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Optimizing Transaction Performance in Adaptive Server® Enterprise 12.5

A Technical White Paper

WHITE PAPER

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1. Overview

The transaction logging subsystem is one of the most critical components of a database server. To be able to accomplish the goal of providing recoverability of databases, transactions write log records to persistent storage. Since a number of such log record writes is directly dependent on the number of executing transactions, the logging system can potentially become a bottleneck in high throughput OLTP environments. All the users working on a particular database share the log; thus, to guarantee high performance of the application, it is essential for the DBA to monitor and configure the log to provide for best throughput and response time of the application. Out-of-the-box, Adaptive Server Enterprise (ASE) already provides a high performance logging subsystem that scales to thousands of users and very large database (VLDB) environments. ASE also provides options for the DBA to customize the logging subsystem to satisfy their unique environments for best throughput and response times.

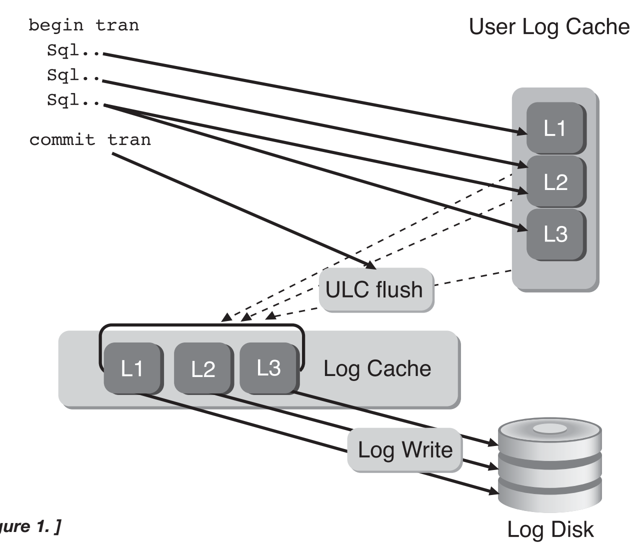
There are two aspects of optimizing the logging subsystem.

1. To follow the best practices in writing SQL applications to use the logging subsystem efficiently.
2. To configure and tune the logging subsystem to get the best performance out of it.

The former is the responsibility of application designer while the later is the responsibility of the database administrators. In this paper we discuss only the aspects pertaining to system configuration, which is the latter part.

ASE provides a rich set of options to monitor and configure the logging subsystem for high throughput OLTP systems. Apart from implementing various cutting edge solutions to resolve logging contentions, ASE allows the administrator to fine tune the logging subsystem to suit the application behavior and requirements. In this paper, we present the ASE logging subsystem architecture and explain how one can monitor and tune the subsystem to get the best performance out of it.

2. Transaction Logging Subsystem



[Figure 1.]

Figure 1 illustrates how traditional logging is done in ASE. Each user task has a private log cache, which it uses to save the log records during transaction processing. This is known as the **User Log Cache** (ULC). The User Log Cache is private to the task and not visible to other tasks. ULC eliminates the need to insert every log record to the shared log cache. This resolves a major contention that would have otherwise been caused by every task trying to insert their log record into the shared log cache. Figure 1 shows that the user transaction has populated 3 log pages, L1-L3 in the ULC.

During the commit operation, these pages are first transferred to the shared log cache. To do so, the user task acquires a lock guarding the end of the log and then copies the contents of the ULC to the shared log cache. This is the only time tasks contend to acquire lock on the log. This operation is known as ULC flush. Once the flush is complete, the task releases the log lock and then proceeds to write these pages to the disk. It does so by walking through all the dirty pages in the shared log cache and issuing writes on those pages. Once the writes complete the task returns indicating the completion of the "commit" operation. In case of transaction abort or system crash, the log will be read to perform undo operations to reverse any modification caused by this transaction.

There are three kinds of resources involved in the transaction logging subsystem. They are:

- **Log Device**
- **Shared Log Cache**
- **ULC**

It is essential to understand how these resources are consumed and manipulated, so that one can configure them properly.

3. Log Device

It is vital for the response time and throughput of an application to properly configure the log device. One of the main characteristics of logging, is that data is written in a sequential fashion.

3.1 Selecting the Disk Device

Log disks demand faster response time than the data devices. It is best to have log disk service time well under 5 milliseconds. With the ever increasing speed of CPUs, OLTP applications can hit the throughput ceiling very quickly with a slow log disk. Here are some of the best practices to follow while choosing the log disk.

- RAID 0/1 array with controller having NV RAM to cache the write data
- Stripe size of the RAID being same or less than log page size (i.e. if log page size is 2K, you can have stripe size being 2k or 1k)
- For best results, the log should be kept on a separate physical disk. Since data access is random in nature, mixing log and data together can cause excessive disk arm movement. Such irregular arm movements can result in longer latency and service time. Any delay in writing log pages can cause critical resources like locks held for longer time
- It is recommended to use ‘raw devices’ instead of file systems to host logs. By its nature, log is a write intensive device and file system performs poorly when there are more writes than reads
- It is recommended to keep the log device under a separate controller to eliminate any operating system or device contention

3.2 Log Page Size

Selecting database page size has a direct impact on the performance, because of its direct influence on the number of log pages generated. If server page size is 2k and if each transaction generates a large number of log pages, then the server will be issuing too many log page writes. In such cases, increase the page size to see if the number of I/Os (including the log page) go down. It is very important to note that by increasing the page size for the database, we not only affect the I/O on the log pages, but also on the data pages.

On the other hand with a large page size, if the system is not writing enough log records to fill the log page, then the server may be issuing writes on the last log page more than once. Writing a half-filled last log pages can cause context switches to the task. The ASE logging system has group commit algorithm in place to reduce the number of such partial writes on the last log page. But if the page fills too slowly, then it is not practical to delay writing the last log page until it is completely filled. So, it is essential to pick the proper page size based on the rate at which the log pages are filled.

3.3 Log on a Separate Database Device

Transaction log writes occur frequently so it is imperative that the log device does not contend with other I/O in the database, which is typically random in nature. It is recommended that log be kept on a separate database device backed by an isolated disk underneath. Keeping data and log on the same device can result in:

- Writes mixed with reads
- Irregular write pattern causing longer disk latency
- Server issuing writes to ensure consistency when trying to maintain log and data on the same device

3.4 Guidelines for Configuring Log Disks

- Make sure that log disk is isolated from other data disks and has optimal response time; it is recommended to have a hardware level redundancy to ensure recoverability (ex. Hardware RAID 0/1)
- Select appropriate database page size based on the transaction throughput and number of log pages generated by individual transactions
- Always keep log on separate database device

4. Log Cache Configuration

The log cache represents the working set of log pages in memory. If no named cache were configured for the transaction log, the log pages would reside in the "default data cache". **However, having the log pages reside in the default data cache can result in poor response time under a high throughput OLTP environment.** This is because the log pages may replace data pages residing in the cache. To avoid such I/Os, it is recommended to bind log to its own cache and keep it separate from the data pages. The following snippet shows how it can be done.

First, configure a cache for the log by putting the following options in the server configuration file:

```
[Named Cache:log_cache]
            cache size = <SIZE>
            cache status = log only
            cache replacement policy = DEFAULT
            local cache partition number = 1
```

Bind the cache to the log by doing the following:

```
sp_bindcache "log_cache", <DBNAME>, "syslogs"
go
```

Note, that the database has to be put in "single user" mode and checkpoint needs to be issued once this option is set.

Size of the log cache depends on the transaction rate and the response time for rollbacks. Larger cache size will help to reduce the transaction rollback response time, as it can potentially cache a large part of the log pages required for the rollback.

It is best recommended to set "local cache partition" for the "log cache" to 1 owing to the serial nature of the log.

4.1 Configuring the Log I/O Size

Log I/O size specifies the unit of I/O on the transaction logs. To accomplish a particular unit of log I/O, the cache for the transaction log would need to be configured with the appropriate pool size. In general, high throughput OLTP systems stand to benefit doing larger units of I/O for the transaction log. ASE provides an easy mechanism to configure a different I/O size for the log independent of I/O size for data pages.
The following section provides some guidelines on how to determine the ideal log I/O size for a production environment. Running sp_sysmon against the production system can provide clues on what needs to be done. Based on the report generated by sp_sysmon, one can make inferences on tuning the log I/O size.

- Increase the log I/O size if:
    - The log device is overloaded because the server is issuing too many writes; with large I/O size, multiple writes are coalesced to a single write request
    - Throughput is a very important requirement and the Group commit logic is effective; look at the "Last Log Page Writes" in the taskmgmt section of sp_sysmon, and ensure that all the values are relatively low.

```
Task Management          per sec       per xact    count   % of total
---------------------   ------------  ---------   -------   -------
Task Context Switches by Engine 0
Last Log Page Writes     13.8           0.01       256      0.05 %
```

    - There are stringent response time requirements and the system throughput is also high, then in such cases ensure that there are sufficient CPU resources available to ensure group commit works well; for more information on this please refer to "Task Management" section under the chapter "Monitoring Performance with sp_sysmon" in the Performance & Tuning manual

- Decrease the log I/O size if:
    - The transaction profile section of sp_sysmon indicates a low transaction rate
    - Response time is a very critical requirement for the application and throughput is not as important. One should ensure that the I/O subsystem has enough bandwidth to be able to handle the extra I/O. If not, decreasing the log I/O size could potentially cause response time degradation
    - The value of "Avg # writes per log page" sp_sysmon report is much higher than the minimum possible value (e.g. 0.5 in the case of 2k server page size where log I/O is configured to be 4k)

To be able to increase the log I/O size the following steps are to be followed.

a. Configure a buffer pool whose buffer size is the same as the desired log I/O size. The following example shows how to configure a 4k buffer pool of 50M size on a log cache named 'log_cache':

```
[Named Cache:log_cache]
        cache size = 100M
        cache status = log only
        cache replacement policy = DEFAULT
        local cache partition number = 1

[4K I/O Buffer Pool]
        pool size = 50M
        wash size = 4000 K
        local async prefetch limit = DEFAULT
```

b. After creating the buffer pool, the I/O size for the log can be configured as follows:

```
1> use mydb
2> go
1> sp_logiosize "4K"
2> go
Log I/O size is set to 4 Kbytes.
The transaction log for database 'mydb' will use I/O size of 4
Kbytes.
(return status = 0)
```

The default log I/O size for a 2K page sized server is 4K. So, if a 4K pool exists for the default data cache when no named cache exists for the transaction log or for the named cache to which the transaction log is bound, the server will automatically perform 4K log I/O.

4.2 Guidelines for Configuring Log Cache

The following section provides a general set of guidelines on configuring the log cache for best results.

1. For high throughput OLTP databases, it is recommended to dedicate a named cache to the transaction log of the database.
2. It is also recommended to have a large I/O pool for the named cache. The default log I/O size for a 2K page sized server is 4K. So having a 4K pool would help improve the log I/O performance under certain scenarios which were explained earlier.
3. If the application is sensitive to rollback response time, then it is important to take that into account while sizing the named cache and the associated buffer pools.
4. If the applications use triggers that reference inserted and deleted tables extensively, that would also play a role in sizing the named cache.
5. If the application performs deferred mode updates frequently, then the named cache size for the transaction log should take that into account.

5. ULC

There is one user log cache for each configured user connection. ASE uses these user log caches to buffer the user transaction log records, which reduces the contention at the end of the transaction log especially for SMP systems. When a user log cache becomes full or when another event occurs (such as when the transaction completes), ASE "flushes" all log records from the user log cache to the database transaction log. The server configuration parameter, "user log cache size" controls the size of ULC allocated for each user connection. This option can be changed by editing the configuration file or by using the sp_configure interface as shown below.

```
[User Environment]
user log cache size = 4096
user log cache spinlock ratio = DEFAULT
```

or

```
1> sp_configure "user log cache size",4096
2> go
 Parameter Name       Default  MemoryUsed ConfigValue RunValue Unit  Type
 ---------------      -------- ---------- ----------- -------- ----  ----
 user log cache size  2048           0       4096      2048   bytes static
```

Note, that this option is static and the server will need to be rebooted for this change to take effect.

5.1 Guidelines for Configuring the ULC

To determine the correct size for the user log cache, identify the maximum number of log records written by the applications transaction and configure the 'user log cache size' to that value. The ULC size should also be validated, by running sp_sysmon during the representative workload. If the value for "ULC Flushes to Xact Log" is high on account of "by Full ULC" then increasing the "user log cache size" would help. In the following snippet, the percentage of ULC flushes on account of the ULC being full is 70%, so increasing the ULC size in this case would help.

```
 ULC Flushes to Xact Log     per sec  per xact   count  % of total
-------------------------    -------  --------  ------  ---------
  by Full ULC                   21.0      55.0    5435     70.0 %
```

If there is a high percentage of "ULC Flushes to Xact Log" on account of "By change of database", it would help to see if the application can potentially use a single database.

```
 ULC Flushes to Xact Log    per sec  per xact  count  % of total
-------------------------   -------  --------   -----  ----------
 by change of database         13.0      30.0   4356       57.0 %
```

If there is a high percentage of "ULC Flushes to Xact Log" on account of "By Other", one of the potential causes could be on account of having a number of row locked tables. Selectively identifying tables, which require row level locking scheme using sp_object_stats and having page level locking scheme for the remaining tables, could potentially alleviate this problem.

```
ULC Flushes to Xact Log    per sec    per xact count  % of total
------------------------- ---------   -------   ------  ---------
 by Other                      0.0       0.0   8934    89.0 %
```

If the "Log Semaphore Requests" waited value is a high percentage, it would help to evaluate some of the "Advanced ASE logging features" such as "Async Log Service". More details are provided in the "Advanced ASE logging features" section.

6. Advanced ASE Logging Feature

Sybase ASE has proven time and again as the database server of choice for high throughput OLTP applications having very stringent response time requirements. Server consolidation and database consolidation are real trends emerging in the market. Customers are constantly upgrading their hardware from 4-8 CPU systems to 16-32 and even to 64 CPU machines capable of executing millions of transactions for easier management and lower total cost of ownership. ASE's architecture keeps pace with the ever-increasing number of CPUs. Additional CPUs, increases contention on some of the key shared resources such as the log and spinlocks guarding other key resources. To enable ASE to scale on such state of the art hardware, a new service called "Asynchronous Logging" is introduced in ASE 12.5.0.3. The core idea of this service is to eliminate the burden of writing the log data by the user tasks and chartering dedicated threads to write the ULC data to the log cache and also flushing the log cache to disk. This may improve the performance significantly while eliminating the log contention almost completely.

To enable the Asynchronous Logging service on a specific database in ASE 12.5.0.3, issue the following command.

```
sp_dboption  <db Name>, "async logging service", "true"
```

This service should be used if the databases experience all the following symptoms:

• Heavy contention on the last Log page

```
Log Semaphore Requests
  Granted                       0.8     2.0      20      20.0 %
  Waited                        3.2     8.0      80      80.0 %
------------------------     ------  ------    ----     ------
Total Log Semaphore Req        4.0    10.0     100
```

• Heavy contention on the cache manager spinlock for the log Cache

```
Cache: default data cache
                            per sec   per xact   count  % of total
  ----------------------    -------   --------   ------  ----------
  Spinlock Contention          n/a       n/a       n/a       54.0 %
```

• Log I/O device bandwidth is under utilized

By enabling Asynchronous Logging services on a specific database, two dedicated system threads will now be chartered to do flushing of User log Cache and writing the log pages from shared log cache to the disk, for that database. It is not recommended to enable this feature under lighter load conditions or on a system with less than four CPUs. For more information please refer to ASE 12.5.0.3 Manual under What's New in ASE 12.5.0.3.

7. Conclusion

An optimal logging subsystem is critical to providing high levels of throughput and to satisfy stringent response time requirements. This paper has covered the critical aspects of the logging subsystem and summarized the best practices in tuning each component as:

- Log Device
  - Ensure that the I/O response times on the log device are within reasonable bounds
  - Do not mix log and data on the same device
- Log Cache
  - It is best recommended to configure 4K log I/O for typical high throughput OLTP systems
  - Having a separate named cache for the transaction log for high throughput databases is highly recommended
- ULC
  - Ensure that the ULC is adequately sized based on the amount of log records each transaction in the application generates
  - The ULC can significantly reduce the load on the logging subsystem in highly concurrent OLTP environments
- Asynchronous Logging Service
  - Use this feature to address logging contentions on a high throughput OLTP systems running on high-end SMP machines

Sybase ASE has time and again demonstrated exceptional levels of scaling on industry standard benchmarks, OLTP benchmarks such as TPC-C and other customer benchmarks. This has been made possible largely on account of efficient and scalable logging in ASE. More detailed information on each of the topics covered in this paper can be accessed on the web from http://sybooks.sybase.com/asg1250e.html.

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