

Reading Sample

In Chapter 1, Richard Bremer and Lars Breddemann introduce you to the SAP HANA database architecture. Get the foundational information you need to understand the comprehensive administration concepts and tasks covered in the rest of the book.



"Architecture of the SAP HANA Database"



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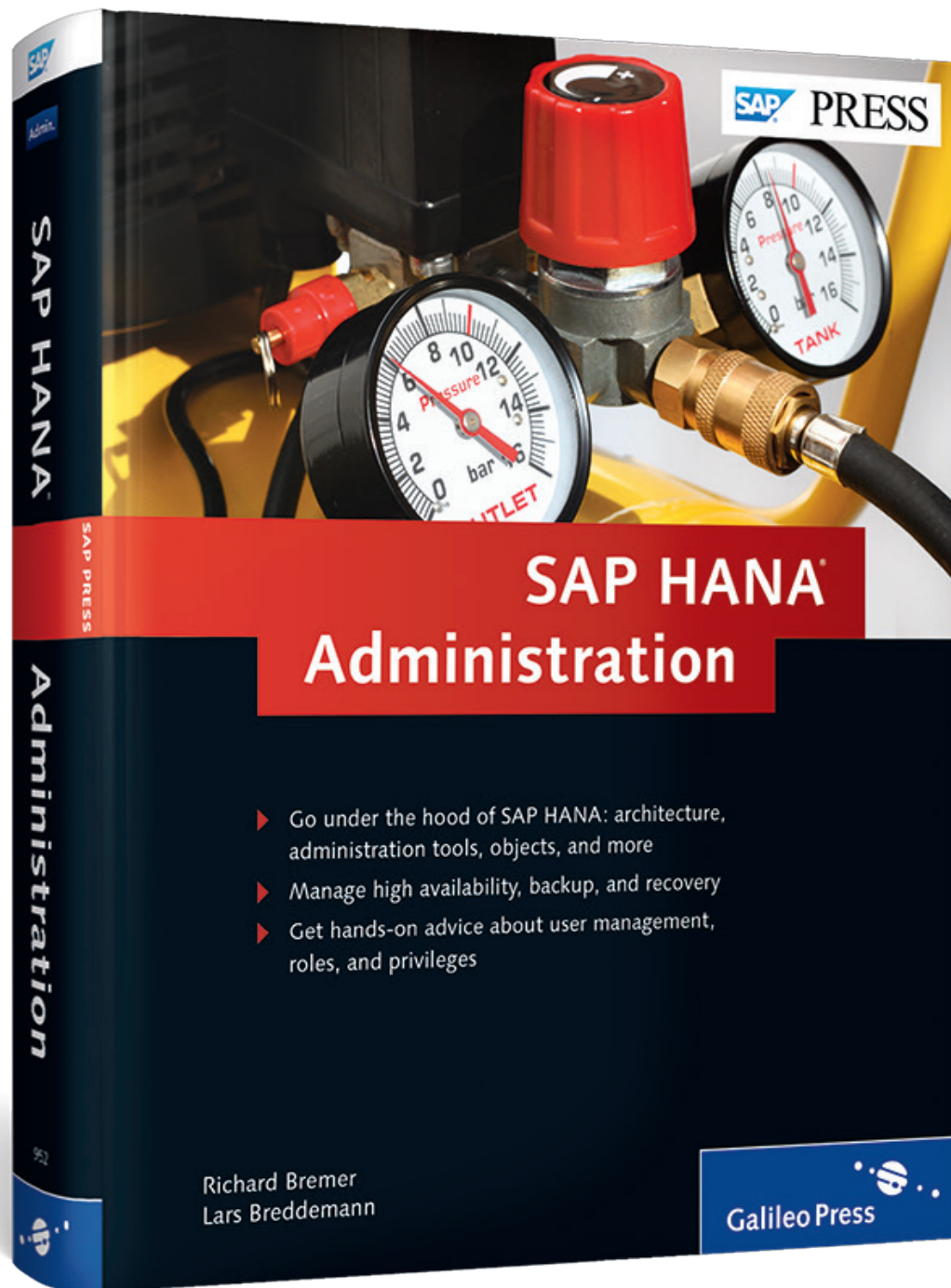
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Although the variety of components and setup options for SAP HANA may seem confusing, the system is not so complex if you understand the building blocks. The purpose of our first chapter is to help you understand how simple and beautiful SAP HANA systems really are.

1 Architecture of the SAP HANA Database

Since its first release three years ago, SAP HANA has evolved beyond being just another relational database management system. In this chapter, we will help you understand what this means for you, the administrator. In the first few sections, we will approach SAP HANA from the outside and slowly zoom in, shedding light on the hardware composition of the system, showing you what the operating system will see, and finally looking into the database processes to understand the internal architecture of the system. In addition to this, we will shed some light on distributed SAP HANA instances that allow scaling out the database, thereby increasing data storage and computing capacity. Following this journey into the database, we will again take a step back and talk about the appliance concept of SAP HANA before finishing up with some insight into the software release cycle.

1.1 The Basics

Before we really dive into the details, let's try to make good on our promise in the chapter's introduction and spend a page explaining what SAP HANA actually is. Today, SAP HANA is a technology platform for the new generation of SAP. (Notice that we say new, not next! SAP HANA is already a reality at SAP.)

The SAP HANA system contains many components that administrators need to understand (which you'll learn all about in this book). However, for the interactions of end users and developers in an SAP HANA system, only two are visible: a relational database system fulfilling the famous *ACID* requirements (atomicity, consistency, isolation, and durability) and a development platform and application server within the same environment. By bringing application development

and data storage more closely together than in previous SAP systems, SAP HANA extends the toolset available to SAP developers to cater to all requirements in the modern world of business software.

Consider the highly simplified architectural overview of systems with SAP HANA in Figure 1.1; the two main components described in the previous paragraph are represented by two “server” components of the SAP HANA system. The database management system is the *index server component*, and most components of the development platform reside in the *XS server*.

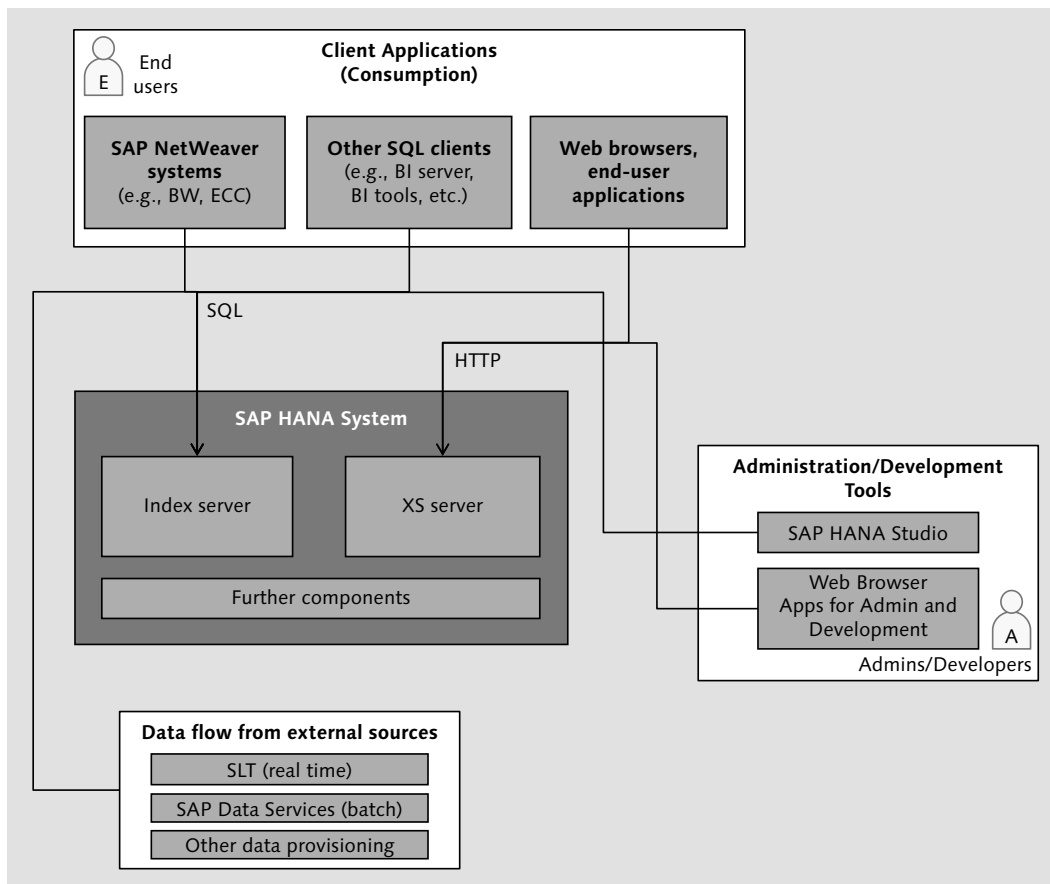


Figure 1.1 Simplified View of an SAP HANA System

In Figure 1.1, the world outside of SAP HANA is divided into three parts (we hope the French do not mind); the client applications inhabit one of these, the admin-

istrators and developers another, and the external data sources the third. As opposed to the people of Gaul 2,000 years back, these parts communicate via the same language—or rather, the same two languages (by and large)—depending on which component of SAP HANA they converse with. SQL is the most prominent native language of the index server, and applications of the XS server are mostly exposed via HTML5 user interfaces.

Because we promised to keep it simple, we will stop here, and feed you the rest of the details step-by-step in the rest of the chapter. Before we go any further, though, we want to establish a few definitions that we’ll use consistently throughout the book:

► **Instance**

We will use the term *SAP HANA instance* (or simply *instance*) to refer to the collection of those processes that make up one SAP HANA environment on a single-node database server. For all practical purposes, these are the processes and programs that are created when you run the install program for the server components of the SAP HANA database. The instance consists mainly of the start processes, the core database processes, and some of the SAP HANA auxiliary processes (all of which we’ll describe in more detail in this chapter).

As with other SAP systems, an instance has two identifiers: the system ID (SID)—which is a three-letter alphanumeric identifier starting with a letter—and the two-digit instance number. The SID uniquely identifies the database instance. Except for special setups, there is a 1:1 mapping of SID to instance number, that is, the instance number is often a unique identifier as well. The instance number is used in defining the internal and external network ports of the SAP HANA system.

It is possible to install more than one SAP HANA instance on a single physical database server, and you can even operate SAP NetWeaver and SAP HANA instances on the same server.

Note

In the context of distributed systems that we will cover in Section 1.5 and in Chapter 6, we will not use the term “instance.” The reason is that “instance” is a widely used term in SAP NetWeaver systems, and the concept of instances in distributed SAP NetWeaver systems can’t be applied perfectly to the individual hosts of a distributed SAP HANA system.

► **System**

We will mostly use the term *system* to refer to the physical database server, the operating system, and the SAP HANA instance (or instances) installed on that server, as well as any required auxiliary components.

► **Host and scale-out system**

We use the term *host* to refer to a physical machine. A host is a device you can touch. We continue the definition of system as the entire database system, including its hardware and software components. A *scale-out system* therefore is a collection of multiple hosts, with SAP HANA software running on all of them.

► **Node and distributed system**

Especially in the context of scale-out systems, we use the term *node* to refer to the SAP HANA software that runs on one host. There is, however, no fixed relationship between a node and a host; that is to say, one can move a node from one host to another (for example, in a failover situation). There is to our knowledge no good term referring to only the software processes on all hosts of the database system. We therefore use the term *distributed system* also to refer to a collection of multiple nodes.

Within this choice of terminology, we mainly use the term *node* to define a semantic relationship. There can be different types of nodes, and the node type defines the role of this node within the SAP HANA system.

1.2 The Physical View: SAP HANA Servers

Let's begin the architectural overview with a glimpse at the hardware of an SAP HANA server. Assume that your server is a typical computer server, consisting of a mainboard with CPU and RAM, network interfaces, disks, and other devices you would expect to find in a computer system.

In Figure 1.2, we have cut down the database into its three most prominent internal and one very important external building blocks: the data and processing layer, the persistence layer, and the network layer. We will now discuss each of these building blocks in more detail.

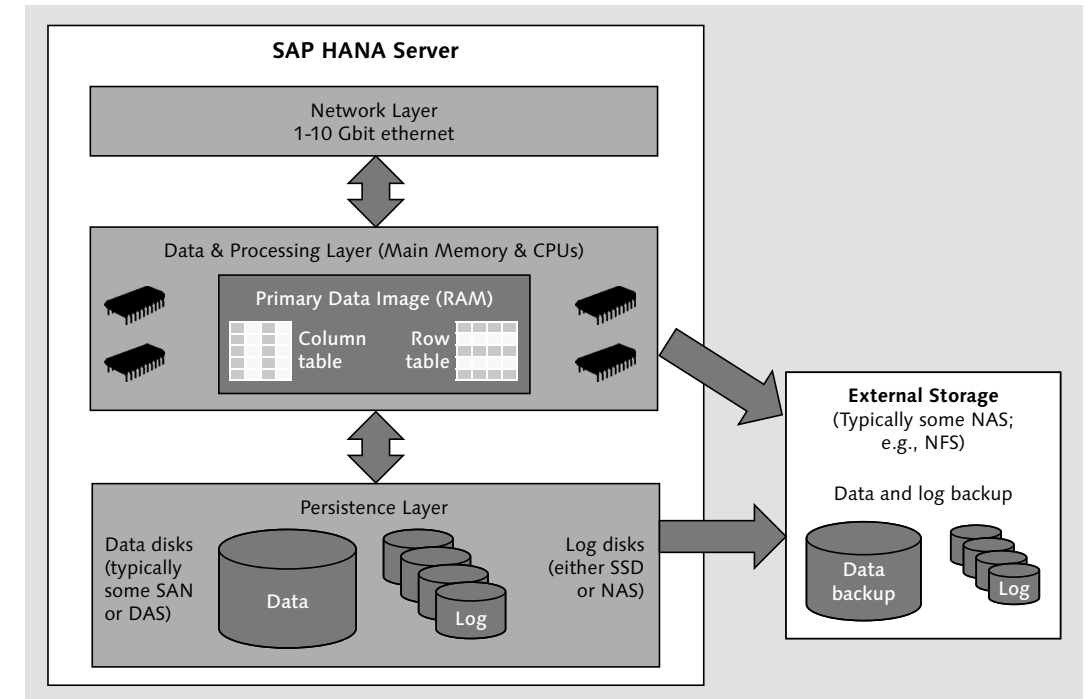


Figure 1.2 Hardware Building Blocks of an SAP HANA Server

1.2.1 Data and Processing Layer

The heart of SAP HANA is what we call here the *data and processing layer*, represented in the hardware world by the main memory and the CPUs (and auxiliary components). You may have heard that SAP HANA is an in-memory database, which means that the *primary* image of all data is in RAM and that all internal algorithms are optimized to work on data that is present in memory. Put simply, the database attempts to keep all database tables fully in main memory during regular operations. This leads to extreme demands for the amount of main memory installed in the database, and SAP HANA systems come with copious amounts of this once-rare resource.

The maximally possible amount of main memory in a single database server is determined by two choices made by SAP:

► **The type of CPUs supported**

Presently, SAP HANA will only run on the Intel X86 architecture; more specif-

ically, the database code is optimized for the newer generations of the Intel XEON architecture (Westmere-EX and Ivy Bridge-EX), making use of its advanced SIMD instruction sets like SSE3 and SSE4.

At the time of writing, SAP HANA servers can contain a maximum of 8 CPUs with 10 CPU cores each (15 cores for Ivy Bridge), that is, 80 (120) CPU cores in total.

► **The maximum ratio of main memory to number of installed CPUs**

Based on use-case studies, SAP has set a maximum ratio of main memory to number of installed CPUs of about 16 GB per CPU core for analytic use cases. In response to these two restrictions, the current generation of SAP HANA servers comes with at most one or two terabytes (TB) of main memory installed for the Westmere- and Ivy Bridge-based models, respectively.

For operating SAP Business Suite systems—which have mostly an OLTP workload—SAP allows larger amounts of main memory in a single server, bringing the currently available maximum to 6 TB of RAM.

Intel's Processor Architecture

Readers interested in more details about how SAP makes use of Intel's processor architecture can consult a joint white paper by Intel and SAP on the topic, which is referenced in "Intel & SAP HANA Solution Brief: Scaling Real-Time Analytics across the Enterprise—and into the Cloud":

www.saphana.com/docs/DOC-2592

1.2.2 Persistence Layer

SAP HANA could not be a database if it did not store data on a nonvolatile medium. Of course, the system also comes with enough disk storage to keep all data and other required information. Similar to most other database systems, SAP HANA writes transaction logs synchronously and keeps a full data image in asynchronously updated data volumes.

In general, these two systems come with two dedicated sets of disks. The data volumes always reside on classical discs whose total capacity must equal three times the installed RAM of the server according to the *SAP HANA Server Installation Guide* (downloadable from the SAP Community Network: <https://scn.sap.com>). For the log volumes, SAP initially required SSD storage with a capacity equaling the amount of installed RAM.

In certain systems, classical hard drive technology is also supported. Both sets of disks need to fulfill SAP's specifications for data throughput, I/O operations per second, and so on, which are available to SAP HANA hardware partners. Additional disks are needed for the software installation of SAP HANA and all related SAP components.

Internal or External Disks

As for the interesting question of whether the disks are internal to the database server or whether you may make use of your existing enterprise storage—we'll get to that in Section 1.6.

Although the data and log disks are intrinsic components of the database, SAP does not define the required nature of the devices to keep data and log backups. There are two backup methods available: file-based backup and network-pipe-based backups. For file-based backup, a dedicated storage device must be available in the file system of the SAP HANA server, and customers are free to choose the storage technology.

1.2.3 Network Layer

The number of network interfaces required in an SAP HANA system depends on several aspects of the system setup, such as clustering, implemented high-availability concepts, and more. These options will be covered later. For now, we will make some simplifications and only state that an outbound network interface must be available for SAP HANA to communicate with other IT systems. This interface must have a nominal throughput of at least 1 gigabit (Gbit), and 10 Gbit Ethernet is recommended.

Network topologies around SAP HANA systems can vary widely, but generally speaking SAP HANA can be treated like other databases in terms of network considerations for SAP NetWeaver systems or SAP BusinessObjects BI systems.

1.3 The Operating System View: Database Processes

If you log on to the operating system of an SAP HANA database, the first thing you will notice is that it is a Linux OS. Up to and including SPS 7, the only supported operating system was SUSE Linux Enterprise Server (SLES) 11 or SUSE Linux

Enterprise Server for SAP Applications 11, most probably on service pack level 2 or 3. With SPS 8, SAP introduced support also for Red Hat Enterprise Linux 6.5; see SAP Note 2009879.

We have divided the processes that belong to an SAP HANA database server into four factions, as displayed in Figure 1.3. We will now walk you through this quartet of process groups.

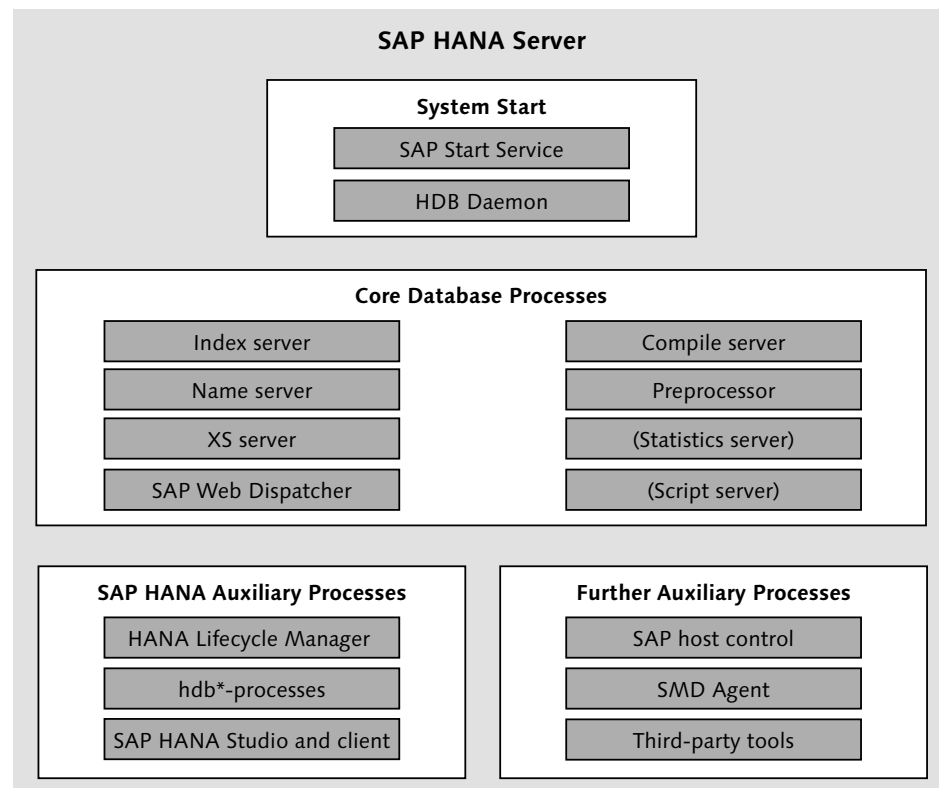


Figure 1.3 Operating System Processes of the SAP HANA Database

1.3.1 System Start

All SAP systems are started by a process named *SAP Start Service* (see Figure 1.4), which in Linux operating systems is represented by the `sapstartsrv` OS process. SAP HANA is no exception to this rule. You will find `sapstartsrv` running for each instance of the SAP HANA database on your server.

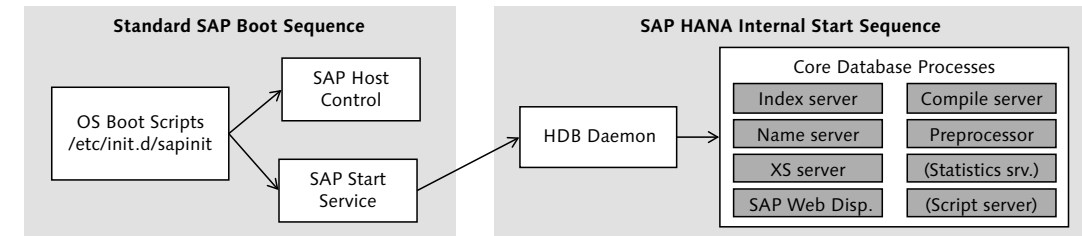


Figure 1.4 Boot Sequence of an SAP HANA System

SAP Start Service

Documentation for SAP Start Service is available as part of the public documentation of SAP NetWeaver available via the SAP Help Portal.

We will not go into much detail here, because SAP Start Service is well known to SAP administrators. For those not familiar with the service, it provides functionality to start and stop the SAP system along with rudimentary monitoring capabilities, such as access to trace files, logs, and configuration of the system, through a common API regardless of what SAP system is being monitored.

The generic SAP Start Service only kicks off one single process of the SAP HANA system, which is called the *HDB daemon*. Even though the daemon is in fact a core process of the database, we moved it into the group of processes for system start to accentuate its purpose. The daemon process has two tasks: start all required core processes of the SAP HANA database system, and keep them running, that is, restart them if a process should fail.

The list of required processes is mostly predefined by SAP, but there are a few choices an administrator can make, because there are a few nonmandatory core processes in SAP HANA. All processes to be started by the HDB daemon have entries in the daemon configuration file `hdbdaemon.ini`.

1.3.2 Core Database Processes

The most interesting processes for us are of course the core database processes. Purists might argue that our definition is not quite correct, because we include here the SAP Web Dispatcher, which is not an SAP HANA process but rather a standard SAP component. However, for our purposes a “core process” is an OS process that is started by the HDB daemon, and the SAP Web Dispatcher is one of

them. It is also the only process whose activity is not monitored in the list of running services in SAP HANA Studio (Figure 1.5).

| Active | Host | Port | Service | Detail | Start Time | Process ID | SQL Port |
|--------------------------|--------|-------|---------------|--------|---------------------|------------|----------|
| <input type="checkbox"/> | Id9506 | | sapstartsv | | | | |
| <input type="checkbox"/> | Id9506 | 34200 | daemon | | 20.12.2013 22:06:37 | 130979 | |
| <input type="checkbox"/> | Id9506 | 34201 | nameserver | master | 20.12.2013 22:06:39 | 130995 | |
| <input type="checkbox"/> | Id9506 | 34202 | preprocessor | | 20.12.2013 22:06:43 | 131272 | |
| <input type="checkbox"/> | Id9506 | 34203 | indexserver | master | 20.12.2013 22:06:44 | 131303 | 34215 |
| <input type="checkbox"/> | Id9506 | 34207 | xsengine | | 20.12.2013 22:06:44 | 131306 | |
| <input type="checkbox"/> | Id9506 | 34210 | compileserver | | 20.12.2013 22:06:43 | 131276 | |

Figure 1.5 Active Processes of a Typical SAP HANA Database System

Next, we will give you an idea of the purpose of all of these processes that, combined, represent a fully functioning SAP HANA database. We will choose a somewhat arbitrary ordering, based on what we perceive are the most important processes. (Here again, we will keep it simple and provide further details for some processes in Section 1.4.)

The Index Server

For most practical purposes, the *index server* is the database process in SAP HANA. It has the following jobs:

- ▶ It provides the SQL interface on SAP HANA's SQL port.
- ▶ It manages all database tables and other objects of the database catalog.
- ▶ It processes all SQL queries in the database.

As such, the index server will under normal circumstances have the largest resource footprint among all the processes on the SAP HANA server—for memory as well as for CPU usage.

The Name Server

SAP HANA needs a logical view of itself—for example, its components and locations of data—which is called the *topology*. The topology is managed by the *name server* component. The name server becomes particularly important in distributed

database systems (which we have not mentioned yet; they will be covered in Section 1.5). The name server also hosts the backup manager, responsible for coordinating synchronized backups of all system components.

The XS Server and the SAP Web Dispatcher

Since the beginning, but especially since the SPS 5 release, SAP HANA has been a development platform built around the integrated database kernel. Of course, the database itself (index server) offers development capabilities, such as designing database schemas, views, and SAP HANA data models or stored procedures. The *XS server*—which was introduced with SPS 5—targets the development layer on top of these rather technical tools.

Among the features provided by the XS server, you can find:

- ▶ Server-side JavaScript
- ▶ OData services and XMLA
- ▶ Development of user interfaces (HTML5) with SAPUI5
- ▶ Application definitions to expose sets of development artifacts as applications

Applications created in SAP HANA XS server are exposed through HTTP. As a web-server component, SAP HANA uses the *SAP Web Dispatcher*, which will be well-known to all SAP NetWeaver administrators.

SAP Web Dispatcher

Documentation of the SAP Web Dispatcher is available as part of the documentation of the SAP NetWeaver Application Server on the SAP Help Portal.

The Compile Server

With the release of SAP HANA SPS 6 (revision 60), the compiling of L-script procedures has been moved from the index server process into the newly established compile server process. This is a mandatory, automatically installed component of SAP HANA that, in our experience, you do not need to know much about.

The Preprocessor

For processing unstructured data, SAP HANA's *preprocessor* component creates searchable, full-text indexes and offers capabilities such as tokenization, normal-

ization, stemming, and extraction processing. It might be regarded as a supporting component to the index server for text search and text analysis.

The Statistics Server

The *statistics server* is a database process which provides the *statistics service*. Starting with SPS 7 (revision 70), it is possible to have the statistics service integrated into the index server and name server processes, thus eliminating the need for a dedicated further database process. The statistics server is thus an optional process that is enabled in the default configuration and also in SPS 7.

Statistics Service

The statistics service, on the other hand, is not optional; it has to be available for the database to be functional. It is SAP HANA's offering for information collection, checking, and alerting on all system components.

The Script Server

The *script server* is an optional component that is at present only required for certain functionalities associated with the Application Function Library (AFL). It is not enabled by default.

1.3.3 SAP HANA Auxiliary Processes

All processes mentioned so far are required for the regular operations of an SAP HANA system. The auxiliary components we discuss next are native parts of SAP HANA but are only used for specific tasks, such as updating the software.

SAP HANA Lifecycle Manager

Software updates are the main topic of the SAP HANA Lifecycle Manager (HLM), which is a graphical application that supports updating just the database or all components of a so-called SAP HANA Support Package Stack (see Section 1.7.1) by using corresponding components installed on the database server. The frontend application is available from within the administration tool SAP HANA Studio and also accessible through a web interface. HLM's functionality extends beyond updating, with support for system landscape modification (renaming the system, provisioning additional database instances, etc.) and more.

In the SPS 8 release of SAP HANA, the functionalities for system lifecycle management have mostly been switched off, and `hdblcm` (discussed ahead) is now the preferred tool for all related tasks.

The hdb* Tools

SAP HANA comes with a range of command-line tools, which we here summarize as *hdb*-tools*, because their names begin with the acronym `hdb`. These tools are installed into the directory `/usr/sap/<SID>/HDB<instance>/exe`. Among these tools, you can find:

► `hdblcm` and `hdblcmgui`

These are new applications for installing and updating the database introduced with SPS 7. It is planned that `hdblcm` will become the backend tool used by HLM in higher support packages.

► `hdbsql`

This is a command-line SQL console that comes with the client package (it is thus available on any computer that has the SAP HANA client installed).

► `hdbuserstore`

This is a secure store for database credentials that can be used for password-free authentication, for example, in `hdbsql`. It is also used by SAP NetWeaver Application Servers on SAP HANA to store their database credentials. `hdbuserstore` is also part of the client package.

SAP HANA Studio and Client

With a fully installed instance of the SAP HANA database, you will always also get SAP HANA Studio and the client locally installed on the database server. However, in most cases, database administrators (DBAs) will use a local installation of SAP HANA Studio to connect to the server. The local installation of these tools is meant for emergency and bootstrapping DBA tasks when a remote connection is not available.

1.3.4 Further Auxiliary Processes

As an SAP system, SAP HANA comes with several standard SAP components used for basic operation and monitoring. There may also be additional components installed by vendors other than SAP.

SAP Host Agent

The SAP Host Agent is a tool for monitoring and controlling SAP instances. Part of this tool is the already mentioned SAP Start Service. There are further components, for example, `saposcol`, which collect information on an operating system level, and `saphostctrl`, which is used by HLM for providing user access to the HLM backend (for more information, see Section 12.4.1 in Chapter 12).

Further Resources

Database administrators who may not be familiar with traditional SAP landscapes can find information about the SAP Host Agent in the SAP NetWeaver documentation on the SAP Help Portal.

SMD Agent

The SAP Solution Manager Diagnostics Agent (SMD Agent) is another tool for collecting status and other monitoring information. In this case, it collects information to feed SAP Solution Manager. For information on integrating SAP Solution Manager with SAP HANA, see <https://service.sap.com/solman-hana/>.

Third-Party Tools

Depending on preferences and requirements, customers may operate certain non-SAP software components on their SAP HANA servers, such as antivirus software, monitoring agents, or backup management tools.

1.4 The Logical View: Internal Architecture of the Database

Let's now take a look at the architecture within the database core processes. Figure 1.6 shows how these processes interact with each other. In the figure, we only highlight a few internal components of each of the core processes to keep it simple.

We also show optional services in the figure, such as the script server and the statistics server. You may remember that the statistics service can be moved from the dedicated statistics server process into the other database processes. In that setup, the statistics scheduler will run in the name server, and all other parts of the statistics service will be integrated into the index server (see Chapter 5 for details).

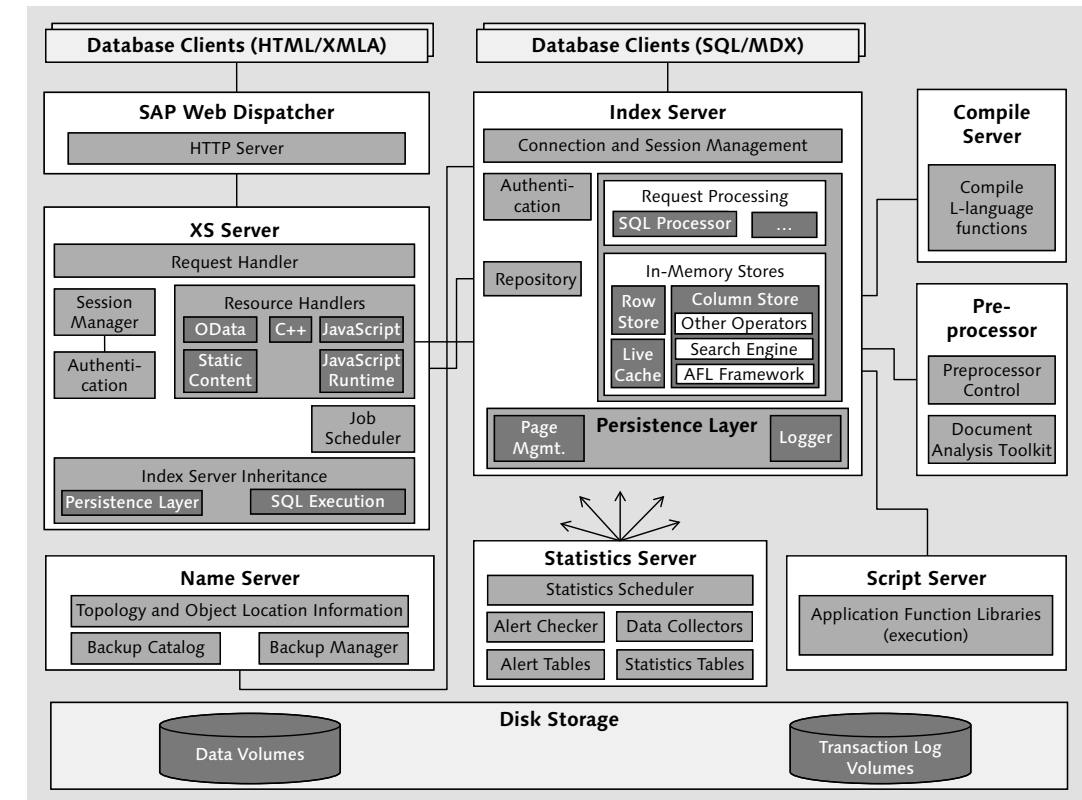


Figure 1.6 Internal Architecture of SAP HANA Database

Note that there are two entry points for the interactions of database clients with the SAP HANA system: the index server for SQL-based requests (including MDX) and the XS server for HTTP-based requests. Because it is the server relevant for administrators, this section focuses on the index server. For the sake of completeness, we briefly mention the XS server, but a detailed discussion would be outside the scope of this book.

1.4.1 Index Server Architecture

Any SQL-based or MDX-based interaction with SAP HANA will enter the index server component and (assuming successful authentication and authorization tests) be executed by the SQL processor. Depending on the nature of the query and the database objects accessed, different internal engines of the database will

be involved in the query execution, such as the processing engines of the row and column store. Also—and especially in distributed SAP HANA systems—the name server component will be involved to find the location of database objects required for query processing.

For certain functionalities, the index server will delegate a part of the workload to other processes: to the compile server for compiling functions in the SAP-internal L-language; to the script server for executing L-functions of the Application Function Libraries (AFL); or to the preprocessor for creating full text indexes and for other parts of processing unstructured data. The database clients will not notice these delegations; they simply converse with the index server.

L-Language

L-language is an internal, C-like language that is dynamically compiled with an optimizing compiler. It is not available for application development to SAP HANA users.

Both the index server and the XS server make use of SAP HANA's repository for storing development artifacts. Although the XS server—which is technically an extended index server—comes with its own repository, all processes use the repository in the index server.

Underlying all of these database components is the disk storage, in which those processes that control data on their own create data and log volumes; see Chapter 5.

Note

Multiple core processes of SAP HANA own data and thus create data and log volumes. Processes creating data and log volumes are the index server, the name server, the XS server, the statistics server, and the script server.

A simplified schematic of the index server is shown in Figure 1.7.

When communicating with the database, clients first need to open a connection and acquire a session through the connection and session management component, which will also involve the authentication manager to validate the credentials provided with the connect attempt.

Upon successful authentication, the clients can send commands to the database, typically in the form of SQL statements. All statements are executed in the context

of a transaction—coordinated by the *Transaction Manager*, which is responsible for transactional isolation and keeping track of open and closed transactions. Upon events such as committing or rolling back transactions, the Transaction Manager informs the involved relational stores so that they can take appropriate action. In combination with the persistence layer, the Transaction Manager is also responsible for achieving atomic and durable transactions.

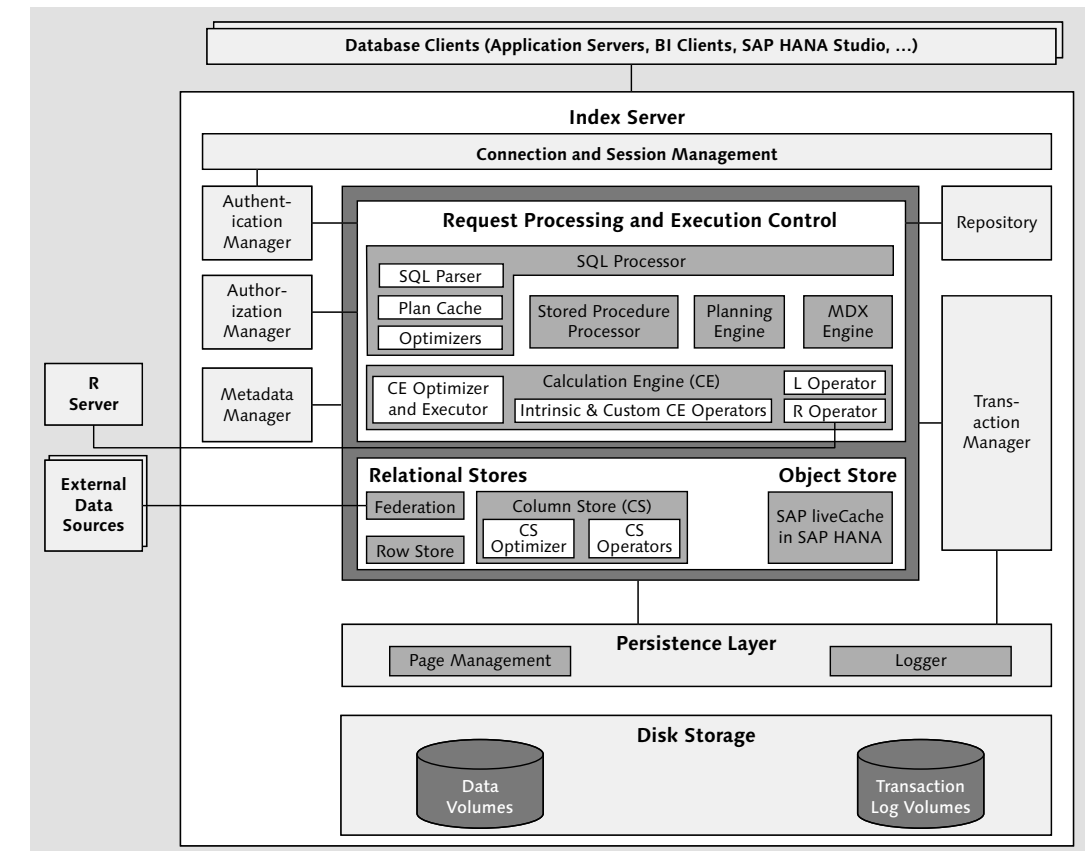


Figure 1.7 Internal Architecture of the Index Server

Note

For an in-depth discussion of session and transaction management, including concurrency control, see Chapter 10.

Actual statement execution involves the components listed under Request Processing and Execution Control in Figure 1.7. Statements first have to be parsed, checked, and optimized to generate an execution plan. Depending on the nature and content of the statement, different execution engines might be involved, such as the stored procedure processor (for SQLScript procedures) or the planning engine.

Several functionalities of the database have been implemented in a common infrastructure called the *calculation engine*. To many people, the calculation engine will be best known for its set of intrinsic calculation engine operators that can be used within SQLScript procedures. There is, however, more to this engine, such as operators for L and R, or planning operators.

All of these processing engines operate on top of the in-memory stores of the database. SAP HANA presently offers four such stores. The most important one is the *column store*, which manages column store tables that are typically used to store application data; it also contains, for example, the text-search capabilities of the database. The *row store* is a row-oriented in-memory store, typically used for system/basis tables (e.g., for basis tables of SAP NetWeaver systems) but not for application data. *Data federation* allows transparent access to objects in remote databases (a concept typically termed Smart Data Access in SAP HANA) and is in fact a virtual store, as its data has no local persistence within SAP HANA. Finally, the *liveCache* is an in-memory object store, well-known from the SAP Business Suite, where it is used in applications such as the SAP SCM component SAP Advanced Planning and Optimization (APO).

The *Metadata Manager* is a component for maintaining metadata of the database catalog, such as table and view definitions. It is a single metadata catalog for all in-memory stores, technically implemented as a collection of row store tables.

The interface between the in-memory store and the data volumes on disk is implemented in the *persistence layer*. This component manages the data pages for the in-memory stores and their persistence in the data volume; it also controls the writing of transaction log entries to the log volumes.

1.4.2 XS Server Architecture

As we mentioned earlier, a detailed discussion of the XS server is outside the scope of this book; however, Figure 1.8 shows a diagram of its basic architecture.

HTML access enters the system through the SAP Web Dispatcher, which delegates the access request to the XS server. Depending on the request, different processors in the XS server will be involved in the request processing, for example, the JavaScript runtime or the OData handler.

In most cases, the request will involve application data, which in SAP HANA is always stored in one of the relational stores of the index server process. Hence, the XS server will involve the appropriate index server component for such data access through a database-internal network protocol (even if both components are on the same physical server).

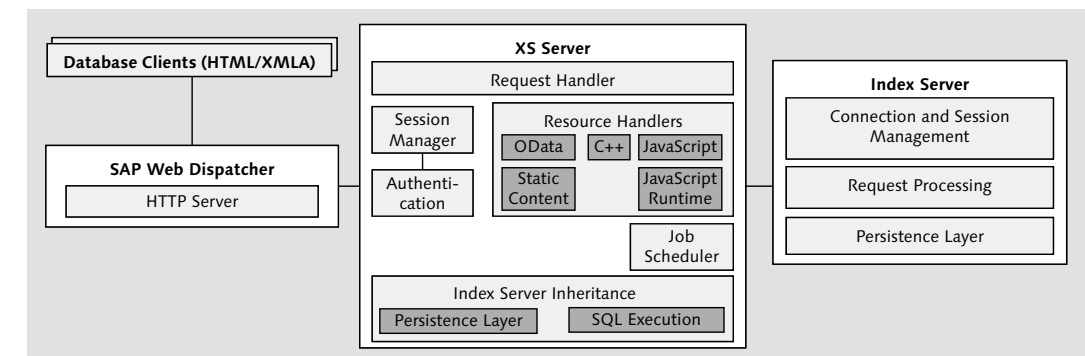


Figure 1.8 XS Server Architecture

1.5 Distributed SAP HANA Systems

Now that you know the fundamental concepts behind SAP HANA systems, we will go one step further and introduce distributed SAP HANA systems.

As we mentioned earlier, the database size of SAP HANA servers is restricted to 2 TB of main memory (6 TB for SAP Business Suite systems). If that was the end of the story, we would not need to talk about SAP HANA as a serious player in today's database market. The way to implement larger database systems is through scaling out, that is, building database systems that span multiple physical servers. To avoid confusion with the server processes, from now on we will use the term *host* to denote a single physical server machine in an SAP HANA system. Hence, there can be single-host database systems (which we have covered so far) and multihost systems, also called *distributed systems* or *scale-out systems*.

In a distributed SAP HANA system, most core components of the system exist on each of the individual hosts, as depicted in Figure 1.9. In some cases, a component can play different roles, depending on which host it is running on, such as the name server, which runs as an active master name server on one host (host 1 in our figure) and as a read-only slave on the other hosts. In Figure 1.9, we have marked in **bold** those components that can play different roles on the different hosts of the scale-out instance.

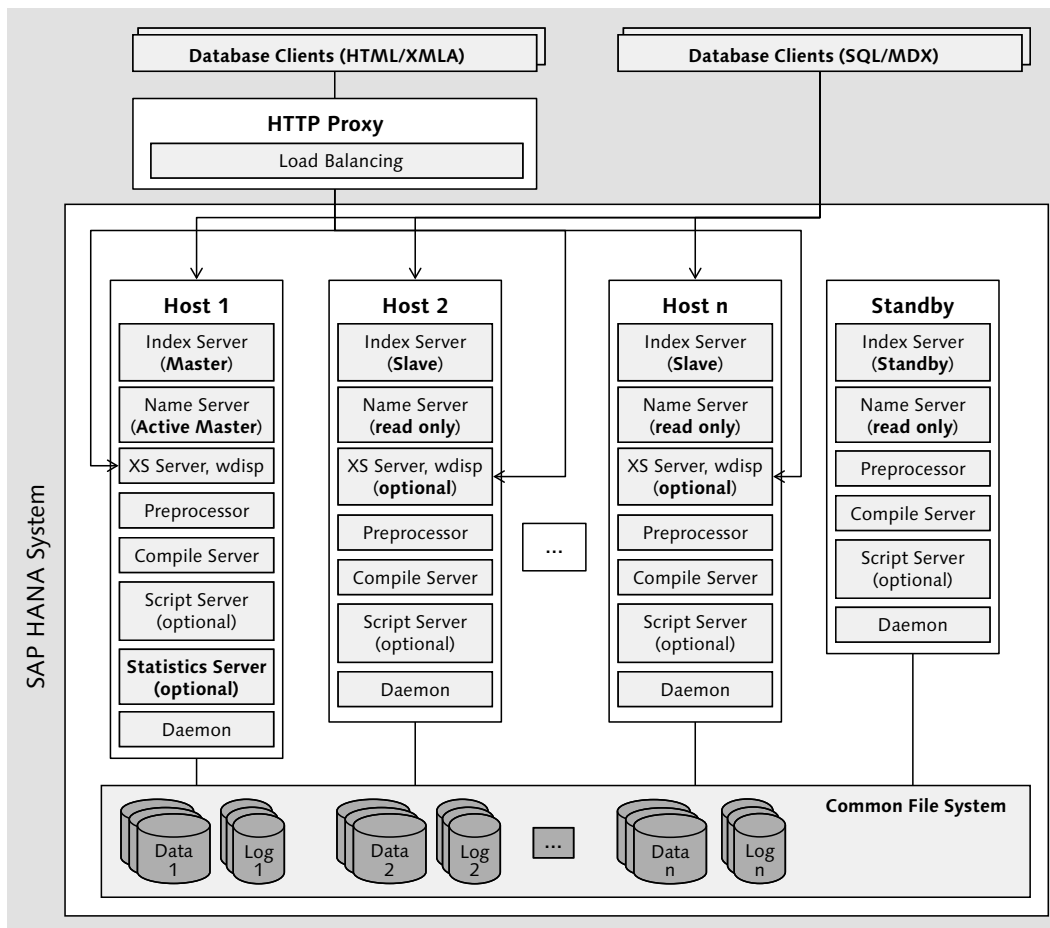


Figure 1.9 SAP HANA Core Components in a Distributed System

In this figure, hosts 1 through n are active, that is, they control data and take part in database operations, such as query executions. The last host is called standby.

This host is a high-availability component, technically identical to the others, but on standby and ready to take the workload of an active host that might fail for whatever reason. For more details on high-availability features in SAP HANA scale-out systems, see Chapter 6.

More on Nodes

Recall our definition of nodes from Section 1.1. In Figure 1.9, the first host houses the master node of our SAP HANA system, whereas hosts 2 through n house the slave nodes, and the master and slave nodes combined are the worker nodes. The standby hosts house standby nodes. In the case of a host failure, the node of the failing host will be moved to a standby host.

In this section, we discuss the three major components that allow SAP HANA to operate as a single database over several nodes. Conceptually, it boils down to one index server process per node, which all access a shared storage system. These multiple index server processes are coordinated by the name server process. Let's look into this one by one.

1.5.1 The Name Server in Distributed Systems

In distributed SAP HANA systems, the name server process plays a particularly important role. It maintains the system topology, which describes the system in two aspects: the logical description of the database (which hosts exist, what is the role of the hosts, etc.) and the map of data locations (the mapping of database objects to hosts and processes on the hosts).

This topology information will be required for query execution in the distributed database system. In order to avoid excessive network communication, a copy of the topology is held available on each host.

To avoid the complexities involved in keeping a resource consistent even though it is changed by multiple processes, there is at any point in time only one name server process that is allowed to modify topology information. This process is named the *active master name server*. All other name servers only hold a read-only copy of the topology.

Because the topology is a highly critical resource, there is built-in redundancy in the topology management: The system can have up to three configured *name server masters*. One of these—initially the first one that becomes active upon

system start, typically the one on the master node—is the active master name server. The other two masters constantly monitor the availability of the active master name server. If the active master name server fails, one of the other master name servers will be appointed the new active master name server and thus gain write access to the topology. This redundancy process for the name server functionality is independent from the host failover we mentioned earlier.

1.5.2 Distributed Index Servers: Data and Query Distribution

Many data objects in the SAP HANA database can be distributed across multiple database nodes, either by moving entire objects from one host to another, or—in the case of database tables—by partitioning the table into multiple physical partitions and distributing these partitions across the nodes (see Chapter 9).

In a scale-out scenario, one of the index server processes plays a special role. It is called the *master index server* and typically resides on the first host of the database system (the order of hosts is determined at installation time). The extended responsibilities of the master index server include (but are not limited to) the following items:

► Metadata management

Similar to topology management, the metadata catalog of the database is centrally managed and replicated to all other index servers. If metadata changes are required on an arbitrary host, this host will signal the metadata change to the Master Metadata Manager on the master index server.

► Transaction management

Transaction handling in distributed architectures requires particular efforts to ensure consistency throughout the transactions. In SAP HANA, this is implemented via *distributed transactions* and a *two-phase commit* mechanism. If a transaction is started that involves data owned by different index server processes, a primary transaction will be started on the Master Transaction Manager, and all other involved index servers will start local transactions that are linked to this primary transaction.

During the commit phase, the Master Transaction Manager will send requests to all of these local transactions to prepare the commit and will, upon successful acknowledgement, finally commit the transaction—or upon an error message, it will initiate a rollback.

► Row store

The row store in SAP HANA can be distributed as well, albeit with a smaller feature set than the column store. It is, for example, not possible to partition row store tables. In a typical system configuration, all row store tables of applications are located on the master index server.

► liveCache

The SAP liveCache cannot be distributed. If implemented in a distributed landscape, it will reside on an additional dedicated host (not on the master index server).

1.5.3 Distributed Persistence

All processes that own data create data and log volumes. Hence, if a system consists of four worker nodes, the four index server processes (and other data-owning processes) will each create a data volume and log volumes. In Table 1.1, we give an overview of all database processes and whether or not they have their own data and log volumes on the master or slave nodes of an SAP HANA system.

| Process | Persistence on Master | Persistence on Slave |
|-------------------|----------------------------|---------------------------|
| Index server | Yes | Yes |
| Name server | Yes | No |
| XS server | Yes | Yes (if enabled on slave) |
| Statistics server | Yes (if dedicated process) | N/A |
| Script server | Yes (if running) | Yes (if enabled) |
| Compile server | No | No |
| Preprocessor | No | No |

Table 1.1 Data Persistence in SAP HANA Scale-Out Systems

In the terminology of nodes and hosts we introduced earlier, data volumes in a distributed SAP HANA system belong to a node, not to a host. This becomes evident if you consider a failover of a node from one host to another; in this case, the previous failover-host must assign all data volumes of the worker node on the failing host.

In order to facilitate host-independent data volumes, they must reside on a common file system that can be accessed from all hosts of the database system. Such

a common file system may be established by using traditional filer concepts or by other means, such as file systems that stretch across local disks of multiple hosts. In SAP HANA setups, this is a choice made by the hardware vendor. We will not cover vendor-specific details in this book.

1.6 The Appliance Concept of SAP HANA

Initially, SAP HANA was only available as a so-called appliance, that is, a bundle of SAP software preinstalled on a certified piece of hardware from one of the SAP HANA certified hardware vendors. By 2014, SAP partially lifted some of the restrictions related to SAP HANA by introducing a concept called *Tailored Data Center Integration* that adds the ability to reuse certain data center components for an on-premise installation of SAP HANA. Meanwhile, SAP HANA is also available as a hosting or cloud offering from different service providers, including SAP itself.

In this section, we will briefly discuss these three installation options. We will conclude the section by diving into some details of how SAP HANA may and may not be used.

1.6.1 SAP HANA Appliance Offerings

When planning an on-premise installation of SAP HANA, the easiest way to make sure the system hardware is tailored for optimal system performance and matches SAP's requirements is to choose a system from the wide range of SAP HANA appliance offerings from certified hardware partners.

The list of all certified appliance systems based on the Intel Westmere architecture is maintained in the Product Availability Matrix (PAM) for SAP HANA, available on SAP Service Marketplace at <https://service.sap.com/sap/support/pam>. The certified systems based on the more recent Intel Ivy Bridge architecture are listed on SCN at <https://scn.sap.com/docs/DOC-52522>.

Appliance systems are usually classified by the system size in terms of installed main memory or other characteristics, such as disk space or number of CPUs, that follow directly from that choice. For the system sizes of single-host systems, there is a schema similar to T-shirt sizes in the fashion industry, as listed in Table 1.2. In this table, we denote Ivy Bridge configurations with the addendum "Ivy" in the

first column. There is also now more liberty regarding the file system sizes for log and data volumes, which we indicate by listing typical minimum configurations.

| Size | RAM | CPUs * Cores | Data file system | Log file system |
|--------|---------|--------------|------------------|-----------------|
| XS | 128 GB | 2 * 10 | 1 TB | 160 GB |
| S | 256 GB | 2 * 10 | 1 TB | 320 GB |
| M | 512 GB | 4 * 10 | 2 TB | 640 GB |
| L | 1024 GB | 8 * 10 | 4 TB | 1280 GB |
| XS Ivy | 128 GB | 2 * 15 | > 1 TB | > 128 GB |
| S Ivy | 256 GB | 2 * 15 | > 1 TB | > 320 GB |
| M Ivy | 512 GB | 2 * 15 | >= 1.5 TB | >= 512 GB |
| L Ivy | 1 TB | 4 * 15 | >= 3 TB | >= 512 GB |
| XL Ivy | 2 TB | 8 * 15 | >= 6 TB | >= 512 GB |

Table 1.2 General-Purpose Configurations of SAP HANA Appliance

Amount of Disk Storage Built into SAP HANA Systems

In Table 1.2, we explicitly list file system sizes, not storage sizes, because all hardware vendors build some sort of redundancy into their storage components. The amount of installed disk space will typically be much larger than the required file system sizes, at least for the data and log areas.

When deciding on a SAP HANA system setup, several aspects have to be considered. The most important ones—scaling the right size, whether or not the system should be used for a SAP Business Suite system, and how the actual deployment will be handled—are discussed next.

Scaling SAP HANA System Sizes

As the amount of data in a database system grows, the system's hardware needs to be scaled to accommodate the added data volume (or the increased workload). In the world of SAP HANA, there are two options available: *scale up* and *scale out*.

For database sizes up to 1 TB of RAM, several hardware vendors have setups that are ready for scale up. You might start with a database size of, say, 256 GB of RAM and if needed increase the database size to 512 GB or 1 TB of RAM by adding more CPUs, disk space, and RAM to the existing hardware server.

Scale-out systems are typically configurations of multiple M- or L-sized hosts, but some vendors also offer configurations based on S-sized hosts. Be warned, though, that with most hardware vendors a scale-out system does not use the same hardware components as a single-host system, especially when it comes to “external” factors, such as the chassis and so on. As an example, for a given vendor a single-host system might be delivered as a rack-mounted server, whereas the same vendor’s scale-out systems are based on blade server technology.

In most cases, the transition from a single-host system (database sizes of up to 1 TB of RAM) to a scale-out system requires an exchange of hardware in the system being scaled. In most likely all cases, hardware components such as additional network devices, additional disks, or other storage system components will need to be added.

Specific details on the scalability options are available from the individual hardware vendors.

SAP HANA for SAP Business Suite Systems

The system configurations from Table 1.2 are available for all types of SAP HANA installations. For SAP Business Suite systems only, with their typical OLTP workload and comparatively large amounts of data that is not accessed frequently, special configurations are available with a higher ratio of RAM to CPU power, as listed in Table 1.3. These configurations are not supported for installations other than SAP Business Suite.

| RAM | CPUs * Cores | Data file system | Log file system |
|------|--------------|------------------|-----------------|
| 1 TB | 4 * 10 | 4 TB | 1 TB |
| 2 TB | 8 * 10 | 8 TB | 2 TB |
| 4 TB | 8 * 10 | 16 TB | 4 TB |

Table 1.3 SAP HANA Appliance Configurations for Business Suite Systems

Deployment Process of SAP HANA Appliance Systems

Next to the preselection and certification of hardware components, the appliance concept comes with further simplifications related to the deployment of an SAP HANA system. The initial installation of the operating system, file system layout,

and SAP HANA software will be performed by the hardware vendor so that customer teams do not need to have dedicated installation knowledge for SAP HANA systems.

There is also an integrated support concept, in which SAP customer incidents serve as a single point of entry for all issues related to the SAP HANA system. SAP Support will distribute these incidents to the support teams of the hardware or OS vendor if necessary.

1.6.2 Tailored Data Center Integration

Especially for larger customers with standardized hardware landscapes and tiered IT operations, the appliance concept for SAP HANA servers will often not fit well into the existing structure of the data center. To address this situation, SAP started opening up the appliance concept in 2013 with Tailored Data Center Integration.

In this concept, the supported hardware systems are still restricted to those certified systems listed in the Product Availability Matrix for SAP HANA. Customers can, however, buy these servers without disks (this refers to storage for data and logs) and use their existing enterprise storage systems instead. For this purpose, the integration of custom storage adapter technologies, such as fiber channel adapters for SAN boot, is permitted.

Note

Not all storage systems are supported in SAP HANA Tailored Data Center Integration. Supported storage systems will be made available online in SAP’s Partner Information Center at <https://global.sap.com/partners/directories/SearchSolution.epx>.

Currently (July 2014), the list of certified storage solutions is available on SCN. “SAP Certified Enterprise Storage Hardware for SAP HANA” can be found at <https://scn.sap.com/docs/DOC-48516>.

Further steps are already planned for Tailored Data Center Integration, such as opening of the network layer to use the existing enterprise network.

With Tailored Data Center Integration, responsibility is shifted from the hardware vendor to the project team in multiple areas. One area is the hardware setup—in particular, the integration of the existing enterprise components into the SAP HANA server. SAP provides a tool for measuring throughput and latency between the SAP

HANA server and enterprise storage system as part of the SAP HANA software, starting with SPS 7. Documentation of this tool is available in SAP Note 1943937.

The second area of shifted responsibility is software installation. With Tailored Data Center Integration, hardware vendors are no longer responsible for installing the SAP HANA software. Instead, this is (generally speaking) the responsibility of the project team. SAP only supports SAP HANA installations that have been performed by persons who have successfully achieved the “SAP Certified Technology Specialist [Edition 2013]—SAP HANA Installation” (E_HANAINS131) certification.

1.6.3 Hosting and Cloud Offerings

In addition to on-premise installations, SAP HANA is also available through hosting and cloud offerings. For classical hosting, many service providers offer SAP HANA as part of their hosting portfolio; contact your favorite service providers for details.

For cloud offerings, there are presently three categories available:

► Cloud on SAP HANA

Cloud on SAP HANA refers to applications hosted by SAP on SAP HANA hardware, such as SAP Sales and Operations Planning (S&OP).

► Cloud platform services

Developers or partners who want to develop applications on SAP HANA that can be hosted on cloud infrastructure should look into the *SAP HANA Cloud Platform*. This offering allows development and operation of applications on SAP HANA hosted in SAP's data centers. The development toolset includes SAP HANA's native development capabilities as well as a full, Java-based development environment.

For simpler use cases, there is also the *SAP HANA One* offering, which is a SAP HANA system hosted on Amazon Web Services. It is mostly intended for test cases and prototypes but also supported for production usage.

► Cloud infrastructure services

Similar to hosting, SAP HANA cloud infrastructure services allow running SAP HANA systems (and other components of the SAP landscape) in a “foreign” data center. One such offering is *SAP HANA Enterprise Cloud* (HEC); an alternative offering is the *SAP HANA Infrastructure Subscription*, presently offered by SAP and by Amazon Web Services.

Further Resources

The SAP HANA Cloud Marketplace can be accessed via <https://marketplace.saphana.com/>. For more information about SAP HANA Cloud Platform, we recommend www.saphana.com/community/about-hana/cloud-platform. Finally, an overview of the SAP HANA cloud offerings (with the exception of Cloud on SAP HANA) is available online at www.saphana.com/community/about-hana/deployment-options.

1.6.4 Generic Deployment Considerations

Regardless of how SAP HANA is installed—on premise or hosted, appliance or tailored—there are certain generic restrictions and guidelines regarding the usage of the SAP HANA system, especially on production instances. We will now touch on several of these properties.

Multiple SAP HANA Instances on One Hardware System

If an SAP HANA instance is used in the production tier of a system landscape, there is only one SAP HANA instance allowed on the physical SAP HANA system. That is, you must not install multiple SAP HANA instances on the same single-host or scale-out server in production usage.

In nonproduction tiers of the system landscape, such as development, test, quality assurance, or sandbox systems, multiple SAP HANA instances may be installed on the same physical server. See Chapter 3 for details, and refer to SAP's statement in SAP Note 1681092.

Multiple Applications on One SAP HANA Instance

If you want to run multiple applications which use (i.e., store data and perform queries in) the same instance of SAP HANA, the situation is less restrictive but more complicated. SAP supports concurrent applications on the same SAP HANA instance in many cases, but there is a body of rules surrounding this topic.

The rule set is maintained in several SAP Notes, starting with SAP Note 1661202. This note lists all applications that may be set up with the same SAP HANA instance as the primary database. Because the content of this white list is changing with time, we will not reproduce it here. The range of applications includes SAP BW on SAP HANA, custom data marts, accelerators, and many more.

For the particular case of planning an SAP BW on SAP HANA system, more detailed considerations are listed in SAP Note 1666670. The most important of these may be that SAP does not support running multiple instances of SAP BW on the same *production* instance of SAP HANA. For the nonproduction tiers of the system landscapes, multiple SAP BW systems may be using the same physical SAP HANA system, but each SAP BW instance will need its dedicated SAP HANA instance.

Finally, for the SAP Business Suite, there is a dedicated white list maintained in SAP Note 1826100, which lists those applications that may be installed on the same database instance and server (in production) as an SAP Business Suite component, with specific considerations for individual components of SAP Business Suite.

In the scope of this book, more important than the application white lists themselves are the administration considerations that should in many cases discourage you from running multiple applications on the same database—at least if one of these applications is critical in some sense (security, business processes, etc.). We briefly mention the most prominent of these considerations here without going into detail yet; that's what the rest of the book is for:

► **Lifecycle management**

You can only patch the entire database software at once, not “the portion of the database used by application <x>.” The same is true for database backup and recovery.

► **Resource and workload management**

The resource and workload management features of SAP HANA currently (as of SPS 8) are limited in scope but constantly improving. Today, depending on the criticality of the applications it may not be recommended to operate multiple applications on the same database system.

► **Security**

Although you can restrict developers to work only in a certain area of the database system, this is not entirely possible for database administrators and, in many scenarios, also not for application support staff.

SAP HANA and SAP NetWeaver Application Servers

Starting with SAP NetWeaver 7.40 and SAP HANA SPS 7, operating instances of SAP NetWeaver Application Server on the same hardware as instances of the SAP HANA database is supported. See SAP Note 1953429 and www.saphana.com/docs/DOC-4391 (“Overview—SAP HANA and SAP NetWeaver AS ABAP on One Server”) for details.

Support of Scale Out for Specific Scenarios

Although scale out is a generic, publically available feature of SAP HANA, managing data appropriately in a distributed landscape and for performance-critical application is far from a trivial operation.

Although SAP BW on SAP HANA actively manages data distribution in distributed SAP HANA instances, such application support is not possible in all circumstances, especially not in custom data marts. SAP recommends that customers planning to use SAP HANA scale out for scenarios other than SAP BW contact SAP HANA product management for best practices and expert advice.

Note

Scale-out support for SAP Business Suite systems is in a pilot phase as of July 2014.

Virtualization

On-premise operation of SAP HANA on virtualized servers is for production (since SPS 8) as well as nonproduction (since SPS 6) use, as described in SAP Note 1995460 and www.saphana.com/docs/DOC-3334 (“SAP HANA Virtualized—Overview”). Several restrictions apply for the deployment of SAP HANA on virtualized hardware. We list the most relevant ones here:

- The only hypervisor supported for production usage is VMware vSphere 5.5. vSphere 5.1 is supported only for nonproduction use.
- Virtual machines must be hosted on certified SAP HANA hardware, and only single-host systems are supported as hardware platforms.
- The initial VM installation (including SAP HANA instance in the VM) must be performed by the hardware vendor team or a certified person.
- Memory overcommitment is not supported.

1.7 Release Cycles of SAP HANA Database Software

SAP HANA software is released in two categories of software bundles: Support Package Stacks and revisions. Support Package Stacks are major releases of SAP HANA in which new functionality and significant changes can be introduced, including, in rare cases, even incompatible changes. Revisions are patches to the software for the purpose of minor improvements and bug fixes.

1.7.1 Support Package Stacks

An *SAP HANA Support Package Stack* (SPS) is a bundle of the core database software (SAP HANA database, client [driver] package, SAP HANA Studio, etc.) with additional components that are part of (at least certain) SAP HANA license bundles, such as the real-time data replication technology SAP Landscape Transformation (SLT).

Support package stacks presently have a loosely defined release cycle: SAP intends to release (and has released since the beginning of SAP HANA) a new support package stack every six months, in May and in November of each year. We write “loosely defined,” because there are no fixed and committed release dates for future support package stacks, and it may happen that the release of a support package stack is delayed by a few weeks.

SAP intends to end the lifecycle of a support package stack a few months after the release of the successive SPS; customers operating an older SPS level will have to upgrade to the latest SPS after the end of the lifecycle for their SPS.

1.7.2 Revisions

An *SAP HANA revision* (also called an *SAP HANA Support Package* or SP) contains the core database software, including the database clients and SAP HANA Studio, as well as certain add-on components, such as the Application Function Libraries (AFL). Revisions do not follow a fixed release cycle; instead, they are released when needed. If there are very important bug fixes, there might be two revisions within two weeks, and there may be a month or more without a new revision.

In order to support better planning of SAP HANA patching, SAP introduced two special types of revisions, as described in SAP Note 2021789.

SAP HANA Datacenter Service Points

SAP HANA Datacenter Service Point revisions are only released after testing in SAP's own production systems. Next to the regular scenario and regression testing performed for all revisions, they have undergone real-life testing in production systems with significant workloads, including SAP BW and SAP Business Suite components. SAP plans to release one such revision for each Support Package Stack of SAP HANA approximately three months after the release of the SPS.

SAP HANA Maintenance Revisions

SAP HANA Maintenance Revisions contain major bug fixes and—as opposed to regular revisions—may be made available on the code base of an older SPS (e.g., for the code base of SPS 7 after the release of SPS 8). Sometimes, there are restrictions for updating from a maintenance revision to certain higher revisions; these restrictions are maintained in SAP Note 1948334.

SAP intends to end provisioning of new maintenance revisions for a given SPS with the release of the SAP HANA Datacenter Service Point revision of the successor SPS.

1.8 Summary

You should leave this chapter with a good understanding of the major building blocks of SAP HANA systems in the hardware world as well as in terms of processes running on the operating system of your SAP HANA server.

If you remember that the database server is a typical server and that the three main processes in the database are the index server (the database itself) and the XS server (development platform/application server) as the system's work horses and the name server (owner of the system topology) as the bookkeeper of the system's overall structure, then you have understood the big picture.

You should now also have a basic understanding of the properties of distributed SAP HANA instances and of the different options of deploying SAP HANA, including the concepts of SAP HANA appliances and Tailored Data Center Integration.

We hope that we have accomplished the goal of this chapter: to make you feel that SAP HANA systems are not that complicated to understand after all. Continue reading, and we will thoroughly destroy this impression by showing you thousands of fascinating details that administrators can and should know about our favorite SAP technology platform.

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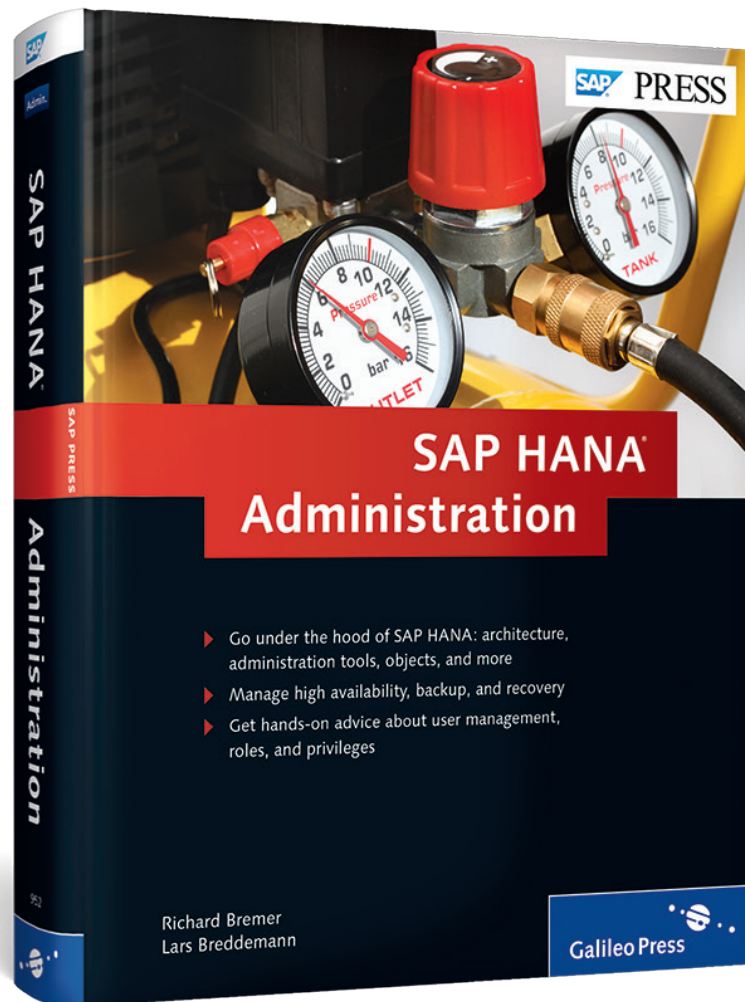
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