Taming the PDB

Resource Management & Lockdown Profiles in Oracle Database 18c & 19c

Markus Flechtner

markusdba

markusdba.de|.net

BASEL | BERN | BRUGG | BUCHAREST | DÜSSELDORF | FRANKFURT A.M. | FREIBURG I. BR.
GENEVA | HAMBURG | LAUSANNE | MANNHEIM | MUNICH | STUTTGART | VIENNA | ZURICH

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Markus Flechtner

- Principal Consultant / Trivadis Germany GmbH
- Studied Mathematics a long time ago
- Focus
  - Oracle High Availability
  - Database Upgrade + Migration
- Teacher:
  RAC, New Features, Multitenant, PostgreSQL

@markusdba

www.markusdba.net|.de

RACSIG Real Application Clusters Special Interest Group

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Motivation

- In a Multitenant Database, ..
  - ... PDBs should be isolated from each other
  - … 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
  - ... the DBaaS customer should be hindered from lifting these restrictions
  - … charging the customers by resource usage (storage, I/O, CPU, memory) should be possible

Agenda

- **Resource Management in a Container Database**
  - CPU
  - Memory
  - I/O
  - Other Resources

- **Lockdown Profiles**

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Resource Management in a Container Database in general

Resource Management for CDBs (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 CDBs (2)

- For some of the resource limits, the following procedure applies
  1. Resource limits are defined in CDB$ROOT
  2. Resource limits are activated in the PDB ("ALTER SYSTEM ..")

- To prevent a PDB administrator from disabling these resource limits, PDB resource management should be combined with lockdown profiles
  - Restrict "ALTER SYSTEM .." on PDB level

Evolution of Resource Management for CDBs

- **Oracle 12c Release 1:**
  - Resources are managed using Resource Manager (CPU share, CPU Limit (%), Parallel Server Limit (%))

- **Oracle 12 Release 2:**
  - Parameter CPU_COUNT can be set on PDB level (CPU threads)
  - Oracle Recommendation: do not use Resource Manager for CPU resources (CPU share, CPU limit), use CPU_COUNT instead

Evolution of Resource Management for CDBs

- **Oracle 18c:**
  - Parameter PARALLEL_SERVERS_TARGET can be set on PDB level
    Default:
    PARALLEL_THREADS_PER_CPU * CPU_COUNT * concurrent_parallel_users * 2
  - Oracle Recommendation: do not use Resource Manager (Parallel Server Limit)

- **Oracle 19c:**
  - Parameter CPU_MIN_COUNT: specifies the minimum number of CPU (threads) for a PDB

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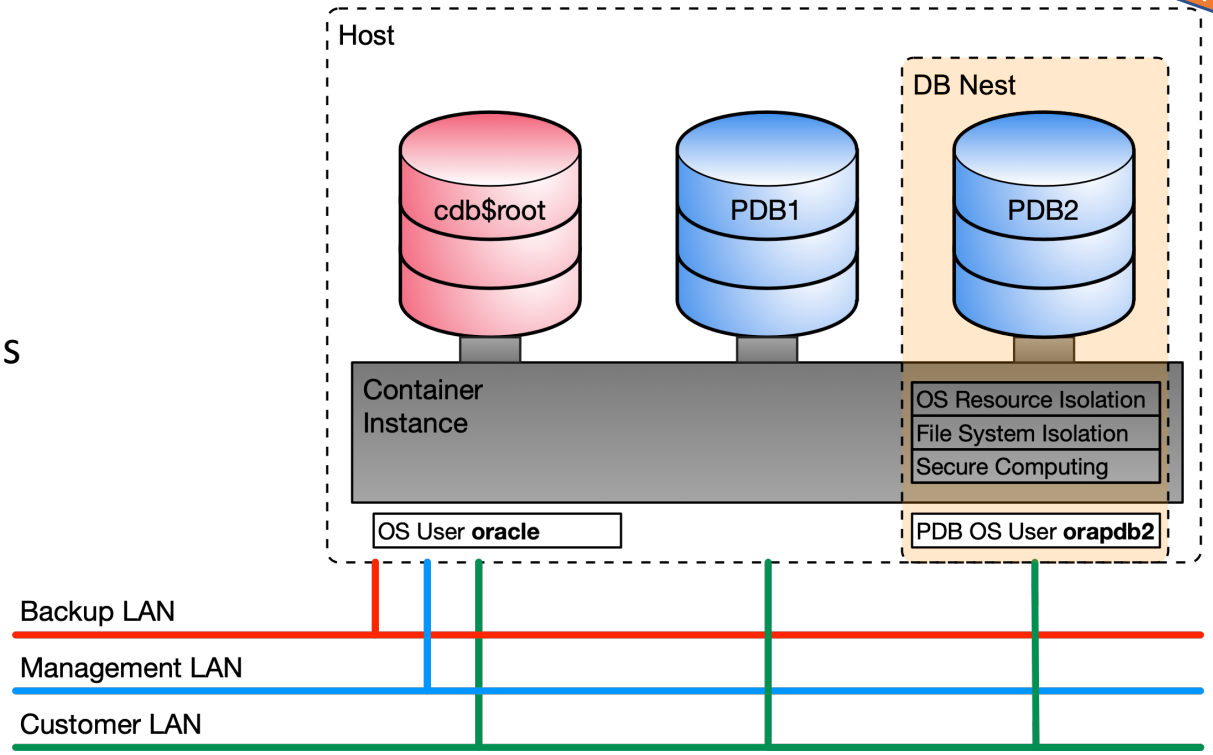
Evolution of Resource Management for CDBs

Not covered in this presentation

- **Oracle 21c – DB Nest**
- Control and isolation of
  - OS resources used by a PDB
  - File system isolation per PDB
  - Secure computing
- Concept analog to Container Technologies like Docker
- Use of Linux Namespaces and CGROUPS
- DB Nest isolate database instance from…
  - … other database instance
  - … other applications
  - … as well as PDBs from each other and from the CDB



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CPU

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Two ways to limit CPU resources

- Initialization parameters
  - CPU_COUNT (on PDB level) – since Oracle 12.2
  - CPU_MIN_COUNT (19c)

- Resource Manager (12.1)
  - Takes precedence over parameter settings (CPU_COUNT, CPU_MIN_COUNT)

CPU_COUNT and CPU_MIN_COUNT (19c)

- Dynamic PDB level parameters for instance caging on PDB level
- Resource Manager must be enabled
- Preferred method for limiting CPU resources (threads) on PDB level
- Advantages
  - Values are transferred when the PDB is unplugged and plugged into another CDB
  - Values are "static" and do not depend on the CPU shares of the other PDB

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

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Managing CPU Resources with Resource Manager

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- Only method in Oracle 12.1, not recommended for Oracle 12.2 and higher
- 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 (consumer groups) within specific PDBs
  - As we know it from Non-CDBs

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 the instance parameter PARALLEL_SERVERS_TARGET
- One row in the table is defined as a default ("CDB plan directive")

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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 );
```

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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;
```

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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
```

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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 );
```

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Example for 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		
Consumer Group	Shares	Util Limit
OLTP	1	30 %
BATCH	2	20 %
BOARD	2	50 %

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

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Performance Profiles

- 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

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

  - The parameter is static; the PDB has to be bounced to activate the setting

Management of Parallel Server Processes on PDB level

- **Oracle 12.1 and Oracle 12.2**
  - Resource Manager
  - Resource "PARALLEL_SERVER_LIMIT" (Percentage of parallel server processes specified by the instance parameter PARALLEL_SERVERS_TARGET)
  - Not recommended in Oracle 18c and higher
- **Oracle 18c**
  - Set parameter **PARALLEL_SERVERS_TARGET** on PDB level
  - Default:
    PARALLEL_THREADS_PER_CPU * CPU_COUNT * *concurrent_parallel_users* * 2

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I/O

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I/O Rate Limits for PDBs (1)

- New parameters on container level (CDB$ROOT or PDB):
  - Values set in CDB$ROOT are the default for PDBs

```
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
- DBWR-I/O, Controlfile-I/O and Password file are exempted
- Not supported on Exadata or on Non-CDB databases (IORM is used)

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

```
SQL> select * from dba_tab_columns;
.. 9 seconds

SQL> alter system set max_iops=50 scope=both;
SQL> alter system set max_mbps=12 scope=both;

SQL> select * from dba_tab_columns;
.. 19 seconds

SQL> select con_id,event,total_waits,time_waited from v$session_event
  2  where event='resmgr: I/O rate limit';

    CON_ID EVENT                          TOTAL_WAITS TIME_WAITED
---------- ------------------------------ ----------- -----------
         7 resmgr: I/O rate limit                  32        1559
```

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Memory

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Memory Management for PDBs (1)

- 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_TARGET	(targeted) Maximum PGA size 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 (IMCS, available and modifiable since 12.1.0.2, In-Memory-Option required (see notes))

- Memory distribution is managed by the resource manager

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Memory Management for PDBs (2)

- Requirements
  - Parameter NONCDB_COMPATIBLE=FALSE in CDB$ROOT
  - MEMORY_TARGET not set in CDB$ROOT (or MEMORY_TARGET=0)
- Restrictions (PGA)
  - PGA_AGGREGATE_LIMIT: not more than PGA_AGGREGATE_LIMIT in CDB$ROOT
  - PGA_AGGREGATE_LIMIT: at least 2 x PDB_AGGREGATE_TARGET of the PDB
  - PGA_AGGREGATE_TARGET: not more than PGA_AGGREGATE_TARGET in CDB$ROOT
  - PGA_AGGREGATE_TARGET: max. 50% of PGA_AGGREGATE_LIMIT (PDB and CDB$ROOT)
- INMEMORY_SIZE
    - Overprovisioning allowed

Memory Management for PDBs (3)

- if SGA_TARGET=0 on instance (CDB) level:
  - Sum of all minimal 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
- If SGA_TARGET>0 on instance (CDB) level:
  - The value of SGA_TARGET in the PDB must be less than or equal to the SGA_TARGET value at the CDB level.
  - The value of SGA_TARGET in the PDB must be less than or equal to the SGA_MAX_SIZE value at the CDB level.
  - The value of SGA_TARGET in the PDB must be twice the PDB's DB_CACHE_SIZE value, if the PDB's DB_CACHE_SIZE value is set.
  - The value of SGA_TARGET in the PDB must be twice the PDB's SHARED_POOL_SIZE value, if the PDB's SHARED_POOL_SIZE value is set.
  - The value of SGA_TARGET in the PDB must be twice the PDB's SGA_MIN_SIZE value, if the PDB's SGA_MIN_SIZE value is set.

Other resources

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Other resource-relevant Parameters on PDB-level

Parameter	Default	Meaning
MAX_DATAPUMP_JOBS_PER_PDB	100	Maximum number of concurrent DataPump Jobs in the PDB (max. 252 or "AUTO") (Value in CDB$ROOT is the default for the PDBs) (available since Oracle 12.2)
AWR_PDB_MAX_PARALLEL_SLAVES	10	Amount of resources dedicated to AWR snapshot flushing in PDBs (number of MMON slave processes) (available since 18c)
SESSIONS	from CDB$ROOT	Maximum of concurrent sessions in the PDB (available since Oracle 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

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Restricting directory access

```
SQL> create pluggable database PDBTEST
   2 admin user PDBADMIN identified by manager roles=(DBA)
   3 path_prefix='/u02/' create_file_dest='/u02/';
```

- **PATH_PREFIX**
  - Is added to relative paths e.g. for directory objects, absolute paths result in "ORA-65254: invalid path specified for the directory"
- **CREATE_FILE_DEST**
  - Restricts the path for database files

```
SQL> create tablespace T2 datafile '/u01/oradata/t2.dbf' size 10M;
create tablespace T2 datafile '/u01/oradata/t2.dbf' size 10M
ERROR at line 1:
ORA-65250: invalid path specified for file - /u01/oradata/t2.dbf
```

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Database Maintenance Jobs in a Multitenant Database

- Since Oracle 10g, Oracle runs various maintenance jobs (e.g. Statistics Gathering, Tuning Advisor etc.) in a defined maintenance window
- 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
- 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;
```

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Resource Monitoring for PDBs (1)

- The view V$RSRCPDBMETRIC contains data for the last minute (available since 12.2)
- V$RSRCPDBMETRIC_HISTORY (with the same structure) contains data for every minute of the last hour
- The AWR-View **CDB_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.)

Resource Monitoring for PDBs (2)

```
SQL> SELECT p.pdb_name,h.begin_time,h.end_time,h.iops,h.iombps, h.cpu_consumed_time cpu_time,
  2         trunc(h.sga_bytes/1024/1024)+1 sga_mb, trunc(h.pga_bytes/1024/1024)+1 pga_mb
  3  FROM cdb_hist_rsrc_pdb_metric h, cdb_pdbs p
  4  WHERE p.dbid = h.dbid
  5    AND begin_time > sysdate-12/24
  6    AND p.pdb_name='PDB01'
  7  ORDER BY p.pdb_name, h.begin_time;

PDB_NAME   BEGIN_TIME         END_TIME           IOPS     IOMBPS   CPU_TIME SGA_MB   PGA_MB
--------   ---------------    ---------------  -------- -------- -------- -------  ------
PDB01      13.06.2019 13:00   13.06.2019 13:38      .68      .00       10      50       7
PDB01      13.06.2019 13:38   13.06.2019 14:00     2.66      .04     1067     121       7
PDB01      13.06.2019 14:00   13.06.2019 15:00     1.66      .03    16940     127       9
PDB01      13.06.2019 15:00   13.06.2019 16:00      .99      .02      438     139      14
PDB01      13.06.2019 19:59   13.06.2019 20:03      .07      .00       10     116       7
PDB01      13.06.2019 20:03   13.06.2019 20:59     1.08      .02      151     177       9
PDB01      13.06.2019 20:59   13.06.2019 21:59      .55      .01      490     203      22
```

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Lockdown Profiles

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Lockdown Profiles (1)

- Restrict feature usage on PDB level
- Available since Oracle Database 12.2
- Areas
  - Network access
  - Common user or object access
  - Administrative features
  - XML database access
  - Database options (e.g. Partitioning)
- Use cases
  - DBaaS
  - Other variations of role separation between CDB administrator and PDB administrator

Lockdown Profiles (2)

- Create a lockdown profile in CDB$ROOT and assign the restrictions

```
SQL> CREATE LOCKDOWN PROFILE demo_lckdprf;
SQL> ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE STATEMENT = ('ALTER SYSTEM');
SQL> ALTER LOCKDOWN PROFILE demo_lckdprf ENABLE STATEMENT = ('ALTER SYSTEM')
  2 CLAUSE = ('flush shared_pool');
SQL> ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE STATEMENT = ('ALTER SYSTEM')
  2  CLAUSE = ('SET') OPTION=('OPTIMIZER_INDEX_COST_ADJ')
  3  MINVALUE='80' MAXVALUE='120';
SQL> ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE FEATURE = ('NETWORK_ACCESS');
SQL> ALTER LOCKDOWN PROFILE demo_lckdprf DISABLE OPTION = ('Partitioning');
```

- In the example, the lockdown profile restricts the values for "OPTIMIZER_INDEX_COST_ADJ" from 80 to 120. Trying to set the parameter to a value out of this range will result in an error ("ORA-01031: insufficient privileges")

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Lockdown Profiles (3)

- Activate the lockdown profile

```
SQL> ALTER SESSION SET CONTAINER=PDB1;
SQL> ALTER SYSTEM SET PDB_LOCKDOWN = demo_lckdprf SCOPE = BOTH;
```

- 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
```

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Lockdown Profiles - Data Dictionary

```
SQL>  select
  2       PROFILE_NAME,
  3       RULE_TYPE,
  4       RULE,
  5       clause,
  6       status
  7  from dba_lockdown_profiles
  8  order by profile_name;

PROFILE_NAME          RULE_TYPE    RULE             CLAUSE                 STATUS
--------------------- ------------ ---------------- ---------------------- -------
DEMO_LCKDPRF          STATEMENT    ALTER SYSTEM                            DISABLE
DEMO_LCKDPRF          STATEMENT    ALTER SYSTEM     FLUSH SHARED_POOL      ENABLE
DEMO_LCKDPRF          FEATURE      NETWORK_ACCESS                          DISABLE
DEMO_LCKDPRF          OPTION       PARTITIONING                            DISABLE
PRIVATE_DBAAS                                                              EMPTY
PUBLIC_DBAAS                                                               EMPTY
SAAS                                                                       EMPTY
```

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Lockdown Profiles - Enhancements in Oracle 18c

18c

- PDB lockdown profiles in the Application root, as well as in the CDB root
- Create PDB lockdown profile that is based on another PDB lockdown profile

```
SQL> REM Static dependency
SQL> CREATE LOCKDOWN PROFILE <profile> FROM <other profile>;
SQL> REM Dynamic dependency
SQL> CREATE LOCKDOWN PROFILE <profile> INCLUDING <other_profile>;
```

- New view V$LOCKDOWN_RULES to see the lockdown rules

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Lockdown Profiles – Local vs. Common Users

18c

- A lockdown profile can have different restrictions for local and common users

```
SQL> ALTER LOCKDOWN PROFILE demo_lockdown_profile
  2  DISABLE STATEMENT = ('ALTER SYSTEM');

SQL> ALTER LOCKDOWN PROFILE demo_lockdown_profile
  2  ENABLE STATEMENT = ('ALTER SYSTEM') CLAUSE = ('SET') USERS=COMMON;
```

- Valid Clauses for “USERS=” are "ALL", "LOCAL" and "COMMON"
- Recommendation
  - Disable "ALTER SYSTEM" for local users only, so that they cannot disable the lockdown profile or modify resource restrictions
  - Administrators (common users) like SYS are still able to disable the lockdown profile

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Summary
&
Further Information

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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
- Use lockdown profile to prevent PDB users from lifting restrictions
- Be careful when defining resource limits!

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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
- Presentation "PDB Isolation and Security" by Stefan Oehrli http://www.oradba.ch/download/UKOUG_PDB-Isolation-Security.pdf

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Questions & Answers

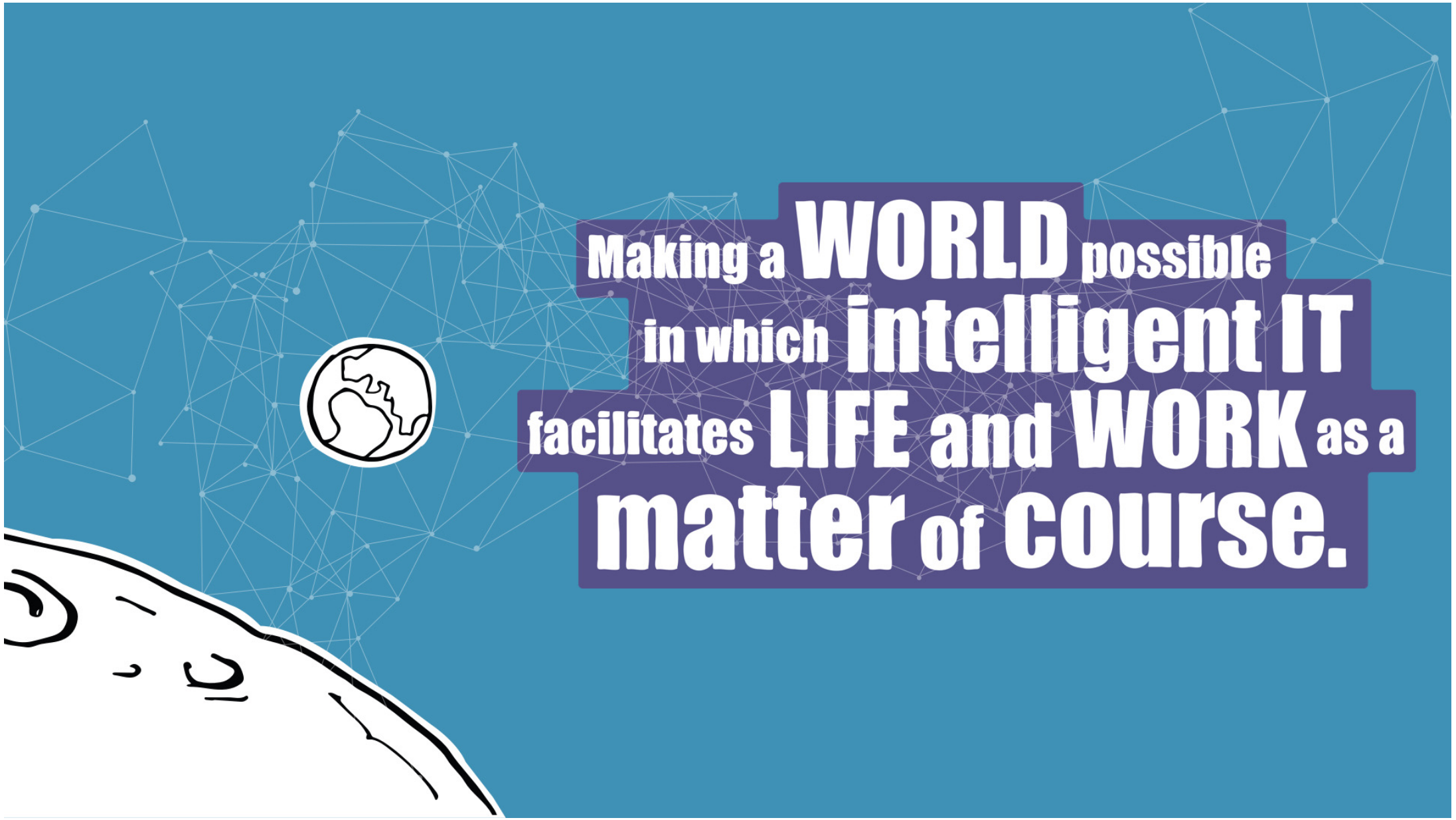
Markus Flechtner

markus.flechtner@trivadis.com

Phone +49 211 5866 64725

 @markusdba

 markusdba.de|.net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in which intelligent IT
facilitates LIFE and WORK as a
matter of course.