SAP HANA Database Backup & Restore

Best Practice

Version 1.00 09/2014 - SPS 8

Active Global Support

SAP AG

1 Purpose

The following document introduces the SAP HANA database specifics in the area of backup and restore. The current version is based on the functionality provided with SAP HANA SPS8. This functionality is described in detail in the SAP HANA Administration Guide. This document is not meant as a general introduction into the backup and restore topic. For this purpose please check Best Practice Backup and Restore for SAP System Landscapes. Here complementing information to the latter is provided.

2 Table of Contents

3 Introduction

A solid backup and restore strategy is an essential part of the availability concept of the system landscape. Database backups are used to protect against the complete or partial loss of data volumes, i.e. disk failure or data corruption, and against logical errors. The possibility to choose backups taken at different points in time as a starting point of a database restore, i.e. a point in time before a data corruption occurred, and to roll forward to a certain point in time, i.e. before a logical error occurred, provides great flexibility in resolving certain error situations. Incomplete point in time restores on productive systems ought to be avoided as they result in data loss with the consequence of having to redo the lost changes and the need of resynchronization with other systems in the landscape. The functionality to restore a backup on a different database, which is widely used for system copies like a refresh of a quality system from the production environment, can be utilized in case of an incomplete restore with a subsequent data reconciliation of the restored and the original system.

Two of the essential questions when defining a backup and restore strategy are:
1) How much data am I allowed to lose? This is defined by the so called Recovery Point Objective (RPO).
2) How much time do I have for the restore? This is defined by the so called Recovery Time Objective (RTO).
For production systems, typically an RPO = 0 and a small RTO is requested.

In order to help in preparing for these objective for an SAP HANA database, the following document starts with an architecture overview of the backup and restore relevant parts of the database. The next section discusses the topics which are relevant in the planning and execution phase, like the available backup and restore options, typical setups and information on how to estimate the required backup storage space. After required housekeeping and monitoring activities are described the document finishes with first customer examples, useful SQL statements and links for further readings.

4 Architecture Overview

The SAP HANA database is an in-memory database optimized for high performance. On the operating system level the database consists of several multi-threaded processes. In the context of SAP HANA these processes are called servers, like name server or index server. In the latter they are in general referred to as SAP HANA database services, or in short just services if the context is clear, in order to avoid confusion with hardware servers. Which services are active depends on the SAP HANA revision and the configuration. All of the services can run on a single host or can be distributed over several hosts, the so-called scale-out configuration.
In-memory indicates that all data that is required for the business application should reside in memory to allow fast access times. To avoid data loss in case the memory part of the SAP HANA database is not available anymore, data is also persisted on disk. Changes to the database are performed in memory and written to disk

1) at latest with the database commit to the log volumes and
2) at regular intervals to the data volumes (“savepoint”).

The persistence is service specific, which means for instance that data belonging to the name server and to the index server are stored in separate files, respectively.
The decision which of the persisted data needs to be considered for backup is very important. The relevance of the following five parts are explained in the next sections: data volumes, log volumes, configuration files, diagnostic files and SAP HANA software.

4.1 Data Volumes

The data volumes contain the database content. This includes system and application tables, their definition as well as their content, views, and models. The SAP HANA database comprises several services. Some of these have their own persistent data: Name server, index server, statistics server (optionally embedded in the index server as of SPS07), extended application services (XS) and script server.
Out of these, the index server is with respect to size the most important one as it holds the application data. Other processes, like the preprocessor, do not own data and therefore do not need a permanent storage.
The data of the services with own persistency typically reside in one file per process. But in order to avoid file size limitations the file can be split into several files. The SAP HANA database persistency layer can automatically detect these limitations, e.g. for the Ext3 file system, and creates a new file if the limit is reached. The stored information in the file system is disjunctive; the services do not store shared information. This is also true for a scale-out environment, when more than one service of the same type exists.
The information in the data volumes is not updated immediately when a data record is changed. The update of the data volumes is done periodically during savepoint writing. Data records are not updated in place but written to a new location within the data volume (“copy on write”). A savepoint contains committed and uncommitted data. It

also contains the information which data record has not been committed yet. By this mechanism it is ensured that a savepoint captures a consistent state of a service. During normal operation, the savepoints for each service are written independently of each other.

For column store tables the persistent information is also updated during the delta merge process. Delta merges are required as the columnar tables consists of a read optimized highly compressed main part and a write optimized delta part. Data changes are initially recorded in the delta part and in order to keep the size of the delta part at a small level, it has to be merged regularly into the main part. During this process the main part of the column store table is completely written anew.
The data volumes alone cannot ensure current information up to the latest committed transaction. This gap is bridged by the database log volumes which are described in the next section. A restart of the SAP HANA database based on the data volumes only, e.g. because someone deleted the log volumes erroneously, will fail. In this case a restore of the SAP HANA database is required.

4.2 Log Volumes

The log volumes store the redo information for data changing transactions. The undo information is stored in the data volumes, as described in the previous section. In order to ensure that all changes are persisted in the log volumes the information has to be written at latest at commit time. In need of a recovery or a restore, the last successfully completed savepoint or database backup is used as a starting point and the database logs written after the savepoint or the chosen backup can be used to roll forward up to the last committed transaction.
As for the data volumes all services with an own persistency write into their own log volumes. For each service an initial set of log segments (files) are created within the log volume. Their number and size are defined by the parameters log_preformat_segment_count and log_segment_size_mb. The default value for log_segment_size_mb varies for the services. When a log segment is full and no other log segment is free a new log segment will be created. The point in time when a log segment is released for overwrite is determined by two factors: the log_mode parameter (persistence section of global.ini) and whether it is still required for crash recovery. A log segment can be overwritten if a savepoint has been successfully completed since the log segment has been filled and for log mode NORMAL additionally a successful backup of this log segment is required. The state ‘Free’ in monitoring view M_LOG_SEGMENTS which can be displayed for instance in the volumes section of SAP HANA Studio or queried directly indicates that a log segment can be overwritten.

4.3 Configuration Files

Database configuration parameters are stored in the so called ini files. These files exist for default values, for customer specific global parameter changes and for host specific changes. None of them are part of a database backup. Especially, the files of the host and global custom settings need to be saved in order not to lose these configuration settings when the disk hosting these files becomes unavailable. The locations of these files are listed below:

```
/usr/sap/<SID>/SYS/global/hdb/custom/config        - global custom settings
/usr/sap/<SID>/HDB<instnr>/<hostname>              - host specific custom settings
/usr/sap/<SID>/HDB<instnr>/exe/config              - default values
```

A convenient way to display the custom settings in a SAP HANA database is provided in SQL8. These specific parameter changes are not required for a restore. If not available, the SAP HANA database will run with the default configuration afterwards.
In case the SAP HANA database is restored on a different host, the configuration files should not be blindly copied from the source system configuration files. In this case, great care should be taken with parameter values that depend on the system environment like the landscape section of the nameserver.ini file. Other parameters might be affected as well.

4.4 Diagnostic Files

The SAP HANA database writes a set of diagnostic files which are stored in the trace directory `/usr/sap/<SID>/HDB<instnr>/<hostname>/trace`.

In the context of backup and restore the two files backup.log and if a third party backup tool is used also backint.log record detailed information about any backups and restores that have been performed. In a scale-out environment, these two files are written by the master node only. After a failover of the master to a standby node, the new master will continue this task by writing the information to the files in its directory. The two files do not exist on a node that has never been master, if necessary they will be automatically created.

The diagnostic files are not required to restore a database and there are no standard recommendations for the backup of these files. They can be included in regular file system backups and will not be considered in the remainder of this document.

4.5 SAP HANA Software

The SAP HANA software used for installation or update should be kept in a secure location as long as the software might be required for the installation or update of a SAP HANA system. Please note, that not all released SAP HANA revisions will be provided at a specific time on the SAP Service Marketplace. With the release of a new revision older revisions might be removed from the download area.
The installed database executables are located in a shared directory. It is common practice to include this directory in regular file system backups.

5 Planning & Execution

5.1 Backup Options

5.1.1 Data Volumes

SAP HANA offers the possibility of a full online data backup or as an alternative a snapshot based procedure. For both options the database has to be up and running and remains operational.
In all cases a database internal snapshot is created to provide a consistent state of the database that can be backed up. In order to achieve this a global savepoint is triggered. Global here means a synchronized savepoint across all active services with own persistency across all hosts of the SAP HANA database. This global savepoint holds as any savepoint the current data, before images and the information which data has not been committed yet. It is not an exact copy of the data volumes, but contains only the payload, the occupied pages on disk. The database snapshot ensures that the information contained in the global savepoint is available as long as needed for the backup procedure. The way how this internal database snapshot is transferred to the backup location and when it is released differentiates the backup procedures and is explained in the next two sections.
Currently, the SAP HANA database only supports one internal database snapshot which means that data backups cannot overlap and no additional internal database snapshot can be triggered while a data backup is active. Neither regular savepoints nor savepoints used for system replication are blocked by an internal database snapshot.
Although only online backups are supported, a consistent restore or database copy with an online data backup can be performed without the database log files as all required information is contained in the data backup. Partial data or offline backups are currently not supported. When using SAP HANA system replication the backup has to be taken from the primary site. Additional functionality might be added in future releases.

5.1.1.1 Standard Data Backup Procedure

When the internal database snapshot is completed its content is transferred for each service simultaneously to the specified backup location. The data is read highly parallelized from the data volumes and written with one output stream per service. During this phase the technical consistency of the backup relevant objects is checked on block level by calculating check sums. The internal database snapshot is kept until the data backup is completed or cancelled.
During this time the occupied space of the SAP HANA database might increase until the snapshot is released automatically. After the data backup is finished the backup catalog (see 5.1.3 Backup Catalog), which keeps the history of the performed backups, is also backed up. With the completion of this catalog backup the data backup is marked as valid in the backup history.
When performing a database backup two different destinations are supported, backup to file and via backint to a third party backup agent running on the database host which sends the backup to the corresponding third party backup server. When using the file based approach, please make sure your are not using an unsupported files system (see SAP Note 1820529 - Unsuitable network file systems for backup and recovery).
The third party tool has to be SAP-certified, which means that the proper functioning with respect to the backint - interface has been validated by SAP. An overview of supported third party backup tools and the associated support process is given in SAP Note 2031547.
The usage of backint for SAP HANA creates some overhead during the backup writing. On the other hand third party tools can extend the native SAP HANA backup functionality in the areas of monitoring and alerting, backup scheduling and lifecycle management, encryption, compression and I/O throttling.

Currently, a backint based backup cannot be used for system copy[1]. The recommended workaround is to create a specific file based backup for this purpose.

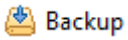
5.1.1.2 Storage Snapshot based Data Backup procedure

Storage snapshots of internal database snapshots provide an alternative approach for data backups. Prerequisite for using database snapshots as part of the backup strategy is that the underlying storage system allows storage snapshots, so that the database snapshot can be preserved.
In case this procedure is used, an internal database snapshot is taken in the so-called prepare phase followed by the storage snapshot. If the successful execution of the storage snapshot is confirmed, the internal snapshot is released and the backup catalog is updated including the external backup identifier (EBID). With the completion of this catalog backup the snapshot is marked as valid in the backup history. The saving of the storage snapshot is not controlled by the SAP HANA database it is performed directly at storage level.
The storage snapshot based approach is from a functional perspective equivalent to a standard backup and can be used as a starting point for a restore and roll-forward to a specific point in time using database logs. The main advantages of this procedure are the provided functionality of creating, copying, restoring snapshots with the accompanying features at storage level and the achievable performance.
The little involvement of the SAP HANA database also means little resource consumption on the SAP HANA database. As the SAP HANA database is not in charge of the backup writing there are also no consistency checks executed during this approach. For this reason it is not recommended to solely base the backup procedure on snapshots. If snapshots are used a mixed approach should be followed which includes standard backups at regular intervals. For further information refer to SAP Note 2039883 - FAQ: SAP HANA database and storage snapshots.

5.1.1.3 Estimating the Size of a Data Backup

a) on an available SAP HANA database

The size of recent backups is stored in the backup catalog.

They are displayed for instance in the SAP HANA Studio in the 

section or can be directly accessed via SQL statement to the monitoring views SYS.M_BACKUP_CATALOG and SYS.M_BACKUP_CATALOG_FILES (SQL2 in 7 Appendix ‘Useful SQL-Statements’).
In case you want to estimate the size of the next backup, you can query the information stored in the monitoring view M_CONVERTER_STATISTICS (SQL1 in 7 Appendix ‘Useful SQL-Statements’).

For the snapshot based approach, more space is required when moving the storage snapshot to a different location. The relevant mount point for the data volumes is larger than the internal database snapshot. In the backup catalog only the size of the internal database snapshot is displayed. The size of the data volumes are accessible at file system level or also via the monitoring view M_DATA_VOLUMES (SQL3 in 7 Appendix ‘Useful SQL-Statements’).

b) without an available SAP HANA database

As the database backup only stores the occupied pages a first estimate of the backup size is the result of a SAP HANA database sizing exercise. The expected data volume taking into account SAP HANA database compression can be used. Dependent on the SAP HANA scenario different sizing approaches are available. The SAP Quick Sizer can be used or additional information is available in SAP Notes 1514966, 1637145 and 1793345.

c) compression and deduplication

The SAP HANA database stores data internally in a compressed format. The SAP HANA database does not additionally compress the output files when performing a backup. Compression can be done in a subsequent step or is offered as built-in functionality by third party vendors when using backint.
Tests have shown that using gzip on backup files of an SAP internal Suite on SAP HANA development system can achieve a compression of about 50 %. This value could differ significantly for other systems, but it should provide an indication that it might be worthwhile exploring this possibility.

[1] This functionality is within the scope of SAP HANA SPS9.

Of course, compression and if required also decompression comes at an additional cost of processing time, which needs to be taken into account for the RTO, and the associated hardware resources. Parallel compression tools, like pigz, provide performance advantages if free hardware resources are available.

When storing several generations, deduplication can be used to avoid redundant data storage.
At the moment not enough information is available to give an estimate of typical deduplication rates. However, we expect in general a smaller gain compared to other databases as the delta merge process rewrites the complete column store table or partition in case of partitioned tables. We also expect a strong dependency on the application running on the SAP HANA database.

5.1.2 Log Volumes

The backup of log segments can and should be triggered by the SAP HANA database which needs to be online to perform this task. For production systems, the recommended parameter settings for the following three logging relevant parameters are:

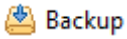
log_mode	normal
enable_auto_log_backup	yes
log_backup_timeout_s	900

Please note that a change of the log_mode requires a SAP HANA database restart[2]. Also, an initial data backup is required to activate the log_mode 'normal'. Otherwise the SAP HANA database will continue to work in the log_mode overwrite, which allows log segments to be overwritten after a successful savepoint.

With these settings, automated log backups are performed when a log segment has been filled or a certain time (log_backup_timeout_s) has passed since the last log backup occurred and the log segment contains at least one commit. Log segments that are in the process of being written are not secured via log backups when lost. They need to be protected by other means, like hardware mirroring or SAP HANA system replication. Equivalent to data backups, the destination of a log backup can be file or via backint a SAP-certified third party tool. The destination of the log backups do not need to be the same as for the data backup, a mixture is possible, i.e. data backups via backint and log backups to file. Both destinations can be mixed also only for log backups. If for instance the third party backup server is not available due to maintenance reasons, the destination can be switched to file based log backups and reverted back to backint after the maintenance is completed without losing the restore capability. The usage of backint for SAP HANA creates some overhead during the backup writing, as additional components are involved and additional steps need to be performed. The extra processing time when using backint depends on the third party tool. To minimize the impact of this overhead by reducing the log backup frequency larger log segment sizes and a larger timeout between two log backups compared to the default values can be chosen (see SAP Note 2063454 - Long running log backups).

5.1.2.1 Estimating the Size of Daily Log Backups

a) on an available SAP HANA database

The size of recent log backups is recorded in the backup catalog. It can be displayed for instance in the SAP HANA Studio in the 

section or can be directly accessed via SQL statements to the monitoring view M_BACKUP_CATALOG and M_BACKUP_CATALOG_FILES (SQL4 in 7 Appendix 'Useful SQL-Statements'). The size of an individual log backup is in general, with the exception of the backup size of the backup catalog (see 5.1.3 Backup Catalog), not very meaningful as the maximum size is defined by the log_segment_size_mb. More important is the frequency or the total size of log backups written in a certain time interval, for instance per day (SQL5 in 7 Appendix 'Useful SQL-Statements').

b) without an available SAP HANA database

If the SAP HANA database hosts an application that was running on a different database before the amount of log backups can be roughly estimated by the amount of logs written on the other database.

[2] It is planned to make this parameter online changeable with SPS9.

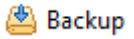
From the first customers migrating to SAP HANA, it looks like the log volume on SAP HANA is significantly smaller than on other databases. The observed reduction of the amount of log volumes written per day is in the order of 30 %.
Another way of estimating the amount of database logs written is to compare it to the database size for other production systems that run the same application. For SAP's internal Suite on HANA production systems, the amount of daily written database logs is a about 10 – 15 % of the data volume. For other customer SAP Suite on HANA production systems up to 25 % were observed.

c) compression

The SAP HANA database does not compress log backups. Compression can be done in a subsequent step when writing to a file or is offered as built-in functionality by third party vendors when using backint.
When using gzip on backup log files of an SAP internal Suite on SAP HANA development system, a compression of about 60 % was observed.
Of course, compression and if required also decompression comes at an additional cost of processing time, which needs to be taken into account for the RTO, and the associated hardware resources.

5.1.3 Backup Catalog

The backup catalog keeps track of the log and data backups. When a log or data backup is performed, information regarding status, duration, size, backup_id etc. it is added to the backup catalog and a backup of the complete backup catalog will follow the data or log backup. Only with the completion of the catalog backup the corresponding data or log backup is marked as valid in the backup history. The backup of the backup catalog is written to the backup log area. The naming convention is described in SAP Note 1812980. The storage of the backup catalog outside the database ensures its availability for determining a suitable recovery strategy if the SAP HANA database is not accessible anymore. In the exceptional case that the backup of backup catalog is also not available anymore, it is still possible to recreate it via hdbbackupdiag (SAP Note 1812057).
The backups of the backup catalog are processed sequentially. It is therefore important to test the duration of catalog backups before going live to ensure that the expected number of backups can be processed fast enough by the chosen solution. As described in section 5.1.2 Log Volumes, it might be required to adjust the default parameterization for the log segment size and the log timeout. In addition, an improvement is planned for SPS9 in case a backlog of backups has built up. Reasons could be for instance slow backup processing, temporary non-availability of the backup solution or lack of backup storage space. With the planned improvement, the number of catalog backups will be reduced as (a) several log segments can be processed in a single backup call requiring only one backup of the backup catalog and (b) pending requests for backups of the backup catalog will be collected and processed by the next backup.

The size of recent backup catalog backups is itself recorded in the backup catalog and can be displayed for instance in the SAP HANA Studio in the 

section or can be directly accessed via SQL statements to the monitoring view M_BACKUP_CATALOG_FILES (SQL6 in 7 Appendix 'Useful SQL-Statements').
Example:

- A single node system with 4 SAP HANA database services with persistency,
- default configuration of the log_backup_timeout_s parameter of 900 s,
- Log_segment_size_mb is larger than the expected amount of logs written within 900 seconds,
- At least on commit per service every 900 s.

This would lead to about 23 000 (= 4 (services) * 4 (per hour) * 24 (hours) * 28 (days retention) * 2 (backup and catalog backup)) entries in the backup catalog which corresponds to about 5 MB size for the backup of the catalog which leads to an additional amount of about 2 GB backup space per day. This size can be checked via access to M_BACKUP_CATALOG and M_BACKUP_CATALOG_FILES (SQL7 in 7 Appendix 'Useful SQL-Statements').

5.1.4 Configuration Files

The ini files are neither included in data backups nor in log backups. They should be copied to an external location. This is recommended at least after an upgrade or a configuration change of the SAP HANA database.
The size of the configuration files usually ranges from a few bytes to several kiloBytes. In total, usually less than 1 MB.

5.2 Restore Options

In the following it is assumed that the issue that was the cause for the necessity to perform a SAP HANA database restore has been resolved, e.g. a faulty hardware component was exchanged. It is also assumed that there is a SAP HANA database installation available on which the restore can be performed.
How the SAP HANA database can then be restored depends on the way backups were performed. If the backups were written to file they need to be restored from file and if they were saved via backint, they need to be retrieved via backint. And if snapshots were used they have to be made available again for the restore.
Currently, only full SAP HANA database restores are supported which implies that currently SAP HANA does not offer the functionality to restore individual services with defect persistency.
Which backup or snapshot is to be used as the starting point of a restore and to which state the database should be restored is decided at the start of the restore. The end state of the restore could be a specific backup, a specific point in time or most commonly the last committed transaction. These options are independent of the chosen backup procedure and are also possible for the snapshot based approach. Only the restore to the last committed transaction ensures that no data changes are lost. To be able to reach this state, log segments that contain committed database changes and have not been backed up still need to be available. A prerequisite to reach the selected end state from a valid backup or snapshot is an uninterrupted log chain from the start to the end point.
Please note that in case backup to file was used, all required logs must be already available at the start of the restore. Depending on the error situation, it might be necessary to not use the latest available backup as a starting point, which will however result in a longer duration of rolling forward the database logs during the restore.
There are several additional points to note regarding a SAP HANA database restore:
If a restore fails or is cancelled, a complete new restore including a complete restore of the data files has to be performed. It is currently not possible to interrupt a restore and restart from that point onwards. Delta merges of column store tables are not written to the database logs. This means that the delta merges are not performed during the roll forward of the database logs, but only at the end of the restore process. Depending on the amount of logs that need to be rolled forward, this could lead to larger delta sizes than during normal database operations.

5.3 Backup Scheduler

SAP Hana data backups can be triggered via the administration tools offered by SAP or directly via an SQL command by the administrator. The SAP HANA database has currently no own scheduler that could be used for this purpose. Therefore an outside scheduler is required.
Using SAP Netweaver this could be achieved via the database planning calendar within the transaction DBAcockpit. The possibility to create secondary database connections within the DBAcockpit allows the scheduling of backups not only on the local but also on remote databases. As prerequisites, the SAP Netweaver release needs to fulfil some minimum requirements and the SAP HANA dependent kernel and client library must be installed.
Another option is to use a script based approach on operating system level and schedule backups via crontab. An example script is provided in SAP Note 1651055.
When using a third party tool, the scheduling of the backups can be performed by this external tool.

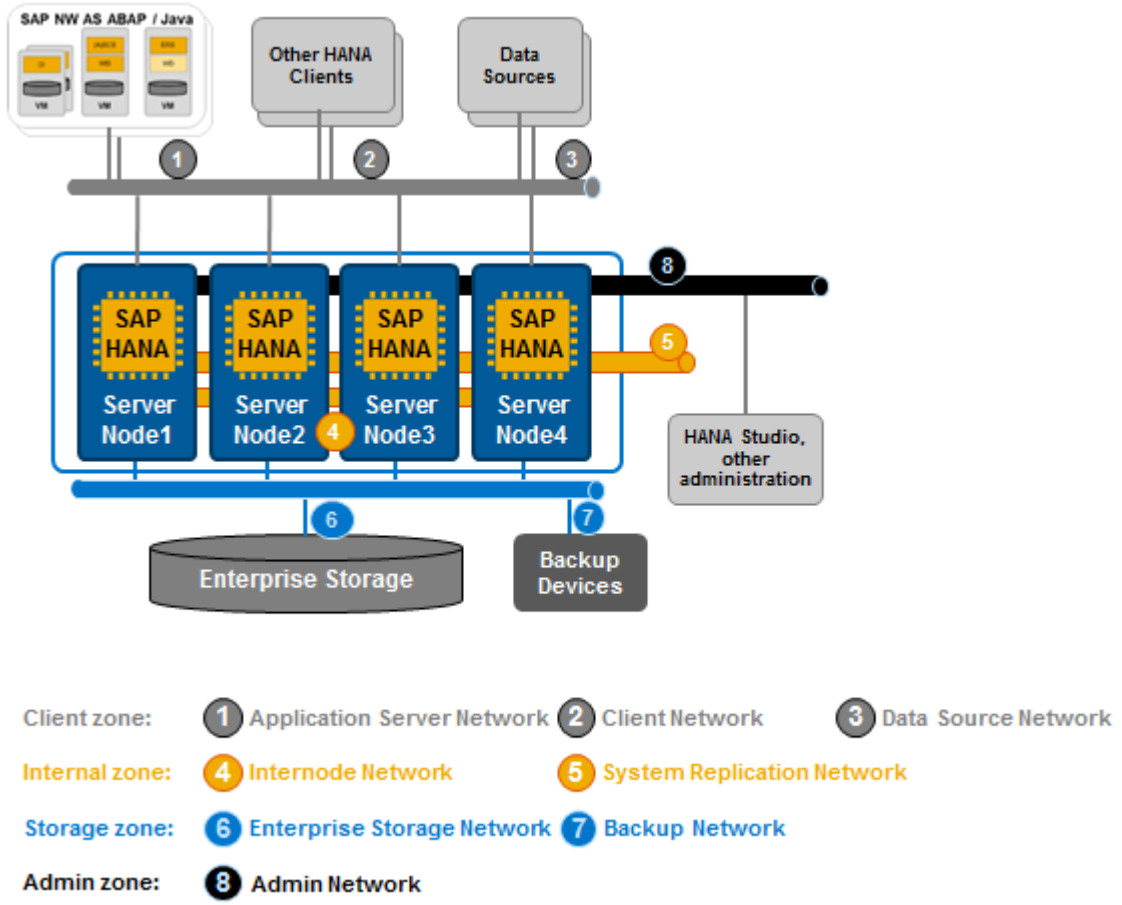
Please note that the SAP HANA database itself does not add a version or identification number to the data backup files. The data backup files are identified with a prefix which is specified when performing a data backup. If this prefix is not changed, a previous backup with the same prefix in the backup location will be overwritten.

In contrast to data backups, log backups are created automatically when a log segment is full or a certain time interval has passed without log backup via the appropriate parameter configuration as described in section 5.1.2 Log Volumes. In contrast to the data backup files, log backup files contain log sequence numbers and the backup_id in the file name.

Besides the scheduling of the backups, additional scheduling functionality is needed when automation is required for instance, when the first backup location is not the final location or when replicas of the backups should be created or compression should be applied, consistency checks performed etc.

5.4 Backup Infrastructure

The infrastructure to support backups and if the necessity arises also a restore depends on the business requirements and the chosen backup procedure.
The schematic network layout for a SAP HANA database and connected components is shown below.



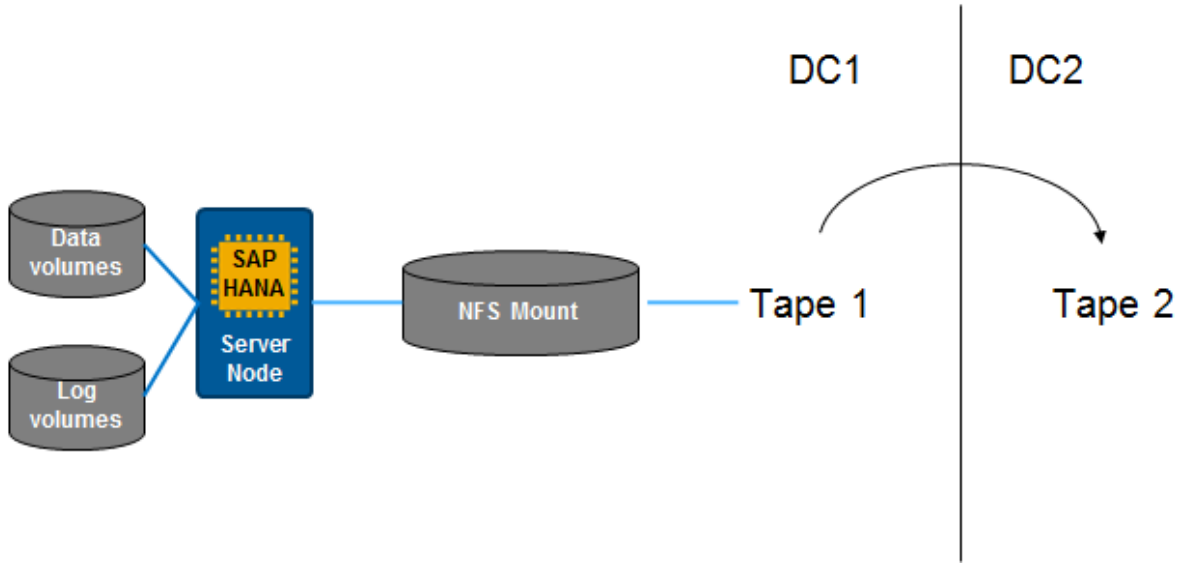
Depending on the SAP HANA set-up not all of the shown components might be present. For example, an enterprise storage may be part of the landscape but might not be. Also the SAP HANA database might not be distributed over several hosts. The backup devices are ideally connected via separate network cards on the SAP HANA database hosts. The backup network is typically a 10-gigabit Ethernet or 8-gigabit Fibre Channel.
The backup devices may or may not be shared with other systems.

In the following different set-ups with differing amount of complexity and protection against specific kinds of failures are discussed.

5.4.1 Configuration A: SAP HANA file based backup

A minimal set-up of the backup infrastructure that provides protection against loss of the SAP HANA database storage is a network file system that is mounted to the SAP HANA database hosts. The file system must be accessible from all hosts if a SAP HANA scale-out configuration is used. The underlying hardware resources for the network and the storage system determine the achievable backup and restore times.
This simple set-up is not widely adopted, a more common configuration is that such a network file system is used as a staging area where a few recent data backups with the necessary log backups are kept and older backup files are transferred to a secondary storage. For this scenario, please review SAP Note 1817703 (Archiving file system-based backups). In this secondary storage, the backup files are kept for the complete retention period, probably multiple copies of them in different data centers and depending on the storage type in a compressed format.

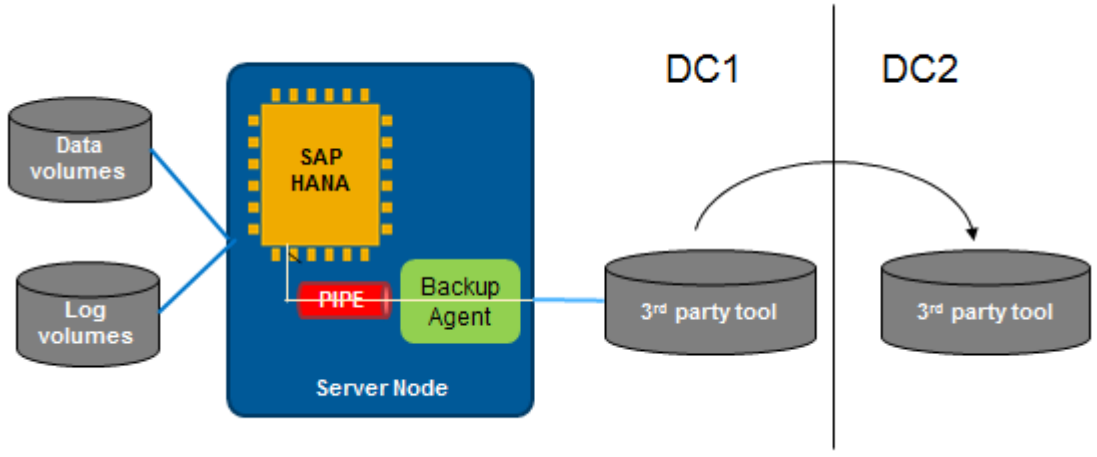
The typical set-up is shown below: the data and log volumes reside on an internal storage or as shown in the previous graphic on an external shared storage (in case of a scale-out configuration). Tape 1 and Tape 2 do not need to be real tapes, they are to be understood as a synonym for economic storage space:



A disk based backup on the storage of the SAP HANA database is not recommended. It creates additional I/O load on the storage and only protects against a storage failure after the backup files have been moved to a different location.

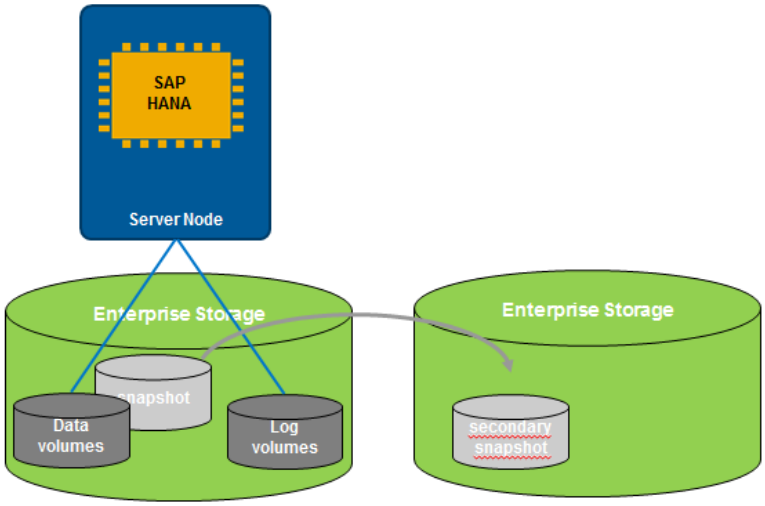
5.4.2 Configuration B: Backup via Backint

When using backint as backup destination the intermediate staging area is not required and the backups can be directly written to the third party server. This task is performed by the third party backup agent that is started by the SAP HANA database for each data and log backup. For a data backup several backup agents are started, one per SAP HANA database service to be backed up. In a scale-out configuration the backup agent is started on the host where the respective service is running. If in parallel log backups are running additional backup agents are started, up to one for each service.
Creating additional copies of the backup files in the same or different locations will be handled by the third party tool. Please ask your third party tool vendor if this functionality is supported, in case you like to use it.



5.4.3 Configuration C: Storage Snapshot based Backup

A snapshot based procedure can be used for the data backups. It is still accompanied by a standard backup procedure of the log segments, either with or without backint usage. The snapshots are usually transferred to a different location, but one or several snapshots are typically kept in the storage system where the snapshot was taken, in order to have the possibility to perform a fast restore without the necessity of retransferring the snapshot. As described above (see section) even when choosing a storage based approach, standard data backups should also be performed at regular intervals. The storage space for these backups also needs to be provided.



5.5 Backup Strategy

The backup strategy should be built on the business requirements for RTO and RPO and should for production systems comply with the following standard recommendations:

- Daily backups of the database plus more frequent backups of the database logs to remote location.
- A minimum retention time of 28 days for database and log backups.
- Consistency checks at least once in a backup cycle.
- Restore tests at regular intervals.

Moreover, as a unusable log backup interrupts the chain for a roll forward recovery, a secondary copy of each log backup should be created.

5.5.1 Size Estimates for required Backup Storage

In the following, the above given recommendations are applied to an example customer that runs a SAP HANA database with a payload of data of 1 TB and writes about 200 GB of log backups per day.
Note: For any estimation regarding storage requirements the data growth needs to be taken into consideration. For clarity this has been omitted in this document.

Purely applying the recommendations without taking into account any compression or deduplication, the result would be for a single storage of the data backups and log backups:

Data:	28 (days) * 1 TB	=	28 TB
Logs:	28 (days) * 200 GB	=	5.6 TB

If a second version of log backups is used, the size required for the logs doubles to 11.2 TB. If compression is used, the amount of storage space is reduced by the average compression factor, which should take into account that probably not all backup generations are compressed.

When using an intermediate staging area, it is best practice to keep at least the last successful backup and the required log files to save the restore time from a secondary storage location if a restore is required for the most common case which is a restore of the last backup.

Staging Area:	Data:	2 (days) * 1 TB	=	2 TB
	Logs:	1.5 (days) * 200 GB	=	300 GB

The disk should be able to hold two data backups, so the older one can be kept until the newer one was completed successfully. Therefore also more than one day of log space is required for the storage of the log backups.
On the staging area usually no additional explicit compression is used.
Note: A larger disk space of the staging area should be reserved for the following events.

1. If a backup fails and the error cannot be solved within a few hours, more than 1,5 days of logs might be required for a restore.
2. In case the latest backup is unusable and an earlier one has to selected for a restore, all log files since this backup until the timestamp to be reached by the restore need to be available at the start of the restore.

As a general recommendation, any interruption of the transfer of log files to the next stage should be taken into account during planning: the previous stage should be sufficiently large to avoid disk full situations. Sufficient in this case means, estimate how much time it will take to fill up the available space and whether within this time the errors can be solved.

The probability that a certain backup is required for a restore decreases with time. This can be exploited to reduce the space requirements on the backup locations by deleting older data backups according to a certain pattern, e.g. every second one that is older than two weeks. This would save about 25 % of the space needed to keep the database backups, while still retaining the option to restore from the oldest backup within the backup cycle. Of course, this comes at a penalty of a longer restore time if the best backup for a restore starting point has been already deleted.
Log backups from the latest 28 days cannot be deleted without losing the capability to restore the latest available backup in the backup cycle that was taken 28 days ago. As mentioned above as each log file is required, it is even recommended to create a copy of the log backups, in case one becomes unreadable. These copies of the backup log files are certainly good candidates for compression. It is needless to say, that these copies should be stored separately from the original log backups.

When using a snapshot based approach, a similar calculation as for the backup to backint applies. The achievable compression factors however might differ.

5.6 Consistency Checks

When performing data and log backups the SAP HANA database is executing technical consistency checks on block level. However, to permanently ensure that a database can be restored from the available backups several additional measures should be taken.
Several checks can be performed to test the integrity and completeness of the available backups written to file or backint. This is especially recommended if the backup files are transferred between different storage layers. The purpose and functionality of hdbbackupcheck and hdbbackupdiag utilities are described in the SAP HANA Administration Guide. Additional information is provided in SAP notes 1869119 and 1873247 and references therein.
The best test however if a restore of the database is possible is a complete restore itself which should be part of the backup verification procedure. Restore tests can be done to a separate hardware and could be part of standard system refresh activities, when for instance the production system is copied to a quality assurance system. Currently, system copies from backups to file and taken via the storage snapshot based approach are supported. The support of system copies from backups to backint is planned for SPS9.
Not only the backups should be checked for consistency, but also the SAP HANA database itself (SAP Note 1977584). A copy of the production database is also best suited to run database consistency checks in order to not interfere with business critical processes.

5.7 Monitoring

The statistics server offers the following alerts for monitoring the logging and backup procedure (taken from the statistics server table "_SYS_STATISTICS"."STATISTICS_ALERT_INFORMATION)":

ALERT_ID	ALERT_NAME	ALERT_DESCRIPTION
2	Disk usage	Determines what percentage of each disk containing data, log, and trace files is used. This includes space used by non-SAP HANA files.
30	Check internal disk full event	Determines whether or not the disks to which data and log files are written are full. A disk-full event causes your database to stop and must be resolved.
33	Log mode OVERWRITE	Determines whether or not the database is running in log mode "overwrite". Log mode "overwrite" does not support point-in-recovery (only recovery to a data backup) and is not recommended for productive systems.
34	Unavailable Volumes	Determines whether or not all volumes are available.
35	Existence of data backup	Determines whether or not a data backup exists. Without a data backup, your database cannot be recovered.
36	Status of most recent data backup	Determines whether or not the most recent data backup was successful.
37	Age of most recent data backup	Determines the age of the most recent successful data backup.
38	Status of most recent log backups	Determines whether or not the most recent log backups for services and volumes were successful.
65	Runtime of the log backups	Determines whether or not the most recent log backup terminates in

	currently running	the given time.
66	Storage snapshot is prepared	Determines whether or not the period, during which the database is prepared for a storage snapshot, exceeds a given threshold.
69	Enablement of automatic log backup	Determines whether automatic log backup is enabled.

Automated email notifications can be configured in case an alert was issued. Knowledgebase articles are listed in section 8 References which provide information how to handle these alerts.
Backup and restore activities are recorded in the backup.log file and if backint is used also in the backint.log file. In a scale-out configuration, these files are written by the master node only. They are located in the same directory as the other diagnostic files (see section 4.4 Diagnostic Files). In case of a backup error these files would be the starting point of the root cause analysis.

5.8 Housekeeping

Regular housekeeping activities need to be set up in order to delete backups and related information that is no longer required.
The deletion of data and log backups should be performed via the SAP HANA database; this ensures that the backup catalog is kept to the minimum size and in sync with the available backup files. A growing size of the backup catalog can occupy a significant amount of space in the backup location as the backup catalog is backed up with each log or data backup. SQL statements to determine the current size of the backup catalog and the size of backups of the backup catalog written per day are provided in 7 Appendix 'Useful SQL-Statements' (SQL6 & SQL7).
In addition, old information from the log files backup.log and backint.log should be regularly deleted to keep the file sizes small.

6 Reference Values

For an SAP internal Suite on HANA 4 TB single node production system the following figures for regular data backups and a specific restore test were obtained:

Backup Size	1.7 TB
Backup Duration	55 minutes
Data Restore	70 minutes
Log Size for Roll Forward	6.7 TB (equivalent of about 3 weeks)
Log Roll Forward Duration	9 hours

The data and log backups were performed to an NFS share. The duration for the data restore and the log roll forward does not include the time to copy the required data and log file from the secondary storage to the NFS share.
The restore could be performed on the 4 TB host although the SAP HANA database was growing due to the fact that delta merges are only performed at the end of the roll forward. The first immediate backup of the SAP HANA database after the restore completed was about 4 TB.

7 Appendix 'Useful SQL-Statements'

SQL1: Estimated Size of a Data Backup

```
select to_decimal(sum(allocated_page_size/1024/1024/1024),10,2) as
Estimated_Backup_Size_GB from M_CONVERTER_STATISTICS
```

SQL2: Size of recent Data Backups

```
SELECT
        TOP 100 t1.BACKUP_ID,
```

```
        t1.ENTRY_TYPE_NAME,
       (SELECT
        to_decimal(sum(t2.BACKUP_SIZE/1024/1024/1024),10,2)
       FROM SYS.M_BACKUP_CATALOG_FILES t2
       WHERE t2.BACKUP_ID = t1.BACKUP_ID
       GROUP BY t2.BACKUP_ID) as Backup_Size_GB,
        t1.UTC_START_TIME,
        t1.UTC_END_TIME
FROM SYS.M_BACKUP_CATALOG t1
WHERE t1.state_name = 'successful'
AND (t1.ENTRY_TYPE_NAME = 'complete data backup'
      OR t1.ENTRY_TYPE_NAME = 'data snapshot')
ORDER BY t1.UTC_START_TIME desc
```

SQL3: Allocated Database Size on Disk

```
select
    to_decimal(sum(size/1024/1024/1024),10,2) as Data_Volume_Size_GB
 from  M_DATA_VOLUMES
```

SQL4: Size of recent Log Backups

```
SELECT
        TOP 100 t1.BACKUP_ID,
        t1.ENTRY_TYPE_NAME,
        t2.service_type_name,
        t2.source_type_name,
        to_decimal(t2.BACKUP_SIZE/1024/1024/1024,10,4) as Backup_Size_GB,
        t1.UTC_START_TIME,
        t1.UTC_END_TIME
FROM SYS.M_BACKUP_CATALOG t1, SYS.M_BACKUP_CATALOG_FILES t2
WHERE t2.BACKUP_ID = t1.BACKUP_ID
AND t1.state_name = 'successful'
AND (t1.ENTRY_TYPE_NAME = 'log backup')
ORDER BY t1.UTC_START_TIME desc
```

SQL5: Size of Daily Log Backups

```
SELECT
        to_date(A.UTC_START_TIME) as Date,
        to_decimal(SUM(B.BACKUP_SIZE/1024/1024/1024),10,2) AS
DAILY_LOG_BACKUP_SIZE_GB
FROM "PUBLIC"."M_BACKUP_CATALOG" AS A JOIN "PUBLIC"."M_BACKUP_CATALOG_FILES" AS B ON
A.BACKUP_ID = B.BACKUP_ID
WHERE entry_type_name = 'log backup'
AND state_name = 'successful'
GROUP BY
        to_date(A.UTC_START_TIME)
ORDER BY
         to_date(A.UTC_START_TIME) desc
```

SQL6: Size of recent Backup Catalog Backups

```
select
     TOP 10 to_decimal((BACKUP_SIZE/1024/1024),10,2) AS BACKUP_CATALOG_SIZE_MB
FROM
     M_BACKUP_CATALOG_FILES
where
      source_type_name = 'catalog'
ORDER BY
    backup_id desc
```

SQL7: Size of daily Backup Catalog Backups

```
 SELECT
```

```
        to_date(A.UTC_START_TIME) as Date,
        to_decimal(SUM(B.BACKUP_SIZE/1024/1024/1024),10,2) AS
DAILY_CATALOG_BACKUP_SIZE_GB
FROM
"PUBLIC"."M_BACKUP_CATALOG" AS A JOIN "PUBLIC"."M_BACKUP_CATALOG_FILES" AS B ON
A.BACKUP_ID = B.BACKUP_ID
WHERE entry_type_name = 'log backup'
AND source_type_name = 'catalog'
AND state_name = 'successful'
GROUP BY
        to_date(A.UTC_START_TIME)
ORDER BY
        to_date(A.UTC_START_TIME) desc
```

SQL8: Custom SAP HANA database parameter settings

```
SELECT
        FILE_NAME as INI_FILE,
        LAYER_NAME,
        HOST,
        SECTION,
        KEY as PARAMETER,
        VALUE
FROM M_INIFILE_CONTENTS
WHERE layer_name != 'DEFAULT'
```

8 References

General backup and restore best practice document:
Best Practice Backup and Restore for SAP System Landscapes.

Overview information on SAP HANA backup and recovery:
http://www.saphana.com/docs/DOC-1220

SAP HANA Database backup and restore functionality in detail

SAP HANA Administration Guide

SAP HANA Technical Operations Manual.

Important SAP Notes:

- General

1642148 - FAQ: SAP HANA Database Backup & Recovery

- File Based Backups

1820529 - Unsuitable network file systems for backup and recovery
1817703 - Archiving file system-based backups

- Backups using Backint

1730932 - Using backup tools with Backint for HANA
2031547 - Overview of SAP-certified 3rd party backup tools and associated support process

- Backups using Storage Snapshots

2039883 - FAQ: SAP HANA database and storage snapshots

- Execution and Monitoring

1651055 - Scheduling SAP HANA Database Backups in Linux

1869119 - Checking backups with "hdbbackupcheck"
1873247 - Checking recoverability with hdbbackupdiag --check

1835075 - Analyze backup and recovery performance issues
2063454 - Long running log backups

1900682 - How to handle alert 'Check availability of volumes for backup'
1900795 - How to handle alert 'Check last data backup'
1900788 - How to handle alert 'Check last log backups'
1900730 - How to handle alert 'Check the age of last data backup'
1900728 - How to handle alert 'Check whether a data backup exists'

9 Acknowledgements

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10 Contact

In case of comments or any other kind of feedback please contact axel.steinmetz@sap.com.