18^c ORACLE®
Database

Oracle ACFS 18c
ASM Cluster File System

What is it and How to use it

ORACLE WHITE PAPER | FEBRUARY 2018

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Introduction

Cloud. Present and future are bound towards a Cloud world. Companies that design, plan and correctly implement their business around a Cloud centric architecture will thrive and succeed. In order to do so, several components should be taken into account; none more important that the foundations, which have the storage layer as a key component. This storage layer must possess a wide arrange of features that suits this Cloud bound destination.

Oracle ASM Cluster File System (hereinafter Oracle ACFS) offer all of these, and more. Fulfilling all industry standards, complying to POSIX, X/OPEN and Windows, Oracle ACFS offers support to multiple Operating Systems such as Oracle Linux, Redhat, Novell SLES, Solaris, AIX and Windows. Oracle ACFS is deployed in a wide arrange of server platforms, ranging from traditional server environments, Oracle Engineered Systems such as the Oracle Exadata Database Machine and the Oracle Database Appliance, and it is steadily becoming the storage foundation of choice for diverse Cloud offerings.

Throughout years of constant growth and evolution, Oracle ACFS has broaden its scope as a cluster file system, incorporating diverse features and functionality to its offering and becoming the preferred storage management solution of choice for application files and Oracle Database files. Oracle ACFS allows for file system snapshots, providing its user with the capability of provisioning test and development environments in a simple and efficient way. Tagging, Encryption, Security and Auditing offer a framework for different storage management operations as well.
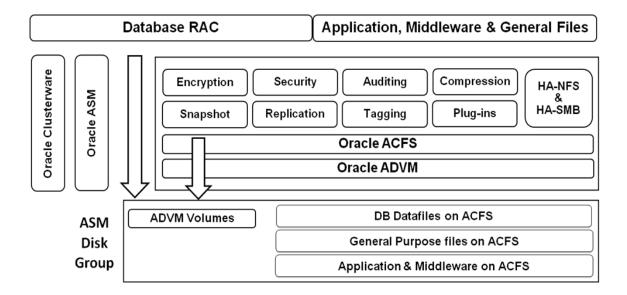
Customers can leverage Oracle ACFS replication capabilities to have a disaster recovery site for their application and database data or in order to provision test and development environments in a different cluster. Furthermore, Oracle ACFS provides customers with a comprehensive set of features such as compression, highly available NFS and SMB services, automatic resize, support for sparse files, metadata acceleration, remote service, file system freezing and more.

Oracle ACFS, through is wide arrange of features and functionality, provides a scalable, high performance and highly available solution that simplifies system and storage management and lays the foundation for your Cloud architecture.

What is Oracle ACFS?

Architecture

Oracle ACFS, as part of Oracle Grid Infrastructure, is integrated with Oracle ASM, Oracle ADVM and Oracle Clusterware as shown in diagram 1 below. It communicates with Oracle ASM to store metadata locally which allows for direct access to ASM disk group storage for maximum performance. It also communicates with Oracle Clusterware to facilitate resource management for ACFS.

Upon creation of an Oracle ADVM volume a dynamic volume file is created for interface purposes of ACFS with ASM storage. Communication between Oracle ACFS and the Oracle ASM instance will now be performed through the Oracle ACFS driver. However, all I/O will go directly from Oracle ACFS to the Oracle ASM storage.

Grid Infrastructure integration allows for Oracle ACFS to leverage Clusterware resources, like cluster membership state transitions, driver loading, mount and unmount of file systems, enabling and disabling of volumes; all these provides High Availability for both Oracle ACFS and Oracle ADVM resources.

Oracle ACFS is a complete storage solution, that eliminates the need for expensive third party solutions, bringing together high availability and best in class features to manage your storage needs. Oracle ACFS offers a complete cluster file system with the best performance, simplicity in its management and high availability as part of the Grid Infrastructure stack. Also, as part of its offering, the following features standout:

» Encryption:
    » Encryption capabilities for all your application data. It allows for data-at-rest protection, which can be encrypted using keys based at the file or volume level. Oracle ACFS encryption offers support for both Oracle Key Vault and Oracle Cluster Registry for key store purposes.

» Security:

» Fine-grained control for higher level security for your file system. Oracle ACFS security offers a realm-based security solution in order to enforce security policies for OS users and groups.

» Audit:

» Oracle ACFS provides an audit framework for your file system with its auditing capabilities. Providing a separate audit trail for each of your file systems and on a per node basis.

» Compression:

» Oracle ACFS introduced compression to its set of features in 12c Release 2. This solution comes from Oracle Database Advanced Compression and is available for your application data.

» Snapshots:

» Oracle ACFS provides the ability to generate point in time read-write or read-only copies of Oracle ACFS File systems and Oracle Databases. This provides for an efficient tool for test and development environment provisioning purposes.

» Replication:

» Oracle ACFS provides the capability to replicate an entire file system to a different location so that customers can provide for test and development or in case of disaster recovery. Starting in 12c release 2, Oracle ACFS replication evolved to a snapshot based replication, enhancing its already existing capabilities and providing maximum efficiency and flexibility in its replication. Starting in 18c, Oracle ACFS introduces role reversal, allowing a standby site to become an active site and active site to become a standby site in case this is required.

» Tagging:

» Oracle ACFS offers tagging capabilities in order to assign a naming attribute to any file or group of files. This capability allows for files to be grouped in categories and hence replicate only such groups, avoiding a complete file system to be replicated.

» Plugins:

» Users can leverage the Oracle ACFS Plugin functionality to collect updated filesystem and volume metric information.

» Accelerator Volumes:

» Oracle ACFS provides the ability to create accelerator volumes on specific, faster storage, in order to improve performance and access time to relevant filesystem metadata.

» NAS Maximum Availability eXtensions

» Oracle ACFS can be leveraged by customers to provide service of network file systems such as NFS or SMB without requiring any additional infrastructure. Oracle ACFS NAS Max eXtensions provide the ability for the aforementioned protocols to run in high availability mode in an Oracle RAC Cluster.

» ACFS Remote Service

» Oracle ACFS provides functionality for Oracle Domain Services Cluster deployment. Starting in release 18c, Oracle ACFS remote is introduced, allowing customers to leverage native Oracle ACFS functionality on an Oracle Database Member Cluster. For more information on Oracle Domain Services Cluster architecture please review the associated collateral on the Oracle Clusterware product page1.

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[1] Oracle Clusterware www.oracle.com/goto/clusterware

What is new in Oracle ACFS 18c

Oracle ACFS is a mature cluster file system that has evolved constantly since its inception as part of the Oracle Grid Infrastructure stack. In release 18c, Oracle ACFS offers the following new features:

Role Reversal Replication	ACFS FS size reduce	ACFS Remote Service
• **Role reversal** • **Standby** assumes **Active** Role	• New capability of **reducing** ACFS file systems size	• **Native** ACFS Functionality on **Member** Clusters
Storage Usage Info	Command Enhancements	Temporarily Freezing
• `acfsutil info storage` shows information on ASM disk group storage usage by ASM, ACFS and ADVM	• Further functionality for `acfsutil snap` command • Further functionality for diagnostics commands	• `acfsutil freeze/thaw` for temporarily halting/resuming activity in an ACFS FS

» Role Reversal Replication
  » Oracle ACFS replication introduces role reversal, allowing the original primary and standby locations to switch roles. One single commands allow users to change the original primary location to become the new standby, and the original standby location to become the new primary.
» File System size reduce
  » A single command allows for file system size reduction; this new feature helps to free unused storage space on the fly, this operation will go through regardless of the need or not to move user files and metadata.
» Storage information commands
  » Platform independent information related to storage is now available via one single command. Information available comprises of Oracle ASM disk group information and its consumption by components of the storage stack such as ASM, ACFS and ADVM.
» Oracle ACFS Snapshot commands enhancements
  » Oracle ACFS administration commands have been enhanced, offering new options for improved management of ACFS snapshots.
  » Oracle ACFS snapshot links are introduced in release 18c. A snapshot link basically presents an alternate path that provides access to a snapshot and its contents. By default, snapshots are stored and created in a specific directory; snapshot links allow for access to the snapshots using a provided new path.
  » Oracle ACFS allows for the creation of duplicated snapshots or file systems. In Oracle ACFS 12c Release 2, command acfsutil snap duplicate apply was introduced, allowing for duplicated snapshots or file systems to be updated from their original source, using the same duplication stream and also generating an extra backup snapshot if desired. In Oracle ACFS 18c the ability to name and single out this specific back up snapshot is introduced.
» Oracle ACFS file system temporarily freezing
  » Oracle ACFS 18c introduces new commands to temporarily pause and resume file system activity.

» Oracle ACFS file system diagnostic commands
  » Oracle ACFS 18c updates commands that present diagnostic and management information pertaining to file system metadata.
» Oracle ACFS Remote Service
  » As stated previously, Oracle ACFS 18c introduces support for native Oracle ACFS functionality on both database member clusters and application clusters. Oracle member clusters with no local storage can leverage all Oracle ACFS feature and functionality through Oracle ACFS Remote Service.

Oracle ACFS Platform Support

Exadata Database Machine	Oracle Database Appliance	Generic Hardware
*Starting with GI 12.1.0.2	Oracle ACFS is the primary file system to store all database files and general purpose data on ODA	Multi OS Support Windows, Oracle Unbreakable Linux, Oracle Linux with RedHat, RedHat, Novell SLES, Solaris, AIX.
Supported database versions: 10.2.0.4/5, 11.2.0.4+, 12.1.0.2+	Supported database versions: 11.2.0.4+, 12.1.0.2+	

Oracle ACFS is supported on multiple operating systems including Linux, Windows, Novell SLES, Solaris and AIX, for further information regarding kernel and Operating System specifics refer to My Oracle Support note 1369107.1[2] Oracle Engineered Systems where Oracle ACFS is supported include Oracle Database Appliance (ODA) and Oracle Exadata Database Machine.

Oracle ACFS on Oracle Database Appliance

Oracle ACFS is the primary cluster file system to store database files and general purpose data in the Oracle Database Appliance. Since Oracle ACFS is built on top of Oracle ASM, the Oracle Database Appliance leverages the best of both products. Oracle Database Appliance adoption of Oracle ACFS provides with a wide array of functionalities requiring no additional effort or management.

File system management in the Oracle Database Appliance is done automatically by the integrated Appliance Manager, which means that all storage, including ACFS file systems and their underlying ASM diskgroups require no administration. By default, three file systems are created in the Oracle Database Appliance. These file systems are created in the already existing Oracle ASM disk groups, DATA, RECO and REDO. Oracle Database Appliances leverages Oracle ACFS snapshotting capabilities, allowing for provision of test and development environments in the fastest and efficient way and performance equivalent to Oracle ASM.

2
https://support.oracle.com/epmos/faces/DocContentDisplay?id=1369107.1

Oracle ACFS on Exadata Database Machine

Oracle Exadata Database Machines run Oracle Linux and support Oracle ACFS for all database files and general purpose files starting with Oracle ACFS 12c Release 1 (12.1.0.2). Oracle Database files supported in Oracle ACFS on Exadata Database Machines are limited to Oracle Database 10g Rel 2 (10.2.0.4 and 10.2.0.5), 11g (11.2.0.4 and higher) and Oracle Database 12c (12.1.0.1 and higher).

Oracle ACFS, as of now, does not use Oracle Smart Scan (predicate processing) and is not able to push database operations directly to storage leveraging Oracle Exadata storage. Oracle ACFS snapshot and tagging capabilities are supported for database files, however replication, security, encryption and audit capabilities are supported only for general-purpose files.

Oracle ACFS Use Cases

Oracle ACFS can be used in multiple scenarios that can leverage and benefit from its features and functionality. Oracle ACFS is ideal for Oracle RAC cluster environments, standalone deployments, Oracle middleware and Oracle Application environments and other vendor provided environments. Oracle ACFS use cases range from managing Oracle Database files, general purpose files, shared database homes, administrative files, log files, trace and audit files, storing and managing business and unstructured data, delivering NFS/SMB exported file systems, leveraging NFS/SMB to off host backups, complementing Oracle Data Guard for Disaster Recovery solutions with Oracle ACFS snapshot based Replication, leveraging snapshotting for quick provisioning test and development environments, among many other possible implementations. Please see below for a detailed list of Oracle ACFS use cases present among our extensive list of customers:

Oracle Database files	Shared homes	Business data
• Leverages **standard** UI • **Advanced** functionality	• For DB, Apps and middleware files • HA and **simple** management	• Business data storage

Test & Dev Provisioning	Backups	General purpose files
• Leverage of Oracle ACFS snapshot technology	• **Simply** host backups using ACFS NFS / CIFS	• OVM Repository, Golden Gate trail files, trace files, etc.

Remote ACFS	Oracle Database Appliance	Exadata Cloud Service
• Access to DB on ACFS on remote clusters	• Default File System on ODA • ODA Leverages ACFS Snapshot technology	• DB Home on ACFS • General Purpose Files

Oracle Cloud Infrastructure	HA/NFS server	
• DB on ACFS, RAC • VM images, General purpose files	• Leverage existing storage at **zero cost**	

Oracle ACFS Performance

Oracle ACFS underlying architecture delivers optimal performance for general-purpose files and Oracle Database files. Oracle ACFS utilizes a direct I/O path from the database to the ASM disk group devices and hence bypasses the traditional OS VM page caching mechanism used for file system applications. This model enables ACFS-based databases to achieve performance metrics comparable to databases configured to use Oracle ASM directly. Comprehensive internal benchmarks using OLTP and DSS workloads have proven the performance of Oracle ACFS and Oracle ASM to be similar, for further information please visit the Oracle ACFS OTN page.[3]
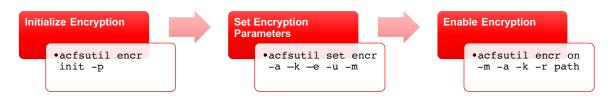
How to use Oracle ACFS

Oracle Grid Infrastructure installation process includes the Oracle ASM, ACFS and ADVM products. Once the installation is completed, it is fairly easy to take advantage of all the features and functionalities that Oracle ACFS brings to the table. Users only need to open Oracle ASM Configuration assistant, under the grid user, normally invoked via the command asmca, and then as simple as the three following steps, an Oracle ACFS file system will be created and mounted on all nodes of your cluster and ready to use.

1. Select the "Volumes" tab and create a Volume indicating relevant volume information.
2. Select the "ASM Cluster File Systems" tab and create a file system indicating relevant file system information such as mount point, size, etc.
3. Run the requested scripts as root

Once you have created and mounted an Oracle ACFS system, it should be ready and available throughout all your nodes in your cluster, and it will support all your files such as Oracle Database data files, trace files, alert logs, application files, video, audio, text images, general-purpose application file data, etc. The following section will cover how to use Oracle ACFS based on its most relevant features and functionalities.

Oracle ACFS Encryption

Oracle ACFS offers encryption capabilities for its data. ACFS allows for the encryption to be applied to directories, file systems or individual files. Encrypted and non-encrypted files can be present in the same file system. As shown below, the process is straightforward and simple for users to leverage the functionality of this feature:

Initialize Encryption		Set Encryption Parameters		Enable Encryption
• `acfsutil encr init –p`	→	• `acfsutil set encr –a –k –e -u -m`	→	• `acfsutil encr on –m -a –k –r path`

`acfsutil encr init` command allows for encryption to be initialized on any given Oracle ACFS file system and must be run first on any use case, regardless of the key store intended to be used. As a result of this command, storage for the encryption keys is created. Optionally, you can run it with the –p option which allows for the keys storage to be password protected, hence you will be requested to provide a password.

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[3] www.oracle.com/goto/acfs

`acfsutil set encr -a –k –e -u –m` command configures encryption parameters for your Oracle ACFS file system, this allows for initial setting of changes of this parameters if required. On execution of the command, the encryption parameters are set, a volume encryption key is generated and stored in storage created in the `init` step. The options to be set are:

- » `-a` which allows for the encryption algorithm to be set, currently AEK is the only supported algorithm, however, when `–k` option is set, `-a AEK` must be specified.
- » `–k` option that specifies the encryption key length, available options are 128, 192 (default) and 256.
- » `–e` if used, indicates that Oracle Key Vault will be used as the key store.
- » `–u` reverses encryption from an Oracle ACFS file system, by decrypting all encrypted files.
- » `–m` option for specifying the mount point of the file system.

`acfsutil encr on –m –a –k –r path` command allows for encryption to take place on an entire file system or given directory or file. For operations with this command, user must have root privileges if it intends to encrypt an entire file system. All options are the same as describe in the previous commands except for `–r` & `path`. The `–r` option allows for encryption to be executed recursively for all existing contents under a specified directory. The `path` option specifies which single or multiple directories will be encrypted.
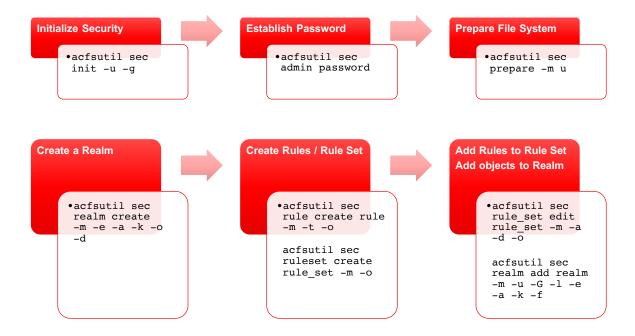
Important elements to be considered when using Oracle ACFS Encryption:

- » Oracle ACFS can be used for storage of Oracle Database files, however, ACFS Encryption is not supported for database files, in this case users must use the Oracle Advanced Security option.
- » Oracle ACFS can use the Oracle Cluster Registry (OCR) as a key store. In this case, it is recommended to back up the Oracle Cluster Registry upon creation of the encryption key to ensure availability of encryption keys backup.
- » Oracle ACFS encrypted file copies will not be encrypted, encryption is only guaranteed if the copy takes place in an already encrypted directory.
- » Oracle ACFS does not support encryption of files great than 128 megabytes.
- » Oracle ASM disk group compatibility attributes require to be set in certain fashion in certain use cases, please review the Oracle Automatic Storage Management Administrator's guide for further guidance.[4]

Oracle ACFS Security

Oracle ACFS provides realm-based security. A realm, under Oracle ACFS, is a group of files or directories; only a defined user or set of users can access this group. Each realm has a set of rules to enforce fine grain access control beyond what is provided initially by the operating system. Oracle ACFS security rules can be seen as Boolean expressions, enabling authorization for files and directories. Oracle ACFS Security provides a protection framework that prevents unauthorized access to security objects (realms, rules, rules sets), security directories (log files and metadata backup files) and realm-secured user files and directories. As shown below, the process is straightforward and simple for users to leverage the functionality of Oracle ACFS Security:

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[4] Oracle Automatic Storage Management Administrator's Guide - https://docs.oracle.com/database/122/OSTMG/OSTMG.pdf

Initialize Security		Establish Password		Prepare File System
•`acfsutil sec init -u -g`	→	•`acfsutil sec admin password`	→	•`acfsutil sec prepare -m u`

Create a Realm		Create Rules / Rule Set		Add Rules to Rule Set / Add objects to Realm
•`acfsutil sec realm create -m -e -a -k -o -d`	→	•`acfsutil sec rule create rule -m -t -o` `acfsutil sec ruleset create rule_set -m -o`	→	•`acfsutil sec rule_set edit rule_set -m -a -d -o` `acfsutil sec realm add realm -m -u -G -l -e -a -k -f`

`acfsutil sec init` command allows for security to be initialized on any given Oracle ACFS file system and must be run first. This command also creates any required storage for security credentials. Options —u -g specifies the security administrator user and its security group.

`acfsutil sec admin password` command updates the security password for the administrator user. This command can only be executed by the administrator.

`acfsutil sec prepare` command allows for an Oracle ACFS file system to be prepared for security. This simple command entails two options, —m & -u. Option —m specifies the mount point of the file system. Option —u removes all security from the specified file system.

`acfsutil sec realm create` command creates a new realm in the Oracle ACFS file system. Options —realm sets the realm name, -m specifies the file system mount point, —e sets encryption on or off, —a sets the encryption algorithm (AEK is the only supported), —k sets the encryption key length (128, 192 which is the default or 156), —o sets security on or off for the specified realm and option —d allows for users to add a realm description.

`acfsutil sec rule create` command creates a new rule in the Oracle ACFS file system. Options —rule sets the rule name, —m specifies the file system mount point, -t specifies the rule type (`application`, `hostname`, `time` and `username`) and value in case of time, hence restricting or granting access only to applications or specific hostname or during a certain time or to a specific user. Option —o sets the option to allow or deny access according to the rule type, available options are `allow` or `deny`, being deny the default option.

`acfsutil sec ruleset create` command creates a new rule set in the Oracle ACFS file system. Options -rule_set sets the rule name, —m specifies the file system mount point, —o sets the option for ALL_TRUE or ANY_TRUE, hence allowing for multiple rules to be enforced if all conditions of individual rules are true or if one of all fulfils the requirement.

`acfsutil sec ruleset edit` command allows for rules to be added to a specific rule set. Options —`rule_set` sets the rule name, —`m` specifies the file system mount point, –`a` specifies which rule is going to be added, —`d` if used, specifies which rule is going to be removed, –`o` updates the option value to either `ALL_TRUE` or `ANY_TRUE`.
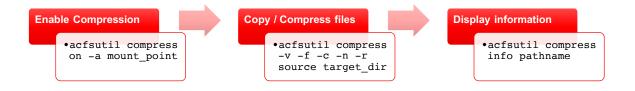
`acfsutil sec realm add` command add the specified objects to an Oracle ACFS security realm. This command is the last step, and entails multiple options in order to provide for a more versatile management of the security the user is setting up in the Oracle ACFS file system.

> » `realm` sets the realm name and -m specifies the file system mount point.
> » –`u` adds the specified user names to the realm, -G adds the specified file system groups to the realm.
> » –`l commandrule:ruleset` specifies which rule set is associated with specific commands (i.e. `CHGRP`, `CHMOD`, `CHOWN`, `MKDIR`, `RENAME`, `TRUNCATE`, etc.) For a full list of commands please review the Oracle Automatic Storage Management Administrator's guide. [4]
> » –`e` enables encryption on the specific realm, —`a` specifies the encryption algorithm and —`k` sets the encryption key length.
> » –`f[-r] path` add files or directories to the realm, if –`r` is included, files within the specified directory will be added recursively.

Please review the Oracle Automatic Storage Management Administrator's guide [4] for Oracle ACFS security exceptions, ASM disk group compatibility settings and other details.

Oracle ACFS Compression

Oracle ACFS introduced Compression on release 12cR2, this feature, is derived from Oracle's Database Advanced Compression. Oracle ACFS allows for compression of different files such as RMAN files, data pump files, general purpose files and archive logs, this excludes redo logs, control files and flashback logs. Oracle ACFS Compression allows the user to reduce its storage footprint. Once Oracle ACFS compression is enabled on a file system, only files created afterwards are compressed, also, when disabling Oracle ACFS compression, compressed files are not automatically uncompressed. As shown below, the process is straightforward and simple for users to leverage the functionality of Oracle ACFS Compression:

Enable Compression	Copy / Compress files	Display information
• `acfsutil compress on -a mount_point`	• `acfsutil compress -v -f -c -n -r source target_dir`	• `acfsutil compress info pathname`

`acfsutil compress on —a —m` command allows for compression to be enabled on the specified Oracle ACFS file system. Option —`a` specifies compression algorithm, as of now, the only supported algorithm is `lzo`, `mount_point` specifies the name of the file system mount point. Once compression is enabled all files created subsequently will be compressed, files previous to this step remain uncompressed.

`acfsutil compress copy —v —f —c —n —r source target_dir` command compresses and copies the specified files.

- » `-v` enables verbose mode.
- » `—f` overwrites any existing copies of the file to copy/compress.
- » `—c size source` copies file specified by field source while using compression unit specified by size. Size formats supported: 4K, 8K, 16K, 32K, 64K and 128K.
- » `—n source` disables compression for copied files.
- » `—r source` specifies that copy process is done recursively for files under source.
- » `source` specifies the specific source where files will be copied from.
- » `target_dir` specifies the specific directory where files will be copied to.

`acfsutil compress info pathname` command displays information pertaining compressed files such as compression unit size, disk storage used, disk storage saved and percentages of storage use compared to uncompressed files.
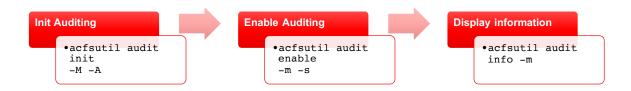
Important elements to be considered when using Oracle ACFS Compression:

- » Oracle ACFS Compression is not supported for Oracle Database files.
- » Oracle ACFS Compression is only supported with Oracle ACFS Replication in release 12cR2 onwards.
- » Oracle ACFS Compression requires for ADVM compatibility to be set to 12.2 or higher.
- » For further information, please review the Oracle Automatic Storage Management Administrator's guide. [4]

Oracle ACFS Auditing

Oracle ACFS Auditing offers the possibility to audit Oracle ACFS security and encryption. All sources of events in security and encryption are called audit sources, while written logs called audit trails will contain all audit records. Audit trails are handled separately for every Oracle ACFS file system; on a cluster environment this includes separation by individual nodes.

Oracle ACFS Auditing can be enabled at the realm level, this allows for auditing of authorizations and security violations. Oracle ACFS Auditing provides the entire underlying framework for the import of data into the Database Firewall and the Oracle Audit Vault by an audit vault collector. Oracle ACFS Auditing enables for separation of duties of the management and review of the audit to be enforced. As shown below, the process is straightforward and simple for users to leverage the functionality of Oracle ACFS Auditing:

Init Auditing
- acfsutil audit init —M —A

Enable Auditing
- acfsutil audit enable —m —s

Display information
- acfsutil audit info —m

`acfsutil audit init —M —A` command allows for initialization of auditing to take place on an Oracle ACFS file system. Option `—M` specifies which Operating System group will assign users to the Oracle ACFS `audit_manager_group` and hence be assigned the Audit Manager Role. Option `—A` specifies which Operating System group will assign users to the Oracle ACFS `auditor_group` and hence be assigned the Auditor Role.

`acfsutil audit enable –m –s{encr|sec}` command enables auditing on an Oracle ACFS file system. Option `–m` specifies where the file system is mounted. Option `–s{encr|sec}` sets auditing for either encryption or security.
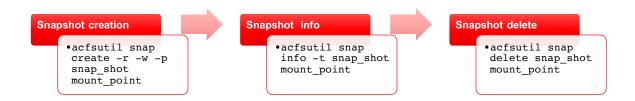
`acfsutil audit info –m` command displays information pertaining audited file system, such as audit trail size, audit sources, if security or encryption are enabled, etc.

Please review the Oracle Automatic Storage Management Administrator's guide[4] for further information pertaining Oracle ACFS Auditing.

Oracle ACFS Snapshots

Oracle ACFS snapshotting functionality provides the ability to generate point in time read-write or read-only copies of Oracle ACFS file systems. Oracle ACFS snapshots use space-efficient copy-on-write functionality. In order to maintain a point-in-time view consistency of the file system, Oracle ACFS file extent values are preserved before they are modified in any way. Oracle ACFS Snapshots are stored within the originating ACFS file system, if additional storage for files and snapshots is needed, Oracle ACFS allows for dynamic resizing of the file system. Oracle ACFS snapshots are ready and available to be used upon creation as long as the file system is mounted; up to 1023 snapshots can be hosted on an Oracle ACFS file system. Oracle ACFS supports creation of snapshots of snapshots, this entails full inheritance at any given point in the hierarchy.

Oracle ACFS 18c introduces snapshot links with one single command; this allows for a link to be created, which will offer access to a snapshot contents via an alternate path, hence providing easier snapshot management. As shown below, the process is straightforward and simple for users to leverage the functionality of Oracle ACFS Snapshotting capabilities, also, further snapshot commands will be briefly explained:

Snapshot creation
- `acfsutil snap create –r –w –p snap_shot mount_point`

Snapshot info
- `acfsutil snap info –t snap_shot mount_point`

Snapshot delete
- `acfsutil snap delete snap_shot mount_point`

`acfsutil snap create –r –w –p parent_snapshot snap_shot mount_point` command creates a snapshot following the user specified options which are:
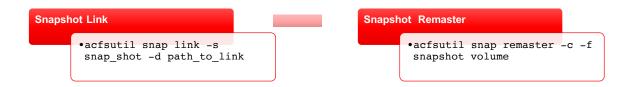
- » `[–r|–w]` snapshots are by default read-only, if –w option is selected the snapshot will be read-write. A snapshot can be later converted from read-write to read-only or vice versa with the `acfsutil snap convert` command.
- » `snap_shot` indicates the snapshot name. A snapshot name can be changed via the `acfsutil snap rename` operation.
- » `–p parent_snap_shot` when performing a snapshot of a snapshot, the parent snapshot named must be specified via this option.
- » `mount_point` this options specifies the file system mount point.
- » * a quota for a snapshot can be established through the `acfsutil snap quota` command.

`acfsutil snap info —t snap_shot mount_point` command provides information regarding a specific snapshot (specified by `snap_shot`) on the file system mounted on the specified mount point (`mount_point`). Option —t indicates that the output should contain a tree structure of the snapshot.

`acfsutil snap delete snap_shot mount_point` command deletes the specified snapshot (`snap_shot`) on the file system mounted on the specified mount point (`mount_point`).

Oracle ACFS introduced in 12c Release 2 the snap duplicate create and snap duplicate apply operations. This allows users to create a duplicated snapshots and a duplication stream to apply any changes in the original snapshot to the duplicated snapshot; furthermore, users can create new Oracle ACFS file systems out of a snapshot and apply changes in the source snapshot to the newly created file system. Please review the Oracle Automatic Storage Management Administrator's guide[4] for more information on snap duplicate create and apply operations.

Further snapshot enhancements have been introduced, such as Snapshot links in Oracle ACFS 18c and remastering of a file system based on an existing snapshot in Oracle ACFS 12c Release 2. An Oracle ACFS snapshot link presents an alternate path that provides access to a snapshot and its contents. Finally, remastering of an Oracle ACFS file system allows for an existing snapshot to be used as a base for a file system; all existing contents of the Oracle ACFS file system will be removed and replaced with the contents of the selected snapshot. Please see below, a basic explanation on how to create snapshot links and file system remastering:

Snapshot Link

- `acfsutil snap link —s snap_shot -d path_to_link`

Snapshot Remaster

- `acfsutil snap remaster -c —f snapshot volume`

`acfsutil snap link —s snap_shot —d path_to_link` command creates a snapshot link based on the specified snapshot and the provided link name. If used, the d option, deletes the specified snapshot link.

`acfsutil snap remaster —c —f snapshot volume` command remasters an Oracle ACFS file system, using as a base the specified snapshot in the specified volume. In case of any interruption, the remastering of the file system will continue by executing the command again with the —c option. Option —f will force the operation.

Oracle ACFS in conjunction with Oracle Multitenant, allows customers to leverage snapshotting and pluggable database technology. Using copy on write technology, Oracle ACFS allows for the creation of snapshot clones of pluggable databases, further broadening the customer's choices for test and development environments provisioning. Customers can use the pluggable database clones for testing of new applications, run all their test scenarios and more without ever jeopardizing production data. Databases stored on Oracle ACFS require just a few steps in order to leverage this functionality. For further information, please review the Oracle Database 12c Multitenant Snapshot Clones white paper. [5]
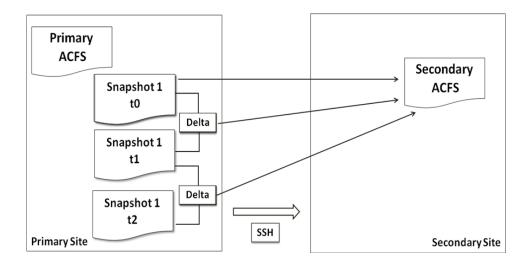
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[5] http://www.oracle.com/technetwork/database/multitenant/learn-more/pdb-cloudfs-snapclone-2212051.pdf

Oracle ACFS Snapshot-based Replication

Oracle ACFS provides maximum efficiency and flexibility in asynchronous replication for your file system and Oracle Database files. Replication was first introduced in Oracle ACFS on release 11.2.0.2; this feature has seen constant evolution from log based replication for application files only, to its current state, based on snapshot-based replication allowing for entire file system, application and database files. Oracle ACFS provides a framework for replicating an Oracle ACFS file system across the network from a primary to a standby site. Complemented with Oracle Data Guard, Oracle ACFS Snapshot-based Replication provides the customer with an end-to-end DR solution for all files.

Oracle ACFS Snapshot-based replication works by transferring the differences between consecutive snapshots from the primary file system to the standby file system using the simple ssh protocol. Once an initial snapshot is replicated from the active to the standby file system, the changes of the successive snapshots will continue to be replicated. Oracle ACFS Snapshot-based replication carries a timestamp that can be queried for the purpose of synchronizing database transactions with file system data.

Oracle ACFS Replication on primary sites running AIX, Linux or Solaris works with standby sites running on any of the mentioned operating systems, but a primary site running on Windows is able to only replicate to a standby site also running on Windows. Oracle ACFS Replication allows for auditing, realm-based security and encryption to be enabled, thus securing the replicated standby file system with any of the policies in place in the primary file system.

Starting in Oracle ACFS 18c, role reversal replication is introduced, allowing the original primary and standby locations to switch roles. One single commands allow users to change the original primary location to become the new standby, and the original standby location to become the new primary. For more information on Oracle ACFS snapshot-based replication please review the Oracle ACFS replication white paper[6] and the Oracle Automatic Storage Management Administrator's guide. [4]

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6 ACFS File System Snapshot-Based Replication: How to Setup Guide

　http://www.oracle.com/technetwork/database/database-technologies/cloud-storage/acfs/learnmore/acfs-replication-122-3634228.html

Oracle ACFS Tagging

Oracle ACFS Tagging allows a user to associate one or more files as a group by assigning a unique 'tag name' attribute. Group operations can be performed based on tagged files that may span across different directories within an Oracle ACFS file system and within a single node or a cluster. By using Oracle ACFS Tagging, different groups of tagged files may be replicated as groups of related files, hence not having to replicate entire Oracle ACFS cluster file systems. Please see below, a basic introduction on Oracle ACFS tagging commands:

Tag set	Tag information	Tag unset
•acfsutil tag set tagname path -r -v	•acfsutil tag info -t path -r -c	•acfsutil tag unset all tagname path -r -v

`acfsutil tag set tagname path —r –v` command sets the specified tag to a specific file or directory. If option `—r` is selected, the tag will be set recursively to all the contents of the specified directory. Option `–v` shows the progress of the tagging operation.

`acfsutil tag info —t path —r –c` command displays information of all tagged files and directories in the specified path. If no path is specified, then all information of tagged files and directories in the file system will be displayed. If option `—t tagname` is used, then only the files and directories with the matching tag will be shown. Option `—c` habilitates for the search to be case-insensitive.

`acfsutil tag unset all tagname path —r –v` command removes the specified tag from the specified file or directory. If option `—r` is selected, the tag will be recursively removed to all the contents of the specified directory. Option `all` indicates that all tags in the specified path must be removed. Option `–v` shows the progress of the tagging operation.
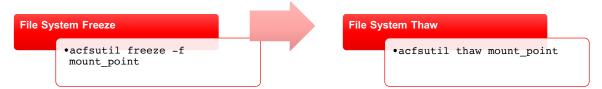
Oracle ACFS Automatic Resize and File System Reduce

`acfsutil size` was introduced in Oracle ACFS 12c Release 2, this command provides an option for automatic file system resizing. The command allows the user to specify how much a file system should grow in case the available free space reaches certain threshold; Also, the user can specify the maximum size a file system can reach, once the threshold is reached, the system will be automatically resized.

Starting on Oracle ACFS 18c, `acfsutil size` command allows for a size reduction of the file system, this operation was available in previous releases but it had a major limitation; file system reduction would not take place if it required for existing files in the Oracle ACFS file system to be moved. Now, the operation will go through regardless of the need or not to move user files and metadata. Users can use the -q option in order to obtain an estimate on the required data to be moved, helping further in calculating the time the command could take to complete. Oracle ACFS `size` operations, either increasing or reducing a file system, also modifies the respective Oracle ADVM volume where the file system is mounted; this is performed in order to have volumes matching the new specified size. For more information, please review the Oracle Automatic Storage Management Administrator's guide. [4]

Oracle ACFS File System Freeze

Oracle ACFS 18c introduces the `acfsutil freeze` and `acfsutil thaw` commands, allowing for pausing and resuming of activities in an Oracle ACFS file system. `acfsutil freeze` command pauses all activity on the file system, across all nodes in the cluster, allowing for certain snapshot operations, if required, to be performed by the user. Once system resume is ready to take place, users can execute `acfsutil thaw` command and activity on the file system across nodes will resume. Please see below, a basic introduction on Oracle ACFS freeze and thaw commands:

File System Freeze
- `acfsutil freeze -f mount_point`

File System Thaw
- `acfsutil thaw mount_point`

`acfsutil freeze —f mount_point` pauses activity on the specified file system. Option `-f` requires for all data to be flushed to disked before any operations pause.

`acfsutil thaw mount_point` command resumes activity on the specified file system.

Oracle ACFS File System Storage Info

Oracle ACFS 18c introduces the `acfsutil info storage` command, providing users with Platform independent information related to storage. Information available comprises of Oracle ASM disk group information and its consumption, gather from sources as file system information, snapshot information and disk group views. The command provides a simple way to get the aforementioned information with a basic set of configurable options: unit of measurement, disk group(s) to be queried and whether additional information is required to be displayed or not. For more details, please review the Oracle Automatic Storage Management Administrator's guide. [4]

Oracle ACFS File System Diagnostic Commands

Oracle ACFS 18c updates commands that present diagnostic and management information pertaining to the file system metadata and tuning parameters. The acfsutil meta command copies metadata from the specified Oracle ACFS file system and generate a file with all the collected information; this command has been enhanced to simplify the metadata collection process for file system diagnostic and support. Given the diagnostic and support nature of this tool, it presents a comprehensive list of option to determine its operation mode, for further and more detailed information please review the Oracle Automatic Storage Management Administrator's guide. [4]

Oracle ACFS Remote Service

Oracle Cluster Domain and Oracle Domain Services Cluster architecture was introduced in Oracle Clusterware 12c Release 2 in order to enable customers to optimize and centralize their Oracle RAC deployments on their private database clouds. The architecture allows for a cluster to group multiple configurations and services and them share them across the private cloud to more dedicated and lightweight clusters. Services such as Trace File Analyzer, Storage Management Service, Rapid Home Provisioning and a centralized Grid Infrastructure Management Repository will be on the domain services cluster and be shared and utilized by the Cluster Domain and Member Clusters when required.

ACFS 18c introduces support for native Oracle ACFS functionality on both database member clusters and application clusters. Oracle member clusters with no local storage can leverage all Oracle ACFS feature and functionality through Oracle ACFS Remote Service; this includes all Oracle ACFS features including snapshots, replication, etc. Deployment and use of the Oracle ACFS remote service allows for Application Cluster and Database Member clusters to leverage Oracle ACFS functionality. For further information regarding requirements and setup please review the Oracle Automatic Storage Management Administrator's guide. [4]

Oracle ACFS NAS Maximum Availability eXtensions (MAX)

Oracle ACFS Maximum Availability eXtensions, while in use, guarantee that NFS or SMB will run in High Availability mode. This means that as long as there is one cluster node available, the NFS or SMB exports will be available. Oracle ACFS NAS Maximum Availability eXtensions integrate with NAS protocols and the Oracle ACFS stack, meaning ease of use without any additional infrastructure.

The High Availability Network File Storage (HANFS) feature enables highly available NFS servers to be configured using Oracle ACFS clusters, thus providing continuous service of NFS v2/v3/v4 exported paths. The HANFS cluster configurations may be built from your existing infrastructure or commodity servers and storage. Oracle ACFS now also supports HANFS NFS v4 with NFS Locks (limited to certain operating systems only – see documentation for details[4]).

Oracle ACFS NAS Maximum Availability eXtensions offer support for SMB provided to interface with Active Directory Domains and Microsoft servers. Samba or Microsoft SMB must be in place in order to ensure Oracle ACFS HA-SMB. For further information please refer to Oracle ACFS NAS Maximum Availability eXtensions whitepaper[7].

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[7] http://www.oracle.com/technetwork/database/database-technologies/cloud-storage/acfs/learnmore/acfs-nas-max-wp-3618364.html

Conclusion

Oracle ASM Cluster File System offers a complete, stable and mature storage solution that has evolved through the years to become the storage foundation for cloud architectures throughout the world. Oracle ACFS is used by customers in over 60 countries, and its features and functionalities are leveraged across all industries, including 40 of the top S&P 500 companies.

Oracle ACFS offers advanced functionality that has evolved throughout the years, as shown below, it offers best in class snapshot based replication, file compression, tagging for group operations, advanced security, encryption and auditing capabilities, file system resizing, remote services, network file system export extensions and many more; based on all these, Oracle ACFS provides a complete storage solution.

Encryption	Security & Auditing	Remote Service	Compression	Tuning & Performance
Snapshot	Replication	Tagging	Freeze & Thaw	HA-NFS & HA-SMB

Oracle ACFS offers a universal way to manage your data, providing high availability, high performance, scalability, simplicity in its administration, data integrity, fast recovery and savings in licensing costs.

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Integrated Cloud Applications & Platform Services

Oracle ACFS – What is it and How to use it
January 2018
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Oracle is committed to developing practices and products that help protect the environment