Chapter 28: Oracle

Database System Concepts, 6th Ed.

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Introduction

- This chapter surveys a subset of the features, options, and functionality of Oracle products
- New versions of the products are being developed continually, so all product descriptions are subject to change
- The feature set is based on the first release of Oracle10g

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Database Design and Querying Tools [1/2]

- Various Oracle Tools for
  - Database design
  - Querying
  - Report generation
  - Data analysis, including OLAP (Online Analytical Processing)

- Oracle Developer Suite
  - Forms development
  - Data modeling
  - Reporting
  - Querying

Database Design and Querying Tools [2/2]

- Tools in Oracle Developer Suite
  - Oracle Designer
    - E-R diagrams
    - Information engineering
    - Object analysis and design
  - Oracle Repository
    - Configuration management for database objects
    - Forms applications
    - Java classes
    - XML files
  - JDeveloper
    - End-to-end development of J2EE applications
  - Oracle Warehouse Builder
    - Schema design and Metadata management
    - Data loading, Data mapping and transformations
  - Oracle Application Server Discoverer
    - Web-based Query Tool / Ad-hoc query
    - Reporting / Analysis
    - Web publishing tool

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle SQL Variations and Extensions [1/2]

- Oracle supports all core SQL:1999 features fully or partially
- Oracle-specific in syntax or functionality
  - **connect by**: for transitive closure
  - **upsert**
    - Upsert combines update and insert
    - Useful for merging new data with old data
    - If a new row has the same key value as an old row ➔ The old row is updated
    - Otherwise, the new row is inserted
  - **multitable inserts**
    - Update multiple tables based on a single scan of new data
  - **with** clause
    - Described in Section 3.8.2
  - **model** clause
    - Array algebra calculations on relational data

Oracle SQL Variations and Extensions [2/2]

Example: Inserting new customer information from the *customers_new* table into two tables, *customers* and *customers_special.*

```
INSERT FIRST
WHEN cust_credit_limit >=4500 THEN
    INTO customers_special VALUES(cust_id,cust_credit_limit)
ELSE
    INTO customers
SELECT  *  FROM customers_new;
```

Oracle SQL OR Features

- Object-Relational (OR) Features
  - Object types
  - Collection types
  - Object tables
  - Table functions
  - Object views
  - Methods
  - User-defined aggregate functions
  - XML as a native data types

Oracle SQL OLAP

- OLAP
  - Now, OLAP processing is done inside the RDB
  - Reasons for moving away from a separate multidimensional storage engine
    - A relational engine can scale to much larger data sets
    - A common security model can be used for the analytical applications and the data warehouse
    - Multidimensional modeling can be integrated with data warehouse modeling
    - The relational database management system has a larger set of features and functionality in many areas such as high availability, backup and recovery, and third-party tool support
    - There is no need to train database administrators for two database engines

Oracle SQL Triggers

Triggers :

- For triggers that execute on DML statements such as insert, update, and delete, Oracle supports
  - **Statement triggers**

    Executed just once per statement.
  - **Row triggers**

    Executed once for every row that is affected (updated or deleted, for example) by the DML operation
- The creation of **instead of** triggers
  - For views that cannot be subject to DML operation
  - A user can create an **instead of** trigger on a view to specify manually what operations on the base tables are to occur in response to the DML operation on the view

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle Storage Structure

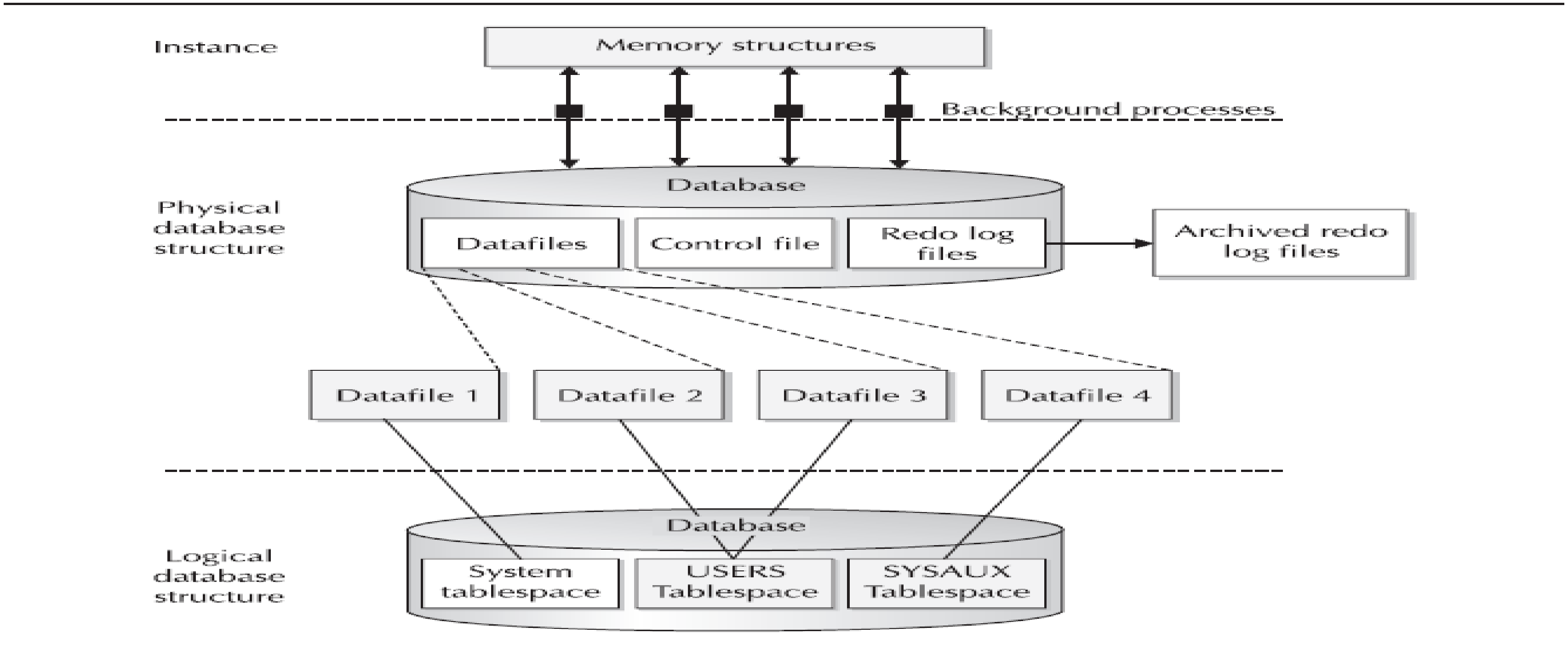


FIGURE 1-3. *Oracle physical storage structures*

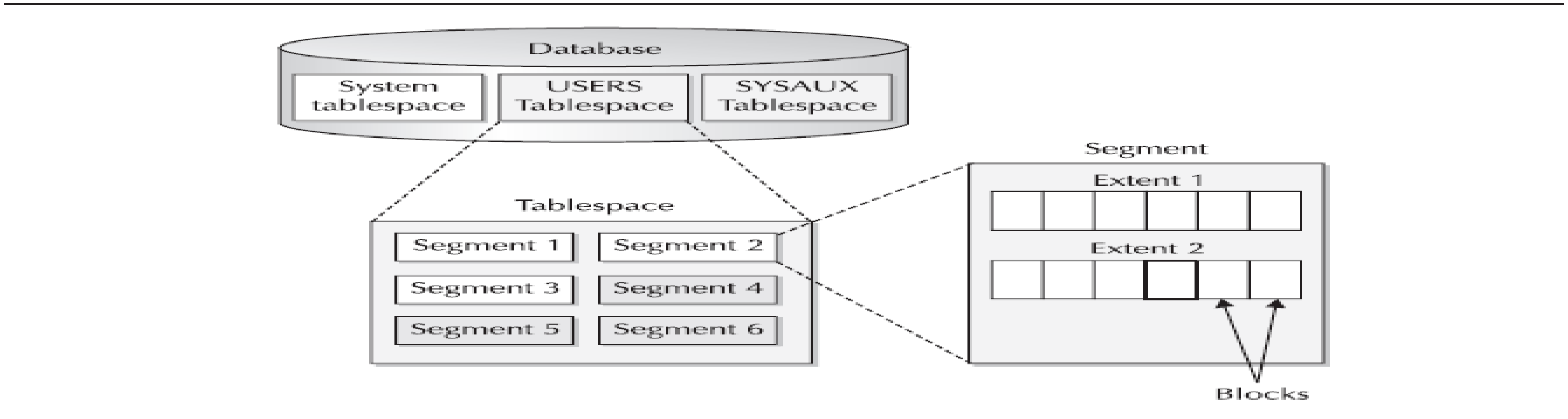


FIGURE 1-2. *Logical storage structures*

Oracle Table Space

Table Spaces :

- A database consists of one or more logical storage units called **tablespaces**
- Each table space consists of one or more physical structures called **data files**

- **System** tablespace
  - Data-dictionary table, storage for triggers and stored procedures
- User data tablespace
  - Created to store user data
- Temporary tablespace
  - When DB operations require sorting the data
  - If the sort cannot be done in memory, the sort routine stores the data temporarily on disk

Oracle Segments

Segments :

- The space in a table space is divided into units, called **segments**, that each contain data for a specific data structure
- **Data segments**
  - Where table data are stored
- **Index segments**
  - Each index in a tablespace has its own index segment
- **Temporary segments**
  - When a sort operation need to write data to disk
  - Or when data are inserted into temporary table
- **Rollback segments**
  - Contain undo information to roll back an uncommitted transaction

Storage and Indexing (cont.)

Segments (cont.) :

- Below the level of segment, space is allocated at a level of granularity called *extent*
- Each extent consists of a set of contiguous database *blocks*
- A database block is the lowest level of granularity at which Oracle performs disk I/O
- A database block does not have to be the same as an OS block in size, but should be a multiple thereof

Storage and Indexing (cont.)

Tables :

- A standard table in Oracle is heap organized
  - The storage location of a row in a table is not based on the values contained in the row, and is fixed when the row is inserted
- If the table is partitioned, the content of the row affects the partition in which it is stored
- Therefore, there are several features and variations

Storage and Indexing (cont.)

Tables (cont.) :

- Oracle supports nested tables
  - A table can have a column whose data type is another table
  - The nested table is not stored in line in the parent table, but is stored in a separate table
- Oracle supports temporary tables
  - The duration of the data is either the transaction in which the data are inserted, or the user session
  - The data are removed automatically at the end of duration

Storage and Indexing (cont.)

Tables (cont.) :

- *Cluster*
  - Another form of organization for table data
  - Rows from different tables are stored together in the same block on the basis of some common columns
  - For example, a department table and an employee table could be clustered so that each row in the department table is stored together with all the employee rows for those employees who work in that department
  - Advantage: When two tables are joined
    - Performance benefits without the space penalty
  - Trade-off: Need to have a larger number of blocks

Storage and Indexing (cont.)

Index-Organized Tables :

- Records are stored in an Oracle B-tree index instead of in a heap
- An index-organized table requires that a unique key be identified for use as the index key
- Index-organized table can improve both performance and space utilization
- Secondary indices on nonkey columns of an index-organized table are different from indices on a regular heap table
- A secondary index on an index-organized table contains not normal row-ids, but **logical row-ids** instead

Oracle Index Support [1/6]

- Oracle supports several different types of indices
  - B-tree Index
  - Bitmap Index
  - Function-Based Index
  - Join Index
  - Domain Index

Oracle Index Support [2/6]

1. B-tree indices :

- Format: *<col1><col2><col3><row-id>*
  <*col1*> : the value for column 1
  <*row-id*> : row-id for the row

- Oracle can optionally compress the prefix of entry to save space

- The representation of each distinct <*col1*><*col2*> prefix can be shared

Oracle Index Support [3/6]

2. Bitmap Indices :

- Use a bitmap representation for index entries

- The form of bitmap index entry

  <col1><startrow-id><endrow-id><compressedbitmap>

- 1 bit : the column value of that row is that of the index entry

- 0 bit : the row has some other value, or does not actually exist in the table

- The compression algorithm, like BBC, deals with long strings of consecutive zeros

Oracle Index Support [4/6]

3. Function-Based Indices :

- Oracle allows indices to be created on expressions that involve one or more columns
  - ➔ *col1* + *col2* * 5

- For example, in order to find all rows with name “van Gogh”

  upper(name) = ‘VAN GOGH’

- Oracle then matches the condition with the index definition

Oracle Index Support [5/6]

4. Join Indices :

- A join index is an index where the key columns are not in the table that is referenced by the row-ids in the index

- For example, if there is a column for product names in a product dimension table
  ➔ A bitmap join index on the fact table with this key column could be used to retrieve the fact table rows that correspond to a product with a specific name

- Oracle allows bitmap join indices to have more than on key column

Oracle Index Support [6/6]

5. Domain Indices :

- Support to develop so-called **cartridges** with functionality for specific application domains

- For example, a domain index for advanced text searches may support an operator *contains*

- Once this operator has been registered, the domain index will be considered as an access path for a query like

  select *

  from *employees*

  where *contains* (*resume*, ‘LINUX’)

Oracle Partitioning

- Oracle supports various kinds of horizontal partitioning of tables and indices
- And this feature plays a major role in Oracle's ability to support very large databases
- The ability to partition a table or index has advantages
  - Backup and recovery are easier and faster
  - Loading operations in a data warehousing environment are less intrusive
  - Query performance benefits substantially
- Several ways to map column values to partitions, giving rise to several types of partitioning, each with different characteristics
  - **Range Partitioning**
    ➔ Criteria: the range of value
  - **Hash Partitioning**
    ➔ Hash function maps rows to partitions
  - **Composite Partitioning**
    ➔ Table is range partitioned, but each partition is subpartitioned by using hash or list partitioning
  - **List Partitioning**
    ➔ The values associated with a particular partition are state in a list

Oracle Materialized View

- Allows the result of an SQL query to be stored in a table and used for later query processing

- Oracle maintains the materialized result, updating it when the referenced tables in the query are updated

- Materialized views are used in data warehousing to speed up query processing
  - ➔ A common usage is to summarize data

- While it can improve query performance, it uses up space, and creating and maintaining it consumes resources.

- To help resolve this trade-off
  - ➔ Oracle provides an advisor that can help a user create the most cost-effective materialized views, given a particular query workload as input

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle Query Processing

Execution Methods :

Data can be accessed through a various access methods

- **Full table scan**: scans the entire table.
- **Index scan**: scans to a relevant part of the index
- **Index fast full scan**: scans the extents in the same way as the table extent in a full table scan
- **Index join**: is used If a query needs only a small subset of the columns of a wide table, but no single index contains all those columns
- **Cluster and hash cluster access**: accesses the data by using the cluster key

Oracle Query Optimization

Optimization :

- **Query Transformations**
  - Oracle does query optimization in several steps
  - One step is to perform various query transformations and rewrites
  - Another step is to perform access-path selection
  - Major types of transformations and rewrites
    - **View merging**
    - **Complex view merging**
    - **Subquery flattening**
    - **Materialized view rewrite**
    - **Star transformation**
- **Access-Path Selection**
  - Oracle has a cost-based optimizer that determines join order, join methods, and access paths
  - Each operation that the optimizer considers has an associated cost function
  - The optimizer tries to generate the combination of operations that has the

Oracle Query Optimization Tools

SQL Tuning Advisor :

- Improves the performance of high-load SQL statements by making various kinds of recommendations
- Four categories :
  - **Statistics Analysis**
  - **SQL Profiling**
  - **Access-Path Analysis**
  - **SQL Structure Analysis**

Oracle Parallel Query Processing [1/2]

Parallel Execution :

- Oracle allows the execution of a single SQL statement to be parallelized by dividing the work between multiple processes on a multiprocessor computer
- Several ways to spilt up the work
  - **For operations that access base object** (tables and indices)
    # Divide the work by horizontal slices of data
  - **For joins**

    # Divide one of the inputs to the join
    # Large table ⟶ Small table
    # By hashing on the value of the join columns
  - **For sort operations**
    # Parallelize by value ranges of the column on sorting

Oracle Parallel Query Processing [2/2]

Parallel Execution (cont.) :

- The processes involved in the parallel execution of an SQL statement consist of :
  - A coordinator process
  - A number of parallel server processes
- The coordinator
  - Assigns work to the parallel servers
  - Collects and returns data to the user process that issued the statement
- The degree of parallelism
  - = The number of parallel server processes
  - Is determined by the optimizer

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle Concurrency Control and Recovery

Concurrency Control :

- Oracle’s concurrency control differs from the concurrency mechanisms used by most other database vendors
  - Basically the multiversion two-phase locking protocol
  - Using System Change Number (SCN)
- During recovery from a backup, Oracle performs two steps to reach a consistent state
  - First, Oracle rolls forward by applying the (archived) redo logs to the backup
  - Second, Oracle rolls back uncommitted transactions by using the rollback segment
- **Recovery Manager**
  - A GUI tool which automates most of backup and recovery tasks

Oracle Redo Log Structure

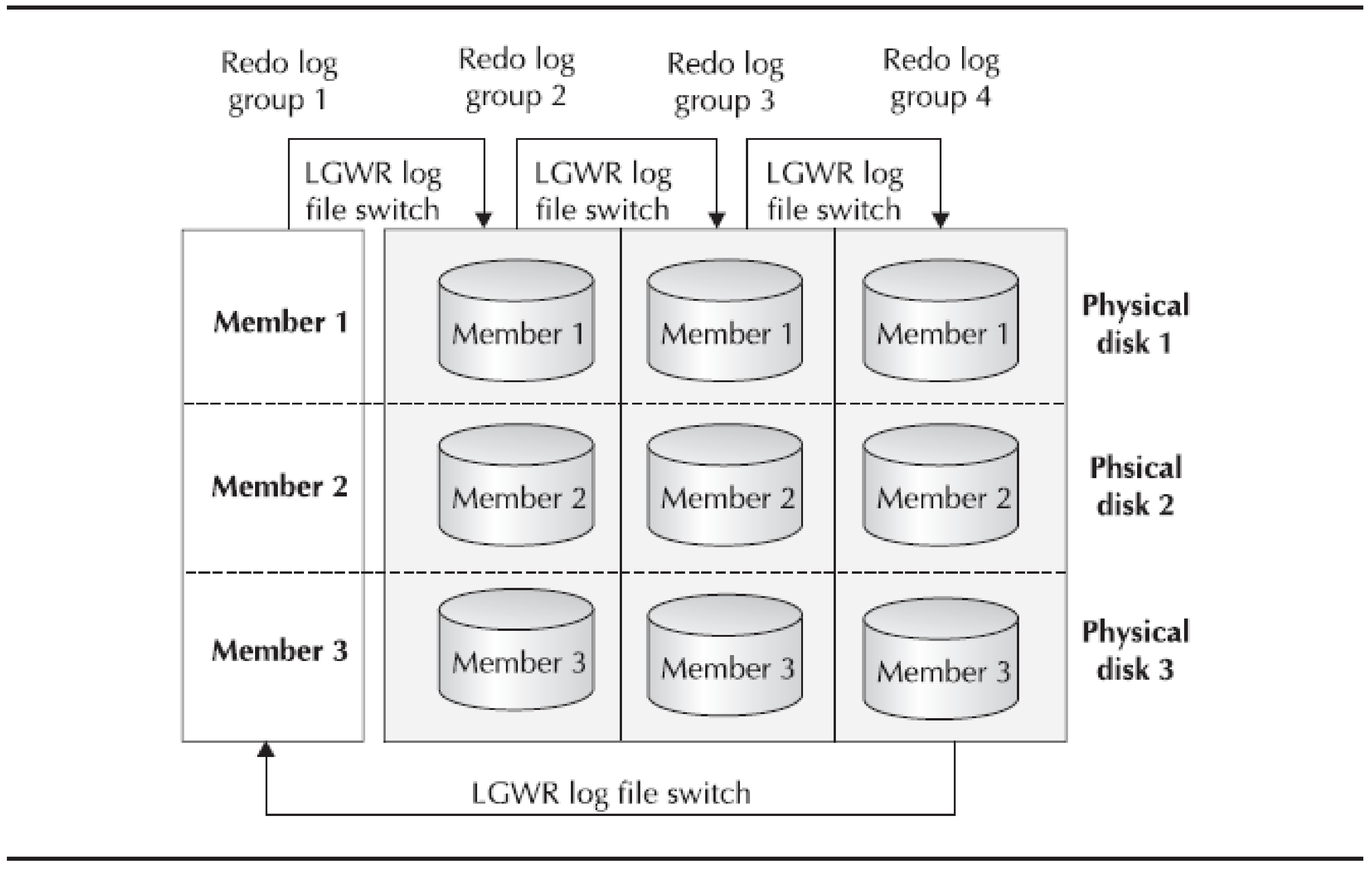


FIGURE 1-4. *Multiplexing redo log files*

Oracle Back-up Utility

Oracle Data Guard :

- To ensure high availability, Oracle provides a standby database feature, *Data Guard*

- A standby database is a copy of the regular database that is installed on a separate system

- When a failure occurs on the primary system, the standby system is activated and takes over

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle Dedicated Server: Memory Structure [1/2]

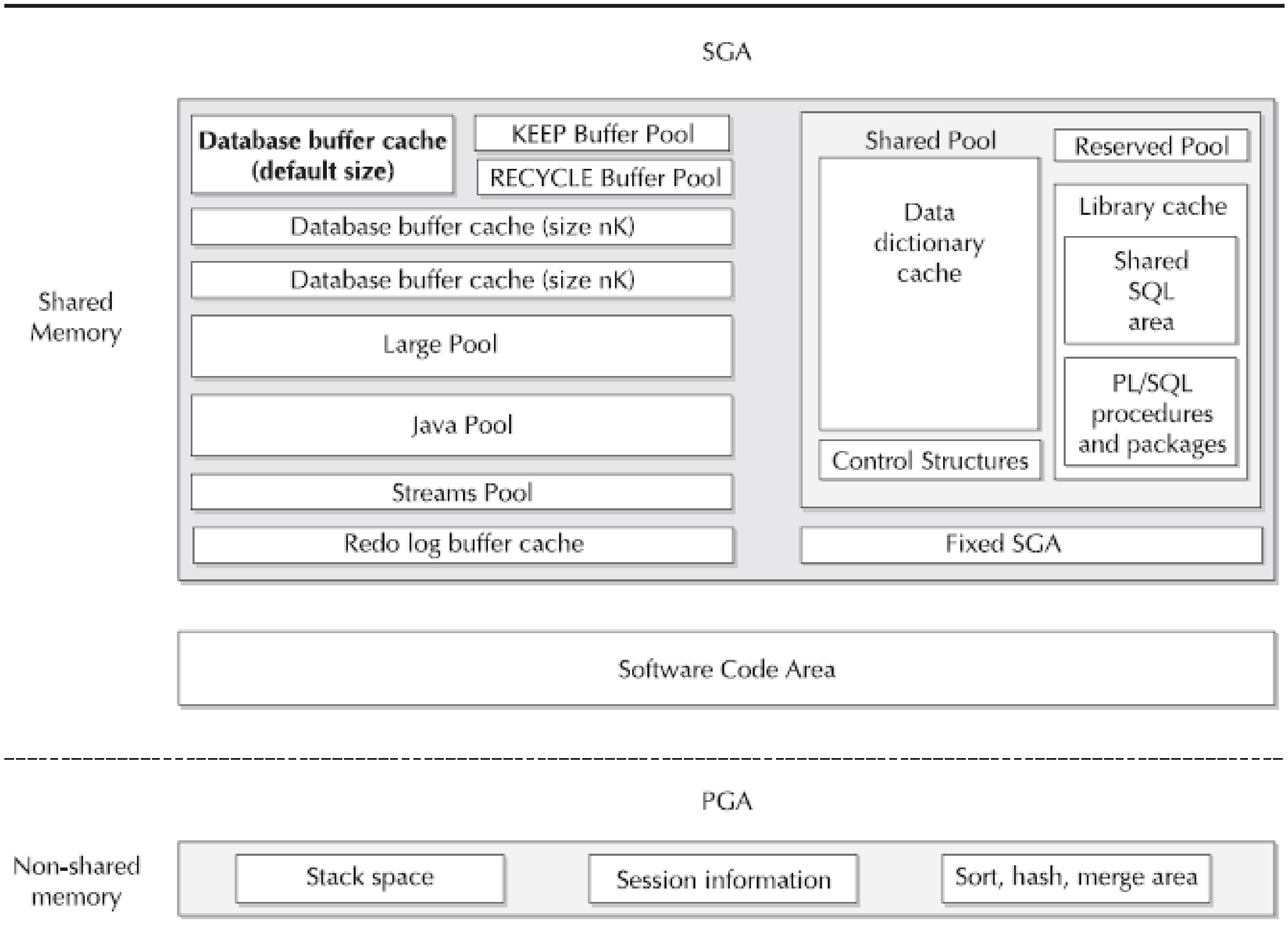


FIGURE 1-5. *Oracle logical memory structures*

Oracle Dedicated Server: Memory Structure [1/2]

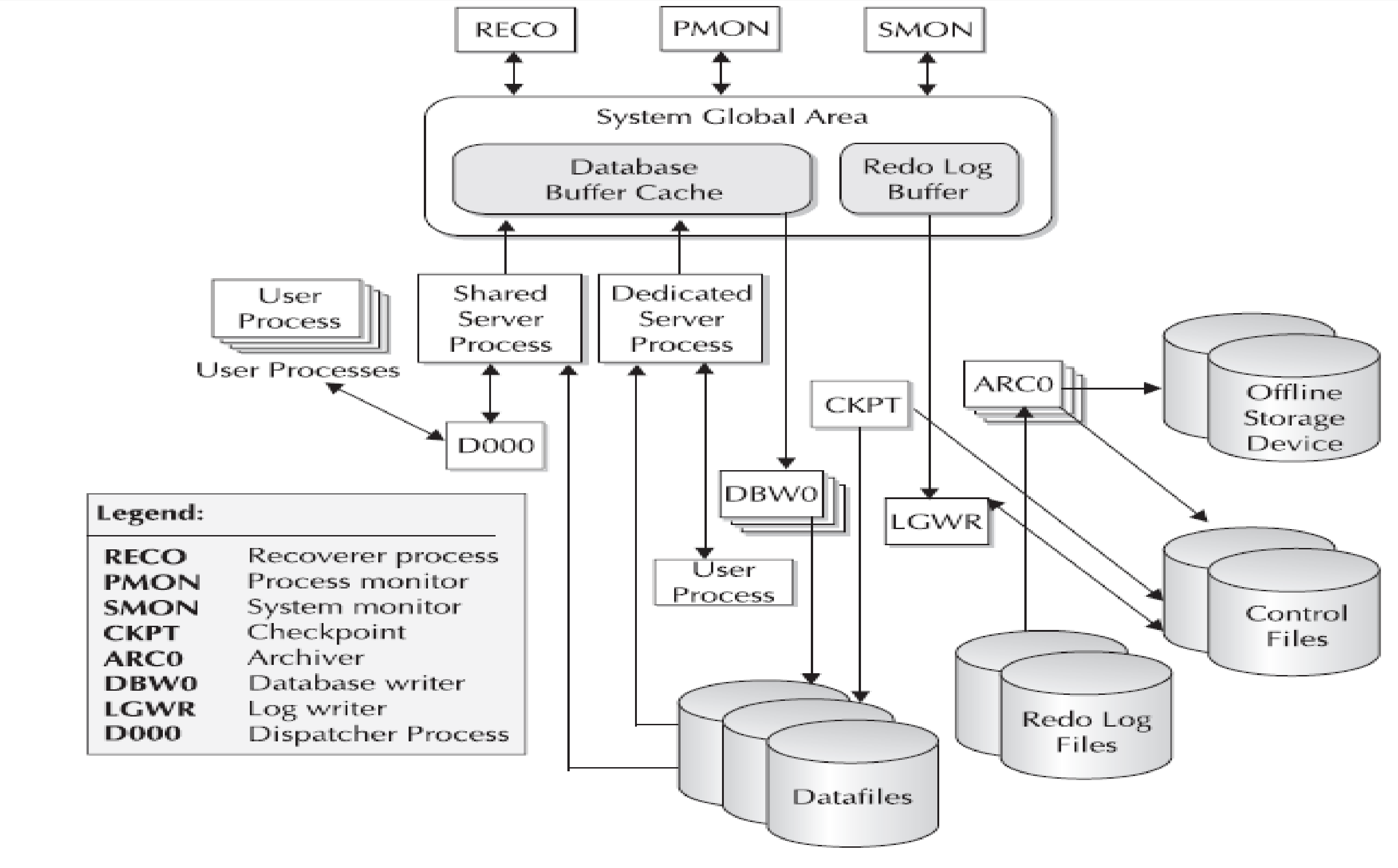
- The memory used by Oracle falls mainly into three categories:
  - Software code areas
    - the parts of the memory where the Oracle server code resides
  - System global area (SGA)
    - a memory area for structures that are shared among users
  - Program global area (PGA)
    - allocated for each process to hold its local data and control information
  - SGA Structure
    - Buffer cache
      - Keeps frequently accessed data blocks in memory to reduce the need to perform physical disk I/O
    - Redo log buffer
      - Contains the part of the redo log that has not yet been written to disk
    - Shared pool
      - The sharable parts of the data structures representing the SQL statement are stored

Oracle Dedicated Server: Process Structure

Two types of processes that execute Oracle server code

- **Server processes**
  - Process SQL statements
- **Background processes**
  - Perform various administrative and performance-related tasks
  - **Database writer**
    - When a buffer is removed from the buffer cache, it must be written back to disk if it has been modified since it entered the cache
  - **Log writer:** Writes entries in the redo log buffer to the redo log file on disk
  - **Checkpoint:** Updates the headers of the data file when a checkpoint occurs
  - **System monitor:** Performs crash recovery if needed
  - **Process monitor:** Performs process recovery
  - **Recoverer:** Resolves failures and conducts cleanup for distributed transactions
  - **Archiver:** Copies the online redo log file to an archived redo log

Oracle Dedicated Server: Background Processes



Legend:

RECO	Recoverer process
PMON	Process monitor
SMON	System monitor
CKPT	Checkpoint
ARC0	Archiver
DBW0	Database writer
LGWR	Log writer
D000	Dispatcher Process

FIGURE 1-6. *Oracle background processes*

Oracle Shared Server

- The shared server configuration increases the number of users that a given number of server processes can support by sharing server processes among statements

- Differences from the dedicated server architecture
  - A background dispatch process routes user requests to the next available server process
  - Since a server process is shared among multiple SQL statements, Oracle stores the session-specific data in the SGA

- **Oracle Real Application Clusters**

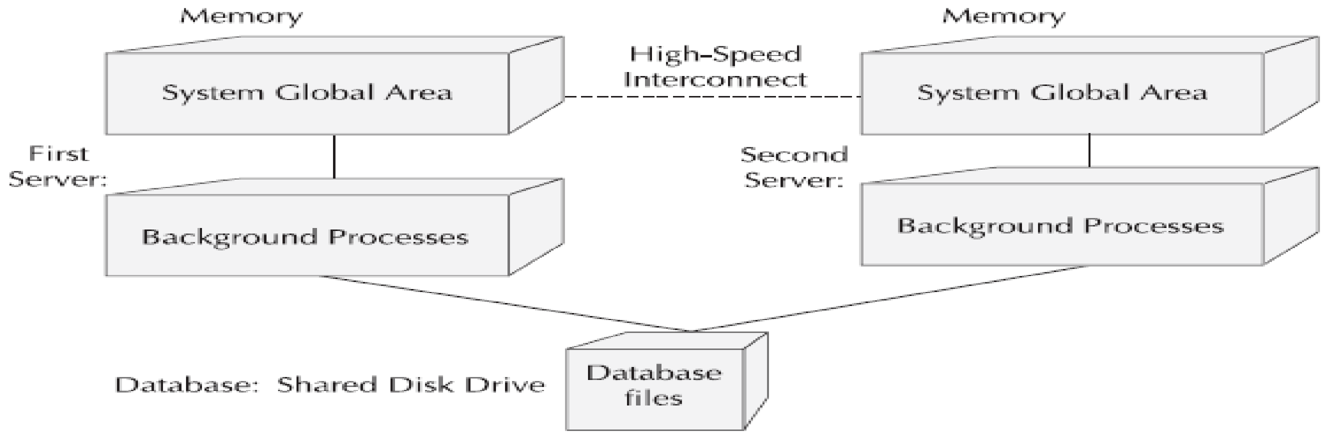


FIGURE 1-7. *A two-node Real Application Clusters (RAC) configuration*

Oracle Real Application Clusters

- Oracle Real Application Clusters (RAC) is a feature that allows multiple instances of Oracle to run against the same database
- An instance is the combination of background processes and memory areas (in Oracle terminology)
- This feature enables Oracle to run on clustered and MPP (shared-disk and shared-nothing) hardware architectures
- The ability to cluster multiple nodes has important benefits for scalability and availability
  - High Scalability: More nodes mean more processing power
  - High Availability
    - If one node fails, the remaining ones are still available to the application accessing the database
    - The remaining instances will automatically roll back uncommitted transactions
  - Having multiple instances run against the same database gives rise to some technical issues
  - There is always the possibility of overlap, which affects locking and cache management
  - Oracle supports the *cache fusion* feature
    - It allows data blocks to flow directly among caches on different instances without being written to disk

# Cache Fusion

Oracle's cache fusion architecture is a new shared cache architecture that provides e-business applications the benefits of both shared-disk and shared-nothing databases without the drawbacks of either architecture

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle Replication

Replication :

- Data in a master site are replicated to other sites in the form of **snapshots**
  - A snapshot does not have to contain all the master data
  - It can, for example, exclude certain columns from a table for security reasons
  - Two types of snapshots
    - *read only*
    - *Updatable*
- Oracle supports multiple master sites for the same data, where all master sites act as peers

Oracle Distribution

Distributed Databases :

- Oracle supports queries and transactions spanning multiple databases on different systems
  - Oracle can optimize a query that includes tables at different sites, retrieve the relevant data, and return the result
  - Oracle also transparently supports transactions spanning multiple sites by a built-in two-phase-commit protocol

Oracle External Data Sources

- Oracle has several mechanisms for supporting external data sources
- The most common usage is in data warehousing when large amounts of data are regularly loaded from a transactional system
- **SQL*Loader**
  - Oracle has a direct load utility that supports fast parallel loads of large amounts of data from external files
- **External Tables**
  - An external table is defined by metadata that describe the Oracle column types and the mapping of the external data into those columns
  - The external table feature is primarily intended for extraction, transformation, and loading (ETL) operations in a data warehousing environment
  - Data can be loaded into the data warehouse from a flat file using,

create table *table* **as**

select … from <external table>

where …

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Database Administration Tools

Automatic Workload Repository (AWR) (infrastructure for manageability)**:**

- In the release Oracle10g, much emphasis was put on the concept of *manageability*
- Oracle monitors the activity on the database system and records various information about workloads and resource consumption

Database Resource Management :

- This feature allows the DBA to divide users into resources consumer groups with different priorities and properties
- For example,
  - A group of high-priority, interactive users / A low-priority group
- DBA can also set the degree of parallelism, time limit, and number of user sessions for each group

Oracle Enterprise Manager (OEM) (gui tool for database-systems management)**:**

- Configuration
- Performance monitoring
- Resource management
- Security management
- Access to various advisors

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary
- Bibliographical Notes

Oracle Data Mining

- Oracle provides functionality for both supervised and unsupervised learning
  - Classification
  - Regression
  - Attribute importance
  - Clustering
  - Market basket analysis
  - Feature extraction
  - Text mining
  - Bioinformatics (BLAST)

Chapter 28: Oracle

- 28.1 Introduction
- 28.1 Database Design and Querying Tools
- 28.2 SQL Variations and Extensions
- 28.3 Storage and Indexing
- 28.4 Query Processing and Optimization
- 28.5 Concurrency Control and Recovery
- 28.6 System Architecture
- 28.7 Replication, Distribution, and External Data
- 28.8 Database Administration Tools
- 28.9 Data Mining
- Summary and Bibliographical Notes

Summary [1/2]

- This chapter surveys a subset of the features, options, and functionality of Oracle products
- Oracle provides various tools for database design, querying, report generation, and data analysis including OLAP
- Oracle supports all core SQL:1999 features fully or partially
- Oracle database consists of information stored in files and is accessed through an instance
- Oracle supports a large variety of processing techniques in its query-processing engine

Summary [2/2]

- Oracle supports concurrency-control and recovery techniques
- Oracle has two server architecture: dedicated and multithreaded
- Oracle provides support for replication and distributed transactions with two-phase commit
- Oracle provides users a number of tools and features for system management and application development
- Oracle Data Mining provides various algorithms that embed the data-mining process inside the database

Bibliographical Notes [1/2]

- Up-to-date product information, including documentation, on Oracle products can be found at the Web sites http://www.oracle.com and http://technet.oracle.com
- Extensible indexing in Oracle is described in Srinivasan et al. [2000b] and Srinivasan et al. [2000c]
- Index-organized tables are described in Srinivasan et al. [2000a], Banerjee et al. [2000], Murphy and Banerjee [2003]]
- Krishnaprasad et al. [2004] describe XML support in Oracle
- Bello et al.[1998] describe materialized views in Oracle
- Antoshenkov [1995] describes the byte-aligned bitmap compression technique used in Oraclel; see also Johnson [1999]
- Lahiri et al. [2001b] describe the cache fusion functionality of Oracle Real Application Clusters

Bibliographical Notes [2/2]

- Recovery in Oracle is described in Joshi et al. [1998] and Lahiri et al. [2001a]
- Messaging and queuing in Oracle are described in Gawlick[1998]
- Witkowski et al. [2003a] and Witkowski et al. [2003b] describe the MODEL clause
- The memory management algorithms for sorting and hashing are described in Dageville and Zait [2002]
- Poess and Potapov [2003] describe Oracle's table compression feature
- The frequent item set algorithm for market basket analysis in Oracle Data Mining is described in Li and Mozes [2004]
- Automatic SQL tuning is described in Dageville et al. [2004b]
- Cruanes et al. [2004] describe parallel execution in Oracle