizations, rights profiles and role designations. The relationship between these elements and descriptions of each is included below:

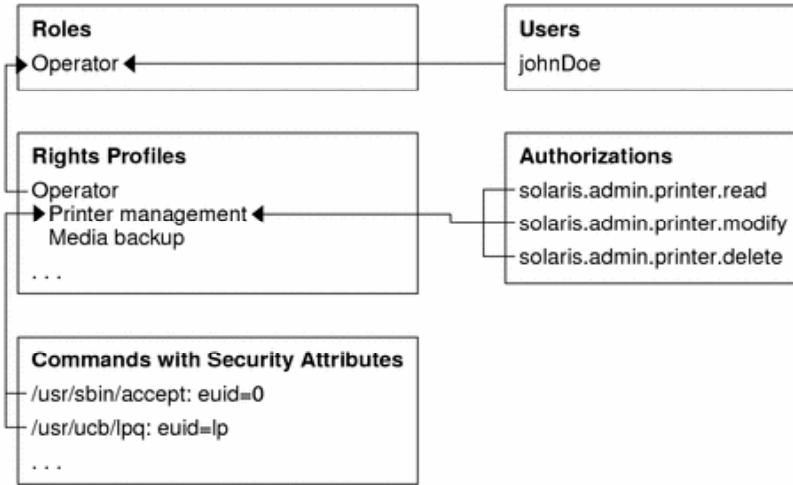


Figure 1. RBAC Elements

## Authorizations

An authorization is a permission that can be assigned to a role or user (or embedded in a rights profile) for performing a class of actions that are otherwise prohibited by security policy. Very often, authorizations are used in concert with privileged programs or services for the purpose of access control. For example, consider this reference from `crontab(1)`:

Access to `crontab` is denied:

- If `/etc/cron.d/cron.allow` exists and the user's name is not in it
- If `/etc/cron.d/cron.allow` does not exist and user's name is in `/etc/cron.d/cron.deny`

If neither file exists, only a user with the `solaris.jobs.user` authorization is allowed to submit a job.

In this case, the `solaris.jobs.user` authorization can be used to grant access to the `cron` facility (when other access control mechanisms are not present). Authorizations are defined in the `/etc/security/auth_attr` (or an equivalent naming service table). Similarly, authorizations are assigned to users and roles in the `/etc/user_attr` file (or an equivalent naming service table) and queried using the `auths(1)` command. Other examples illustrating the use of authorizations are covered in the [Service Management Facility \(SMF\)](#) section.

## Rights Profiles

A rights profile is a collection of capabilities that can be assigned to a role or user. A rights profile can consist of authorizations, individual commands and other rights profiles. Each of the commands stored in a rights profile can define security attributes that determine how the program will be run. The following is the list of security attributes that can be assigned to commands in a rights profile:

- `uid (euid)`. The `uid` and `euid` attributes contain a single user name or a numeric user ID. Commands designated with `euid` run with the effective UID indicated, which is similar to setting the `setuid` bit on an executable file. Commands designated with `uid` run with both the real and effective UIDs.
- `gid (egid)`. The `gid` and `egid` attributes contain a single group name or a numeric group ID. Commands designated with `egid` run with the effective GID indicated, which is similar to setting the `setgid` bit on a file. Commands designated with `gid` run with both the real and effective GIDs.
- `privs`. The `privs` attribute contains a privilege set which will be added to the inheritable set prior to running the command. A listing of available privileges can be found in `privileges(5)`.
- `limitprivs`. The `limitprivs` attribute contains a privilege set which will be assigned to the limit set prior to running the command. A listing of available privileges can be found in `privileges(5)`.

To determine which rights profiles have been assigned to a given user or role, use the **profiles(1)** command:

```
# profiles lp
Printer Management
Basic Solaris User
All
```

To further determine exactly which commands are included in these rights profiles the **-l** option to the **profiles(1)** command can be used:

```
# profiles -l lp
Printer Management:
/usr/lib/lp/local/lpadmin    uid=lp, gid=lp
/usr/sbin/lpfilter      euid=lp, uid=lp
/usr/sbin/lpforms       euid=lp
/usr/sbin/lpusers        euid=lp
/usr/sbin/ppdmgr        euid=0

All:
*
```

## Users and Roles

An Oracle Solaris role is a special identity for running privileged applications that can be assumed by assigned users only. A role is similar to a normal user in that it has its own UID, GID, home directory, shell and password. A role differs from a normal user in two ways:

- By default, a role cannot be used to (initially) log directly into a system either at the console or by any remote access service. Users must first log into the system before assuming a role using either **su(1M)** or **smc(1M)**. One exception involves the use of the **allow\_remote** option to **pam\_roles.so.1** in the **/etc/pam.conf** file. If this option is set, remote users are able to directly assume a role on the local system. Remote roles should only be permitted from remote services that can be trusted to provide an accurate PAM\_AUSER name. For more information, see **pam\_roles(5)**.
- A role can only be accessed by a user who has previously been authorized to assume that role. Lacking this authorization, a user will not be able to assume a role even if he or she is in possession of the correct role password or authentication token. Note that roles are not permitted to assume other roles.

Most often, roles are used for administrative accounts to restrict access to sensitive operations as well as for service accounts (e.g., web server or application server UID) since it is important to ensure that actions taken by such accounts be attributable back to a specific user (who accessed the role). It should also be noted that delayed jobs (e.g., **cron** or **batch**) are independent of role assumption.

To determine if a given account is a role, query the `/etc/user_attr` file (or naming service table) and check for the `type=` parameter. If this parameter is set to `role`, then the account is an Oracle Solaris role:

```
$ grep "^\root:" /etc/user_attr
root:::::type=role;auths=solaris.*;solaris.grant;profiles=Web Console
Management,All;lock_after_retries=no;clearance=admin_high;
min_label=admin_low
```

To determine what roles are assigned to a given user, use the `roles(1)` command:

```
$ roles gbrunett
root
```

### Converting the `root` Account to a Role

Taken together, authorizations, rights profiles and roles offer organizations the ability to delegate access to administrative functions with a level of detail that can be customized based upon the organization's policies and requirements. One of the most often cited examples of RBAC is the conversion of the `root` account to a role.

By implementing this change, `root` no longer will be able to directly log into the system, and `root` will only be able to be accessed by those possessing the correct credentials and explicit approval to assume that role. It is critical therefore that at least one user account be assigned to the `root` role – otherwise the role itself would no longer be able to be accessed. Note that the risk of administrators being unable to log in and assume the `root` role to perform privileged operations can be reduced by ensuring that their accounts have account lockout disabled, are stored in the local ("files") password tables, and have home directories that are mounted locally rather than over NFS. In addition, booting the Solaris system into single user mode will enable administrators to log into the system directly as `root`, thereby providing a worst-case mechanism to access a privileged shell.

To convert the `root` account to a role, take the following actions:

```
# usermod -K type=role root
# usermod -R root joe
```

The first command is responsible for converting `root` to a role. The second command assigns the user `joe` to the `root` role. This can be verified by looking at their respective entries in `/etc/user_attr`:

```
# egrep "^\root|^joe" /etc/user_attr
root:::::type=role;[...omitted for brevity...]
joe:::::type=normal;roles=root
```

In addition, there are a number of other rights profiles provided in Oracle Solaris by default including:

- **Primary Administrator.** Provides all of the capabilities of “superuser” in one profile. This profile grants rights that are equivalent to `root`.
- **System Administrator.** Provides a profile that can do most of the “superuser” tasks but fewer connected with security administration. For example, this role can create accounts but it cannot set or reset user passwords.
- **Operator.** Provides limited capabilities to manage files and offline media.

A complete listing of profiles can be found in `smc(1M)` or in the `/etc/security/prof_attr` file (or naming service table). For more information on each of these profiles, see Chapter 8, “Roles, Rights Profiles and Privileges,” in the Oracle Solaris 10 *System Administration Guide: Security Services*: <http://download.oracle.com/docs/cd/E19253-01/index.html>.

For more information on Oracle Solaris RBAC, see:

- OpenSolaris Community Project: Role-based Access Control (RBAC):  
<http://hub.opensolaris.org/bin/view/Community+Group+security/rbac>
- Blogs:

“Using Solaris RBAC to only allow scp/sftp”:

[http://blogs.oracle.com/darren/entry/using\\_solaris\\_rbac\\_to\\_only](http://blogs.oracle.com/darren/entry/using_solaris_rbac_to_only)

“SPOTD: The Guide Book for Solaris Role-Based Access Control”:

[http://blogs.oracle.com/sunsecurity/entry/spotd\\_the\\_guide\\_book\\_to](http://blogs.oracle.com/sunsecurity/entry/spotd_the_guide_book_to)

- Archived Oracle technical papers:

“Enforcing the Two-Person Rule via RBAC in the Solaris 10 Operating System”:

<http://www.oracle.com/technetwork/server-storage/archive/a11-011-two-person-rule-role-access-438989.pdf>

“Restricting Service Administration in the Solaris 10 OS”:

<http://www.oracle.com/technetwork/server-storage/archive/a11-010-restricting-svcadmin-sol10-438978.pdf>

## Process Rights Management (Privileges)

In Oracle Solaris 10, the traditional concept of a UNIX superuser was eliminated. It was replaced with a fine-grained approach to privilege delegation that enables organizations to limit what privileges are granted to services and processes running on their systems. Traditionally, UNIX-based systems have relied on the concept of a superuser called `root` (that was required to have a special user identifier, 0). In Oracle Solaris 10, this dependency has been in large part removed. It has been replaced with the ability to grant one or more specific privileges that enable processes to perform otherwise restricted operations.

## Privileges Overview

The single, all-powerful UID 0 has been replaced with over 60 discrete privileges that can individually be assigned to processes using the [Service Management Facility \(SMF\)](#), [Role-based Access Control \(RBAC\)](#), or using the command-line program, `ppriv(1)`. More information on the use of privileges with SMF and RBAC are covered in their respective sections. To obtain a list of privileges as well as their individual uses on the system, see `privileges(5)` or the output of the `ppriv(1)` command, as shown in the following example:

```
# ppriv -vl file_dac_read
file_dac_read
    Allows a process to read a file or directory whose permission
    bits or ACL do not allow the process read permission.
```

Oracle Solaris supports the notion of four distinct privilege sets:

- **Effective.** The set of privileges that is currently active (in effect) in the process.
- **Permitted.** The maximum set of privileges available to the process.
- **Inherited.** The set of privileges that will be inherited by a child process upon `exec(2)`.
- **Limit.** The upper bound of all privileges that a process or its children can obtain.

Figure 2 shows a graphical representation for the relationship among privilege sets:

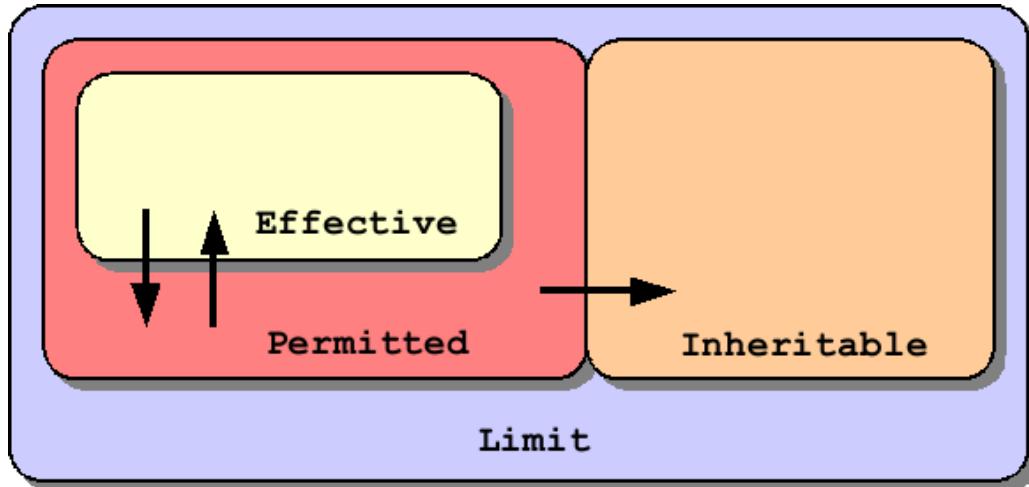


Figure 2. Relationship Among Privilege Sets

For more information on these privileges and privilege sets, see `privileges(5)` as well as:

- “Privileges Overview” in Chapter 8, Using Roles and Privileges (Overview),” in the Oracle Solaris 10 *System Administration Guide: Security Services*:  
<http://download.oracle.com/docs/cd/E19253-01/index.html>
- Blog: “Solaris Privileges”: <http://blogs.oracle.com/casper/date/20040722>
- Archived Oracle technical paper: “Limiting Service Privileges in the Solaris 10 Operating System”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-009-limiting-privileges-sol10-438977.pdf>

### Privilege Bracketing

The implementation of Oracle Solaris privileges empowers application developers to control how privileges are used within their programs. Using a technique called privilege bracketing, developers can write their programs such that they are only running with privileges when they are needed. Even more importantly, programs can not only enable or disable their privileges, but they can also drop any privileges granted to them (assuming they will not be needed) and even relinquish them (so they can no longer be used) when there is no longer a need for the privilege. Just as importantly, programs can also restrict which of their privileges can be passed along to their children (e.g., programs that they execute themselves).

It is worth noting that there are many `set-uid` programs and system services that use this technique including (but not limited to):

- **set-uid programs:** `/usr/bin/rmformat`, `/usr/lib/fs/ufs/quota`,  
`/usr/sbin/ping`, `/usr/sbin/traceroute`, `/usr/lib/fs/ufs/ufsdump`,  
`/usr/bin/rsh`, etc.
- **system services:** `/usr/sbin/in.ftp`, `/usr/sbin/rpcbind`, `/usr/lib/nfs/nfssd`,  
`/usr/lib/rmvolmgr`, `/usr/sbin/nis_cachemgr`, `/usr/lib/nfs/mountd`, etc.

The use of privileges by each of these programs can be seen and verified by looking at the source code for these programs using the OpenSolaris Source Code Browser: <http://src.opensolaris.org/source/>.

For more information on privilege bracketing, see the following archived Oracle technical paper:

“Privilege Bracketing in the Solaris 10 Operating System”:

<http://www.oracle.com/technetwork/server-storage/archive/a11-015-privilege-bracketing-sol10-439767.pdf>

## Privilege Debugging

There are often times when organizations may not already know what privileges are needed by an application. This can be a result of unfamiliarity with Oracle Solaris privileges or even the lack of source code for the application in question. In such circumstances, an OpenSolaris tool called `privdebug.pl` can be used to profile an application's use of privileges. The `privdebug.pl` command, when run from an Oracle Solaris 10 global zone, will enable organizations to see exactly which privileges were being used or attempted.

For more information on `privdebug.pl` or privilege debugging in general, see:

- OpenSolaris Community Project: Privilege Debugging:  
<http://hub.opensolaris.org/bin/view/Community+Group+security/privdebug>
- Archived Oracle technical paper: "Privilege Debugging in the Solaris 10 Operating System":  
<http://www.oracle.com/technetwork/server-storage/archive/a11-012-privilege-debugging-sol10-439762.pdf>

## Service Management Facility (SMF)

In Oracle Solaris 10, the Service Management Facility is used to add, remove, configure, and manage services in Oracle Solaris. It is important therefore that SMF provide organizations with a way to control access to services as well as a means to control how those services are started, stopped, etc.

### Access Control

The Service Management Facility leverages the use of the Oracle Solaris Role-based Access Control (RBAC) facility in order to control access to service management functions on the system. In particular, SMF uses Authorizations to determine who may manage a service and what functions that person may perform. Many of the services shipped by default in Oracle Solaris have authorizations defined. For example:

```
$ svcprop -p general/action_authorization dns/server  
solaris.smf.manage.bind
```

SMF supports three primary types of authorizations:

- **action\_authorization**. This authorization allows a user or role to manipulate the state of a service (e.g., restart, temporarily disable or enable, set to maintenance mode, etc.)
- **modify\_authorization**. This authorization allows a user or role to add, modify or remove any property associated with a given service. This is by far the most powerful authorization and should be granted with care.
- **value\_authorization**. This authorization allows a user or role to manipulate existing service properties. Unlike the **modify\_authorization**, this authorization does not grant the ability to add or remove properties. Only the values of existing properties can be changed.

For more information on the access control capabilities of SMF, see `smf_security(5)` as well as:

- Archived Oracle technical paper: “Restricting Service Administration in the Solaris 10 Operating System”: <http://www.oracle.com/technetwork/server-storage/archive/a11-010-restricting-svcadmin-sol10-438978.pdf>
- Blog: “Securing MySQL using SMF—the Ultimate Manifest”: [http://blogs.oracle.com/bobn/entry/securing\\_mysql\\_using\\_smf\\_the](http://blogs.oracle.com/bobn/entry/securing_mysql_using_smf_the)
- Center for Internet Security BIND Security Benchmark: <http://www.cisecurity.org>

### Execution Contexts

In addition to access control, SMF also enables organizations to more carefully define the context under which programs are run. Unlike previous service management models in Oracle Solaris, SMF enables organizations to specifically define how services are to be started, stopped, restarted, etc. For each of the service methods, organizations can define which user, group, or even privileges will be assigned when a service method is invoked. The full list of method context parameters can be found in `smf_method(5)`, but a few key security-relevant items include:

- `use_profile`. A Boolean that specifies whether a rights profile should be used instead of the user, group, privileges, and `limit_privileges` properties.
- `environment`. Environment variables to insert into the environment of the method, in the form of a number of `NAME=value` strings.
- `profile`. The name of an RBAC (role-based access control) rights profile which, along with the method executable, identifies an entry in `exec_attr(4)`.
- `user`. The user ID in numeric or text form.
- `group`. The group ID in numeric or text form.
- `supp_groups`. An optional string that specifies the supplemental group memberships by ID, in numeric or text form.
- `privileges`. An optional string specifying the privilege set as defined in `privileges(5)`.
- `limit_privileges`. An optional string specifying the limit privilege set as defined in `privileges(5)`.

The execution context assigned to a service can be queried using `svcpool(1)`, as in the following example:

```
$ svcpool -p start dns/server
start/exec astring /lib/svc/method/dns-server\ %m\ %i
start/group astring root
start/limit_privileges astring :default
start/privileges astring
basic,!proc_session,!proc_info,!file_link_any,net_privaddr,file_dac_read,
file_dac_search,sys_resource,proc_chroot
start/project astring :default
start/resource_pool astring :default
start/supp_groups astring :default
start/timeout_seconds count 60
start/type astring method
start/use_profile boolean false
start/user astring root
start/working_directory astring :default
```

For more information on SMF execution contexts, see `smf_method(5)` as well as:

- Archived Oracle technical paper: “Limiting Service Privileges in the Solaris 10 Operating System”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-009-limiting-privileges-sol10-438977.pdf>
- Blog: “Securing MySQL using SMF—the Ultimate Manifest”:  
[http://blogs.oracle.com/bobn/entry/securing\\_mysql\\_using\\_smf\\_the](http://blogs.oracle.com/bobn/entry/securing_mysql_using_smf_the)

## Cryptographic Services Management

The Solaris Cryptographic Framework provides cryptographic services to users and applications through individual commands, a user-level programming interface, a kernel programming interface, and user-level and kernel-level frameworks. The Solaris Cryptographic Framework provides these cryptographic services to applications and kernel modules in a manner seamless to the end user, and brings direct cryptographic services, like encryption and decryption for files, to the end user. Figure 3 is an illustration of the Solaris Cryptographic Framework.

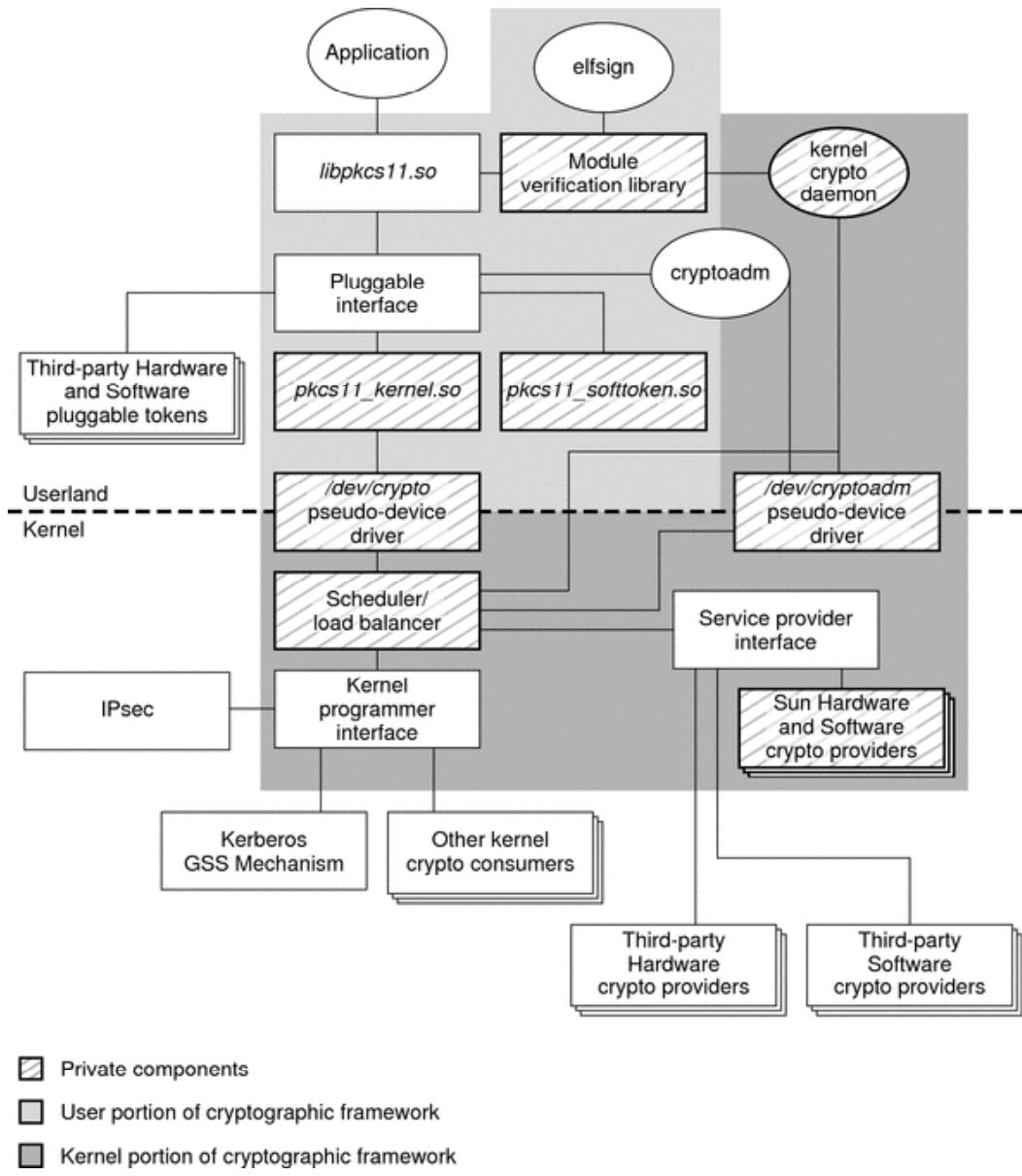


Figure 3. Solaris Cryptographic Framework

## Command-line Utilities

The Solaris Cryptographic Framework includes a number of command-line utilities such as:

- **encrypt** (**decrypt**). This utility encrypts (decrypts) a given file or content from **stdin** using the algorithm specified. For more information on these utilities, see **encrypt(1)** and **decrypt(1)**.
- **digest**. This utility calculates the message digest of a given file, set of files, or from **stdin** using the algorithm specified. For more information on this utility, see **digest(1)**.
- **mac**. This utility calculates the message authentication code (MAC) of a given file, set of files, or from **stdin** using the algorithm specified. For more information on this utility, see **mac(1)**.

## Administration

In addition, the Solaris Cryptographic Framework includes the **cryptoadm(1M)** command that displays cryptographic provider information for a system, configures the mechanism policy for each provider, and installs (or uninstalls) a cryptographic provider. The cryptographic framework supports three types of providers: a user-level provider (a PKCS#11 shared library), a kernel software provider (a loadable kernel software module), and a kernel hardware provider (a cryptographic hardware device).

In the following example, the software and hardware implementations of the MD5 algorithm are disabled. The first command impacts the kernel MD5 provider whereas the second command impacts the user-land software MD5 provider:

```
# cryptoadm disable provider=md5 mechanism=CKM_MD5
# cryptoadm disable \
    provider='/usr/lib/security/$ISA/pkcs11_softtoken_extra.so' \
    mechanism=CKM_MD5

# digest -v -a md5 /usr/bin/ls
digest: no cryptographic provider was found for this algorithm - md5

# cryptoadm list -p

User-level providers:
=====
/usr/lib/security/$ISA/pkcs11_kernel.so: all mechanisms are enabled.
/usr/lib/security/$ISA/pkcs11_softtoken_extra.so: all mechanisms are
enabled, except CKM_MD5. random is enabled.

Kernel software providers:
=====
des: all mechanisms are enabled.
aes256: all mechanisms are enabled.
arcfour2048: all mechanisms are enabled.
blowfish448: all mechanisms are enabled.
```

```
sha1: all mechanisms are enabled.  
sha2: all mechanisms are enabled.  
md5: all mechanisms are enabled, except CKM_MD5.  
rsa: all mechanisms are enabled.  
swrand: random is enabled.  
  
Kernel hardware providers:  
=====
```

This type of policy configuration could be used, for example, to enforce the use of FIPS 180-2 algorithms by prohibiting the Solaris Cryptographic Framework from supporting algorithms such as MD5.

For more information, see:

- OpenSolaris Community Project: Cryptographic Framework :  
<http://hub.opensolaris.org/bin/view/Project+crypto/WebHome>
- OpenSolaris Community Project: Key Management Framework:  
<http://hub.opensolaris.org/bin/view/Project+kmf/WebHome>
- Chapter 8, “Introduction to the Oracle Solaris Cryptographic Framework,” in *Developer’s Guide to Oracle Solaris Security*:  
<http://download.oracle.com/docs/cd/E19963-01/index.html>
- Archived Oracle technical paper: “Using the Cryptographic Accelerators in the UltraSPARC T1 and T2 Processors”: <http://www.oracle.com/technetwork/server-storage/archive/a11-014-crypto-accelerators-439765.pdf>

## Compartmentalization (Zones)

Zones are an operating system abstraction for partitioning systems, allowing multiple applications to run in isolation from each other on the same physical hardware. This isolation prevents processes running within a zone from monitoring or affecting processes running in other zones, seeing each other's data, or manipulating the underlying hardware. Zones also provide an abstraction layer that separates applications from physical attributes of the machine on which they are deployed, such as physical device paths and network interface names.

## General Zones Recommendations

Organizations are strongly encouraged to leverage Oracle Solaris zones for compartmentalization whenever possible. This includes cases where there may only be one exposed service on a given system. The rationale for this is simple. Zones offer a number of security protections that would otherwise not be available. Deploying services within a zone enables organizations to take advantage of capabilities such as:

- Access to raw kernel memory is not permitted in a non-global zone. As a result, the installation of kernel root kits or attempts to unload or manipulate kernel modules will fail.
- Direct access to devices is not permitted unless explicitly authorized by the global zone.
- Non-global zones operate with inherently fewer privileges than a global zone. While the actual set of privileges is configurable, there are still quite a few (potentially dangerous) privileges that are restricted from being offered in a non-global zone.
- Resource management controls can be implemented on a per-zone basis.
- Large portions of the operating system are mounted read-only (when using sparse root configurations discussed below). This has the effect of limiting the scope and impact of quite a large set of user-land root kits, Trojans, and other malicious programs.
- In shared IP networking configurations, the network interfaces and IP addresses assigned to a zone are defined in the global zone. This model prevents a non-global zone from network sniffing as well as changing its IP address. Conversely, in exclusive IP networking configurations, network interfaces can be dedicated to a specific non-global zone in order to provide greater network-level compartmentalization.
- Non-global zones can have their own users, groups, hardening configurations, etc. based upon the types of services that they need to expose.
- Security monitoring can occur in the global zone thereby ensuring that activities in non-global zones are not only monitored but attackers in non-global zones may not know that they are being monitored nor will they have access to monitoring services, configurations, and data.

When non-global zones are used to host users and services, the global zone can be used effectively as a system controller. The global zone would be responsible for zone configuration, resource management and monitoring whereas individual (non-global) zones would be responsible for supporting business or operational services and functions.

For more detailed information on Oracle Solaris Zones security, see:

- Archived Oracle technical paper: “Understanding the Security Capabilities of Solaris Zones Software”: <http://www.oracle.com/technetwork/server-storage/archive/a11-018-sec-capabilities-sol-zones-439776.pdf>
- “How to Eliminate Web Page Hijacking Using Oracle Solaris 10 Security”: <http://www.oracle.com/technetwork/server-storage/solaris/documentation/howto-elimwebhijack-solaris10-163574.pdf>

### Sparse and Whole Root Zones

By default, Solaris zones are created in a sparse root configuration. Essentially, this means that the `/usr`, `/lib`, `/platform`, and `/sbin` directories are all mounted from the global zone (into the non-global zone) as a read-only loopback mount. In addition to consuming less disk space, the use of sparse root configurations is recommended because file systems mounted in this way are immutable from the viewpoint of a non-global zone. The `zonecfg(1M)` command can be used to determine if a zone is configured in this manner:

```
$ zonecfg -z <zone name> info inherit-pkg-dir
inherit-pkg-dir:
    dir: /lib
inherit-pkg-dir:
    dir: /platform
inherit-pkg-dir:
    dir: /sbin
inherit-pkg-dir:
    dir: /usr
```

In addition to being read-only, file systems mounted in a sparse root configuration are also mounted with the `nodevices` and `nosub` mount options that were mentioned earlier in the [File System Security](#) section. By way of comparison, all sparse root zones associated with the same global zone will have the same core operating system software packages installed. There is no way to minimize one non-global zone relative to another as they all share directories such as `/usr` using read-only loopback mounts. If there is a requirement to minimize the contents of a non-global zone, whole root zones should be considered.

### IP Instances for Zones

Introduced in Solaris 10 8/07, IP Instances for Zones extends the virtualization capabilities of Solaris zones deeper into the networking area. In particular, Solaris can now be configured to assign an exclusive IP network stack to individual non-global zones. To accomplish this, each non-global zone, using an exclusive IP stack, is assigned its own “data link name” (and today is assigned a dedicated physical network interface). Not only does this capability result in greater network isolation between zones, it also enables zones to manage their own network configuration (e.g., IP addresses, routes, etc.) in addition to supporting functionality such as IP Filter or IPsec within the zone itself.

Traditionally, Oracle Solaris zones have used a shared IP stack and therefore have been separated (at the network level) by their IP address. As a result, security capabilities such as IP Filter and IPsec had to be configured and managed from within the Oracle Solaris global zone.

By default, an Oracle Solaris non-global zone is configured to use a shared IP stack configuration. To configure a zone to use an exclusive IP stack, set the `ip-type` parameter in `zonecfg(1M)` as in:

```
$ zonecfg -z myzone info ip-type
ip-type: exclusive
```

In addition, a dedicated network interface should be assigned to the zone:

```
# zonecfg -z myzone info net
net:
    address not specified
    physical: bge0
```

Note that a zone configured with an exclusive IP stack should not assign a network address to the dedicated interface using `zonecfg(1M)` as would have been done when using a shared IP configuration. The IP address should be set manually or using a zone specific `sysidcfg(4)` file.

In order to leverage IP Instances functionality, a Generic Network Driver (GLD) version 3 interface must be used. To determine if a particular network interface is using GLDv3, use the `dladm(1M)` command:

```
# dladm show-link
hme0          type: legacy      mtu: 1500        device: hme0
```

If a particular interface reports its type as `legacy`, then it is not using the GLDv3 framework and therefore cannot be used by IP Instances. Attempts to use such an interface as part of an exclusive IP stack in a non-global zone will result in an error message such as:

```
zoneadm: zone 'myzone': WARNING: unable to hold network interface 'hme0'.:.
Invalid argument
```

Similarly, if an interface reports its type as `non-vlan`, then it is using the GLDv3 framework.

For more information on IP Instances for Zones, see:

- “Networking in Shared-IP Non-Global Zones” in Chapter 27, “Solaris Zones Administration (Overview),” in *System Administration Guide: Oracle Solaris Containers-Resource Management and Oracle Solaris Zones*: <http://download.oracle.com/docs/cd/E19253-01/index.html>
- OpenSolaris Community Project: Crossbow: “IP Instances Design Document”: <http://hub.opensolaris.org/bin/download/Project+crossbow/Docs/si-design.pdf>
- OpenSolaris Community Project: Crossbow: “Network Virtualization/Resource Control (Crossbow) FAQ”: <http://hub.opensolaris.org/bin/view/Project+crossbow/faq>

## Cross-zone Network Communication

Solaris zones are only permitted to communicate with one another over the network. This is only possible if they exist on the same network or they are able to reach one another through some external router. When two non-global zones exist on the same logical network, they communicate over a loopback interface in Oracle Solaris for performance reasons (rather than passing packets out to the NIC). Prior to Solaris 10 11/06, there was no way to limit or filter communications flowing over this pathway. Starting with Solaris 10 11/06, IP Filter is now able to filter communication occurring over the loopback interface by setting the following parameter at the top of `/etc/ipf/ipf.conf`:

```
set intercept_loopback true;
```

Care should be taken when enabling this functionality as all loopback (including lo0) network traffic will be subject to the IP Filter policy defined on the system.

## Configurable Privileges

Starting in Solaris 10 11/06, it is now possible to adjust the Oracle Solaris privileges that are available to non-global zones. This is often necessary in order to enable certain types of applications to run in a non-global zone. In order to promote strong security protections, the privileges available to non-global zones are still limited. A listing of privileges that are prohibited from being used in a non-global zone can be found in Appendix B of the “Configurable Privileges for Zones” project proposal at <http://arc.opensolaris.org/caselog/PSARC/2006/124/proposal.opensolaris>.

To adjust the default privileges granted to a non-global zone, the `limitpriv` option to `zonecfg(1M)` should be used, as in the following example:

```
$ zonecfg -z myzone info limitpriv
limitpriv: default,sys_time
```

It is also possible to query a running zone to verify that the privilege is in fact available:

```
$ zlogin myzone ppriv -l zone | grep sys_time
sys_time
```

In this case, the `sys_time` privilege was granted to the zone `myzone` allowing that non-global zone to set the system clock in the global zone (and all other non-global zones since there is only one clock on an Oracle Solaris system). This could be useful in a case where a non-global zone was acting as a Network Time Protocol (NTP) server, for example.

## Integrity Management

This section discusses several capabilities in Oracle Solaris that can be used to inspect and validate the integrity of file system objects. Each of these capabilities can be used together or in isolation depending on the goals or requirements of an organization.

### Signed ELF Objects

Starting in Oracle Solaris 10, the majority of compiled (ELF object) code has been cryptographically signed by Oracle. This includes ELF objects such as binaries, libraries, shared objects, device drivers, kernel modules, and even plugins for the Solaris Cryptographic Framework. The `elfsign(1)` tool is used to both sign ELF objects as well as verify their signatures:

```
$ elfsign verify -e /usr/bin/ls
elfsign: verification of /usr/bin/ls passed.
```

Using the `-v` argument, information such as the format (of the signature) and the signer can also be inspected:

```
$ elfsign verify -v -e /usr/bin/ls
elfsign: verification of /usr/bin/ls passed.
format: rsa_md5_sha1.
signer: CN=SunOS 5.10, OU=Solaris Signed Execution, O=Sun Microsystems Inc.
```

Currently, these signatures can only be inspected manually using the `elfsign(1)` command. The only exception to this is related to the Solaris Cryptographic Framework. Cryptographic plugins (both user-land and kernel) must be signed by Sun and must pass a signature verification check prior to the ELF object being used.

For more information on signed ELF objects in Oracle Solaris, see `elfsign(1)` as well as these blogs:

- “Signed Solaris 10 Binaries?”: [http://blogs.oracle.com/darren/entry/signed\\_solaris\\_10\\_binaries](http://blogs.oracle.com/darren/entry/signed_solaris_10_binaries)
- “Integrity Checking in Depth”: [http://blogs.oracle.com/davew/entry/integrity\\_checking\\_in\\_depth](http://blogs.oracle.com/davew/entry/integrity_checking_in_depth)

### Basic Audit Reporting Tool (BART)

The Basic Audit Reporting Tool is a program used to capture and record file integrity information. The BART utility supports two primary modes of operation: `create` and `compare`. When run in its `create` mode, BART will create a manifest for each file processed that contains information regarding the attributes of the files. Information collected includes the object name, object type, owner (`uid`), group (`gid`), permissions and access control lists, as well as an MD5 fingerprint of the contents (if a file). For example:

```
# find /etc/security | bart create -I
! Version 1.0
! Tuesday, September 18, 2007 (11:24:33)
# Format:
#fname D size mode acl dirmtime uid gid
#fname P size mode acl mtime uid gid
#fname S size mode acl mtime uid gid
#fname F size mode acl mtime uid gid contents
#fname L size mode acl lnmtime uid gid dest
```

```

#fname B size mode acl mtime uid gid devnode
#fname C size mode acl mtime uid gid devnode
/etc/security D 512 40755 user::rwx,group::r-x,mask:r-x,
    other:r-x 46dcb5b6 0 3
/etc/security/audit D 512 40755 user::rwx,group::r-x,mask:r-x,
    other:r-x 46dc91e4 0 3
/etc/security/audit/localhost D 512 40755 user::rwx,group::r-x,
    mask:r-x,other:r-x 46dc91e4 0 3
/etc/security/audit/localhost/files L 21 120777 - 46dc91e4 0 0
    ../../var/audit
/etc/security/audit_class F 2399 100644 user::rw-,group::r--,mask:r--,
    other:r-- 46d105cb 0 3 0d1c8c3cdafa3a874dc877ba1bba8380a
/etc/security/audit_control F 1014 100644 user::rw-,group::r--,mask:r--,
    other:r-- 46d105cb 0 3 0e2909e9477baa8dd973f57394b6779e
/etc/security/audit_event F 22330 100644 user::rw-,group::r--,mask:r--,
    other:r-- 46d105cb 0 3 3922a92f76c93d59785214045107a37d
/etc/security/audit_startup F 1116 100744 user::rwx,group::r--,mask:r--,
    other:r-- 46d105cb 0 3 944d347e1c6ac495ebdb4a66d50e690d
/etc/security/audit_user F 1053 100644 user::rw-,group::r--,mask:r--,
    other:r-- 46d105cb 0 3 2913855b950db00b595cf7b5dd1fff31
/etc/security/audit_warn F 7501 100740 user::rwx,group::r--,mask:r--,
    other:--- 46d10907 0 3 ae7290b8d5d63af3703f33f7e7010e46
[...]

```

In this example, BART was used to catalog the /etc/security directory. The manifest is directed to standard output but could have been easily saved to a file. BART can also be used in a compare mode where it takes two existing manifests and reports any differences. For example:

```

# bart compare manifest-before manifest-after
/etc/security/exec_attr:
    size control:29654 test:29664
    mtime control:46e8a76e test:46efee70
    contents control:caf727cccd4de989974c2c81fa7cfdf29
        test:071e79250e05b2363415ee5f05d25324

```

In this case, after comparing two manifests, `manifest-before` and `manifest-after`, BART detected a change to the /etc/security/exec\_attr file. The changes to this file included its size, its modification time and its MD5 fingerprint. BART can be used on both the global zone and non-global zones to detect changes occurring across file systems.

Organizations are encouraged to develop their own policy for BART and use it to regularly take point-in-time snapshots of their system configuration and compare those with a known good baseline so that unauthorized changes can be more quickly and easily detected. When used in concert with Solaris Auditing, these changes can often be traced back to specific users resulting in more effective incident response.

For more information on the Basic Audit Reporting Tool, see **bart(1)** as well as the following Archived Oracle technical papers:

- “Automating Centralized File Integrity Checks in the Solaris 10 Operating System”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-007-file-integrity-checks-sol10-438975.pdf>
- “Integrating BART and the Solaris Fingerprint Database in the Solaris 10 Operating System”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-008-bart-fingerprint-db-sol10-438976.pdf>

### Solaris Fingerprint Database

The Solaris Fingerprint Database is a collection of MD5 fingerprints for files included with Oracle Solaris (directly or within a patch). This database can be queried using a web-based interface or using a tool such as the Solaris Fingerprint Database Companion (**sfpC**) to determine if a given MD5 fingerprint belongs to a file shipped by Oracle. Often used for integrity validation and forensics, the Solaris Fingerprint Database can quickly and easily help organization determine the integrity of files as well as detect various conditions such as upgrade and downgrade attacks. For example, the fingerprint generated by the following command:

```
$ digest -a md5 -v /usr/bin/ls
md5 (/usr/bin/ls) = b526348af2d57610dd3635e46602d2a
```

generated the following response from the Solaris Fingerprint Database, thereby validating the object as a binary shipped by Oracle, **/usr/bin/ls**, included in the **SUNWcsu** package as part of Oracle Solaris 10 for the SPARC platform:

```
b526348af2d57610dd3635e46602d2a -- 1 match(es)
* canonical-path: /usr/bin/ls
* package: SUNWcsu
* version: 11.10.0,REV=2005.01.21.15.53
* architecture: sparc
* source: Solaris 10/SPARC
```

When a BART content comparison fails, it is a good idea to submit the MD5 fingerprint to the Solaris Fingerprint Database. This technique will enable organizations to determine if the file failing the check is in fact a valid file that was produced by Oracle. Very often, failures can occur when performing BART manifest comparisons after a set of patches has been applied to a system. Clearly, a number of files will be replaced by those patches. In this case, the use of BART with the Solaris Fingerprint Database will help an organization to validate that the new files did in fact come from Oracle patches.

For more information on the Solaris Fingerprint Database, see:

- Archived Oracle technical papers:

“The Solaris Fingerprint Database: A Security Tool for Solaris Operating Environment Files”:

<http://www.oracle.com/technetwork/server-storage/archive/a11-001-solaris-fingerprint-db-438963.pdf>

“Integrating BART and the Solaris Fingerprint Database in the Solaris 10 Operating System”:

<http://www.oracle.com/technetwork/server-storage/archive/a11-008-bart-fingerprint-db-sol10-438976.pdf>

- OpenSolaris Community Project: “Solaris Fingerprint Database Tools”:

<http://hub.opensolaris.org/bin/view/Project+forensics/sfpdb-tools>

## Auditing

Solaris Auditing helps to detect potential security breaches by revealing suspicious or abnormal patterns of system usage. Oracle Solaris auditing also provides a means to trace suspect actions back to a particular user, thus serving as a deterrent. Users who know that their activities are being audited are less likely to attempt malicious activities. The CIS Solaris 10 Security Benchmark recommends enabling Solaris Auditing in a section titled “Enable Kernel Level Auditing.”

### Audit Policy Configuration

In addition to selecting which events to audit, globally or for specific users, Solaris Auditing also supports a number of other configuration options. These configuration options are specified using the `auditconfig(1M)` program and stored in the `/etc/security/audit_startup` file. A few of the most often used policy settings are listed in the following table. For more information on each of these options as well as how they can be set, see `auditconfig(1M)`:

TABLE 5. FREQUENTLY USED POLICY SETTINGS	
AUDIT POLICY	DESCRIPTION
ahlt	Halt the machine if an asynchronous audit event occurs that cannot be delivered because the audit queue has reached the high-water mark or because there are insufficient resources to construct an audit record. By default, this option is not set and audit records are dropped (when either of these conditions occurs) and a count is kept of the number of dropped records. This count can be queried using the <code>auditstat(1M)</code> command.
arge	Include the <code>execv(2)</code> system call environment arguments to the audit record. This information is not included by default in Oracle Solaris, but it is enabled by the CIS item titled “Enable Kernel Level Auditing.”
argv	Include the <code>execv(2)</code> system call parameter arguments to the audit record. This information is not included by default in Oracle Solaris, but it is enabled by the CIS item titled “Enable Kernel

	Level Auditing."
public	Audit public files. By default, read operations are not audited for certain files which meet public characteristics: owned by <code>root</code> , readable by all, and not writable by all. This option, when enabled, helps to reduce some of the non-security relevant events or "noise" commonly found in audit trails.
seq	Include the sequence token as part of every audit record. By default, the sequence token is not included. The sequence token attaches a sequence number to every audit record.
zonename	Include the zone name token as part of every audit record. By default, the zone name token is not included. The zone name token gives the name of the zone from which the audit record was generated.
ahlt	Halt the machine if an asynchronous audit event occurs that cannot be delivered because the audit queue has reached the high-water mark or because there are insufficient resources to construct an audit record. By default, this option is not set and audit records are dropped (when either of these conditions occurs) and a count is kept of the number of dropped records. This count can be queried using the <code>auditstat(1M)</code> command.

### Audit Record Selection and Display

Once Solaris Auditing has been enabled, organizations can use the audit trails to better understand what actions are being taken on their systems. In particular, the commands `auditreduce(1M)` and `praudit(1M)` can be used to select and display events respectively. For example, the following audit record shows that the user `gbrunett` successfully used the `su` command to access a root shell in the global zone on `sec-b1600-0`:

```
# auditreduce -u gbrunett -m AUE_su | praudit -s
header,104,2,AUE_su,,sec-b1600-0,2007-09-23 15:29:00.248 -04:00
subject,gbrunett,root,gbrunett,gbrunett,692,2868335681,0 0
sec-b1600-0
text,success for user root
return,success,0
zone,global
```

This same information can also be represented in XML in Oracle Solaris 10:

```
# auditreduce -u gbrunett -m AUE_su | praudit -x
<?xml version='1.0' encoding='UTF-8' ?>
<?xml-stylesheet type='text/xsl'
    href='file:///usr/share/lib/xml/style/adt_record.xsl.1' ?>

<!DOCTYPE audit PUBLIC '-//Sun Microsystems, Inc.//DTD Audit V1//EN'
    'file:///usr/share/lib/xml/dtd/adt_record.dtd.1'>
<audit>
<file iso8601="2007-09-23 15:29:00.000 -04:00"></file>
<record version="2" event="su" host="sec-b1600-0" iso8601="2007-09-23
15:29:00.248 -04:00">
<subject audit-uid="gbrunett" uid="root" gid="gbrunett" ruid="gbrunett"
rgid="gbrunett" pid="692" sid="2868335681" tid="0 0 sec-b1600-0"/>
<text>success for user root</text>
<return errval="success" retval="0"/>
<zone name="global"/>
</record>
<file iso8601="2007-09-23 15:29:00.000 -04:00"></file>
</audit>
```

Similarly, in Oracle Solaris 10, Solaris Auditing can be configured to forward audit events to `syslog`. Regardless of whether the use of `syslog` has been configured, audit events are always recorded in binary format and stored in the audit directory, by default `/var/audit`, on the system. When using the `syslog` plugin, the above audit event would be recorded as:

```
Sep 23 15:29:00 sec-b1600-0 audit: [ID 702911 audit.notice] su ok session
2868335681 by gbrunett as root:gbrunett in global from sec-b1600-0 text
success for user root
```

Note that when using the `syslog` plugin, only a subset of audit event fields is displayed. The complete set of fields for each audit record is available from the binary format that is stored in the audit directory. For more information on Solaris Auditing, see:

- OpenSolaris Community Project: OpenSolaris Security Audit:  
<http://hub.opensolaris.org/bin/view/Project+audit/WebHome>
- “Using Solaris Auditing in Zones” in Chapter 27, “Solaris Zones Administration (Overview),” of *System Administration Guide: Oracle Solaris Containers-Resource Management and Oracle Solaris*:  
<http://download.oracle.com/docs/cd/E19253-01/index.html>
- Archived Oracle technical paper: “Enforcing the Two-Person Rule via Role-Based Access Control in the Solaris 10 Operating System”: <http://www.oracle.com/technetwork/server-storage/archive/a11-011-two-person-rule-role-access-438989.pdf>

- Blogs:

“Defining your own audit class”:

[http://blogs.oracle.com/martin/entry/defining\\_your\\_own\\_audit\\_class](http://blogs.oracle.com/martin/entry/defining_your_own_audit_class)

“Measuring the impact of auditing”:

[http://blogs.oracle.com/martin/entry/measuring\\_the\\_impact\\_of\\_auditing](http://blogs.oracle.com/martin/entry/measuring_the_impact_of_auditing)

“How system calls are audited”:

[http://blogs.oracle.com/martin/entry/how\\_system\\_calls\\_are\\_audited](http://blogs.oracle.com/martin/entry/how_system_calls_are_audited)

“ZFS the perfect file system for audit trails”:

[http://blogs.oracle.com/martin/entry/zfs\\_the\\_perfect\\_file\\_system](http://blogs.oracle.com/martin/entry/zfs_the_perfect_file_system)

“How to determine if there are audit records in a crash dump”:

[http://blogs.oracle.com/martin/entry/how\\_to\\_determine\\_if\\_there](http://blogs.oracle.com/martin/entry/how_to_determine_if_there)

“Adding auditing to your application (part 1)”:

[http://blogs.oracle.com/martin/entry/adding\\_auditing\\_to\\_your\\_application](http://blogs.oracle.com/martin/entry/adding_auditing_to_your_application)

“Adding auditing to your application (part 2)”:

[http://blogs.oracle.com/martin/entry/adding\\_auditing\\_to\\_your\\_application2](http://blogs.oracle.com/martin/entry/adding_auditing_to_your_application2)

## Packet Filtering

### IP Filter

Solaris IP Filter integrates the open source IP Filter software into Oracle Solaris 10. IP Filter provides stateful packet filtering capabilities and can filter packets by IP address or network, port, protocol, network interface, and traffic direction. In addition, it also has the ability to perform network address translation (NAT) and port address translation (PAT). IP Filter supports both IPv4 and IPv6, and is configured using a simple firewall rules policy language. Information and examples on the syntax of the policy language can be found in *ipf(4)*.

IP Filter can be enabled using the SMF service `svc:/network/ipfilter:default` or `ipfilter`, for short:

```
$ svcs ipfilter
STATE          STIME      FMRI
disabled       Sep_16    svc:/network/ipfilter:default

$ svcadm enable -r ipfilter

$ svcs ipfilter
STATE          STIME      FMRI
online         14:39:44  svc:/network/ipfilter:default
```

By default, the IP Filter configuration is stored in `/etc/ipf/ipf.conf`. Using the `ipfstat(1M)` command, the list of incoming and outgoing rules being enforced can be displayed:

```
# ipfstat -io
pass out quick all keep state keep frags
block in quick from any to any port = 137
block in quick from any to any port = 138
block in quick from any to any port = 139
pass in quick proto udp from any to any port = ike
pass in quick proto udp from any to any port = 4500
pass in quick proto esp from any to any
pass in log quick proto tcp from 192.168.1.0/24 to any port = ssh
block in log all
block in from any to 255.255.255.255/32
block in from any to 127.0.0.1/32
```

The example shown above illustrates an example IP Filter rule set that could be used on a desktop or laptop since it does not restrict outbound communication but blocks nearly everything attempting to communicate to the system. The above example also includes support for IPsec/IKE and incoming Secure Shell (from a specific network). The `ipfstat(1M)` command can also be used to collect valuable information and statistics regarding how IP Filter is functioning.

IP Filter can log information to the `syslog` facility. The following example illustrates a blocked `telnet` connection attempt from 192.168.0.1 to 192.168.0.2:

```
Sep 18 14:47:50 blackhole ipmon[7237]: [ID 702911 local0.warning]
14:47:50.075431 ip.tun0 @0:12 b 192.168.0.1,52854 -> 192.168.0.2,23 PR tcp
len 20 52 -S IN
```

For more information on IP Filter, see:

- Chapter 25, “Oracle Solaris IP Filter (Overview),” in the Oracle Solaris 10 *System Administration Guide: IP Services*: <http://download.oracle.com/docs/cd/E19253-01/index.html>
- Open Source IP Filter: <http://coombs.anu.edu.au/~avalon/>

## TCP Wrappers

TCP Wrappers is a collection of programs and libraries that enable organizations to restrict access to TCP-based network services. As originally discussed in the CIS Solaris 10 Security Benchmark section called “Configure TCP Wrappers,” access policy is configured using a pair of files:

/etc/hosts.allow and /etc/hosts.deny. In Oracle Solaris 10, both Secure Shell and sendmail(1M) are configured to always use TCP Wrappers if either of the /etc/hosts.allow or /etc/hosts.deny files exist. In addition, the RPC port mapping daemon, rpcbind, and inetd can be optionally configured to restrict access using TCP Wrappers as in the following example for rpcbind:

```
# svccfg -s rpc/bind setprop config/enable_tcpwrappers=true  
# svcadm refresh rpc/bind
```

The `inetd` service can be configured using a similar SMF property. In addition, services started by the `inetd` service can be configured to individually use TCP Wrappers using per-service configuration parameter as shown in the following example based on the `telnet` service:

```
$ inetadm -l telnet | grep tcp_wrappers  
default  tcp_wrappers=FALSE  
  
$ pfexec inetadm -m telnet tcp_wrappers=TRUE  
  
$ inetadm -l telnet | grep tcp_wrappers  
tcp_wrappers=TRUE
```

In the CIS Solaris 10 Security Benchmark section titled “Configure TCP Wrappers,” the example provided shows how to configure a single, default deny policy for all services. It should be noted that TCP Wrappers supports a rich configuration policy language that enables organizations to specify policy not only globally but on a per-service basis. Further access to services can be permitted or restricted based upon host name, IPv4 or IPv6 address, netgroup name, network, and even DNS domain. More information and examples of the syntax of this access control language can be found in `host_access(4)`.

For more information on configuring and using TCP Wrappers, see `tcpd(1M)`, `tcpdchk(1M)`, `tcpd-match(1M)`, and `hosts_access(4)` as well as:

- “How to Use TCP Wrappers to Control Access to TCP Services,” in Chapter 5, “How to Use TCP Wrappers to Control Access to TCP Services,” of the Oracle Solaris 10 *System Administration Guide: IP Services*: <http://download.oracle.com/docs/cd/E19253-01/index.html>
- Blog: “Enabling TCP Wrappers on Solaris 10”:  
[http://blogs.oracle.com/gbrunett/entry/tcp\\_wrappers\\_on\\_solaris\\_10](http://blogs.oracle.com/gbrunett/entry/tcp_wrappers_on_solaris_10)

## Remote Access Security

### Internet Protocol Security (IPsec)

Oracle Solaris 10 supports IP Security (IPsec) for both IPv4 and IPv6. Originally introduced in the Solaris 8 OS, IPsec and its key exchange protocol, IKE, have been enhanced in Oracle Solaris 10 to provide complete support for tunnel mode, IKE NAT traversal (RFC 3947 and RFC 3948), and the Solaris Cryptographic Framework.

In particular, the Solaris Cryptographic Framework provides a `softtoken` keystore for applications that use the `metaslot`. When IKE is configured to use the `metaslot`, organizations have the option of storing the keys on disk, on an attached hardware keystore, or in the `softtoken` keystore. For more information on the `softtoken` keystore, see `cryptoadm(1M)`.

For more information, see:

- Oracle Solaris 10 *System Administration Guide: IP Services*:  
<http://download.oracle.com/docs/cd/E19253-01/index.html>
- “Protecting Traffic with IPsec” in Chapter 20, “Configuring IPsec (Tasks),” in the Oracle Solaris 10 *System Administration Guide: IP Services*: <http://download.oracle.com/docs/cd/E19253-01/index.html>
- OpenSolaris Community Project: IPsec Tunnel Reform:  
<http://hub.opensolaris.org/bin/view/Project+tref/WebHome>

### Secure Shell

Originally based upon a fork of the OpenSSH software, Solaris Secure Shell enables users or services to access or transfer files between remote systems over an encrypted communications channel. In Solaris Secure Shell, authentication is provided by the use of passwords, public keys, or both. All network traffic is encrypted. Thus, Solaris Secure Shell prevents a would-be intruder from being able to read an intercepted communication. Solaris Secure Shell also prevents an adversary from spoofing the system. Solaris Secure Shell can also be used as an on-demand virtual private network that can forward X Window system traffic or can connect individual port numbers between the local machines and remote machines over an authenticated and encrypted network link.

The configuration of Solaris Secure Shell is contained in the following files:

- `/etc/ssh/ssh_config`. This file provides the system-wide default settings for the client portion of the Solaris Secure Shell software, `ssh(1)`. For more information on what settings are available, see `ssh_config(4)`. These settings can also be overridden on a per-user basis by creating a file `$HOME/.ssh/config`.
- `/etc/ssh/sshd_config`. This file provides the system-wide default settings for the server portion of the Solaris Secure Shell software, `sshd(1M)`. For more information on what settings are available, see `sshd_config(4)`.

Secure Shell configuration recommendations are covered in the CIS Solaris 10 Security Benchmark section called “Configure SSH.”

For more information on Solaris Secure Shell, see:

- OpenSolaris Community Project: “Solaris Secure Shell (SunSSH)”:  
<http://hub.opensolaris.org/bin/view/Community+Group+security/SSH>
- Chapter 19, “Using Solaris Secure Shell (Tasks),” in the Oracle Solaris 10 *System Administration Guide: Security Services*: <http://download.oracle.com/docs/cd/E19253-01/index.html>

## Kerberos

The Kerberos service is a client-server architecture that provides secure transactions over networks. The service offers strong user authentication, as well as integrity and privacy. Authentication guarantees that the identities of both the sender and the recipient of a network transaction are true. The service can also verify the validity of data being passed back and forth (integrity) and encrypt the data during transmission (privacy). Using the Kerberos service, you can log in to other machines, execute commands, exchange data, and transfer files securely. Additionally, the service provides authorization services, allowing administrators to restrict access to services and machines. Moreover, as a Kerberos user, you can regulate other people's access to your account.

The Kerberos service is a single-sign-on system, which means that you only need to authenticate yourself to the service once per session, and all subsequent transactions during the session are automatically secured. After the service has authenticated you, you do not need to authenticate yourself every time you use a Kerberos-based command such as `ftp` or `rsh`, or to access data on an NFS file system. Thus, you do not have to send your password over the network, where it can be intercepted, each time you use these services.

The Solaris Kerberos service is based on the Kerberos V5 network authentication protocol that was developed at the Massachusetts Institute of Technology (MIT). Because the Kerberos V5 protocol is a de facto industry standard for network security, the Solaris version promotes interoperability with other systems. In other words, because the Solaris Kerberos service works with systems that use the Kerberos V5 protocol, the service allows for secure transactions even over heterogeneous networks. Moreover, the service provides authentication and security both between domains and within a single domain.

The Kerberos service allows for flexibility in running Solaris applications. You can configure the service to allow both Kerberos-based and non-Kerberos-based requests for network services such as the NFS service, `telnet`, `ftp`, `rlogin` and Secure Shell. As a result, current Solaris applications still work even if they are running on systems on which the Kerberos service is not enabled. Of course, you can also configure the Kerberos service to allow only Kerberos-based network requests.

The Kerberos service provides a security mechanism which allows the use of Kerberos for authentication, integrity, and privacy when using applications that use the Generic Security Service Application Programming Interface (GSS-API). However, applications do not have to remain committed to the Kerberos service if other security mechanisms are developed. Because the service is designed to integrate modularly into the GSS-API, applications that use the GSS-API can utilize whichever security mechanism best suits their needs.

For more information configuring and using Kerberos, see:

- OpenSolaris Community Project: Kerberos:  
<http://hub.opensolaris.org/bin/view/Project+kerberos/>
- “Kerberos Service” in the Oracle Solaris 10 *System Administration Guide: Security Services*:  
<http://download.oracle.com/docs/cd/E19253-01/index.html>

## Oracle Solaris Trusted Extensions

Oracle Solaris Trusted Extensions is an optionally enabled layer of secure labeling technology that allows data security policies to be separated from data ownership. While it has its roots in the multilevel Trusted Solaris 8 OS, it has been integrated into the standard Oracle Solaris 10 Operating System. This new approach allows Oracle Solaris to support both traditional Discretionary Access Control (DAC) policies based on ownership, as well as label-based Mandatory Access Control (MAC) policies. The label-based policies for file systems and networks are light-weight and have been implemented within the standard Oracle Solaris 10 kernel, services and utilities. Unless the Trusted Extensions layer is enabled, all labels are equal so the kernel is not configured to enforce the MAC policies. For efficiency, a Boolean value is maintained in the kernel to indicate whether labeling comparisons should be used in policy enforcement.

When the label-based MAC policies are enabled, all data flows are restricted based on a comparison of the labels associated with the subjects requesting access and the objects containing the data. Like other multilevel operating systems, Trusted Extensions meets the requirements of the Common Criteria Labeled Security Protection Profile (LSPP), the Role-Based Access Protection Profile (RBACPP) and the Controlled Access Protection Profile (CAPP). However, the Trusted Extensions implementation is unique in its ability to provide high assurance, while maximizing compatibility and minimizing overhead.

For more information, see:

- OpenSolaris Community Project: Trusted Extensions:  
<http://hub.opensolaris.org/bin/view/Community+Group+security/tx>
- “Solaris Trusted Extensions Architectural Overview”:  
<http://hub.opensolaris.org/bin/download/Community+Group+security/tx/TrustedExtensionsArch.pdf>
- *Oracle Solaris Trusted Extensions Developer's Guide*:  
<http://download.oracle.com/docs/cd/E19253-01/index.html>
- Blogs:
  - “Remote Multilevel Desktop Sessions”:  
[http://blogs.oracle.com/gfaden/entry/remote\\_multilevel\\_desktop\\_sessions](http://blogs.oracle.com/gfaden/entry/remote_multilevel_desktop_sessions)
  - “Label-aware Web Services”: [http://blogs.oracle.com/gfaden/entry/label\\_aware\\_web\\_services](http://blogs.oracle.com/gfaden/entry/label_aware_web_services)

## Additional References

### Books

*Solaris 10 Security Essentials* (ISBN: 978-0137012336), by Sun Microsystems Security Engineers (2009)

### Training and Certifications

- Configuring Security on the Solaris 10 OS (SC-301-S10):  
[http://education.oracle.com/pls/web\\_prod-plq-dad/db\\_pages.getCourseDesc?dc=D61816GC10](http://education.oracle.com/pls/web_prod-plq-dad/db_pages.getCourseDesc?dc=D61816GC10)
- Solaris Trusted Extensions Installation, Configuration (SC-327-S10):  
[http://education.oracle.com/pls/web\\_prod-plq-dad/db\\_pages.getCourseDesc?dc=D61906GC10](http://education.oracle.com/pls/web_prod-plq-dad/db_pages.getCourseDesc?dc=D61906GC10)
- Sun Certified Security Administrator for the Solaris 10 OS (CX-310-303):  
<http://www.oracle.com/partners/en/knowledge-zone/server-storage/cx-310-303-exam-page-170485.html>

### Best Practices and White Papers

- Solaris 10/OpenSolaris Security Community Library:  
<http://hub.opensolaris.org/bin/view/Community+Group+security/library>
- Center for Internet Security Solaris 10 Security Benchmark:  
<http://benchmarks.cisecurity.org/en-us/?route=downloads.show.single.solaris10.500>
- Archived Oracle technical paper: “Toward Systemically Secure IT Architectures”:  
<http://www.oracle.com/technetwork/server-storage/archive/a11-013-systemically-sec-it-arch-439763.pdf>

### Presentations

- Solaris 10/OpenSolaris Security Community Presentation Library:  
<http://hub.opensolaris.org/bin/view/Community+Group+security/preso>
- Solaris 10 Security Technical Deep Dive (Updated for Solaris 10 05/09):  
<http://hub.opensolaris.org/bin/download/Project+isc/WebHome/s10-security-dive-20091021.pdf>

### Additional Web Sites

- Sun Product Security Community Blog: <http://blogs.oracle.com/sunsecurity/>
- Oracle Solaris Security:  
<http://www.oracle.com/us/products/servers-storage/solaris/security/index.html>
- Oracle Solaris Security for System Administrators:  
<http://www.oracle.com/technetwork/server-storage/solaris/overview/security-163473.html>

- Solaris Security Certifications Resource Center:  
<http://www.oracle.com/technetwork/systems/security/overview/index.html>
- OpenSolaris Security Community:  
<http://hub.opensolaris.org/bin/view/Community+Group+security/WebHome>

## Conclusion

This document provided an overview of the security features and capabilities found in Oracle Solaris 10, including those that were not appropriate for the CIS guide. Specific recommendations and references for more detailed information were provided wherever possible.



An Overview of Oracle Solaris 10 Security  
Controls

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