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Oracle Exadata Storage Server and I/O Resource Management

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Objectives

After completing this lesson, you should be able to use Exadata I/O Resource Management to manage workloads within a database and across multiple databases.

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I/O Resource Management Overview

- Traditional benefits of shared storage:
 - Lower administration costs
 - More efficient use of storage
- Common challenge for shared storage:
 - Workloads interfere with each other. For example:
 - Large queries impact on each other
 - Data loads impact on warehouse queries
 - Batch workloads interfere with OLTP performance
- Exadata I/O Resource Management allows you to govern I/O resource usage amongst different:
 - User types
 - Applications
 - Workload types
 - Databases

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I/O Resource Management Overview

Storage is often shared by different workloads on multiple databases. Shared storage provides some important benefits:

- When a storage system is dedicated to a single database, the administrator must size the storage system based on the database's peak anticipated load and size. The correct balance of storage resources across is seldom achieved because real-world workloads are very dynamic. This leads to unused I/O bandwidth and space on some systems while others suffer with insufficient bandwidth and space. Sharing facilitates more efficient usage of storage, both from a space standpoint as well as a bandwidth standpoint.
- Sharing lowers administration costs by reducing the number of storage systems.

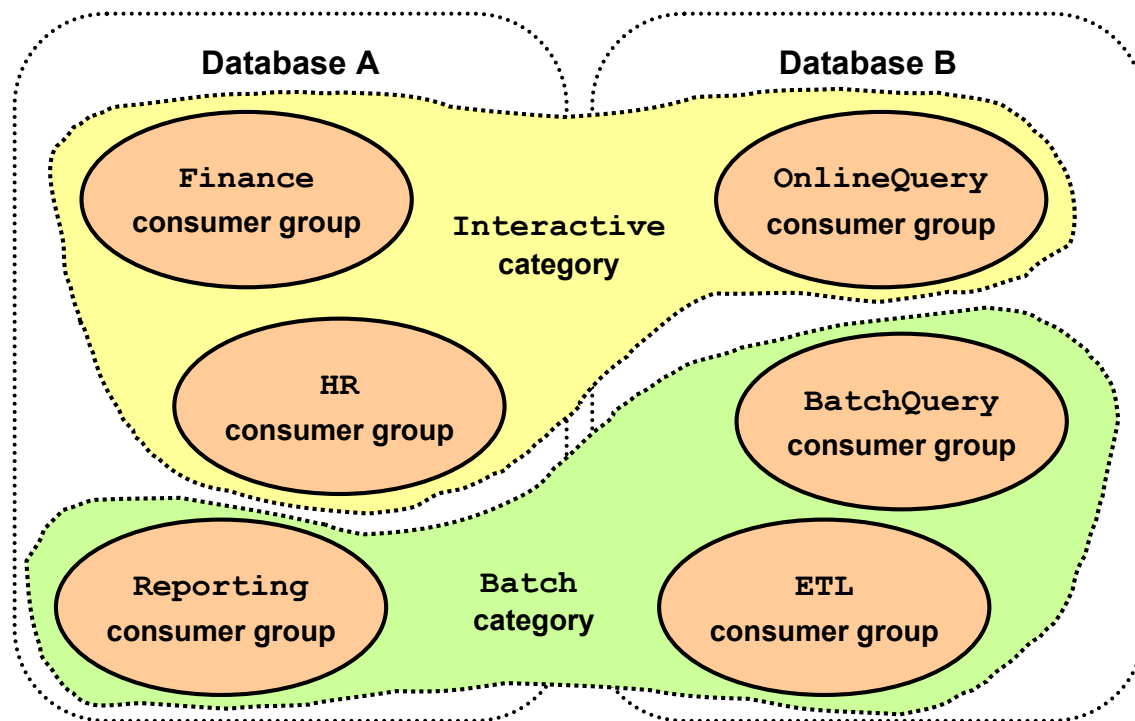
Shared storage, however, is not a perfect solution. Running multiple types of workloads and databases on shared storage often leads to performance problems. For example, large parallel queries on one production data warehouse can impact the performance of critical queries on another production data warehouse. Also, a data load on a data warehouse can impact the performance of critical queries also running on it. You can mitigate these problems by over provisioning the storage system, but this diminishes the cost-savings of shared storage. You can also avoid running noncritical tasks at peak times, but manually achieving this is laborious. When databases have different administrators who do not coordinate their activities the task is even more difficult.

I/O Resource Management Overview (continued)

I/O Resource Management (IORM) allows workloads and databases to share Exadata I/O resources automatically according to user-defined policies. To manage workloads within a database, you can define intradatabase resource plans using the Database Resource Manager (DBRM), which has been enhanced to work in conjunction with Exadata. To manage workloads across multiple databases, you can define IORM plans.

For example, if a production and test database are sharing an Exadata cells, you can configure resource plans that give priority to the production database. In this case, whenever the test database load would affect the production database performance, I/O Resource Management will schedule the I/O requests such that the production database I/O performance is not impacted. This means that the test database I/O requests are queued until they can be issued without disturbing the production database I/O performance.

I/O Resource Management Concepts



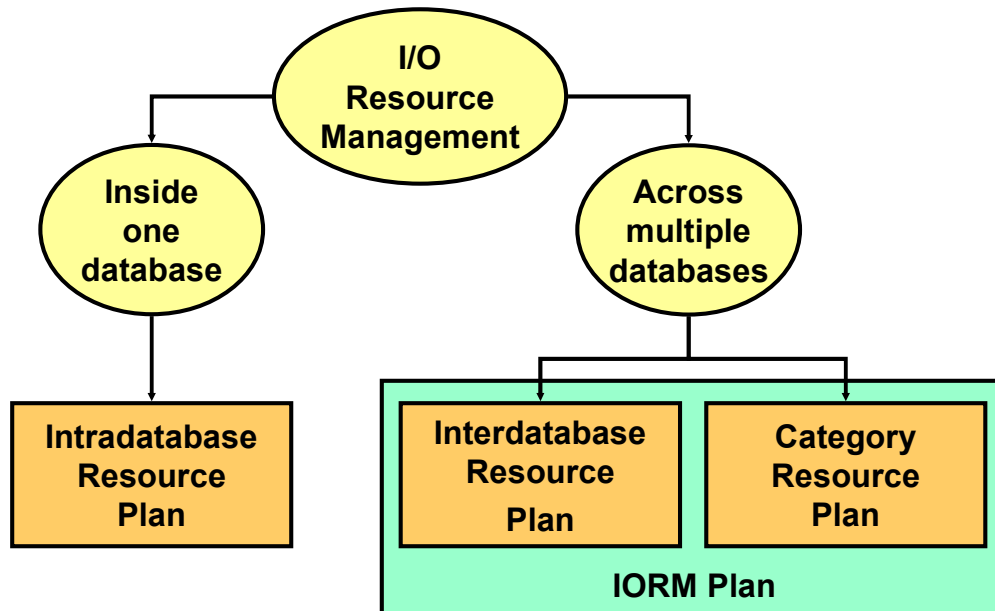
I/O Resource Management Concepts

A database often has many types of workloads. These workloads may differ in their performance requirements and the amount of I/O that they issue. Resource consumer groups provide a way to group sessions that comprise a particular workload. For example, if your database is running four different applications, then you can create four consumer groups, one for each application. Alternatively, if your data warehouse has three types of workloads, such as critical queries, normal queries, and ETL (extraction, transformation, and loading), then you can create a consumer group for each type of workload. Once you have created the consumer groups, you must create rules that specify how sessions are mapped to consumer groups.

The database resource plan, or intradatabase resource plan, specifies how CPU and I/O resources are allocated among consumer groups in a database. A database may have multiple resource plans however only one resource plan can be active at any point in time. This allows database resource management to cater for different requirements associated with different time periods.

Exadata I/O Resource Management (IORM) extends the consumer group concept using categories. While consumer groups represent collections of users within a database, categories represent collections of consumer groups across all databases. You can manage I/O resources based on categories by creating a category plan. For example, you can specify precedence to consumer groups in the Interactive category over consumer groups in the Batch category for all databases sharing an Exadata cell.

I/O Resource Management Plans



I/O Resource Management Plans

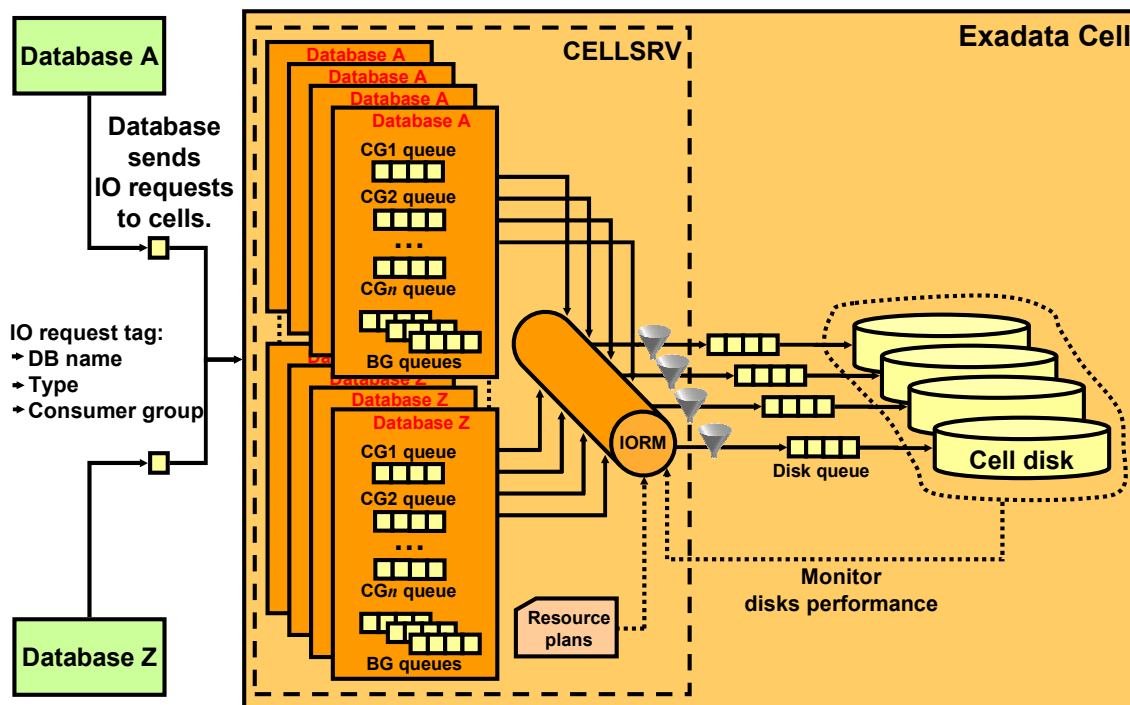
IORM provides different approaches for managing resource allocations. Each approach can be used independently or in conjunction with other approaches.

Database resource management enables you to manage workloads within a database. Database resource management is configured at the database, using Database Resource Manager to create intradatabase resource plans. You should use this feature if you have multiple types of workloads within a database and you need to define a policy for specifying how these workloads share the database resource allocation. If only one database is using the Exadata cell, then this is the only IORM feature that you need.

Interdatabase resource management is managed with an interdatabase plan. An interdatabase plan specifies how resources are allocated among multiple databases for each cell. The directives in an interdatabase plan specify allocations to databases, rather than consumer groups. Category resource management is an advanced feature. It is useful when your Exadata cell is hosting multiple databases and you want to allocate resources primarily by the category of the work being done. For example, suppose all databases have three categories of workloads: OLTP, reports, and maintenance. To allocate the I/O resources based on these workload categories you would use category resource management.

Note: The combination of the interdatabase plan and the category plan is called the IORM plan.

IORM Architecture



IORM Architecture

IORM manages Exadata I/O resources on a per-cell basis. Whenever the I/O requests start to saturate the cell, IORM schedules incoming I/O requests according to the configured resource plans.

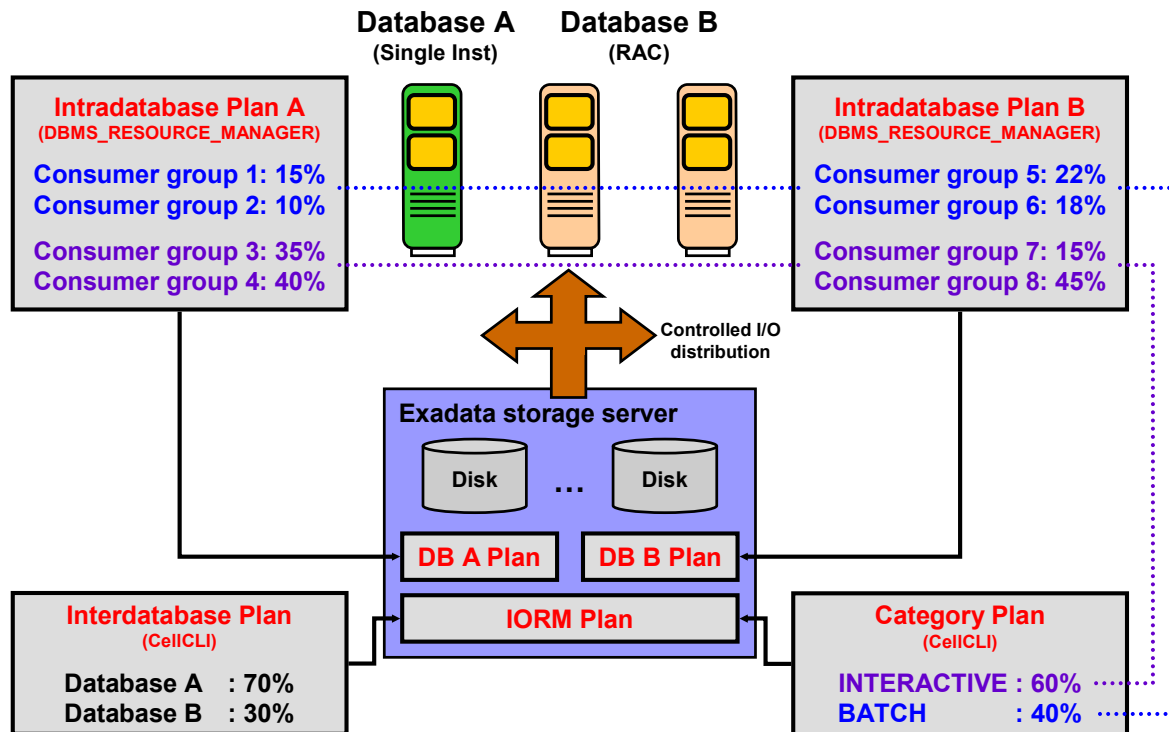
IORM schedules I/O by immediately issuing some I/O requests and queuing others. I/O requests are issued immediately for workloads that have not exceeded their resource allocation according to the resource plans. I/O requests are queued for workloads that have exceeded their resource allocation. Queued I/Os are issued by IORM according to the allocations in the resource plans. The goal of IORM is to fully utilize the available resources. Any allocation that is not fully utilized is made available to other workloads in proportion to the configured resource plans.

IORM only intervenes when needed to maintain the desired allocation of resources. Specifically, IORM does not intervene if there is only one consumer group and database active at any time because there is no possibility of contention with another consumer group or database.

Background I/Os are scheduled based on their priority relative to the user I/Os. For example, redo writes and control file I/Os are critical to performance and are always prioritized above all user I/Os. Writes by the database writer process (DBWR) are scheduled at the same priority level as user I/Os.

The diagram in the slide illustrates the high-level implementation of IORM. Basically, each database accessing the cell has one I/O queue per consumer group and three background I/O queues per cell disk. The background I/O queues correspond to high, medium, and low priority requests; background I/Os are enqueued based on their I/O type. If you do not set an intradatabase resource plan, all nonbackground I/O requests are grouped into a single consumer group called `OTHER_GROUPS`.

I/O Resource Management Plans Example



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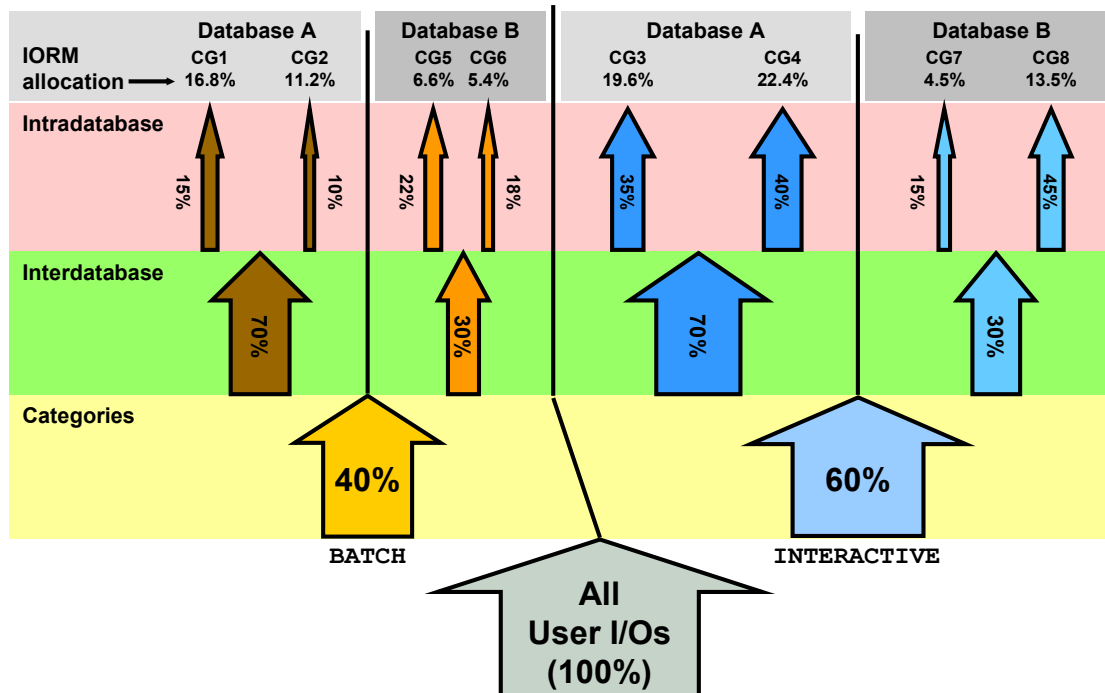
I/O Resource Management Plans Example

For each database, you can use the DBRM to create resource consumer groups, assign user sessions to consumer groups and specify resource allocation plans to distribute I/O resources among consumer groups. When you set an intradatabase resource plan, a description of the plan is automatically sent to each cell. When a new cell is added or an existing cell is restarted, the current intradatabase plan is automatically sent to the cell. The intradatabase resource plan is used to manage resources on both the database server and cells. In the example on the slide Database A and Database B have separate intradatabase plans. Each consumer group in each intradatabase plan is associated with either the `INTERACTIVE` or `BATCH` category.

At each cell, an interdatabase plan can be configured and enabled. In the example on the slide the interdatabase plan is configured with a larger resource allocation for Database A (70%) than for Database B (30%).

Also within each cell, you can categorize consumer groups from different databases and distribute I/O resources according to the various categories. In the example on the slide the `INTERACTIVE` category (60%) is allocated a greater resource share than the `BATCH` category (40%).

I/O Resource Management Plans Example



I/O Resource Management Plans Example (continued)

The category, interdatabase, and intradatabase plans together are used by Exadata to allocate I/O resources.

The category plan is first used to allocate resources among the categories. When a category is selected, the interdatabase plan is used to select a database; only databases that have consumer groups with the selected category can be selected. Finally, the selected database's intradatabase plan is used to select one of its consumer groups. The percentage of resource allocation represents the probability of making a selection at each level.

Expressing this as a formula:

$$P_{cgn} = c_{gn} / \text{sum}(catcgs) * db\% * cat\%$$

where:

- P_{cgn} is the probability of selecting consumer group n
- c_{gn} is the resource allocation for consumer group n
- $\text{sum}(catcgs)$ is the sum of the resource allocations for all consumer groups in the same category as consumer group n
- $db\%$ is the database allocation percentage in the interdatabase plan
- $cat\%$ is the category allocation percentage in the category plan

I/O Resource Management Plans Example (continued)

The hierarchy used to distribute I/Os is illustrated in the slide. The example is continued from the previous slide.

Notice that although each consumer group allocation is expressed as a percentage within each database, IORM is concerned with the ratio of consumer group allocations within each category. For example, Consumer Group 1 will nominally receive 16.8% of I/O resources from IORM ($\frac{15}{15+10} * 70% * 40%$) however this would not change if the Intradatabase plan allocations for consumer groups one and two were doubled to 30% and 20% respectively. This is because the allocation to Consumer Group 1 would remain 50% greater than the allocation to Consumer Group 2. This behaviour also explains why Consumer Group 1 (16.8%) and Consumer Group 3 (19.6%) have a similar allocation through IORM even though Consumer Group 3 belongs to the higher priority category (60% versus 40%) and has a much larger intradatabase plan allocation (35% versus 15%).

Note: ASM I/Os (for rebalance and so on) and I/Os issued by Oracle background processes are handled separately and automatically by Exadata. For clarity, background I/Os are not shown in the example.

Enabling Intradatabase Resource Management

- Enabling Intradatabase Resource Management:
 - Manually:
 - Set the database's `RESOURCE_MANAGER_PLAN` parameter.
 - Automatically:
 - Create a job scheduler window.
 - Associate a resource plan with the window.
- Exadata cells are notified when plan is set or modified
 - Enabled or modified plan sent to each cell using `iDB`
- You must activate the `IORMPLAN` on all Exadata cells.
- Commonly used intradatabase plans:
 - `mixed_workload_plan`
 - `dss_plan`
 - `default_maintenance_plan`

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Enabling Intradatabase Resource Management

An intradatabase resource plan can be manually enabled with the `RESOURCE_MANAGER_PLAN` initialization parameter or automatically enabled using the job scheduler.

When you set an intradatabase resource plan on the database, a description of this plan is automatically sent to each cell. When a new cell is added or an existing cell is restarted, the current plan of the database is automatically sent to the cell. This resource plan is used to manage resources on both the database server and cells.

Before `IORM` can be used, you must activate the `IORMPLAN` on all corresponding Exadata cells.

Oracle Database provides several predefined intradatabase plans. The most commonly used are `mixed_workload_plan`, `dss_plan`, and `default_maintenance_plan`.

Intradatabase plans do not contain a directive for background I/O activity. Background I/Os are scheduled based on their priority relative to the user I/Os. For example, redo writes, and control file reads and writes are critical to performance and are always prioritized above all user I/Os.

Note: When an Oracle RAC database uses an Exadata cell, all instances in the Oracle RAC cluster must be set to the same resource plan.

Intradatabase Plan Example

```
BEGIN
  DBMS_RESOURCE_MANAGER.CREATE_SIMPLE_PLAN(SIMPLE_PLAN => 'my_simple_plan',
    CONSUMER_GROUP1 => 'high_priority', GROUP1_PERCENT => 80,
    CONSUMER_GROUP2 => 'low_priority' , GROUP2_PERCENT => 20);
END;
/
```

```
ALTER SYSTEM SET RESOURCE_MANAGER_PLAN = 'my_simple_plan';
```

The plan is sent directly to the Exadata cells via iDB.

Consumer Group	Level 1	Level 2	Level 3
SYS_GROUP	100%		
HIGH_PRIORITY		80%	
LOW_PRIORITY		20%	
OTHER_GROUP			100%

Percentages are used for both CPU and I/O resources.

```
CellCLI> ALTER IORMPLAN ACTIVE
```

Intradatabase Plan Example

The intradatabase I/O resource plan specifies how I/O resources are allocated among consumer groups in a specific database.

An intradatabase I/O resource plan is created with the procedures in the PL/SQL DBMS_RESOURCE_MANAGER package. There are no specific I/O resource parameters or procedures. You create an intradatabase I/O resource plan exactly the same way as you would create a CPU resource plan. When you specify a plan directive percentage, this percentage applies to both CPU and I/O resources if Exadata storage is used. There are no specific I/O settings because typically you are constrained by CPU or I/O, but not both at the same time.

The intradatabase I/O resource plan is applicable only when the database uses Exadata storage.

The example in the slide uses the CREATE_SIMPLE_PLAN procedure to create MY_SIMPLE_PLAN. This resource plan is used to manage CPU resources at the database level, and I/O resources at the Exadata cell level.

Before I/O resources for an intradatabase plan can be managed by the I/O Resource Management on the Exadata cells, you need to make sure that the IORMPLAN is active. This can be done by executing the ALTER IORMPLAN ACTIVE command.

Enabling IORM for Multiple Databases

- Configured with CellCLI on each cell
- Managed with the `IORMPLAN`:
 - The category plan assigns I/O resources using categories.
 - The interdatabase plan assigns I/O resources using database names.
 - All combinations are possible.
 - Default: All databases get equal allocations in the absence of `IORMPLAN`.
- Configure the same `IORMPLAN` on each cell.
- Only one `IORMPLAN` can be active at a time on a cell.
- `IORMPLAN` settings are persistent across cell reboots.

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Enabling IORM for Multiple Databases

I/O resource management for multiple databases is configured with the `IORMPLAN`. The `IORMPLAN` specifies how I/O resources are allocated among multiple databases for each cell. If you are using multiple cells, you need to configure them all. In most cases all your cells should use the same `IORMPLAN`.

The `IORMPLAN` contains both an interdatabase plan (also called a “DB plan”) and a category plan. The directives in the DB plan specify I/O resource allocations to database names, rather than consumer groups. The directives in the category plan specify I/O resource allocations to categories, rather than databases or consumer groups. The `IORMPLAN` is configured and enabled with CellCLI at each cell. Only one `IORMPLAN` can be active on a cell at any given time.

At startup, the plan is an empty string, which effectively turns off IORM. In that case, or if an `IORMPLAN` is not specified, all databases receive an equal allocation.

The `IORMPLAN` must be activated for I/O resource management to occur. When the `IORMPLAN` is deactivated, IORM will not manage I/O resources, even if an intradatabase resource plan is set or an `IORMPLAN` is configured.

Interdatabase Plan Example

```
CellCLI> alter iormplan
>         dbplan=((name=sales_prod, level=1, allocation=80),
>                 (name=finance_prod, level=1, allocation=20),
>                 (name=sales_dev, level=2, allocation=100),
>                 (name=sales_test, level=3, allocation=50),
>                 (name=other, level=3, allocation=50)),
>         catplan=''
CellCLI> alter iormplan active
```



Database	Level 1	Level 2	Level 3
sales_prod	80%		
finance_prod	20%		
sales_dev		100%	
sales_test			50%
other			50%

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Interdatabase Plan Example

On each Exadata storage server, an interdatabase plan specifies how resources are divided among multiple databases. The directives in an interdatabase plan specify allocations to databases, rather than consumer groups. The interdatabase plan is configured and activated with CellCLI, on each cell.

The above example implements an interdatabase plan following the directives shown in the table.

The interdatabase plan is created by specifying the DBPLAN part of the IORMPLAN. The interdatabase plan is similar to an intradatabase plan in that each directive consists of a `level` from 1 to 8 and an `allocation` amount in percentage terms. For a given plan, all allocations at any level must add up to 100 or less. An interdatabase plan differs from an intradatabase plan in that it cannot contain subplans and it only contains I/O resource directives.

As a best practice, you should create a directive for each database using the same Exadata storage. To make sure that any database without an explicit directive can be managed, you need to create an allocation named `OTHER`.

Interdatabase Plan Example (continued)

The `role` attribute indicates that the directive is applied only when the databases are in that database role. This provides the flexibility to automatically adjust the IORM plan according to the role of the database in an Oracle Data Guard environment. If the `role` attribute is not specified, then the directive is applied regardless of the database role. Following is an example of an interdatabase plan using the `role` attribute:

```
ALTER IORMPLAN dbplan=( -  
    (name=sales1, level=1, allocation=30, role=primary), -  
    (name=sales2, level=1, allocation=35, role=primary), -  
    (name=sales1, level=2, allocation=20, role=standby), -  
    (name=sales2, level=2, allocation=25, role=standby), -  
    (name=other, level=3, allocation = 50))
```

You can remove an interdatabase plan using:

```
ALTER IORMPLAN dbplan=' '
```

Category Plan Example

DBA_RSRC_CONSUMER_GROUPS

CONSUMER_GROUP	CATEGORY
SYS_GROUP	ADMINISTRATIVE
BATCH_GROUP	BATCH
INTERACTIVE_GROUP	INTERACTIVE
ORA\$...	MAINTENANCE
OTHER_GROUPS	OTHER
DEFAULT_CONSUMER_GROUP	OTHER
LOW_GROUP	OTHER
AUTO_TASK_CONSUMER_GROUP	OTHER

dbms_resource_manager.create_category

Category	Level 1	Level 2	Level 3
Interactive	90%		
Batch		80%	
Maintenance			50%
Other			50%

```

CellCLI> alter iormplan
>      dbplan= ''
>      catplan=(
              (name=interactive, level=1, allocation=90), -
              (name=batch, level=2, allocation=80), -
              (name=maintenance, level=3, allocation=50), -
              (name=other, level=3, allocation=50) -
              )
CellCLI> alter iormplan active
      
```

Category Plan Example

Database Resource Manager enables you to specify a category for every consumer group. The predefined categories and their associated consumer groups are listed in the slide. This is the default situation after database creation. If you decide to use these default categories, you should map all administrative consumer groups in all databases to the ADMINISTRATIVE category. All high-priority user activity, such as consumer groups for important OLTP transactions and time-critical reports, should be mapped to the INTERACTIVE category. All low-priority user activity, such as reports, maintenance, and low-priority OLTP transactions, should be mapped to the BATCH, MAINTENANCE, and OTHER categories.

You can create your own categories using the CREATE_CATEGORY procedure in the DBMS_RESOURCE_MANAGER package, and then assign your category to a consumer group using the CREATE_CONSUMER_GROUP or UPDATE_CONSUMER_GROUP procedures.

You can then manage I/O resources based on categories by creating a category plan. The example shown in the slide implements a category plan based on the allocations described in the table. With this plan, consumer groups associated with the INTERACTIVE category get up to 90 percent of I/O resources. 80 percent of the remainder, including any unutilized allocation from the INTERACTIVE category, is allocated to the BATCH category. The MAINTENANCE and OTHER categories share the remainder.

Any consumer group without an explicitly specified category defaults to the OTHER category.

Quiz

If a consumer group does not require its full resource allocation, what happens to the leftover allocation?

1. It remains unused.
2. It is divided equally among other consumer groups.
3. It is allocated to other active consumer groups, according to the resource plan.

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Answers: 3

Quiz

Which of the following conditions are required for IORM to intervene and control the allocation of I/O resources.

1. The IORM plan must be active.
2. More than one consumer group must be active.
3. The disks must be heavily utilized.

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Answers: 1, 2, 3

All of the conditions listed in this question must be present for IORM to intervene.

Quiz

The different I/O resource plans are applied in which order to allocate I/O resources?

1. Category, intradatabase, interdatabase
2. Interdatabase, category, intradatabase
3. Category, interdatabase, intradatabase
4. Interdatabase, intradatabase, category
5. Intradatabase, interdatabase, category

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Answers: 3

Quiz

You can create categories using the CellCLI utility.

1. TRUE
2. FALSE

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Answers: 2

You can create your own categories using the `CREATE_CATEGORY` procedure in the `DBMS_RESOURCE_MANAGER` package, and then assign your category to a consumer group using the `CREATE_CONSUMER_GROUP` or `UPDATE_CONSUMER_GROUP` procedures.

You can then manage I/O resources based on categories by creating a category plan. The category plan can be created using the CellCLI utility.

Summary

In this lesson, you should have learned how to use Exadata I/O Resource Management to manage workloads within a database and across multiple databases.

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Demonstration Overview

The demonstrations associated with this lesson cover the following topics:

- A
- B
- C

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