SQL Server 2012 Internal

> **Tip**
>
> Use the command line to detect and resolve the errors!

> **Warning**
>
> DON'T DELETE THE `package.json` file!

> **Caution**
>
> Don't execute the code without commenting the test cases.

> **Important**
>
> Read the contribution guideline before adding a pull request.

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1. SQL Server 2012 architecture and configuration

1. Architecture

1.1 The SQLOS

The SQL Server Operating System (SQLOS) is a separate application layer at the lowest level of the SQL Server Database Engine that both SQL Server and SQL Reporting Services run atop. Earlier versions of SQL Server have a thin layer of interfaces between the storage engine and the actual operating system through which SQL Server makes calls to the operating system for memory allocation, scheduler resources, thread and worker management, and synchronization objects. However, the services in SQL Server that need to access these interfaces can be in any part of the engine. SQL Server requirements for managing memory, schedulers, synchronization objects, and so forth have become more complex. Rather than each part of the engine growing to support the increased functionality, a single application layer has been designed to manage all operating system resources specific to SQL Server.

The two main functions of SQLOS are **scheduling** and **memory management**, both of which are discussed in detail in this chapter. Other functions of SQLOS include the following.

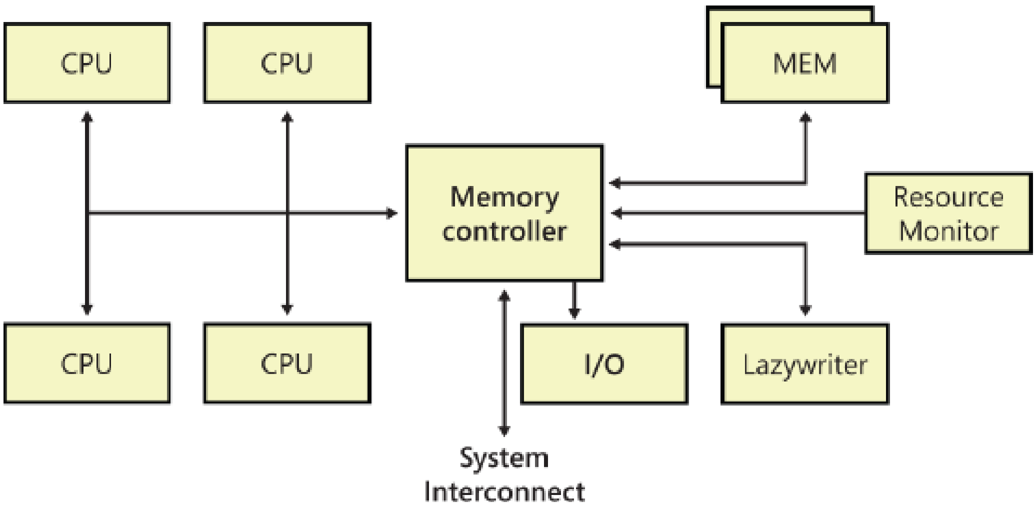
- **Synchronization** This object type includes spinlocks, mutexes (mutual exclusions), and special reader/writer locks on system resources.
- **Memory brokers** Memory brokers distribute memory allocation between various components within SQL Server but don't perform any allocations, which are handled by the Memory Manager.
- **SQL Server exception handling** This involves dealing with user errors as well as system-generated errors.
- **Deadlock detection** This mechanism doesn't just involve locks but checks for any tasks holding onto resources that are mutually blocking each other.
- **Extended Events** Tracking extended events is similar to the SQL Trace capability but is much more efficient because the tracking runs at a much lower level than SQL Trace. Also, because the Extended Event layer is so low and deep, many more types of events can be tracked.
- **Asynchronous I/O** The difference between asynchronous and synchronous is what part of the system is actually waiting for an unavailable resource. When SQL Server requests a synchronous I/O, if the resource isn't available, the Windows kernel puts the thread on a wait queue until the resource becomes available. For asynchronous I/O, SQL Server requests that Windows initiate an I/O. Windows starts the I/O operation and doesn't stop the thread from running. SQL Server then places the server session in an I/O wait queue until it gets the signal from Windows that the resource is available.
- **CLR hosting** Hosting Common Language Runtime (CLR) inside the SQLOS allows managed .NET code to be used natively inside SQL Server.

1.1.1 NUMA Architecture

Non-Uniform Memory Access (NUMA) architectures have become common in most datacenters today. The SQLOS has automatically recognized the existence of hardware NUMA support and optimizes scheduling and memory management by default.

Only a few years ago, hardware NUMA required specialized hardware configurations using multiple server nodes that functioned as a single server. Modern server processor architectures from AMD and Intel now offer hardware NUMA in most standard server configurations through the inclusion of an onboard memory controller for each processor die and interconnected paths between the physical sockets on the server motherboard. Regardless of the specific hardware implementation of NUMA, SQLOS performs the same internal configuration of SOS Memory Nodes and uses the same optimizations for memory management and scheduling.

The main benefit of NUMA is scalability, which has definite limits when you use symmetric multiprocessing (SMP) architecture. With SMP, all memory access is posted to the same shared memory bus. This works fine for a relatively small number of CPUs, but problems appear when you have many CPUs competing for access to the shared memory bus. The trend in hardware has been to have more than one system bus, each serving a small set of processors. NUMA limits the number of CPUs on any one memory bus. Each processor group has its own memory and possibly its own I/O channels. However, each CPU can access memory associated with other groups coherently, as discussed later in the chapter. Each group is called a NUMA node, which are linked to each other by a high-speed interconnection. The number of CPUs within a NUMA node depends on the hardware vendor. Accessing local memory is faster than accessing the memory associated with other NUMA nodes—the reason for the name Non-Uniform Memory Access. Figure below shows a NUMA node with four CPUs.



SQL Server 2012 allows you to subdivide one or more physical NUMA nodes into smaller NUMA nodes, referred to as software NUMA or soft-NUMA. You typically use soft-NUMA when you have many CPUs but no hardware NUMA, because soft-NUMA allows for the subdividing of CPUs but not memory. You can also use soft-NUMA to subdivide hardware NUMA nodes into groups of fewer CPUs than is provided by the hardware NUMA. Your soft-NUMA nodes can also be configured to listen on their own ports. Only the SQL Server scheduler and Server Name Indication (SNI) are soft-NUMA–aware. Memory nodes are created based on hardware NUMA and therefore aren't affected by soft-NUMA. TCP/IP, Virtual Interface Adapters (VIAs), Named Pipes, and shared memory can take advantage of NUMA round-robin scheduling, but only TCP and VIA can set the processor affinity to a specific set of NUMA nodes.

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1.1.2 The Scheduler

1.1.2.1 Intro

Because the Windows scheduler knew nothing about the needs of a relational database system, it treated SQL Server worker threads the same as any other process running on the operating system. However, a high-performance system such as SQL Server functions best when the scheduler can meet its special needs. SQL Server 7.0 and all subsequent versions are designed to handle their own scheduling to gain a number of advantages, including the following.

- A private scheduler can support SQL Server tasks by using fibers as easily as it supports using threads.
- Context switching and switching into kernel mode can be avoided as much as possible.

One major difference between the SOS Scheduler and the Windows scheduler is that the SQL Server scheduler runs as a cooperative rather than as a preemptive scheduler. It relies on the workers, threads, or fibers to yield voluntarily often enough so that one process or thread doesn't have exclusive control of the system. Each task that executes inside SQL Server has a quantum of 4 milliseconds on the scheduler.

- Understanding SQL Server schedulers

In SQL Server 2012, each actual CPU (whether hyperthreaded or physical) has a scheduler created for it when SQL Server starts. This is true even if the Affinity Mask server configuration options are configured so that SQL Server is set to not use all available physical CPUs. In SQL Server 2012, each scheduler is set to either ONLINE or OFFLINE based on the process affinity settings; the default is that all schedulers are ONLINE.

Introduced for the first time in SQL Server 2008 R2, process affinity replaced the 'affinity mask' sp_configure option and is accomplished through the use of ALTER SERVER CONFIGURATION for setting processor affinity in SQL Server. Changing the process affinity value can change the status of one or more schedulers to OFFLINE, which you can do without having to restart your SQL Server. Note that when a scheduler is switched from ONLINE to OFFLINE due to a configuration change, any work already assigned to the scheduler is first completed and no new work is assigned.

1.1.2.2 SQL Server workers

You can think of the SQL Server scheduler as a logical CPU used by SQL Server workers.

A worker can be either a thread or a fiber bound to a logical scheduler. If the Affinity Mask configuration option is set (as discussed in Chapter 1, "SQL Server 2012 architecture and configuration"), or process affinity has been configured using ALTER

SERVER CONFIGURATION, each scheduler is mapped to a particular CPU. Thus, each worker is also associated with a single CPU.

Each scheduler is assigned a worker limit based on the configured Max Worker Threads and the number of scheduler.

A worker can't move from one scheduler to another, but as workers are destroyed and created, it can appear as though workers are moving between schedulers.

Workers are created when the scheduler receives a request (a task to execute) and no workers are idle. A worker can be destroyed if it has been idle for at least 15 minutes or if SQL Server is under memory pressure. Each worker can use at least half a megabyte of memory on a 32-bit system and at least 2 MB on a 64-bit system, so destroying multiple workers and freeing their memory can yield an immediate performance improvement on memory-starved systems.

SQL Server actually handles the worker pool very efficiently, and you might be surprised to know that even on very large systems with hundreds or even thousands of users, the actual number of SQL Server workers might be much lower than the configured value for Max Worker Threads.

1.1.2.3 SQL Server tasks

The unit of work for a SQL Server worker is a request, which you can think of as being equivalent to a single batch sent from the client to the server. When a request is received by SQL Server, it's bound to a task that's assigned to a worker, and that worker processes the entire request before handling any other request. If a request executes using parallelism, then multiple child tasks, and therefore workers, can be created based on the degree of parallelism being used to execute the request and the specific operation being performed.

Keep in mind that a session ID (SPID) isn't the same as a task. A SPID is a connection or channel over which requests can be sent, but an active request isn't always available on any particular SPID. In SQL Server 2012, a SPID isn't bound to a particular scheduler. Each SPID has a preferred scheduler, which is one that most recently processed a request from the SPID. The SPID is initially assigned to the scheduler with the lowest load. However, when subsequent requests are sent from the same SPID, if another scheduler has a load factor that is less than a certain percentage of the average of the scheduler's entire load factor, the new task is given to the scheduler with the smallest load factor. One restriction is that all tasks for one SPID must be processed by schedulers on the same NUMA node. The exception to this restriction is when a query is being executed as a parallel query across multiple CPUs. The optimizer can decide to use more available CPUs on the NUMA node processing the query so that other CPUs (and other schedulers) can be used.

1.1.2.4 Threads vs. fibers

> **Note**
>
> The scheduler in SQL Server 7.0 and SQL Server 2000 was called the User Mode Scheduler (UMS) to reflect that it ran primarily in user mode, as opposed to kernel mode. SQL Server 2005 and later versions call the scheduler the SOS Scheduler and improve on UMS even more.

As mentioned earlier, the UMS was designed to work with workers running on either threads or fibers.

Windows fibers have less overhead associated with them than threads do, and multiple fibers can run on a single thread. You can configure SQL Server to run in fiber mode by setting the Lightweight Pooling option to 1. Although using less overhead and a "lightweight" mechanism sounds like a good idea, you should evaluate the use of fibers carefully.

Certain SQL Server components don't work—or don't work well—when SQL Server runs in fiber mode. These components include SQLMail and SQLXML. Other components, such as heterogeneous and CLR queries, aren't supported at all in fiber mode because they need certain thread-specific facilities provided by Windows.

Fiber mode was actually intended just for special niche situations in which SQL Server reaches a limit in scalability due to spending too much time switching between thread contexts or switching between user mode and kernel mode. In most environments, the performance benefit gained by fibers is quite small compared to the benefits you can get by tuning in other areas. If you're certain you have a situation that could benefit from fibers, be sure to test thoroughly before you set the option on a production server. Also, you might even want to contact Microsoft Customer Support Services.

1.1.2.5 NUMA and schedulers

With a NUMA configuration, every node has some subset of the machine's processors and the same number of schedulers. If the machine is configured for hardware NUMA, the number of processors on each node is preset, but for soft-NUMA that you configure yourself, you can decide how many processors are assigned to each node.

You still have the same number of schedulers as processors, however. When SPIDs are first created, they are assigned round-robin to nodes. The Scheduler Monitor then assigns the SPID to the least loaded scheduler on that node. As mentioned earlier, if the SPID is moved to another scheduler, it stays on the same node. A single processor or SMP machine is treated as a machine with a single NUMA node. Just like on an SMP machine, no hard mapping occurs between schedulers and a CPU with NUMA, so any scheduler on an individual node can run on any CPU on that node. However, if you have set the Affinity Mask configuration option, each scheduler on each node is fixed to run on a particular CPU.

Every hardware NUMA memory node has its own lazywriter as well as its own I/O Completion Port (IOCP), which is the network listener.

Every node also has its own Resource Monitor, which a hidden scheduler manages (you can see the hidden schedulers in sys.dm_os_schedulers). Each Resource Monitor has its own SPID, which you can see by querying the sys.dm_exec_requests and sys.dm_os_workers DMVs:

```
SELECT session_id,
CONVERT (varchar(10), t1.status) AS status,
CONVERT (varchar(20), t1.command) AS command,
CONVERT (varchar(15), t2.state) AS worker_state
FROM sys.dm_exec_requests AS t1
JOIN sys.dm_os_workers AS t2
ON t2.task_address = t1.task_address
WHERE command = 'RESOURCE MONITOR';
```

Every node has its own Scheduler Monitor, which runs on any SPID and in a preemptive mode. The Scheduler Monitor thread wakes up periodically and checks each scheduler to see whether it has yielded since the last time the Scheduler Monitor woke up (unless the scheduler is idle). The Scheduler Monitor raises an error (17883) if a non-idle thread hasn't yielded. This error can occur when an application other than SQL Server is monopolizing the CPU. The Scheduler Monitor knows only that the CPU isn't yielding; it can't ascertain what kind of task is using it. The Scheduler Monitor is also responsible for sending messages to the schedulers to help them balance their workload.

1.1.2.6 Dynamic affinity

In SQL Server 2012 (in all editions except SQL Server Express), processor affinity can be controlled dynamically. When SQL Server starts up, all scheduler tasks are started, so each CPU has one scheduler. If process affinity has been set, some schedulers are then marked as offline and no tasks are assigned to them.

When process affinity is changed to include additional CPUs, the new CPU is brought online. The Scheduler Monitor then notices an imbalance in the workload and starts picking workers to move to the new CPU. When a CPU is brought offline by changing process affinity, the scheduler for that CPU continues to run active workers, but the scheduler itself is moved to one of the other CPUs that are still online. No new workers are given to this scheduler, which is now offline, and when all active workers have finished their tasks, the scheduler stops.

1.1.2.7 Binding schedulers to CPUs

Remember that, normally, schedulers aren't bound to CPUs in a strict one-to-one relationship, even though you have the same number of schedulers as CPUs. A scheduler is bound to a CPU only when process affinity is set, even if you specify that process affinity use all the CPUs, which is the default setting.

Configuring process affinity using ALTER SERVER CONFIGURATION SET PROCESS AFFINITY CPU requires only that you specify the specific CPUIDs.

For an eight-processor machine, a process affinity set with ALTER SERVER CONFIGURATION SET PROCESS AFFINITY CPU = 0 TO 1 means that only CPUs 0 and 1 are used and two schedulers are bound to the two CPUs. If you set the process affinity set with ALTER SERVER CONFIGURATION SET PROCESS AFFINITY CPU 0 TO 7, all the CPUs are used, just as with the default.

In addition to being able to set process affinity based on specific CPUIDs, SQL Server 2012 can set process affinity based on NUMA nodes using ALTER SERVER CONFIGURATION SET PROCESS AFFINITY NUMANODE = . The NUMA node range specification is identical to the CPU range specification. If you want an instance to use only the CPUs within a specific NUMA node, you simply specify that NUMA NodeID for the process affinity.

1.1.2.8 Observing scheduler internals

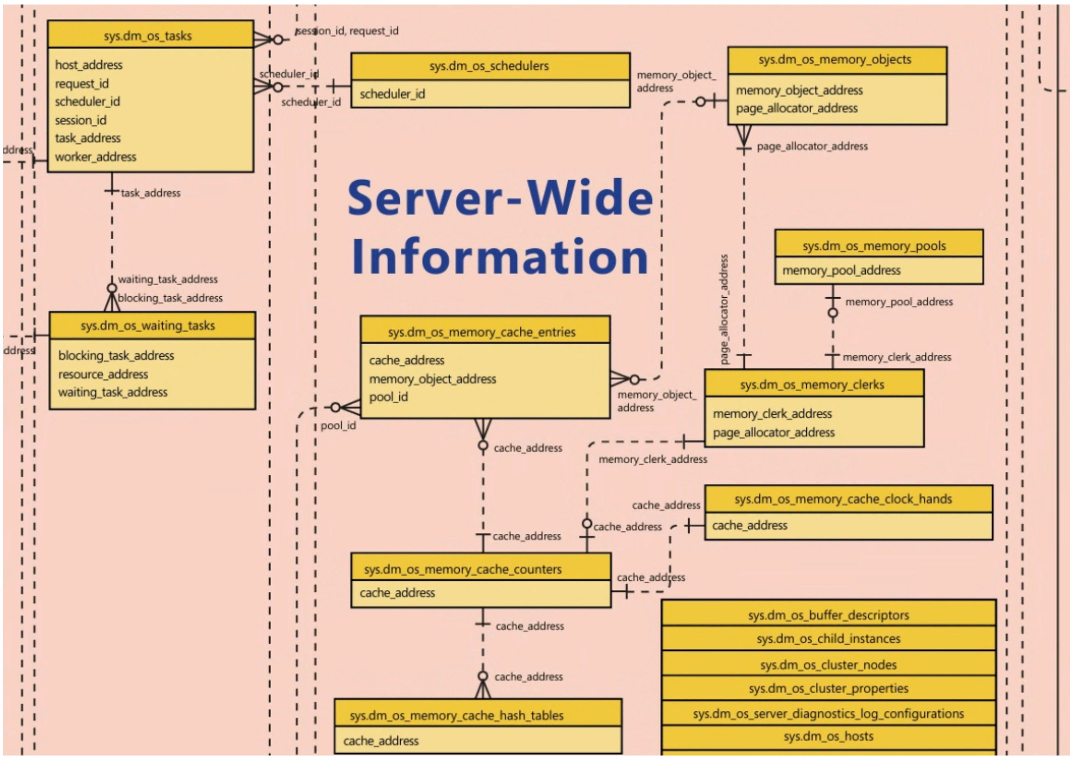
SQL Server 2012 has several DMVs that provide information about schedulers, workers, and tasks.

- [sys.dm_os_schedulers] This view returns one row per scheduler in SQL Server. Each scheduler is mapped to an individual processor in SQL Server. Interesting columns include the following:
    - [parent_node_id] The ID of the node that the scheduler belongs to. This represents a NUMA node.
    - [scheduler_id] The ID of the scheduler. All schedulers that run regular queries have IDs of less than 1048576.
    - [cpu_id] The CPUID assigned to the scheduler. A cpu_id of 255 no longer indicates no affinity as it did in SQL Server 2005.
    - [is_online] If SQL Server is configured to use only some of the available processors on the server, this can mean that some schedulers are mapped to processors not in the affinity mask. If that’s the case, this column returns 0, meaning that the scheduler isn’t being used to process queries or batches.
    - [current_tasks_count] The number of current tasks associated with this scheduler, including the following. (When a task is completed, this count is decremented.): • Tasks waiting on a resource to be acquired before proceeding • Tasks that are currently running or that can run but are waiting to be executed
    - [runnable_tasks_count] The number of tasks waiting to run on the scheduler.

- [current_workers_count] The number of workers associated with this scheduler, including workers not assigned any task.
  - [active_workers_count] The number of workers assigned a task.
  - [work_queue_count] The number of tasks waiting for a worker. If current_workers_count is greater than active_workers_count, this work queue count should be 0 and shouldn't grow.
  - [pending_disk_io_count] The number of pending I/Os. Each scheduler has a list of pending I/Os that are checked on every context switch to determine whether the I/Os are completed. The count is incremented when the request is inserted and decremented when the request is completed. This number doesn't indicate the state of the I/Os.
  - [load_factor] The internal value that indicates the perceived load on this scheduler. This value determines whether a new task should be put on this scheduler or another scheduler. It's useful for debugging purposes when schedulers appear to be unevenly loaded.
- [sys.dm_os_workers] This view returns a row for every worker in the system. Interesting columns include the following:
  - [is_preemptive] A value of 1 means that the worker is running with preemptive scheduling. Any worker running external code is run under preemptive scheduling.
  - [is_fiber] A value of 1 means that the worker is running with lightweight pooling.
- [sys.dm_os_threads] This view returns a list of all SQLOS threads running under the SQL Server process. Interesting columns include the following:
  - [started_by_sqlserver] The thread initiator. A 1 means that SQL Server started the thread; 0 means that another component, such as an extended procedure from within SQL Server, started the thread.
  - [creation_time] The time when this thread was created.
  - [stack_bytes_used] The number of bytes actively being used on the thread.
  - [affinity] The CPU mask on which this thread is running. This depends on the value configured by the ALTER SERVER CONFIGURATION SET PROCESS AFFINITY statement, which might be different from the scheduler in the case of soft-affinity.
  - [locale] The cached locale LCID for the thread.
- [sys.dm_os_tasks] This view returns one row for each task that is active in the instance of SQL Server. Interesting columns include the following:
  - [task_state] The state of the task. The value can be one of the following: • PENDING Waiting for a worker thread • RUNNABLE Capable of being executed, but is waiting to receive a quantum • RUNNING Currently running on the scheduler • SUSPENDED Has a worker but is waiting for

an event • DONE Completed • SPINLOOP Processing a spinlock, as when waiting for a signal

  - [context_switches_count] The number of scheduler context switches that this task has completed.
  - [pending_io_count] The number of physical I/Os performed by this task.
  - [pending_io_byte_count] The total byte count of I/Os performed by this task.
  - [pending_io_byte_average] The average byte count of I/Os performed by this task.
  - [scheduler_id] The ID of the parent scheduler. This is a handle to the scheduler information for this task.
  - [session_id] The ID of the session associated with the task.
- [sys.dm_os_waiting_tasks] This view returns information about the queue of tasks waiting on some resource. Interesting columns include the following:
  - [session_id] The ID of the session associated with the task.
  - [exec_context_id] The ID of the execution context associated with the task.
  - [wait_duration_ms] The total wait time (in milliseconds) for this wait type. This time is inclusive of signal_wait_time.
  - [wait_type] The name of the wait type.
  - [resource_address] The address of the resource for which the task is waiting.
  - [blocking_task_address] The task currently holding this resource.
  - [blocking_session_id] The ID of the session of the blocking task.
  - [blocking_exec_context_id] The ID of the execution context of the blocking task.
  - [resource_description] The description of the resource being consumed.



1.1.2.9 Understanding the Dedicated Administrator Connection (DAC)

Under extreme conditions, such as a complete lack of available resources, SQL Server can enter an abnormal state in which no further connections can be made to the SQL Server instance. SQL Server 2005 introduced a special connection called the Dedicated Administrator Connection (DAC) that was designed to be accessible even when no other access can be made.

You can connect to the DAC using the command-line tool SQLCMD and specifying the -A (or /A) flag. This method of connection is recommended because it uses fewer resources than the graphical user interface (GUI).

Through SSMS, you can specify that you want to connect using DAC by preceding the name of your SQL Server with ADMIN: in the Connection dialog box. For example, to connect to a default SQL Server instance on a machine named TENAR, you enter ADMIN:TENAR. To connect to a named instance called SQL2008 on the same machine, you enter ADMIN:TENAR\SQL2008.

The DAC is a special-purpose connection designed for diagnosing problems in SQL Server and possibly resolving them.

Under normal circumstances, you can check whether a DAC is in use by running the following query when not connected to the DAC. If a DAC is active, the query returns the SPID for the DAC; otherwise, it returns no rows:

```sql
SELECT s.session_id
FROM sys.tcp_endpoints as e
INNER JOIN sys.dm_exec_sessions as s
ON e.endpoint_id = s.endpoint_id
WHERE e.name = N'Dedicated Admin Connection';
```

Keep the following points in mind about using the DAC.

- By default, the DAC is available only locally. However, administrators can configure SQL Server to allow remote connection by using the Remote Admin Connections configuration option.
- The user login to connect via the DAC must be a member of the sysadmin server role.
- There are only a few restrictions on the SQL statements that can be executed on the DAC. (For example, you can't run parallel queries or commands—for example, BACKUP or RESTORE—using the DAC.) However, you are recommended not to run any resource-intensive queries that might exacerbate the problem that led you to use the DAC. The DAC connection is created primarily for troubleshooting and diagnostic purposes. In general, you use the DAC for running queries against the DMO, some of which you've seen already and many more of which are discussed later in this book.
- A special thread is assigned to the DAC that allows it to execute the diagnostic functions or queries on a separate scheduler. This thread can't be terminated; you can kill only the DAC session, if needed. The DAC has no lazywriter thread, but it does have its own I/O Completion Port (IOCP), a worker thread, and an idle thread.

1.1.3 Memory

1.1.3.1 Intro

> **Important**
>
> El Buffer Manager es el Buffer Cache?

Because memory management is a huge topic, covering every detail of it would require a whole book in itself. SQL Server 2012 introduces a significant rewrite of the SQLOS Memory Manager and has the first significant changes in memory management since SQLOS was introduced in SQL Server 2005. The goal of this section is twofold:

- To provide enough information about how SQL Server uses its memory resources so that you can determine whether memory is being managed well on your system.

- To describe the aspects of memory management that you have control over so that you can understand when to exert that control

By default, SQL Server 2012 manages its memory resources almost completely dynamically. When allocating memory, SQL Server must communicate constantly with the operating system, which is one of the reasons the SQLOS layer of the engine is so important.

- The buffer pool and the data cache **The main memory component in SQL Server is the buffer pool.** All memory not used by another memory component remains in the buffer pool to be used as a data cache for pages read in from the database files on disk.The buffer manager manages disk I/O functions for bringing data and index pages into the data cache so that data can be shared among users.

  Other components requiring memory can request a buffer from the buffer pool. A buffer is a page in memory that has the same size as a data or index page. You can think of it as a page frame that can hold one page from a database. Most buffers taken from the buffer pool for other memory components go to other kinds of memory caches, the largest of which is typically the cache for procedure and query plans, which is usually called the plan cache.

  CONSULTAR CON CHATGPT SI EL DIAGRAMA QUE ARME EN RELACION A ESTO ESTA BIEN?

- Column store object pool In addition to the buffer pool, SQL Server 2012 includes a new cache store specifically optimized for usage by the new column store indexing feature. The column store object pool allocates memory from the any-page allocator just like the buffer pool, but rather than cache data pages, the memory allocations are used for column store index objects.

  The memory for the column store object pool is tracked by a separate memory clerk, CACHESTORE_COLUMNSTOREOBJECTPOOL, in SQLOS.

- Access to in-memory data pages Access to pages in the data cache must be fast. Even with real memory, scanning the whole data cache for a page would be ridiculously inefficient when you have gigabytes of data. Pages in the data cache are therefore hashed for fast access. Hashing is a technique that uniformly maps a key via a hash function across a set of hash buckets. A hash table is a structure in memory that contains an array of pointers (implemented as a linked list) to the buffer pages.

  Given a dbid-fileno-pageno identifier (a combination of the database ID, file number, and page number), the hash function converts that key to the hash bucket that should be checked.

  Similarly, it takes only a few memory reads for SQL Server to determine that a desired page isn't in cache and must be read in from disk.

- Page management in the data cache **You can use a data page or an index page only if it exists in memory**. Therefore, a buffer in the data cache must be available for the page to be read into. Keeping a supply of buffers available for immediate use is an important performance optimization.

  In SQL Server 2012, a single mechanism is responsible both for writing changed pages to disk and for marking as free those pages that haven't been referenced for some time. SQL Server maintains a linked list of the addresses of free pages, and any worker needing a buffer page uses the first page of this list.

  Every buffer in the data cache has a header that contains information about the last two times the page was referenced and some status information, including whether the page is dirty (that is, it has been changed since it was read into memory or from disk).

  The reference information is used to implement the page replacement policy for the data cache pages, which uses an algorithm called LRU-K (Least Recently Used (LRU)). An LRU-K algorithm keeps track of the last K times a page was referenced and can differentiate between types of pages, such as index and data pages, with different frequency levels. SQL Server 2012 uses a K value of 2, so it keeps track of the two most recent accesses of each buffer page.

  The data cache is periodically scanned from start to end by the lazywriter process, which functions similar to a ticking clock hand, processing 16 pages in the data cache for each tick. **Because the buffer cache is all in memory**, these scans are quick and require no I/O. During the scan, a value is associated with each buffer based on the time the buffer was last accessed. When the value gets low enough, the dirty page indicator is checked. If the page is dirty, a write is scheduled to commit the modifications to disk.

  Instances of SQL Server use write-ahead logging so that the write of the dirty data page is blocked while the log page recording the modification is first written to disk.

  After the modified page is flushed to disk or if the page wasn't dirty to start with, it is freed. The association between the buffer page and the data page that it contains is removed by deleting information about the buffer from the hash table, and the buffer is put on the free list.

- The free buffer list and the lazywriter **The work of scanning the buffer pool, writing dirty pages, and populating the free buffer list is primarily performed by the lazywriter.**

  Each instance of SQL Server has one lazywriter thread for each SOS Memory node created in SQLOS, with every instance having at least one lazywriter thread. As explained earlier, the lazywriter works like a clock hand and ticks, with each tick processing 16 buffers in the data cache.

The location of the previous tick is tracked internally, and the buffers in the data cache are scanned sequentially from start to finish as the lazywriter ticks during execution. When the end of the data cache is reached, the process repeats from the beginning of the data cache on the next tick.

If the instance experiences memory pressure in the data cache, individual workers can assist the lazywriter as they allocate memory, and the number of pages available on the free list is too low. When this condition occurs, the individual workers execute an internal routine, HelpLazyWriter, which performs an additional lazywriter tick on the worker thread, processing the next 16 buffers in the data cache and returning buffers that exceed the current time of last access value to the free list.

When SQL Server uses memory dynamically, it must constantly be aware of the amount of free memory available in Windows. One SQLOS component is the Resource Monitor, which, among other tasks, monitors the Windows operating system for low memory notifications by using the QueryMemoryResourceNotification Windows Server application programming interface (API) to get status. If the available memory in Windows drops below 32 MB for servers with 4 GB of RAM or 64 MB for servers with 8 GB or higher, a LowMemoryResourceNotification flag is set. This notification is returned by the QueryMemoryResourceNotification call, and Resource Monitor forces the external clock hands on the internal caches in SQLOS to sweep the caches to clean up and reduce memory usage, allowing SQL Server to return memory to Windows. As memory is released by SQLOS to Windows, it can be committed by other applications or, if a stable state occurs, the Windows operating system sets a HighMemoryResourceNotification when the available memory on the server is three times the low memory notification size. When this occurs, the Resource Monitor detects the change in notification, and the SQLOS can then commit additional memory from Windows, if required.

- Checkpoints The checkpoint process also scans the buffer cache periodically and writes all the dirty data pages for a particular database to disk. The difference between the checkpoint process and the lazywriter is that the checkpoint process never puts buffers on the free list.

  The only purpose of the checkpoint process is to ensure that pages modified before a certain time are written to disk, so that the number of dirty pages in memory is always kept to a minimum, which in turn ensures that the length of time SQL Server requires for recovery of a database after a failure is kept to a minimum.

  When a checkpoint occurs, SQL Server writes a checkpoint record to the transaction log, which lists all active transactions. This allows the recovery process to build a table containing a list of all the potentially dirty pages. Checkpoints occur automatically at regular intervals but can also be requested manually. Checkpoints are triggered when any of the following occurs:

- A database owner (or backup operator) explicitly issues a CHECKPOINT command to perform a checkpoint in that database.
- A backup or database snapshot is created of a database.
- The log is filling up (more than 70 percent of capacity) and the database is in autotruncate mode.
- The recovery time exceeds the Recovery Interval server configuration option. A Recovery Interval setting of 1 means that checkpoints occur about every minute as long as transactions are being processed in the database. A default recovery interval of 0 means that SQL Server chooses an appropriate value; for the current version, this is one minute.
- The recovery time exceeds the Target Recovery Time database configuration option.
- An orderly shutdown of SQL Server is requested, without the NOWAIT option. A checkpoint operation is then run in each database on the instance. An orderly shutdown occurs when you explicitly shut down SQL Server, unless you do so by using the SHUTDOWN WITH NOWAIT command. An orderly shutdown also occurs when the SQL Server service is stopped through Service Control Manager or the net stop command from an operating system prompt.

You can also use the sp_configure Recovery Interval option to influence checkpointing frequency, balancing the time to recover against any effect on runtime performance. If you're interested in tracing when checkpoints actually occur, you can use the SQL Server Extended Events sqlserver.checkpoint_begin and sqlserver.checkpoint_end to monitor checkpoint activity.

The checkpoint process goes through the buffer pool, scanning the pages nonsequentially. When it finds a dirty page, it looks to see whether any physically contiguous (on the disk) pages are also dirty so that it can do a large block write. But this means that it might, for example, write buffers 12, 13, 14, 15, 16, and 17 when it sees that buffer 14 is dirty. (These pages have contiguous disk locations even though they can be in different memory regions in the buffer pool. In this case, the noncontiguous pages in the buffer pool can be written as a single operation called a gather-write.) The process continues to scan the buffer pool until it gets to page 17.

In some cases, checkpoints might issue a substantial amount of I/O, causing the I/O subsystem to get inundated with write requests, which can severely affect read performance. On the other hand, relatively low I/O activity can be utilized during some periods. SQL Server 2012 includes a command-line option that allows throttling of checkpoint I/Os. Use the SQL Server Configuration Manager and add the –k parameter, followed by a decimal number, to the list of startup parameters for the SQL Server service. The value specified indicates the number of megabytes per second that the checkpoint process can write. Backups might require slightly more time to finish because a checkpoint process that a backup initiates is also delayed. Before enabling this option on a production system, make sure that you have enough hardware to sustain the I/O requests posted by SQL Server and that you have thoroughly tested your applications on the system. The –k option doesn't apply to indirect checkpoints.

- Memory management in other caches **Buffer pool memory not used for the data cache is used for other types of caches, primarily the plan cache.** The page replacement policy for other caches, as well as the mechanism by which pages that can be freed are searched for, are quite a bit different than for the data cache.

  SQL Server 2012 uses a common caching framework that all caches except the data cache use. The framework consists of the Resource Monitor and a set of three stores: **cache stores, user stores (which don't actually have anything to do with users), and object stores.**

  The plan cache is the main example of a cache store, and **the metadata cache** is the prime example of a user store. Both cache stores and user stores use the same LRU mechanism and the same costing algorithm to determine which pages can stay and which can be freed. Object stores, on the other hand, are just pools of memory blocks and don't require LRU or costing. One example of the use of an object store is the SNI, which uses the object store for pooling network buffers.

  For the rest of this section, the discussion of stores refers only to cache stores and user stores.

  The Resource Monitor is in charge of moving the external hands whenever it notices memory pressure. When the Resource Monitor detects memory pressure, it writes an entry into one of many in-memory ring buffers maintained by SQLOS for storing diagnostics information about SQL Server. A ring buffer is a memory structure that functions as a first-in-first-out queue with a fixed or variable number of entries that can be maintained within the memory structure. The ring buffer entries from the Resource Monitor can be monitored as follows:

```
SELECT *
FROM sys.dm_os_ring_buffers
WHERE ring_buffer_type=N'RING_BUFFER_RESOURCE_MONITOR';
```

  If the memory pressure is external to SQL Server, the value of the IndicatorsSystem node is 2. If the memory pressure is internal to SQL Server, the value of the IndicatorsProcess node is 2.

  Also, if you look at the DMV sys.dm_os_memory_cache_clock_hands—specifically at the removed_last_round_count column—you can look for a value that is very large compared to other values. A dramatic increase in that value strongly indicates memory pressure.

The companion website for this book contains a comprehensive white paper titled "Troubleshooting Performance Problems in SQL Server 2008," which includes many details on tracking down and dealing with memory problems. Buscar este paper para ver cuales son las queries

- The Memory Broker Because so many SQL Server components need memory, and to make sure that each component uses memory efficiently, SQL Server uses a Memory Broker, whose job is to analyze the behavior of SQL Server with respect to memory consumption and to improve dynamic memory distribution. The Memory Broker is a centralized mechanism that dynamically distributes memory between the buffer pool, the query executor, the Query Optimizer, and all the various caches, and it attempts to adapt its distribution algorithm for different types of workloads.

  You can monitor Memory Broker behavior by querying the Memory Broker ring buffer as follows:

  ```
  SELECT *
  FROM sys.dm_os_ring_buffers
  WHERE ring_buffer_type=N'RING_BUFFER_MEMORY_BROKER';
  ```

- Memory sizing SQL Server memory involves more than just the buffer pool. As mentioned earlier in this discussion, SQL Server 2012 included a rewrite of the Memory Manager in SQLOS and no longer allocates or manages memory in the same manner as previous versions of SQL Server.

  In SQL Server 2012, the sys.dm_os_memory_clerks DMV has been reworked to reflect the changes to the Memory Manager and, therefore, no longer has separate single_page_kb and multi_pages_kb columns. Instead, a new pages_kb column reflects the total memory allocated by a component from the any-page allocator in SQLOS:

  ```
  SELECT type, sum(pages_kb) AS pages_kb
  FROM sys.dm_os_memory_clerks
  WHERE pages_kb != 0
  GROUP BY type;
  ```

- Buffer pool sizing When SQL Server starts, it computes the size of the virtual address space (VAS) of the SQL Server process.

  A 32-bit machine can directly address only 4 GB of memory and, by default, Windows itself reserves the top 2 GB of address space for its own use, which leaves only 2 GB as the maximum size of the VAS for any application, such as SQL Server. If you need to access more than 3 GB of RAM with SQL Server 2012, you have to use a 64-bit platform.

On a 64-bit platform, the Windows policy option Lock Pages in Memory is available, although it's disabled by default. This policy determines which accounts can make use of a Windows feature to keep data in physical memory, preventing the system from paging the data to virtual memory on disk.

A DMV called [sys.dm_os_sys_info] contains one row of general-purpose SQL Server configuration information, including the following columns:

- physical_memory_kb: The amount of physical memory available
- virtual_memory_kb: The amount of virtual memory available to the process in user mode
- commited_kb: The committed memory in kilobytes in the Memory Manager; doesn't include reserved memory in the Memory Manager
- commit_target_kb: The amount of memory, in kilobytes, that SQL Server Memory Manager can consume

Also, a DMV called [sys.dm_os_process_memory] contains one row of information about the SQL Server process memory usage, including the following columns:

- physical_memory_in_use_kb: The size of the process working set in KB
- large_page_allocations_kb: The amount of physical memory allocated by using large page APIs
- locked_page_allocations_kb: The amount of memory pages locked in memory
- total_virtual_address_space_kb: The total size of the user mode part of the virtual address space
- virtual_address_space_reserved_kb: The total amount of virtual address space reserved by the process
- virtual_address_space_committed_kb: The amount of reserved virtual address space that has been committed or mapped to physical pages
- virtual_address_space_available_kb: The amount of virtual address space that's currently free

- DMVs for memory internals SQL Server includes several DMO that provide information about memory and the various caches.

    - [sys.dm_os_memory_clerks] This view returns one row per memory clerk that's currently active in the instance of SQL Server. You can think of a clerk as an accounting unit. following query returns a list of all the types of clerks.

      ```
      SELECT DISTINCT type
      FROM sys.dm_os_memory_clerks;
      ```

      Interesting columns include the following. • [pages_kb] The amount of page memory allocated in kilobytes for this memory clerk. • [virtual_memory_reserved_kb] The amount of virtual memory reserved by a memory clerk. • [virtual_memory_committed_kb] The amount of memory committed by the clerk. The amount of committed memory should always be less than the amount of Reserved Memory. • [awe_allocated_kb] The amount of memory in kilobytes locked in the physical memory and not paged out by Windows.

   - [sys.dm_os_memory_cache_counters] This view returns a snapshot of the health of each cache of type userstore and cachestore. It provides runtime information about the cache entries allocated, their use, and the source of memory for the cache entries. Interesting columns include the following. • [pages_kb] The amount of memory in kilobytes allocated in the cache. • [pages_in_use_kb] The amount of memory in kilobytes (KB) that is allocated and used in the cache. • [entries_count] The number of entries in the cache. • [entries_in_use_count] The number of entries in use in the cache.

   - [sys.dm_os_memory_cache_hash_tables] This view returns a row for each active cache in the SQL Server instance. This view can be joined to [sys.dm_os_memory_cache_counters] on the cache_address column. Interesting columns include the following. • [buckets_count] The number of buckets in the hash table. • [buckets_in_use_count] The number of buckets currently being used. • [buckets_min_length] The minimum number of cache entries in a bucket. • [buckets_max_length] The maximum number of cache entries in a bucket. • [buckets_avg_length] The average number of cache entries in each bucket. **If this number gets very large, it might indicate that the hashing algorithm isn't ideal. •** [buckets_avg_scan_hit_length] The average number of examined entries in a bucket before the searched-for item was found. **As above, a big number might indicate a less-than-optimal cache. You might consider running DBCC FREESYSTEMCACHE to remove all unused entries in the cache stores.**

   - [sys.dm_os_memory_cache_clock_hands] This DMV, discussed earlier, can be joined to the other cache DMVs using the cache_address column. Interesting columns include the following. • [clock_hand] The type of clock hand, either external or internal. Remember that every store has two clock hands. • [clock_status] The status of the clock hand: suspended or running. A clock hand runs when a corresponding policy kicks in. • [rounds_count] The number of rounds the clock hand has made. All the external clock hands should have the same value in this column. • [removed_all_rounds_count] The number of entries removed by the clock hand in all rounds.

- Read-ahead SQL Server supports a mechanism called read-ahead, whereby the need for data and index pages can be anticipated and pages can be brought into the buffer pool before they're actually needed. This performance optimization allows large amounts of data to be processed effectively and typically keeps the necessary pages in the buffer pool before they are needed by the execution engine.

Read-ahead is managed completely internally, and no configuration adjustments are necessary.

Read-ahead comes in two types: **one for table scans on heaps** and **one for index ranges**. **For table scans**, the table's allocation structures are consulted to read the table in disk order. Up to 32 extents (32 * 8 pages/extent * 8,192 bytes/page = 2 MB) of read-ahead might be outstanding at a time. Up to eight contiguous extents (64 contiguous pages) can be read at a time are read with a single 512 KB scatter read from one file. If the table is spread across multiple files in a file group, SQL Server attempts to distribute the read-ahead activity across the files evenly. **For index ranges**, the scan uses level 1 of the index structure (the level immediately above the leaf) to determine which pages to read ahead. When the index scan starts, read-ahead is invoked on the initial descent of the index to minimize the number of reads performed. For instance, for a scan of WHERE state = 'WA', read-ahead searches the index for key = 'WA', and it can tell from the level-1 nodes how many pages must be examined to satisfy the scan. If the anticipated number of pages is small, all the pages are requested by the initial read-ahead; if the pages are noncontiguous, they're fetched in scatter reads. If the range contains a large number of pages, the initial read-ahead is performed and thereafter, every time another 16 pages are consumed by the scan, the index is consulted to read in another 16 pages. This has several interesting effects.

- Small ranges can be processed in a single read at the data page level whenever the index is contiguous.
- The scan range (for example, state = 'WA') can be used to prevent reading ahead of pages that won't be used because this information is available in the index.
- Read-ahead isn't slowed by having to follow page linkages at the data page level. (Read-ahead can be done on both clustered indexes and nonclustered indexes.)

As you can see, memory management in SQL Server is a huge topic, and this discussion provided you with only a basic understanding of how SQL Server uses memory. This information should give you a start in interpreting the wealth of information available through the DMVs and troubleshooting. The companion website includes a white paper that offers many more troubleshooting ideas and scenarios.

QQ

> ⚠ Warning

> QQ SOS Schduler que es? Cual es la diferencia entre whether hyperthreaded or physical? What "a fiber bound" is? What "Windows fibers" is? What "SQL Server runs in fiber mode" is? Terminar de entender que es el Affinity Mask? No entendi un porogon del 1.1.2.5 Dynamic affinity!!

2. Configuration

2.1. Intro

This book, SQL Server 2012 Internals, covers only the main features of the core database engine.

2.2. SQL Server metadata

Three types of system metadata objects are intended for general use: Compatibility Views, Catalog Views, and Dynamic Management Objects.

2.2.1. Compatibility Views

2.2.2. Catalog views

The SQL Server Books Online topic, “Mapping System Tables to System Views,” categorizes its objects into two lists: those appearing only in master and those appearing in all databases. As views, these metadata objects are based on an underlying Transact-SQL (T-SQL) definition. The most straightforward way to see the definition of these views is by using the object_definition function. (You can also see the definition of these system views by using sp_helptext or by selecting from the catalog view sys.system_sql_modules.) So to see the definition of sys.tables, you can execute the following: SELECT object_definition (object_id('sys.tables'));

2.2.3. Dynamic Management Objects

Metadata with names starting with sys.dm_, such as the just-mentioned sys.dm_exec_cached_plans, are considered Dynamic Management Objects. Although Dynamic Management Objects include both views and functions, they are usually referred to by the abbreviation DMV.

They are all in the sys schema and have a name that starts with dm_, followed by a code indicating the area of the server with which the object deals. The main categories are:

- **dm_exec_** This category contains information directly or indirectly related to the execution of user code and associated connections. For example, sys.dm_exec_sessions returns one row per authenticated session on SQL Server.
- **dm_os_** This category contains low-level system information such as memory and scheduling. For example, sys.dm_os_schedulers is a DMV that returns one

row per scheduler.

- **dm_tran_** This category contains details about current transactions. For example, sys.dm_tran_locks returns information about currently active lock resources.
- **dm_logpool** This category contains details about log pools used to manage SQL Server 2012’s log cache, a new feature added to make log records more easily retrievable when needed by features such as AlwaysOn.
- **dm_io_** This category keeps track of input/output activity on network and disks. For example, the function sys.dm_io_virtual_file_stats returns I/O statistics for data and log files.
- **dm_db_** This category contains details about databases and database objects such as indexes. For example, the sys.dm_db_index_physical_stats function returns size and fragmentation information for the data and indexes of the specified table or view.

2.2.4. Other metadata

- System functions Most SQL Server system functions are **property functions**. Property functions provide individual values for many SQL Server objects as well as for SQL Server databases and the SQL Server instance itself. The values returned by the property functions are scalar as opposed to tabular, so they can be used as values returned by SELECT statements and as values to populate columns in tables. The following property functions are available in SQL Server 2012:

    - SERVERPROPERTY
    - COLUMNPROPERTY
    - DATABASEPROPERTYEX
    - INDEXPROPERTY
    - INDEXKEY_PROPERTY
    - OBJECTPROPERTY
    - OBJECTPROPERTYEX
    - SQL_VARIANT_PROPERTY
    - FILEPROPERTY
    - FILEGROUPPROPERTY
    - FULLTEXTCATALOGPROPERTY
    - FULLTEXTSERVICEPROPERTY
    - TYPEPROPERTY
    - CONNECTIONPROPERTY
    - ASSEMBLYPROPERTY

  In addition to the property functions, the system functions include functions that are merely shortcuts for catalog view access. For example, to find out the database ID for the AdventureWorks2012 database, you can either query the sys.databases catalog view or use the DB_ID() function. Both of the following SELECT statements should return the same result:

SELECT database_id FROM sys.databases WHERE name = 'AdventureWorks2012'; SELECT DB_ID('AdventureWorks2012');

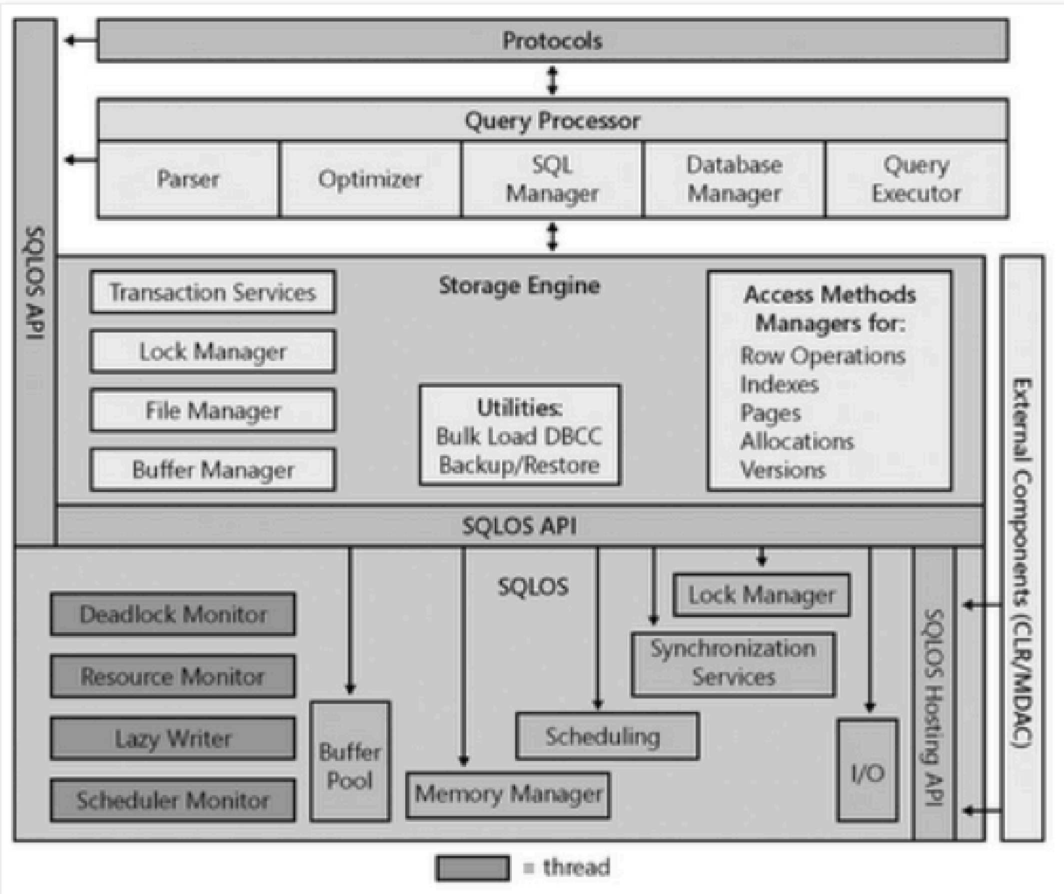
- System stored procedures System stored procedures are the original metadata access tool, in addition to the system tables themselves. Most of the system stored procedures introduced in the very first version of SQL Server are still available. However, catalog views are a big improvement over these procedures: You have control over how much of the metadata you see because you can query the views as though they were tables. With the system stored procedures, you have to accept the data that it returns.

Summary

Terminar de entender la/s diferencias entre [Catalog View], [Dynamic Management Objects] y [Other Metadata]

2.3. Components of the SQL Server Engine

Below figure shows the general architecture of SQL Server and its four major components: The Protocol Layer, The Query Processor (also called the relational engine), The Storage Engine, and The SQLOS. Every batch submitted to SQL Server for execution, from any client application, must interact with these four components.



1.3.1 Protocols

When an application communicates with the Database Engine, the application programming interfaces (APIs) exposed by the protocol layer formats the communication using a Microsoft-defined format called a tabular data stream (TDS) packet. The SQL Server Network Interface (SNI) protocol layer on both the server and client computers encapsulates the TDS packet inside a standard communication protocol, such as TCP/IP or Named Pipes. On the server side of the communication, the network libraries are part of the Database Engine. On the client side, the network libraries are part of the SQL Native Client. The configuration of the client and the instance of SQL Server determine which protocol is used. You can configure SQL Server to support multiple protocols simultaneously, coming from different clients. Each client connects to SQL Server with a single protocol. If the client program doesn't know which protocols SQL Server is listening on, you can configure the client to attempt multiple protocols sequentially. The following protocols are available:

- Shared Memory The simplest protocol to use, with no configurable settings. Clients using the Shared Memory protocol can connect to only a SQL Server instance running on the same computer, so this protocol isn't useful for most database activity. Use this protocol for troubleshooting when you suspect that the other protocols are configured incorrectly. Clients using MDAC 2.8 or earlier can't use the Shared Memory protocol. If such a connection is attempted, the client is switched to the Named Pipes protocol.
- Named Pipes A protocol developed for local area networks (LANs). A portion of memory is used by one process to pass information to another process, so that the output of one is the input of the other. The second process can be local (on the same computer as the first) or remote (on a network computer).
- TCP/IP The most widely used protocol over the Internet. TCP/IP can communicate across interconnected computer networks with diverse hardware architectures and operating systems. It includes standards for routing network traffic and offers advanced security features. Enabling SQL Server to use TCP/IP requires the most configuration effort, but most networked computers are already properly configured.

1.3.2 Query processor

As mentioned earlier, the query processor is also called the relational engine. It includes the SQL Server components that determine exactly what your query needs to do and the best way to do it. In Figure 1-2, the query processor is shown as two primary components: Query Optimization and query execution. This layer also includes components for parsing and binding (not shown in the figure). By far the most complex component of the query processor—and maybe even of the entire SQL Server product—is the Query Optimizer, which determines the best execution plan for the queries in the batch. Chapter 11, "The Query Optimizer," discusses the Query Optimizer in great detail; this section gives you just a high-level overview of the Query Optimizer as well as of the other components of the query processor. The query processor also manages query execution as it requests data from the storage engine and processes the results returned. Communication between the query processor and the storage engine is generally in terms of Object Linking and Embedding (OLE) DB rowsets. (Rowset is the OLE DB term for a result set.)

1.3.2.1 Parsing and binding components

It checks for proper syntax and spelling of keywords. After a query is parsed, a binding component performs name resolution to convert the object names into their unique object ID values. After the parsing and binding is done, the command is converted into an internal format that can be operated on. This internal format is known as a query tree. If the syntax is incorrect or an object name can't be resolved, an error is immediately raised that identifies where the error occurred. However, other types of error messages can't be explicit about the exact source line that caused the error.

1.3.2.2 The Query Optimizer

The Query Optimizer takes the query tree and prepares it for optimization. Statements that can't be optimized, such as flow-of-control and Data Definition Language (DDL) commands, are compiled into an internal form. Optimizable statements are marked as such and then passed to the Query Optimizer.

The Query Optimizer is concerned mainly with the Data Manipulation Language (DML) statements SELECT, INSERT, UPDATE, DELETE, and MERGE, which can be processed in more than one way; the Query Optimizer determines which of the many possible ways is best. It compiles an entire command batch and optimizes queries that are optimizable. The query optimization and compilation result in an execution plan.

The first step in producing such a plan is to normalize each query, which potentially breaks down a single query into multiple, fine-grained queries. After the Query Optimizer normalizes a query, it optimizes it, which means that it determines a plan for executing that query. Query optimization is cost-based; the Query Optimizer chooses the plan that it determines would cost the least based on internal metrics that include estimated memory requirements, CPU utilization, and number of required I/Os. The Query Optimizer considers the type of statement requested, checks the amount of data in the various tables affected, looks at the indexes available for each table, and then looks at a sampling of the data values kept for each index or column referenced in the query. The sampling of the data values is called distribution statistics. (Chapter 11 discusses statistics in detail.) Based on the available information, the Query Optimizer considers the various access methods and processing strategies that it could use to resolve a query and chooses the most cost-effective plan.

The Query Optimizer also uses pruning heuristics to ensure that optimizing a query doesn't take longer than required to simply choose a plan and execute it. The Query Optimizer doesn't necessarily perform exhaustive optimization; some products consider every possible plan and then choose the most cost-effective one. The advantage of this exhaustive optimization is that the syntax chosen for a query theoretically never causes a performance difference, no matter what syntax the user employed. But with a complex query, it could take much longer to estimate the cost of every conceivable plan than it would to accept a good plan, even if it's not the best one, and execute it.

After normalization and optimization are completed, the normalized tree produced by those processes is compiled into the execution plan, which is actually a data structure. Each command included in it specifies exactly which table is affected, which indexes are used (if any), and which criteria (such as equality to a specified value) must evaluate to TRUE for selection. This execution plan might be considerably more complex than is immediately apparent. In addition to the actual commands, the execution plan includes all the steps necessary to ensure that constraints are checked. Steps for calling a trigger are slightly different from those for verifying constraints. If a trigger is included for the action being taken, a call to the procedure that comprises the trigger is appended. If the trigger is an instead-of trigger, the call to the trigger's plan replaces the actual data modification command. For after triggers, the trigger's plan is branched to right after the plan for the modification statement that fired the trigger, before that modification is committed. The specific steps for the trigger aren't compiled into the execution plan, unlike those for constraint verification.

1.3.2.3 The Query Executor

The query executor runs the execution plan that the Query Optimizer produced, acting as a dispatcher for all commands in the execution plan. This module goes through each command of the execution plan until the batch is complete. Most commands require interaction with the storage engine to modify or retrieve data and to manage transactions and locking.

1.3.3 The storage engine

The SQL Server storage engine includes all components involved with the accessing and managing of data in your database. In SQL Server, the storage engine is composed of three main areas: access methods, locking and transaction services, and utility commands.

1.3.3.1 Access methods

When SQL Server needs to locate data, it calls the access methods code, which sets up and requests scans of data pages and index pages and prepares the OLE DB rowsets to return to the relational engine. Similarly, when data is to be inserted, the access methods code can receive an OLE DB rowset from the client. The access methods code contains components to open a table, retrieve qualified data, and update data. It doesn't actually retrieve the pages; instead, it makes the request to the buffer manager, which ultimately serves up the page in its cache or reads it to cache from disk. When the scan starts, a look-ahead mechanism qualifies the rows or index entries on a page. The retrieving of rows that meet specified criteria is known as a qualified retrieval. The access methods code is used not only for SELECT statements but also for qualified UPDATE and DELETE statements (for example, UPDATE with a WHERE clause) and for any data modification operations that need to modify index entries. The following sections discuss some types of access methods.

- **Row and index operations** You can consider row and index operations to be components of the access methods code because they carry out the actual method of access. Each component is responsible for manipulating and maintaining its respective on-disk data structures—namely, rows of data or B-tree indexes, respectively. They understand and manipulate information on data and index pages. The row operations code retrieves, modifies, and performs operations on individual rows. It performs an operation within a row, such as "retrieve column 2" or "write this value to column 3." As a result of the work performed by the access methods code, as well as by the lock and transaction management components (discussed shortly), the row is found and appropriately locked as part of a transaction. After formatting or modifying a row in memory, the row operations code inserts or deletes a row. The row operations code needs to handle special operations if the data is a large object (LOB) data type—text, image, or ntext—or if the row is too large to fit on a single page and needs to be stored as overflow data. The index operations code maintains and supports searches on B-trees, which are used for SQL Server indexes. An index is structured as a tree, with a root page and intermediate-level and lower-level pages. (A very small tree might not have intermediate-level pages.) A B-tree groups records with similar index keys, thereby allowing fast access to data by searching on a key value. The B-tree's core feature is its ability to balance the index tree (B stands for balanced). Branches of the index tree are spliced together or split apart as necessary so that the search for any particular record always traverses the same number of levels and therefore requires the same number of page accesses.
- **Page allocation operations** The allocation operations code manages a collection of pages for each database and monitors which pages in a database have already been used, for what purpose they have been used, and how much space is available on each page. Each database is a collection of 8 KB disk pages spread across one or more physical files. SQL Server uses 13 types of disk pages. The ones this book discusses are data pages, two types of Large Object (LOB) pages, row-overflow pages, index pages, Page Free Space (PFS) pages, Global Allocation Map and Shared Global Allocation Map (GAM and SGAM) pages, Index Allocation Map (IAM) pages, Minimally Logged (ML) pages, and Differential Changed Map (DIFF) pages. Another type, File Header pages, won't be discussed. All user data is stored on data, LOB, or row-overflow pages. Index rows are stored on index pages, but indexes can also store information on LOB and row-overflow pages. PFS pages keep track of which pages in a database are available to hold new data. Allocation pages (GAMs, SGAMs, and IAMs) keep

track of the other pages; they contain no database rows and are used only internally. BCM and DCM pages are used to make backup and recovery more efficient.

- **Versioning operations** Another type of data access, which was added to the product in SQL Server 2005, is access through the version store. Row versioning allows SQL Server to maintain older versions of changed rows. The row-versioning technology in SQL Server supports snapshot isolation as well as other features of SQL Server 2012, including online index builds and triggers, and the versioning operations code maintains row versions for whatever purpose they are needed.

1.3.3.2 Transaction services

A core feature of SQL Server is its ability to ensure that transactions are atomic—that is, all or nothing. Also, transactions must be durable, which means that if a transaction has been committed, it must be recoverable by SQL Server no matter what—even if a total system failure occurs one millisecond after the commit was acknowledged.

Transactions must adhere to four properties, called the ACID properties: atomicity, consistency, isolation, and durability.

In SQL Server, if work is in progress and a system failure occurs before the transaction is committed, all the work is rolled back to the state that existed before the transaction began.

Write-ahead logging makes possible the ability to always roll back work in progress or roll forward committed work that hasn't yet been applied to the data pages. Write-ahead logging ensures that the record of each transaction's changes is captured on disk in the transaction log before a transaction is acknowledged as committed, and that the log records are always written to disk before the data pages where the changes were actually made are written.

Writes to the transaction log are always synchronous—that is, SQL Server must wait for them to complete. Writes to the data pages can be asynchronous because all the effects can be reconstructed from the log if necessary. The transaction management component coordinates logging, recovery, and buffer management, topics discussed later in this book; this section looks just briefly at transactions themselves.

The transaction management component delineates the boundaries of statements that must be grouped to form an operation. It handles transactions that cross databases within the same SQL Server instance and allows nested transaction sequences. (However, nested transactions simply execute in the context of the first-level transaction; no special action occurs when they are committed. Also, a rollback specified in a lower level of a nested transaction undoes the entire transaction.) For a distributed transaction to another SQL Server instance (or to any other resource manager), the transaction management component coordinates with the Microsoft

Distributed Transaction Coordinator (MS DTC) service, using operating system remote procedure calls. The transaction management component marks save points that you designate within a transaction at which work can be partially rolled back or undone. The transaction management component also coordinates with the locking code regarding when locks can be released, based on the isolation level in effect. It also coordinates with the versioning code to determine when old versions are no longer needed and can be removed from the version store. The isolation level in which your transaction runs determines how sensitive your application is to changes made by others and consequently how long your transaction must hold locks or maintain versioned data to protect against those changes.

Concurrency models SQL Server 2012 supports two concurrency models for guaranteeing the ACID properties of transactions:

- **Pessimistic concurrency** This model guarantees correctness and consistency by locking data so that it can't be changed. Every version of SQL Server prior to SQL Server 2005 used this currency model exclusively; it's the default in both SQL Server 2005 and later versions.
- **Optimistic currency** SQL Server 2005 introduced optimistic concurrency, which provides consistent data by keeping older versions of rows with committed values in an area of tempdb called the version store. With optimistic concurrency, readers don't block writers and writers don't block readers, but writers still block writers. The cost of these non-blocking operations must be considered. To support optimistic concurrency, SQL Server needs to spend more time managing the version store. Administrators also have to pay close attention to the tempdb database and plan for the extra maintenance it requires.

Five isolation-level semantics are available in SQL Server 2012. Three of them support only pessimistic concurrency: Read Uncommitted, Repeatable Read, and Serializable. Snapshot isolation level supports optimistic concurrency. The default isolation level, Read Committed, can support either optimistic or pessimistic concurrency, depending on a database setting.

The behavior of your transactions depends on the isolation level and the concurrency model you are working with.

A complete understanding of isolation levels also requires an understanding of locking because the topics are so closely related.

Locking operations Locking is a crucial function. SQL Server lets you manage multiple users simultaneously and ensures that the transactions observe the properties of the chosen isolation level. Even though readers don't block writers and writers don't block readers in snapshot isolation, writers do acquire locks and can still block other writers, and if two writers try to change the same data concurrently, a conflict occurs that must be resolved.

Read the book related to this topic.

2.4. Services of the SQL Server

2.4.1. Service Broker

SQL Server BrowserOne related service that deserves special attention is the SQL Server Browser service, particu-larly important if you have named instances of SQL Server running on a machine. SQL Server Browser listens for requests to access SQL Server resources and provides information about the various SQL Server instances installed on the computer where the Browser service is running.Prior to SQL Server 2000, only one installation of SQL Server could be on a machine at one time, and the concept of an "instance" really didn't exist.SQL Server always listened for incom-ing requests on port 1433, but any port can be used by only one connection at a time. When SQL Server 2000 introduced support for multiple instances of SQL Server, a new protocol called SQL Server Resolution Protocol (SSRP) was developed to listen on UDP port 1434. This listener could reply to clients with the names of installed SQL Server instances, along with the port numbers or named pipes used by the instance. SQL Server 2005 replaced SSRP with the SQL Server Browser service, which is still used in SQL Server 2012.If the SQL Server Browser service isn't running on a computer, you can't connect to SQL Server on that machine unless you provide the correct port number. Specifically, if the SQL Server Browser service isn't running, the following connections won't work:

- Connecting to a named instance without providing the port number or pipe
- Using the DAC to connect to a named instance or the default instance if it isn't us-ing TCP/IP port 1433
- Enumerating servers in SQL Server Management Studio. You are recommended to have the Browser service set to start automatically on any machine on which SQL Server will be accessed using a network connection.

2.5. SQL Server system configuration

Although discussing operating system and hardware configuration and tuning is beyond the scope of this book, a few issues are very straightforward but can have a major effect on the performance of SQL Server.

2.6. SQL Server configuration settings

SQL Server 2012 has 69 server configuration options that you can query, using the catalog view sys.configurations. You should change configuration options only when you have a clear reason for doing so and closely monitor the effects of each change to determine whether the change improved or degraded performance. You first need to change the show advanced options setting to be 1:

```
EXEC sp_configure 'show advanced options', 1; RECONFIGURE;
GO
```

To see which options are advanced, you can query the sys.configurations view and examine a column called is_advanced, which lets you see which options are considered advanced:

```
SELECT * FROM sys.configurations
WHERE is_advanced = 1;
GO
```

If you use the sp_configure stored procedure, no changes take effect until the RECONFIGURE command runs. In some cases, you might have to specify RECONFIGURE WITH OVERRIDE if you are changing an option to a value outside the recommended range. Dynamic changes take effect immediately on reconfiguration, but others don't take effect until the server is restarted. If after running RECONFIGURE an option's run_value and config_value as displayed by sp_configure are different, or if the value and value_in_use in sys.configurations are different, you must restart the SQL Server service for the new value to take effect. You can use the sys.configurations view to determine which options are dynamic:

```
SELECT * FROM sys.configurations
WHERE is_dynamic = 1;
GO
```

2.6.1. Memory Options

Min Server Memory and Max Server Memory By default, SQL Server adjusts the total amount of the memory resources it will use. However, you can use the Min Server Memory and Max Server Memory configuration options to take manual control. The default setting for Min Server Memory is 0 MB, and the default setting for Max Server Memory is 2147483647.

2.6.2. Scheduling options

SQL Server 2012 has a special algorithm for scheduling user processes using the SQLOS, which manages one scheduler per logical processor and ensures that only one process can run on a scheduler at any specific time. The SQLOS manages the assignment of user connections to workers to keep the number of users per CPU as balanced as possible.

Five configuration options affect the behavior of the scheduler: **Lightweight Pooling, Affinity Mask, Affinity64 Mask, Priority Boost, and Max Worker Threads.**

- **Lightweight Pooling** By default, SQL Server operates in thread mode, which means that the workers processing SQL Server requests are threads. As described earlier, SQL Server also lets user connections run in fiber mode. Fibers are less expensive to manage than threads. The Lightweight Pooling option can have a value of 0 or 1; 1 means that SQL Server should run in fiber mode. Using fibers can yield a minor performance advantage, particularly when you have eight or more CPUs and all available CPUs are operating at or near 100 percent. However, the tradeoff is that certain operations, such as running queries on linked servers or executing extended stored procedures, must run in thread mode and therefore need to switch from fiber to thread. The cost of switching from fiber to thread mode for those connections can be noticeable and in some cases offsets any benefit of operating in fiber mode. If you're running in an environment that uses a high percentage of total CPU resources, and if System Monitor shows a lot of context switching, setting Lightweight Pooling to 1 might yield some performance benefit.
- **Max Worker Threads** SQL Server uses the operating system's thread services by keeping a pool of workers (threads or fibers) that take requests from the queue. It attempts to divide the worker threads evenly among the SQLOS schedulers so that the number of threads available to each scheduler is the Max Worker Threads setting divided by the number of CPUs. Having 100 or fewer users means having usually as many worker threads as active users (not just connected users who are idle). With more users, having fewer worker threads than active users often makes sense. Although some user requests have to wait for a worker thread to become available, total throughput increases because less context switching occurs. The Max Worker Threads default value of 0 means that the number of workers is configured by SQL Server, based on the number of processors and machine architecture. For example, for a four-way 32-bit machine running SQL Server, the default is 256 workers. This doesn't mean that 256 workers are created on startup. It means that if a connection is waiting to be serviced and no worker is available, a new worker is created if the total is now below 256. If, for example, this setting is configured to 256 and the highest number of simultaneously executing commands is 125, the actual number of workers won't exceed 125. It might be even smaller than that because SQL Server destroys and trims away workers that are no longer being used. You should probably leave this setting alone if your system is handling 100 or fewer simultaneous connections. In that case, the worker thread pool won't be greater than 100. Table below lists the default number of workers, considering your machine architecture and number of processors. (Note that Microsoft recommends 1,024 as the maximum for 32-bit operating systems.)

Default settings for Max Worker Threads

TABLE 1-2 Default settings for Max Worker Threads

CPU	32-bit computer	64-bit computer
Up to 4 processors	256	512
8 processors	288	576
16 processors	352	704
32 processors	480	960

Even systems that handle 5,000 or more connected users run fine with the default setting. When thousands of users are simultaneously connected, the actual worker pool is usually well below the Max Worker Threads value set by SQL Server because from the perspective of the database, most connections are idle even if the user is doing plenty of work on the client.

2.6.3. Disk I/O options

No options are available for controlling the disk read behavior of SQL Server. All tuning options to control read-ahead in previous versions of SQL Server are now handled completely internally. One option is available to control disk write behavior; it controls how frequently the checkpoint process writes to disk.

Recovery interval This option can be configured automatically. SQL Server setup sets it to 0, which means autoconfiguration. In SQL Server 2012, this means that the recovery time should be less than one minute.

This option lets database administrators control the checkpoint frequency by specifying the maximum number of minutes that recovery should take, per database. SQL Server estimates how many data modifications it can roll forward in that recovery time interval. SQL Server then inspects the log of each database (every minute, if the recovery interval is set to the default of 0) and issues a checkpoint for each database that has made at least that many data modification operations since the last checkpoint. For databases with relatively small transaction logs, SQL Server issues a checkpoint when the log becomes 70 percent full, if that is less than the estimated number.

The frequency of checkpoints in each database depends on the amount of data modifications made, not on a time-based measure. So a database used primarily for read operations won't have many checkpoints issued. To avoid excessive checkpoints, SQL Server tries to ensure that the value set for the recovery interval is the minimum amount of time between successive checkpoints.

SQL Server provides a new feature called indirect checkpoints that allow the configuration of checkpoint frequency at the database level using a database option called TARGET_RECOVERY_TIME.

As you'll see, most writing to disk doesn't actually happen during checkpoint operations. Checkpoints are just a way to guarantee that all dirty pages not written by other mechanisms are still written to the disk in a timely manner. **For this reason, you should keep the checkpoint options at their default values.**

Affinity I/O Mask and Affinity64 I/O Mask These two options control the affinity of a processor for I/O operations and work in much the same way as the two options for controlling processing affinity for workers. Setting a bit for a processor in either of these bitmasks means that the corresponding processor is used only for I/O operations.You'll probably never need to set these options.

These are some options to reduce the I/O **Backup Compression DEFAULT**, **Filestream access level**.

2.7. Query Processing Options

SQL Server has several options for controlling the resources available for processing queries. As with all the other tuning options, your best bet is to leave the default values unless thorough testing indicates that a change might help.

- **Min Memory Per Query** When a query requires additional memory resources, the number of pages that it gets is determined partly by this option. This option is relevant for sort operations that you specifically request using an ORDER BY clause; it also applies to internal memory needed by merge-join operations and by hash-join and hash-grouping operations. This configuration option allows you to specify a minimum amount of memory (in kilobytes) that any of these operations should be granted before they are executed. Sort, merge, and hash operations receive memory very dynamically, so you rarely need to adjust this value.
- **Query wait** This option controls how long a query that needs additional memory waits if that memory isn't available. A setting of –1 means that the query waits 25 times the estimated execution time of the query, but it always waits at least 25 seconds with this setting. A value of 0 or more specifies the number of seconds that a query waits. If the wait time is exceeded, SQL Server generates error 8645: Server: Msg 8645, Level 17, State 1, Line 1. A time out occurred while waiting for memory resources to execute the query. Re-run the query.

Keep in mind that this option affects only queries that have to wait for memory needed by hash and merge operations. Queries that have to wait for other reasons aren't affected.

- **Blocked Process Threshold** This option allows administrators to request a notification when a user task has been blocked for more than the configured number of seconds. When Blocked Process Threshold is set to 0, no notification is given. You can set any value up to 86,400 seconds.

When the deadlock monitor detects a task that has been waiting longer than the configured value, an internal event is generated. You can choose to be notified of this event in one of two ways. You can create an Extended Events session to capture events of type blocked_process_report. As long as a resource stays blocked on a deadlock-detectable resource, the event is raised every time the deadlock monitor checks for a deadlock.

Alternatively, you can use event notifications to send information about events to a service broker service. You also can use event notifications, which execute asynchronously, to perform an action inside a SQL Server 2012 instance in response to events, with very little consumption of memory resources. Because event notifications execute asynchronously, these actions don't consume any resources defined by the immediate transaction.

- **Index Create Memory** The Min Memory Per Query option applies only to sorting and hashing used during query execution; it doesn't apply to the sorting that takes place during index creation. Another option, Index Create Memory, lets you allocate a specific amount of memory (in kilobytes) for index creation.
- **Query Governor Cost Limit** You can use this option to specify the maximum number of seconds that a query can run. If you specify a non-zero, non-negative value, SQL Server disallows execution of any query that has an estimated cost exceeding that value. Specifying 0 (the default) for this option turns off the query governor, and all queries are allowed to run without any time limit.
- **Max Degree Of Parallelism and Cost Threshold For Parallelism** SQL Server 2012 lets you run certain kinds of complex queries simultaneously on two or more processors. The queries must lend themselves to being executed in sections; the following is an example:

```
SELECT AVG(charge_amt), category FROM charge GROUP BY category
```

If the charge table has 1 million rows and 10 different values for category, SQL Server can split the rows into groups and have only a subset of them processed on each processor. For example, with a four-CPU machine, categories 1 through 3 can be averaged on the first processor, categories 4 through 6 can be averaged on the second processor, categories 7 and 8 can be averaged on the third, and categories 9 and 10 can be averaged on the fourth. Each processor can come up with averages for only its groups, and the separate averages are brought together for the final result.

During optimization, the Query Optimizer always finds the cheapest possible serial plan before considering parallelism. If this serial plan costs less than the configured value for the Cost Threshold For Parallelism option, no parallel plan is generated. Cost Threshold For Parallelism refers to the cost of the query in seconds; the default value is 5. (As in the preceding section, this isn't an exact clock-based number of seconds.) If the cheapest serial plan costs more than this configured threshold, a parallel plan is produced based on assumptions about how many processors and how much memory will actually be available at runtime. This parallel plan cost is compared with the serial plan cost, and the cheaper one is chosen. The other plan is discarded.

A parallel query execution plan can use more than one thread; a serial execution plan, used by a nonparallel query, uses only a single thread. The actual number of threads used by a parallel query is determined at query plan execution initialization and is the Degree of Parallelism (DOP). The decision is based on many factors, including the Affinity Mask setting, the Max Degree Of Parallelism setting, and the available threads when the query starts executing.

You can observe when SQL Server is executing a query in parallel by querying the DMV sys.dm_os_tasks. A query running on multiple CPUs has one row for each thread, as follows:

```
SELECT
task_address, task_state, context_switches_count, pending_io_cour
scheduler_id, session_id, exec_context_id, request_id, worker_ad(
FROM sys.dm_os_tasks
ORDER BY session_id, request_id;
```

3. REsource Governor

3.1 Code example

```
--- Create a resource pool for production processing and set limits.
USE master;
GO
CREATE RESOURCE POOL pProductionProcessing
WITH
(
    MAX_CPU_PERCENT = 100,
    MIN_CPU_PERCENT = 50
);
GO

-- Create a workload group for production processing and configure t
CREATE WORKLOAD GROUP gProductionProcessing
WITH(IMPORTANCE = MEDIUM)

-- Assign the workload group to the production processing resource p
USING pProductionProcessing;
GO
-- Create a resource pool for off-hours processing and set limits.
CREATE RESOURCE POOL pOffHoursProcessing
WITH
(
    MAX_CPU_PERCENT = 50,
    MIN_CPU_PERCENT = 0
);
GO

-- Create a workload group for off-hours processing and configure th
CREATE WORKLOAD GROUP gOffHoursProcessing
WITH(IMPORTANCE = LOW)

-- Assign the workload group to the off-hours processing resource po
USING pOffHoursProcessing;
GO
-- Any changes to workload groups or resource pools require that the
ALTER RESOURCE GOVERNOR RECONFIGURE;
GO

USE master;
GO
CREATE TABLE tblClassifierTimeTable (
strGroupName sysname not null,
tStartTime time not null,
tEndTime time not null
);
GO

-- Add time values that the classifier will use to determine the wor
INSERT into tblClassifierTimeTable VALUES('gProductionProcessing',
GO

-- Create the classifier function
```

```
CREATE FUNCTION fnTimeClassifier()
RETURNS sysname
WITH SCHEMABINDING
AS
BEGIN
    DECLARE @strGroup sysname
    DECLARE @loginTime time

    SET @loginTime = CONVERT(time,GETDATE())

    SELECT TOP 1 @strGroup = strGroupName
    FROM dbo.tblClassifierTimeTable
    WHERE tStartTime <= @loginTime and tEndTime >= @loginTime

    IF(@strGroup is not null)
    BEGIN
        RETURN @strGroup
    END

    -- Use the default workload group if there is no match on the lo
    RETURN N'gOffHoursProcessing'
END;
GO

-- Reconfigure the Resource Governor to use the new function
ALTER RESOURCE GOVERNOR with (CLASSIFIER_FUNCTION = dbo.fnTimeClass:
ALTER RESOURCE GOVERNOR RECONFIGURE;
GO
```

3.2 Resource Governor metadata

You want to consider three specific catalog views when working with the Resource Governor.

- [sys.resource_governor_configuration] This view returns the stored Resource Governor state
- [sys.resource_governor_resource_pools] This view returns the stored resource pool configuration. Each row of the view determines the configuration of an individual pool.
- [sys.resource_governor_workload_groups] This view returns the stored workload group configuration.

Also, three DMVs are devoted to the Resource Governor.

- [sys.dm_resource_governor_workload_groups] This view returns workload group statistics and the current in-memory configuration of the workload group.
- [sys.dm_resource_governor_resource_pools] This view returns information about the current resource pool state, the current configuration of resource pools, and resource pool statistics.

- [sys.dm_resource_governor_configuration] This view returns a row that contains the current in-memory configuration state for the Resource Governor.

Finally, six other DMVs contain information related to the Resource Governor.

- [sys.dm_exec_query_memory_grants] This view returns information about the queries that have acquired a memory grant or that still require a memory grant to execute. Queries that don't have to wait for a memory grant don't appear in this view. The following columns are added for the Resource Governor: group_id, pool_id, is_small, and ideal_memory_kb.
- [sys.dm_exec_query_resource_semaphores] This view returns the information about the current query-resource semaphore status.
- [sys.dm_exec_sessions] This view returns one row per authenticated session on SQL Server.
- [sys.dm_exec_requests] This view returns information about each request executing within SQL Server.
- [sys.dm_exec_cached_plans] This view returns a row for each query plan cached by SQL Server for faster query execution.
- [sys.dm_os_memory_brokers] This view returns information about allocations internal to SQL Server that use the SQL Server Memory Manager. The following columns are added for the Resource Governor: pool_id, allocations_kb_per_sec, predicated_allocations_kb, and overall_limit_kb.

4. Extended Events

- Core Concepts Extended Events uses two-part naming for all objects that can be used in defining an event session. Objects are referenced by package name and the object name. In SQL Server 2012 there are seven packages for use by event sessions. The packages and objects in Extended Events available for use in user-defined event sessions can be determined using the capabilities column within the DMV, which will either be NULL or will return a value of 0 for a bitwise AND operation for a value of 1:

  ```
  SELECT *
  FROM sys.dm_xe_packages AS p
  WHERE (p.capabilities IS NULL
  OR p.capabilities & 1 = 0);
  ```

- Events Events correspond to well-known points in SQL Server code. The following query lists of all events available in SQL Server 2012 from the sys.dm_xe_objects metadata view:

```sql
SELECT p.name AS package_name,
o.name AS event_name,
o.description
FROM sys.dm_xe_packages AS p
INNER JOIN sys.dm_xe_objects AS o
ON p.guid = o.package_guid
WHERE (p.capabilities IS NULL
OR p.capabilities & 1 = 0)
AND (o.capabilities IS NULL
OR o.capabilities & 1 = 0)
AND o.object_type = N'event';
```

Events in XE are categorized using the Event Tracing for Windows (ETW) method of categorizing events—using channels and keywords. The channel specifies the type of event and can be Admin, Analytic, Debug, or Operational. The following describes each event channel.

- Admin events are expected to be of most use to systems administrators. This channel includes events such as error reports and deprecation announcements.
- Analytic events fire regularly—potentially thousands of times per second on a busy system—and are designed to be aggregated to support analysis about system performance and health. This channel includes events around topics such as lock acquisition and SQL statements starting and completing.
- Debug events are expected to be used by DBAs and support engineers to help diagnose and solve engine-related problems. This channel includes events that fire when threads and processes start and stop, various times throughout a scheduler's life cycle, and for other similar themes.
- Operational events are expected to be of most use to operational DBAs for managing the SQL Server service and databases. This channel's events relate to databases being attached, detached, started, and stopped, as well as issues such as the detection of database page corruption.

- Actions Actions in Extended Events provide the capability to execute additional operations when an event fires inside the engine. The most common usage of actions is to add global state data to a firing event—for example, session_id, nt_username, client_app_name, query_hash, query_plan_hash, and many others. To see a list of the available actions, you should query sys.dm_xe_objects:

```
SELECT p.name AS package_name,
o.name AS action_name,
o.description
FROM sys.dm_xe_packages AS p
INNER JOIN sys.dm_xe_objects AS o
ON p.guid = o.package_guid
WHERE (p.capabilities IS NULL
OR p.capabilities & 1 = 0)
AND (o.capabilities IS NULL
OR o.capabilities & 1 = 0)
AND o.object_type = N'action';
```

- Predicates Predicates provide the ability to filter the events during event execution. Predicates can be defined by using events data columns or against global state data exposed as pred_source objects in the Extended Events metadata. The available pred_source objects can be found in sys.dm_xe_objects using the following query:

```
SELECT p.name AS package_name,
o.name AS source_name,
o.description
FROM sys.dm_xe_objects AS o
INNER JOIN sys.dm_xe_packages AS p
ON o.package_guid = p.guid
WHERE (p.capabilities IS NULL
OR p.capabilities & 1 = 0)
AND (o.capabilities IS NULL
OR o.capabilities & 1 = 0)
AND o.object_type = N'pred_source';
```

Predicates in Extended Events also can be defined using common Boolean expressions similar to the standard syntax used in Transact-SQL WHERE clause criteria. However, Extended Events also contains 77 comparison functions in SQL Server 2012 that you can use for defining the filtering criteria for events in text. These comparison functions are exposed as pred_compare objects in the metadata and can be found in sys.dm_xe_objects using the following query:

```sql
SELECT p.name AS package_name,
o.name AS source_name,
o.description
FROM sys.dm_xe_objects AS o
INNER JOIN sys.dm_xe_packages AS p
ON o.package_guid = p.guid
WHERE (p.capabilities IS NULL
OR p.capabilities & 1 = 0)
AND (o.capabilities IS NULL
OR o.capabilities & 1 = 0)
AND o.object_type = N'pred_compare';
```

- Types and Maps In Extended Events, two kinds of data types can be defined: scalar types and maps. A scalar type is a single value—something like an integer, a single Unicode character, or a binary large object. A map, on the other hand, is very similar to an enumeration in most object-oriented systems. Types and maps, like the other objects, are visible in the sys.dm_xe_objects DMV. To see a list of both types and maps supported by the system, use the following query:

  ```sql
  SELECT *
  FROM sys.dm_xe_objects
  WHERE object_type IN (N'type', N'map');
  ```

  The following query returns all the wait types exposed by the SQL Server engine, along with the map keys (the integer representation of the type) used within Extended Events that describe waits:

  ```sql
  SELECT *
  FROM sys.dm_xe_map_values
  WHERE name = N'wait_types';
  ```

- Targets After all this takes place, the final package of event data needs to go somewhere to be collected. This destination for event data is one or more targets. The list of available targets can be seen by running the following query:

```sql
SELECT p.name AS package_name,
o.name AS target_name,
o.description
FROM sys.dm_xe_packages AS p
INNER JOIN sys.dm_xe_objects AS o ON p.guid = o.package_guid
WHERE (p.capabilities IS NULL
OR p.capabilities & 1 = 0)
AND (o.capabilities IS NULL
OR o.capabilities & 1 = 0)
AND o.object_type = N'target';
```

Extended Events targets can be classified into two different types of operations: data collecting and data aggregating.

5. Extended Events DDL and querying

- Creating an event session The primary DDL hook for Extended Events is the CREATE EVENT SESSION statement, which allows you to create sessions and map all the various Extended Events objects. An ALTER EVENT SESSION statement also exists, allowing you to modify a session that has already been created. The following T-SQL statement creates a session and shows how to configure all the Extended Events features and options reviewed in this chapter:

```sql
CREATE EVENT SESSION [statement_completed]
ON SERVER
ADD EVENT
sqlserver.sp_statement_completed
( ACTION (sqlserver.session_id)
WHERE (sqlserver.is_system = 0)),
ADD EVENT
sqlserver.sql_statement_completed
( ACTION (sqlserver.session_id)
WHERE (sqlserver.is_system = 0))
ADD TARGET
package0.ring_buffer
( SET max_memory=4096)
WITH
( MAX_MEMORY = 4096KB,
EVENT_RETENTION_MODE = ALLOW_SINGLE_EVENT_LOSS,
MAX_DISPATCH_LATENCY = 1 SECONDS,
MEMORY_PARTITION_MODE = NONE,
TRACK_CAUSALITY = OFF,
STARTUP_STATE = OFF);
```

The session is called statement_completed, and two events are bound: sp_statement_completed and sql_statement_completed, both exposed by the sqlserver package. These events fire inside the engine whenever a stored procedure, function, or trigger statement completes execution or when a SQL statement completes inside a SQL batch, respectively. Both events collect the session_id action when they fire, and they have been filtered on the is_system pred_source object to exclude system sessions from generating events. When the sql_statement_completed event fires for session ID 53, the event session invokes the session_id action. This action collects the session_id of the session that executed the statement that caused the event to fire and adds it to the event's data. After the event data is collected, it's pushed to the ring_buffer target, which is configured to use a maximum of 4,096 KB of memory. Some session-level options have also been configured. The session's asynchronous buffers can't consume more than 4,096 KB of memory, and if they fill up, events are allowed to be dropped. That's probably not likely to happen, though, because the dispatcher has been configured to clear the buffers every second. Because memory isn't partitioned across CPUs, three buffers are the result. Also, causality tracking isn't in use. Finally, after the session is created, it exists only as metadata; it doesn't start until the following statement is issued:

```
ALTER EVENT SESSION [statement_completed]
ON SERVER
STATE=START;
```

- Querying eent data everything is on XML so you have to use XQuery and T-SQL Below query is an example of querying data from an EX

```
SELECT
ed.value('(@name)[1]', 'varchar(50)') AS event_name,
ed.value('(data[@name="source_database_id"]/value)[1]', 'bigint') AS
ed.value('(data[@name="object_id"]/value)[1]', 'bigint') AS object_
ed.value('(data[@name="object_type"]/value)[1]', 'bigint') AS objec
COALESCE(ed.value('(data[@name="cpu"]/value)[1]', 'bigint'),
ed.value('(data[@name="cpu_time"]/value)[1]', 'bigint')) AS cpu,
ed.value('(data[@name="duration"]/value)[1]', 'bigint') AS duration
COALESCE(ed.value('(data[@name="reads"]/value)[1]', 'bigint'),
ed.value('(data[@name="logical_reads"]/value)[1]', 'bigint')) AS rea
ed.value('(data[@name="writes"]/value)[1]', 'bigint') AS writes,
ed.value('(action[@name="session_id"]/value)[1]', 'int') AS session_
ed.value('(data[@name="statement"]/value)[1]', 'varchar(50)') AS st
FROM
(
SELECT
CONVERT(XML, st.target_data) AS target_data
FROM sys.dm_xe_sessions s
INNER JOIN sys.dm_xe_session_targets st ON
s.address = st.event_session_address
WHERE s.name = N'statement_completed'
AND st.target_name = N'ring_buffer'
) AS tab
CROSS APPLY target_data.nodes('//RingBufferTarget/event') t(ed);
```

You can also read from the event_file target via T-SQL, using the sys.fn_xe_file_target_read_file table-valued function.

- Stopping an removing the event session Stopping and removing the event session After you finish reading data from the event session, it can be stopped using the following code:

```
ALTER EVENT SESSION [statement_completed]
ON SERVER
STATE=STOP;
```

Stopping the event session doesn't remove the metadata. To eliminate the session from the server completely, you must drop it using the following statement:

```
DROP EVENT SESSION [statement_completed]
ON SERVER;
```

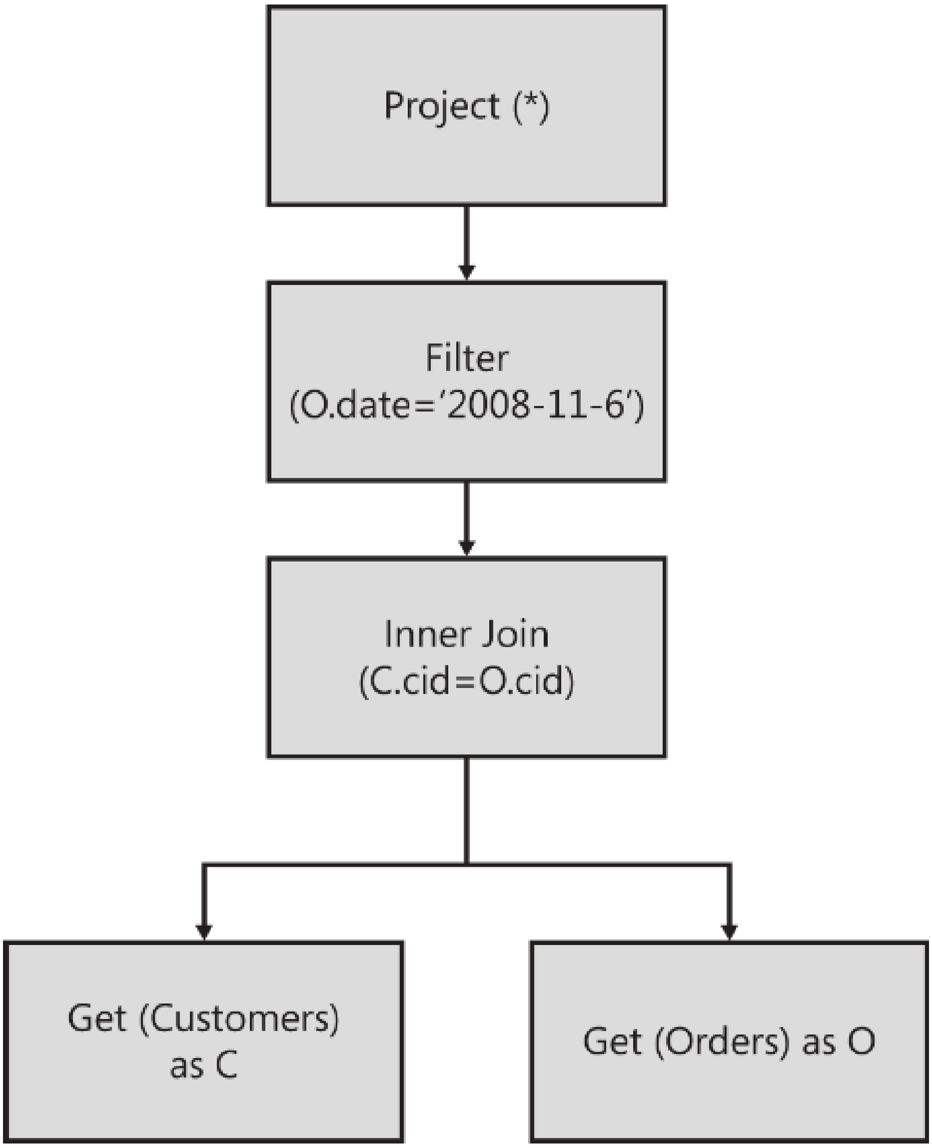
6.

[Cap 11] The Query Optimizer

- Overview When a query is compiled, the SQL Statement is first parsed into an equivalent tree representartion. For queries witht valid SQL syntax, the next stage performs a series of validation steps on the query, generally called binding, where the columns and tablesin the tree are compared to databases metadata to ensure that those columns and tables exist and are visible to the current user. This stage also performs semantic checks on the query to ensure that it's valid, such as making sure that the columns bound to a GROUP BY operation are valid. After the query tree is bound and is determined to be a valid quert, the Query Optimizer takes the query and start evaluating different possible quer plans. The query optimizer perform this serach, selects the query plan to be executed, and then returns it to the system to execute. The execution component runs the query plan and returns the query results.
- Understanding the tree format When you submit a SQL query to the query processor, the SQL string is parsed into a tree representation. Each mode in the tree represents a query operation to be performed. For example, the query

```
SELECT * FROM Customers C INNER JOIN Orders O ON C.cid = O.cid WHERI
```

might be represented internally as:



- Understanding optimization Another major job of the Query Optimizer is to find an efficient query plan. At first you might think that every SQL query would have an obvious best plan. Unfortunatelly, finding an optimal query plan is actually a much more difficult algorithmic problem for SQL Server. As the number of tables increases, the set of alternatives to consider quicly grows to be larger than what any computer can count. The storage of all possible query plans also becomes a problem. The Query Optimizer solves this problem using heuristics and statistics to guide those heuristics.
- Search space and heuristics The QO uses a framework to search and compare many different possible plan alternative efficiently.
    - Rules The QO is a search framework. The QO considers transformation of a spacefic query tree from the current state to a different. In the framework used in SQL Server, the transformations are done via RULES, wich are very similar to the mathematical theorems. Rules are matches to tree patterns and are the applied if they are suitable to generate new alternatives. The QO has different kinds of RULES:

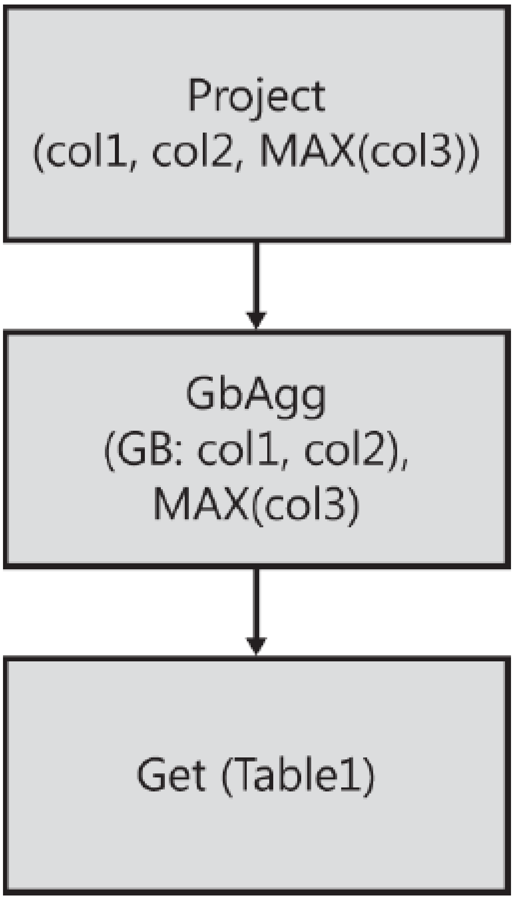
1. Riles that heuristically rewrite a query tree into a new shape are called SUBSTITUTION RULES
2. Rules that consider mathematical equivalences are called EXPLIRATION RULES. These rules generate new tree shapes but can't be directly executed.
3. Rules that convert logical trees into physical tress to be executed are called IMPLEMENTATION RULES.

The best of these generated physical alternatives from implementation rules is eventually output by the QO as the final query execution plan.

- Properties The serach framework collects information about the query tree in a format that can make it easier for rules to work. For example, one property used in SQL Server is the set of columns that maje up a UQ on the data. Consider the following query:

```sql
SELECT col1, col2, MAX(col3) FROM Table1 GROUP BY col1, c
```

This query is represented internally as a tree, as show below:



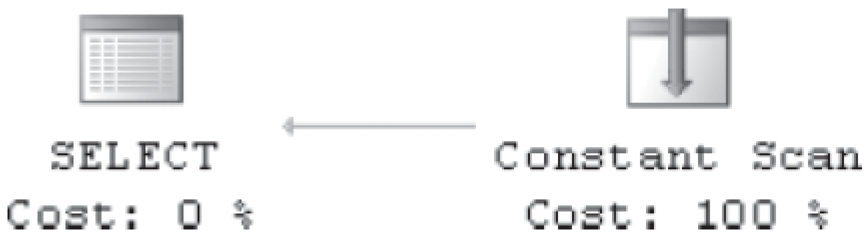
If the columns (col1, col2) make up a unique key on table groupby, doing grouping isn't necessary at all because each group has exactly one row. So, writing a rule that removes the groupby from the query tree completely is possible. Figure below shows this rule in action

```
CREATE TABLE groupby (col1 int, col2 int, col3 int);
ALTER TABLE groupby ADD CONSTRAINT unique1 UNIQUE(col1, col2);
SELECT col1, col2, MAX(col3) FROM groupby GROUP BY col1, col2;
```

By looking at the final query plan you can see that the QO performs no grouping operation, even though the query uses a GROUP BY. The properties collected during optimization enable this rule to perform a trees transformation to maje the resulting query plan complete more quicly.

One useful app of this scalar property is in CONTRADICTION DETECTION. The QO can determine whether the query is written in such a way as to never return any rows at all. When the QO detects a contradiction, it reqrites the query to remove the portion of the query containing the contradiction. Figure below shows an example of a contradiction detected during optimization.

```
CREATE TABLE DomainTable(col1 int);
GO
SELECT *
FROM DomainTable D1
INNER JOIN DomainTable D2
ON D1.col1=D2.col1
WHERE D1.col1 > 5 AND D2.col1 < 0;
```



The final query plan doesn't even reference the table at all; it's replaced with a special Constant Scan operator that doesn't access the storage engine and, in this case, returns zero rows. This means that the query runs faster, consumes less memory, and doesn't need to acquire locks against the resources referenced in the section containing the contradiction when being executed.

Like with rules, both logical and physical properties are available.

        - Logical properties cover things like the output column set, key columns, and whether or not a column can output any nulls.
        - Physical properties are specific to a single plan, and each plan operator has a set of physical properties associated with it.
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