ORACLE

Oracle ACFS

Advanced Cluster File System

Snapshot-based Replication
Step-by-Step Guide

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INTRODUCTION

In Oracle Release 11.2.0.2, the ACFS File System Replication feature was introduced. ACFS replication enables an ACFS file system to be replicated across a network to a remote site. This capability is useful for disaster recovery. Similarly to Data Guard, which replicates databases by capturing database redo, ACFS Replication captures ACFS file system changes on a primary file system and transmits these changes to a standby file system. Oracle ACFS replication functionality before release 12.2 replicated changes continuously, building on Oracle networking technologies, notably Network Foundation Technologies (NFT), to ensure connectivity between the primary and standby clusters.

This technical brief describes configuring Oracle ACFS snapshot-based replication (available since release 12.2 and above). Except where otherwise indicated, the technical brief describes release 19.11 and later releases. The snapshot-based replication technology uses snapshots of the primary file system and transfers the differences between successive snapshots to the standby file system using the standard ssh command. This change in the design and implementation of Oracle ACFS replication introduces some differences in how replication is configured and used. First, using SSH means that some attention must be paid to appropriately setting up public host and user keys on the primary and standby nodes that will perform replication. Second, though we have tried to minimize changes to the replication CLI in designing the new technology, a few differences are still visible.

Starting in Oracle ACFS 23ai, a new transport based on Secure Sockets Layer (SSL) was introduced; this guide covers SSH-based transport. Please review "Configuring SSL-Based Replication" on Oracle ACFS product documentation for more information on SSL-based replication.[1] When the SSL-based transport is used, the configuration of SSH (as described below under Configuring Password-less SSH Login) is not necessary. SSL is configured in place of SSH.

The combination of Oracle Real Application Clusters, Data Guard, and ACFS Replication provides comprehensive site and Disaster Recovery policies for all files inside and outside the database.

[1] https://docs.oracle.com/en/database/oracle/oracle-database/23/acfsg/acfs-advanced-topics.html#ACFSG-GUID-4D1976CC-7D75-4999-9414-33E676064820

OVERVIEW

In the 18c release, snapshot-based replication can process either an ACFS file system or a read-write filesystem snapshot. Either one of these is referred to as a storage location, or "*location*" for short.

In all releases, the source ACFS storage location is referred to as a primary, and the target ACFS location is a standby. Replication works by taking snapshots of the primary. A first replication operation transfers the initial snapshot's contents to the standby. Subsequent replication operations transfer just the delta between the most recent primary snapshot and the last previous snapshot.

Beginning in the 19.5 release, replication supports both switchover and failover. In these operations, the existing standby is converted to the new primary, and the existing primary may either become the new standby or be replaced as the new standby by a different storage location.

As described below, replication requires user keys to be set up for SSH in both the primary and the standby clusters. In 19.10 and earlier releases, these keys needed to be set up for both the root and replication users ("*repluser*"). Starting on 19.11, these keys must be set up only for the "*repluser*". This paper describes the situation as of 19.11.

In all cases, the standby file system is read-only. One use case for the standby file system is that it can be the backup source.

PLANNING FOR ACFS REPLICATION

Examples described in this white paper assume that Grid Infrastructure software has been installed on nodes hosting the ACFS filesystem and that the Oracle ASM Dynamic Volume Manager (Oracle ADVM) volumes and ACFS file systems are mounted. The primary and standby sites can have differing configurations; i.e., primary can be a multi-node cluster, and standby can be a single-node cluster. If a standby node is used for disaster recovery purposes, it is recommended that the standby node have a similar configuration, such as cluster configuration.

There are no rigid primary or standby node roles, i.e., a primary node can provide the primary role for one storage location and standby for another. However, for simplicity, this paper will use the term "*primary node*" to indicate the node hosting the primary location and the "*standby node*" for the node hosting the standby location.

TAGGING CONSIDERATIONS

ACFS tagging is an essential adjunct to ACFS replication. Rather than replicating an entire storage location, ACFS tagging enables users to select specific files and directories for replication. Using tagging with ACFS replication requires a tag to be specified when replication is initiated on the primary node. You can also add tags to files after replication has started. ACFS implements tagging with extended attributes. Note that some editing tools and backup utilities do not retain these extended attributes of the original file by default. Please review the ACFS Tagging section of the "*Oracle Automatic Storage Management Administrator's Guide*" for the list of standard utilities and their respective switch settings so that ACFS tag names are preserved on the original file.

Before implementing ACFS replication, it is essential to determine how and what will be replicated. Will all storage location data be copied, including only certain directories or specific ACFS-tagged files? This choice may affect file system sizing. ACFS tagging assigns a common naming attribute to a group of files. ACFS Replication uses this tag to filter files with unique tag names for remote file system replication. Tagging enables data or attribute-based replication.

The following example illustrates recursively tagging all files of the "`/acfs`" directory with the tag "*reptag*":

```
[root@primary-node1 ~]# /sbin/acfsutil tag set -r reptag /acfs
```

Remember that the tags specified on the "*acfsutil repl init*" command line will be applied to files created after replication initialization and to files that existed during initialization. For example, you can replicate files with tags Boston and Milan when, at the time of replication, only files with tag Boston exist, i.e., when no files exist with the tag Milan. Any subsequent files tagged with Milan will also begin to be replicated.

CHOOSING A REPLICATION USER

Oracle ACFS Replication, starting in release 12.2, uses Secure Shell, also known as SSH, to transport between the primary and standby clusters. Hence, the user identity under which replication is performed on standby must be carefully managed. A minimally privileged user identity should be used. Generally, a user identity such as `sysasm` will already be defined on the standby node. That identity is suitable for the "replication user" –the user that ssh will log in as on the standby node. If a different user is employed instead, that user should have "ASM admin privileges and Oracle install privileges." Usually, this means that the user belongs to the same group specified to the installer when Oracle Grid Infrastructure (GI) was first installed. Log in as this user on the standby node should also be possible. Here is an example of adding the user "repluser" to the existing group "asmadmin":

```
# useradd -g asmadmin repluser
# passwd repluser
# mkdir -p /home/repluser/.ssh
# chown repluser:asmadmin /home/repluser/.ssh
```

In this article, we will use the name **repluser** to refer to the user that ssh will use to log in on the standby host. When using commands like the ones below, replace "*repluser*" with the username you chose to use in your deployment.

CONFIGURING PASSWORD-LESS SSH LOGIN

Why password-less SSH login

In the passwordless SSH login method, we exchange encrypted keys instead of entering the actual password while connecting to remote systems using SSH. So, nobody can easily hack or guess your password because we no longer use passwords to access remote systems. More importantly, hidden key loggers and brute-force attacks do not work if we use password-less SSH.

Step 1: Distributing a public key for repluser from primary to standby

First, look for the file "`~repluser/.ssh/id_rsa.pub`" on your primary. This contains a public key for "*repluser.*" If the public key file exists, you should add it to the set of keys authorized to log in as "*repluser*" on each node of your standby using the ssh-copy-id command, as explained below. Append the key to the file "`~repluser/.ssh/authorized keys`" on each standby node.

If the public key file does not exist, generate a public/private key pair on the primary by running this command as "***repluser***":

```
[repluser@primary-node1 ~]$ ssh-keygen -t rsa

Generating public/private RSA key pair.
Enter file in which to save the key (~repluser/.ssh/id_rsa): ## Press Enter
Enter passphrase (empty for no passphrase):              ## Enter Passphrase
Enter same passphrase again:                             ## Re-enter Passphrase
Your identification has been saved in ~repluser/.ssh/id_rsa.
Your public key has been saved in ~repluser/.ssh/id_rsa.pub.
The key fingerprint is:
b9:71:f7:e9:3f:8d:2a:34:67:fc:96:40:a1:2a:56:1c repluser@node1
The key's randomart image is:
+--[ RSA 2048]----+
|                 |
|         E    .  |
|        . . . .  |
|         o.. .   |
```

```
|         .S..o.   |
|      o .+o.=. . |
|     . ... + ooo.|
|           .  .=..|
|            ..o..o|
+------------------+
```

The key files will be stored under your "*~repluser/.ssh*" directory. The above command will create two keys. One is private, and the other is public. The private key should be kept only in the directory where it was created -- you don't have to transfer it to the remote standby systems. The public key should be transferred to all remote standby systems where replication may run. The primary can access the standby if the local primary system presents a public key that matches a key authorized to log in on the remote standby system. If the public key presented isn't authorized to log in, authentication and replication will fail, too.

Now, copy the public key file to all your remote standby systems (using the "ssh-copy-id" command):

```
[~repluser@primary-node1 ~]$ ssh-copy-id -i ~repluser/.ssh/id_rsa.pub repluser@<standby hostname>
```

Output (example):

```
$ ssh-copy-id -i ~repluser/.ssh/id_rsa.pub repluser@rwsam001
The authenticity of host 'standby (10.220.220.20)' can't be established.
RSA key fingerprint is 4c:95:a6:39:34:a1:ef:e7:d1:71:e9:05:b6:b6:e7:4a.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'standby,10.220.220.20' (RSA) to the list of known hosts.
repluser@standby's password:
Now try logging into the machine, with "ssh 'repluser@rwsam001'", and check-in:


.ssh/authorized_keys
to make sure we haven't added extra keys that you weren't expecting.
```

Suppose the "*ssh-copy-id*" command is not available. In that case, an alternative is to manually append the public key for "*repluser*" from each primary node to the "*~repluser/.ssh/authorized_keys*" file on each standby node.

Now, ssh to your remote standby as shown here. You should be able to access the remote system getting the system date without having to enter a password for "*repluser*":

```
[repluser@primary-node1 ~]$ ssh repluser@<standby hostname> date
```

When your primary cluster has multiple nodes, you can define a separate key pair for each node, as described above. Alternatively, you can specify the key pair on one node and then copy the key pair to the other nodes. If you copy the key pair this way, you must ensure that the public key on every node has permissions "0644" and that the private key on every node has "0600". (Otherwise, ssh will not use them.)

Step 2: Getting the standby host_key

A host key for each standby node where replication may run must be known for "repluser" on each primary node where replication may run. One way to generate the correct key is to run SSH manually as a "repluser" from each primary node to each standby node. If the correct host key is not known already, then a warning displays, and you can enable ssh to add the key. We saw this already when we ran ssh-copy- id in the previous steps. Running ssh-copy-id on a given primary node, targeting a given standby node, made a host key for that standby node known on that primary node. There's no need to do anything further to make a host key known.

Because the local node always connects to the remote node as user "repluser", the host key for the standby node must be added to the "*known_hosts*" file for "*repluser*".

The following is an example of obtaining a host key for "*repluser*":

```
[repluser@primary-node1 ~]$ ssh repluser@standby date
```

```
The authenticity of host 'standby (10.137.13.85)' can't be established. RSA key fingerprint is
1b:a9:c6:68:47:b4:ec:7c:df:3a:f0:2a:6f:cf:a7:0a. Are you sure you want to continue connecting (yes/no)?
```

If you respond with yes, then the ssh setup is complete. A host key for host standby is stored in the known_hosts file ("*~repluser/.ssh/known_hosts*") on the primary host for the user "*repluser.*"

After the host key setup for standby nodes is complete on a given primary node, you must perform an additional step if you use a Virtual IP address (VIP) to communicate with your standby cluster. You must add the VIP name or address at the start of each line of the *known_hosts* file that refers to a host in the standby cluster. For example, if you use a VIP with the name standby12_vip, and your *known_hosts* file contains the following two lines that refer to your standby:

```
standby1,10.242.20.22 ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAABAQC3pM2YTd4UUiEWEoCKDGgaTgsmPkQToDrdtU+JtVIq/96muivU
BaJUK83aqzeNIQkh+hUULsUdgKoKT5bxrWYqhY6AlTEqNgBHjBrJt9C73BbQd9y48jsc2G+WQWyuI/
+s1Q+hIJdBNMxvMBQAfisPWWUcaIx9Y/JzlPgF6lRP2cbfqAzixDot9fqRrAKL3G6A75A/6TbwmEW07d1zqOv
l7ZGyeDYf5zQ72F/V0P9UgMEt/5DmcYTn3kTVGjOTbnRBe4A4lY4rVw5c+nZBDFre66XtORfQgwQB5ztW/Pi
08GYbcIszKoZx2HST9AZxYIAgcrnNYG2Ae0K6QLxxxScP
standby2,10.242.20.23 ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAABAQDIszcjzNtKN03SY8Kl846skFTVP1HF/ykswbmkctEjL6KTWTW+NR
U4MGbvkBqqdXxuPCR7aoGO2U3PEOg1UVf3DWUoux8IRvqKU+dJcdTibMFkDAIhTnzb14gZ/lRTjn+GYsuP5
Qz2vgL/U0ki887mZCRjWVL1b5FNH8sXBUV2QcD7bjF98VXF6n4gd5UiIC3jv6l2nVTKDwtNHpUTS1dQAi+1D
tr0AieZTsuxXMaDdUZHgKDotjciMB3mCkKm/u3IFoioDqdZE4+vITX9G7DBN4CVPXawp+b5Kg8X9P+08Eehu
tMlBJ5lafy1bxoVlXUDLVIIFBJNKrsqBvxxxpS7
```

To enable the use of the VIP, you would modify these two lines to read as follows:

```
standby12_vip,standby1,10.242.20.22 ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAABAQC3pM2YTd4UUiEWEoCKDGgaTgsmPkQToDrdtU+JtVIq/96muivU
BaJUK83aqzeNIQkh+hUULsUdgKoKT5bxrWYqhY6AlTEqNgBHjBrJt9C73BbQd9y48jsc2G+WQWyuI/
+s1Q+hIJdBNMxvMBQAfisPWWUcaIx9Y/JzlPgF6lRP2cbfqAzixDot9fqRrAKL3G6A75A/6TbwmEW07d1zqOv
l7ZGyeDYf5zQ72F/V0P9UgMEt/5DmcYTn3kTVGjOTbnRBe4A4lY4rVw5c+nZBDFre66XtORfQgwQB5ztW/Pi
08GYbcIszKoZx2HST9AZxYIAgcrnNYG2Ae0K6QLxxxScP

standby12_vip,standby2,10.242.20.23 ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAABAQDIszcjzNtKN03SY8Kl846skFTVP1HF/ykswbmkctEjL6KTWTW+NR
U4MGbvkBqqdXxuPCR7aoGO2U3PEOg1UVf3DWUoux8IRvqKU+dJcdTibMFkDAIhTnzb14gZ/lRTjn+GYsuP5
Qz2vgL/U0ki887mZCRjWVL1b5FNH8sXBUV2QcD7bjF98VXF6n4gd5UiIC3jv6l2nVTKDwtNHpUTS1dQAi+1D
tr0AieZTsuxXMaDdUZHgKDotjciMB3mCkKm/u3IFoioDqdZE4+vITX9G7DBN4CVPXawp+b5Kg8X9P+08Eehu
tMlBJ5lafy1bxoVlXUDLVIIFBJNKrsqBvxxxpS7
```

Ultimately, the host key configuration performed on this first node of your primary cluster must be performed on every node in your primary cluster; the result of the above sequence, or an equivalent, must exist on each primary node. One way to minimize the manual effort required to achieve this configuration is to update the "*known_hosts*" file on one primary cluster node and then copy the updated file to the other cluster nodes.

Note: By default, replication enables strict host key checking by SSH to ensure that the primary node connects to the intended standby node or cluster when it runs SSH. However, if you are certain this checking is unneeded, such as when the primary and standby clusters communicate over a private network, SSH's strict host key checking can be turned off. For information about turning off strict host key checking, refer to the "***sshStrictKey=no***" option of the "*acfsutil repl init primary*" command. If strict host key checking is disabled, no setup is required.

Step 3: Validating ssh-related key configuration

After establishing the host and user keys for ssh, you can use the command "`acfsutil repl info -c -u`" to validate the keys. You run this command as "repluser" on each primary cluster node. It takes all the hostnames or addresses on the standby cluster as arguments that the primary may use in the future to perform replication.

If you are not using a VIP to connect to your standby cluster, only one standby hostname or address is provided to "`acfsutil repl info -c -u`" for a given replication relationship. However, if future relationships may involve other standby host addresses, specify the complete set of addresses when running the "`acfsutil repl info -c -u`" command.

If you are using a VIP to connect to your standby cluster, then you should specify the names or host-specific addresses of all standby hosts on which the VIP may be active. Do not specify the VIP name or an address associated with the VIP. When replication uses SSH to connect to a VIP, the host key returned is the key associated with the host where the VIP is currently active. In this situation, only the hostnames or addresses of individual standby nodes are used by ssh.

The validation command has the following format. Here we show it being run as "repluser":

```
[repluser@primary-node1 ~]$ acfsutil repl info -c -u repluser standby-addr1 [standby-addr2 ...] standby-mountpoint
```

The command confirms that "repluser" can use ssh to connect to each standby-addr given and log in as "repluser", in the same way as replication does.

To validate the key setup for the standby1 and standby2 clusters presented in the previous command, you can use the following command:

```
[repluser@primary-node1 ~]$ acfsutil repl info -c -u repluser standby1 standby2 standby-mountpoint
```

The same command (specifying VIP hostname) will be used if you use the VIP "*standby12_vip*" to connect to the cluster.

If you plan to turn off strict host key checking, you can skip this checking by adding the "***-o sshStrictKey=no***" option to the command line.

Step 4: Repeating key setup in the reverse direction

As noted earlier, ACFS replication supports switchover and failover, in which the primary and standby clusters reverse their "role" in performing replication. For these capabilities to work quickly and automatically when required, the SSH key setup steps 1 - 2 described above must be performed in the opposite "direction." That is:

- A public key for "*repluser*" must be distributed from standby to primary.
- A host key for each primary node must be known on each standby node.

Then step 3 should be performed, running "*acfsutil repl info -c -u*" on each standby node to verify that it can use password-less ssh to contact each primary node.

SSH Login Troubleshooting

NOTE ON PERMISSIONS FOR SSH-RELATED FILES

For ssh to work with the keys you have established, you must ensure that permissions are correctly set on each node for the relevant "~/.ssh" directory and some of the files the directory contains. This refers to the "~/.ssh" directory for "repluser" on each primary node and standby node. In each case, the permissions for the files listed below must be at least as restrictive as shown in the *chmod* commands below:

```
$ chmod go-w $HOME
$ chmod go-rwx $HOME/.ssh
$ chmod go-rwx $HOME/.ssh/id_rsa
$ chmod go-rwx $HOME/.ssh/authorized_keys
```

Problem 1: If the 'ssh' version differs between the primary and standby systems, you must set permissions for your remote system's '.ssh' directory. To do that, run the following command:

```
$ ssh repluser@<standby hostname> "chmod 700 ~/.ssh; chmod 640 ~/.ssh/authorized_keys"
```

Problem 2: If you still can't SSH to remote systems, go to your standby remote system and enable SSH key authentication. To do that, edit the following file on Linux: "*/etc/ssh/sshd_config*". Find, uncomment, and change the following lines as shown below:

```
PubkeyAuthentication                        yes
AuthorizedKeyFile                           .ssh/authorized_keys
ChallengeResponseAuthentication             no
```

Save and close the file. Restart the ssh service using the command (on Oracle Linux 6):

```
[root@primary-node1 ~]# service sshd restart
```

(on Oracle Linux 7/8):

```
[root@primary-node1 ~]# systemctl restart sshd.service
```

NOTE ON SSHD CONFIGURATION

On some platforms, the SSH daemon "*sshd*" may be configured to log a message via "syslog" or a similar facility each time an SSH connection is established. To avoid this, the server configuration file "/etc/ssh/sshd_config" can be modified to specify a lower logging level. The parameter that controls logging is called LogLevel. Connection messages are issued at level INFO. Any lower level (such as ERROR) will suppress these messages. So, for instance, adding this line to the file would suppress the message: "LogLevel ERROR."

USING REPLICATION COMMANDS

The CLI for snapshot-based replication is similar to the one for pre-12.2 replication. There are differences in the interface to three commands: "*repl init*", "*repl info*" and "*repl update*". Also, unlike pre-12.2 replication, "*repl*" commands need not be run as `root`. Instead, these rules apply:

- The `acfsutil repl info` and `acfsutil repl bg info` commands may be run by any Oracle ASM administrator user.
- The `acfsutil repl compare` command can be run by any Oracle ASM administrator user but should be run as `root` to maximize its access to the files being compared.
- All other acfsutil repl commands may be run as root or *repluser*.

Starting Replication

Once you are ready to initiate replication, the essential parts of the needed command lines are as follows. You will note that these command lines are similar but not identical to the ones used in replication before the 12.2 release.

In replication in 18c or later releases, a primary or a standby may be either a file system or a read/write snapshot of a file system. Either of these is called a storage location. As always, you specify a file system using its mount point. You select a snapshot using the syntax "*snapname@mountpoint*".

You initialize replication in the standby cluster and then in the primary cluster. On the standby, the only information you need to provide is:

- The name of the standby storage location
- The name of the replication user that will be used to replicate changes to the standby storage location

Most of the parameters affecting replication are specified on the primary. These include:

- The name of the primary storage location
- The ssh-style connection string (*username@network_addr*) to be used to connect to the standby cluster ("-s" option)
- The name of the standby storage location ("-m")
- The "style" of replication, one of:
  - Interval-based, in which a replication operation will start once per specified interval ("-i")
  - Constant-mode, in which a new replication operation starts as soon as the previous one ends ("-C")
  - Manual-mode, in which replication occurs only when requested using "`acfsutil repl sync`" ("-M")
- Optionally, the network endpoint to be used for the primary, when and if it ever serves as a standby, as following a failover operation – see below for more details ("-p")

First, on the standby node, run a command like this one:

```
[joe@stdby-node1 ~]$ acfsutil repl init standby -u repluser /smntpt
```

This command specifies that the user *repluser* will replicate changes to the file system mounted at "/smntpt". The public key of *repluser* , as defined on the primary host, must be authorized to log in as user *repluser* on the standby.

Note: the acfs filesystem on standby must be empty at replication init time.

Next, on the primary node, run a command like this one:

```
[joe@primary-node1 ~]$ acfsutil repl init primary \
                            { -i interval | -C | -M } \
                              -s repluser@standby_host \
                            [ -m /smntpt ] /pmntpt
```

This command specifies that the user *repluser* will connect to the standby host to replicate the file system at primary mount point "`/pmntpt`" to the file system at standby mount point "`/smntpt`". The interval at which replication sessions are started is specified with -C (constant mode) or -i (the interval between starting successive replication operations). When "-C" is given, a new replication session begins after the previous session completes. Alternatively, "-M" may be provided to say that replication sessions will start only on request.

When "-i" is given, the value interval has two parts – a count plus a unit indicator. The indicator must be one of s, m, h, d or w – for seconds, minutes, hours, days or weeks, respectively. For instance, "30s" indicates an interval of 30 seconds, "5m" indicates an interval of 5 minutes, and so on.

When the primary or standby cluster contains multiple nodes, and replication is to run on all nodes, it is recommended to use a VIP (like the SCAN VIP) instead of the address of a single host as the network endpoint specified to "`acfsutil repl init primary.`"

In the 19c release, by default, the network endpoint used for replication in the primary cluster will be the node hostname on which "`acfsutil repl init primary`" is run. To use a different endpoint, specify it with the option "-p".

From the 21c release onward, by default, the SCAN VIP (if present) will be used as the network endpoint for replication in the primary cluster; if the SCAN VIP cannot be determined, the hostname of the node on which "`acfsutil repl init primary`" is run will be used. To use a different endpoint, specify it with the option "-p".

A new option "`-o param=value`" option is used to override specific details of replication's operation.

The parameter strings currently defined are:

- **sshCmdPath** – the value string specifies the pathname for which the ssh command will be looked.
- **sshCipher** – the value string specifies the cipher that will be passed to ssh to encrypt its sessions.

If tagging was enabled for this directory, then a tagname "reptag" can be added in the initialization command:

```
[joe@primary-node1 ~]$ acfsutil repl init primary \
                                { -i interval | -C } \
                                  -s repluser@<standby hostname> \
                                [ -m /smntpt ] \
                                  reptag \
                                  /pmntpt
```

If the diskgroup-compatible ADVM attribute is not at the required version, you may get an error such as:

```
acfsutil repl init: ACFS-03322: The ADVM compatibility attribute for the diskgroup is below
       the required version (12.2.0.0.0) for the 'acfsutil repl' commands
```

You could set up the required diskgroup compatible ADVM attribute as in the following (as grid user connected to ASM instance):

```
SQL> ALTER DISKGROUP DATA SET ATTRIBUTE 'compatible.asm' = '12.2.0.0.0', 'compatible.advm' =
'12.2.0.0.0';
```

Or using ASMCMD:

```
$ asmcmd --nocp setattr -G DATA compatible.asm 12.2.0.0.0
$ asmcmd --nocp setattr -G DATA compatible.advm 12.2.0.0.0
```

Verify that replication on the Primary File System has been initiated:

```
[joe@primary-node1 ~]$ /sbin/acfsutil repl info -c /pmntpt

Primary hostname:                    primary-node1
Primary path:                        /pmntpt
Primary status:                      Running
Background Resources:                Active

Standby connect string:               repluser@standby
Standby path:                         /smntpt

Replication interval:                 0 days, 0 hours, 0 minutes, 0 seconds
Sending primary as of:                Fri Nov 06 05:33:22
Status:                               Send Completed
Retries made:                         0
Last send started at:                 Fri Nov 06 05:33:22
Last send completed at:               Fri Nov 06 05:33:22
Elapsed time for last send:           0 days, 0 hours, 0 minutes, 0 seconds
Next send starts at:                  now
Replicated tags:
Data transfer compression:            Off
ssh strict host key checking:         On
Debug log level:                      3
```

Once the "`acfsutil repl init`" primary command completes successfully, replication will transfer copies of all specified files to the standby file system.

The average rate of data replication on the primary file system can be monitored using the "`acfsutil repl info -s <mountpoint>`" command, with the -s flag indicating the sample rate. The amount of change includes all user and metadata modifications to the file system. The following example illustrates its usage:

The rate of data change on the primary file system can be monitored using the "*`acfsutil info fs -s <mountpoint>`*"

```
[joe@primary-node1 ~]$ /sbin/acfsutil repl info -s /pmntpt

-------------------------------------------------------
Fri Nov 06 05:33:22  - Fri Nov 06 05:33:22
-------------------------------------------------------

Data replicated:                              0.00GB
Avg. rate of data replication:                ~MB/minute
Avg. time from capture to apply:              00:00:00
```

Pausing / Resuming Replication

The "`acfsutil repl pause`" and "`acfsutil repl resume`" commands may be used only on the primary site. The acfsutil repl pause should be followed later by the acfsutil repl resume. The effect of the command acfsutil repl pause is to stop the replication daemon's operation temporarily. Naturally, the impact of the command "`acfsutil repl resume`" is to resume the operation of the daemon.

If "`acfsutil repl pause`" is run while a replication operation is active, the operation will be allowed to complete – that is, the pause will not be effective until the current data stream has been applied on the standby. At that point, no more work will be performed for this replication until the "`acfsutil repl resume`" command is issued.

Synchronizing the Primary and Standby Sites

The replication command "`acfsutil repl sync`" can synchronize the state of the primary and standby sites. This command can only be run on the primary site. Users should first quiesce their applications and issue the OS "*sync*" command so that the synchronized state is known and meaningful to the user. The "`acfsutil repl sync`" command will then cause all outstanding replication data to be shipped from the primary site to the standby site. Specifically, the command will allow any in-progress replication operation to be completed. Then, replication will be performed one final time to ensure that all changes on the primary have been replicated.

The command will return success when all of these changes have been successfully applied to the file system on the standby site. Applications may now be restarted unless the last node on the primary site cluster is about to be unmounted (see next paragraph). The apply keyword is supported for backward compatibility but does not affect the operation of this command.

Successfully unmounting a replicated file system on the primary site does not imply that all changes made before the unmount have been successfully sent to the standby site or applied to the standby file system. If the primary file system is unmounted on one primary site node but remains mounted on one or more primary site nodes, changes to the file system made before the unmount continue to be transported to the standby site from the other nodes after the unmount. But if the administrator is unmounting the primary file system on the last primary site node where it is mounted and if they wish to know that all file system changes made on the primary file system up to that point have been successfully applied to the standby file system, the administrator may wish to quiesce applications on the primary site which modify the file system and then run "`acfsutil repl sync,`" to be sure that the standby file system is up to date. Then, the unmount can be done.

Updating Replication Parameters

The "`acfsutil repl update`" command can be used to update all of the parameters established by the "`acfsutil repl init`" command, except for the mount point being used. In addition to the compression setting, these parameters include the replication interval, debugging level, and user or connect string used to communicate between primary and standby.

If run on the primary site, this command can alter the username and network interface name (hostname or VIP name) used to connect to the standby site. It can also change the replication interval or tracing level, the cipher used by or the pathname used for SSH, and whether compression is used.

In releases before 19.5, any new hostname or VIP name specified to connect to the standby site must resolve to the same cluster as the previous hostname or VIP name—that is, this command may not be used to change to a different standby cluster.

If run on the standby site, this command can only alter the username used by the primary to connect.

This command will succeed when the updated information is accepted on the local site. The command should be run on the primary and standby sites to change the username. If the replication interval is changed using -C or -i, a replication operation will occur when "`acfsutil repl update`" is run. Then, the next replication operation will happen based on the newly specified interval.

The "`acfsutil repl update`" command may be used for Oracle configuration changes. For example, the system administrator may need to change the network interface used by replication to connect to the remote site. In this case, issuing the "`acfsutil repl update`" command will allow replication to continue uninterrupted.

Administering Background Process

ACFS replication uses a background process on the primary cluster to transport file system changes to the standby file system. This process must be running for replication to function. The background process is started when replication is started via the "`acfsutil repl init`" command. The process is present and is registered with Oracle Clusterware whenever replication is active. The primary file system is mounted, so the process will automatically be restarted after a reboot or system crash. This process is cluster-wide.

Issue the following command on the primary cluster to see if the ACFS replication background process runs at the primary site.

```
[joe@primary-node1 ~]$ acfsutil repl bg info /pmntpnt
Resource:              ora.repl.dupd.data.datclone.acfs
Target State:          ONLINE
Current State:         ONLINE on primary-node1
```

In this example, the command reports that the background process is running. If it were not, the following message would be displayed:

```
[joe@primary-node1 ~]$ acfsutil repl bg info /pmntpnt
ACFS cluster-wide replication background process is stopped
```

Comparing Mount Points

The "`acfsutil repl compare`" command verifies that all or part of the primary mount point has been replicated to the standby mount point. The standby mount point must be mounted locally to the primary (i.e., using NFS) for comparison. This command continuously checks all files on the primary file system against those on the standby file system.

If the "-a" option is used, the command also tests for extra files on the standby file system that do not exist on the primary. In this case, it will also try to check extended attributes. However, if NFS is used to mount the standby file system locally, the standby cannot be checked for matching extended attributes due to limitations in the NFS protocol.

The "-t" option is used when tags were specified during the "`acfsutil repl init`" operation. The "-t" operation locates all file names on the primary file system with the specified tag names and compares them to the corresponding files on the standby. If the "-t" option is used with all arguments, all tag names supplied during the "`acfsutil repl init`" operation are selected. The "-t" option also tests for extra files on the standby file system that do not have an associated tag name specified during the "`acfsutil repl init`" operation. If NFS is used to mount the standby file system locally, the standby cannot be checked for matching tag names due to limitations in the NFS protocol.

The "-a" and "-t" options may not be specified.
When "-a" or "-t" is given, the option "-s" may also be given to skip extended attribute comparisons for symlinks.
In all cases, the "-v" option may be used to output the name of each file after it is compared (verbose output).

Replication Failover and Switchover

The "`acfsutil repl failover`" and "`acfsutil repl switchover`" commands are run in the standby cluster and reverse the role of a replication standby location such that it becomes a replication primary location.

The switchover commands assume that both the primary and the standby clusters function usually and terminate if this is not the case. The command reverses the replication relationship and ensures no data loss. Not that switchover fails if replication is paused. To enable it to succeed, run "`acfsutil repl resume.`"

The failover command ensures that the standby location contains an exact copy of the results of the last successful replication transfer. If necessary, the command restores the location to its state as of that transfer. "`acfsutil repl failover`" behaves differently based on the scenario in which it was run. We cover three scenarios:

1. Both the standby location and corresponding primary location are operating normally.
In this scenario, the command reverses the replication relationship. There is no data loss. Note that failover fails in this case if replication is paused. To enable this case to succeed, run "`acfsutil repl resume.`" This is equivalent to what the "`acfsutil repl switchover`" command does.

2. The primary location is unavailable, but the user wants to wait until it is eventually back online.

In this scenario, the command verifies the status of the replication primary. If the primary is inaccessible and the timeout period has expired (if specified), the command restores the standby location to its state as of the last successful replication transfer and converts it into a replication primary. Some data loss is possible, such as if there was a transfer in progress when the primary location became unavailable. When the original primary location becomes available, it is aware that the failover command has been run and converts itself into a replication standby location. At that point, replication is again active from the new primary location to the new standby location.

3. The primary location is unavailable, and the user does not want to wait until it is back online.

In this scenario, the command verifies the status of the replication primary. If the primary is inaccessible and the timeout period has expired (if specified), the command restores the standby location to its state as of the last successful replication transfer and converts it into a replication primary. Some data loss is possible, for instance, if there was a transfer in progress when the primary location became unavailable. After the failover command has been run, the user has two options:

- First, a new standby location can be configured using the `acfsutil repl update` command. It is harmless if the original primary returns (as a standby) after the user has specified the new standby. The original primary will remain idle (as a standby) until the user runs "`acfsutil repl terminate standby`" for it.
- Alternatively, the user can terminate replication by running "`acfsutil repl terminate primary`" on the new primary.

Remember that replication will not protect your data until an active standby is in place following a failover.

When the current primary location is active, you should quiesce application updates to the primary before running "`acfsutil repl failover.`" Any updates attempted to the current primary location before its conversion to a standby are discarded. Any updates attempted after its conversion fail, just as updates would be done to any other standby location.

When application updates are resumed, they must be directed to the new primary location.
You run the failover command in the standby cluster simply by naming the standby storage location to be used for it:

```
[joe@primary-node1 ~]$ acfsutil repl failover /smntpt
```

Termination of Replication

When administrators need to dissolve the instantiated replication, the "`acfsutil repl terminate`" command is used on both the primary and standby locations. Note that this is performed at the file system level, not the node level. To perform graceful ACFS Terminate, it is recommended to terminate the primary file system first, followed by a terminate command at the standby file system.

Note: "`acfsutil repl terminate primary`" does not wait for an in-progress replication operation to complete. Termination is effective immediately.

TERMINATE REPLICATION ON PRIMARY NODE

```
[joe@primary-node1 ~]$ acfsutil repl terminate primary /pmntpnt
```

TERMINATE REPLICATION ON STANDBY NODE

```
[joe@standby-node1 ~]$ acfsutil repl terminate standby /smntpnt
```

Once replication termination has been completed for a specific file system on a given Primary and a given Standby, no replication infrastructure exists between that primary and standby file system. Termination of replication is a permanent operation requiring a full re-initialization to instantiate replication.

As previously illustrated, the "`acfsutil repl init`" command restarts replication.

UPGRADING FROM PRE-12.2 TO SNAPSHOT-BASED REPLICATION

These commands support upgrading an active, preexisting replication relationship to snapshot-based replication. This support aims to provide an active snapshot-based replication relationship between the same primary and standby, with no need to terminate or re-initiate replication and no data lost in replicating.

Before the upgrade, the user must ensure that the primary file system is mounted on only one cluster node. As noted below, it is also recommended that the user pause any application activity targeting the primary or standby file system. However, the upgrade will proceed even if this restriction is not obeyed.

It should also be noted that once the procedure has been started, it must be completed – there is no provision for aborting the upgrade.

The first step in the procedure is to run the "`acfsutil repl upgrade prepare`" command on the primary cluster. This command specifies the user, host, or interface name used for snapshot-based replication and the primary mount point. The user and host names are given the option -s, precisely as they are for the "`acfsutil repl init primary`" command for snapshot-based replication.

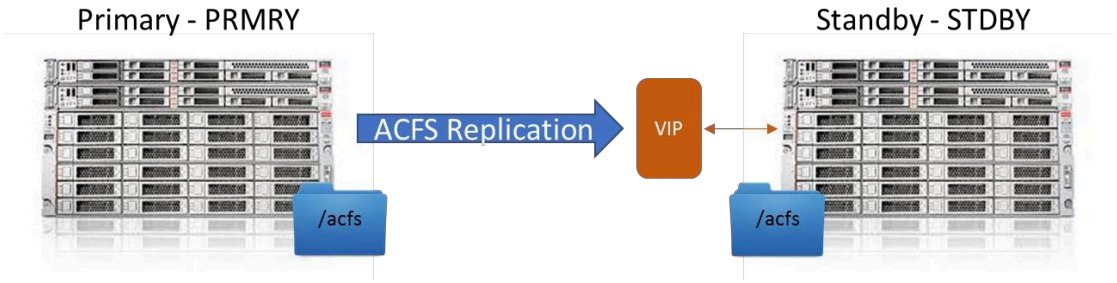
The next step is for the user to upgrade the standby. The user runs the "`acfsutil repl upgrade standby`" command on the standby. This command specifies the user that will be used for snapshot-based replication and the standby mount point. The user name is established with "-u," precisely as it is for the "`repl init standby`" command for snap-based replication. Once this command has been issued, the upgrade must be completed by issuing the "`acfsutil repl upgrade primary`" command.

The final step in the upgrade procedure is to run the "`acfsutil repl upgrade primary`" command on the primary. This is the command that atomically terminates original replication and initiates snap-based replication. This command accepts any command-line options accepted by the "`repl init primary`" command for snap-based replication, except for the -m option and -s option. Instead of using these options, the command obtains information from other sources.

It is recommended that the user request that any applications using the primary or standby file systems be upgraded. This will ensure an optimal upgrade.

APPENDIX A – CASE STUDY

ACFS replication between two Oracle Database Appliance (ODA) through a Virtual IP (VIP) on the standby. Note that the steps described here will set up replication in just one direction –the steps are insufficient to support failover (as described above).




```
standby-node1: 10.10.10.11
standby-node2: 10.10.10.12
repvip(VIP) : 10.10.10.100
```

STEPS

1. Add a VIP configuration to the Oracle Clusterware on Standby ODA (as `root`) using 'appvipcfg':

```
Usage: appvipcfg create -network=<network_number> \
                        -ip=<ip_address> \
                        -vipname=<vipname> \
                        -user=<user_name>[-group=<group_name>] \
                       [-failback=0 | 1]

Example:
[root@primary-node1 ~]# /u01/app/12.1.0.2/grid/bin/appvipcfg create \
                                                  -network=1 \
                                                  -ip=10.10.10.100 \
                                                  -vipname=repvip
                                                  -user root
                                                  -failback=1
```

After you have created the application VIP using this configuration script, you can view the VIP profile using the following command:

```
$GRID_HOME/bin/crsctl status res repvip -p
```

As root, start the VIP resource:

```
[root@primary-node1 ~]# crsctl start resource repvip
```

2. On standby, create the "repluser" on both ODA nodes:

```
[root@standby-node1 ~]# useradd -g asmadmin repluser
[root@standby-node1 ~]# passwd repluser
[root@standby-node1 ~]# mkdir -p /home/repluser/.ssh
[root@standby-node1 ~]# chown repluser:asmadmin /home/repluser/.ssh

[root@standby-node2 ~]# useradd -g asmadmin repluser
[root@standby-node2 ~]# passwd repluser
[root@standby-node2 ~]# mkdir -p /home/repluser/.ssh
[root@standby-node2 ~]# chown repluser:asmadmin /home/repluser/.ssh
```

3. On Primary, on both nodes generate the authorized key (as *repluser*):

```
[repluser@primary-node1 ~]$ ssh-keygen -t rsa
[repluser@primary-node2 ~]$ ssh-keygen -t rsa
```

4. Copy the new keys to the standby:

```
[repluser@primary-node1 ~]$ ssh-copy-id -i ~repluser/.ssh/id_rsa.pub repluser@standby-node1
[repluser@primary-node2 ~]$ ssh-copy-id -i ~repluser/.ssh/id_rsa.pub repluser@standby-node1
[repluser@primary-node1 ~]$ ssh-copy-id -i ~repluser/.ssh/id_rsa.pub repluser@standby-node2
[repluser@primary-node2 ~]$ ssh-copy-id -i ~repluser/.ssh/id_rsa.pub repluser@standby-node2
```

Note that on both STDBY nodes the "authorized_keys" file will be as following:

```
$ cat /home/repluser/.ssh/authorized_keys
```

```
ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEAr4xwODqKntKgq7TWYzWs0G8fsjRdmHUgFCYM5Gw+ibsXwcvXZtfKOec
7ypmUL3YK4zbUtqKUl4lYPr4iI0l5RgAPSomZc+vpPPCD9Rbz2dKQPVjH4n6m991fTxrp96VeUIc2yk29xt
MT66V7RmqGrJMfBFuX8w1VAxJ4rLq4QDU/b3+xMAIrx2e6a213H1yqhywgl+CNtzCGc8yVWhACLrHgEFaUz
8P5/eg+QM1aLysaTcx7OHHgHtHUqADPCJ8mCWuujk1SI2qpcoIZXQr+feIW8X3Knmg4qUzrjPKXMvupur3w
Phbo/z3SvspBDfWN3DiV571en/b21wVpeGjgcQ== repluser@primary-node1


ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEA2rI13+gdbGIdmUuqNYoUAnQyvVuKOl4Uj5MR04x/kVOIJIxdjnJhbwS
BM270eln25d4eAbKdMjORnE2AIG3E/av2E2dyLAIJ4+hnqPXapgsIvbzG2PBrZ3RaXVvllq2BBK/t3FH05y
VUjl7HQ7gyzDxvRyo652E7994a7BK/AawokWNJ68LDdT8URnCwUnShlwsc2/0dsl5nUhgLjTB2A7UOPfT14
F3DkujfxDORPB2blgU7PvOVnIzXcF58oux0W4xcLXyAeOPIK7S/u48PSnFjnKJjdx/pX7OwLFdbECndOKpl
isFmKLmcMI24KUV459YW08mymuPdrjoyA+JF0Q== repluser@primary-node2
```

At this time, you can connect from Primary ODA to Standby ODA as "repluser" with password-less functionality:

```
[repluser@primary-node1 ~]$ ssh repluser@standby-node1 date
Fri Nov 6 11:30:03 SAST

[repluser@primary-node1 ~]$ ssh repluser@standby-node2 date
Fri Nov 6 11:30:12 SAST


[repluser@primary-node2 ~]$ ssh repluser@standby-node1 date
Fri Nov 6 11:30:29 SAST

[repluser@primary-node2 ~]$ ssh repluser@standby-node2 date
Fri Nov 6 11:30:34 SAST
```

The "known_hosts" file on the Primary will be something like:

```
  $ cat ~repluser/.ssh/known_hosts
```

```
standby-node1.it.oracle.com,10.10.10.11 ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEAsvEtyJXoxUXwL1zIOq9JjbZIBCy0HSw+gvR0XFf+Uk2hxfWWAV82oZ4
qYEykCXU+pJBB0wcTM871tPQuEmaMJ9vJv5Gp1NVPz3UOZQovxsgjE7yLWolOFT0S4xztm5XhUOlx7sjmGY
I3nAA8vTf17s9Q2AGEXSzFYh0BCWQ9Q7Es5BCEpcLeHjZAmimktjaixgKp9ABOxOnTYfwJXhRM/5RJ+k4HP
4yRwvEYUKlM3FkZ2uBJNkdaMwV7I+8Lr4MkVwik3V0ukKZ5O43YFnji8wyHnlA9kuoqeHKC+eALPA5Lmlfh
r0f2q1/RA1cO9j5qWdxBYtWWrP9VNcI195qZfQ==


standby-node2.it.oracle.com,10.10.10.12 ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEArkmXmij6Xz57KH0O10V7BTT8/rnvHq7PSizqTs/FI9SsePqq3byOKbx
ekik/C185xC3NYqp6577B+c7t36wjob8vLdlbuMSySOTk6cFiVb87sIJWNW/iHYLdFfjdtkZ1pvR1W6uNRz
R8DryksjiMqgFF8g2k75r08jnCdK5yCfSslRstOFdHjPtrj6c/uabH8Ve8EhdO6IwztwjSqjwuW7l1U/GT2
680qOFUrZMP+A36GSiYnquanpMwUxvVWHswqUkrqEKTJWkD2EaOERlFtxsecnsdfxw0wG6gjbwxhFGUUCu1
OKpURgLdJuAH9Q9RaSBzoYGj9JYxlimXLQZQ2w==
```

As we need to use the Standby VIP (`10.10.10.100`) created above, you need to modify "known_hosts" on Primary to read as follows:

```
  $ cat ~repluser/.ssh/known_hosts
```

```
repvip.it.oracle.com,standby-node1.it.oracle.com,10.10.10.11,10.10.10.100 ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEAsvEtyJXoxUXwL1zIOq9JjbZIBCy0HSw+gvR0XFf+Uk2hxfWWAV82oZ4qYEykCXU+p
JBB0wcTM871tPQuEmaMJ9vJv5Gp1NVPz3UOZQovxsgjE7yLWolOFT0S4xztm5XhUOlx7sjmGYI3nAA8vTf17s9Q2AGEXS
zFYh0BCWQ9Q7Es5BCEpcLeHjZAmimktjaixgKp9ABOxOnTYfwJXhRM/5RJ+k4HP4yRwvEYUKlM3FkZ2uBJNkdaMwV7I+8
Lr4MkVwik3V0ukKZ5O43YFnji8wyHnlA9kuoqeHKC+eALPA5Lmlfhr0f2q1/RA1cO9j5qWdxBYtWWrP9VNcI195qZfQ==
```

```
repvip.it.oracle.com,standby-node2.it.oracle.com,10.10.10.12,10.10.10.100 ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEArkmXmij6Xz57KH0O10V7BTT8/rnvHq7PSizqTs/FI9SsePqq3byOKbxekik/C185x
C3NYqp6577B+c7t36wjob8vLdlbuMSySOTk6cFiVb87sIJWNW/iHYLdFfjdtkZ1pvR1W6uNRzR8DryksjiMqgFF8g2k75
r08jnCdK5yCfSslRstOFdHjPtrj6c/uabH8Ve8EhdO6IwztwjSqjwuW7l1U/GT2680qOFUrZMP+A36GSiYnquanpMwUxv
VWHswqUkrqEKTJWkD2EaOERlFtxsecnsdfxw0wG6gjbwxhFGUUCu1OKpURgLdJuAH9Q9RaSBzoYGj9JYxlimXLQZQ2w==
```

5. Validate the SSH setup by issuing the following commands (as *repluser*):

```
[repluser@primary-node1 ~]$ acfsutil repl info -c -u repluser standby-node1 standby-node2 /acfs

A valid 'SSH' connection was detected for standby node standby-node1 as the user repluser
A valid 'SSH' connection was detected for standby node standby-node2 as the user repluser

[repluser@primary-node2 ~]$ acfsutil repl info -c -u repluser standby-node1 standby-node2 /acfs

A valid 'SSH' connection was detected for standby node standby-node1 as the user repluser
A valid 'SSH' connection was detected for standby node standby-node2 as the user repluser
```

The commands above should be run on each primary host. Each command line run should name every standby host.

6. Initialize the replication on Standby first:

```
[joe@standby-node1 ~]$ acfsutil repl init standby -u repluser /acfs
```

7. Then initialize the replication on Primary:

```
[joe@primary-node1 ~]$ acfsutil repl init primary -C -s repluser@rep-stdby -m /acfs /acfs
```

8. You can check the replication by issuing:

```
[joe@primary-node1 ~]$ acfsutil repl info /acfs
Time: Fri Nov 06 12:12:09
Event: Replication Initialization Started
Initialization Start Time: Fri Nov 06 12:12:09

Time: Fri Nov 06 12:12:04
Transfer completed at:                      Fri Nov 06 12:12:04
Transfer status:                            0

Time: Fri Nov 06 12:12:04
Event: Clone Created
The session started at:                             Fri Nov 06 12:12:04
Session ended at:                           Fri Nov 06 12:12:04
Number of bytes transmitted:                20759

Time: Fri Nov 06 12:12:04
Create completed at:                        Fri Nov 06 12:12:04
Create Status:                              0

Time: Fri Nov 06 12:12:04
Create started at:                          Fri Nov 06 12:12:04

Time: Fri Nov 06 12:12:04
Transfer started at:                        Fri Nov 06 12:12:04

Number of Events: 6
```

CONNECT WITH US

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