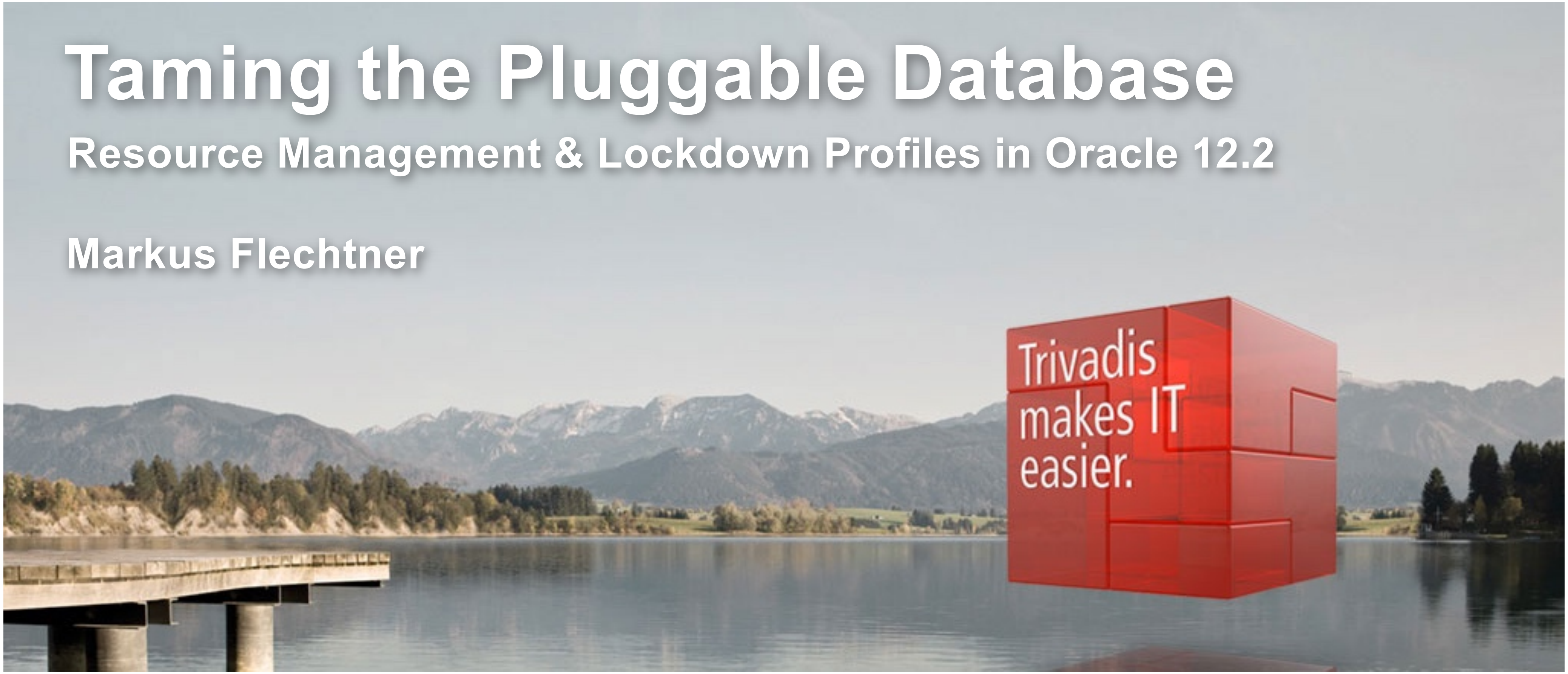
Taming the Pluggable Database

Resource Management & Lockdown Profiles in Oracle 12.2

Markus Flechtner



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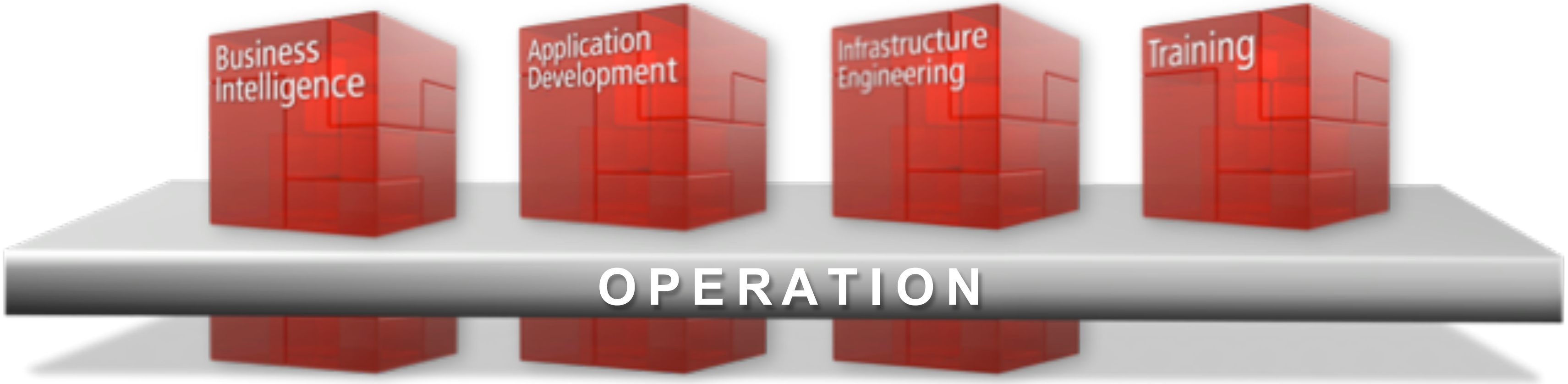

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  - Development (Forms, Reports, PL/SQL)
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  - O-NF12CDBA – Oracle 12c New Features for the DBA

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Motivation

- In a Multitenant Database, ..
  - .. access to common resources like OS and network should be restricted
  - .. the system resources like CPU, memory and I/O should be distributed among the PDBs in a controlled way
  - .. charging the customers by resource usage (storage, I/O, CPU) should be possible

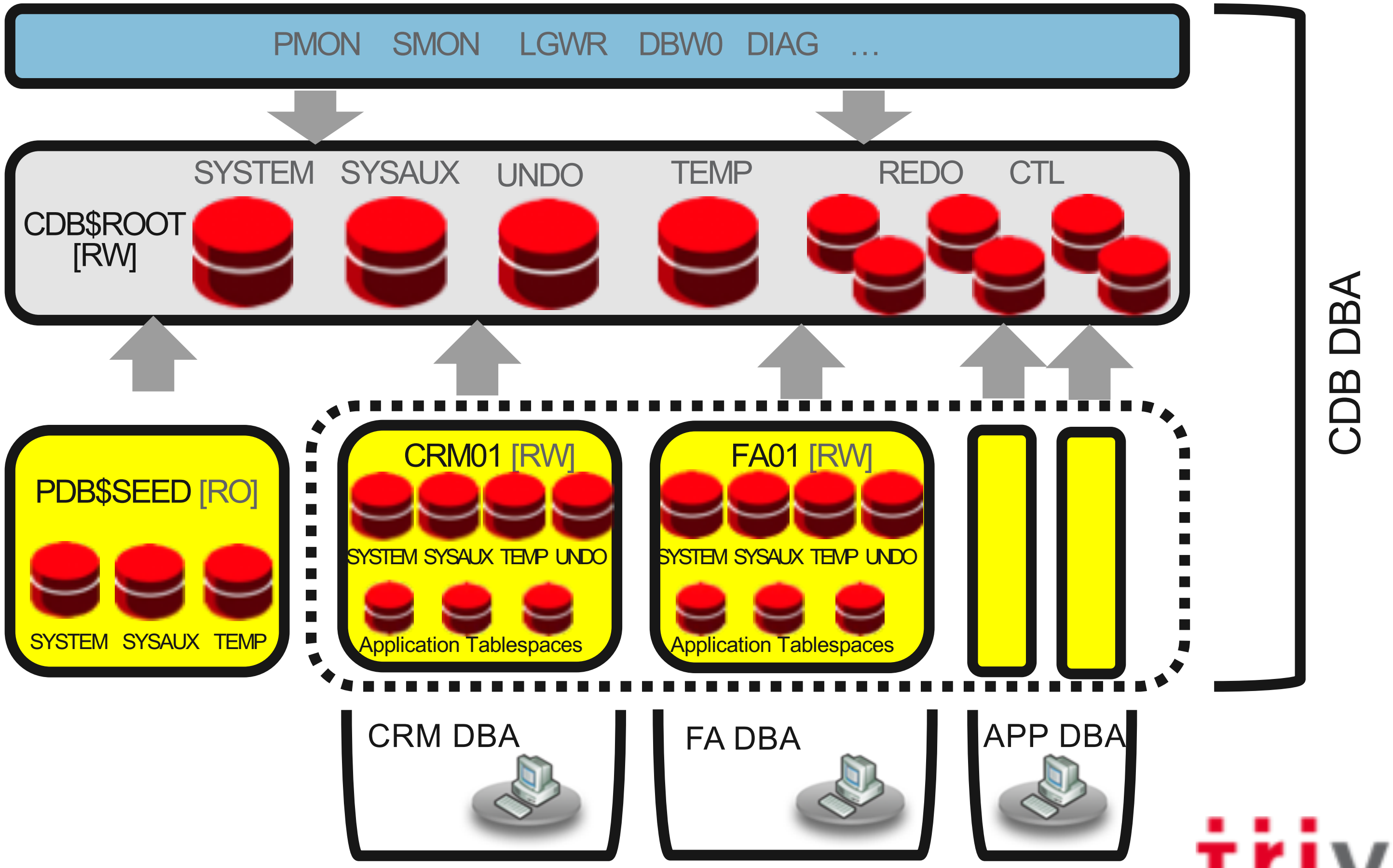
- Oracle Database 12c Release 2 brings improvements in all three areas

Agenda

1. **Container Database Architecture**
2. **Resource Management**
   - I/O
   - CPU
   - Memory
3. **Lockdown Profiles**
4. **Miscellaneous**
5. **Summary**

Container Database Architecture

Container Database Architecture (1) – The Big Picture

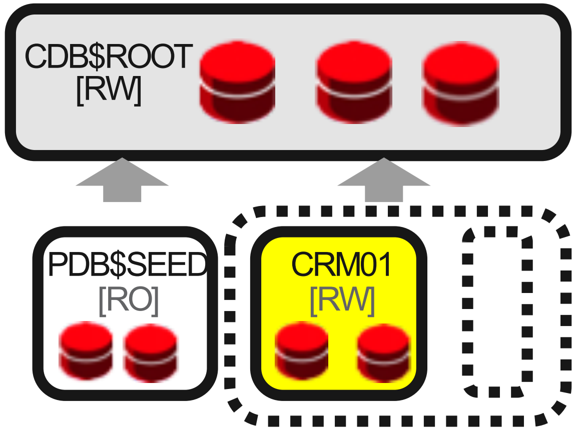


Container Database Architecture (2)

- The new Container Database Architecture (“**multitenant architecture”)** enables an Oracle database to work as a **container database** (CDB)
- A CDB consists of:
  - The root container **CDB$ROOT** – stores system metadata and common users/roles
  - The seed container **PDB$SEED** – default template used for cloning (cannot be modified)
  - Up to **252** user created **Pluggable Databases** (PDB) (in 12.2 up to 4096 on Exadata and Oracle Cloud)
- A new database architecture designed for:
  - consolidation/database virtualization
  - fast and easy provisioning
  - separation of administrative duties
  - rapid movement of user data (unplug/plug)
- Pluggable databases are **compatible** with traditional non-CDB (same behaviour from the application point of view)

Container Database Architecture (3)

- All database containers **share** the default block size
- PDBs created in a CDB share the character set with CDB$ROOT
  - PDBs which are plugged into a CDB can have a different character set (binary subset of the CDB$ROOT-character set) (12.2)
- All PDBs **belong** to the same CDB$ROOT container and **share**:
  - the Oracle instance (background processes, shared memory segment, semaphores)
  - the system metadata stored in the ROOT (Oracle-supplied PL/SQL code, metadata for the data dictionary objects)
  - redo thread(s) and control files
  - UNDO tablespace (12.1, still available in 12.2 but not recommended)
- Each PDB
  - has its own SYSTEM, SYSAUX and UNDO (12.2) tablespace
  - has it's own temporary tablespace
  - is a self-contained set of database data files



Resource Management

Resource Management for Container Databases (1)

- Adequate resource management is essential for Multitenant Databases
- Very often, with DBaaS Service Level Agreements (SLAs) guarantee a certain amount of resources
- Oracle can manage the following resources
  - CPU
  - Number of parallel server processes
  - Memory (since Oracle 12.2)
  - I/O (since Oracle 12.2)
- On Exadata and Oracle Super Cluster I/O-management is available since Oracle 12.1
  - Not covered in this presentation

Resource Management for Container Databases (2)

- For some of the resource limits, the following procedure applies
  - Resource limits are **defined** in CDB$ROOT
  - Resource limits are **activated** in the PDB ("ALTER SYSTEM ..")
  - PDB has to be bounced (close/open) after defining the limit on PDB level
- To prevent a PDB administrator from disabling these resource limits, PDB resource management should be combined with Lockdown Profiles
  - Disable "ALTER SYSTEM .." on PDB level

Managing CPU Resources

- Two ways to limit CPU resources
  - Parameter CPU_COUNT (on PDB level) – since Oracle 12.2
  - Resource Manager
- Parameter CPU_COUNT
  - Dynamic parameter
  - Allows instance caging on PDB level
  - Resource Manager must be enabled (RESOURCE_MANAGER_PLAN set)

```
SQL> ALTER SYSTEM SET cpu_count = 4;
```

Resource Manager 12c for Multitenancy

- Within container databases it is possible to use Resource Manager to control resource consumption of individual tenants (PDBs)
- CDB Level – between PDBs
  - Define resource allocation to specific PDBs
  - Limit resource utilizations for specific PDBs
  - CDB DBA can give more resources to more important PDBs
  - System resource shares and limits can be configured
- PDB Level – within PDBs
  - Define resource allocations within specific PDBs
- No Resource Manager for CDB$ROOT

Example for CDB Resource Plan

	Shares	Utilization Limit %	Parallel Server Limit %
Default per PDB	1	100	100
PDB1	1	50	20
PDB2	2	75	20
PDB3	3	100	100

- PDB1 gets guaranteed 1 share of total 6, so 17% of system resources (CPU, Exadata I/O Bandwidth, queued parallel statements) – PDB2 33% – PDB3 50%
- PDB1 can utilize max. 50% of system resources
- PDB1 can utilize max. 20% of parallel server processes specified by init parameter parallel_servers_target
- One row in the table is defined as a CDB plan directive (= default)

CDB Resource Plan (1)

- Create a pending area and a new CDB plan

```
SQL> execute dbms_resource_manager.create_pending_area;
SQL> execute dbms_resource_manager.create_cdb_plan(
   2 plan                   => 'MY_PLAN',
   3 comment                => 'My CDB plan'
   4 );
```

- Create a CDB plan directive for each PDB

```
SQL> execute dbms_resource_manager.create_cdb_plan_directive(
   2 plan                  => 'MY_PLAN',
   3 pluggable_database    => 'PDB1',
   4 comment               => 'give 1 share',
   5 shares                => 1,
   6 utilization_limit     => 50,
   7 parallel_server_limit => 20
   8 );
```

CDB Resource Plan (2)

- Update the Default Directive

```
SQL> execute dbms_resource_manager.update_cdb_default_directive(
  plan                        => 'MY_PLAN',
  new_shares                  => 1,
  new_utilization_limit       => 100,
  new_parallel_server_limit => 100 );
```

- Update the directive for the automated maintenance tasks in CDB$ROOT

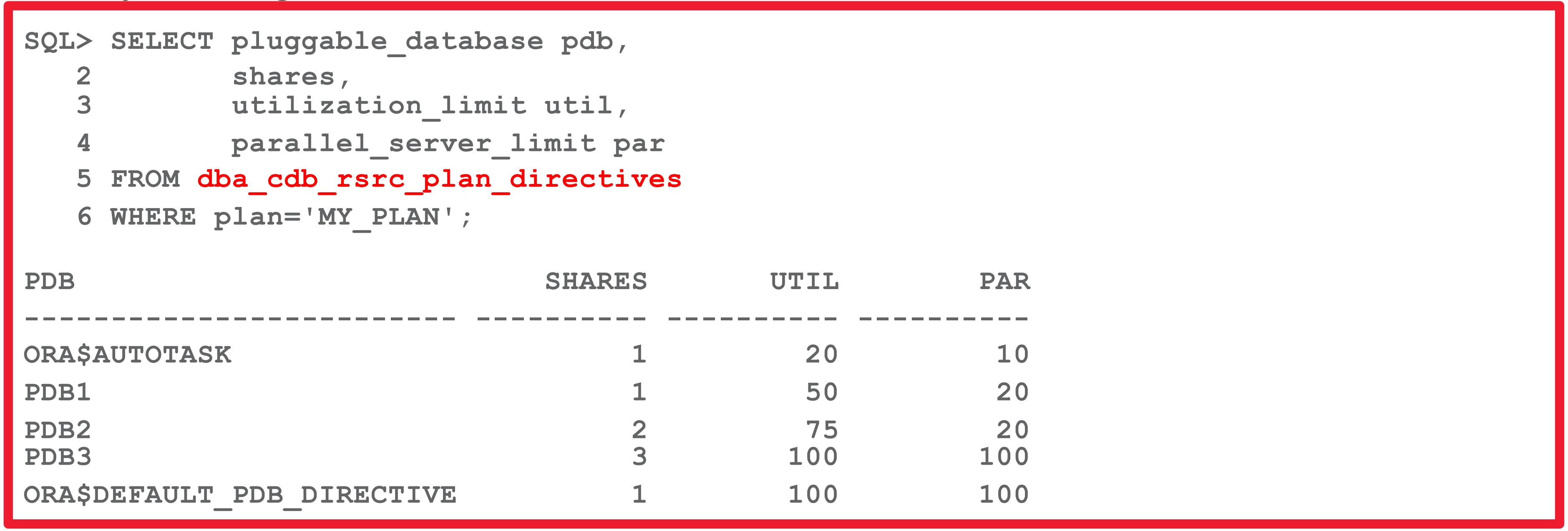
```
SQL> execute dbms_resource_manager.update_cdb_autotask_directive(
   2 plan                        => 'MY_PLAN',
   3 new_shares                  => 1,
   4 new_utilization_limit       => 20,
   5 new_parallel_server_limit => 10);
```

- Validate and submit

```
SQL> execute dbms_resource_manager.validate_pending_area;
SQL> execute dbms_resource_manager.submit_pending_area;
```

Query CDB Resource Plans

- Query the assigned directives



```
SQL> SELECT pluggable_database pdb,
  2         shares,
  3         utilization_limit util,
  4         parallel_server_limit par
  5 FROM dba_cdb_rsrc_plan_directives
  6 WHERE plan='MY_PLAN';

PDB                          SHARES       UTIL        PAR
------------------------- ---------- ---------- ----------
ORA$AUTOTASK                      1         20         10
PDB1                              1         50         20
PDB2                              2         75         20
PDB3                              3        100        100
ORA$DEFAULT_PDB_DIRECTIVE         1        100        100
```

Activate a CDB Resource Plan

- Activate instantly

```
SQL> ALTER SYSTEM SET resource_manager_plan = MY_PLAN
```

- Regularly via Scheduler Window

```
SQL> execute dbms_scheduler.create_window(
   2 window_name     => 'MY_WINDOW',
   3 resource_plan   => 'MY_PLAN',
   4 start_date      => to_timestamp_tz('24.07.2013 20:00:00',
   5                                'DD.MM.YYYY HH24:MI:SS'),
   6 repeat_interval => 'freq=daily',
   7 duration        => INTERVAL '2' HOUR
   8 );
```

Combined CDB and PDB Resource Plan Usage

- CDB resource plans and PDB resource plans can be combined:

CDB

PDB	Shares	Util Limit
PDB1	1	20 %
PDB2	2	100 %
PDB3	3	50 %

PDB3

Cons. Group	Shares	Util Limit
OLTP	1	30 %
BATCH	2	20 %
BOARD	2	50 %

- How much CPU resources gets BOARD in PDB3 ?
  - Guaranteed is: 3/6 * 2/5 = 6/30 = 20%
  - Limited to: 50 % * 50 % = 25 %

Performance Profiles

12.2

- A performance profile is a collection of resource manager settings for PDBs
- E.g. SLA level (gold, silver, bronze)
- Easy way to modify the resource limits for a group of PDBs

```
DBMS_RESOURCE_MANAGER.CREATE_CDB_PROFILE_DIRECTIVE(
  plan => 'newcdb_plan',
  profile => 'gold',
  shares => 3,
  utilization_limit => 100,
  parallel_server_limit => 100);
```

- Activation on PDB level (static parameter DB_PERFORMANCE_PROFILE)

```
ALTER SYSTEM SET DB_PERFORMANCE_PROFILE=gold SCOPE=SPFILE;
```

Memory Management for PDBs (1)

12.2

The following memory related parameters can be set on PDB level:

Parameter	Meaning
DB_CACHE_SIZE	Minimum guaranteed buffer cache for the PDB
SHARED_POOL_SIZE	Minimum guaranteed shared pool for the PDB
PGA_AGGREGATE_LIMIT	Maximum PGA size for the PDB
SGA_MIN_SIZE	Minimum SGA size for the PDB
SGA_TARGET	Maximum SGA size for the PDB
INMEMORY_SIZE	Maximum Size of the In-Memory-Column-Store

Memory Management for PDBs (2)

12.2

- Requirements
  - Parameter NONCDB_COMPATIBLE=FALSE in CDB$ROOT
  - MEMORY_TARGET not set in CDB$ROOT
- Restrictions for SGA related parameters (if SGA_TARGET=0)
  - Sum of all values for SGA (DB_CACHE_SIZE, SGA_MIN_SIZE, SHARED_POOL_SIZE) for all PDBS must no be higher than 50% of the corresponding value for CDB$ROOT
- Restrictions (PGA)
  - PGA_AGGREGATE_LIMIT: not more than PGA_AGGREGATE_LIMIT in CDB$ROOT
- INMEMORY_SIZE
  - Over-Provisioning allowed

I/O Rate Limits for PDBs (1)

12.2

- New parameters on container level (CDB$ROOT or PDB):

```
ALTER SYSTEM SET MAX_IOPS = 1000 SCOPE = BOTH
```

```
ALTER SYSTEM SET MAX_MBPS = 5 SCOPE = BOTH
```

- To disable a limit, set the parameter to 0 (Default)
- Event "resmgr: I/O rate limit“ (V$SYSTEM_EVENT, V$SESSION_EVENT) is raised when the limit is hit
- Values set in CDB$ROOT are the default for PDBs
- Not supported on Exadata
- DBWR-I/O, Controlfile-I/O and Password file are exempted
- Parameters are not supported on Non-CDBs
("ORA-56739: cannot modify max_iops or max_mbps parameter")

I/O Rate Limits for PDBs (2) - Example

12.2

```
SQL> REM No limits set
SQL> SELECT * FROM DBA_TAB_COLUMNS;
[..]
.. Takes 11 seconds
SQL> alter system set max_iops=80 scope=both;
SQL> alter system set max_mbps=8 scope=both;
SQL> alter system flush buffer_cache;
SQL> alter system flush shared_pool;
SQL> SELECT * FROM DBA_TAB_COLUMNS;
[..]
.. Takes 23 seconds
SQL> select con_id,event,time_waited from v$session_event
  2 where event='resmgr: I/O rate limit';
CON_ID EVENT                                      TIME_WAITED
------ ---------------------------------------- -----------
     0 resmgr: I/O rate limit                            95
     1 resmgr: I/O rate limit                           215
```

Database Maintenance Jobs (1)

- Since Oracle 10g, Oracle runs maintenance jobs (e.g. Statistics Gathering, Tuning Advisor etc.) in a defined maintenance window
- Default window
  - Weekdays: 10 PM – 2 AM
  - Weekend: 6 AM – 2 AM
- In a Multitenant database this window is the default window for all PDBs!
  - ➔ in a CDB with a huge number of PDBs this can lead to high load during the maintenance window

Database Maintenance Jobs (2)

- **Workarounds:**
  - Define different maintenance windows for the PDBs (depending on SLA, ETL jobs etc.)
  - Change the number of concurrent maintenance jobs (Default value is 2)

```
ALTER SYSTEM SET AUTOTASK_MAX_ACTIVE_PDBS = 4 SCOPE = BOTH
```

  - Deactivate automatic maintenance jobs on PDB level (Default: TRUE)

```
ALTER SYSTEM SET ENABLE_AUTOMATIC_MAINTENANCE_PDB = FALSE SCOPE = BOTH
```

Other resource-relevant Parameters on PDB-level

12.2

Parameter	Meaning
MAX_DATAPUMP_JOBS_PER_PDB	Maximum number of concurrent DataPump Jobs in the PDB (Value in CDB$ROOT is the default for the PDBs)
SESSIONS	Maximum of concurrent sessions in the PDB (available since 12.1)

- Not limiting the number of sessions in a PDB can lead to the problem that one PDB takes all available sessions (instance parameter SESSIONS)
  - ➔ no logins to the other PDBs and to CDB$ROOT possible

Resource Monitoring - V$RSRCPDBMETRIC (1)

12.2

- The view **V$RSRCPDBMETRIC** contains resource usage data for the last minute
- **V$RSRCPDBMETRIC_HISTORY** (with the same structure) contains date for the last hour
- The AWR-View **DBA_HIST_RSRC_PDB_METRIC** (Diagnostic Pack required!) contains persistent snapshots of the view V$RSRCPDBMETRIC
- Can be used for PDB charging (e.g. by used memory, I/O etc.)

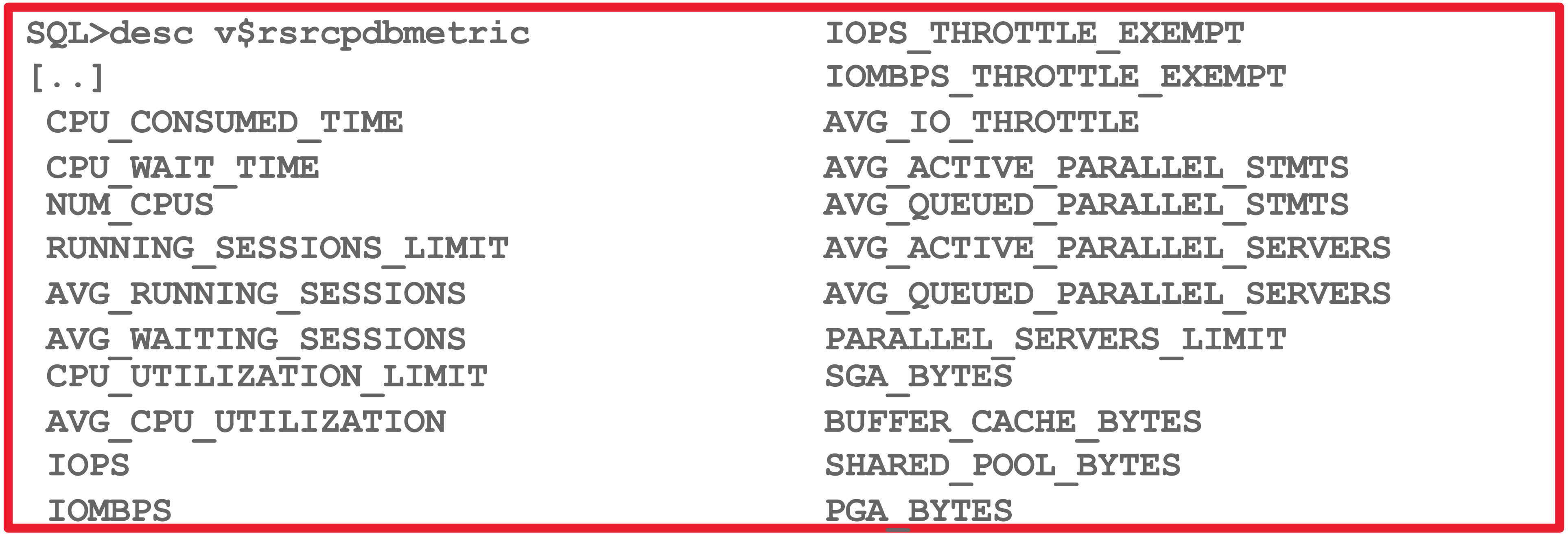
```
SELECT r.CON_ID, p.PDB_NAME, r.IOPS,r.SGA_BYTES, r.SHARED_POOL_BYTES
FROM V$RSRCPDBMETRIC r, CDB_PDBS p
WHERE r.CON_ID = p.CON_ID;

CON_ID PDB_NAME   IOPS       SGA_BYTES SHARED_POOL_BYTES
------ --------- ---------- ---------- -----------------
3      PDB01     .440423759   86405592           7401944
4      PDB02     .464230449   51885608          12138024
```

Resource Monitoring - V$RSRCPDBMETRIC (2)

12.2

- What is logged in V$RSRCPDBMETRIC?



```
SQL>desc v$rsrcpdbmetric                 IOPS_THROTTLE_EXEMPT
[..]                                     IOMBPS_THROTTLE_EXEMPT
 CPU_CONSUMED_TIME                       AVG_IO_THROTTLE
 CPU_WAIT_TIME                           AVG_ACTIVE_PARALLEL_STMTS
 NUM_CPUS                                AVG_QUEUED_PARALLEL_STMTS
 RUNNING_SESSIONS_LIMIT                  AVG_ACTIVE_PARALLEL_SERVERS
 AVG_RUNNING_SESSIONS                    AVG_QUEUED_PARALLEL_SERVERS
 AVG_WAITING_SESSIONS                    PARALLEL_SERVERS_LIMIT
 CPU_UTILIZATION_LIMIT                   SGA_BYTES
 AVG_CPU_UTILIZATION                     BUFFER_CACHE_BYTES
 IOPS                                    SHARED_POOL_BYTES
 IOMBPS                                  PGA_BYTES
```

Lockdown Profiles

PDB Lockdown Profiles (1) – Use cases

12.2

- Enforce the separation of duties in a Container Database:
  - CDB administrator: "infrastructure administrator"
  - PDB administrator: "application DBA with restricted privileges
- Control Feature Usage on PDB level
  - Create a CDB with all options
  - Disable options on PDB level which were not ordered by the DBaaS-customer
- Disable access to OS and network resources
  - E.g. use of packages like UTL_FILE, UTL_MAIL, UTL_HTTP, ..

PDB Lockdown Profiles (2)

12.2

- Restrict feature usage on PDB level
- Areas
  - Network access
  - Common user or object access
  - Administrative features
  - XML database access
  - Database options (e.g. Partitioning)
- Default lockdown profiles (empty, i.e. no limits defined)
  - SAAS
  - PUBLIC_DBAAS
  - PRIVATE_DBAAS

PDB Lockdown Profiles (3)

12.2

- Create a lockdown profile in CDB$ROOT

```
CREATE LOCKDOWN PROFILE demo_lckdprf;
ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE STATEMENT = ('ALTER SYSTEM');
ALTER LOCKDOWN PROFILE demo_lckdprf ENABLE STATEMENT = ('ALTER SYSTEM') CLAUSE
= ('flush shared_pool');
ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE FEATURE = ('NETWORK_ACCESS');
ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE OPTION = ('Partitioning');
```

PDB Lockdown Profiles (4)

12.2

- Set the lockdown profile on PDB level (static parameter PDB_LOCKDOWN)
  - Bounce the PDB to activate the lockdown profile

```
ALTER SESSION SET CONTAINER=PDB1;
ALTER SYSTEM SET PDB_LOCKDOWN = demo_lckdprf SCOPE = SPFILE;
ALTER PLUGGABLE DATABASE PDB1 CLOSE;
ALTER PLUGGABLE DATABASE PDB1 OPEN;
```

- **Recommendation:** Disable „ALTER SYSTEM“ via lockdown profile
  - However, this makes it difficult to disable the lockdown profile ☹
- When PDB_LOCKDOWN is set in CDB$ROOT, this will be the default lockdown profile for all PDBs
  - A "local" lockdown profile set in a PDB overrides the global profile

PDB Lockdown Profiles (5)

12.2

- What happens in the PDB?

```
SQL> ALTER SYSTEM FLUSH BUFFER_CACHE;
Error at line 1:
ORA-01031: insufficient privileges

SQL> ALTER SYSTEM FLUSH SHARED_POOL;
System altered.

SQL> CREATE TABLE .. PARTITION BY ..
ERROR at line 1:
ORA-00439: feature not enabled: Partitioning
```

PDB Lockdown Profiles (6)

12.2

- Options, which can be disabled:
  - Database Queueing
  - Partitioning
- Statements, which can be disabled:
  - ALTER DATABASE
  - ALTER PLUGGABLE DATABASE
  - ALTER SESSION
  - ALTER SYSTEM
- For statements, specific clauses can be enabled/disabled.

```
ALTER LOCKDOWN PROFILE demo_prf DISABLE STATEMENT = ('ALTER SYSTEM') CLAUSE =
('SUSPEND', 'RESUME');
```

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PDB Lockdown Profiles (7)

12.2

- Features (excerpt)
  - AWR Access
  - Network Access (UTL_TCP, UTL_HTTP, UTL_MAIL, UTL_SNMP, UTL_INADDR and DBMS_DEBUG_JDWP, XDB Protocols
  - JAVA
  - OS Access (UTL_FILE or DBMS_FILE_TRANSFER)

- Please see "Oracle 12.2 SQL Reference" for a complete list

Miscellaneous

OMF/ASM – CREATE_FILE_DEST

12.2

- CREATE_FILE_DEST specifies the default location for OMF data files in the pluggable database (PDB). When not set, the PDB inherits the value from the root container.

```
CREATE_FILE_DEST = +U01
```

- CREATE_FILE_DEST can be specified when creating a PDB

```
SQL> create pluggable database DEMOPDB2
  2 admin user admin identified by manager role=(DBA) create_file_dest='+DATA';
```

- Trying to create a file outside CREATE_DEST results in an error

```
SQL> create tablespace DEMO datafile '/u01/oradata/TVDCDB2/DEMOPDB2/demo.dbf';
*
ERROR at line 1:
ORA-65250: invalid path specified for file - /u01/oradata/TVDCDB2/DEMOPDB2/demo.dbf
```

PDB OS User

12.2

- Ability to set the identity of the operating System user for PDBs
- Define OS user by setting the parameter **PDB_OS_CREDENTIAL** in the PDB
- Create a credential with **DBMS_CREDENTIAL.CREATE_CREDENTIAL**

```
BEGIN DBMS_CREDENTIAL.CREATE_CREDENTIAL (
  credential_name => 'CDB1_PDB1_OS_USER', username => 'os_admin',
  password => 'password');
END;
```

- Limited OS interactions
  - External jobs that do not already have an operating system credential specified
  - External table per-processors
  - PL/SQL library executions

Summary

Summary

- Resource management and resource monitoring is a must for DBaaS
- Oracle 12.2 can manage all kinds of resources (CPU, I/O, memory)

- Lockdown Profiles allow fine granular access to features and administrative commands

- Be careful when defining resource limits!

Further Information

- MOS Note 2171135.1: Managing OS Resources Among PDBs Using PDB Performance Profiles - 12.2 New Feature
- MOS-Note 2170772.1: How to Control and Monitor the Memory Usage (Both SGA and PGA) Among the PDBs in Multitenant Database- 12.2 New Feature
- MOS-Note 2326708.1: How to Provision PDBs, based on CPU_COUNT
- Whitepaper PDB Isolation: http://www.oracle.com/technetwork/database/multitenant/learn-more/isolation-wp-12c-3614475.pdf

Questions and Answers

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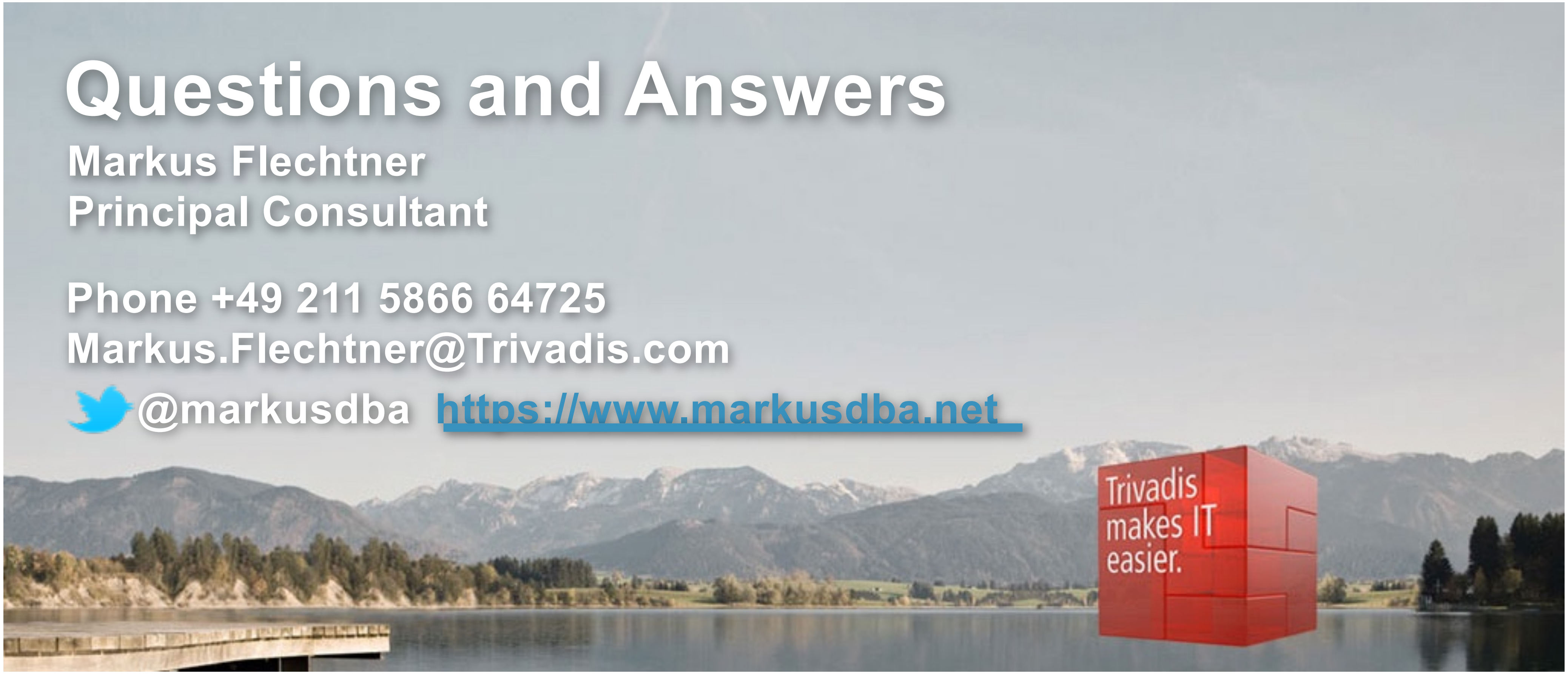

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